UNITED STATES PATENT AND TRADEMARK OFFICE

_____

BEFORE THE PATENT TRIAL AND APPEAL BOARD

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

v.

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

_____

Case IPR2025-01539
Patent No. 11,668,420

_____

DECLARATION OF DR. ROBERT A. DURHAM

I. INTRODUCTION 9
II. EXPERIENCE AND QUALIFICATIONS 9
III. TASK SUMMARY AND MATERIALS REVIEWED 16
IV. LIST OF EXHIBITS 16
V. SUMMARY OF CONCLUSIONS AND GROUNDS FOR CHALLENGE 22
VI. LEGAL STANDARDS 23
A. Level of Ordinary Skill in the Art 23
B. Legal Standard for Claim Construction 23
C. Anticipation 25
D. Obviousness 26
E. Priority Date 29
VII. OVERVIEW OF THE CHALLENGED PATENT 31
A. Disclosure of the '420 Patent 31
B. Priority Date of the '420 Patent 34
C. Challenged Claims 35
VIII. PROSECUTION HISTORY 39
IX. LEVEL OF ORDINARY SKILL IN THE ART 39
X. CLAIM CONSTRUCTION 40
XI. TECHNOLOGY BACKGROUND AND STATE OF THE ART 40
A. Well Drilling, Completion, and Production 40
B. History of Hydraulic Fracturing 42
C. Types of Pumps – Fracturing Pump Chain 46
D. Pumping and Cavitation 52
E. Simultaneous or Sequential Fracturing (Simulfrac or zipper frac) 56
F. Turbine Generators on Fracturing Sites 65
XII. OVERVIEW OF THE PRIOR ART 73
A. Cicci (Ex. 1004) 73

B. Coli (Ex. 1006) 75
C. *Liu* (Ex. 1007) 78
D. *Kajaria* (Ex. 1008) 79
E. *Dixon Catalogs* (Ex. 1009 & Ex. 1012) 82
F. *Gardner-Denver Catalog* (Ex. 1010) 88
G. *ANSI/HI 6.1* (Ex. 1011) 91

XIII. GROUND 1: THE COMBINATION OF *CICCI, COLI, DIXON,* AND *LIU* RENDER CLAIMS 1-7, 9-16, 18-19 OBVIOUS. 96

A. Motivation to Combine the References 96
B. Independent Claim 1 117
1. 1[p]: "A hydraulic fracturing system for fracturing a subterranean formation, comprising:" 117
2. 1[a]: "an electric powered multi-plunger hydraulic fracturing pump having an inlet and an outlet, the outlet coupled to a well associated with the subterranean formation and powered by at least one electric motor;" 119
3. 1[b]: "a fluid source, coupled to the inlet of the electric powered multi-plunger hydraulic fracturing pump, the fluid source providing a slurry for injection into the subterranean formation;" 124
4. 1[c]: "a hose extending between the fluid source and the electric powered multi-plunger hydraulic fracturing pump, the hose comprising:" 126
5. 1[d]: "a first end, for coupling to the fluid source, having a first diameter;" 127
6. 1[e]: "a second end, for coupling to the inlet of the electric powered multi-plunger hydraulic fracturing pump, having a second diameter; and" 128
7. 1[f]: "a body between the first end and the second end having a third diameter, the third diameter being less than both the first diameter and the second diameter; and" 129
8. 1[g]: "a pair of fittings, a first fitting forming the first end and a second fitting forming the second end, each fitting of the pair of

fittings having a shank end for receiving at least a portion of the body and a union for engaging the respective fluid source and electric powered multi-plunger hydraulic fracturing pump." 142

C. Dependent Claim 2: "2. The system of claim 1, wherein the third diameter is approximately 5 inches and the second diameter is approximately 6 inches."....151

D. Dependent Claim 3: "3. The system of claim 1, wherein each fitting of the pair of fittings further comprises: a reducer between the union and the shank end." 155

E. Dependent Claim 4: "4. The system of claim 3, wherein at least a portion of the reducer extends into a groove formed in the union, the union extending farther laterally than the reducer." 158

F. Dependent Claim 5: "5. The system of claim 3, wherein each fitting of the pair of fittings is formed as an integral piece with at least one rigid coupling between at least one of the union, the shank end, and the reducer." 161

G. Dependent Claim 6: "6. The system of claim 1, wherein the third diameter is particularly selected based at least in part on a threshold, the threshold corresponding to a drop out rate for the slurry."....164

H. Dependent Claim 7: "7. The system of claim 1, wherein the third diameter is particularly selected based at least in part on a pressure drop rate, a damage accumulation rate, or a suggested flow rate." 168

I. Dependent Claim 9.....172

1. 9[a]: "The system of claim 1, further comprising: a plurality of electric powered multi-plunger hydraulic fracturing pumps, each electric powered multi-plunger hydraulic fracturing pump receiving fluid from the fluid source;".....173
2. 9[b]: "a plurality of hoses having the third diameter; and".....176
3. 9[c]: "a plurality of fittings between respective hoses of the plurality of the hoses and respective electric powered multi-plunger hydraulic fracturing pumps of the plurality of electric powered multi-plunger hydraulic fracturing pumps, each of the electric powered multi-plunger hydraulic fracturing pumps having a connection having the second diameter."....177

J. Dependent Claim 10: "10. The system of claim 1, further comprising: a distribution system, positioned between the well and the electric powered multi-plunger hydraulic fracturing pump, the distribution system collecting the slurry from electric powered multi-plunger hydraulic fracturing pump for injection into the subterranean formation."....179

K. Independent Claim 11 182

1. 11[p]: "11. A hydraulic fracturing system for fracturing a subterranean formation, comprising:"....182
2. 11[a]: "an electric powered multi-plunger hydraulic fracturing pump having an inlet and an outlet, the outlet coupled to a well associated with the subterranean formation and powered by at least one electric motor;"....183
3. 11[b]: "a fluid source, coupled to the inlet of the electric powered multi-plunger hydraulic fracturing pump, the fluid source providing a slurry for injection into the subterranean formation;" 184
4. 11[c]: "a hose extending between the fluid source and the electric powered multi-plunger hydraulic fracturing pump, the hose comprising:"....184
5. 11[d]: "a first end, for coupling to the fluid source, having a first diameter;"....184
6. 11[e]: "a second end, for coupling to the inlet of the electric powered multi-plunger hydraulic fracturing pump, having a second diameter; and" 185
7. 11[f]: "a body between the first end and the second end having a third diameter, the third diameter being less than both the first diameter and the second diameter and" 185
8. 11[g]: "a pair of fittings, wherein a first fitting of the pair of fittings is at the first end and a second fitting of the pair of fittings is at the second end, each fitting of the pair of fittings comprising:" 185
9. 11[h]: "a union arranged at a first fitting end, the union having a union diameter, larger than the first diameter;" 186

10. 11[i]: "a shank end at a second fitting end, the shank end configured to receive at least a portion of the hose, the shank end being securable to at least the portion of the hose, the shank end including an opening to receive the hose; and".....191

11. 11[j]: "a reducer positioned between the union and the shank end, the reducer being welded to the respective union and shank end at each end, the reducer having an increasing diameter along its axial length, the reducer extending at least partially into the union.".....196

L. Dependent Claim 12: "12. The system of claim 11, wherein the third diameter is approximately 5 inches and the second diameter is approximately 6 inches.".....200

M. Dependent Claim 13: "13.The system of claim 11, wherein at least a portion of the reducer extends into a groove formed in the union, the union extending farther laterally than the reducer." 200

N. Dependent Claim 14: "14. The system of claim 11, wherein each fitting of the pair of fittings is formed as an integral piece with at least one rigid coupling between at least one of the union, the shank end, and the reducer." 201

O. Dependent Claim 15: "15. The system of claim 11, wherein the third diameter is particularly selected based at least in part on a threshold, the threshold corresponding to a drop out rate for the slurry.".....201

P. Dependent Claim 16: "16. The system of claim 11, wherein the third diameter is particularly selected based at least in part on a pressure drop rate, a damage accumulation rate, or a suggested flow rate.".....201

Q. Dependent Claim 18.....202

1. 18[a]: "18. The system of claim 11, further comprising: a plurality of electric powered multi-plunger hydraulic fracturing pumps, each electric powered multi-plunger hydraulic fracturing pump receiving fluid from the fluid source;".....202

2. 18[b]: "a plurality of hoses having the third diameter; and".....202

3. 18[c]: "a plurality of fittings between respective hoses of the plurality of the hoses and respective electric powered multi-

plunger hydraulic fracturing pumps of the plurality of electric powered multi-plunger hydraulic fracturing pumps, each of the electric powered multi-plunger hydraulic fracturing pumps having a connection having the second diameter.”.....203

R. Dependent Claim 19: “19. The system of claim 11, further comprising: a distribution system, positioned between the well and the electric powered multi-plunger hydraulic fracturing pump, the distribution system collecting the slurry from electric powered multi-plunger hydraulic fracturing pump for injection into the subterranean formation.”.....203

XIV. Ground 2: THE COMBINATION OF *CICCI, COLI, DIXON, LIU* AND *GARDNER-Denver* RENDERS CLAIMS 1-19 OBVIOUS.....203

A. Motivation to Combine.....204

B. Independent Claim 1.....209

1. Limitations 1[p] – 1[e].....209

2. Limitation 1[f].....209

3. Limitation 1[g].....210

C. Dependent Claim 2: “2. The system of claim 1, wherein the third diameter is approximately 5 inches and the second diameter is approximately 6 inches.”.....211

D. Dependent Claim 8: “8. The system of claim 1, wherein the third diameter is associated with a second threshold, corresponding to a maximum suggested flow rate, an operating window for the electric powered multi-plunger hydraulic fracturing pump exceeding the maximum suggested flow rate.”.....216

E. Dependent Claims 3-7, 9-10.....224

F. Independent Claim 11.....225

1. Limitations 11[p] – 1[e], 11[g], 11[i].....225

2. Limitation 11[f].....225

3. Limitation 11[h].....225

G. Dependent Claims 13-16, 18-19.....226

H. Dependent Claim 12: "12. The system of claim 11, wherein the third diameter is approximately 5 inches and the second diameter is approximately 6 inches." 226

I. Dependent Claim 17: "17. The system of claim 11, wherein the third diameter is associated with a second threshold, corresponding to a maximum suggested flow rate, an operating window for the electric powered multi-plunger hydraulic fracturing pump exceeding the maximum suggested flow rate." 226

XV. Grounds 3A AND 3B: THE COMBINATION OF *CICCI, COLI, DIXON, LIU*, and *Kajaria*, with or without *gardner-denver* RENDERS CLAIM 20 OBVIOUS 227

A. Motivation to Combine 227

B. Dependent Claim 20: "20. The System Of Claim 11, Further Comprising: A Third Fitting Positioned On A Third End Of The Hose For Coupling To A Second Electric Powered Multi-Plunger Hydraulic Fracturing Pump, Having The Second Diameter." 234

XVI. Ground 4: THE COMBINATION OF *CICCI, COLI, DIXON, LIU, GARDNER-DENVER* AND *ANSI 6.1* RENDERS CLAIMs 8 AND 17 OBVIOUS 239

A. Motivation to Combine 239

B. Dependent Claim 8: "8. The system of claim 1, wherein the third diameter is associated with a second threshold, corresponding to a maximum suggested flow rate, an operating window for the electric powered multi-plunger hydraulic fracturing pump exceeding the maximum suggested flow rate." 246

C. Dependent Claim 17: "17. The system of claim 11, wherein the third diameter is associated with a second threshold, corresponding to a maximum suggested flow rate, an operating window for the electric powered multi-plunger hydraulic fracturing pump exceeding the maximum suggested flow rate." 251

XVII. CONCLUSION 251

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. 11,668,420, which I may abbreviate as "the '420 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 '420 Patent. I am being compensated at my normal 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 detailed more fully in my curriculum vitae, which is included as Appendix A. My CV also lists publications on which I am a named author and identifies parties on behalf of whom.

4. I am a consulting engineer with experience in a number of technical areas. I have expertise in the oil and gas industry, spanning from drilling and completion to downstream operations. As a consultant, I have worked with oil field

production companies, refining and chemical plants, equipment manufacturers, and technology development companies for over twenty years. My work relates to the subject matter of the U.S. Pat. No. 11,668,420 ("the '420 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 leadership positions 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 to 2012, I served as Secretary, Vice Chair, and 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, wellhead, 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 equipment operations in the Oil and Gas Industry. The PCIC Standards Subcommittee 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 eight years, holding two-year terms in each position: Secretary, Vice Chair, Chair, and Chair of the Advisory and Awards Committee.

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 IEEE membership 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 was administratively 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, where I was responsible for Engineering and Project Management of generation and cogeneration facilities across the U.S., I transitioned to the role of consulting engineer. In that role, I have served as a consulting engineer, designing, constructing, and analyzing various systems, particularly those in the oil and gas industry. This has included the design and selection of equipment, as well as the analysis of equipment failures in the oil and gas field, spanning from drilling and completion sites to production facilities, midstream locations, and downstream (refinery) sites.

10. I am also a Principal of PEDOCS, Inc., an oil and gas production company that has operated over 50 oil and gas production wells in Oklahoma. As such, I am familiar with oil and gas well operations, including well stimulation, completion, hydraulic fracturing, and production.

11. I have been familiar with oil and gas drilling, fracturing (fracing), completion and production 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, completion and

production sites over my engineering consulting engagements, including numerous water collection, storage and disposal facilities.

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 the 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 the design, construction, and maintenance of several hundred miles of medium-voltage (5–25 kV) distribution lines, switchgear, drives, and motors used for oil and gas drilling, completion, and production. Over the last ~ 20 years, I have consulted with numerous clients, ranging from utilities to oil and gas development and production companies, on the design, upgrades, and maintenance of generation and power distribution facilities.

13. I have been familiar with the design, specification, construction and operation of Adjustable Speed Drive (ASD) systems for over 30 years. While at AEP, I gained my first exposure to ASDs (sometimes referred to as variable

frequency drives or VFDs). Between 1990 and 1992, while employed by Public Service Company of Oklahoma (an AEP company), I was responsible for overseeing the field installation of multiple 4,500+ hp VFDs for fans and pumps. I continued working with ASDs and related technologies, such as back-to-back inverter systems, throughout my career at AEP. When I took over as Manager of Electric Infrastructure at New Dominion, I was responsible not only for overhead lines but also for the specification, installation, and operation of all ASDs for production pump applications on both downhole and surface pumping systems. These ASDs ranged from a few hundred to around 1,000 HP at both medium and low voltages. At EDG Power Group, I was responsible for specifying and overseeing the installation of VFDs that ran pumps and fan motors on power generation facility installations. Since I began consulting nearly 20 years ago, I have specified, installed, analyzed, and torn down ASDs on numerous projects. As Standards Chair of the PCIC, I have been responsible for overseeing the management of several standard working groups for ASD applications in the Oil and Gas Industry, including IEEE 1662, 1826, and 1566. I am comfortable in stating that I have worked with several hundred ASDs throughout my career.

14. I have been familiar with control systems, Supervisory Control and Data Acquisition (SCADA) systems, and remote-control operations for over thirty

years. I have been familiar with web-based control systems over the last decade as part of my various consulting engagements, including drilling systems, fluid handling systems, production systems, and others. Throughout my career, I have designed control systems, including remote control systems, for various facilities, such as oil and gas production, water storage and disposal facilities, water treatment facilities, power generation plants, generator systems, and aggregate conveying systems, among others. The first control system I designed, for a water treatment facility, was as a junior engineer in 1990-1991. I am a licensed controls system engineer and a licensed petroleum engineer.

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

16. Therefore, based on my education, professional experience of over 30 years, and scholarly books and publications, I am an expert in the relevant field of the ’420 Patent and have been an expert in this field since before the ’420 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 ’420 Patent and the prior art references at the time of filing.

III. TASK SUMMARY AND MATERIALS REVIEWED

17. I have been asked to review the Challenged Patent and its prosecution history, to provide an understanding of the technology relevant to the Challenged Patent, to review certain prior-art references, and analyze whether or not those references disclose or teach limitations of the 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) at the time of the '420 Patent.

IV. LIST OF EXHIBITS

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

Ex.	Description
1001	U.S. Patent No. 11,668,420 to Oehring et al. (filed May 17, 2021, and issued June 6, 2023) **("'420 Patent"** or **"Challenged Patent")**
1003	File History of U.S Patent No. 11,668,420 (App. No. 17/321,936) **("File History")**
1004	U.S. Patent No. 11,549,348 to Cicci et al. (filed Nov. 20, 2020 and issued Jan 10, 2023)
1005	U.S. Provisional Application No. 62/941,459 (*"Cicci Provisional")*
1006	U.S. Patent Publication No. 2012/0255734 to Coli (filed April 6, 2023, and published Oct. 11, 2012) **("*Coli*")**

1007	Henry Liu, *Pipeline Engineering*, 2003 ("***Liu***")
1008	U.S. Patent No. 9,127,545 to Kajaria et al.
1009	2018 Australia Dixon Product Catalog, available at https://australia.dixonvalve.com/sites/default/files/downloadable_resources/product_literature/ADPL718%20Catalog_optimized_0.pdf
1010	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.
1011	American National Standard for Reciprocating Power Pumps, ANSI/HI 6.1 (2015)
1012	2018 U.S. Dixon Product Catalog
1013	Declaration of Holly Langenfelder
1014	Declaration of Dr. Sylvia Hall-Ellis, Ph.D.
1015	Michael Morton, "Unlocking the Earth: A Short History of Hydraulic Fracturing," Academia, GEO ExPro, Vol. 10, No. 6, December 2013 https://geoexpro.com/unlocking-the-earth-a-short-history-of- hydraulic-fracturing/ (last accessed November 30, 2023)
1016	B.A. Wells and K.L. Wells. "Shooters – A "Fracking" History." American Oil & Gas Historical Society, (https://aoghs.org/technology/hydraulic-fracturing) (last accessed November 30, 2023)
1017	Carl T. Montgomery and Michael B. Smith, "Hydraulic Fracturing: History of an Enduring Technology," *Journal of Petroleum Technology*, Vol. 62, Issue 12 (Dec. 2010).
1018	Bourgoyne, A. T., et al. (1986). Applied Drilling Engineering, Society of Petroleum Engineers Textbook Series, Vol. 2.

1019	Vassiliou, M. S., Historical Dictionary of the Petroleum Industry, Rowman & Littlefield (2018)
1020	U.S. Patent Application Publication No. 2013/0306322 to Sanborn *et al.* entitled "System and Process for Extracting Oil and Gas by Hydraulic Fracturing" ("*Sanborn*")
1021	U.S. Patent No. 11,959,371 to Oehring et al.
1022	Waters, George, et al., Continental Resources, *Simultaneous Hydraulic Fracturing of Adjacent Horizontal Wells in the Woodford Shale*. Paper presented at the SPE Hydraulic Fracturing Technology Conference, The Woodlands, Texas, January 2009. doi: https://doi.org/10.2118/119635-MS ("*Waters*")
1023	Pearson, C.M., Bond, A.J., Eck, M.E., and J.H. Schmidt. "Results of Stress-Oriented and Aligned Perforating in Fracturing Deviated Wells." J Pet Technol 44 (1992): 10–18. doi: https://doi.org/10.2118/22836-PA
1024	Mutalik, P N, and Bob Gibson. "Case History of Sequential and Simultaneous Fracturing of the Barnett Shale in Parker County." Paper presented at the SPE Annual Technical Conference and Exhibition, Denver, Colorado, USA, September 2008. doi: https://doi.org/10.2118/116124-MS ("*Mutalik*")
1025	Mayerhofer, M. J., Lolon, E. P., Warpinski, N. R., Cipolla, C. L., Walser, D., and C. M. Rightmire. "What is Stimulated Reservoir Volume (SRV)?" Paper presented at the SPE Shale Gas Production Conference, Fort Worth, Texas, USA, November 2008. doi: https://doi.org/10.2118/119890-MS ("*Mayerhofer*")
1026	Roussel, Nicolas P., and Mukul M. Sharma. "Optimizing Fracture Spacing and Sequencing in Horizontal-Well Fracturing." SPE Prod & Oper 26 (2011): 173–184. doi: https://doi.org/10.2118/127986-PA ("*Roussell*")
1027	K. R. Webster, W. C. Goins, Jr., and S. C. Berry, "A Continuous Multistage Tracing Technique," *Journal of Petroleum Technology,* vol. 17, no. 06, pp. 619-625, 1965, doi: 10.2118/977-pa. ("*Webster*")

1028	A. Casero, G. Pace, B. Malone, F. Cantaloube, L. Tealdi, H. Malonga, and R. Seale, "Continuous Pumping, Multistage, Hydraulic Fracturing in Kitina Field, Offshore Congo, West Africa," in *SPE International Symposium and Exhibition on Formation Damage Control*, 2008, vol. All Days, SPE-112442-MS, doi: 10.2118/112442-ms. [Online]. Available: https://doi.org/10.2118/112442-MS ("*Casero*")
1029	S. Rassenfoss, "A Look Into What Fractures Really Look Like," *Journal of Petroleum Technology,* vol. 70, no. 11, pp. 28-36, 2018, doi: 10.2118/1118-0028-jpt. ("*Rassenfoss*")
1030	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
1031	ADM Callaghan "GTS Admiral W.M. Callaghan" available at: https://maritime.dot.gov/multimedia/gts-admiral-wm-callaghan
1032	GE Power & Water, Power Generation Products, https://web.archive.org/web/20140717214839/https://www.ge-distributedpower.com/products/power-generation
1033	GE Power & Water, GE's TM2500+ Aeroderivative Mobile Gas Turbine Brochure, available at: https://web.archive.org/web/20140717215045/https://www.ge-distributedpower.com/component/cck/?task=download&file=seb_media_document&id=13183
1034	Eugene A. Avallone et al., Marks' Standard Handbook for Mechanical Engineers (11th ed. 2007)
1035	Solar Turbines Turbomachinery Systems for Oil and Gas Applications brochure, available at:

	https://web.archive.org/web/20061102043710/http://mysolar.cat.com/cda/files/127587/7/bo&g.pdf
1036	Solar Turbines – Titan 130 Generation Set, available at: https://web.archive.org/web/20060318215809/http://mysolar.cat.com/cda/layout?m=36056&x=7
1037	Solar Turbines – Gas Turbine Products for the Oil and Gas Industry, available at: https://web.archive.org/web/20060712013257/http://mysolar.cat.com/cda/layout?m=35881&x=7
1038	U.S. Patent No. 2019/0249754 to Oehring
1039	CRC Press Books, About Us, available at https://www.routledge.com/corporate/about-us/crc-press?srsltid=AfmBOoo4LdrPswlrDh199mp0iAWleSZK26v7xZFamobLss_WyPVplVts
1040	Dixon Product Literature website, available at https://australia.dixonvalve.com/en/knowledge-center/references-and-education/product-literature
1041	Amazon.com Dixon Frac Fitting, HUF100300CS, available at https://www.amazon.com/Dixon-FEMALE-SUB-FIG-HUF100300CS/dp/B00LT0TT2U
1042	Dixon History: 100 years: available at https://australia.dixonvalve.com/en/about-dixon/history
1043	Dixon History, First Commercial Hydraulic Fracturing Wells Drilled March 17, 1949, available at https://australia.dixonvalve.com/en/about-dixon/history
1044	Intentionally Left Blank
1045	Docket Weld Fitting Types and Applications – Complete Specification, ASME B16.11-2004, available at:

	https://web.archive.org/web/20180210052553/https://www.octalsteel.com/socket-weld-pipe-fittings/.
1046	Cambridge English Dictionary, definition of "weld," https://web.archive.org/web/20170709094317/https://dictionary.cambridge.org/dictionary/english/weld
1047	Collin's English Dictionary definition of "quintuplex": https://www.collinsdictionary.com/dictionary/english/quintuplex
1048	Jacobs, Trent. "*The Shale Evolution: Zipper Fracture Takes Hold*," JPT Technology Writer, October 2014: 60–67
1049	Turbines: Solar Mobile Turbomachinery, available at https://www.solarturbines.com/en_US/solutions/oil-and-gas/solar-mobile-turbomachinery.html
1050	CNC Flow Control, Oilfield Solutions: Valves, Fittings, & Flow Lines
1051	GTS Admiral W.M. Callaghan, available at https://www.maritime.dot.gov/multimedia/gts-admiral-wm-callaghan
1052	Intentionally Left Blank
1053	Affidavit of Mina Ching, dated September 23, 2025
1054	Hydraulic Fracturing Institute Reciprocating Pump Standards: available at https://web.archive.org/web/20171029162737/http:/estore.pumps.org/Standards/Reciprocating/PumpsPDF.aspx
1055	Hydraulic Fracturing Institute Reciprocating Pump Standards: available at https://web.archive.org/web/20150808112714/http://estore.pumps.org/Standards/Reciprocating/Hardcopy.aspx
1056	File History for U.S. Patent No. 11,009,162
1057	Variable Speed Pumping: A Guide to Successful Applications

1058	Langewis, C. et al., "Practical Hydraulics for Positive Displacement Pumps for High-Pressure Waterflood Installations," Journal of Petroleum Engineering 173 (1971)_
1059	Claim Listing

Other than prosecution histories, Ex. 1003 and Ex. 1056, and Exhibits 1010 and 1053 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

19. After reviewing the materials identified in the List of Exhibits, I have concluded that each of the Challenged Claims of the '420 Patent would have been obvious to a person of ordinary skill in the art, based on the following grounds.

Ground	Claims	Basis (35 U.S.C. §)	Prior Art
1	1-7, 9-16, 18-19	103	*Cicci, Coli, Dixon,* and *Liu*
2	1-19	103	*Cicci, Coli, Dixon, Liu,* and *Gardner-Denver*
3A	20	103	*Cicci, Coli, Dixon, Liu,* and *Kajaria*
3B	20	103	*Cicci, Coli, Dixon, Liu, Gardner-Denver,* and *Kajaria*
4	8, 17	103	*Cicci, Coli, Dixon, Liu, Kajaria, Gardner-Denver, and ANSI/HI 6.1*

VI. LEGAL STANDARDS

A. LEVEL OF ORDINARY SKILL IN THE ART

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

21. I have been instructed by counsel that the person of ordinary skill in the art (**"POSITA"**) is a hypothetical person who is presumed to know the relevant prior art. I understand that the actual inventor's skill is not determinative of the level of ordinary skill. I further understand that the factors that may be considered in determining the level of skill include: the types of problems encountered in the art; prior art solutions to those problems; rapidity with which innovations are made; sophistication of the technology; and educational level of active workers in the field. I understand that not all such factors may be present in every case, and one or more of them may predominate.

B. LEGAL STANDARD FOR CLAIM CONSTRUCTION

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

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

24. It is my understanding that in proceedings before the USPTO, the claims of a patent are to be construed under what is referred to as the "Phillips standard." I understand that this means that the claim terms of a patent are given the meaning the terms would have to a POSITA, in view of the description provided in the patent itself and the patent's file history.

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

history, may also be useful in interpreting patent claims when the intrinsic evidence itself is insufficient.

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

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

C. ANTICIPATION

28. It is my understanding that a prior art reference anticipates the claims of a patent if each and every element of the claim is found either explicitly or inherently in a single prior art reference or system. I understand that inherency requires a showing that the missing descriptive matter in the claim is necessarily or implicitly present in the allegedly anticipating reference, and that it would have been

recognized by a POSITA. In addition, I understand that an enabling disclosure is a disclosure that allows a POSITA to make the invention without undue experimentation. Although anticipation typically involves the analysis of a single prior art reference, I understand that additional references may be used to show that the primary reference has enabling disclosure, to explain the meaning of a term used in the primary reference, and/or to show that a characteristic is inherent in the primary reference.

D. OBVIOUSNESS

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

than all of the elements of a patent claim may render a patent claim obvious if including the missing element would have been obvious to one of skill in the art (e.g., the missing element represents only an insubstantial difference over the prior art or a reconfiguration of a known system).

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

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

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

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

- the taking of licenses under the patent by others; and
- deliberate copying of the invention.

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

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

- the claimed subject matter is simply a combination of prior art elements according to known methods to yield predictable results;
- the claimed subject matter is a simple substitution of one known element for another to obtain predictable results;
- the claimed subject matter uses known techniques to improve similar devices or methods in the same way;
- the claimed subject matter applies a known technique to a known device or method that is ready for improvement to yield predictable results;
- the claimed subject matter would have been "obvious to try" choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success;
- there is known work in one field of endeavor that may prompt variations of it for use in either the same field or a different one based on design incentives or other market forces if the variations would have been predictable to a POSITA;
- there existed at the time of the invention a known problem for which there was an obvious solution encompassed by the patent's claims; and

- there is some teaching, suggestion, or motivation in the prior art that would have led a POSITA to modify the prior art reference or to combine prior art reference teachings to arrive at the claimed subject matter.

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

E. PRIORITY DATE

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

37. I understand that it is not enough for a patent to merely claim the benefit of an earlier-filed application, but that additional criteria must be met. In particular, the prior application itself must describe the claimed invention, and must do so in sufficient detail that one skilled in the art can clearly conclude that the inventor invented the claimed invention as of the filing date sought. First, I understand that a priority-date analysis is on a claim-by-claim basis. Second, I understand that, in order for a patent claim to be entitled to the filing date of an earlier patent application,

a "Section 112 analysis" must be conducted. I am informed that a "Section 112" analysis encompasses looking to the earlier patent application, and ascertaining whether that earlier patent application meets both the written-description and enablement requirements as of the filing date of the earlier application. I understand that it is not enough that the claim would have been obvious from the earlier application, but that application itself must describe the claimed invention.

38. I understand that in order to satisfy the written description requirement, the earlier application must reasonably convey to those skilled in the art that the inventors had possession of the subject matter of the patent as of the filing date of the earlier application. I have been informed that it is the disclosures of the earlier patent application that count, and that while the meaning of terms, phrases, or diagrams in the earlier patent application must be interpreted from the vantage point of one skilled in the art, all of the claimed limitations must appear in the specification. Further, I understand that this analysis is not a question of whether one skilled in the art might be able to construct the claimed invention from the teachings of the disclosure. The question is not whether a claimed invention is an obvious variant of that which is disclosed in the specification; rather, I understand that an earlier application must itself describe each of the claim limitations.

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

VII. OVERVIEW OF THE CHALLENGED PATENT

A. DISCLOSURE OF THE '420 PATENT

40. The '420 Patent relates to a "system and method for integrated flow supply line."[1] The '420 Patent describes a conventional fracturing system comprising "an electric powered pump having an inlet and an outlet, the outlet coupled to a well associated with [a] subterranean formation and powered by at least one electric motor."[2] The '420 Patent also describes "a fluid source, coupled to the inlet of the electric powered pump, the fluid source providing a slurry for injection into the subterranean formation."[3] The '420 patent describes a "hose extending between the fluid source and the electric powered pump."[4]

41. Figure 1, below, illustrates a hydraulic fracturing system.[5]

[1] Ex. 1001 ('420 Patent), at cover.
[2] Ex. 1001 ('420 Patent), at Abstract.
[3] Ex. 1001 ('420 Patent), at Abstract.
[4] Ex. 1001 ('420 Patent), at Abstract.
[5] Ex. 1001 ('420 Patent), at 4:28-29.

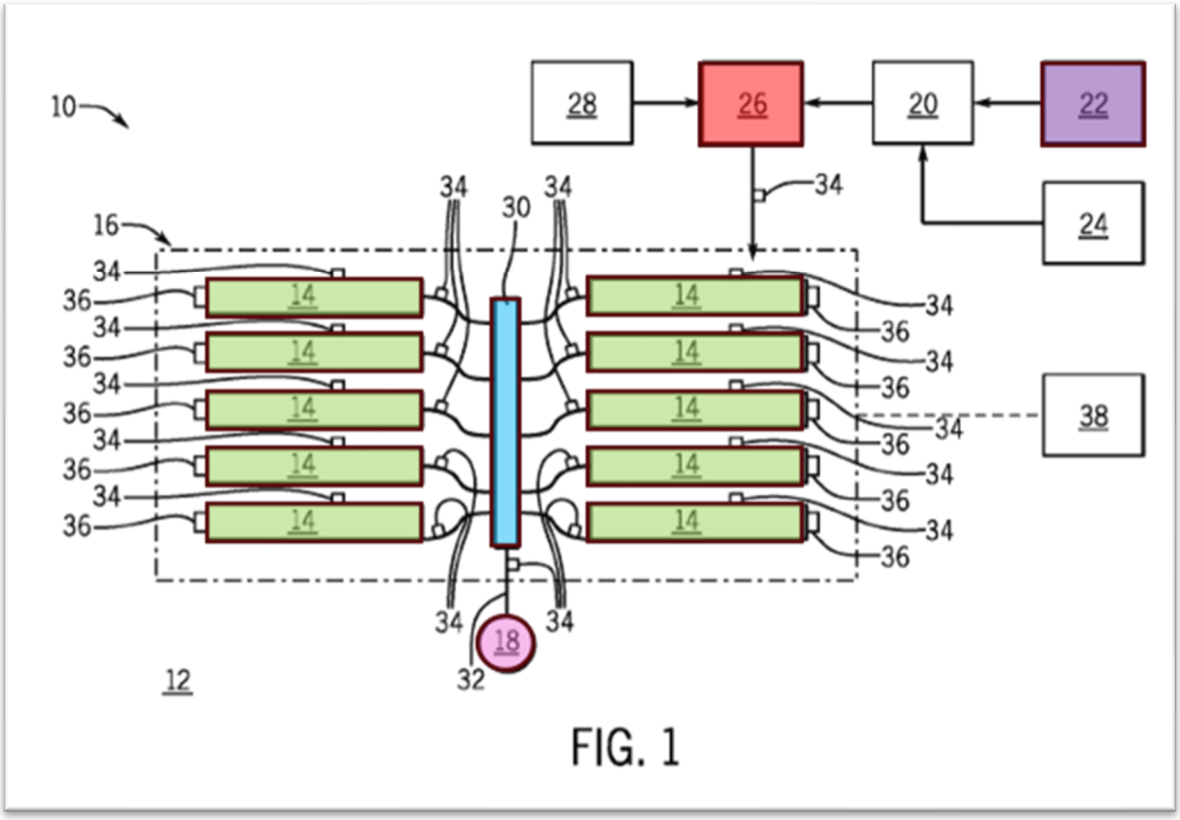


FIG. 1

Ex. 1001 (’420 Patent) Fig 1 (annotated) & 4:28-60.

The blender unit 26 (highlighted in red) receives fluid from the fluid source 22 (highlighted in purple) and adds proppant to form a slurry.[6] The pumps 14 (highlighted in green) pressurize the slurry.[7] The distribution system 30 (highlighted in blue), such as a missile, receives the slurry from the pump for injection into the wellhead.[8]

[6] Ex. 1001 (’420 Patent), at 4:35-39.
[7] Ex. 1001 (’420 Patent), at 4:30-32.
[8] Ex. 1001 (’420 Patent), at 4:45-47.

42. The patent also describes a fitting between the hose and the electric powered pump with "a first end for receiving the hose at the first diameter and a second end for coupling to the electric powered pump at a second diameter,."[9] An embodiment of the fitting is illustrated in Figure 2A, below.

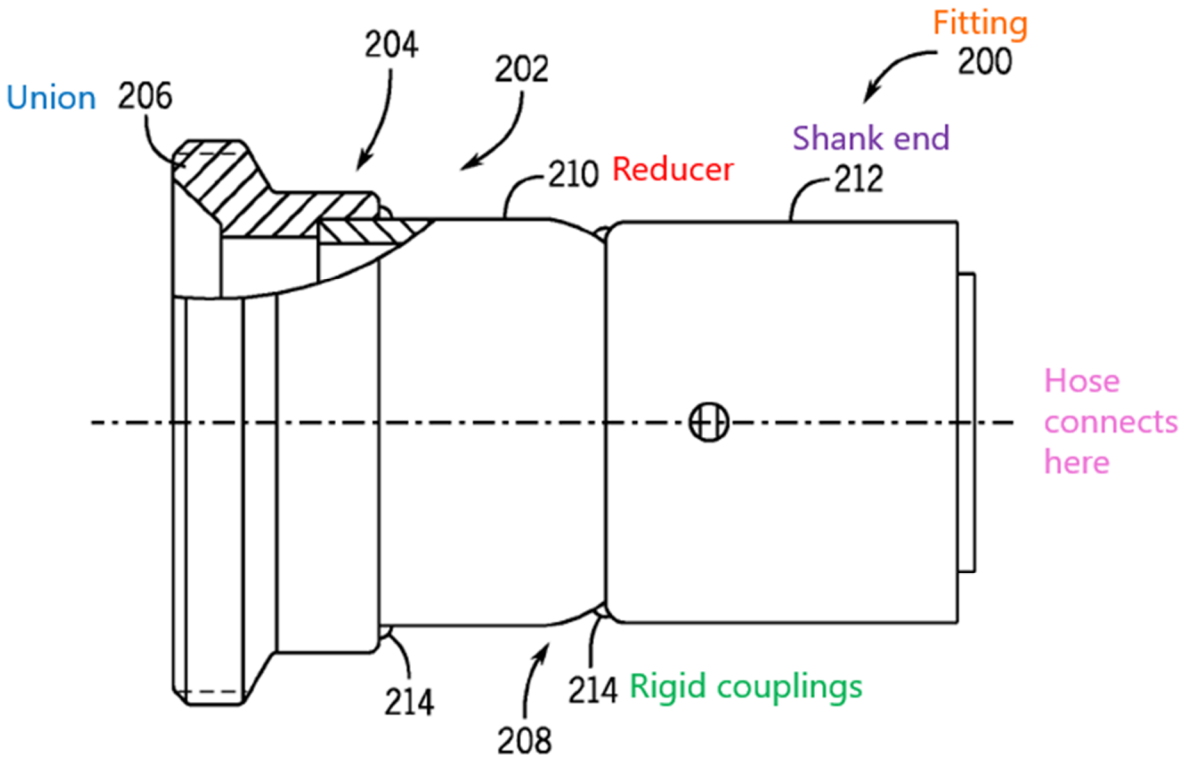


FIG. 2A

[9] Ex. 1001 ('420 Patent), at Abstract.

43. The patent also describes a third diameter, associated with the hose's body.[10] The patent describes embodiments in which the first, second, and third diameters have different relative sizes.[11]

44. As discussed below, fracturing systems as described, using flexible hoses and fittings were well known before the time of the alleged invention of the '420 Patent. Additionally, fittings such as those described in the '420 Patent, with smaller hose ends and larger pump connection ends, were also well known before the time of the alleged invention of the '420 Patent, both as integral fittings, and as an obvious combination of known individual fitting components.

B. PRIORITY DATE OF THE '420 PATENT

45. I understand that the '420 Patent (which was filed as U.S. Patent App. No. 17/321,936, or "'936 Application") was filed on May 17, 2021. I further understand that the '936 Application lists on its face that it is a direct continuation of U.S. Application No. 16/728,359 (the "'359 Application"), filed December 27, 2019, which issued as the '162 Patent. For purposes of this declaration, I have assumed that the earliest possible priority date for the Challenged Claims of the '420 Patent would be no earlier than December 27, 2019, when the '359 Application was

[10] Ex. 1001 ('420 Patent), at 6:30-31.
[11] Ex. 1001 ('420 Patent), at 6:22-38.

filed. Regardless of whether the '420 Patent receives the filing date of May 17, 2021, or the filing date of December 27, 2019, the references that I use below are all Prior Art even before December 27, 2019.

C. CHALLENGED CLAIMS

46. The Challenged Claims of the '420 Patent, which are Claims 1-20, are set forth below. Some of the claim elements have been further subdivided (and labeled as part "1[a]", "1[b]" or similar, where the first number indicates the claim number, and the following letters refer to subparts of that claim) for ease of reference.

Claim	Description
1[p]	1. A hydraulic fracturing system for fracturing a subterranean formation, comprising:
1[a]	an electric powered multi-plunger hydraulic fracturing pump having an inlet and an outlet, the outlet coupled to a well associated with the subterranean formation and powered by at least one electric motor;
1[b]	a fluid source, coupled to the inlet of the electric powered multi-plunger hydraulic fracturing pump, the fluid source providing a slurry for injection into the subterranean formation;
1[c]	a hose extending between the fluid source and the electric powered multi-plunger hydraulic fracturing pump, the hose comprising:
1[d]	a first end, for coupling to the fluid source, having a first diameter;
1[e]	a second end, for coupling to the inlet of the electric powered multi-plunger hydraulic fracturing pump, having a second diameter; and
1[f]	a body between the first end and the second end having a third diameter, the third diameter being less than both the first diameter and the second diameter; and

1[g]	a pair of fittings, a first fitting forming the first end and a second fitting forming the second end, each fitting of the pair of fittings having a shank end for receiving at least a portion of the body and a union for engaging the respective fluid source and electric powered multiplunger hydraulic fracturing pump.
2	The system of claim 1, wherein the third diameter is approximately 5 inches and the second diameter is approximately 6 inches.
3	The system of claim 1, wherein each fitting of the pair of fittings further comprises: a reducer between the union and the shank end.
4	The system of claim 3, wherein at least a portion of the reducer extends into a groove formed in the union, the union extending farther laterally than the reducer.
5	The system of claim 3, wherein each fitting of the pair of fittings is formed as an integral piece with at least one rigid coupling between at least one of the union, the shank end, and the reducer.
6	The system of claim 1, wherein the third diameter is particularly selected based at least in part on a threshold, the threshold corresponding to a drop out rate for the slurry.
7	The system of claim 1, wherein the third diameter is particularly selected based at least in part on a pressure drop rate, a damage accumulation rate, or a suggested flow rate.
8	The system of claim **1,** wherein the third diameter is associated with a second threshold, corresponding to a maximum suggested flow rate, an operating window for the electric powered multi-plunger hydraulic fracturing pump exceeding the maximum suggested flow rate.
9[a]	The system of claim 1, further comprising: a plurality of electric powered multi-plunger hydraulic fracturing pumps, each electric-powered multi-plunger hydraulic fracturing pump receiving fluid from the fluid source;
9[b]	a plurality of hoses having the third diameter; and
9[c]	a plurality of fittings between respective hoses of the plurality of the hoses and respective electric powered multi-plunger hydraulic fracturing pumps of the plurality of electric powered multi-plunger hydraulic fracturing pumps, each of the electric powered multiplunger hydraulic fracturing pumps having a connection having the second diameter.

10	10. The system of claim 1, further comprising: a distribution system, positioned between the well and the electric powered multi-plunger hydraulic fracturing pump, the distribution system collecting the slurry from electric powered multi-plunger hydraulic fracturing pump for injection into the subterranean formation.
11[p]	11. A hydraulic fracturing system for fracturing a subterranean formation, comprising:
11[a]	an electric powered multi-plunger hydraulic fracturing pump having an inlet and an outlet, the outlet coupled to a well associated with the subterranean formation and powered by at least one electric motor;
11[b]	a fluid source, coupled to the inlet of the electric powered multi-plunger hydraulic fracturing pump, the fluid source providing a slurry for injection into the subterranean formation;
11[c]	a hose extending between the fluid source and the electric powered multi-plunger hydraulic fracturing pump, the hose comprising:
11[d]	a first end, for coupling to the fluid source, having a first diameter;
11[e]	a second end, for coupling to the inlet of the electric powered multi-plunger hydraulic fracturing pump, having a second diameter; and
11[f]	a body between the first end and the second end having a third diameter, the third diameter being less than both the first diameter and the second diameter and
11[g]	a pair of fittings, wherein a first fitting of the pair of fittings is at the first end and a second fitting of the pair of fittings is at the second end, each fitting of the pair of fittings comprising:
11[h]	a union arranged at a first fitting end, the union having a union diameter, larger than the first diameter;
11[i]	a shank end at a second fitting end, the shank end configured to receive at least a portion of the hose, the shank end being securable to at least the portion of the hose, the shank end including an opening to receive the hose; and
11[j]	a reducer positioned between the union and the shank end, the reducer being welded to the respective union and shank end at each end, the reducer having an increasing diameter along its axial length, the reducer extending at least partially into the union.

12	12. The system of claim 11, wherein the third diameter is approximately 5 inches and the second diameter is approximately 6 inches.
13	13.The system of claim 11, wherein at least a portion of the reducer extends into a groove formed in the union, the union extending farther laterally than the reducer.
14	14. The system of claim 11, wherein each fitting of the pair of fittings is formed as an integral piece with at least one rigid coupling between at least one of the union, the shank end, and the reducer.
15	15. The system of claim 11, wherein the third diameter is particularly selected based at least in part on a threshold, the threshold corresponding to a drop out rate for the slurry.
16	16. The system of claim 11, wherein the third diameter is particularly selected based at least in part on a pressure drop rate, a damage accumulation rate, or a suggested flow rate.
17	17. The system of claim 11, wherein the third diameter is associated with a second threshold, corresponding to a maximum suggested flow rate, an operating window for the electric powered multi-plunger hydraulic fracturing pump exceeding the maximum suggested flow rate.
18[a]	18. The system of claim 11, further comprising: a plurality of electric powered multi-plunger hydraulic fracturing pumps, each electric powered multi-plunger hydraulic fracturing pump receiving fluid from the fluid source;
18[b]	a plurality of hoses having the third diameter; and
18[c]	a plurality of fittings between respective hoses of the plurality of the hoses and respective electric powered multi-plunger hydraulic fracturing pumps of the plurality of electric powered multi-plunger hydraulic fracturing pumps, each of the electric powered multiplunger hydraulic fracturing pumps having a connection having the second diameter.
19.	19. The system of claim 11, further comprising: a distribution system, positioned between the well and the electric powered multi-plunger hydraulic fracturing pump, the distribution system collecting the slurry from electric powered multi-plunger hydraulic fracturing pump for injection into the subterranean formation.

20	20. The system of claim 11, further comprising: a third fitting positioned on a third end of the hose for coupling to a second electric powered multi-plunger hydraulic fracturing pump, having the second diameter.

VIII. PROSECUTION HISTORY

47. The ’936 Application that ultimately issued as the ’420 Patent was filed on May 17, 2021. The Examiner allowed the claims without any substantive rejections, despite the prior art.[12] The Examiner identified the following as alleged points of novelty: “wherein a system comprising an electric powered multi-plunger hydraulic fracturing pump, a fluid source, and a hose extended between the two, wherein the hose comprises a pair of fittings with the diameters as claimed.”[13]

IX. LEVEL OF ORDINARY SKILL IN THE ART

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

[12] Ex. 1003 (’420 Patent File History), pgs. 16, 160.
[13] Ex. 1003 (’420 Patent File History), pg. 160.

completion, or production including design and/or analysis of hydraulic fracturing systems.

X. CLAIM CONSTRUCTION

49. It is my opinion that a POSITA would have understood all the claim terms to have their plain and ordinary meaning, and I have applied the plain and ordinary meaning, in the context of the '420 Patent, for all claim terms.

XI. TECHNOLOGY BACKGROUND AND STATE OF THE ART

50. In the subsections below, I describe some of the basic principles of engineering that would be used, or at least considered for use, on a hydraulic fracturing site. The principles discussed in the subsections below would have been well-known to a POSITA in the 2019 timeframe, and long before.

A. WELL DRILLING, COMPLETION, AND PRODUCTION

51. Generally, well drilling is the process of drilling a hole into the earth to extract natural resources, such as water, oil, or gas, from the earth formation or to inject a fluid downhole to, *e.g.*, stimulate production of a fluid, monitor formations, or store fluids and/or waste. Well completion is the process of preparing a well for production (or injection) after drilling operations. Well completion may include

running production tubing strings, isolating hydrocarbon-producing zones, perforating the tubing, stimulating the well (such as by injecting hydraulic fracturing fluid), or other processes to facilitate or enhance the recovery or injection of fluids. During production, the hydrocarbon resource is sent to the surface and collected for sale.

52. Various types of surface equipment are used in the drilling, completion, and production processes. For drilling, a drill bit is attached to a drill pipe. Blowout prevention equipment, which includes one or more valves that may be closed in case of a loss of control event (along with other emergency equipment), is installed on the well. Mud pumps are configured to pump mud (drilling fluid) from a mud pit into the drill pipe. A derrick is positioned over the well to suspend the drill string and run it into the well.

53. During completion operations, flow lines and valves on the surface are connected to the well to facilitate and control fluid flow into the well and/or tools run into the well. Pumps are connected to the flow lines to pump fluid through the lines and into the well.

54. During production operations, flow lines extending from the well direct the produced fluid through a series of valves to separate it, transport it to separators, tanks, and/or processing equipment.

B. HISTORY OF HYDRAULIC FRACTURING

55. Fracturing the hydrocarbon-bearing formations is a technique that has been used to increase or speed up oil and gas production for nearly as long as oil and gas production has existed. Fracturing methods as early as the 1850s used explosives such as gunpowder ignited by red-hot iron or nitroglycerin "torpedoes."[14] Hydraulic fracturing, in its modern form of pumping liquids and proppants (*e.g.*, sand) into the formation, began in the 1940s using a process developed by Stanolind Oil and used by Halliburton in the mid-continent region. Early hydraulic fracturing in the 1940s and 1950s utilized frac pumps, including those that could operate at approximately 1,500 hp.[15] On March 17, 1949, Stanolind and Haliburton performed the first commercial application of hydraulic fracturing at a location about 12 miles east of Duncan, Oklahoma.[16]

[14] Ex. 1015, Michael Morton, "Unlocking the Earth: A Short History of Hydraulic Fracturing," GEO ExPro, Vol. 10, No. 6, December 2013 (https://geoexpro.com/unlocking-the-earth-a-short-history-of-hydraulic-fracturing/) (last accessed July 17, 2023).

[15] Ex. 1017, Carl T. Montgomery and Michael B. Smith, "Hydraulic Fracturing: History of an Enduring Technology," *Journal of Petroleum Technology* vol. 62 issue 12 p. 26 (Dec. 2010).

[16] Ex. 1016, B.A. Wells & K.L. Wells, "Shooters – A 'Fracking' History," American Oil & Gas Historical Society, available at: https://aoghs.org/technology/hydraulic-fraturing (last accessed November 30, 2023).



56. The expansion of directional and horizontal drilling extended the use of hydraulic fracturing into previously underdeveloped "tight" formations, including shale.[17] In oil and gas exploration, directional drilling is a technique for accessing hydrocarbon-bearing formations (oil and gas formations) that are not located immediately beneath the surface location, or to increase the amount of formation exposed to the wellbore. A tool or process is used to cause the wellbore to deviate from the vertical, allowing it to reach previously inaccessible formation locations, expose more of the hydrocarbon-bearing formation to the wellbore, or drill several wells from a single surface location, such as an offshore platform or a land-based drilling pad. Like most developments in the oil and gas industry, "the early drilling

[17] Ex. 1017, Carl. T. Montgomery & Michael B. Smith, "Hydraulic Fracturing: History of an Enduring Technology," Journal of Petroleum Technology, Vol. 62 Issue 12, pg. 26 (Dec. 2010)).

of directional wells was clearly motivated by economics."[18] It was the offshore fields of California that gave rise to the technology that led to modern directional and horizontal drilling. In the 1930s, directional drilling was being used in the Huntington Beach, California field to reach an offshore oil-bearing formation from a well initiated on an onshore pad.

57. Throughout the 1980s, directional drilling (a technique for accessing hydrocarbon-bearing formations (oil and gas formations) that are not located immediately beneath the surface location, or to increase the amount of formation exposed to the wellbore) increased. Techniques for drilling wells to intersect natural fractures were particularly focused on offshore pads and in the Austin Chalk trend of central Texas. The Austin Chalk is a soft, loosely cemented, and easily pulverized limestone characterized by natural fractures that are oriented primarily vertically. Horizontally deviated wells were drilled into the chalk to intersect several natural fractures, allowing for the transport of hydrocarbons into the wellbore. This was combined with artificial fracturing to increase the flow rate of hydrocarbons into the wellbore.

[18] Ex. 1018, Bourgoyne, A.T., Jr., K.K. Millheim, M.E. Chenevert & F.S. Young Jr. (1986), Applied Drilling Engineering, Society of Petroleum Engineers, pg. 3.



58. Because more formation is exposed to be fractured, horizontal wells use much higher volumes of fracturing fluid and proppant than do vertical wells. This requires the use of more and bigger blending and pumping systems. As discussed by *Sanborn*, pumping systems of 32,000 hp were typically used as early as 2012.[19] Other references, such as *Coli*, suggest that systems of pumps as large as 2,500 hp each, with a total system power of up to 40,000 hp, were used during the

[19] Ex. 1020, U.S. Patent Application Publication No. 2013/0306322 to Sanborn *et al.* entitled "System and Process for Extracting Oil and Gas by Hydraulic Fracturing" ("*Sanborn*"), [0005].

same period (four trailers, each with four 2,500 hp pumps operating in parallel).[20] These pumps are typically triplex or quintuplex positive displacement (plunger) type pumps.[21] Although some fracturing systems have been converted to electric driven pump motors, the large majority of hydraulic pumping systems "are typically mobilized on skids or tractor-trailers and powered using diesel motors."[22] These diesel engines require large amounts of diesel fuel, along with the requisite extra safeguards to address potential safety concerns.[23]

C. TYPES OF PUMPS – FRACTURING PUMP CHAIN

59. The basics of hydraulic fracturing have not changed significantly since 1949, when Halliburton first commercialized the "hydrafrack" process. Hydraulic fracturing still involves pumping water (or another liquid) blended with a proppant (*e.g.*, sand) and other chemicals into the downhole reservoir at a sufficient pressure to crack (fracture) the downhole rock. The sand-water mixture is then forced into the cracks, where the sand keeps the cracks (fractures) open to allow hydrocarbons,

[20] Ex. 1006 (*Coli*), U.S. Patent Publication No. 2012/0255734 to Coli *et al.* entitled "Mobile, Modular, Electrically Powered System for Use in Fracturing Underground Formations," [0049], FIG. 2.
[21] Ex. 1020, (*Sanborn*), at [0005]; Ex. 1006 (*Coli*), at [0011].
[22] Ex. 1006 (*Coli*), at [0005], [0007] ("standard fluid pumps require large volumes of diesel fuel and extensive equipment maintenance programs").
[23] Ex. 1020 (*Sanborn*), at [0007].

such as oil and natural gas, to flow out of the formation into the well bore. What has changed are the pressures and flowrate of the fracturing jobs, the sizes of equipment and the particular proppants, chemicals and liquids used.

60. A modern fracturing process requires multiple pumps, operating together as a system to provide fracturing fluid with the right composition, at the right flow rate, and at a pressure sufficient to fracture the formation. At the beginning of the pumping chain are the water transfer pumps. These pumps operate at a relatively low pressure to move water from the storage location (e.g., ponds, tanks) to the blender or the hydration unit.

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

62. Once the fracturing slurry is blended to the proper makeup and consistency, it is transferred to the fracturing pumps using a blender discharge pump.

This pump typically operates at a higher pressure than the water or chemical transfer pumps, for several reasons. First, the viscosity of the slurry is normally higher than that of water, which requires higher pressures to move the same volume of slurry. Second, the slurry is heavier than plain water, requiring additional horsepower to move the slurry (as compared to plain water). Finally, the large fracturing pumps are piston (or plunger) pumps, requiring a higher suction (input) pressure to ensure a sufficient flow and prevent cavitation, as explained below.

63. One example of a plunger pump commonly used in fracturing is a Gardner Denver "GD-2500Q Quintuplex Well Servicing Pump". Gardner Denver describes the GD-2500Q as a "high horsepower, high rod load multi-purpose pump for various applications such as oil and gas well fracturing and acidizing."[24] Gardner describes that "[t]he GD-2500Q quintuplex pump uses only two major assemblies: power end and fluid end."[25] A "quintuplex"[26] pump has 5 cylinders. In the case of the GD-2500Q, Gardner provides Figure 2.1, which shows the dimensions and key components of the GD02500Q.

[24] Ex. 1010 (Gardner-Denver), pg. 9.
[25] Ex. 1010 (Gardner-Denver), pg. 10.
[26] *See, e.g.*, Ex. 1047, Collin's Dictionary definition of quintuplex "fivefold, quintuple". https://www.collinsdictionary.com/dictionary/english/quintuplex.

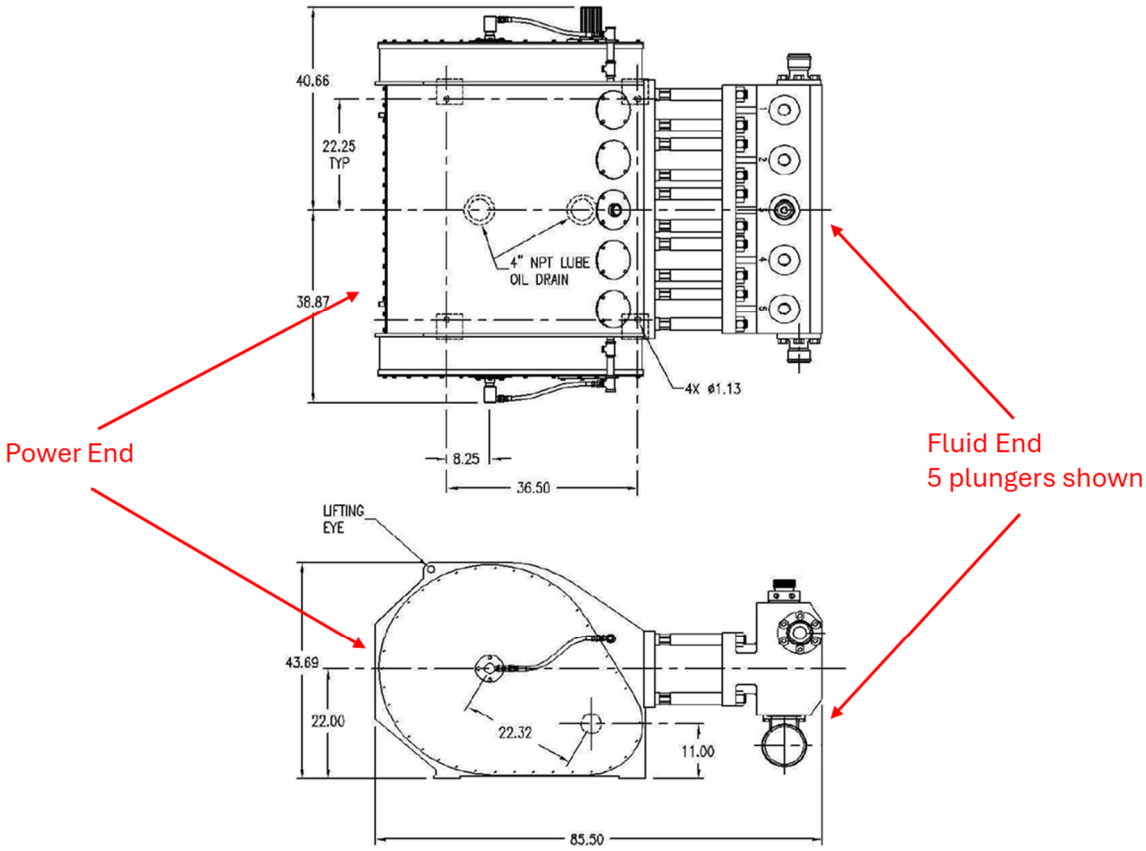


FIGURE 2-1: GD-2500Q Pump

Ex. 1010 (Gardner-Denver) Figure 2.1

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

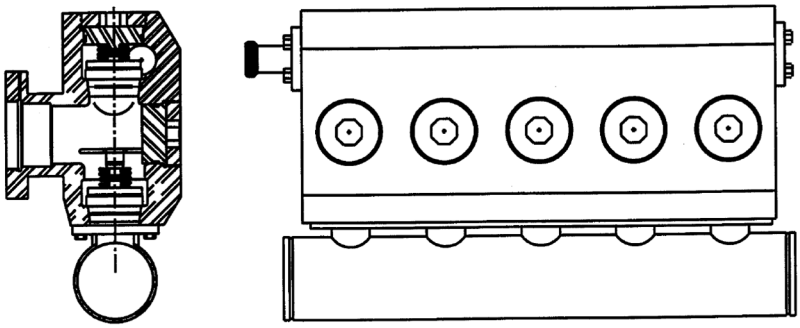


FIGURE 2-5: GD-2500Q Fluid End

64. A key characteristic of this type of fracturing pump is that the same amount of liquid is discharged from the pump with every stroke, largely independent of the pressure downstream. The result is that the flow at a particular pump speed remains relatively constant, while the pressure changes in response to changes in downstream conditions. Accordingly, as fracturing begins, reducing the downstream impedance of the fluid flow system, the pressure tends to drop while the flow rate remains relatively constant. Conversely, pressure rises with a relatively stable flow rate as downstream impedance increases. As a boundary condition, if a valve is closed downstream of a fracturing pump, the flow rate through the pump will remain relatively constant while the pressure rises extremely fast. Pressure will continue to increase until some condition reduces the downstream impedance. This is typically equipment failure, such as pump seals, piping failure, or rupturing of valve bodies.

65. Because the plungers are so large (~5" in diameter with ~8" stroke), a large amount of fluid must flow into the cylinder on each stroke. This tends to lower the suction pressure, as the void of the plunger must be filled by the incoming slurry. If the suction pressure gets too low, then cavitation occurs. Cavitation is a condition in which bubbles form in a liquid because the vapor pressure of the fluid exceeds the suction pressure. When the bubbles collapse, such as when the piston reaches the bottom of its stroke, noise, vibration and damaging forces are created. To avoid cavitation and the associated problems, the suction pressure must be maintained higher than the fluid's vapor pressure of the fluid (e.g., slurry), even during the intake phase of the piston. This is referred to as maintaining a Net Positive Suction Head (NPSH). The amount of NPSH necessary to avoid cavitation depends on several factors, including the suction line design, pump speed, suction valve spring strength, and the temperature and viscosity of the fluid. Gardner teaches several methods to reduce or eliminate cavitation. These techniques include, for example, using a suction stabilizer or pulsation damper, changing the supply line design, and reducing pump speed.[27]

[27] Ex. 1010 (*Gardner-Denver*), pg. 30.

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

D. PUMPING AND CAVITATION

66. Cavitation in pumping, including in positive displacement (e.g., plunger) pumps, has been a well-known problem. Cavitation is described when "the incoming liquid [into a pump] is at a pressure with insufficient margin above the vapour pressure, then vapour cavities or bubbles appear [] [t]his phenomenon is

known as cavitation."[28] Cavitation has at least three negative effects on a pumping system:[29]

> The collapsing cavitation bubbles can erode the vane surface, especially when pumping water-based liquids.
>
> Noise and vibration levels increase, potentially leading to shortened seal and bearing life.
>
> The cavity areas will initially partially block the impeller passages, reducing pump performance. In extreme cases, total loss of pump-developed head occurs.

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

67. *Tutterow* further teaches that "[t]he amount by which the pressure in the pump inlet exceeds the liquid vapour pressure is expressed as a head of liquid and referred to as Net Positive Suction Head Available (NPSHA). This is a characteristic of the system design. The value of NPSH needed at the pump suction to prevent the pump from cavitating is known as NPSH Required (NPSHR)."[30]

[28] Ex. 1057 (*Tutterow*), pg. 20; see also Ex. 1034 (*Mark's Handbook*), pg. 14-2.
[29] Ex. 1057 (*Tutterow*), pg. 20.
[30] Ex. 1057 (*Tutterow*), pg. 20.

68. Further, NPSHR "varies approximately with the square of speed in the same way as pump head."[31] Accordingly, a 10% reduction in pump speed would result in a 19% reduction in NPSHR, and a 10% increase in speed would require a 21% increase in NPSHR. In any given system, reducing pump speed would decrease the risk of cavitation. It follows then that there is a specific speed that would eliminate cavitation for any given pump system. Simply reduce speed until the NPSH required matches or falls below the inlet pressure. It further follows that as speed increases, cavitation increases.

69. With specific regard to PD pumps, "a PD pump needs the incoming liquid to have a pressure margin above liquid vapour pressure to prevent cavitation within the suction passages or pumping chamber."[32] PD pumps also have an additional problem outlined by *Tutterow*:[33]

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

[31] Ex. 1057 (*Tutterow*), pg. 21.
[32] Ex. 1057 (*Tutterow*), pg. 30.
[33] Ex. 1057 (*Tutterow*), pg. 30.

> If the speed is increased, this filling process becomes more problematical, limiting the maximum speed. With viscous liquids, [such as fracturing fluid] the effect is more severe.

70. *Langewis* describes the use of positive displacement pumps to inject produced water into the formation in a waterflood oil & gas operation. The pumps described in *Langewis* are very similar in design and function to those used in hydraulic fracturing. *Langewis* describes "Net positive suction head (NPSH) is defined as the head, in feet of liquid above vapor pressure, required at the suction inlet of the pump to completely fill each cylinder on the suction stroke."[34] *Langewis* further describes NPSH required mathematically:

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

71. H_g represents "minimum pressure required for acceptable pump performance". Further, *Langewis* teaches that "[t]he value of H_g should be obtained from the pump manufacturer. This term is a function of the diameter of the plunger, *speed of the pump*, type of valve used, valve-spring load and tolerance of the equipment. therefore, all pump manufacturers should have this value for their pumps."[35]

[34] Ex. 1058 (*Langewis*), pg. 174.
[35] Ex. 1058 (*Langewis*), pgs. 174-175.

72. The maximum speed of operation of a positive displacement pump to prevent cavitation is the lower of the speed that keeps NPSHR below NPSHA and the speed that allows sufficient time for the cylinders to fill, based on the NPSHA being completely filled.

E. SIMULTANEOUS OR SEQUENTIAL FRACTURING (SIMULFRAC OR ZIPPER FRAC)

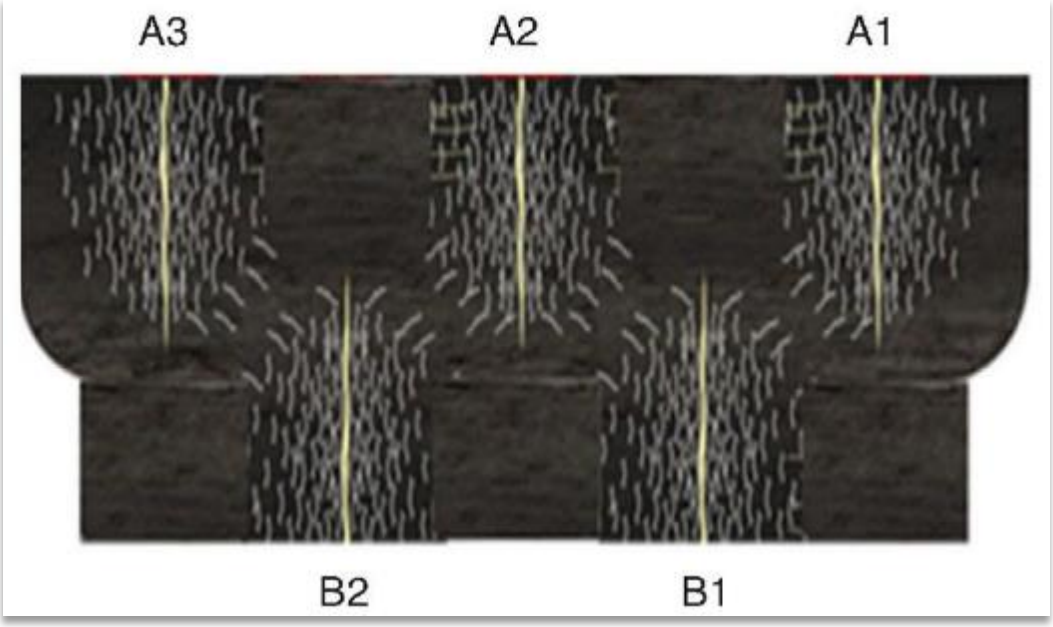
73. For most of the history of hydraulic fracturing, fracturing technology advances have largely been geared towards advancements in chemicals (such as the development of corrosion inhibitors, gels, and slickwater fracing), proppants, and increasing flow and pressure in fracturing operations. The goal, as always, was to create fractures that expose the hydrocarbon-bearing formation to the wellbore, allowing the hydrocarbons to flow into the wellbore. For most of its history, hydraulic fracturing has been performed one well at a time, potentially with several stages (zones) being fractured in a single well. With the increased popularity of horizontal drilling in the 1990s and 2000s, the number of fracturing stages in a well increased dramatically as the "pay zone" (the hydrocarbon-bearing formation) in which the well is exposed increased from tens to hundreds of feet to several thousand feet.

74. In the mid-2000s, operators began experimenting with and then using a technique dubbed "zipper fracturing," in which multiple wells, closely spaced in the

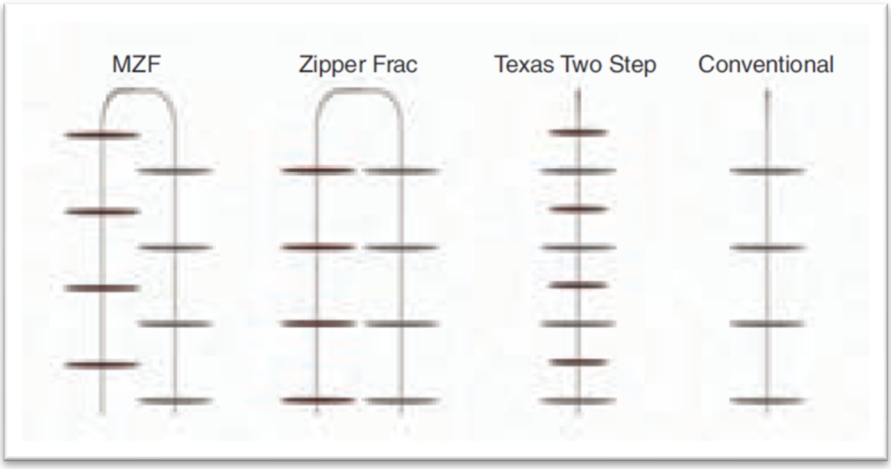
formation and often drilled from the same pad, were fractured simultaneously or sequentially. The result was that the fractures formed in one well were affected by the pressures and fractures in another well, leading to so-called "zipper fractures" that were longer, multidirectional, and exposed more formation to the wellbores than single well fracturing produced.

75. The image below was captured from *Jacobs*[36] and demonstrates the impact that simultaneous or sequential fracturing has on the fractures induced by wells. For the fractures nearest the wellbores, the fractures show a typical pattern of being aligned with the perforations, as shown in the figure below, where A1-A3 are perforations and associated fractures from a first horizontal wellbore, and B1-B2 are the perforations/fractures from a second parallel wellbore. However, for those fractures that are near other wellbores, the fracture lengthens and turns, creating a zipper-like pattern to the fracture. This exposes more of the formation to the wellbore, allowing for earlier and more complete recovery of hydrocarbons from the formation.

[36] Ex. 1048, Jacobs, Trent. "The Shale Evolution: Zipper Fracture Takes Hold," J Pet Technol 66 (2014): 60–67. doi: https://doi.org/10.2118/1014-0060-JPT.



76. The figure below (with the wellbores represented vertically) from *Jacobs* shows various types of fracturing configurations beginning with conventional fracing (to the right) and ending with modified zipper fracturing (MZF) on the left. The changes in location of the perforation and fracturing operations are intended to increase the development of zipper fractures and expand the interface with the hydrocarbon-bearing formation.



Ex. 1022 (*Waters*), at 5.

77. As described by *Waters*, the process for developing zipper fractures involves maintaining pressure in the formation from one wellbore while initiating fractures by pressuring up a proximate wellbore. "In ultra-low permeability reservoirs such as shales, the stimulations do not necessarily have to occur concurrently. Since there is little to no fluid leakoff into the rock matrix, the fracture systems will remain pressurized until they are flown back. This pressurized system can provide the diversion [zipper fracture] desired when the adjacent lateral is stimulated subsequent to the initial stimulation."[37]

[37] Ex. 1022, Waters, George, Dean, Barry, Downie, Robert, Kerrihard, Ken, Austbo, Lance, and Bruce McPherson. "Simultaneous Hydraulic Fracturing of Adjacent Horizontal Wells in the Woodford Shale." Paper presented at the SPE Hydraulic Fracturing Technology Conference, The Woodlands, Texas, January 2009. doi: https://doi.org/10.2118/119635-MS, p. 8.

78. This allows one well stage to be pressurized and shut in (such as with a plug or a ball seal), then an adjacent well stage to be pressurized and gain the benefits of the stress induced by the other pressurized well. This has advantages not only for the development of fractures downhole but also for operational benefits. As *Waters* states below, one fracturing crew and one perforating crew can treat multiple wells simultaneously or in an alternating arrangement, allowing for faster completion of the fracturing process.[38]

- This "Zipper-Frac" method provides some significant operational efficiencies:
  - When two wells drilled from the same pad are being stimulated only one stimulation crew and perforating crew is required. While the fracturing crew is stimulating one well, the perforating crew is setting the frac plug and perforating the adjacent wellbore. The two crews continue to work back and forth between the two wells to efficiently complete them in a timely manner.
  - If more than two wells are being stimulated at the same time then a completion sequence can be developed to most effectively create a dense fracture network throughout the acreage. For example, if four laterals are being stimulated with two crews the outer wells can be stimulated first, followed by the inner wells where a more dense fracture pattern can be created. The treatment sizes can be adjusted based on the order in which the wells are stimulated. The completion sequence utilized will be a function of the well spacing, the structural geology, surface logistics, and the desire for hydraulic fracture density versus fracture length.

79. The advantages of zipper fractures have been known for decades, as demonstrated by Pearson in an article published in the Journal of Petroleum Technology in 1992.[39] While not directly discussing the simultaneous or alternating

[38] Ex. 1022 (*Waters*), at pg. 8.

[39] Ex. 1023, Pearson, C.M., Bond, A.J., Eck, M.E., and J.H. Schmidt. "Results of Stress-Oriented and Aligned Perforating in Fracturing Deviated Wells." J Pet Technol 44 (1992): 10–18. doi: https://doi.org/10.2118/22836-PA.

process, *Pearson* does discuss the results of such a process. "This paper reports the first results of stress-oriented and aligned perforating of deviated wells at the Kuparuk River field, Alaska. Preferred perforation alignment and spacing are calculated for each well so the fractures from individual perforations link to produce a single 'zipper' fracture plane along the deviated [horizontal] wellbore."[40] *Pearson* further states that "[d]uring the past 7 years [before 1992], more than 600 new development wells have been fracture stimulated in the Kapurak River field. The large number of treatments has provided the opportunity for significant advances in the technical and operational aspects of hydraulically fracturing deviated wells."[41]

80. The Zipper-frac process (alternating perforations and pressurization of adjacent wells) has been well-known in the industry since at least 2008, particularly to those operators and fracturing companies operating in Shale regions such as the Barnett, Woodford and Marcellus shale formations. This contributes to the general engineering knowledge that a fracturing designer (engineer) had when planning operations of fracturing systems. *Waters* is one example of the well-documented nature of this process, dating back to 2008.

[40] Ex. 1023 (*Pearson*), at Summary.
[41] Ex. 1023 (*Pearson*), at Introduction.

81. Another example of the well-known nature of the zipper-frac process in shale producing regions is *Mutalik,* a paper published by the SPE in 2008.[42] *Mutalik* discusses multiple case studies of wells using a "simo-frac" process to create more effective downhole formation fractures in the Barnett Shale. "In this paper, the case history of sequential and simultaneous fracturing of four similarly drilled and completed horizontal azimuth wells in Eastern Parker County is discussed."[43] *Mutalik* further describes:[44]

> Simultaneous fracturing (simo-fracs) of paired offset wells is one of the recent trends in Barnett fracturing and is being increasingly used by many operators. In this technique, two or more adjacent wells that are roughly parallel to each other are fractured simultaneously. The goal is to expose the shale to more pressure and produce a more complex, "three-dimensional web" of fractures by increasing the density of the hydraulic fracture network and increasing the surface area created by the frac job.

Mutalik describes the operational benefits of a simultaneous frac process. "Simo-fracs [are] expensive and require[] much more coordination and logistics and a larger location. At the same time, they are cost-effective as the fracturing equipment is being utilized more efficiently and two wells are being completed in one week

[42] Ex. 1024, Mutalik, P N, and Bob Gibson. "Case History of Sequential and Simultaneous Fracturing of the Barnett Shale in Parker County." Paper presented at the SPE Annual Technical Conference and Exhibition, Denver, Colorado, USA, September 2008. doi: https://doi.org/10.2118/116124-MS.
[43] Ex. 1024, (*Mutalik*), at Abstract.
[44] Ex. 1024, (*Mutalik*), at Background.

instead of two weeks."[45] Mutalik further teaches that, as of 2008, "simultaneous fracturing operators are now experimenting with triple fracs ('trifectas') or even quad-fracs in some cases.[46]

82. In addition to the above references, *Mayerhofer*[47] and *Rousell*[48] provide more information of the advantages and benefits of such a process. For example, *Mayerhofer* discusses "it may be more beneficial to drill laterals at closer spacing, with the chance of overlapping SRV's" (Stimulated Reservoir Volume).[49] This is the reason for the so-called "simul-fracs" and "zipper-fracs" in shale reservoirs where multiple parallel wellbores are either stimulated simultaneously or in short alternating sequence from one lateral to the next."[50]

83. *Rousell* teaches that "[t]he numerical calculation of the fracture spacing required to avoid fracture deviation during propagation, for all three fracturing techniques, demonstrate the potential advantages of alternate fracture sequencing

[45] Ex. 1024 (*Mutaik*), at Background.
[46] Ex. 1024 (*Mutaik*), at Background.
[47] Ex. 1025, Mayerhofer, M. J., Lolon, E. P., Warpinski, N. R., Cipolla, C. L., Walser, D., and C. M. Rightmire. "What is Stimulated Reservoir Volume (SRV)?" Paper presented at the SPE Shale Gas Production Conference, Fort Worth, Texas, USA, November 2008. doi: https://doi.org/10.2118/119890-MS.
[48] Ex. 1026, Roussel, Nicolas P., and Mukul M. Sharma. "Optimizing Fracture Spacing and Sequencing in Horizontal-Well Fracturing." SPE Prod & Oper 26 (2011): 173–184. doi: https://doi.org/10.2118/127986-PA.
[49] Ex. 1025 (*Mayerhofer*), at pg. 12.
[50] Ex. 1025 (*Mayerhofer*), at pg. 12.

and zipper-fracs to improve the performance of stimulation treatments in horizontal wells. …. Simultaneous fracturing of two or more parallel adjacent wells, also referred to as simul-fracs or zipper-fracs, aim to generate a more complex fracture network in the reservoir."[51]

84. By at least 2014, the use of the zipper-frac process was widespread in hydraulic fracturing operations. As described by *Jacobs*:

> A horizontal well completion method known as zipper fracturing has been rapidly adopted over the last couple of years by companies in the Eagle Ford shale of south Texas. Instead of drilling and hydraulically fracturing one well at a time, the zipper method involves drilling multiple wells from a pad site and then hydraulically fracturing a stage in one well, while getting ready for the next, as wireline and perforation operations take place in another. The multiwell completion method earns its name from the zipper-like configuration of the fracture stages from wells drilled with relatively tight spacing.

Jacobs at 1. In addition to discussing the production and operational benefits of such a process, *Jacobs* examines the prevalence of this process by 2014. For example, by 2014, nearly half of Schlumberger's completions in North America were completed with the zipper-fracturing method and "in less than 3 years, the proportion of zipper-fracturing completions … in the Eagle Ford shale of Texas…increased threefold to 85%."[52]

[51] Ex. 1026 (*Rousell*), at pg. 1.
[52] Ex. 1048 (*Jacobs*), at pg. 3.

F. TURBINE GENERATORS ON FRACTURING SITES

85. A gas turbine generator (GTG) is a well-known configuration for producing electric energy from natural gas. To begin, a generator is an electrical machine that converts mechanical rotational energy into electrical 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.

86. 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 features turbine blades that rotate 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.

87. The first gas turbine (GT) generator installation was at the Oklahoma Gas & Electric Bell Isle Generating Station. This gas turbine generator, manufactured by GE, had a capacity of 3,500 kW. The GT used for the Bell Isle installation was derived from a portable, locomotive gas turbine, which was also used in "early aircraft gas turbine practice." 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. 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. From 1966 to 1976 (representing a span of only 10 years of that period), GE installed 1,428 of the GT generators across the U.S.[53]

88. Another example of a gas turbine's early usage was the Pratt & Whitney FT4 gas turbines used on the MTS *ADM Callaghan*. By 1969, these FT4 gas turbines

[53] Ex. 1030, 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

"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… "[54]

89. The LM-2500, offered by GE at least since 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. I have extensive experience with GE CF-6 aeroderivative gas turbine generators, having served as the 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.

90. 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+.[55] A picture of the TM2500+ from General Electric is shown below:[56]

[54] Ex. 1051 (*Callaghan)*.
[55] Ex. 1032, GE Power & Water, *Power Generation Products*, https://web.archive.org/web/20140717214839/https://www.ge-distributedpower.com/products/power-generation
[56] Ex. 1033, GE Power & Water, TM2500+ Aeroderivative Mobile Gas Turbine Brochure, available at: https://web.archive.org/web/20140717215045/https://www.ge-distributedpower.com/component/cck/?task=download&file=seb_media_document&id=13183



Among the target applications for the TM2500+ turbine was to generate electricity for "Oil and Gas Mining" in areas with "Limited or no access to the electrical grid."[57]

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: • Lack of robust transmission and distribution network • Delayed grid access • Remote, islanded and mobile operations	Oil and Gas Mining General industry Power generation	**Speed, Mobility, and Reliability** Can deliver power where and when it is needed and bring power online within 10 minutes to stabilize the grid

[57] Ex. 1033, GE TM2500+ Aeroderivative Mobile Gas Turbine Brochure, available at: https://web.archive.org/web/20140717215045/https://www.ge-distributedpower.com/component/cck/?task=download&file=seb_media_document&id=13183

91. The use of gas turbine generators in oil and gas exploration and production operations, including hydraulic fracturing (fracing), was well known even before the 2014 date of the GE TM2500+ websites, long before the priority dates of the Asserted Patents. As one example, while employed as manager of electric infrastructure by New Dominion LLC, an exploration and production company, from 2000 to 2002, I investigated the use of SOLAR brand gas turbines to support drilling, exploration, and production operations, including hydraulic fracturing, in central Oklahoma fields.[58] 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 the expansion of the electric infrastructure made exploration and production in some regions 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.[59] "Solar Turbomachinery" was a specific remote

[58] Ex. 1035, a brochure of Solar Turbines *Turbomachinery Systems for Oil and gas Applications* advertising the "transportability" of its natural gas turbines from 2006 can be found here:
https://web.archive.org/web/20061102043710/http://mysolar.cat.com/cda/files/127587/7/bo&g.pdf

[59] Ex. 1036, Solar Turbines – Titan 130 Generation Set, available at:
https://web.archive.org/web/20060318215809/http://mysolar.cat.com/cda/layout?m=36056&x=7

single-trailer generation design introduced in 1987 for the oil and gas industry, which has sold over 2,000 units with more than 30 million total operating hours.[60] Although at New Dominion, negotiations with the utility company eventually made the decision to purchase and operate a generator less desirable, the use of a GTG for oil and gas operations was well known by at least 2000, and long before. These included many examples of "mobile" or "trailer-mounted" gas turbine generators, including those manufactured by SOLAR Turbine.

92. By 2006, SOLAR sold "Gas Turbine Packages" that included Compressor Sets, Mechanical Drives, and Generator Sets.[61]

93. As another example, U.S. Patent Pub. No. 2012/0255734 to Todd Coli and Eldon Schelske was filed April 6, 2012, based on an application earlier filed on April 7, 2011. The Abstract 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.

[60] Ex. 1049, Turbines: Solar Mobile Turbomachinery, available at: https://www.solarturbines.com/en_US/solutions/oil-and-gas/solar-mobile-turbomachinery.html.

[61] Ex. 1037, Solar Turbines – Gas Turbine Products for the Oil and Gas Industry, available at: https://web.archive.org/web/20060712013257/http://mysolar.cat.com/cda/layout?m=35881&x=7

"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."[62] *Coli* at ¶[0044]. By March 2013, the technology had already been deployed in the field and was described in trade journals. According to the March 2013 *Oilweek*:

> Calgary-based Evolution Well Services had 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.

Eldon Schelske was interviewed in the article and described turbine generators as a known technology. He explained to *Oilweek* 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." He based the idea of using natural-gas fueled electric power from "system[s] for offshore oil and gas development." 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."

[62] Ex. 1038 (*Coli*), [0044].

94. A POSITA would have been motivated to use turbine generators for on-site electrical power in an electrical fracturing site because turbine generators are one of two choices available for local generation, such as at an oil and gas field or fracturing site. The other choice is a reciprocating engine. Reciprocating engines operate in the same manner as a typical car engine. A number of pistons are connected on a shaft so that the linear motion of the piston is converted to rotational motion of the shaft, and vice versa.

95. Both a turbine generator and a reciprocating generator have their advantages and disadvantages. The selection of which particular engine to use is an engineering design choice based on the relative merits of each option and the specific characteristics of the system being powered.

Turbine	Reciprocating Engine
More efficient at high loads	More efficient at low loads
Lighter	Simpler
More compact	Less Expensive
Faster startup	Requires more maintenance
Easier to transport	Designed for a single fuel
Higher power in a single package (trailer)	
Fuel flexible	

96. As one example, turbine generators were known to operate on multiple fuels in the same installation, without extensive modification, such as those I was involved in installing in the early 2000s. Reciprocating engines are typically run on liquid fuels, such as diesel. This type of generating system is often referred to as

"diesel generators." In the vast majority of applications, gas turbine generators are run on natural gas due to its availability, cleanliness (operationally, inside the turbine, and environmentally), and lower cost compared to diesel fuel.

XII. OVERVIEW OF THE PRIOR ART

A. CICCI (EX. 1004)

97. *Cicci* refers to United States Patent 11,549,348, which was filed on November 20, 2020, and issued on January 10, 2023.[63] *Cicci* claims priority to U.S. Provisional Application No. 62/941,459 ("*Cicci Provisional*") (Ex. 1005) filed on November 27, 2019. All of the portions of *Cicci* relied on in my declaration are supported by disclosures in *Cicci Provisional*. Accordingly, I understand *Cicci* to be prior art to the '420 Patent.

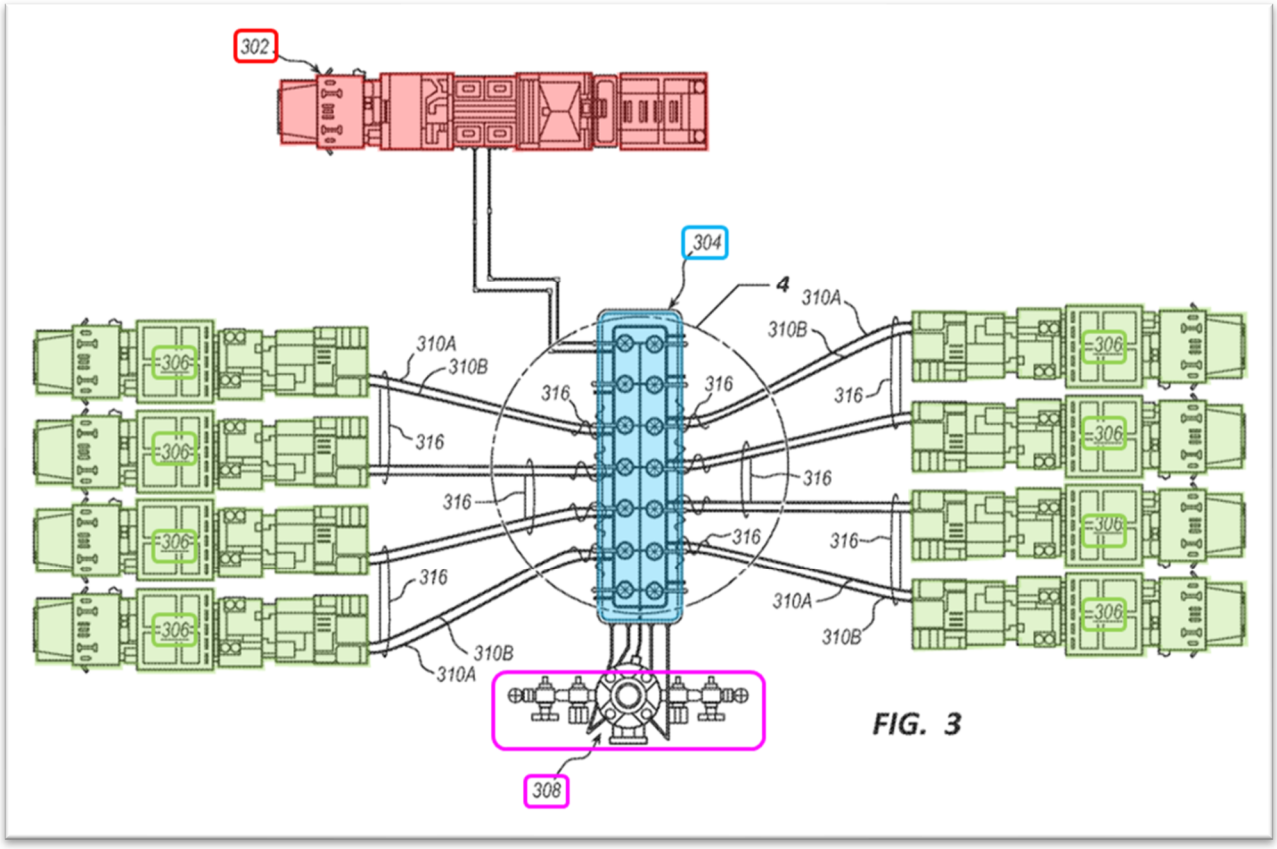
98. *Cicci* describes "a hydraulic fracturing system using flexible hose or pipe".[64] The flexible pipe provides coupling between "a pump and a manifold of the hydraulic fracturing system."[65] *Cicci* also discloses "a fitting affixed to each end of the flexible flow line" for connection to the fluid source (manifold) and the pump.[66] *Cicci* further discloses that the "flexible hose can be connected to the pump

[63] Ex. 1004 (*Cicci*), Cover.
[64] Ex. 1004 (*Cicci*), at Abstract; Ex. 1005 (*Cicci Provisional*), [1], [15].
[65] Ex. 1004 (*Cicci*), at Abstract; Ex. 1005 (Cicci Provisional), [2], [15]-[16].
[66] *See, e.g.*, Ex. 1004 (*Cicci*), 5:30–37; Ex. 1005 (*Cicci Provisional*), [24].

connections by any number of connection methods currently known or developed in the future, including [] wings on a threaded connection, such as a hammer union."[67] *Cicci*'s flexible hoses have "an inner diameter of one to eight inches."[68]

99. *Cicci* discloses blender 302 [highlighted in red] that receives the fracturing fluid and blends it into a slurry.[69] *Cicci* further discloses that "[t]he pumps 306 [highlighted in green] deliver the pressurized fracturing fluid to the missile 304 [highlighted in blue]. The missile 304 then delivers the pressurized fracturing fluid to the wellhead 308 [highlighted in magenta], which routes the fluid into the steel casing in the wellbore (not shown)."[70]

[67] Ex. 1004 (*Cicci*), 7:40-47; Ex. 1005 (*Cicci Provisional*), [30].
[68] Ex. 1004 (*Cicci*), 1:64-65; Ex. 1005 (*Cicci Provisional*), [4].
[69] Ex. 1004 (*Cicci*), 5:14-29; Ex. 1005 (*Cicci Provisional*), [23].
[70] Ex. 1004 (*Cicci*), 5:25-40; Ex. 1005 (*Cicci Provisional*), [23]; *see also* Ex. 1004 (*Cicci*), 1:9-19; Ex. 1005 (*Cicci Provisional*), [1].



Ex. 1004 (*Cicci*), Fig. 3; Ex. 1005 (*Cicci Provisional*), Fig 3 (annotated).

B. COLI (EX. 1006)

100. U.S. Patent Application Publication No. 2012/0255734 by Coli ("*Coli*") was filed on April 6, 2012, and published on October 11, 2012. It claims priority to Provisional Application No. 61/472,861, filed on April 7, 2011.[71] The publication of *Coli* as well as the claimed priority date of *Coli* thus predates the claimed priority date of the Challenged Patent.

[71] Ex. 1006 (*Coli*), Cover.

101. Like the Challenged Patent and *Cicci*, *Coli* involves a "fracturing system" for "delivering fracturing fluid to a wellbore at a fracturing operation."[72] *Coli* further discloses how the electrification of the fracturing operation improves costs,[73] efficiency,[74] safety,[75] and environmental impact.[76] For example, *Coli* discloses the use of natural-gas-powered turbines to generate electricity, which in turn powers electric motors for driving the pumps.[77] 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."[78] 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."[79] Thus, "the number of fracturing modules 20 placed on each trailer 10" is "maximized."[80]

[72] Ex. 1006 (*Coli*), [0034].
[73] Ex. 1006 (*Coli*), [0075].
[74] Ex. 1006 (*Coli*), [0077].
[75] Ex. 1006 (*Coli*), [0066].
[76] Ex. 1006 (*Coli*), [0080].
[77] Ex. 1006 (*Coli*), [0042].
[78] Ex. 1006 (*Coli*), Abstract.
[79] Ex. 1006 (*Coli*), [0049].
[80] Ex. 1006 (*Coli*), [0052].

102. *Coli* further discloses that "[t]he electric motor can be capable of operation in the range of up to 1500 rpm and up to 20,000 [ft-lbs][81] of torque."[82] In addition, "[e]lectric motors controlled via variable frequency drive are far safer and easier to control than conventional diesel powered equipment."[83]

103. *Coli* discloses that the "pump is a quintiplex [quintuplex] or triplex plunger style pump, for example, the SWGS-2500 Well Service Pump sold by Gardner Denver, Inc.," and the "system can deliver a true 2500 hp directly to each pump 22."[84]

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

---

[81] The unit of torque is ft-lb. 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) are 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".

[82] Ex. 1006 (*Coli*), [0011].

[83] Ex. 1006 (*Coli*), [0066].

[84] Ex. 1006 (*Coli*) [0046], [0049]. I understand the Gardner Denver "SWGS-2500" well service pump to be a GD-2500Q power end with a "Super GWS Fluid End", and that "SWGS" is a typo in *Coli* and should be "SGWS".

C. *LIU* (Ex. 1007)

105. *Liu* refers to Pipeline Engineering, by Henry Liu, a textbook published by Lewis Publishers, a CRC Press Company, in 2003. *Liu* bears a copyright date of 2003. CRC Press is a publisher that publishes scientific and technical books.[85] Based on this, I understand that *Liu* would have been publicly available by at least 2003. I have also reviewed the declaration of Dr. Sylvia Hall-Ellis, which confirms that *Liu* was accessible to the public and indexed at the library by at least September 9, 2003, and accordingly would have been searchable and obtainable by the public by at least September 9, 2003.[86] This is consistent with the 2003 copyright date on the face of *Liu*. *Liu* therefore qualifies as prior art as a printed publication to the '420 Patent.

106. *Liu* contains well-known scientific principles regarding the flow of fluids, including slurries, through pipelines. *Liu* describes a "pipeline" as being a "common technology or a single transportation mode that has different applications".[87] *Liu* contains both a "review of fluid mechanics pertinent to pipe

[85] Ex. 1039 (CRC Press Books), About Us, available at https://www.routledge.com/corporate/about-us/crc-press?srsltid=AfmBOoo4LdrPswlrDh199mp0iAWleSZK26v7xZFamobLss_WyPVplVts.
[86] Ex. 1014 (Declaration of Dr. Hall-Ellis), at ¶¶14, 41-49.
[87] Ex. 1007 (*Liu*), Preface.

flow" as well as "more advanced subjects," including "flow of solid/liquid mixtures" (i.e., slurries).[88]

107. Chapter 5 of *Liu* discusses the flow of solid particles transported by a liquid in pipelines, namely slurry pipelines,"[89] and focuses on "horizontal or nearly horizontal pipes with particles suspended by a liquid." This describes piping systems used in hydraulic fracturing nearly perfectly, where slurries are used regularly (such as proppant carried by water with other chemicals), and the piping system is horizontal or nearly horizontal on the surface.

D. *KAJARIA* (EX. 1008)

108. U.S. Patent No. 9,127,545 to Kajaria (Ex. 1008) ("*Kajaria*") was filed on April 25, 2013, and issued on September 8, 2015.[90] *Kajaria* claims priority to a provisional application No. 61/638,818, filed on April 26, 2012.[91] *Kajaria* accordingly qualifies as prior art under 35 U.S.C. § 102(a)(1)-(2).

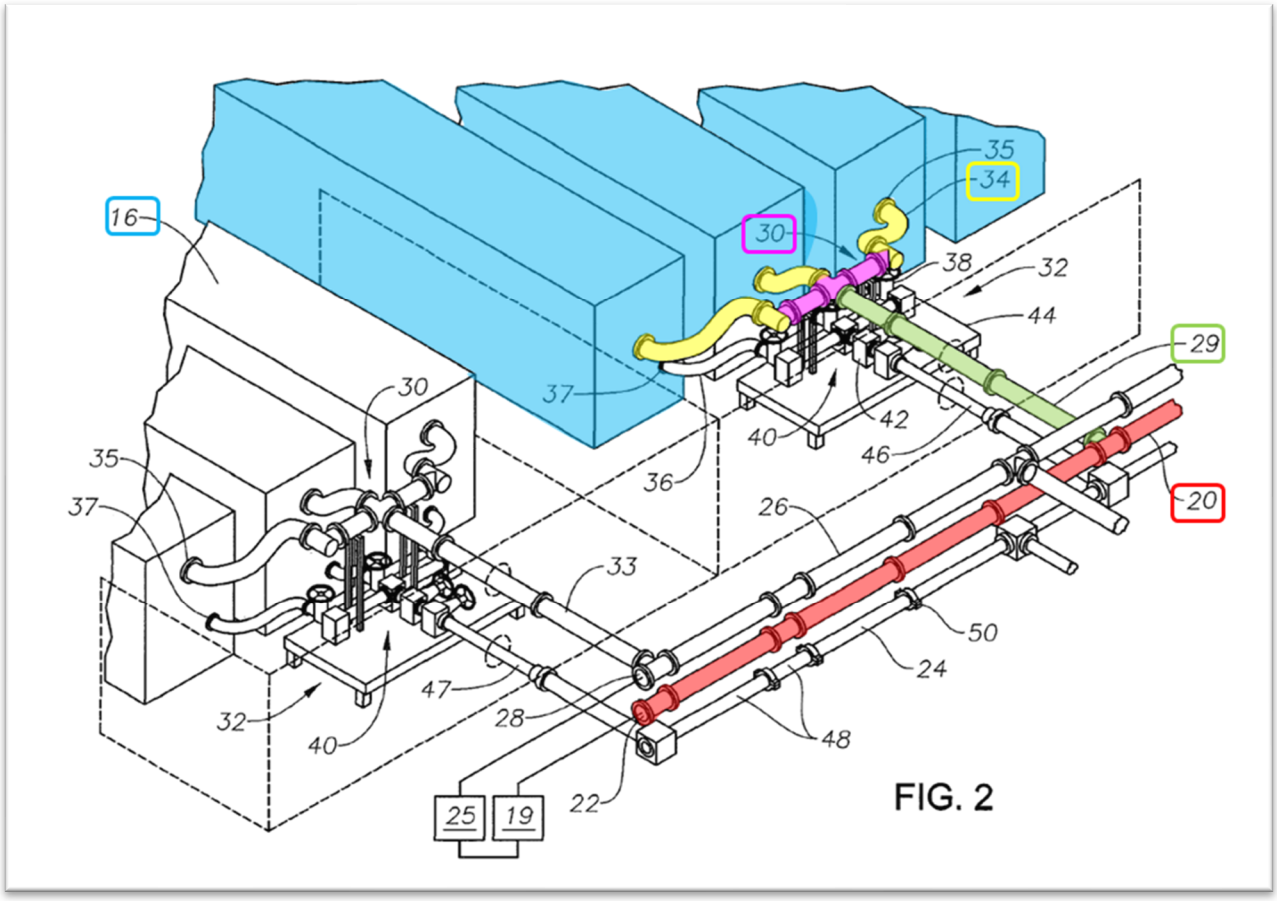
109. *Kajaria* discloses a hydraulic fracturing system for pumping fluid into a wellbore that includes "a tank or other source of low-pressure fracturing fluid, a slurry blender, a plurality of high-pressure, high volume fracturing pumps, and

[88] Ex. 1007 (*Liu*), Preface.
[89] Ex. 1007 (*Liu*), pg. 131.
[90] Ex. 1008 (*Kajaria*), Cover at (22), (45).
[91] Ex. 1008 (*Kajaria*), (60).

various hoses and pipelines to direct the flow of the fracturing fluid to the wellbore."[92]

110. *Kajaria* discloses that "slurry is conveyed to the pump trucks 16 [blue] by way of a slurry pipeline or first low-pressure pipeline 20 [red]."[93] *Kajaria* further discloses "the slurry travels from first low-pressure pipeline 20 to truck slurry supply branch 29 [green]," which is "in fluid communication with a distribution junction 30 [magenta]."[94] *Kajaria*'s "distribution junction 30 is in fluid communication with multiple truck connection lines 34 [yellow] and divides the slurry flowing in truck slurry supply branch 29 between the truck connection lines 34."[95] *Kajaria*'s truck connection line "may be, for example, either a flexible flow line or a rigid pipeline."[96]

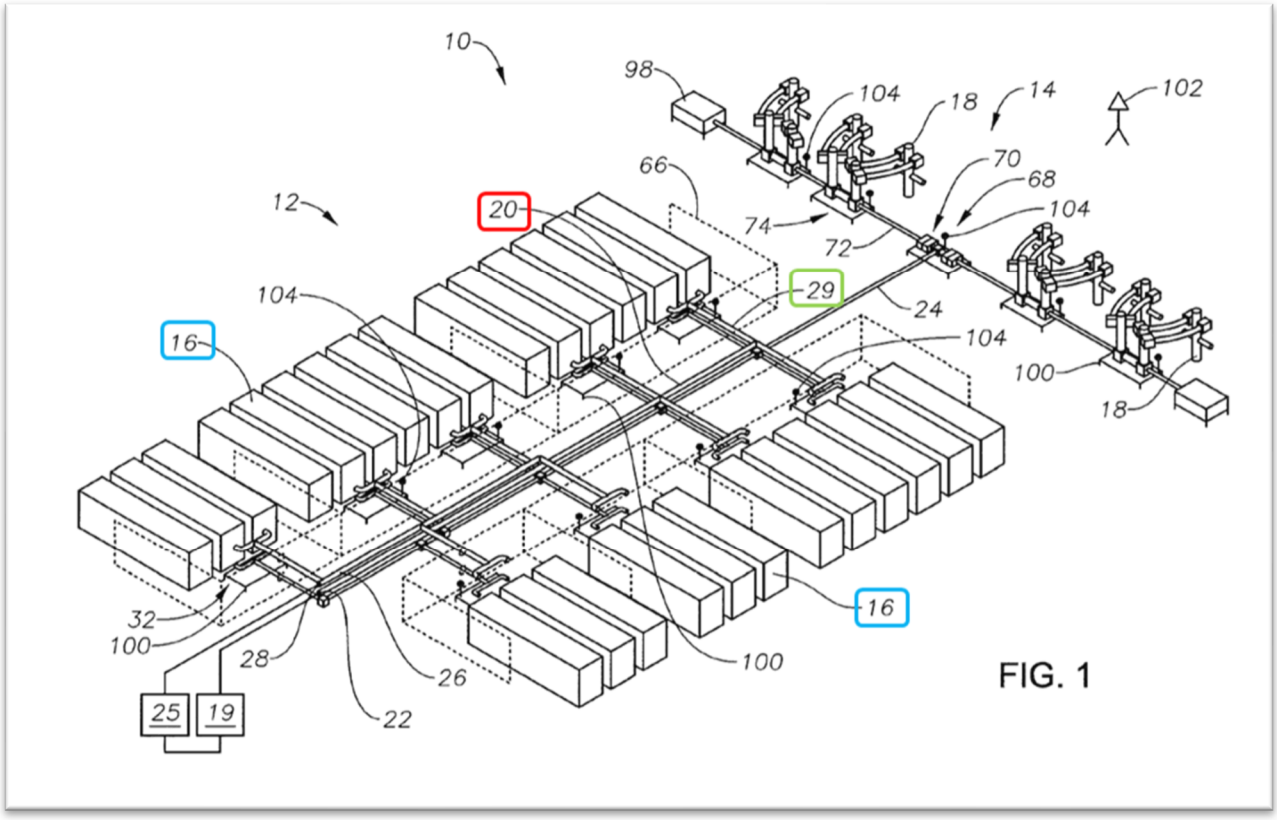
[92] Ex. 1008 (*Kajaria*), 1:19-31.
[93] Ex. 1008 (*Kajaria*), 4:16-18.
[94] Ex. 1008 (*Kajaria*), 4:30-33.
[95] Ex. 1008 (*Kajaria*), 4:37-45.
[96] Ex. 1008 (*Kajaria*), 4:37-45.



Id., Fig. 2 (annotated).

111. Additionally, *Kajaria* discloses connecting to the inlet of a plurality of pumps from a single line connected to the fluid source 20.[97] Although Fig. 2 shows the connection to three pump inlets, other examples are also disclosed, including the connection to two pump inlets from a single line.[98]

[97] Ex. 1008 (*Kajaria*), 1:19-31, 4:16-45, Figs. 1-2.
[98] Ex. 1008 (*Kajaria*), Figs. 1-2.



Ex. 1008 (*Kajaria*), Fig. 1 (annotated).

E. ***DIXON CATALOGS*** **(EX. 1009 & EX. 1012)**

112. *Dixon-Australia* (Ex. 1009) and *Dixon-U.S. (Ex. 1012)* are two publicly accessible product catalogs that were available by at least 2018. Since the product catalogs contain largely the same information for the purposes of my analysis, I will refer to them collectively as simply "Dixon," unless I specify otherwise.

113. *Dixon-Australia* (Ex. 1009) is a product catalog by Dixon for the Australian market that is and has been publicly available on the Dixon website since at least 2018.[99]

114. *Dixon* is publicly available on the Dixon website since at least 2018.[100] The Dixon website lists "Publish Date: October 4, 2018" for the catalog[101]:



This is consistent with the indicia in the catalog itself. For example, the catalog lists a copyright date of "Copyright 2018 by Dixon Valve and Coupling."[102] The catalog is also labeled "ADPL718" in the top right of its cover page, indicating that it would

[99] Ex. 1040 (Dixon Product Literature website), available at https://australia.dixonvalve.com/en/knowledge-center/references-and-education/product-literature), pg. 7; Ex. 1013 (Langenfelder Declaration), ¶¶4-5, 10.
[100] Ex. 1040 (Dixon Product Literature website), pg. 7.
[101] Ex. 1040 (Dixon Product Literature website), pg. 7.
[102] Ex. 1009 (*Dixon-Australia*), pg. 667.

have been made available to the public by July 2018 based on Dixon's numbering convention.[103] The catalog also lists "New Products for 2018."[104] Based on this information, I understand that *Dixon-Australia* would have been publicly accessible by at least October 2018.[105] It is therefore my understanding that *Dixon-Australia* qualifies as prior art to the '420 Patent.

115. *Dixon-U.S.* (Ex. 1012) is a product catalog by Dixon for the U.S. market that was publicly accessible on the Dixon website by at least April 2018.[106] I understand that *Dixon-U.S.* was publicly available on Dixon's website by April 2018.[107] To locate a copy of this catalog, I understand that a member of the public would navigate to the "Product Literature" page of Dixon's website, see a list of Dixon's product literature, be able to search in the "Search" field, and/or be able to filter by product category in the "Product Category" field.[108] I understand that Dixon also distributed almost 1,000 copies of *Dixon-U.S.* to its distributors in 2018.[109] I

[103] Ex. 1009 (*Dixon-Australia*), pg. 667.
[104] Ex. 1009 (*Dixon-Australia*), pg. 10.
[105] Ex. 1013 (Langenfelder Declaration), ¶10.
[106] Ex. 1013 (Langenfelder Declaration), ¶¶4-5, 10.
[107] Ex. 1013 (Langenfelder Declaration), ¶5.
[108] Ex. 1013 (Langenfelder Declaration), ¶6.
[109] Ex. 1013 (Langenfelder Declaration), ¶5.

also understand that a member of the public could also request a copy of this catalog by mail through the Dixon website.[110]

116. This is also consistent with the indicia on the catalog itself. For example, the catalog lists a copyright date of "Copyright 2018 by Dixon Valve and Coupling."[111] The catalog similarly lists "New Products for 2018."[112] The Dixon-U.S. catalog is also labeled "DPL418," which I understand indicates that it would have been made available to the public by April 2018 based on Dixon's numbering convention.[113]

117. Moreover, *Dixon-Australia* and *Dixon-U.S.* reference frac fittings with part numbers of, e.g., HUF100300CS.[114] Frac fittings with this part number appear to have been for sale as early as at least October 3, 2016.[115] It was common practice for a company releasing a product around the 2016-2018 timeframe, as the Dixon frac fittings were, to make a product manual readily available to the public, for example, by offering it for download from the company's website (as Dixon did),

[110] Ex. 1013 (Langenfelder Declaration), ¶7.
[111] Ex. 1012 (*Dixon-U.S.*), pg. 993.
[112] Ex. 1012 (*Dixon-U.S.*), pgs. 2-3.
[113] Ex. 1012 (*Dixon-U.S.*), Title; Ex. 1013 (Langenfelder Declaration), ¶¶4-5.
[114] Ex. 1009 (*Dixon-Australia*), pg. 149; Ex. 1012 (*Dixon-U.S.*), pg. 78.
[115] Ex. 1041 (Amazon.com Dixon Frac Fitting, HUF100300CS), available at https://www.amazon.com/Dixon-FEMALE-SUB-FIG-HUF100300CS/dp/B00LT0TT2U.

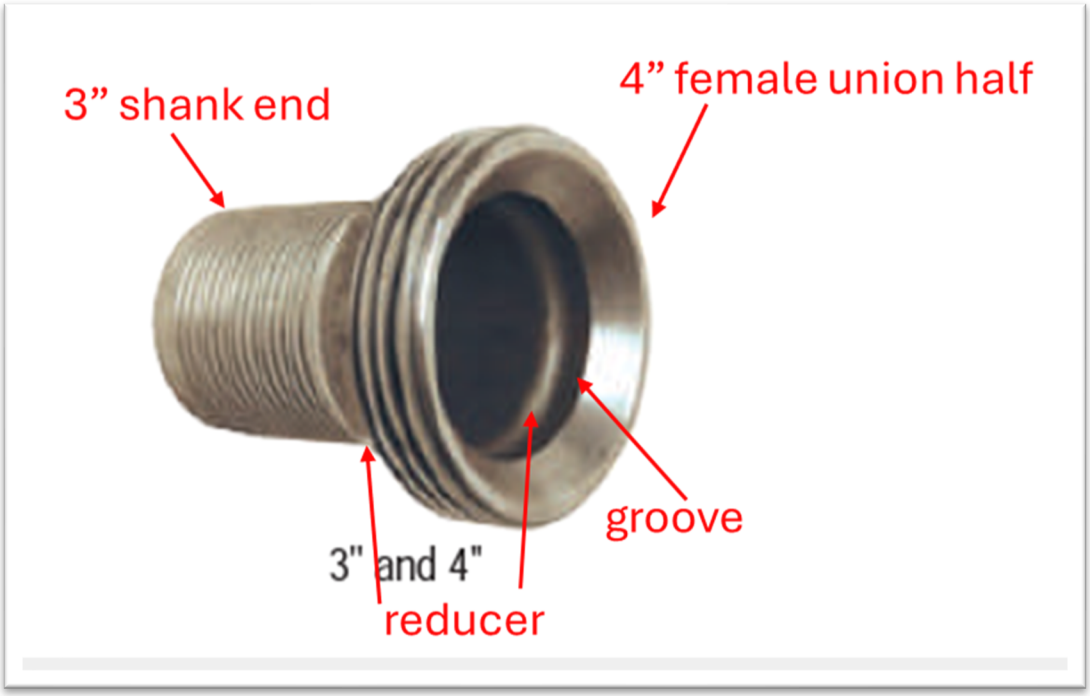
and/or by making a print version publicly available. *Dixon-Australia* and *Dixon-U.S.* indicate on their face, and the Dixon website demonstrates on its face for at least *Dixon-Australia*, that *Dixon-Australia* and *Dixon-U.S.* were published and released in 2018.[116] The Marketing Manager for Dixon, Ms. Holly Langenfelder, also testifies that these catalogs were publicly accessible in 2018. I have no reason to doubt these dates provided by Dixon. It is my understanding, therefore, that *Dixon-Australia* was publicly accessible by at least October 2018, and Dixon-U.S. was publicly accessible by at least April 2018.[117]

118. *Dixon* is a well-established, global valve and fitting company that has been in the industry for over one hundred years.[118] *Dixon* has been offering fittings for hydraulic fracturing wells since at least 1949.[119] I have personally used Dixon fittings, such as hammer unions, for over twenty years, and they were regularly available at oil and gas supply houses for that period. It is my opinion that Dixon would have been a well-known company to a POSITA in 2019.

---

[116] Ex. 1009 (*Dixon-Australia*), pgs. 10, 667; Ex. 1040 (Dixon Product Literature website).
[117] Ex. 1013 (Langenfelder Declaration), ¶10.
[118] Ex. 1042 (Dixon History: 100 years), available at https://australia.dixonvalve.com/en/about-dixon/history.
[119] Ex. 1043 (Dixon History: First Commercial Hydraulic Fracturing Wells Drilled, March 17, 1949), available at https://australia.dixonvalve.com/en/about-dixon/history.

119. *Dixon* discloses a fitting used in hydraulic fracturing operations with a shank end for connecting to a hose, and a hammer union end for connecting to the pump, where the diameter of the end that connects to the pump is larger than the diameter of the end that connects to the hose[120]:



120. *Dixon*’s shank end is securable to a portion of the hose by crimping.[121] Dixon additionally teaches a hose with a diameter of 5 inches.[122] *Dixon*’s frac fitting also includes a reducer that forms an integral piece for the fitting through welding.[123]

[120] Ex. 1009 (*Dixon-Australia*), pg. 149 (annotated); EX1012 (*Dixon-U.S.*), pg. 78.
[121] Ex. 1009 (*Dixon-Australia*), pg. 149; EX1012 (*Dixon-U.S.*), pg. 78.
[122] Ex. 1009 (*Dixon-Australia*), pg. 58.
[123] Ex. 1009 (*Dixon-Australia*), pgs. 149-150; EX1012 (*Dixon-U.S.*), pgs. 78-79.

F. *GARDNER-DENVER CATALOG* (EX. 1010)

121. *Gardner-Denver* is an operating and service manual for Gardner Denver's GD-2500Q Quintuplex well servicing pump (300FWF996 Rev C) that was originally published in 2001, and revised in August 2005,[124] and a GD-2500Q and GD-2500Q-HD Quintuplex Pumps Standard Fluid End Parts List published in 2005.[125] I also understand that, according to the Internet Archive, *Gardner-Denver* was publicly available on the internet as of at least September 2012.[126] The publication of *Gardner-Denver* and its public availability thus predate the claimed priority date of the Challenged Patent.

122. The public accessibility of *Gardner-Denver* by at least 2012 is further confirmed by the reference to *Gardner-Denver*'s pump in *Coli*, which was filed on April 6, 2012, and published on October 11, 2012. *Coli* expressly discloses that the pump is a "quintiplex or triplex plunger style pump, for example, the SWGS-2500 Well Service Pump sold by Gardner Denver, Inc."[127] In my experience, it was common practice for a company releasing a product, such as *Gardner-Denver's*

[124] Ex. 1010 (*Gardner-Denver*), pgs. 1 & 46 of the PDF. *Gardner-Denver* also lists an original copyright date of 2001. Ex. 1010 (*Gardner-Denver*), pg. 46 of the PDF. *Gardner-Denver* lists on its face that "Rev C" was dated "August, 2005." Ex. 1010 (*Gardner-Denver*), pg. 1 of the PDF.
[125] Ex. 1010 (*Gardner-Denver*), pgs. 47, 83 of the PDF.
[126] Ex. 1053 (Affidavit of Mina Ching), pgs. 1, 27-112.
[127] Ex. 1006 (*Coli*), ¶[0046], [0049].

Quintuplex pump, to make a product manual readily available to the public, for example, by offering it for download from the company's, or distributor's, websites (as *Gardner-Denver* did), and/or by making a print version publicly available. *Gardner-Denver* indicates on its face that it was published and released in 2005. I have no reason to doubt this date provided by *Gardner-Denver*.

123. *Gardner's* "SWGS-2500"[128] pump is expressly cited in *Coli* as an example of a suitable "quintiplex [quintuplex] or triplex plunger style pump" coupled to an electric motor and used in a fracturing module.[129] A POSITA would have understood that the "SWGS-2500 quintuplex pump" disclosed by *Coli* refers to a Gardner Denver GD-2500Q power end (or pump end) coupled with a Gardner Denver SGWS fluid end.

124. *Gardner-Denver* 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.[130] In addition, *Gardner-Denver* discloses that the input power to the pump, which is the same as the output power of the

[128] In my opinion, 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 , or a GD-2500Q power end coupled with a Super GWS Fluid End.
[129] Ex. 1006 (*Coli*) [0046].
[130] Ex. 1010 (*Gardner-Denver*), pg. 20 of the PDF.

electric motor coupled to the pump, is 2200 or 2500 bhp."[131] *Gardner-Denver* also discloses that the pump is rated at 2500 bhp (input power).[132]

125. A POSITA would have understood that horsepower ratings for pumps are 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 for the pump to operate according to the specified pressure and flow rate. Output horsepower (sometimes referred to as hydraulic horsepower) is the amount of power delivered to the fluid being pumped. It is often specified in terms of pressure (PSI) and flow rate (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.[133]

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

126. 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 that an electric motor coupled

[131] Ex. 1010 (*Gardner-Denver*), pg. 20 of the PDF.
[132] Ex. 1010 (*Gardner-Denver*), pg. 20 of the PDF.
[133] Ex. 1034 (*Mark's Handbook*), pgs. 14-13, 14-14.

to the Gardner pump would be equipped to provide a maximum continuous power output of more than 1500 horsepower.

127. *Gardner-Denver* also offers a range of suction manifolds with various connection types, including Victaulic and threaded inlets (hammer unions), as well as different sizes, such as 6" and 8" inlet connections.[134]

G. ***ANSI/HI 6.1*** **(Ex. 1011)**

128. *ANSI/HI 6.1* is the "American National Standard for Reciprocating Power Pumps for Nomenclature, Definitions, Application and Operation" and is published by the American National Standards Institute (ANSI) and developed by the Hydraulic Institute.[135]

129. *ANSI/HI 6.1* describes, in the Scope of *ANSI/HI 6.1*, that "[t]he standard applies to reciprocating power pumps. It includes types and nomenclature; definitions; design and application; and installation, operation and maintenance."[136] *ANSI/HI 6.1* further teaches that "[a] reciprocating power pump is one driven by power from an outside source applied to the crankshaft of the pump. [] There are

[134] Ex. 1010 (*Gardner-Denver*), pgs. 76-79 of the PDF.
[135] Ex. 1011 (*ANSI/HI 6.1*), Cover
[136] Ex. 1011 (*ANSI/HI 6.1*), pg. vi.

several variations and types of reciprocating power pumps,"[137] which are shown in Figure 6.1.

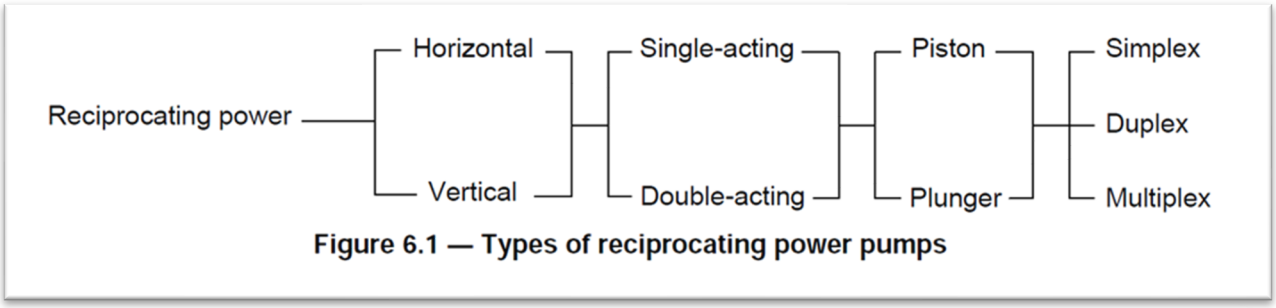


Figure 6.1 — Types of reciprocating power pumps

Ex. 1011 (*ANSI/HI 6.1*) Figure 6.1

130. Further, *ANSI/HI 6.1* describes the use of reciprocating power pumps to pump slurry, such as would have been used in hydraulic fracturing systems. *ANSI/HI 6.1* teaches that, when pumping slurry, "hydraulic passages should be sized so that the lowest velocity of the liquid will be above the critical carrying velocity of 1.2 to 1.8 m/s (4 to 6 ft/s) as an average. The highest velocity should be below that which causes excessive erosion. Typical average operating velocities through a reciprocating slurry pump's passages are 1.8 to 3.6 m/s (6 to 12 ft/s)."[138]

131. Ex. 1011 is a true and correct copy of the *ANSI/HI 6.1* standard published in 2015. *ANSI/HI 6.1* bears a copyright date of 2015.[139] It shows that it

[137] Ex. 1011 (*ANSI/HI 6.1*), pg. 1.
[138] Ex. 1011 (*ANSI/HI 6.1*), pg. 66.
[139] Ex. 1011 (*ANSI/HI 6.1*), Copyright Page.

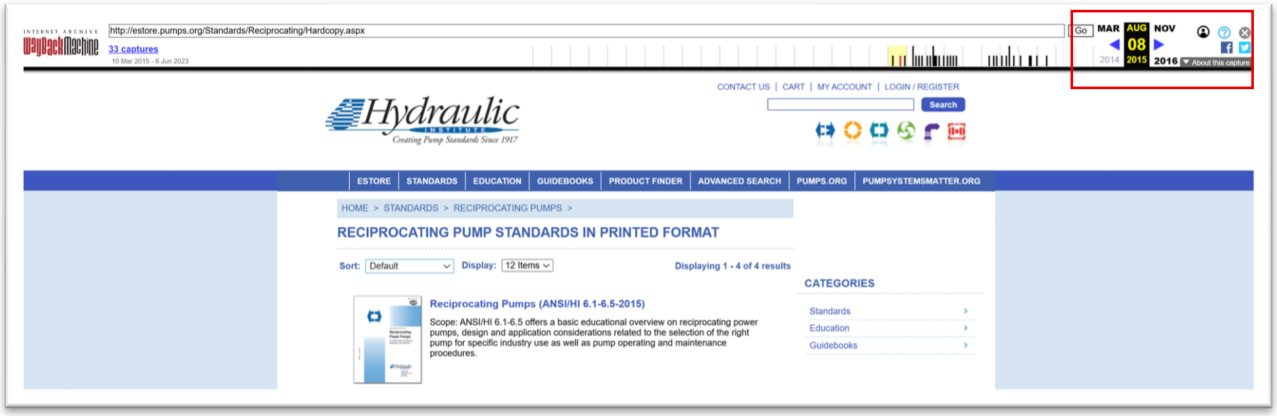
was "approved" by ANSI on March 5, 2015.[140] I am familiar with the ANSI Standards process. I have chaired the Standards Subcommittee of the Petroleum and Chemical Industry Committee (PCIC) of the IEEE, which is responsible for nearly 50 standards related to the oil and gas industry. Several of the Standards that I was responsible for were approved as American National Standards during my tenure. I am currently the Vice-Chair of the PCIC and remain heavily involved in the standards process, including approval as an ANSI Standard. Some examples of the standards I was involved in, which became ANSI Standards, include IEEE 1017, IEEE 1018, and IEEE 1019 (of which I currently serve as chair of the successor standards), IEEE 303, and IEEE 515. Accordingly, I am familiar with the ANSI approval process and the time it takes for the approved standards to be publicly available.

132. In my experience, such standards are publicly accessible from the development organization (such as the IEEE) as soon as possible after approval by ANSI. In my experience, these standards are typically available within 30 days of approval, although they may be made available within 90 days. In no case that I am aware of were the standards not publicly available within 90 days of approval.

[140] Ex. 1011 (*ANSI/HI 6.1*), pg. i.

ANSI/HI 6.1, accordingly, would have been publicly accessible by June 2015, well before December 2019.

133. *ANSI/HI 6.1* was made available online such that a person interested in and ordinarily skilled in the subject matter of hydraulic fracturing pumps (e.g., plunger pumps) could have located it through the exercise of ordinary diligence (e.g., through an Internet search engine using appropriate search terms). These standards are available for purchase from at least the ANSI Store and the Hydraulic Institute's "e-store." For example, a search of the Internet Archive reveals that ANSI/HI 6.1 was available for purchase from the Hydraulic Institute at least by August 8, 2015.[141]



Hydraulic Institute Webstore August 8, 2015.

[141] Ex. 1055 (https://web.archive.org/web/20150808112714/http://estore.pumps.org/Standards/Reciprocating/Hardcopy.aspx); Ex. 1053 (Affidavit of Mina Ching), pgs. 1, 4-8.

An additional page of the Internet Archive additionally shows that ANSI/HI 6.1 was available for purchase from the Hydraulic Institute by at least October 29, 2017[142]:



134. ANSI/HI 6.1 therefore was published and publicly available at least by August 8, 205 2015 and/or October 29, 2017, well before the 2019 priority date, and was a publication that persons of ordinary skill in the art reasonably relied upon in

[142] Ex. 1054 (https://web.archive.org/web/20171029162737/http:/estore.pumps.org/Standards/Reciprocating/PumpsPDF.aspx); Ex. 1053 (Affidavit of Mina Ching), pgs. 1, 4-8.

the 2015-2017 timeframe and later for detailed implementation requirements for reciprocating pumps used in hydraulic fracturing applications.

135. I understand, based on the declaration of Dr. Hall-Ellis, that *ANSI/HI 6.1* was also publicly accessible and indexed at the library, and accordingly would have been searchable and obtainable by the public, by at least October 9, 2014.[143] This is further evidence that *ANSI/HI 6.1* would have been publicly accessible well before December 2019.

XIII. GROUND 1: THE COMBINATION OF *CICCI, COLI, DIXON*, AND *LIU* RENDER CLAIMS 1-7, 9-16, 18-19 OBVIOUS.

136. It is my opinion that the combination of *Cicci, Coli, Dixon* and *Liu* renders claims 1-7, 9-16, and 18-19 of the '420 Patent obvious.

A. MOTIVATION TO COMBINE THE REFERENCES

137. A POSITA would have been motivated to combine *Cicci* and the teachings of *Coli*, *Dixon*, and *Liu*, and would have had a reasonable expectation of success in the combination.

138. A POSITA would have been motivated to combine the teachings of *Coli* with those of *Cicci*. Both *Coli* and *Cicci* are analogous art to the '420 Patent because they are in the same field of endeavor as the '420 Patent regarding hydraulic

[143] Ex. 1014 (Hall-Ellis Declaration), ¶¶50-54.

fracturing systems.[144] For example, the '420 Patent is directed to "[a] hydraulic fracturing system for fracturing a subterranean formation."[145] It also describes in its Technical Field that "[t]his disclosure relates generally to hydraulic fracturing and more particularly to systems and methods for fluid supply lines utilized in hydraulic fracturing."[146]

139. *Cicci* discloses, "[h]ydraulic fracturing systems utilize fracturing fluid to collect gas and/or oil from geological formations deep below the earth's surface. One or more fracturing pumps are used to pressurize the fracturing fluid to a level which exceeds the tensile strength of the subterranean geological formations below the earth's surface. When distributed into a wellbore, the highly pressurized fluid generates micro fissures or cracks within the geological formations surrounding the wellbore. After the wellbore is depressurized, proppant material in the fracturing fluid remain in the fissures to hold the fissures open so that oil and/or gas trapped within the geological formations can be harvested through the wellbore."[147]

140. Similarly, *Coli* discloses that "[t]he present invention provides a method and system for providing on-site electrical power to a fracturing operation,

[144] Ex. 1001 ('420 Patent), Abstract, 1:17-20; Ex. 1004 (*Cicci*), 1:7-19; Ex. 1005 (*Cicci Provisional*), [1]; Ex. 1006 (*Coli*), Abstract, [0003], [0009].
[145] Ex. 1001 ('420 Patent), at Abstract.
[146] Ex. 1001 ('420 Patent), 1:17-19.
[147] Ex. 1004 (*Cicci*), 1:7-19; Ex. 1005 (*Cicci Provisional*), [1].

and an electrically powered fracturing system. Natural gas can be used to drive a turbine generator in the production of electrical power. A scalable, electrically powered fracturing fleet is provided to pump fluids for the fracturing operation."[148]

141. *Coli* also discloses that "[t]his invention relates generally to hydraulic stimulation of underground hydro-carbon-bearing formations, and more particularly, to the generation and use of electrical power to deliver fracturing fluid to a wellbore."[149] *Coli* additionally discloses "[v]arious illustrative embodiments of a system and method for hydraulic stimulation of underground hydrocarbon-bearing formations."[150]

142. *Coli* and *Cicci* disclose similar and compatible hydraulic fracturing systems. Both *Cicci* and *Coli* disclose blending proppant and fluids to create a fracturing fluid. *Cicci* teaches "[t]he hydraulic fracturing system 300 includes a blender 302, a manifold or a missile 304, one or more pumps 306, and a wellhead 308. The blender 302 is configured to receive components of a fracturing fluid (e.g., water, sand, chemicals, etc.) and blend the components into a slurry."[151] *Coli* discloses "providing an electric blender module continuous and/or operatively

[148] Ex. 1006 (*Coli*), at Abstract.
[149] Ex. 1006 (*Coli*), at [0003].
[150] Ex. 1006 (*Coli*), [0009].
[151] Ex. 1004 (*Cicci*), 5:14–20; Ex. 1005 (*Cicci Provisional*), [23]

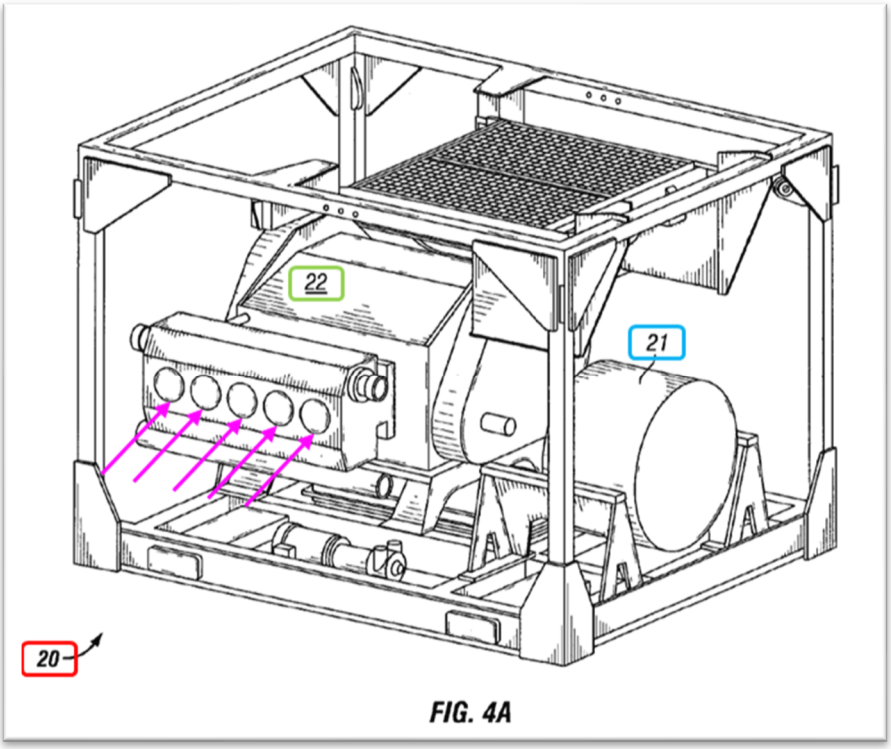
associated with the fluid pump, the blender module comprising: a fluid source, a fluid additive source, and a centrifugal blender tub, and supplying electric power from the dedicated source to the blender module to effect blending of the fluid with fluid additives to generate the treatment fluid."[152]

143. Both *Cicci* and *Coli* disclose pumps used to pump the fracturing fluid downhole and fracture underground formations. *Cicci* discloses, "[o]ne or more fracturing pumps are used to pressurize the fracturing fluid to a level which exceeds the tensile strength of the subterranean geological formations below the earth's surface. When distributed into a wellbore, the highly pressurized fluid generates micro fissures or cracks within the geological formations surrounding the wellbore;"[153] while *Coli* discloses, "providing one or more electric fracturing modules at the site, 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; providing a wellbore treatment fluid for pressurized delivery to a wellbore, wherein the wellbore treatment fluid can be continuous with the fluid pump and with the wellbore; and operating the fracturing unit using electric power from the dedicated source to pump the treatment fluid to the well bore."[154]

[152] Ex. 1006 (*Coli*), [0012].
[153] Ex. 1004 (*Cicci*), 1:9-15; Ex. 1005 (*Cicci Provisional*), [1].
[154] Ex. 1006 (*Coli*), [0009].

144. In light of *Cicci*'s disclosure of a fracturing pump, a POSITA would have been motivated to look at other references, such as *Coli*, for implementation details of appropriate configurations of pumps and how the pumps would have been powered. For example, *Coli* teaches that "an illustrative embodiment of fracturing module 20 [annotated in Fig. 4A in red] is provided. Fracturing module 20 can include an electric motor 21 [annotated in blue] coupled to one or more electric pumps 22 [annotated in green], in certain illustrative embodiments. A suitable pump is a quintiplex [quintuplex] or triplex plunger style pump, for example, the SWGS-2500 Well Service Pump sold by Gardner Denver, Inc."[155] *Coli* also again discloses that "[t]he pump can be a triplex or quintiplex [quintuplex] plunger style fluid pump."[156]

[155] Ex. 1006 (*Coli*), [0046].
[156] Ex. 1006 (*Coli*), [0011].



Ex. 1006(*Coli*) Fig 4A (annotated)

145. A POSITA would have easily recognized that a quintiplex (or quintuplex) pump is one with five plungers and a triplex plunger pump is one with three plungers.[157] A POSITA would have understood both of these to be "multi-plunger" pumps. Fig. 4A shows an embodiment of *Coli* with a quintuplex (5-plunger) pump, with each plunger location identified by a magenta arrow.

146. A POSITA would have been motivated to incorporate *Coli's* teachings on multi-plunger pumps into *Cicci*'s system, as *Coli* provides specific examples of

[157] See Sections XI.B and XI.C above.

pump configurations (triplex or quintuplex) suitable for hydraulic fracturing. Further, *Coli* details a specific example of a suitable pump, "the SWGS-2500 Well Service Pump sold by Gardner Denver, Inc,"[158] which a POSITA would have recognized as being a multi-plunger (quintuplex or five-plunger) pump with a 6-inch inlet connection, as discussed in Section XII.F above.[159] *Coli* additionally provides implementation details of configurations for a plurality of pumps.[160] A POSITA would have been motivated to implement multi-plunger pumps in *Cicci*'s system, as *Coli* discloses that multi-plunger pumps were suitable for fracturing operations.

147. A POSITA also would have been motivated to incorporate *Coli*'s teachings of an electric-powered pump into *Cicci*'s system. *Coli* teaches that the use of electric motors to drive the pumps, rather than diesel motors, allows for an increase in power delivered to the pump from 1,800 hp to 2,500 hp because "parasitic losses are minimal in the electric fracturing system compared to the parasitic losses typical of diesel fueled systems,"[161] and because "pump 22 is directly coupled to

[158] Ex. 1006 (*Coli*), [0046].
[159] Ex. 1006 (*Coli*), [0046]; Ex. 1010 (*Gardner-Denver*), pgs. 77-79.
[160] Ex. 1006 (*Coli*), [0040], [0060], Figs. 2-3.
[161] Ex. 1006 (*Coli*), [0049].

electric motor 21,"[162] without the use of a transmission, torque converter and cooling system, as explained by *Coli*.[163]

148. Furthermore, *Coli* discloses that "the nominal weight of a conventional fluid pump is up to 120,000 lbs. In the present operation, each fracturing module 20 weighs approximately 28,000 lbs., thus allowing 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."[164]

149. A POSITA would have been further motivated to incorporate *Coli*'s teachings of an electric-powered pump into *Cicci*'s system in light of the express benefits disclosed by *Coli*. A POSITA would have been motivated to incorporate *Coli's* teachings of using an electric motor to power the pump to gain the benefits of reduced parasitic losses, increased horsepower delivered to the pump, reduced numbers of pieces of equipment, reduced footprint, reduced weight, reduced emissions, and reduced noise, as described by *Coli* and as would have been well-known to a POSITA

[162] Ex. 1006 (*Coli*), [0049].
[163] *See, e.g.*, Ex. 1006 (*Coli*), [0049].
[164] Ex. 1006 (*Coli*), [0049].

150. For example, *Coli* discloses the use of natural-gas-powered turbines to generate electricity, which in turn powers electric motors for driving the pumps.[165] In one embodiment, 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." [166] 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." [167] Thus, "the number of fracturing modules 20 placed on each trailer 10" is "maximized."[168]

151. *Coli* further discloses that "[t]he electric motor can be capable of operation in the range of up to 1500 rpm and up to 20,000 [ft-lbs][169] of torque."[170]

[165] Ex. 1006 (*Coli*), [0042].
[166] Ex. 1006 (*Coli*), [0036], [0075].
[167] Ex. 1006 (*Coli*), [0049].
[168] Ex. 1006 (*Coli*), [0052].
[169] The unit of torque is ft-lb. 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) are 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".
[170] Ex. 1006 (*Coli*), [0011].

In addition, "[e]lectric motors controlled via variable frequency drive are far safer and easier to control than conventional diesel powered equipment."[171]

152. *Coli* teaches that the use of electric motors to drive the pumps, rather than diesel motors, allows for an increase in power delivered to the pump from 1,800 hp to 2,500 hp because "parasitic losses are minimal in the electric fracturing system compared to the parasitic losses typical of diesel fueled systems,"[172] and because "pump 22 is directly coupled to electric motor 21,"[173] without the use of a transmission, torque converter and cooling system, as explained by *Coli*.[174]

153. Furthermore, *Coli* discloses that "the nominal weight of a conventional fluid pump is up to 120,000 lbs. In the present operation, each fracturing module 20 weighs approximately 28,000 lbs., thus allowing 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."[175]

154. A POSITA would have been motivated to incorporate *Coli's* teachings of using an electric motor to power the pump in order to gain the benefits of reduced parasitic losses, increased horsepower delivered to the pump, reduced numbers of

[171] Ex. 1006 (*Coli*), [0066].
[172] Ex. 1006 (*Coli*), [0049].
[173] Ex. 1006 (*Coli*), [0049].
[174] *See, e.g.*, Ex. 1006 (*Coli*), [0049].
[175] Ex. 1006 (*Coli*), [0049].

pieces of equipment, reduced footprint and reduced weight described by *Coli*. Reduced parasitic losses and increased horsepower delivered to the pump would have made the system more efficient. Reduced numbers of pieces of equipment would have resulted in lower maintenance requirements, as there would be fewer pieces of equipment to maintain. A reduced footprint would have allowed the system to be configured in a smaller space and/or arranged more easily. Reduced weight would have made it easier to transport the electric pumps described by *Coli,* as compared to other options such as diesel-powered pumps. It additionally would have been well-known to a POSITA that an electric motor would have reduced emissions and noise.[176] A POSITA would have been motivated to realize each of these benefits.

155. A POSITA would have had a reasonable expectation of success in the combination. Both *Cicci* and *Coli* disclose equipment used to construct a hydraulic fracturing system. *Cicci* discloses a pump in a hydraulic fracturing system, and *Coli* provides implementation details on appropriate ways to configure and power the pumps.[177] Accordingly, incorporating *Coli's* teachings of electric-powered multi-plunger hydraulic fracturing pumps into *Cicci's* teachings of a hydraulic fracturing system is merely applying a known technique to improve a known system in the

[176] *See, e.g.*, Ex. 1021 (*Oehring*), 1:46-55.
[177] Ex. 1004 (*Cicci*), 1:7-19; Ex. 1005 (*Cicci Provisional*), [1]; Ex. 1006 (*Coli*), Abstract, [0011], [0046], [0049] & Figs. 3, 4A.

same way.[178] Further, combining *Coli*'s teachings would have yielded predictable results for a POSITA, i.e., a fracturing system that is more efficient, has reduced equipment, a smaller footprint, lighter weight, and reduced noise and emissions, as compared to traditional, diesel-powered systems.

156. A POSITA would have been further motivated to incorporate the teachings of *Dixon* into the system of *Cicci/Coli*. *Dixon* is analogous art to the '420 Patent as it is in the same field of endeavor as the '420 Patent regarding hydraulic fracturing systems.[179] For example, *Dixon* discloses "Dixon Frac Fittings" that are "[u]sed in the fast paced transfer of water and sand slurry to a hydraulic fracturing site."[180] *Dixon* also would have been reasonably pertinent to the problem with which the '420 Patent is concerned—fluid flow rates for fracturing operations—as *Dixon*'s frac fittings would have been applicable for use with slurry flow in a hydraulic fracturing system to address such problems.[181]

157. A POSITA would have been motivated by *Cicci*'s disclosure of fittings to look to references that teach about frac fittings and hoses that would have been

[178] *See, e.g.*, Ex. 1021 (*Oehring*), 1:46-65 (electric powered pumps were well known); *see generally* Ex. 1038 (*Oehring*), [0033], [0040] (multi-plunger pumps were well known).
[179] Ex. 1001 ('420 Patent), 1:17-19, Abstract; Ex. 1009 (*Dixon-Australia*), pg. 149.
[180] Ex. 1009 (*Dixon-Australia*), pg. 149.
[181] Ex. 1009 (*Dixon-Australia*), pg. 149; Ex. 1001 ('420 Patent), 1:49-54; Ex. 1056 ('162 Patent File History), pg. 433.

useful in the fracturing system of *Cicci/Coli*. For example, *Cicci* discloses that "[e]ach pump 306 is coupled to the missile 304 by a set of flexible flow lines 310. For example, each pump 306 can have a set of connections configured to interlock, engage, or otherwise *couple to a fitting affixed to each end of the flexible flow line 310*. Similarly, the missile or manifold 304 can include a set of connections configured to interlock, engage, or otherwise *couple to a fitting affixed to each end of the flexible flow line 310*."[182]

158. As another example, *Cicci* teaches "coupling a first end of a first flexible hose to one of the respective pump connections. The flexible hose can be connected to the pump connections by any number of connection methods currently known or developed in the future, [] such as a hammer union."[183]

159. A POSITA would have been motivated to look to *Dixon* for implementation details about such fittings, hoses, and couplings. *Dixon* contains information about commercially available products, including hoses and fittings, for use in "slurry" systems, and, in particular, "frac" systems. For example, on the "Hose & Hose Assemblies Index page (page 11), *Dixon-Australia* specifically calls out "slurry" and "frac" systems in a graphic listing what a POSITA would have

[182] Ex. 1004 (*Cicci*), 5:30-37; Ex. 1005 (*Cicci Provisional*), [24] emphasis added.
[183] Ex. 1004 (*Cicci*), 7:40-47; Ex. 1005 (*Cicci Provisional*), [30].

understood to be systems where *Dixon*'s teachings were applicable (annotated with a red box below).[184]



160. *Dixon* further teaches specific equipment, such as hoses and fittings, explicitly designed and sold for fracturing applications. For example, *Dixon-Australia* discloses an "anti-static high pressure and chemically resistant composite FRAC hose [that] is designed for suction and discharge use with hydraulic fracturing related applications."[185] *Dixon-Australia* further teaches that "[t]he hose construction is medium to light weight and flexible for ease of handling yet remains robust, hard wearing and cost effective."[186]

[184] Ex. 1009 (*Dixon-Australia*) pg. 11 (annotated).
[185] Ex. 1009 (*Dixon-Australia*), pg. 58.
[186] Ex. 1009 (*Dixon-Australia*), pg. 58.

161. As another example, *Dixon* teaches fittings which are "[u]sed in the fast paced transfer of water and sand slurry to a hydraulic fracturing site."[187] These fittings have a one-piece design that "eliminates leak path experienced with two-piece threaded systems."[188] Further, *Dixon* teaches "Frac Fittings," which are used in "Suction Service," and "King Crimp™ Style Short Frac Ferrules" and "King Crimp™ Style Heavy Duty Ferrules" for use in attaching hoses to "crimp style shanks" on the frac fittings.[189]

162. *Dixon* also teaches the use of other fittings which would be useful in fracturing systems, including general information on hammer unions,[190] reducers,[191] hose and hose assemblies, industrial hose fittings and pipe and pipe welding fittings that a POSITA would have found useful in designing the system of *Cicci/Coli*.

163. A POSITA would have been motivated to incorporate *Dixon*'s fittings into the system of *Cicci*/*Coli* to obtain the express benefits of *Dixon*'s fittings. For example, *Dixon*'s fittings have a "[o]ne piece design [which] eliminates leak path

[187] Ex. 1009 (*Dixon-Australia*), pg. 149; Ex. 1012 (*Dixon-U.S.*), pg. 78.
[188] Ex. 1009 (*Dixon-Australia*), pg. 149; Ex. 1012 (*Dixon-U.S.*), pg. 78.
[189] See, e.g., Ex. 1009 (*Dixon-Australia*) pgs. 150–151; Ex. 1012 (*Dixon-U.S.*), pgs. 681-682.
[190] See, e.g., Ex. 1009 (*Dixon-Australia*) pgs. 154-155; Ex. 1012 (*Dixon-U.S.*), pgs. 608, 613, 628.
[191] See, e.g., Ex. 1009 (*Dixon-Australia*), pgs. 359, 405; Ex. 1012 (*Dixon-U.S.*), pgs. 608, 613, 628.

experienced with two-piece threaded systems."[192] These Frac Fittings also are "[d]urable and safe with reliable hose retention when crimped as specified."[193] *Dixon* shows examples of various combinations of fitting sizes, including fittings for connecting the same size hose and union (Complete Male/Female Assembly) and combinations of Male/Female assemblies that would have attached a larger union to a smaller hose.[194]

164. A POSITA further would have been motivated to use *Dixon*'s fittings to connect a pump with a connection of one diameter with a hose with a connection of a different, smaller diameter. Further, as detailed below in Sections XIII.B.7 and XIII.C, a POSITA would have been further motivated to reduce the hose size to 5" to increase the velocity of the contained slurry, thus reducing the propensity of the proppant to drop out of the slurry and form a bed in the bottom of the hoses, potentially causing a screen out (plugging) of the hoses. This is based on scientific principles known to a POSITA, and outlined in the *Liu* textbook.

165. A POSITA would have had a reasonable expectation of success in combining the teachings of *Dixon* with those of *Cicci/Coli*. Such a combination would have been merely applying a known technique (the teachings of hoses and

[192] Ex. 1009 (*Dixon-Australia*), pg. 149.
[193] Ex. 1009 (*Dixon-Australia*), pg. 149.
[194] Ex. 1009 (*Dixon-Australia*), pg. 149.

fittings from *Dixon*) to a known system (the hydraulic fracturing system of *Cicci/Coli*), ready for improvement (actual design and construction of the system) to yield predictable results (a practical fracturing system). *Dixon* teaches specific configurations of fittings that are designed for fracturing systems, as well as teachings regarding other industrial, piping, and weld fittings, which would have been useful in designing the system described by *Cicci/Coli.*[195]

166. A POSITA would have been further motivated to combine the *Cicci-Coli-Dixon* combination with *Liu*. A POSITA would have been further motivated to use *Liu's* teachings of fluid flow, including fluid flow of a slurry, into the system of *Cicci*, *Coli*, and *Dixon*. *Liu* merely compiles established scientific principles into a single reference. *Liu* accordingly is also evidence of knowledge of a POSITA.

167. *Liu* is analogous art to the '420 Patent because it is reasonably pertinent to the problem with which the inventor was involved. The '420 Patent is directed to the problem of fluid flow rates for fracturing operations. For example, the '420 Patent describes "problems with flow rates, as flow rates that drop below a threshold may experience drop out of particulates, leading to blockages and other problems at the well site."[196] Similarly, during prosecution of the application that led to the parent

[195] Ex. 1009 (*Dixon-Australia*), pgs. 11, 58, 149-151, 154, 405; Ex. 1012 (*Dixon-U.S.*), pgs. 78-79, 111-113, 118, 608, 613, 628, 681.
[196] Ex. 1001 ('420 Patent), at 1:14-55.

'162 Patent, the applicant distinguished prior art by arguing that it did not "identify the problem associated with efficient fluid flow rates for fracturing operations."[197] *Liu* teaches scientific principles directly applicable to the hydraulic fracturing systems of the '420 Patent and pertinent to the problem of efficient fluid flow rates for fracturing operations to which the inventor was involved.

168. A POSITA would have been motivated to look to *Liu* because *Liu* discloses scientific principles directly applicable to the hydraulic fracturing system of *Cicci/Coli/Dixon*. *Liu* discloses that the scientific principles it describes are important for "practicing engineers who are confronted with pipeline engineering, construction, and/or operations issues in the real world."[198] The information in *Liu* addresses piping systems containing "crude oil, natural gas, petroleum products, water, solids and slurries."[199] As discussed above, both *Cicci* and *Coli* discuss using fracturing fluid, which is a slurry of proppant (e.g., sand), water and other chemicals, in a fracturing system.[200] Further, as also discussed above, *Dixon* discloses

[197] Ex. 1056 ('162 Patent File History), pg. 433.
[198] Ex. 1007 (*Liu*) Foreword.
[199] Ex. 1007 (*Liu*) Foreword.
[200] Ex. 1004 (*Cicci*), 5:15-20; Ex. 1005 (*Cicci Provisional*), [23]; Ex. 1006 (*Coli*), [0012].

commercially available products, including hoses and fittings, for use in a "slurry" system, and, in particular, "frac" systems."[201]

169. A POSITA further would have been motivated to look to *Liu* because the information in *Liu* is appropriate for analyzing and sizing piping systems (including flexible hoses) for slurries, as disclosed by *Cicci* and *Coli*. *Liu* further teaches that the pipelines addressed are not only the "extensive network of underground pipelines" but also the "[i]n-plant pipelines"[202] used in most industrial plants, of which a fracturing site is one. Further, *Liu* teaches that "[t]his book will be useful not only to those employed by pipeline companies, but also to most mechanical, civil, chemical, mining, petroleum, nuclear, and agricultural engineers who must deal with *piping or pipelines* in their professional work."[203] *Cicci* and *Liu* further describe that "the term 'pipe' and 'hose' are used interchangeably."[204] Accordingly, a POSITA would have understood the teachings of *Cicci* and *Liu* regarding pipe sizing to also apply to hose sizing.

170. A POSITA additionally would have been motivated to look to *Liu* because *Liu* describes piping and hoses used to transport slurries at a fracturing site,

[201] Ex. 1009 (*Dixon-Australia*), pg. 11, 58.
[202] Ex. 1007 (*Liu*) Preface.
[203] Ex. 1007 (*Liu*) Preface emphasis added.
[204] Ex. 1004 (*Cicci*), 4:45-46; Ex. 1005 (*Cicci Provisional*), [19]; Ex. 1007 (*Liu*), pgs. 15, 336.

where the pipes or hoses are horizontal throughout much of their lengths, and thus are "nearly horizontal". For example, Chapter 5 of *Liu* discusses "Flow of Solid-Liquid Mixture in Pipe (Slurry Pipelines)."[205] Further, *Liu* teaches that Chapter 5 "discusses the flow of solid particles transported by a liquid in pipelines, namely, slurry pipelines. For simplicity, the discussion will focus on horizontal or nearly horizontal pipes with particles suspended by the liquid."[206]

171. Accordingly, a POSITA would have been motivated to apply the established scientific principles of *Liu* to understand the fluid dynamics of the *Cicci*/*Coli* system and to size equipment within the system. *Liu* specifically teaches that the principles in *Liu* apply to piping systems, which would include hose systems, at least because *Cicci* teaches the use of piping and hoses interchangeably. Furthermore, *Liu* dedicates an entire chapter to discussing and explaining the scientific principles behind slurry flow, which apply to the slurry used in the *Cicci/Coli* system.[207]

172. Moreover, a POSITA would have been motivated to apply the principles disclosed in *Liu* with the system of *Cicci*/*Coli*/*Dixon* in order to get the benefits of maintaining sufficient fluid velocity and flow, and thus reducing the

[205] Ex. 1007 (*Liu*), pg. 131.
[206] Ex. 1007 (*Liu*), pg. 131.
[207] See, e.g., Ex. 1007 (*Liu*), Chapter 5, pg. 131.

possibility of slurry drop-out, plugging of the hoses, and damaging cavitation, as taught by *Liu*.[208] Further, a POISTA would have been motivated to incorporate the teachings of *Liu* in order to calculate pressure drop in the system and ensure enough Net Positive Suction Head (NPSH) in order to prevent cavitation.

173. A POSITA would have had a reasonable expectation of success in combining the teachings of *Liu* with *Cicci/Coli/Dixon,* as *Liu* teaches scientific principles directly applicable to the slurry piping systems of *Cicci/Coli/Dixon.* Applying *Liu* would have involved merely applying a well-known technique (*Liu's* disclosure of the scientific principles behind fluid flow) to a known system (the hydraulic fracturing system of *Cicci/Coli/Dixon)*, which was ready for improvement to yield predictable results. The predictable results expected would be a hydraulic fracturing system with hoses sized properly to reduce the possibility of plugging the hoses, and minimize pressure drop, as discussed more fully below in Section XIII.B.7 and XIII.G. Further, a POSITA would have expected predictable results in a fracturing system using hoses that are sized appropriately for the fluid flow through them as discussed more fully in Section XIII.G and XIII. H below. Further, a POSITA would have reasonably expected a fracturing system with reduced risk of

[208] Ex. 1007 (*Liu*), pgs. 132-133, 269; see also Section XI.D.

damage, for example, from cavitation, as discussed in Sections XI.D, XIII.B.7 and Sections XIII.G-XIII.H below.

B. INDEPENDENT CLAIM 1

174. It is my opinion that the combination of *Cicci, Coli, Liu* and *Dixon* would have rendered Claim 1 obvious. The combined teachings of *Cicci, Coli, Liu* and *Dixon* disclose or render obvious each and every limitation of Claim 1, as discussed in the sections below.

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

175. To the extent the preamble is limiting, the *Cicci*/*Coli*/*Dixon*/*Liu* combination discloses the preamble. *Cicci* and *Coli* each disclose the preamble.

176. *Cicci* discloses, "[h]ydraulic fracturing systems utilize fracturing fluid to collect gas and/or oil from geological formations deep below the earth's surface. One or more fracturing pumps are used to pressurize the fracturing fluid to a level which exceeds the tensile strength of the subterranean geological formations below the earth's surface. When distributed into a wellbore, the highly pressurized fluid generates micro fissures or cracks within the geological formations surrounding the wellbore. After the wellbore is depressurized, proppant material in the fracturing

fluid remain in the fissures to hold the fissures open so that oil and/or gas trapped within the geological formations can be harvested through the wellbore."[209]

177. Similarly, *Coli* discloses that "[t]he 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. A scalable, electrically powered fracturing fleet is provided to pump fluids for the fracturing operation".[210]

178. *Coli* also discloses that "[t]his invention relates generally to hydraulic stimulation of underground hydro-carbon-bearing formations, and more particularly, to the generation and use of electrical power to deliver fracturing fluid to a wellbore."[211] *Coli* additionally discloses that "[v]arious illustrative embodiments of a system and method for hydraulic stimulation of underground hydrocarbon-bearing formations are provided herein."[212]

179. A POSITA would have understood that *Coli*'s disclosures of hydraulic stimulation of underground hydrocarbon-bearing formations refer to a hydraulic fracturing system for fracturing a subterranean formation.

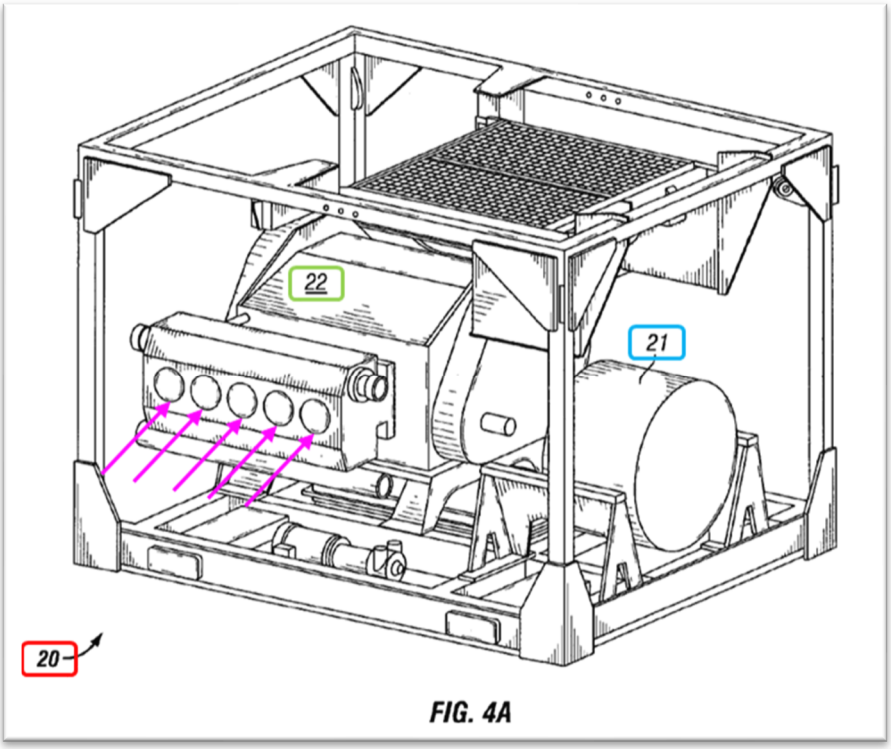
[209] Ex. 1004 (*Cicci*), 1:7-19; Ex. 1005 (*Cicci Provisional*), [1].
[210] Ex. 1006 (*Coli*), at Abstract.
[211] Ex. 1006 (*Coli*), at [0003].
[212] Ex. 1006 (*Coli*), at [0009].

180. Accordingly, both *Cicci* and *Coli* disclose the preamble.

2. 1[a]: "an electric powered multi-plunger hydraulic fracturing pump having an inlet and an outlet, the outlet coupled to a well associated with the subterranean formation and powered by at least one electric motor;"

181. The combination of *Cicci* and *Coli* discloses 1[a]. As discussed above regarding 1[p], both *Cicci* and *Coli* disclose a hydraulic fracturing system for fracturing a subterranean formation. Additionally, as discussed above, both *Coli* and *Cicci* disclose that the hydraulic fracturing system contains pumps. *Coli* discloses using an electric-powered multi-plunger hydraulic fracturing pump as claimed. *Coli* discloses "an illustrative embodiment of fracturing module 20 [annotated in Fig. 4A in red] is provided. Fracturing module 20 can include an electric motor 21 [annotated in blue] coupled to one or more electric pumps 22 [annotated in green], in certain illustrative embodiments. A suitable pump is a quintiplex [quintuplex] or triplex plunger style pump, for example, the SWGS-2500 Well Service Pump sold by Gardner Denver, Inc."[213] *Coli* also again discloses that "[t]he pump can be a triplex or quintiplex plunger style fluid pump."[214]

[213] Ex. 1006 (*Coli*), Fig. 4A annotated & [0046].
[214] Ex. 1006 (*Coli*), [0011].



Ex. 1006 (*Coli*) Fig 4A (annotated)

182. A POSITA would have easily recognized that a quintiplex (or quintuplex) pump is one with five plungers and a triplex plunger pump is one with three plungers.[215] A POSITA would have understood both of these to be "multi-plunger" pumps. Fig. 4A above shows an embodiment of *Coli* with a quintuplex (5-plunger) pump, with each plunger location identified by a magenta arrow.

183. *Coli*'s electric-powered pump is powered by at least one electric motor. Coli further discloses that motor 21 is used to power the pump in order to pump fluid

[215] See Section XI.B and XI.C above.

down the wellbore. *Coli* teaches "[e]ach fracturing module 20 can include an electric motor 21 and a fluid pump 22 coupled thereto. During fracturing, fracturing module 20 is operatively associated with turbine generator 30 to receive electric power therefrom. [] Fracturing modules 20 utilize electric power from turbine generator 30 to pump the fracturing fluid directly to the wellbore."[216] Thus, *Coli* discloses an electric-powered multi-plunger hydraulic fracturing pump, which is powered by at least one electric motor. A POSITA would have been motivated to use *Coli's* teachings of an electric motor driven multi-plunger fracturing pump to improve *Cicci's* teachings of a fracturing system as discussed in Section XIII.A above.

184. Further, *Cicci* discloses "[t]he blender 302 delivers the blended fracturing fluid to the missile 304 at a low pressure. The missile 304 delivers the fracturing fluid to the pumps 306 at a relatively low pressure."[217] *Cicci* thus discloses the delivery of the fracturing fluid from the blender to the pump, and from the pump to the missile. A POSITA would have understood that the delivery of fracturing fluid from the blender to the pump would have been through the pump's inlet, which would have been well-known to a POSITA.

[216] Ex. 1006 (*Coli*), [0040].
[217] Ex. 1004 (*Cicci*), 5:20-23; Ex. 1005 (*Cicci Provisional*), [23].

185. *Cicci* also discloses: "[t]he pumps 306 then pressurize the fracturing fluid to a pressure ranging between 5,000 PSI to 15,000 PSI, or more. The pumps 306 deliver the pressurized fracturing fluid to the missile 304."[218] A POSITA would have understood that the pumps' delivery of the fracturing fluid to the missile would have been through the pump's outlet, which would have been well-known to a POSITA. A POSITA would have accordingly understood from *Cicci*'s disclosures the well-known fact that the pump has an inlet and an outlet.

186. Further, *Cicci* discloses that the outlet is coupled to a well associated with the subterranean formation through the missile 304. *Cicci* discloses that the pump is coupled to the wellbore: "[t]he pumps 306 then pressurize the fracturing fluid to a pressure ranging between 5,000 PSI to 15,000 PSI, or more. The pumps 306 deliver the pressurized fracturing fluid to the missile 304. The missile 304 then delivers the pressurized fracturing fluid to the wellhead 308, which routes the fluid into steel casing in the wellbore (not shown)",[219] which a POSITA would have understood meant that *Cicci*'s pump's outlet is coupled to the wellbore, consistent with what have been well-known to a POSITA. *Cicci* further discloses that the well is associated with the subterranean formation: "[w]hen distributed into a wellbore,

[218] Ex. 1004 (*Cicci*), 5:23-26; Ex. 1005 (*Cicci Provisional*), [23].
[219] Ex. 1004 (*Cicci*), 5:26-29; Ex. 1005 (*Cicci Provisional*), [23].

the highly pressurized fluid generates micro fissures or cracks within the geological formations surrounding the wellbore,"[220] which a POSITA would have understood meant that the well is associated with the subterranean formation, consistent with what would have been well-known to a POSITA.

187. Similarly, *Coli* describes that "[f]racturing modules 20 utilize electric power from the turbine generator 30 to pump the fracturing fluid directly to the wellbore."[221] *Coli* further states that in a fracturing operation, " a 'slurry' of fluids and additives is injected into a hydrocarbon-bearing rock formation at a wellbore to propagate fracturing."[222] A POSITA would have understood that the purpose of hydraulic fracturing operations was to inject fluids into a subterranean formation under pressure to create fissures or "fractures" in the formation[223].

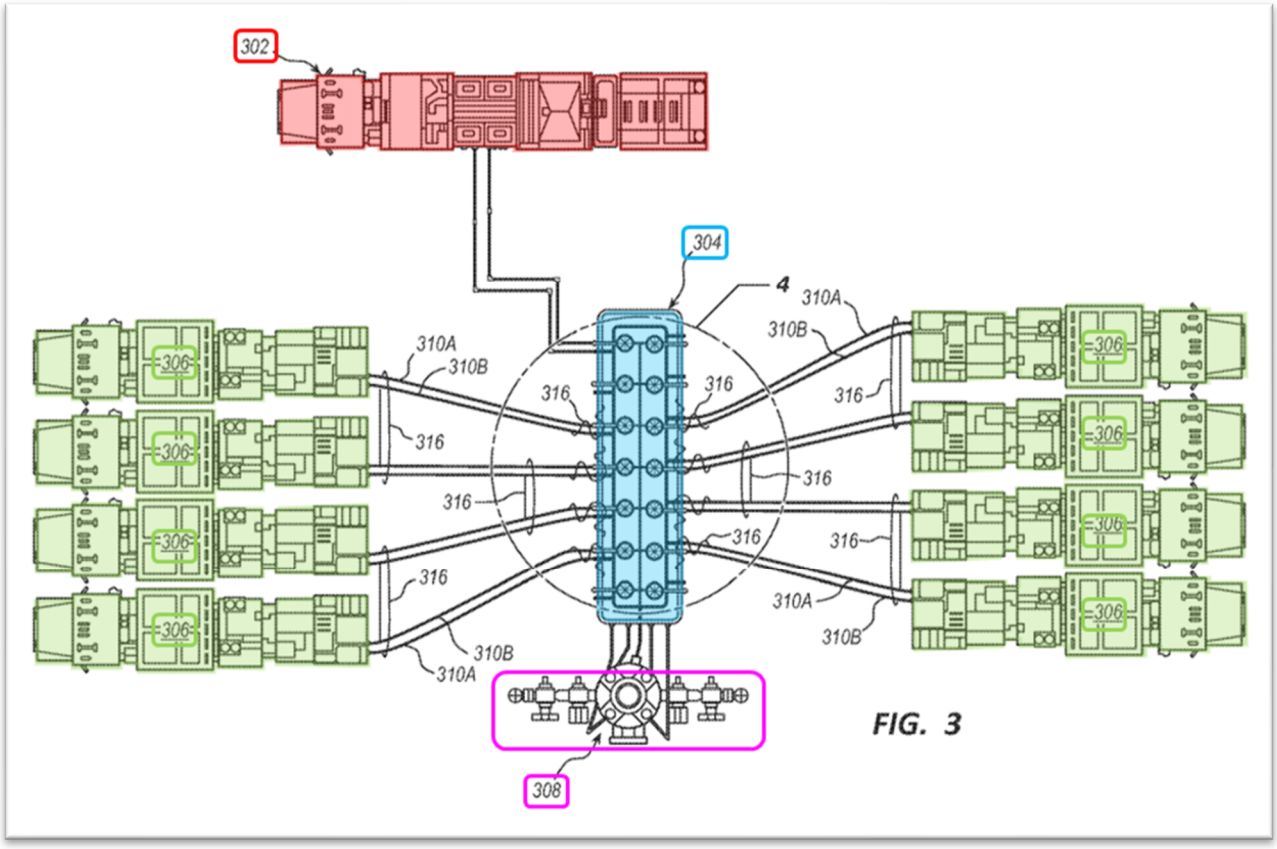
188. Accordingly, the combination of *Cicci* and *Coli* discloses limitation 1[a] and renders limitation 1[a] obvious.

[220] Ex. 1004 (*Cicci*), 1:12-15; Ex. 1005 (*Cicci Provisional*), [1].
[221] Ex. 1006 (*Coli*), [0040], see also Ex. 1006 (*Coli*), [0009].
[222] Ex. 1006 (*Coli*), [0035], see also Ex. 1006 (*Coli*), [0003], [0009].
[223] *See, e.g.*, Ex. 1004 (*Cicci*), 1:7-19; Ex. 1005 (*Cicci Provisional*), [1].

3. 1[b]: "a fluid source, coupled to the inlet of the electric powered multi-plunger hydraulic fracturing pump, the fluid source providing a slurry for injection into the subterranean formation;"

189. The combination of *Cicci* and *Coli* discloses limitation 1[b]. *Cicci* discloses a basic fracturing system: "FIG. 3 is a top view of a hydraulic fracturing system 300 according to the present disclosure. The hydraulic fracturing system 300 includes a blender 302 [annotated in Fig. 3 in red], a manifold or a missile 304 [annotated in blue], one or more pumps 306 [annotated in green], and a wellhead 308 [annotated in magenta]. The blender 302 is configured to receive components of a fracturing fluid (e.g., water, sand, chemicals, etc.) and blend the components into a slurry. The blender 302 delivers the blended fracturing fluid to the missile 304 at a low pressure. The missile 304 delivers the fracturing fluid to the pumps 306 at a relatively low pressure. The pumps 306 then pressurize the fracturing fluid to a pressure ranging between 5,000 PSI to 15,000 PSI, or more. The pumps 306 deliver the pressurized fracturing fluid to the missile 304. The missile 304 then delivers the pressurized fracturing fluid to the wellhead 308, which routes the fluid into steel casing in the wellbore (not shown)."[224]

[224] Ex. 1004 (*Cicci*), 5:14-29; Ex. 1005 (*Cicci Provisional*), [23].



Ex. 1004 (*Cicci*) Fig. 3 (annotated).

190. Accordingly, *Cicci* discloses a fluid source (manifold/missile 304), coupled to the inlet of the pumps (pumps 306), the fluid source providing a slurry for injection into the subterranean formation ("The missile 304 then delivers the pressurized fracturing fluid to the wellhead 308, which routes the fluid into steel casing in the wellbore (not shown).")[225] As discussed above regarding limitation 1[a], once in the wellbore, "the highly pressurized fluid generates micro fissures or

[225] Ex. 1004 (*Cicci*), 5:26-29; Ex. 1005 (*Cicci Provisional*), [23].

cracks within the geological formation surrounding the wellbore."[226] And as discussed above regarding limitation 1[a], the pump is an electric-powered multi-plunger hydraulic fracturing pump.[227]

191. Accordingly, *Cicci* discloses limitation 1[b], and the combination of *Cicci* and *Coli* renders limitation 1[b] obvious.

4. 1[c]: "a hose extending between the fluid source and the electric powered multi-plunger hydraulic fracturing pump, the hose comprising:"

192. The combination of *Cicci* and *Coli* discloses limitation 1[c]. *Cicci* describes a hose extending between the fluid source (missile 304) and the pump, which would have been electric-powered multi-plunger pumps in the combination of *Cicci* and *Coli,* as discussed above. *Cicci* discloses "a flexible pipe or hose (i.e., a flexible flow line) capable of withstanding pressure in excess [of] 15,000 PSI is utilized to couple various components of a fracturing system. For example, a flexible pipe or hose can be used to connect a pump to the manifold."[228] As discussed above in Section XIII.B.2, the combination of *Cicci* and *Coli* discloses that the pump is an electric powered multi-plunger hydraulic fracturing pump.

[226] Ex. 1004 (*Cicci*), 1:12-15; Ex. 1005 (*Cicci Provisional*), [1]; *see also* Ex. 1006 (*Coli*), [0003], [0035].
[227] See Section XIII.B.2,
[228] Ex. 1004 (*Cicci*), 3:42-46; Ex. 1005 (*Cicci Provisional*), [15].

193. Accordingly, *Cicci* discloses limitation 1[c], and the combination of *Cicci* and *Coli* renders limitation 1[c] obvious.

5. 1[d]: "a first end, for coupling to the fluid source, having a first diameter;"

194. *Cicci* discloses a first end for coupling to the fluid source (manifold 304) having a first diameter. *Cicci* discloses "coupling a first end of a first flexible hose (i.e., flexible flow line) with one of the respective pump connections. The method also includes *coupling a second end of the first flexible hose to one of the plurality of manifold connections* [fluid source]."[229]

195. A POSITA would have understood *Cicci*'s hose's second end coupling to the fluid source is the claimed first end. *Cicci* also discloses that "[w]here methods and steps described above indicate certain events occurring in certain order, those of ordinary skill in the art having the benefit of this disclosure would recognize that the ordering of certain steps may be modified and such modifications are in accordance with the variations of the invention."[230] *Cicci* also discloses that "other embodiments are possible having any combination or sub-combination of any features and/or

[229] Ex. 1004 (*Cicci*), 4:30-35; Ex. 1005 (*Cicci Provisional*), [18] emphasis added.
[230] Ex. 1004 (*Cicci*), 8:28-33; Ex. 1005 (*Cicci Provisional*), [34].

components from any of the embodiments described herein. In addition, the specific configurations of the various components can also be varied."[231]

196. Further, a POSITA would have understood that the "end" of a flexible hose has a diameter. *Cicci* discloses that "the plurality of flexible hoses can have an inner diameter of one to eight inches."[232] A POSITA would have understood, based on *Cicci's* disclosure of a hose "inner diameter," that an "end" of the hose would have a diameter (e.g. a first diameter). A POSITA would have understood from *Cicci*'s disclosure that the hose's first end has a first diameter.

197. Accordingly, *Cicci* discloses limitation 1[d].

6. 1[e]: "a second end, for coupling to the inlet of the electric powered multi-plunger hydraulic fracturing pump, having a second diameter; and"

198. As I discussed above, the *Cicci-Coli* combination discloses an inlet of the electric-powered multi-plunger hydraulic fracturing pump. *Cicci* discloses "coupling a first end of a first flexible hose (i.e., flexible flow line) with one of the respective pump connections."[233] Thus, *Cicci* discloses a second end of the hose for coupling to the inlet of the pump. In combination with *Coli*, the "pump" would have

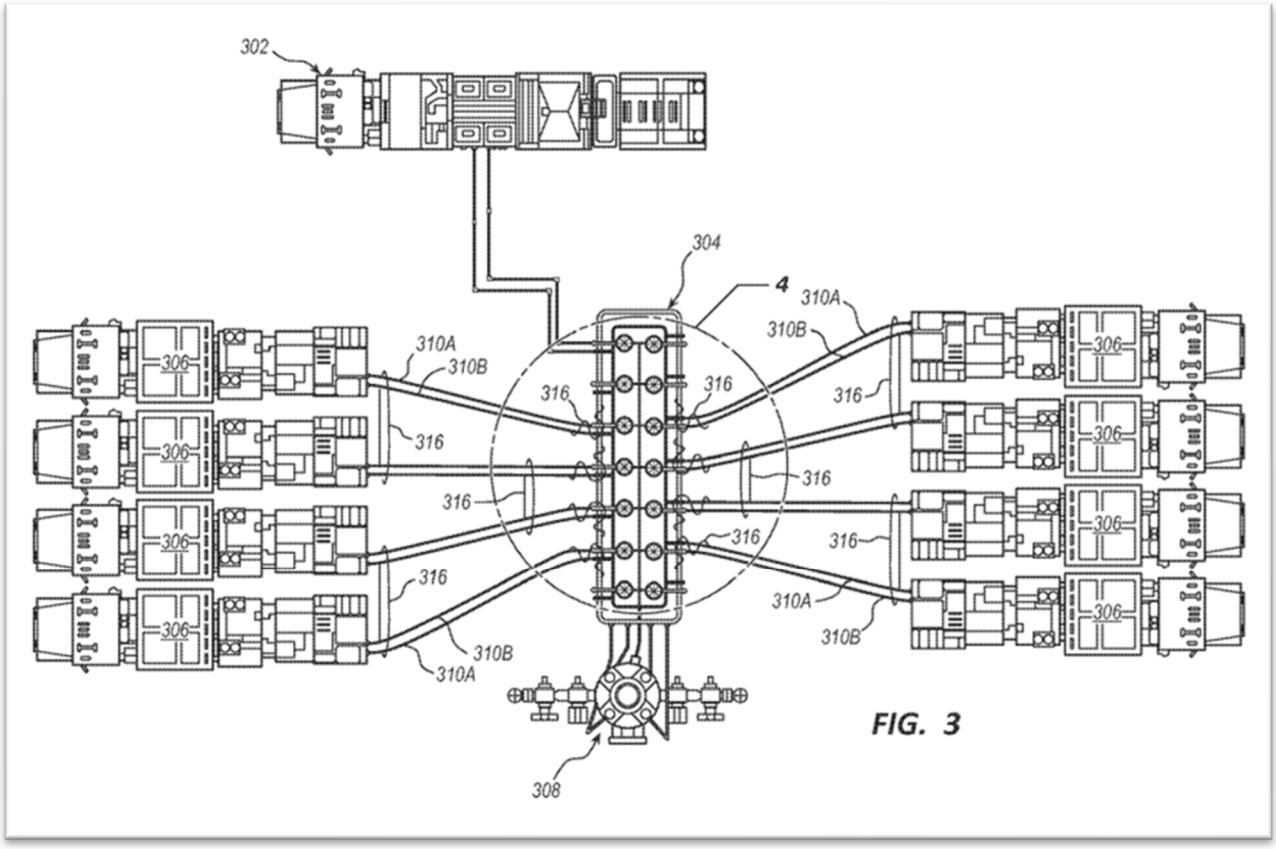
[231] Ex. 1004 (*Cicci*), 8:41-45; Ex. 1005 (*Cicci Provisional*), [35].
[232] Ex. 1004 (*Cicci*), 1:64-65, Claim 7; Ex. 1005 (*Cicci Provisional*), [4].
[233] Ex. 1004 (*Cicci*), 4:30-33; Ex. 1005 (*Cicci Provisional*), [18].

been an electric-powered multi-plunger hydraulic fracturing pump. Further, a POSITA would have understood based on *Cicci*'s disclosure that the second end has a diameter (e.g., a second diameter) for the same reasons as discussed above regarding 1[d].

199. Accordingly, the combination of *Cicci* and *Coli* discloses limitation 1[e].

7. 1[f]: "a body between the first end and the second end having a third diameter, the third diameter being less than both the first diameter and the second diameter; and"

200. *Cicci*'s hose has a body between the first end and the second end. For example, Figure 3 illustrates hoses 310 with a body between their two ends.



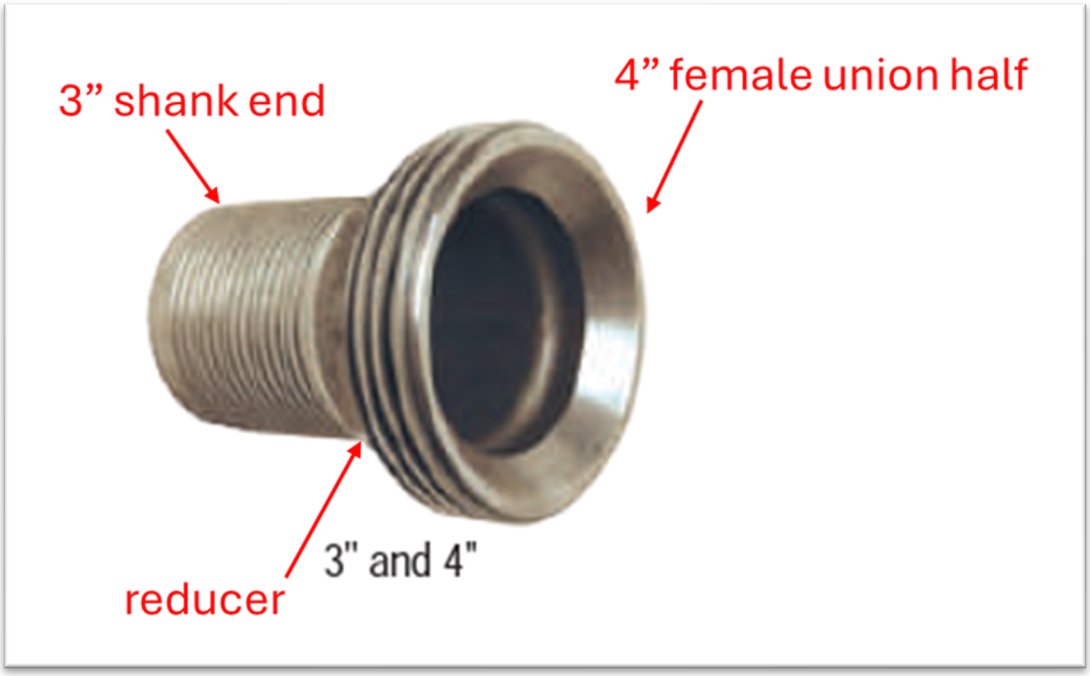
Ex. 1004 (Cicci), Fig. 3; Ex. 1005 (Cicci Provisional), Fig. 3.

201. *Cicci* explicitly discloses that the "body" of the flexible hose has a diameter (e.g., a "third" diameter). *Cicci* discloses that "the plurality of flexible hoses can have an inner diameter of one to eight inches."[234] Accordingly, *Cicci* discloses any flexible hose with an inner diameter of one to eight inches.

202. *Dixon* discloses that the third diameter (hose diameter) is less than the second diameter (pump connection diameter). *Dixon* discloses fittings for fracturing

[234] Ex. 1004 (*Cicci*) 1:64-65; Ex. 1005 (*Cicci Provisional*), [4].

operations that connect larger-diameter unions at the pump end with smaller-diameter hoses.[235] For example, *Dixon* discloses a 3" shank end fitting with a 4" female union half:



Ex. 1009 (*Dixon-Australia*), 149; EX1012 (*Dixon-U.S.*), 78.

A POSITA would have understood that *Dixon*'s 3" end receives the hose, and that the 4" female union couples to the pump. A POSITA accordingly would have understood, based on *Dixon*'s disclosure, that the third diameter is less than the second diameter.

[235] Ex. 1009 (*Dixon-Australia*), pg. 149; Ex. 1012 (*Dixon-U.S.*), pg. 78.

203. Further, the ’420 Patent itself reveals that the third diameter (hose) less than the second diameter (pump), such as *Dixon’s* Frac Fittings would have been obvious. The ’420 Patent admits that 6” fittings, such as “hammer unions, butterfly valves and other 6” steel pipe components” were “standard” in the fracturing industry.[236] This is consistent with *Coli*’s pump (Gardner-Denver SWGS-2500), which had 6” standard fittings.[237] Further, the ’420 Patent admits that 4” supply hoses were “standard” in fracturing systems.[238] And during the prosecution of the patent ’162 Patent, the applicant also admitted that “[t]raditional fracturing systems typically use 6” connections for equipment and 4” hoses for fluid flow.”[239] *Dixon’s* frac fittings to connect a larger-diameter pump (*e.g*. “standard” 6-inch pump connection) and a smaller diameter hose (*e.g*., “standard” 4-inch hose) would have been useful in connecting standard parts. Such a solution would have been obvious based on the *Cicci/Coli/Dixon/Liu* combination.

204. A POSITA additionally would have found it obvious for the hose’s “third diameter” to be less than both the first diameter and the second diameter, based on the teaching of general fluid dynamics taught by *Liu*, in particular those directed

[236] Ex. 1001 (’420 Patent), 4:8-12.
[237] Ex. 1006 (*Coli*), [0046]; Ex. 1010 (*Gardner-Denver*), pgs. 76-79.
[238] Ex. 1001 (’420 Patent), 4:16-23.
[239] Ex. 1056 (’162 Patent File History), pg. 433.

toward the flow of slurries. As *Cicci* discloses, "The blender 302 is configured to receive components of a fracturing fluid (e.g., water, sand, chemicals, etc.) and blend the components into a slurry."[240] Frac sand used as a proppant in fracturing operations has a particle size between ~1.2mm (20 mesh) and ~0.13mm (120 mesh). This corresponds to a particle size between 1,200 μm and 130 μm. A POSITA would have been motivated to look to *Liu* to understand the slurry fluid dynamics for the third diameter size.

205. It would have been obvious to a POSITA, and a POSITA would have been motivated, for the hose's third diameter to be less than the first and second diameters to maintain a slurry velocity high enough to avoid drop out and cavitation, in light of *Liu*. *Liu* discloses sizing the diameter of a slurry piping system (including the third diameter), to maintain velocity high enough to suspend the slurry in the hose and prevent moving bed or stationary bed flow.[241]

206. For example, *Liu* teaches the following:[242]

> When the solid particles [in a slurry] are relatively coarse (say, having diameters greater than 10 μm), the turbulence in the pipe must be sufficiently high in order to be able to suspend the solid particles. Depending on the mean velocity of the flow and the terminal velocity of the solid particles in suspension, the mixture may be in one of the following states or regimes:

[240] Ex. 1004 (*Cicci*), 5:17-20; Ex. 1005 (*Cicci Provisional*), [23].
[241] Ex. 1007 (*Liu*), pg. 132.
[242] Ex. 1007 (*Liu*), pg. 132.

> **Pseudohomogeneous** – This occurs when the particle size is relatively small and the velocity of the pipe flow is relatively high, i.e., relatively fine particles in strongly turbulent flow.
>
> **Heterogeneous** – This occurs when particles are fully suspended but not uniformly distributed – nonhomogeneous. This happens when either the velocity is somewhat smaller or the particle size is somewhat larger than in the previous case.
>
> **Moving-Bed Flow –** Particles settle out of the flow and form a bed. The particles in the bed move in the flow direction by **sliding**, **rolling** or **saltation**. This happens when either the velocity of the flow is less than or the particle size is larger than in the previous case. Saltation refers to the phenomenon that some particles on the surface of the bed layer move intermittently in frog leaps.
>
> **Stationary-Bed Flow** – Particles settle out on the bed, and they do not move in the bed. This happens with very coarse particles or very low velocity in pipes.

207. *Liu* discloses, and a POSITA would have understood, "moving-bed flow" and "stationary bed flow" to refer to drop out of the slurry.[243] For example, *Liu* describes "moving-bed flow" as when "particles settle out of the flow and form a bed," when there is insufficient velocity.[244] *Liu* further describes "stationary-bed flow" as when "particles settle out on the bed, and they do not move in the bed," which also occurs at "very low velocity in pipes."[245] This is consistent with the '420

[243] Ex. 1007 (*Liu*) pg. 132.
[244] Ex. 1007 (*Liu*) pg. 132.
[245] Ex. 1007 (*Liu*) pg. 132.

Patent, which describes "drop out" as particulates "drop[ping] out of the flow" when there is insufficient flow rate.[246]

208. *Liu* further describes that "[t]he four states or regimes described above are illustrated in Figure 5.1."[247]

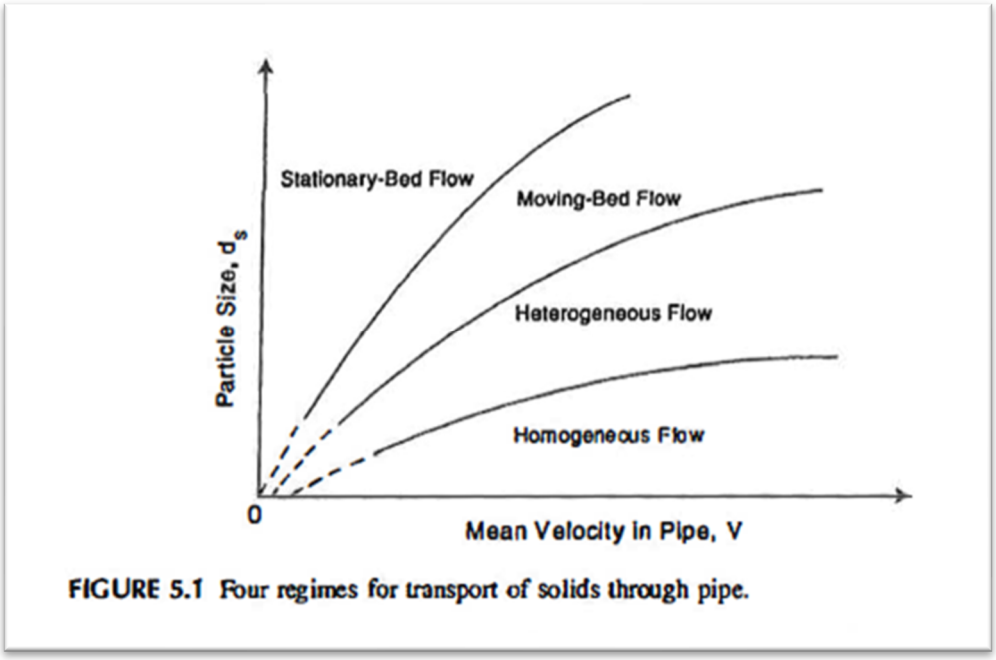


FIGURE 5.1 Four regimes for transport of solids through pipe.

Ex. 1007 (*Liu*), Figure 5.1, pg. 132.

[246] Ex. 1001 ('420 Patent), 1:49-54 (describing "flow rates that drop below a threshold may experience drop out of particulates, leading to blockages and other problems at the well site."), 5:49-53 (discussing "maintaining flow rates above a threshold amount where particulates begin to drop out of the flow").
[247] Ex. 1007 (*Liu*), pg. 133.

209. *Liu*, in Figure 5.1, shows a "drop out rate" or a velocity (tied directly to a flow rate through Eq. 2.6) at which drop out of the slurry in the piping system is avoided.[248]

210. *Liu* then provides various equations and examples for calculating the flow regime that a certain flow arrangement creates. As Figure 5.1 shows, for a given particle size (e.g., mean particle size in a frac proppant), there is a certain velocity that must be maintained in order to stay in Homogeneous Flow or Heterogeneous Flow. As velocity drops, the slurry may enter Moving-Bed Flow or even Stationary-Bed Flow, which would result in proppant settling at the bottom of the hoses, or, in extreme cases, even cause a screen-out in a certain section of the hose.[249] A reduction in the effective pipe diameter, such as in a Moving-Bed or Stationary-Bed regime would increase the pressure drop in the pipe, reduce the suction head (NPSH) at the pump, and reduce the flow through the pipe (all else being equal), which would risk starving the pump of fluid and, at least, damaging cavitation.[250] Accordingly, a POSITA would have known and been motivated to avoid flowing-bed or stationary-bed flow regimes when designing a piping system.

[248] Ex. 1007 (*Liu*), pg. 133, Fig. 5.1.
[249] A "screen out" exists when sand (or other proppant) completely plugs the pipe or hose.
[250] See, e.g., Section XI.C – XI.D above.

211. A POSITA would have been motivated to avoid either a moving bed or a stationary flow regime to avoid the negative consequences of these flow regimes, including increased pressure drop, reduced flow, and cavitation.[251] As velocity drops, the slurry enters Moving-Bed Flow or even Stationary-Bed Flow, which would result in proppant settling at the bottom of the hoses, or even cause a screen-out in a certain section of the hose.[252] A reduction in diameter, such as in a Moving-Bed or Stationary-Bed regime, would increase the pressure drop in the pipe, reduce the suction head (NPSH) at the pump, and reduce the flow through the pipe (all else being equal), which would risk starving the pump of fluid and, at least, damaging cavitation.[253]

212. For example, *Liu* teaches "[c]avitation is a special type of damage caused by liquid flow on solids, including pumps []. It is caused by the low pressure generated by liquids, causing the liquid to vaporize (boil at room temperature). The vaporized liquid forms bubbles."[254] *Liu* further teaches that when these bubbles collapse, "these collapsing bubbles can generate localized high-pressure fluctuations of the order of 100,000 psi. Any solid that comes into contact with such bursting

[251] Ex. 1007 (*Liu*), pgs. 133, 269.
[252] Ex. 1007 (*Liu*), pgs. 133, 269.
[253] Ex. 1007 (*Liu*), pg. 269; see also Section XI.D.
[254] Ex. 1007 (*Liu*), pg. 269.

bubbles can become severely damaged in a relatively short time, on the order of days or weeks."[255] *Liu* goes on to teach that pumps damaged by cavitation "not only lose efficiency but also may develop vibration and other problems."[256] Accordingly, a POSITA would be motivated to avoid cavitation. *Liu* teaches that to avoid cavitation make "sure that the available NPSH [net positive suction head] is at least a few feet greater than the required NPSH."[257] NPSH is the total amount of head (i.e., pressure) that is available at the suction of the pump. An increase in pressure drop caused by the reduction in available cross-sectional area of the hoses, such as occurs when proppant beds form, would reduce the NPSH and risk cavitation.

213. Accordingly, a POSITA would have known and been motivated to avoid flowing-bed or stationary-bed flow regimes when designing a piping system, and when selecting the hose diameter, and would have been motivated to use a hose diameter that keeps velocity high enough to avoid these flow regimes. A POSITA would have been motivated, based on the disclosure of *Liu*, to use a third diameter that is less than both the first and second diameters to avoid moving bed or stationary bed flow regimes and cavitation.

[255] Ex. 1007 (*Liu*), pg. 269.
[256] Ex. 1007 (*Liu*), pg. 269.
[257] Ex. 1007 (*Liu*), pg. 269.

214. A POSITA would have understood that the third diameter affects the velocity of the fluid flow, and accordingly the drop-out threshold, based on the disclosure of *Liu*. *Liu* provides various equations and examples for calculating the flow regime that a certain flow arrangement creates. As Figure 5.1 shows, for a given particle size, there is a certain velocity that must be maintained to stay in Homogeneous Flow or Heterogeneous Flow.[258]

215. Furthermore, *Liu* teaches that the mean velocity of the slurry in the pipe (hose) is a function of the flow rate through the pipe and the pipe diameter (i.e., cross-sectional area). In Eq. (2.6), *Liu* states that velocity (V in m/s) is the ratio of the flow (Q in m^3/s) to the cross-sectional area of the pipe (A in m^2).[259]

$$V = \frac{Q}{A}$$

216. Because the cross-sectional area of the pipe is directly related to diameter, rewriting Eq. (2.6) as a function of fluid flow and diameter (D in m), yields the below.

$$V = \frac{Q}{A} = \frac{4Q}{\pi D^2}$$

[258] Ex. 1007 (*Liu*), pg. 133.
[259] Ex. 1007 (*Liu*), pg. 21, Eq., (2.6). Eq. 2.6 is in a section describing "single-phase" flow, such as water flow with no solids. However, the basic relationship still applies to slurry flow, only with additional factors added to account for the solids.

217. *Liu* discloses scientific principles regarding fluid and slurry flow in piping systems to a POSITA. Based on *Liu*'s disclosure, a POSITA would have been motivated to perform the well-known calculations described in *Liu* and designed the piping system to maintain flow in a homogeneous or, at the very least, a heterogeneous flow regime. This would have involved the third diameter being less than both the first and second diameters.

218. *Liu* also teaches that the pressure drop in the piping system is a function of pipe size and flow rate. *Liu* teaches using the Darcy-Weisbach formula to calculate "head loss" (i.e., pressure drop) in a pipe (including hoses), shown in Equation 2.33, which is reproduced below.[260]

$$h_L = f \frac{L}{D} \frac{V}{2g}$$

Where:

h_L = head loss (pressure drop)

f = friction factor

L = length of the pipe

D = Diameter of the pipe

[260] Ex. 1007 (*Liu*), pg. 37, Eq. (2.33). Eq. 2.33 is in a section describing "single-phase" flow, such as water flow with no solids. However, the basic relationship still applies to slurry flow, only that the friction factor will increase due to the presence of solids.

V = velocity of the fluid

g = gravitational acceleration[261]

219. As discussed above, the velocity of the fluid is a function of the diameter of the hose and the flow rate. A smaller diameter hose, then, would increase velocity and increase pressure drop. A larger diameter hose would reduce velocity, which, if reduced too far, would result in proppant dropping out (settling out) of the slurry, leading to a further reduced diameter and, in some cases, plugging of the line. A reduction in diameter, such as from forming a bed of proppant in the hose, would also increase the pressure drop by reducing the effective diameter of the hose, increasing the risk of cavitation.

220. Pressure drop considerations, then, would place a lower limit on the third diameter while slurry drop out considerations would place an upper limit on the third diameter.

221. Therefore, sizing a hose is a standard engineering tradeoff. For a given flow rate, increasing the diameter of the hose reduces velocity, which in turn reduces the pressure drop in the hose, thereby reducing the risk of cavitation, for example. However, in a slurry flow system, reducing velocity too much leads to proppant drop-out, which reduces the cross-sectional area and increases pressure drop, thereby

[261] See Ex. 1007 (*Liu*), pgs. 26-29.

increasing the risk of cavitation. Selecting a particular hose size is simply optimization of a slurry flow system, and would have been known to a POSITA, at least based on the teachings of *Cicci, Coli* and *Liu.* A POSITA would have selected a hose diameter (e.g., a third diameter) that is smaller than the connection diameters (e.g., first and second diameters) to reduce the possibility of low-velocity flow causing the formation of a proppant bed in the hose, based on the disclosure of *Liu*.

222. Accordingly, based on the teachings of *Cicci, Coli, Dixon,* and *Liu*, modifying *Cicci*'s flexible hose to have a third diameter that is smaller than the first and second diameters, as claimed in limitation 1[f], would have been obvious to a POSITA at the time of the '420 Patent.

8. 1[g]: "a pair of fittings, a first fitting forming the first end and a second fitting forming the second end, each fitting of the pair of fittings having a shank end for receiving at least a portion of the body and a union for engaging the respective fluid source and electric powered multi-plunger hydraulic fracturing pump."

223. The combination of *Cicci, Coli, Dixon, and Liu,* discloses and would have rendered obvious limitation 1[g] to a POSITA. Once a POSITA realized, based on the well-known principles taught by *Liu*, that the hose diameter would need to be smaller to reduce the risk of damaging cavitation, fluid starving the pumps or screen-out of the hoses, a POSITA would have looked to commercially available fittings,

or the teachings of those fittings, such as *Dixon*, to allow the smaller hose to connect to the larger pump coupling.

224. *Cicci* discloses a pair of fittings, a first fitting forming the first end (at the fluid source) and a second fitting forming the second end. *Cicci* discloses that "[e]ach pump 306 is coupled to the missile 304 by a set of flexible flow lines 310. For example, each pump 306 can have a set of connections configured to interlock, engage, or otherwise *couple to a fitting affixed to each end of the flexible flow line 310 [hose]*. Similarly, the missile or manifold 304 can include a set of connections configured to interlock, engage, or otherwise *couple to a fitting affixed to each end of the flexible flow line 310.*"[262]

225. *Cicci* accordingly discloses a pair of fittings where each fitting couples to the hose (flexible flow line). A POSITA would have understood that one fitting (a first fitting) forms the first end of the hose for coupling to missile/manifold 304, and the second fitting (a second fitting) forms the second end of the hose for coupling to the pump inlet, based on *Cicci*'s disclosure that each fitting is "affixed to each end of the flexible flow line."[263] In the combination, the "pump" is an electric-powered multi-plunger hydraulic fracturing pump, as I discuss above. A POSITA would have

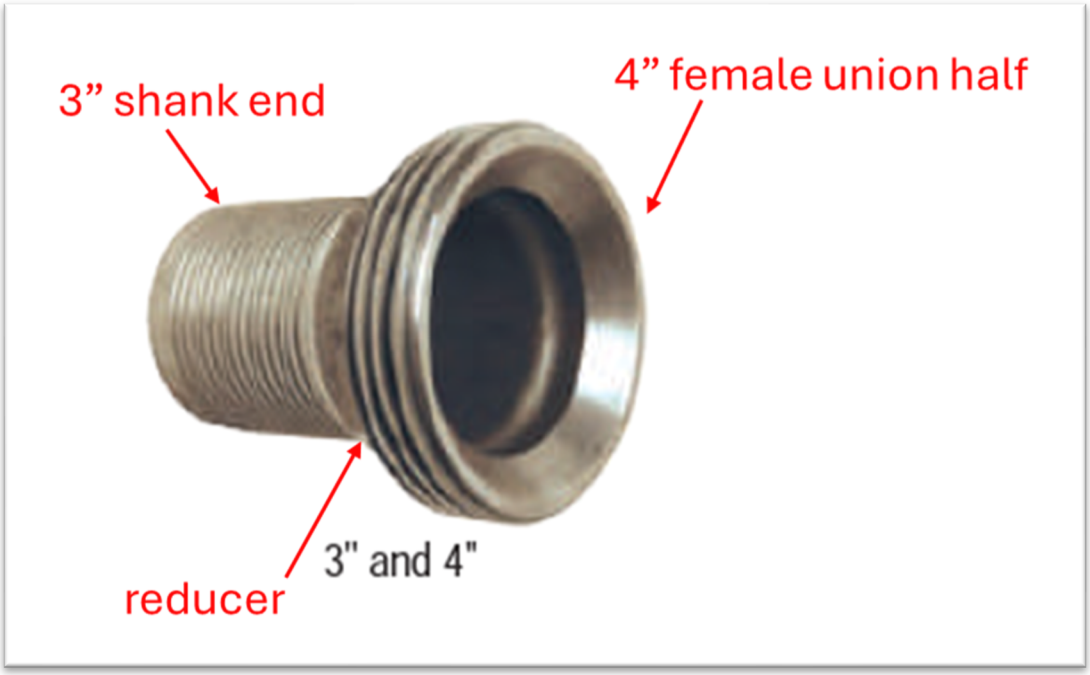
[262] Ex. 1004 (*Cicci*), 5:30-37; Ex. 1005 (*Cicci Provisional*), [24] emphasis added.
[263] Ex. 1004 (*Cicci*), 5:30-37; Ex. 1005 (*Cicci Provisional*), [24].

been motivated to use such a fitting to allow the smaller-diameter hose to the connect to the larger-diameter pump.

226. A POSITA would have understood each fitting of *Cicci*'s pair of fittings to have two ends, one end for receiving at least a portion of the hose body, and another end for engaging the respective fluid source (manifold/missile 304) and pump, respectively.[264] *Cicci* further teaches "coupling a first end of a first flexible hose to one of the respective pump connections. The flexible hose can be connected to the pump connections by any number of connection methods currently known or developed in the future, [] such as a hammer union."[265] A POSITA would have understood from *Cicci*'s disclosure that each fitting has a union for engaging the electric powered multi-plunger hydraulic fracturing pump.

227. *Dixon* also discloses each fitting having a shank end for receiving at least a portion of the hose body and a union for engaging the respective fluid source and pump. *Dixon* discloses fittings for fracturing operations that connect larger-diameter unions with smaller-diameter hoses.[266] For example, *Dixon* discloses a 3" shank end fitting with a 4" female union half, as shown below.

[264] Ex. 1004 (*Cicci*), 5:30-37; Ex. 1005 (*Cicci Provisional*), [24].
[265] Ex. 1004 (*Cicci*), 7:42-47; Ex. 1005 (*Cicci Provisional*), [30].
[266] Ex. 1009 (*Dixon-Australia*), pg. 149; Ex. 1012 (*Dixon-U.S.*), pg.78.



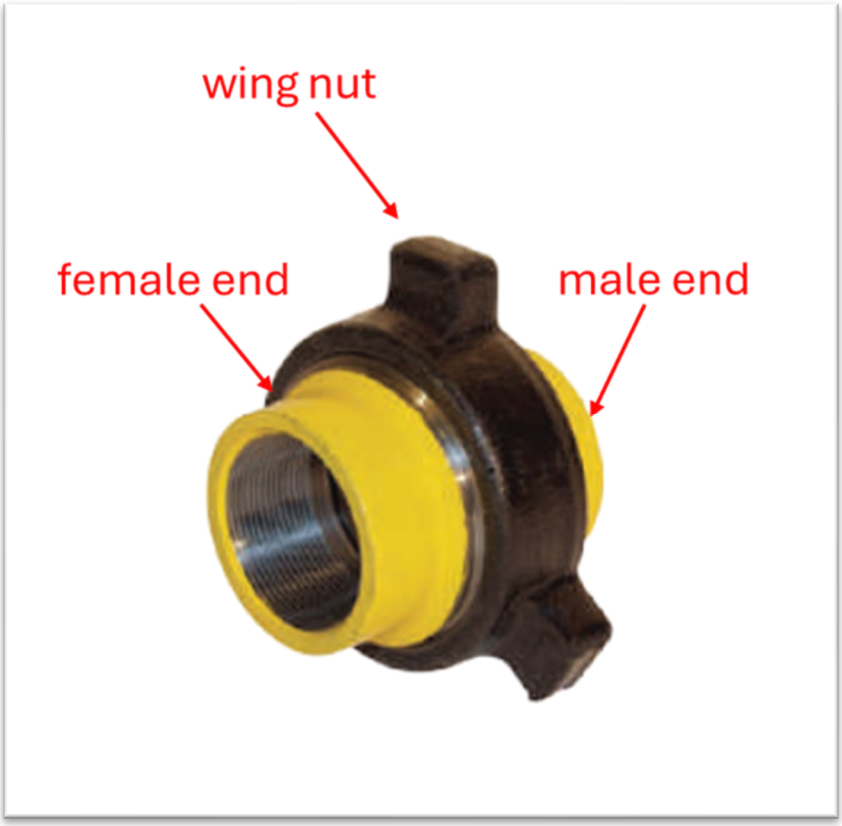
Ex. 1009 (*Dixon-Australia*) pg. 149; Ex. 1012 (*Dixon-U.S.*), pg. 78 excerpted and annotated.

228. A POSITA would have recognized the 3” end to be a “shank end”, at least because *Dixon* uses the term “shank” to mean that type of hose connection throughout *Dixon*.[267] Further, the end of a fitting that inserts into a hose is commonly referred to as a shank. A POSITA would have understood that *Dixon*’s fitting has two ends—a shank end for receiving at least a portion of the hose body hose and a union (4-inch female union) for engaging the fluid source and the pump, respectively.

[267] *See, e.g.,* Ex. 1009 (*Dixon-Australia*), pgs. 85, 91–96, 98–100; Ex. 1012 (*Dixon-U.S.*), pgs. 33-34, 67, 71, 74, 101, 104-106, 109-110 and many others.

229. A hammer union, disclosed by *Cicci* and as described by *Dixon*, is a three-piece system for connecting piping, including hoses, to other fluid connections, such as a pump intake, as described by *Cicci*. *Dixon* teaches that hammer unions come in various sizes (Figure Numbers) and pressure ratings, including hammer unions specifically designed for fracturing suction operations.[268] The figure below, taken from *Dixon*, page 154 and annotated, shows a typical 100 Series (up to 1000 PSI working pressure) hammer union with the three components identified.

[268] Ex. 1009 (*Dixon-Australia*), pgs. 154, 150; Ex. 1012 (*Dixon-U.S.*), pgs. 681-683.



Ex. 1009 (*Dixon-Australia*) pg. 150, 154; Ex. 1012 (*Dixon-U.S.*), pgs. 681-683 excerpted and annotated.

230. *Dixon* discloses just such a fitting for use in fracturing operations that provides an integrated assembly for connecting a larger diameter union with a smaller diameter hose.[269] *Dixon* discloses "Dixon Frac Fittings" that are "[u]sed in the fast paced transfer of water and sand slurry to a hydraulic fracturing site."[270] These fittings have a "[o]ne-piece design [which] eliminates leak path experienced

[269] Ex. 1009 (*Dixon-Australia*), pg. 149; Ex. 1012 (*Dixon-U.S.*), pg. 78.
[270] Ex. 1009 (*Dixon-Australia*), pg. 149; Ex. 1012 (*Dixon-U.S.*), pg. 78.

with two-piece threaded systems."[271] These Frac Fittings also are "[d]urable and safe with reliable hose retention when crimped as specified."[272] *Dixon* shows examples of various combinations of fitting sizes, including fittings for connecting the same size hose and union (Complete Male/Female Assembly) and combinations of Male/Female assemblies that would have connected a larger union to a smaller hose.[273]

231. A POSITA would have understood from *Dixon* that one half of the hammer union (*e.g.*, the male end) would be connected to the pump and the second half (*e.g.*, the female end) would be connected to the hose, or vice versa. Accordingly, each fitting on the hose would comprise a union (½ of the hammer union) which is configured to couple to a mating fitting (the other ½ of the hammer union). This is shown in the examples of the Frac Fittings from Dixon, including, for example, the HUM206600CS Frac Fitting which comprises one-half (male) of the hammer union, as shown below. This fitting would attach to the hose, while the other half of the union (female) would attach to the pump.

[271] Ex. 1009 (*Dixon-Australia*), pg. 149; Ex. 1012 (*Dixon-U.S.*), pg. 78.
[272] Ex. 1009 (*Dixon-Australia*), pg. 149; *see also* Ex. 1009 (*Dixon-Australia*), pgs. 150 and 151 showing the crimp ferrules that would be used with the shanks disclosed on pg. 149; Ex. 1012 (*Dixon-U.S.*), pgs. 78-79, 118.
[273] Ex. 1009 (*Dixon-Australia*), pg. 149; Ex. 1012 (*Dixon-U.S.*), pg. 78.



Ex. 1009 (*Dixon-Australia*), pg. 149; Ex. 1012 (*Dixon-U.S.*), pg. 79.

232. A POSITA would have understood that the other half (female half) of the hammer union would have been attached to the pump. Moreover, it would have been obvious to use a 6-inch hammer union to connect to the 6-inch inlet manifold disclosed by *Coli* as hammer unions were well known.[274]

233. *Dixon* also discloses a shank end, which a POSITA would have understood receives at least a portion of the hose. *Dixon* teaches that the shank is

[274] Ex. 1001 (’420 Patent), 4:8-13.

coupled with a ferrule that is crimped over at least the portion of the hose.[275]; *Dixon* further describes "King Crimp Style Heavy Duty Ferrules" as shown below.[276]

King Crimp™ Style Heavy Duty Ferrules

Feature:	• 400 PSI working pressure with a minimum 4:1 safety factor (hose burst: hose working pressure) is only achieved with heavy duty (HD) crimp ferrules, CF400-6CSHD through CF400-16CSHD.



Hose ID (inch)	Hose OD (mm)		Carbon Steel		Ferrule ID (inch)	Ferrule Wall Thickness (mm)	Ferrule Overall Length (mm)
	From	To	Heavy Duty (HD) Part No.	Price $			
4	114.70	115.90	CF400-6CSHD	81.80	4.625	3.05	102
	116.30	117.50	CF400-7CSHD	97.11	4.688	3.05	102
	117.90	119.10	CF400-8CSHD	97.11	4.750	3.05	102
	119.45	120.65	CF400-9CSHD	97.11	4.813	3.05	102
	121.00	122.25	CF400-10CSHD	97.11	4.875	3.05	102
	122.60	123.80	CF400-11CSHD	49.29	4.938	3.05	102
	124.20	125.40	CF400-12CSHD	68.10	5.000	3.05	102
	125.80	127.00	CF400-13CSHD	236.67	5.063	3.05	102
	127.40	128.60	CF400-14CSHD	69.21	5.125	3.05	102
	129.00	130.20	CF400-15CSHD	62.49	5.188	3.05	102
	130.60	131.80	CF400-16CSHD	81.80	5.250	3.05	102

234. A POSITA would have recognized from *Dixon* that the shank end comprises both the shank interior to and a ferrule around (exterior to) a portion of the hose and that the ferrule is then crimped (squeezed or smashed) over the hose in order for the hose to engage the ribs or barbs of the shank and receive at least a portion of the hose.

[275] Ex. 1009 (*Dixon-Australia*), pg. 149; EX1012 (*Dixon-U.S.*), pg. 78
[276] Ex. 1009 (*Dixon-Australia*), pg. 150-151 (showing the crimp ferules that would be used with the shanks disclosed on pg. 149); Ex. 1012 (*Dixon-U.S.*), pg. 118.

235. A POSITA would have used the teachings of *Dixon* to connect a smaller diameter hose to a larger diameter union based on the teachings of *Dixon's* integral Frac Fittings to connect a smaller diameter hose to a larger diameter union.

236. Accordingly, limitation 1[g] would have been obvious to a POSITA over the combined teachings of *Cicci, Coli, Dixon* and *Liu.*

C. DEPENDENT CLAIM 2: "2. THE SYSTEM OF CLAIM 1, WHEREIN THE THIRD DIAMETER IS APPROXIMATELY 5 INCHES AND THE SECOND DIAMETER IS APPROXIMATELY 6 INCHES."

237. Claim 2 depends from Claim 1. In addition to the teachings regarding Claim 1 as discussed above and incorporated herein by reference, the combination of *Cicci, Coli, Dixon,* and *Liu* would have rendered the additional limitations of Claim 2 obvious.

238. A third (hose) diameter of approximately 5 inches and a second diameter (end for connection to pump) of approximately 6 inches would have been obvious to a POSITA in view of, at least, the teachings of *Cicci. Cicci* discloses that each of "the plurality of flexible hoses can have an inner diameter of one inch to eight inches."[277] Accordingly, *Cicci* discloses a range of flexible hose diameters, including 5 inches. It would have been obvious to a POSITA to use a diameter between 1 and 8 inches, including 5 inches.

[277] Ex. 1004 (*Cicci*), 1:64-65, Claim 7; Ex. 1005 (*Cicci Provisional*), [4].

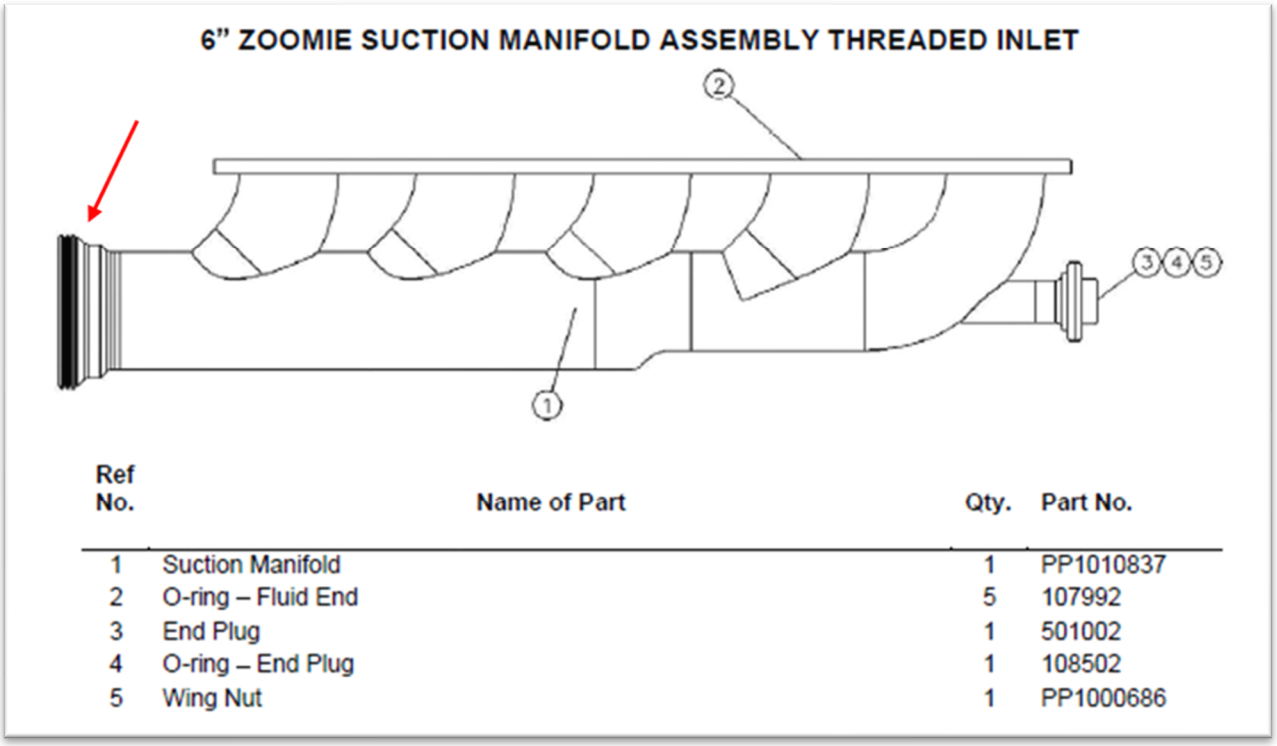
239. A POSITA would have further found it obvious for the third diameter to be approximately five inches because it would have been obvious to use a 5-inch hose in light of *Dixon* and *Cicci*'s disclosures. *Dixon* discloses "Suction Service Fittings" for hydraulic fracturing that have a 5-inch diameter.[278] A POSITA would have found it obvious to use a 5-inch hose based on *Dixon*'s teaching and *Cicci*'s disclosure of hose diameters between 1 and 8 inches.

240. A POSITA would have been motivated to use a 5-inch hose when the flow velocity calculations, such as those discussed above regarding Claim 1, indicate that 5 inches is an appropriate hose diameter size to keep velocity in the proper range to avoid a bed of slurry deposited in the hose, and thus avoid drop-out, as discussed above in Claim 1.

241. It would have been obvious to a POSITA to select a second diameter of 6 inches. For example, *Coli* discloses a "SWGS-2500 Well Service Pump sold by Gardner Denver, Inc."[279] A POSITA would have understood that this disclosure of *Coli* teaches 6" inlet connections with both threaded (for hammer union) and Victaulic style inlet connections, as discussed below.[280] For example, the "6" Zoomie Suction Manifold Assembly Threaded Inlet" shows an inlet that is

[278] Ex. 1009 (*Dixon-Australia*), pg. 150; EX1012 (*Dixon-U.S.*), pg. 79.
[279] Ex. 1006 (*Coli*), [0046].
[280] Ex. 1010 (*Gardner-Denver*), pgs. 76-79.

recognizable to a POSITA as a hammer union end (red arrow in the figure below) connected to a suction manifold.[281] A POSITA would have understood this to be a 6" threaded inlet.

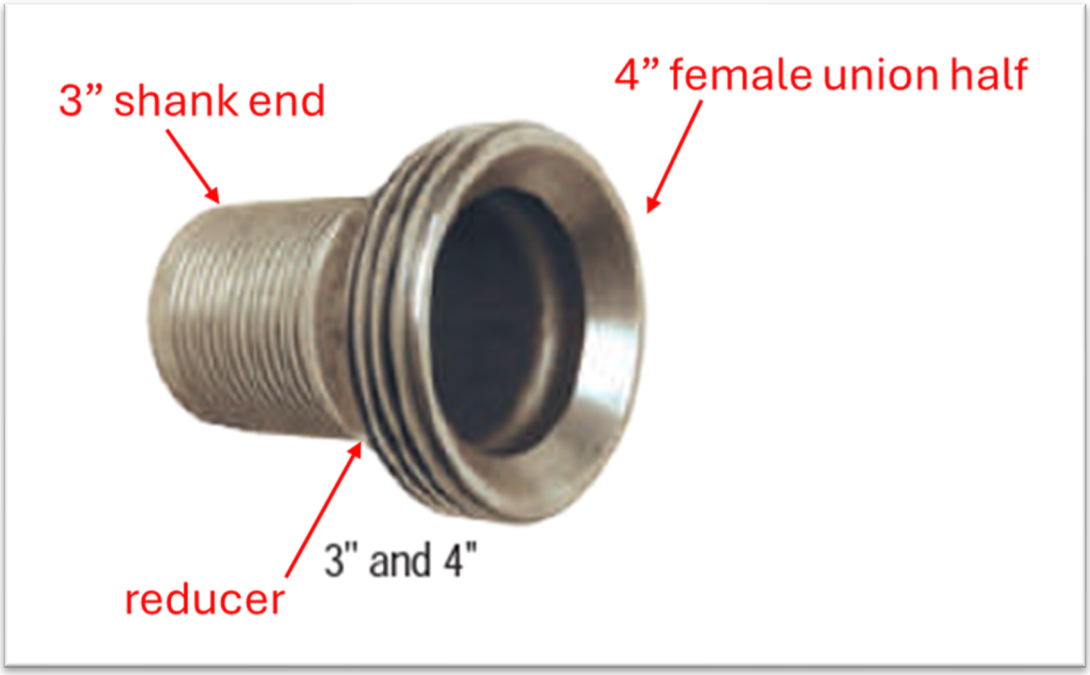


Ref No.	Name of Part	Qty.	Part No.
1	Suction Manifold	1	PP1010837
2	O-ring – Fluid End	5	107992
3	End Plug	1	501002
4	O-ring – End Plug	1	108502
5	Wing Nut	1	PP1000686

Ex. 1010 (*Gardner-Denver*) pg. 77 of the PDF.

A hammer union end from *Dixon* is shown for comparison.[282]

[281] Ex. 1010 (*Gardner-Denver*), pg. 77 of the PDF.
[282] Ex. 1009 (*Dixon-Australia*), pg. 149.



Ex. 1009 (*Dixon-Australia*), pg. 149; Ex. 1012 (*Dixon-U.S.*), pg. 78.

242. Other connections and sizes include 6” Victaulic, 8” threaded (hammer union) and 8” Victaulic.[283] Accordingly, *Gardner-Denver*, which contains information about the GD-2500 pump specifically referenced by *Coli,* discloses a 6” suction end (2nd diameter) for connection to the pump.

243. It would have been obvious to a POSITA to select a fitting diameter consistent with this disclosure. It would have been obvious to use a 6” hammer union to connect to the 6” inlet manifold disclosed by *Coli* as hammer unions were well known long before the ’420 Patent. Additionally, 6 inches was a well-known size

[283] Ex. 1010 (*Gardner-Denver*), pgs. 76-79 of the PDF.

for connection to a fracturing pump. For example, the '420 Patent admits that "6" (0.1524 m) components" used in fracturing operations, such as but not limited to "hammer unions," were "standard" even before the '420 Patent.[284]

244. Additionally, a POSITA would have understood from the teachings of *Dixon* that combinations of sizes other than those specifically disclosed were available.[285]

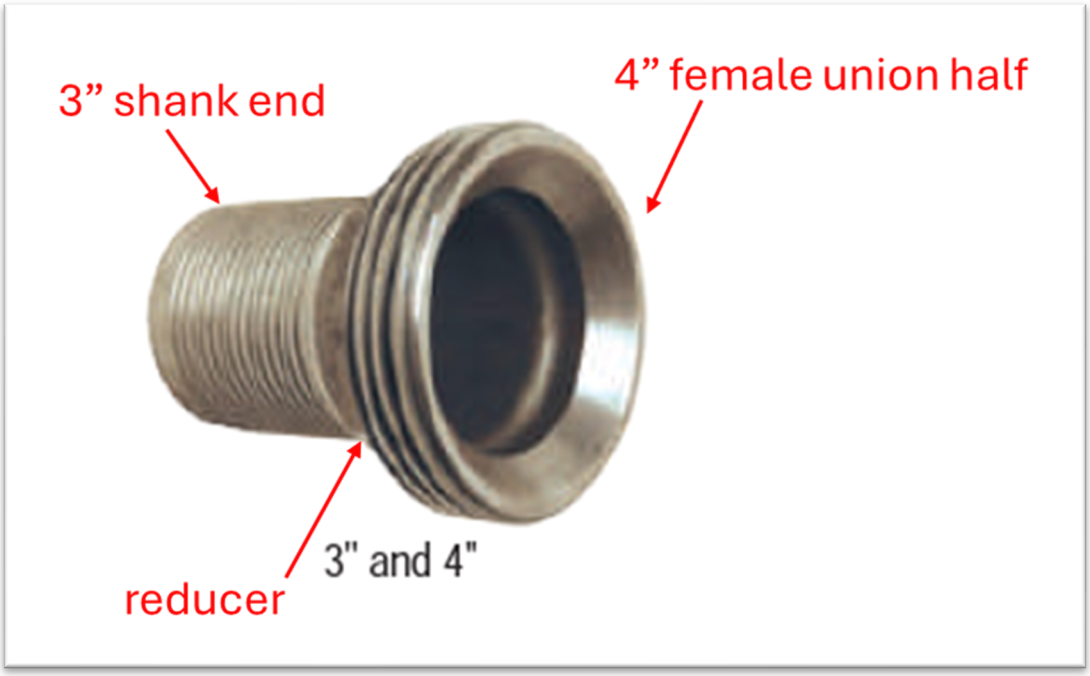
245. Therefore, the combined teachings of *Cicci, Coli, Dixon* and *Liu* would have rendered Claim 2 obvious to a POSITA.

D. DEPENDENT CLAIM 3: "3. THE SYSTEM OF CLAIM 1, WHEREIN EACH FITTING OF THE PAIR OF FITTINGS FURTHER COMPRISES: A REDUCER BETWEEN THE UNION AND THE SHANK END."

246. Claim 3 depends from Claim 1. In addition to the teachings regarding Claim 1 as discussed above and incorporated herein by reference, the combination of *Cicci, Coli, Liu* and *Dixon* discloses and would have rendered the additional limitations of Claim 3 obvious.

[284] Ex. 1001 ('420 Patent), at 4:8-13.
[285] Ex. 1009 (*Dixon-Australia*), pgs. 7 (referencing "made-to-order hose assemblies"), 99 ("[f]ittings are also available on special order for other sizes of hose OD's"); Ex. 1012 (*Dixon-U.S.*), pgs. 138-142.

247. *Dixon* discloses and renders obvious a reducer between the union and the shank end. *Dixon* shows an example of a fitting with a 3" shank end and a 4" union end as shown below.[286]

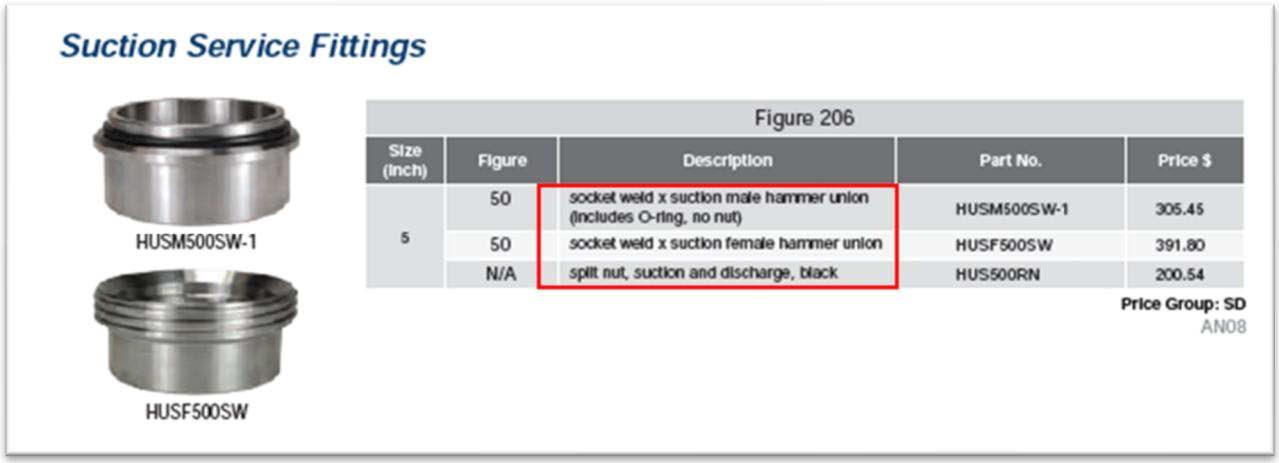


Ex. 1009 (*Dixon-Australia*) pg. 149; Ex. 1012 (*Dixon-U.S.*), pg. 78 (excerpted and annotated)

As shown by *Dixon*, there is (and would need to be) a reducer in the claimed location to enable the connection of the disparate-sized parts, and to allow for a smooth transition of the fluid flow.

[286] Ex. 1009 (*Dixon-Australia*) pg. 149 excerpted and annotated.

248. *Dixon* further teaches individual components of "weld" hammer unions and reducers.[287] A POSITA would have found it obvious to take the teachings of weld unions, as taught on page 150 of *Dixon*, and combine them with the teachings of weld reducers, such as those taught on page 359 of *Dixon* and weld such fittings together to form a reducing fitting, such as the "frac fittings" disclosed by *Dixon*.[288]



Ex. 1009 (*Dixon*) pg. 150 excerpted and annotated.

249. This would have been combined with the teaching of a hose shank, taught in numerous places in *Dixon*[289] to create a fitting that would enable a smaller

[287] See, e.g., Ex. 1009 (*Dixon-Australia*), pg. 150; Ex. 1012 (*Dixon-U.S.*), pg. 79.
[288] Ex. 1009 (*Dixon-Australia*), pg. 150 excerpted and annotated. I am relying on the teachings of *Dixon* that socket weld hammer unions and weld reducers were known, not specifically on the particular parts sold by *Dixon*.
[289] *See, e.g.,* Ex. 1009 (*Dixon-Australia*), pgs. 85, 91–96, 98–100; Ex. 1012 (*Dixon-U.S.*), pgs. 33-34, 67, 71, 74, 101, 104-106, 109-110, and many others.

hose size required by the flow parameters and calculations discussed above in Section XIII.B.7.

250. It would have been obvious for each of the fittings of the pair of fittings to comprise this reducer to allow each fitting to connect the smaller-diameter hose to the larger-diameter pump and fluid source.

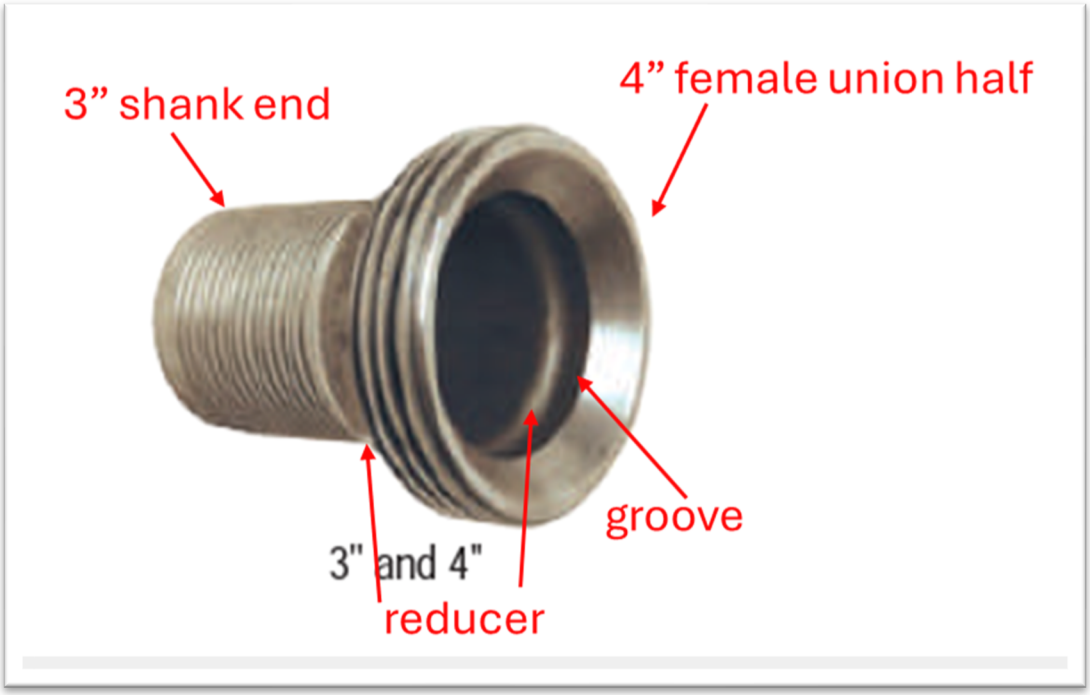
251. Accordingly, the combined teachings of *Cicci, Coli, Dixon* and *Liu* would have rendered Claim 3 obvious to a POSITA.

E. DEPENDENT CLAIM 4: "4. THE SYSTEM OF CLAIM 3, WHEREIN AT LEAST A PORTION OF THE REDUCER EXTENDS INTO A GROOVE FORMED IN THE UNION, THE UNION EXTENDING FARTHER LATERALLY THAN THE REDUCER."

252. Claim 4 depends from Claim 3, which itself depends from Claim 1. In addition to the teachings regarding Claims 1 and 3, as discussed above and incorporated herein by reference, the combination of *Cicci, Coli, Dixon,* and *Liu* discloses and would have rendered the additional limitations of Claim 4 obvious.

253. *Dixon* discloses a groove formed in the union, where at least a portion of the reducer extends into a groove formed in the union. For example, *Dixon* discloses a 3" shank end fitting with a 4" female union half, as shown below.[290]

[290] Ex. 1009 (*Dixon-Australia*), pg. 149 excerpted and annotated.

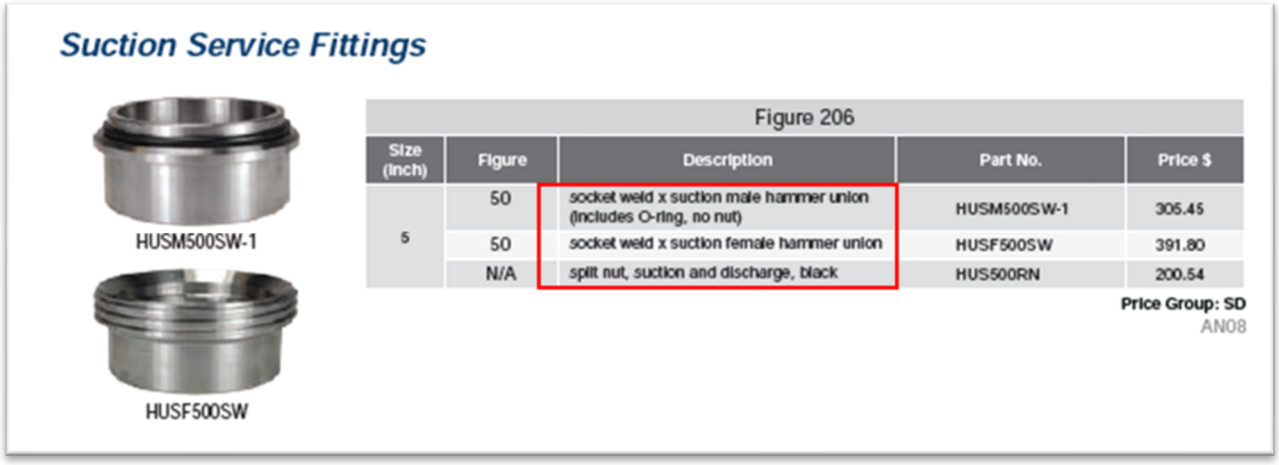


Ex. 1009 (*Dixon-Australia*), pg. 149 excerpted and annotated.

254. A POSITA would have understood that the fitting shown has a groove in the hammer union, with the reducer extending into the groove. A POSITA also would have understood that the fitting shown also discloses that the union extends farther laterally than the reducer, such as the threaded portion of the union.

255. *Dixon* further teaches “suction service fittings” that are designed for “socket weld” connections, as shown in the figure below.[291]

[291] Ex. 1009 (*Dixon-Australia*), pg. 150; Ex. 1012 (*Dixon-U.S.*), pg. 79 (excerpted and annotated).



Ex. 1009 (*Dixon-Australia*), pg. 150; Ex. 1012 (*Dixon-U.S.*), pg. 79 excerpted and annotated.

A POSITA would have recognized "socket weld" to be a weld type where the pipe or other fitting, such as a reducer, is inserted into a recessed area (groove) of another fitting, such as the suction service fittings taught by *Dixon*.[292] Accordingly, by combining the teachings of socket weld unions with those of *Dixon* regarding reducers and shanks, it would have been obvious to create a fitting by using a union with a "socket weld" connection, a reducer of the appropriate size, and a hose shank.[293] In such a combination, a portion of the reducer would fit (and thus extend)

[292] See, e.g., Ex. 1045 (Socket Weld Fittings Types and Applications – Complete Specification, ASME B16.11-2004), available at: https://web.archive.org/web/20180210052553/https://www.octalsteel.com/socket-weld-pipe-fittings/.

[293] Ex. 1009 (*Dixon-Australia*), pgs. 85, 91-95, 98-100, 149-150, 359, 405; Ex. 1012 (*Dixon-U.S.*), pgs. 33-34, 67-, 71, 74, 78-79, 101, 104-106, 109-110, 608, 613, 628.

into a groove formed in the union, and the union would extend farther laterally than the reducer, as a portion of the reducer is actually inside the union.

256. Accordingly, the combined teachings of *Cicci, Coli, Dixon, Liu* would have rendered Claim 4 obvious to a POSITA.

F. DEPENDENT CLAIM 5: "5. THE SYSTEM OF CLAIM 3, WHEREIN EACH FITTING OF THE PAIR OF FITTINGS IS FORMED AS AN INTEGRAL PIECE WITH AT LEAST ONE RIGID COUPLING BETWEEN AT LEAST ONE OF THE UNION, THE SHANK END, AND THE REDUCER."

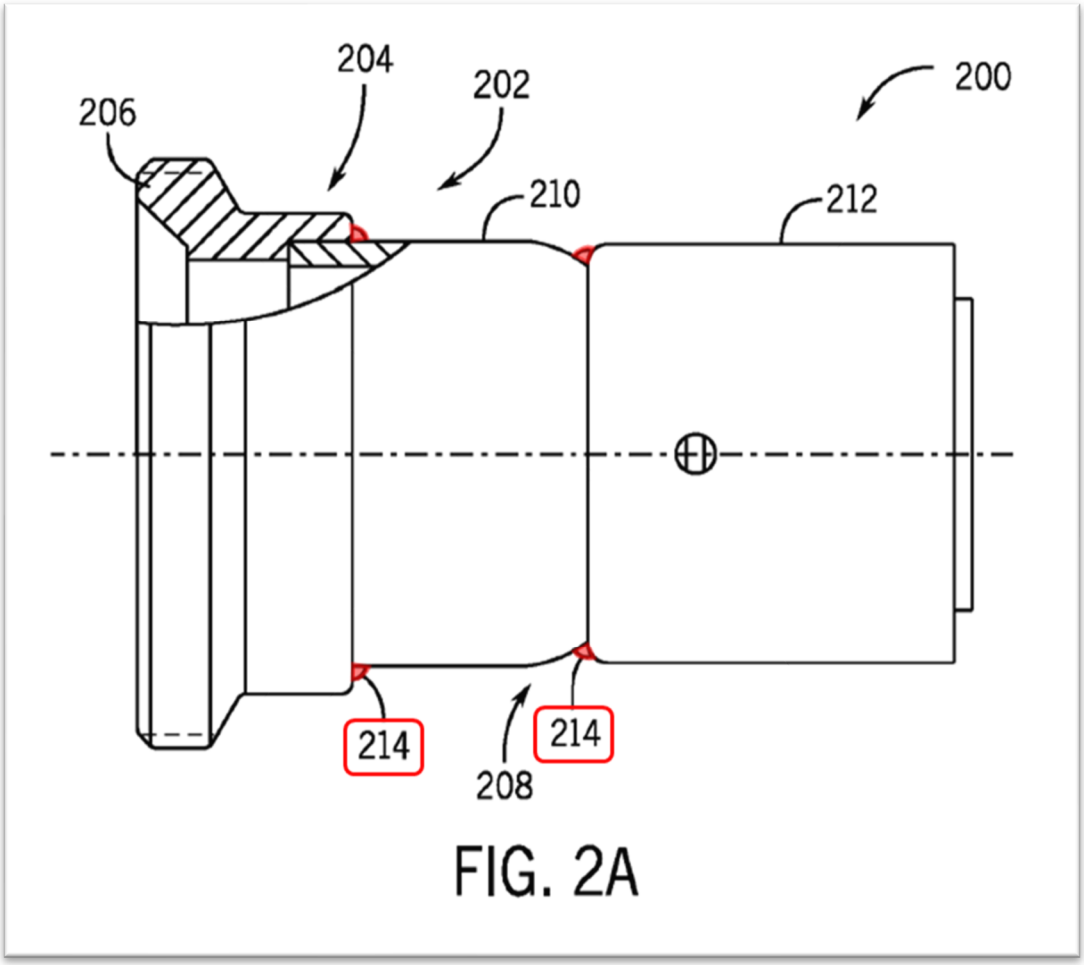
257. Claim 5 depends from Claim 3, which itself depends from Claim 1. In addition to the teachings regarding Claims 1 and 3 as discussed above and incorporated herein by reference, the combination of *Cicci, Coli, Dixon* and *Liu* discloses and would have rendered the additional limitations of Claim 5 obvious.

258. *Dixon* discloses each fitting of the pair of fittings formed as an integral piece. A POSITA would have been motivated to have each fitting of the pair of fittings to be formed as an integral piece, as taught by *Dixon,* at least because, as *Dixon* teaches express benefits that a "[o]ne-piece design eliminates leak path experienced with two-piece threaded systems."[294] A POSITA would have understood that "[o]ne piece design" refers to fittings that are formed as an integral piece.

[294] Ex. 1009 (*Dixon-Australia*), pg. 149; Ex. 1012 (*Dixon-U.S.*), pg. 78.

259. *Dixon* discloses the fittings with at least one "rigid coupling" between at least the union and the reducer. One example of a "rigid coupling" is a weld or weld bead. The weld, once cooled, forms a rigid piece of metal that couples the pieces of metal (such as the socket weld union and reducer) together.[295] This is consistent with the usage of the term "rigid coupling" in the '420 Patent, which shows, for example, in Fig. 2A, that "rigid coupling 214" (annotated in red) is shown as what a POSITA would easily have recognized as a weld bead.

[295] *See, e.g.*, Ex. 1046 (Cambridge English Dictionary) (definition of "weld") describing a "weld (noun)" as "a joint made by welding" and weld (verb) as "to join two pieces of metal together permanently by melting the parts that touch".



Ex. 1001 ('420 Patent) Fig. 2A annotated.

260. Accordingly, by disclosing a "socket weld" union, as discussed above regarding Claim 4, and incorporated herein by reference, *Dixon* is disclosing the fitting with at least one "rigid coupling" between at least the union and the reducer. At least a "weld bead" as a rigid coupling would have been obvious to a POSITA based on the teachings of *Dixon* .

261. Accordingly, the combined teachings of *Cicci, Coli, Dixon* and *Liu* would have rendered Claim 5 obvious to a POSITA.

G. DEPENDENT CLAIM 6: "6. THE SYSTEM OF CLAIM 1, WHEREIN THE THIRD DIAMETER IS PARTICULARLY SELECTED BASED AT LEAST IN PART ON A THRESHOLD, THE THRESHOLD CORRESPONDING TO A DROP OUT RATE FOR THE SLURRY."

262. Claim 6 depends from Claim 1. In addition to the teachings regarding Claim 1 as discussed above and incorporated herein by reference, the combination of *Cicci, Coli, Dixon* and *Liu* would have rendered the additional limitations of Claim 6 obvious. It would have been obvious for the third diameter (hose) to be particularly selected based at least in part on a threshold, the threshold corresponding to a drop-out rate for the slurry.

263. As discussed above regarding limitation 1[f], and incorporated herein by reference, *Liu* discloses selecting the diameter of a slurry piping system (which would include the hose diameter at least based on the teachings of *Cicci*) at least to maintain velocity high enough to suspend the slurry in the pipe and prevent "moving-bed flow" or "stationary-bed flow" (drop out of the slurry).[296] A POSITA would have understood from *Liu* that the velocity of the slurry in the pipe is based on both the flow rate of the system and the diameter of the pipe. The fluid velocity

[296] Ex. 1007 (*Liu*), pg. 132.

is a function of the hose diameter and flow rate. A smaller diameter increases velocity and pressure drop. A larger diameter reduces velocity, and if reduced too fair, results in proppant dropping out (settling out) of the slurry, leading to a further reduced diameter and, in some cases, plugging the line. A reduction in diameter, such as from forming a bed of proppant in the hose, would also increase the pressure drop by reducing the hose's effective diameter, increasing the cavitation risk. Pressure drop considerations thus place a lower limit on the third diameter, while slurry drop-out considerations place an upper-limit on the third diameter.

264. Therefore, sizing a hose, and selecting the third diameter, is a standard engineering tradeoff. For a given flow rate, increasing the diameter of the hose reduces velocity, which in turn reduces the pressure drop in the hose, thereby reducing the risk of cavitation, for example. However, in a slurry flow system, reducing velocity too much leads to proppant drop-out, which reduces the cross-sectional area and increases pressure drop (or screen out), thereby increasing the risk of cavitation. Selecting a particular hose diameter is simply optimization of a slurry flow system, and would have been known to a POSITA, at based on the teachings of *Cicci, Coli, Dixon,* and *Liu.* It would have been obvious to a POSITA, and a POSITA would have been motivated, to particularly select the third diameter based

on the flow rate, to maintain a velocity of the fluid flow high enough to avoid drop out in light of *Liu*'s disclosure.

265. *Liu,* in Figure 5.1, shows a "drop out rate" or a velocity (tied directly to a flow rate through Eq. 2.6) at which drop out of the slurry in the piping system is avoided. A POSITA would have avoided either a moving bed or a stationary flow regime to avoid the negative consequences of these flow regimes, such as those discussed in Section XIII.B.7 above, including increased pressure drop, reduced flow, and cavitation.[297]

266. For example, *Liu* teaches "[c]avitation is a special type of damage caused by liquid flow on solids, including pumps []. It is caused by the low pressure generated by liquids, causing the liquid to vaporize (boil at room temperature). The vaporized liquid forms bubbles []."[298] *Liu* further teaches that when these bubbles collapse, "these collapsing bubbles can generate localized high-pressure fluctuations of the order of 100,000 psi. Any solid that comes into contact with such bursting bubbles can become severely damaged in a relatively short time, on the order of days or weeks."[299] *Liu* goes on to teach that pumps damaged by cavitation "not only lose

[297] See also Section XI.D above.
[298] Ex. 1007 (*Liu*), pg. 269.
[299] Ex. 1007 (*Liu*), pg. 269.

efficiency but also may develop vibration and other problems."[300] Accordingly, a POSITA would be motivated to avoid cavitation. *Liu* teaches that to avoid cavitation make "sure that the available NPSH [net positive suction head] is at least a few feet greater than the required NPSH."[301] NPSH is the total amount of head (i.e., pressure) that is available at the suction of the pump. An increase in pressure drop caused by the reduction in available cross-sectional area of the hoses, such as occurs when proppant beds form, would reduce the NPSH and risk cavitation. Accordingly, it would have been obvious to select a third diameter (hose) particularly based at least in part on a threshold, the threshold corresponding to a drop-out rate for the slurry. The threshold being the velocity at which proppant starts to drop out of the slurry and form a bed in the hose.

267. *Liu* teaches maintaining velocity (and flow) in the pipe high enough to prevent drop-out of solids (proppant) into a bed, thus rendering it obvious to select the third diameter (hose) based on the flow rate, and to particularly select the third diameter to maintain velocity high enough to prevent slurry drop-out. It would have been obvious, and a POSITA would have been motivated, to select the third diameter

[300] Ex. 1007 (*Liu*), pg. 269.
[301] Ex. 1007 (*Liu*), pg. 269; when *Liu* refers to "feet" of head, he is referring to the pressure exerted by a column of water. The greater the height (i.e. feet) of the water column, the greater the pressure.

to maintain a velocity of the fluid flow high enough to avoid drop-out in light of *Liu*'s disclosure. A POSITA would have been motivated to avoid moving-bed or stationary-bed flow regimes when designing a piping system, and would have selected a hose diameter that keeps velocity high enough to avoid those flow regimes. Accordingly, a POSITA would have performed *Liu*'s calculations and designed the piping system, including selecting the third diameter, to maintain flow in a homogenous or, at the very least, a heterogeneous flow regime. This would have involved particularly selecting the third diameter based at least on a threshold corresponding to a drop-out rate for the slurry.

268. Therefore, the combined teachings of *Cicci, Coli, Dixon* and *Liu* and the knowledge of a POSITA regarding socket welds would have rendered Claim 6 obvious to a POSITA.

H. DEPENDENT CLAIM 7: "7. THE SYSTEM OF CLAIM 1, WHEREIN THE THIRD DIAMETER IS PARTICULARLY SELECTED BASED AT LEAST IN PART ON A PRESSURE DROP RATE, A DAMAGE ACCUMULATION RATE, OR A SUGGESTED FLOW RATE."

269. Claim 7 depends from Claim 1. In addition to the teachings regarding Claim 1 as discussed above and incorporated herein by reference, the combination of *Cicci, Coli, Dixon,* and *Liu* would have rendered the additional limitations of Claim 7 obvious.

270. As discussed above regarding limitation 1[f] and Claim 6, and incorporated herein by reference, the velocity of the pipe is based on both the suggested flow rate of the system and the diameter of the pipe. Liu teaches particularly selecting the third diameter to maintain the suggested flow rate or velocity, and avoid increased pressure drop, reduced flow, and cavitation. *Liu* further teaches that pressure drop is a function of hose diameter, and accordingly the third diameter (hose diameter). As *Liu* also teaches maintaining velocity (and flow) in the pipe high enough to prevent the drop-out of solids (i.e., proppant) into a bed, *Liu* makes it obvious to select the pipe based on the suggested flow rate.

271. As discussed above, the fluid velocity is a function of the hose diameter and flow rate. A smaller diameter increases velocity and pressure drop. A larger diameter reduces velocity, and if reduced too fair, results in proppant dropping out (settling out) of the slurry, leading to a further reduced diameter and, in some cases, plugging the line. A reduction in diameter, such as from forming a bed of proppant in the hose, would also increase the pressure drop by reducing the hose's effective diameter, increasing the cavitation risk. Pressure drop considerations thus place a lower limit on the third diameter, while slurry drop-out considerations place an upper-limit on the third diameter.

272. *Liu* teaches that pressure drop is a function of the hose diameter, and accordingly the third diameter. *Liu* also teaches that the pressure drop in the piping system is a function of pipe size and flow rate. *Liu* teaches using the Darcy-Weisbach formula to calculate "head loss" (i.e., pressure drop) in a pipe (including hoses), shown in equation 2.33, which has been duplicated below.[302]

$$h_L = f \frac{L}{D} \frac{V^2}{2g}$$

Where:

h_L = head loss (pressure drop)

f = friction factor

L = length of the pipe

D = Diameter of the pipe

V = velocity of the fluid

g = gravitational acceleration[303]

273. Recall, as discussed above, that the velocity of the fluid is a function of the diameter of the hose and the flow rate. Therefore, sizing a hose, and selecting the

[302] Ex. 1007 (*Liu*), pg. 37, Eq. (2.33). Eq. 2.33 is in a section describing "single-phase" flow, such as water flow with no solids. However, the basic relationship still applies to slurry flow, only that the friction factor will increase due to the presence of solids.
[303] See Ex. 1007 (*Liu*), pg. 26-29.

third diameter, is a standard engineering tradeoff. For a given flow rate, increasing the diameter of the hose reduces velocity, which in turn reduces the pressure drop in the hose, thereby reducing the risk of cavitation, for example. However, in a slurry flow system, reducing velocity too much leads to proppant drop-out, which reduces the cross-sectional area and increases pressure drop (or screen out), thereby increasing the risk of cavitation. Selecting a particular hose diameter is simply optimization of a slurry flow system, and would have been known to a POSITA, at based on the teachings of *Cicci, Coli, Dixon,* and *Liu.*

274. In addition to pressure drop considerations, *Liu* also teaches an additional upper limit on slurry velocity, and the associated lower limit on the third diameter. *Liu* teaches that "[t]he solid particles in a slurry pipeline may cause wear (abrasion) to the pipe and to special equipment such as pumps, valves, and bends. Wear is especially serious when the velocity is high, the slurry is coarse, and the solid particles are dense and possess sharp edges."[304] A POSITA reading *Liu* would have understood that wear (abrasion, sometimes referred to as erosion) considerations would impact the selection of the third diameter, as a smaller pipe would increase velocity, and, for slurry such as is used in hydraulic fracturing, increase wear. As velocity increases, wear or abrasion of the pipe increases. What

[304] Ex. 1007 (*Liu*), pg. 143, emphasis added.

Liu refers to as "wear" or abrasion would have been easily understood by a POSITA to be a damage accumulation rate as the term is used in the '420 Patent.[305]

275. Accordingly, it would have been obvious to a POSITA based on the teachings of *Liu* that a third diameter is particularly selected based at least on a pressure drop rate, a damage accumulation rate (e.g., wear), and/or a suggested flow rate. It would have been further obvious that both pressure drop and wear (abrasion) are based on the suggested flow rate.

276. Accordingly, the combined teachings of *Cicci, Coli, Liu* and *Dixon* would have rendered Claim 7 obvious to a POSITA.

I. DEPENDENT CLAIM 9

277. It is my opinion that the combination of *Cicci, Coli, Dixon,* and *Liu* would have rendered Claim 9 obvious. Claim 9 depends from Claim 1. In addition to the teachings regarding Claim 1 as discussed above and incorporated herein by reference, the combination of *Cicci, Coli, Dixon,* and *Liu* would have rendered the additional limitations of Claim 9 obvious. The combined teachings of *Cicci, Coli, Dixon,* and *Liu* render obvious each and every limitation of Claim 9, as discussed in the sections below.

[305] *See, e.g.*, Ex. 1001 ('420 Patent), at 7:1-10.

1. 9[a]: "The system of claim 1, further comprising: a plurality of electric powered multi-plunger hydraulic fracturing pumps, each electric powered multi-plunger hydraulic fracturing pump receiving fluid from the fluid source;"

278. Both *Cicci* and *Coli* disclose a plurality of pumps. For example, *Cicci* shows a system with eight pump trailers 306 (highlighted in green in the figure below) and discloses "one or more pumps 306"[306] and "a plurality of pumps"[307] disclosing to a POSITA the use of any number of pumps.

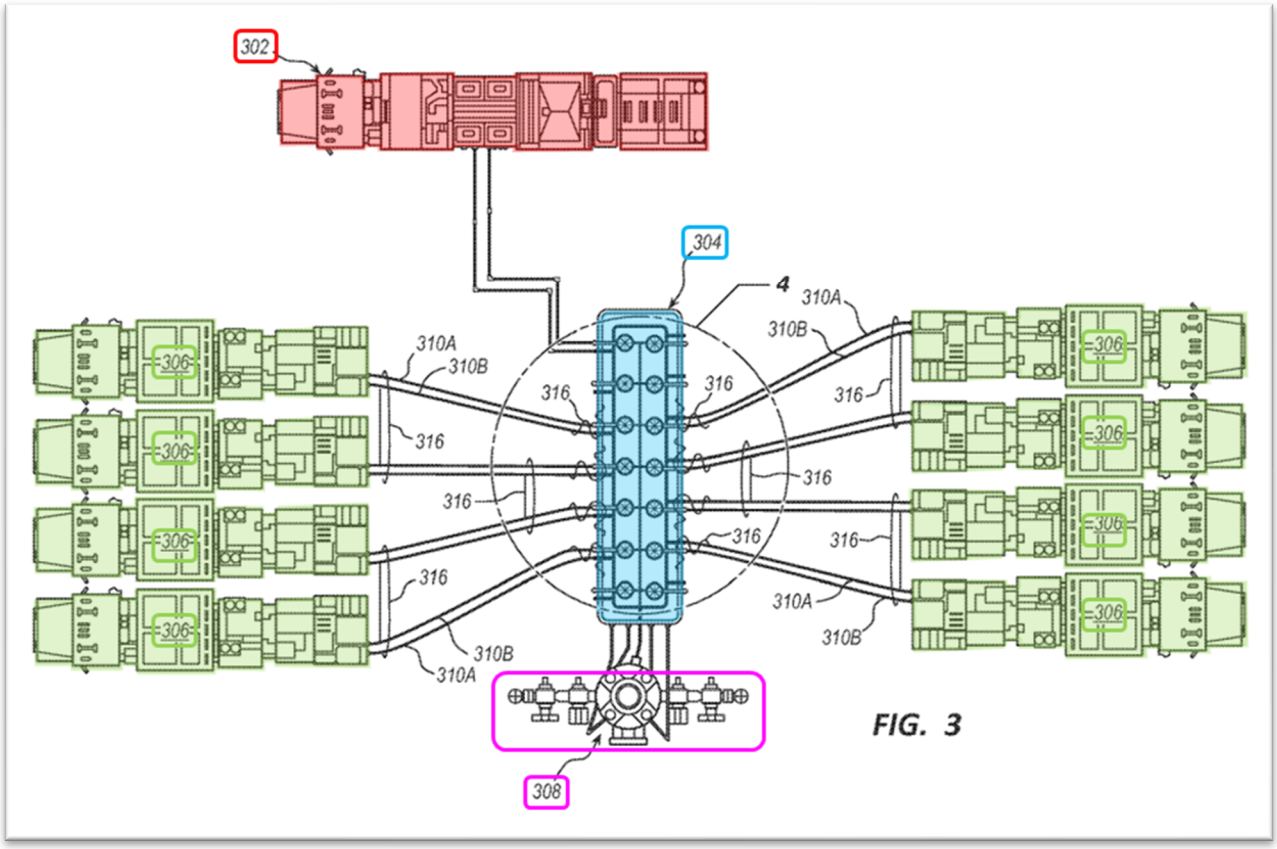
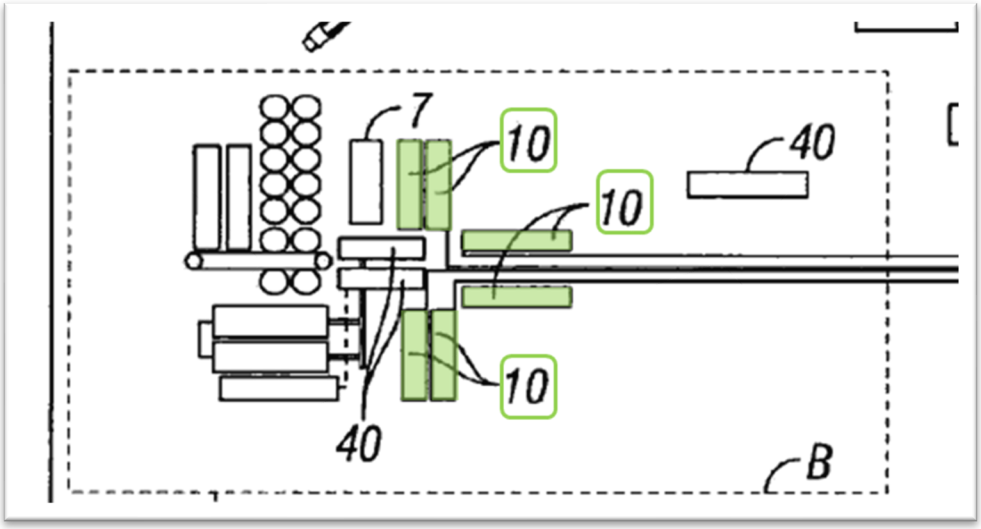


FIG. 3

[306] *See, e.g.*, Ex. 1004 (*Cicci*), 5:15-29; Ex. 1005 (*Cicci Provisional*), [23].
[307] Ex. 1004 (*Cicci*), 1:25-26; Ex. 1005 (*Cicci Provisional*), [2].

Ex. 1004 (*Cicci*), Fig. 3; Ex. 1005 (*Cicci Provisional*), Fig. 3 annotated.

279. *Coli* discloses a different number of pumps. *Coli* teaches the use of six "fracturing trailers 10" (highlighted in green in the figure below).[308]



Ex. 1006 (*Coli*), Fig. 2 excerpted and annotated.

280. *Coli* also teaches that each fracturing trailer 10 (annotated in magenta in the figure below) contains as many as four fracturing modules, with each fracturing module 20 (annotated in red) containing a pump 22 (annotated in blue) and a motor 21 (annotated in green).[309] *Coli* also discloses "a plurality of electric motors 21 and pumps 22 can be transported on a single trailer 10",[310] as shown in Fig. 3 of *Coli*, annotated below.

[308] Ex. 1006 (*Coli*), Fig. 2 excerpted and annotated.
[309] Ex. 1006 (*Coli*), Fig 3 (annotated). See also Section XIII.B.2 above.
[310] Ex. 1006 (*Coli*), [0040].

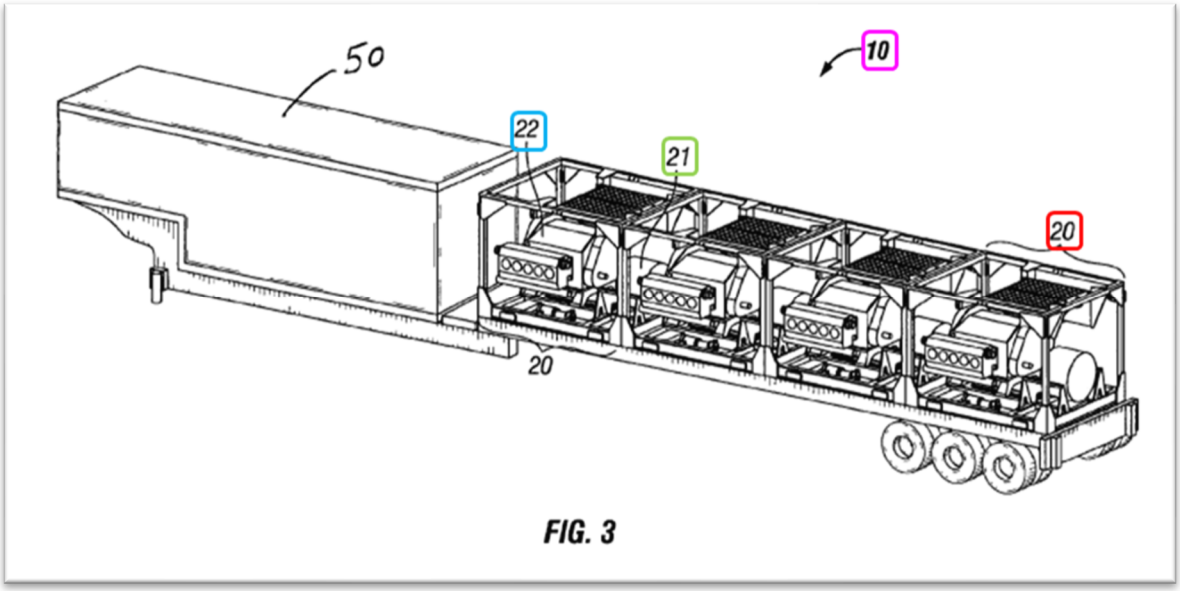


FIG. 3

Ex. 1006 (*Coli*), Fig. 3 annotated.

281. Accordingly, *Coli* at least discloses 24 pumps. *Coli* also discloses "providing one or more electric fracturing modules at the site, each electric fracturing module comprising an electric motor and a coupled fluid pump"[311] at least suggesting any number of pumps.

282. As discussed above regarding limitation 1[a], *Coli* discloses that the pumps are "electric powered multi-plunger hydraulic fracturing pumps"[312]

283. The *Cicci-Coli* combination further discloses the pump receiving fluid from the fluid source from the pump's inlet as I discuss above with respect to limitation 1[b]. For example, *Cicci* further discloses "positioning a plurality of

[311] Ex. 1006 (*Coli*), [0009].
[312] See Section XIII.B.2 above.

pumps adjacent to a manifold."[313] , *Cicci* teaches that "[e]ach pump 306 is coupled to the missile 304 by a set of flexible flow lines 310."[314] Further, *Cicci* teaches "[t]he missile 304 delivers the fracturing fluid to the pumps 306 at a relatively low pressure."[315] Accordingly, each electric-powered multi-plunger hydraulic fracturing pump, using the combined teachings of *Cicci* and *Coli*, receives fluid from the fluid source (missile 304).

284. Accordingly, the combined teachings of *Cicci, Coli, Dixon* and *Liu* disclose and render obvious limitation 9[a].

2. 9[b]: "a plurality of hoses having the third diameter; and"

285. As discussed above regarding limitation 9[a], *Cicci* discloses that "[e]ach pump 306 is coupled to the missile 304 by a set of flexible flow lines 310."[316] Additionally, *Cicci* discloses that "the plurality of flexible hoses can have an inner diameter of one to eight inches."[317] It would have been obvious to a POSITA, and a POSITA would have been motivated, to size the pumps similarly and operate them in a similar manner, so that the flow conditions in each pump would be comparable. For the same reasons discussed above regarding Claims 6–7 and limitation 1[f], it

[313] Ex. 1004 (*Cicci*), 1:25-26; Ex. 1005 (*Cicci Provisional*), [2].
[314] Ex. 1004 (*Cicci*), 5:30-31; Ex. 1005 (*Cicci Provisional*), [24].
[315] Ex. 1004 (*Cicci*), 5:19-26; Ex. 1005 (*Cicci Provisional*), [23].
[316] Ex. 1004 (*Cicci*), 5:30-31; Ex. 1005 (*Cicci Provisional*), [24].
[317] Ex. 1004 (*Cicci*), 1:64-65, Claim 7; Ex. 1005 (*Cicci Provisional*), [4].

would have been obvious to size each of the hoses with the same diameter based on the flow conditions at the pumps. Furthermore, it would have been obvious to a POSITA that each hose would have the same third diameter, allowing the hoses to be interchangeable.

286. Accordingly, the combined teachings of *Cicci, Coli, Dixon* and *Liu* disclose and render obvious limitation 9[b].

3. 9[c]: "a plurality of fittings between respective hoses of the plurality of the hoses and respective electric powered multi-plunger hydraulic fracturing pumps of the plurality of electric powered multi-plunger hydraulic fracturing pumps, each of the electric powered multi-plunger hydraulic fracturing pumps having a connection having the second diameter."

287. For the same reasons discussed above regarding limitation 1[f] and limitation 9 [b], it would be obvious for each of the hoses to have the same second diameter. Furthermore, it would be obvious to a POSITA that each hose should have the same second diameter, allowing the hoses to be interchangeable.

288. *Cicci* discloses that "[e]ach pump 306 is coupled to the missile 304 by a set of flexible flow lines 310. For example, each pump 306 can have a set of connections configured to interlock, engage, or otherwise couple to a fitting affixed to each end of the flexible flow line 310. Similarly, the missile or manifold 304 can include a set of connections configured to interlock, engage, or otherwise couple to

a fitting affixed to each end of the flexible flow line 310."[318] Accordingly, not only does *Cicci* disclose a plurality of fittings on each hose, but also discloses that each pump would have its own hose, resulting in a plurality of fittings between the respective hoses of the plurality of hoses and respective pumps of the plurality of pumps, which are electric-powered multi-plunger hydraulic fracturing pumps in the combination, as discussed above.

289. It would have been obvious to a POSITA for each of the pumps to have a connection having the second diameter, as that is the diameter of the end of the fitting connected to the pump, as I discuss above with respect to limitation 1[e]. A POSITA would have been motivated for each of the pumps (and fittings) to have a connection having the second diameter to obtain the benefits of interchangeability. Furthermore, pump manufacturers offer a limited selection of connection diameters, as I discuss above with respect to Claim 2. It therefore would have at least been obvious to a POSITA to use pumps with the same diameter connection of the limited number of connections available.

290. Accordingly, the combined teachings of *Cicci, Coli, Dixon* and *Liu* disclose and render obvious limitation 9[c].

[318] Ex. 1004 (*Cicci*), 5:30-37; Ex. 1005 (*Cicci Provisional*), [24].

J. DEPENDENT CLAIM 10: "10. THE SYSTEM OF CLAIM 1, FURTHER COMPRISING: A DISTRIBUTION SYSTEM, POSITIONED BETWEEN THE WELL AND THE ELECTRIC POWERED MULTI-PLUNGER HYDRAULIC FRACTURING PUMP, THE DISTRIBUTION SYSTEM COLLECTING THE SLURRY FROM ELECTRIC POWERED MULTI-PLUNGER HYDRAULIC FRACTURING PUMP FOR INJECTION INTO THE SUBTERRANEAN FORMATION."

291. Claim 10 depends from Claim 1. In addition to the teachings regarding Claim 1 as discussed above and incorporated herein by reference, the combination of *Cicci, Coli, Liu* and *Dixon* discloses and would have rendered the additional limitations of Claim 10 obvious.

292. *Cicci* discloses a distribution system (including high pressure hoses 304A and manifold/missile 304)[319] positioned between the well and the pump that collects the slurry from the pump for injection into the wellbore, and subsequently, the subterranean formation. *Cicci* discloses that "[t]he pumps 306 deliver the pressurized fracturing fluid to the missile 304. The missile 304 then delivers the pressurized fracturing fluid to the wellhead 308, which routes the fluid into the steel casing in the wellbore (not shown)."[320] *Cicci* further teaches that "each end of the

[319] It was well known at the time of the '420 Patent that the "missile" contained manifolds for both the low pressure and high pressure connections of the pumps, consistent with *Cicci*'s disclosure regarding missile 304 connecting both suction and discharge lines of the pump. Ex. 1004 (*Cicci*), 5:22-29; Ex. 1005 (*Cicci Provisional*), [23].

[320] Ex. 1004 (*Cicci*), 5:25-29; Ex. 1005 (*Cicci Provisional*), [23].

high-pressure flexible flow lines 310A are coupled 60 to the pumps 306 or the missile 304, respectively."[321] Further, *Cicci* discloses that "[o]ne or more fracturing pumps are used to pressurize the fracturing fluid to a level which exceeds the tensile strength of the subterranean geological formations below the earth's surface. When distributed into a wellbore, the highly pressurized fluid generates micro fissures or cracks within the geological formations surrounding the wellbore."[322]

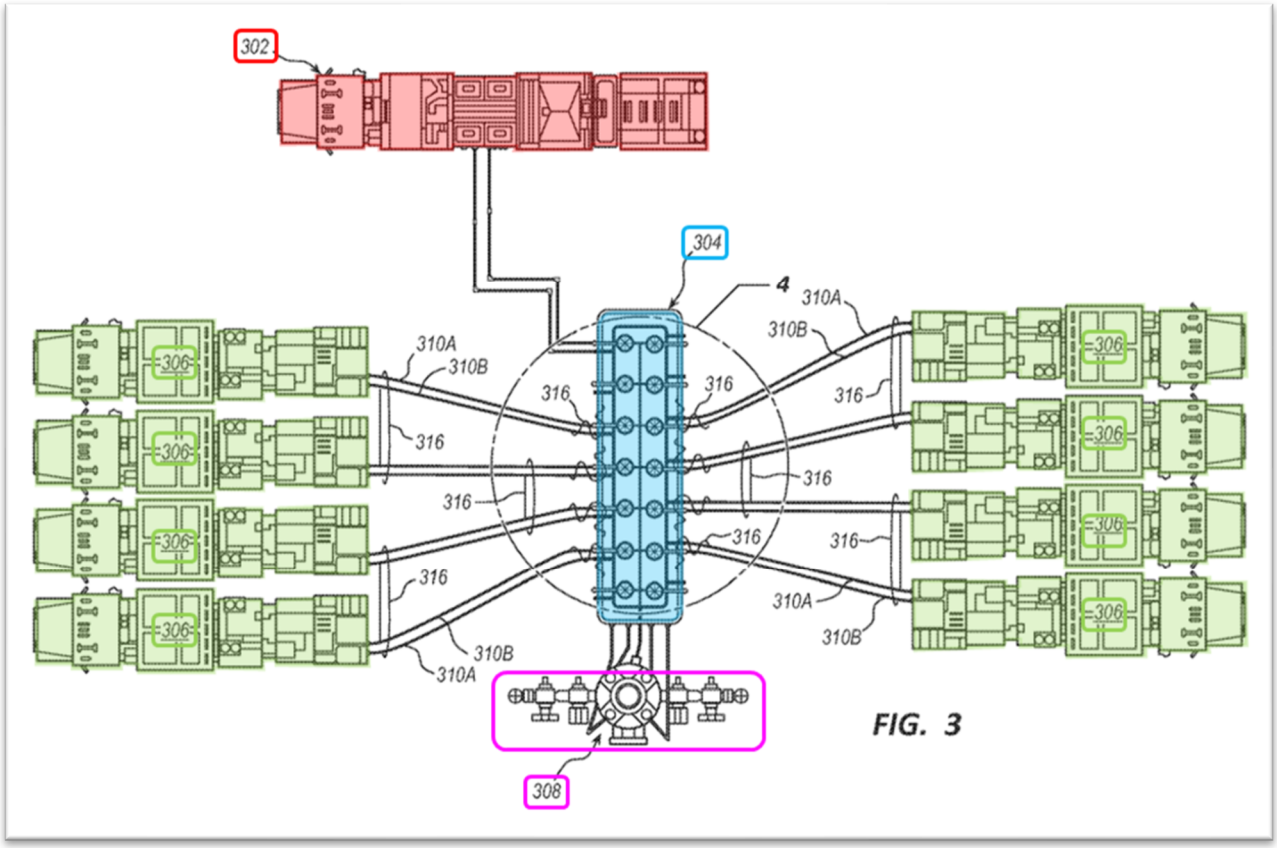


FIG. 3

[321] Ex. 1004 (*Cicci*), 6:58-60; Ex. 1005 (*Cicci Provisional*), [27].
[322] Ex. 1004 (*Cicci*), 1:9-19; Ex. 1005 (*Cicci Provisional*), [1].

Ex. 1004 (*Cicci*), Fig.3; Ex. 1005 (*Cicci Provisional*), Fig. 3 annotated and excerpted.

293. Accordingly, the combined teachings of *Cicci* and *Coli* disclose a distribution system (including high pressure hoses 310A and manifold/missile 304)[323] which is fluidically between the well and the electric powered multi-plunger pump, and the distribution system collects the slurry from the electric powered multi-plunger hydraulic fracturing pump for injection into the wellbore, and subsequently, the subterranean formation. As discussed above, the pump is an electric-powered multi-plunder hydraulic fracturing pump, and the fracturing fluid includes a slurry. Accordingly, the combined teachings of *Cicci* and *Coli* disclose a distribution system (manifold 304) which is fluidically between the well and the electric powered multi-plunger pump, and that the distribution system collecting the slurry from [the] electric powered multi-plunger hydraulic fracturing pump for injection into the wellbore, and subsequently the formation.

294. Accordingly, the combined teachings of *Cicci, Coli, Dixon* and *Liu* render Claim 10 obvious.

[323] It was well known at the time of the '420 Patent that the "missile" contained manifolds for both the low pressure and high pressure connections of the pumps, so the disclosure of *Cicci* regarding missile 304 connecting both suction and discharge lines of the pump is consistent.

K. INDEPENDENT CLAIM 11

295. It is my opinion that the combination of *Cicci, Coli, Dixon* and *Liu* would have rendered Claim 11 obvious. The combined teachings of *Cicci, Coli, Dixon* and *Liu* disclose, or at least suggest, each and every limitation of Claim 11, as discussed in the sections below.

1. 11[p]: "11. A hydraulic fracturing system for fracturing a subterranean formation, comprising:"

296. To the extent the preamble is limiting, *Cicci* and *Coli* each disclose a hydraulic fracturing system, for the same reasons that I discuss above with respect to limitation 1[p].

297. *Cicci* discloses, "[h]ydraulic fracturing systems utilize fracturing fluid to collect gas and/or oil from geological formations deep below the earth's surface. One or more fracturing pumps are used to pressurize the fracturing fluid to a level which exceeds the tensile strength of the subterranean geological formations below the earth's surface. When distributed into a wellbore, the highly pressurized fluid generates micro fissures or cracks within the geological formations surrounding the wellbore. After the wellbore is depressurized, proppant material in the fracturing

fluid remain in the fissures to hold the fissures open so that oil and/or gas trapped within the geological formations can be harvested through the wellbore."[324]

298. Similarly, *Coli* discloses "[t]he 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. A scalable, electrically powered fracturing fleet is provided to pump fluids for the fracturing operation".[325]

299. Accordingly, both *Cicci* and *Coli* disclose the preamble.

2. 11[a]: "an electric powered multi-plunger hydraulic fracturing pump having an inlet and an outlet, the outlet coupled to a well associated with the subterranean formation and powered by at least one electric motor;"

300. This claim limitation is the same as limitation 1[a] and would have been obvious to a POSITA for the same reasons as those discussed in Section XIII.B.2 above.

[324] Ex. 1004 (*Cicci*), 1:7-19; Ex. 1005 (*Cicci Provisional*), [1].
[325] Ex. 1006 (*Coli*), at Abstract.

3. 11[b]: "a fluid source, coupled to the inlet of the electric powered multi-plunger hydraulic fracturing pump, the fluid source providing a slurry for injection into the subterranean formation;"

301. This claim limitation is the same as limitation 1[b] and would have been obvious to a POSITA for the same reasons as those discussed in Section XIII.B.3 above.

4. 11[c]: "a hose extending between the fluid source and the electric powered multi-plunger hydraulic fracturing pump, the hose comprising:"

302. This claim limitation is the same as limitation 1[c] and would have been obvious to a POSITA for the same reasons as those discussed in Section XIII.B.4 above.

5. 11[d]: "a first end, for coupling to the fluid source, having a first diameter;"

303. This claim limitation is the same as limitation 1[d] and would have been obvious to a POSITA for the same reasons as those discussed in Section XIII.B.5 above.

6. 11[e]: "a second end, for coupling to the inlet of the electric powered multi-plunger hydraulic fracturing pump, having a second diameter; and"

304. This claim limitation is the same as limitation 1[e] and would have been obvious to a POSITA for the same reasons as those discussed in Section XIII.B.6 above.

7. 11[f]: "a body between the first end and the second end having a third diameter, the third diameter being less than both the first diameter and the second diameter and"

305. This claim limitation is the same as limitation 1[f] and would have been obvious to a POSITA for the same reasons as those discussed in Section XIII.B.7 above.

8. 11[g]: "a pair of fittings, wherein a first fitting of the pair of fittings is at the first end and a second fitting of the pair of fittings is at the second end, each fitting of the pair of fittings comprising:"

306. *Cicci* discloses limitation 11[g], for the same reasons that I discuss above with respect to limitation 1[g].

307. *Cicci* discloses that "[e]ach pump 306 is coupled to the missile 304 by a set of flexible flow lines 310. For example, each pump 306 can have a set of connections configured to interlock, engage, or otherwise *couple to a fitting affixed to each end of the flexible flow line 310*. Similarly, the missile or manifold 304 can include a set of connections configured to interlock, engage, or otherwise *couple to*

a fitting affixed to each end of the flexible flow line 310."[326] Accordingly, *Cicci* discloses that the hose has two fittings, one on each end of the hose, as claimed by limitation 11[g].

308. Accordingly, *Cicci* discloses limitation 11[g] and limitation 11[g] would have been obvious to a POSITA over the combined teachings of *Cicci, Coli, Dixon* and *Liu.*

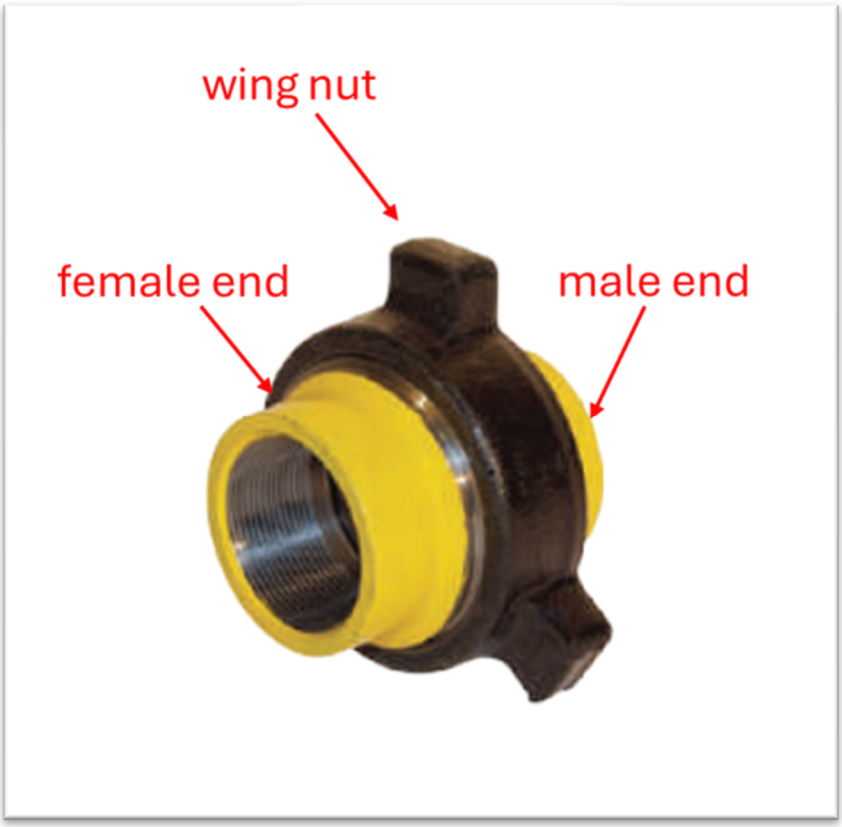
9. 11[h]: "a union arranged at a first fitting end, the union having a union diameter, larger than the first diameter;"

309. The combination of *Cicci*, *Coli*, *Dixon* and *Liu* discloses a union arranged at an end of the fitting for the same reasons that I discuss above with respect to limitation 1[g]. A POSITA would have understood this end is a first end.

310. *Cicci* teaches "coupling a first end of a first flexible hose to one of the respective pump connections. The flexible hose can be connected to the pump connections by any number of connection methods currently known or developed in the future,[] including threading wings onto a threaded connection, such as a hammer union."[327] A hammer union, as described by *Dixon*, is a three-piece system for connecting piping, including hoses, to other fluid connections, such as a pump intake, as described by *Cicci*.

[326] Ex. 1004 (*Cicci*), 5:30-34; Ex. 1005 (*Cicci Provisional*), [24] emphasis added.
[327] Ex. 1004 (*Cicci*), 7:42-47; Ex. 1005 (*Cicci Provisional*), [30].

311. *Dixon* teaches that hammer unions come in various sizes and pressure ratings (Figure Numbers), including hammer unions specifically designed for fracturing suction operations.[328] The figure below, taken from *Dixon*, page 154 and annotated, shows a typical 100 Series (up to 1000 PSI working pressure) hammer union with the three components identified.

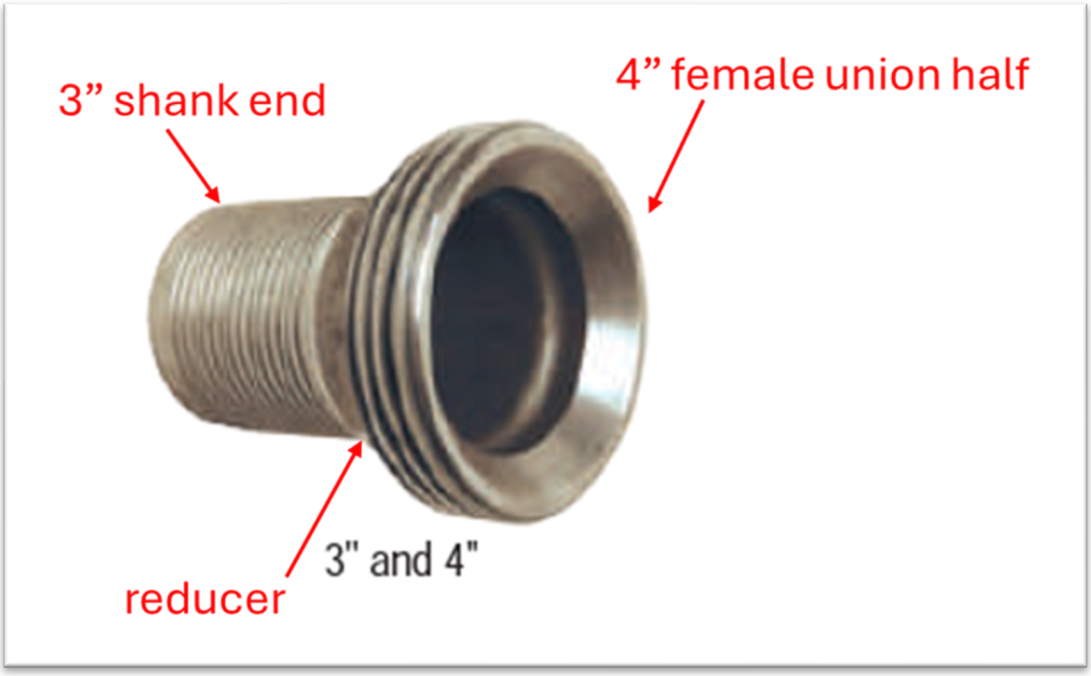


Ex. 1009 (*Dixon-Australia*) pg. 154; Ex. 1012 (*Dixon-U.S.*), pg. 681

[328] Ex. 1009 (*Dixon-Australia*), pgs. 154, 150; Ex. 1012 (*Dixon-U.S.*), pgs. 79, 681.

312. A POSITA would have understood from the description of *Dixon* that one half of the hammer union (e.g., the female end, a first end) would be connected to the pump and one half of the hammer union (e.g., the male end) would be connected to the hose. Accordingly, the fitting on the hose would comprise a union (½ of the hammer union) which is configured to couple to a mating fitting (the other ½ of the hammer union), as further described above in Section XIII.B.8 regarding limitation 1[g]. A POSITA would have understood that the end of the fitting at which the union is arranged is a first fitting end.

313. *Dixon* discloses that the union has a diameter, which a POSITA would have understood is a union diameter. *Id*. For example, *Dixon*'s fittings have a union half with a 4-inch diameter.

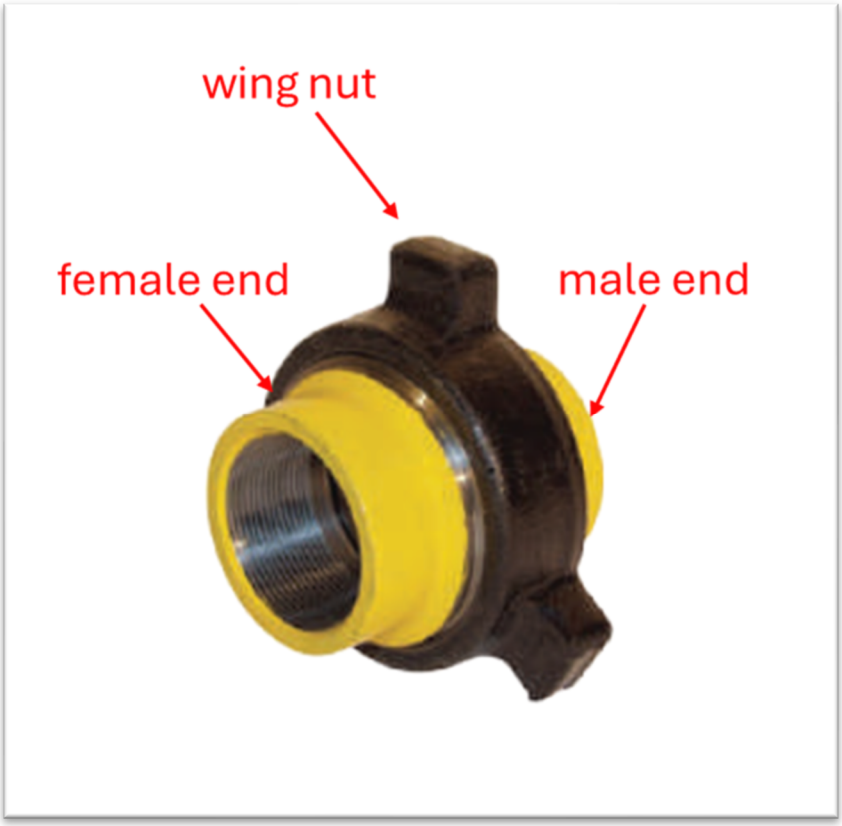


EX1009 (*Dixon-Australia*), pg. 149; EX1012 (*Dixon-U.S.*), pg. 78

314. The union would have a union diameter larger than the first diameter (fluid source diameter), as illustrated above in *Dixon*. Using the example above, the hose would be a 3" hose, and the "first diameter" of the "first end" of the hose would be 3". As can be seen, the union diameter of the 4" female union half is larger than the diameter of the hose it connects to (i.e. first end). This is common for hammer unions where the "union diameter" is taught by *Dixon* as being larger than the diameter of the hose or pipe it is connected to. This allows the threaded portion of the hammer union halves to be connected together using a wing nut.

315. The figure below, taken from Dixon, page 154 and annotated, shows a typical 100 Series (up to 1000 PSI working pressure) hammer union with the three components identified.[329]

[329] Ex. 1009 (*Dixon-Australia*), pg. 154, excerpted and annotated.



Ex. 1009 (*Dixon-Australia*), pg. 154, excerpted and annotated.

316. As can be seen from the figure above, the diameter of the end of the pipe that connects to the hammer union is smaller than the diameter of the union itself. The wing nut then couples the two halves of the union together, and the diameter of the wing nut is noticeably larger than the diameter of the pipe inserted into the internal grooves (threads) of the wing nut.

317. As fracturing pumps have manufacturer-supplied headers with inlet connections of fixed sizes,[330] a POSITA would have recognized that it is easier to combine well-known, commercially available components designed for fracturing systems, to allow for a smaller hose size in order to increase velocity and minimize proppant drop out, than to go back to the manufacturer and get custom inlet headers for the fracturing pumps.

318. Accordingly, limitation 11[h] is disclosed and would have been obvious to a POSITA over the combined teachings of *Cicci, Coli, Dixon* and *Liu.*

10. 11[i]: "a shank end at a second fitting end, the shank end configured to receive at least a portion of the hose, the shank end being securable to at least the portion of the hose, the shank end including an opening to receive the hose; and"

319. Each fitting of the pair of fittings comprises a shank end at the end of the fitting, configured to receive at least a portion of the hose for the same reasons that I discuss above with respect to limitation 1[g]. A POSITA would have understood this end is a second fitting end.

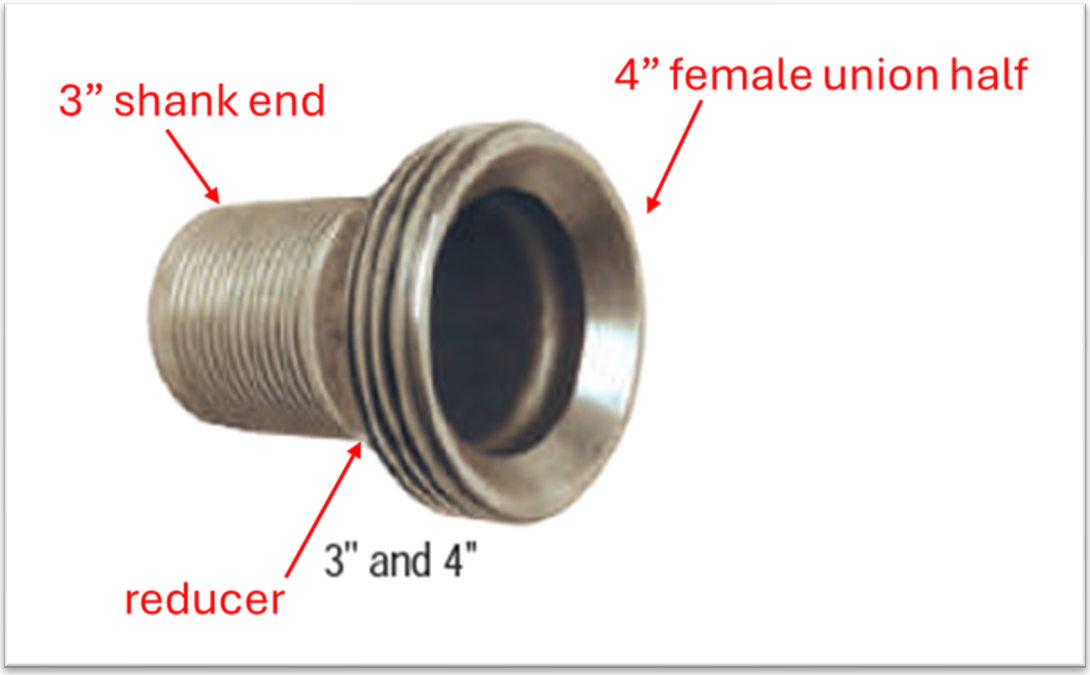
320. *Dixon* discloses a fitting for use in fracturing operations that provides an integrated assembly for connecting a larger diameter union with a smaller

[330] For example, the Gardner Denver 2500 referenced by *Coli* has 6" or 8" headers, as described more fully below regarding Claim 2.

diameter hose.[331] *Dixon* discloses "Dixon Frac Fittings" that are "[u]sed in the fast paced transfer of water and sand slurry to a hydraulic fracturing site."[332] These fittings have a "[o]ne piece design [which] eliminates leak path experienced with two-piece threaded systems."[333] These Frac Fittings also are "[d]urable and safe with reliable hose retention when crimped as specified."[334] *Dixon* shows examples of various combinations of fitting sizes, including fittings for connecting the same size hose and union (Complete Male/Female Assembly) and combinations of Male/Female assemblies that would have connected a larger union to a smaller hose.[335]

321. *Dixon* discloses a shank end at the first end. *Dixon* shows an example of a fitting with a 3" shank end and a 4" union end as shown below.[336]

[331] Ex. 1009 (*Dixon-Australia*), pg. 149.
[332] Ex. 1009 (*Dixon-Australia*), pg. 149.
[333] Ex. 1009 (*Dixon-Australia*), pg. 149; Ex. 1012 (*Dixon-U.S.*), pg. 78.
[334] Ex. 1009 (*Dixon-Australia*), pg. 149; *see also* Dixon ppg. 150 and 151 showing the crimp ferrules that would be used with the shanks disclosed on pg. 149.
[335] Ex. 1009 (*Dixon-Australia*), pg. 149.
[336] Ex. 1009 (*Dixon-Australia*) pg. 149 excerpted and annotated.



Ex. 1009 (*Dixon-Australia*) pg. 149 excerpted and annotated.

322. A POSITA would have recognized the 3” end to be a “shank end”, at least because *Dixon* uses the term “shank” to mean that type of hose connection throughout *Dixon*.[337] Further, the end of a fitting that couples to a hose is commonly referred to as a shank.

323. *Dixon* discloses that the shank end is securable to at least the portion of the hose, for example, by crimping it to the hose. *Dixon* teaches that the shank is coupled with a ferrule that is crimped over at least the portion of the hose. For example, Dixon teaches a feature of its Frac Fittings that they are “[d]urable and safe

[337] *See, e.g.,* Ex. 1009 (*Dixon-Australia*) ppg 85, 91–96, 98–100; Ex. 1012 (Dixon-U.S.), pgs. 33-34, 67, 71, 74, 101, 104-106, 109-110 and many others.

with reliable hose retention when crimped as specified."[338] Further, a "400 PSI working pressure with a minimum 4:1 safety factor (hose burst: hose working pressure) is only achieved with Dixon carbon steel ferrule" and then goes on to quote specific part numbers.[339] A POSITA would have understood from *Dixon*'s disclosure that when the shank end of the ferrule is crimped over at least a portion of the hose, it is securable to at least the portion of the hose.

324. *Dixon* further describes "King Crimp Style Heaving Duty Ferrules".[340]

King Crimp™ Style Heavy Duty Ferrules

Feature:	• 400 PSI working pressure with a minimum 4:1 safety factor (hose burst: hose working pressure) is only achieved with heavy duty (HD) crimp ferrules, CF400-6CSHD through CF400-16CSHD.

Hose ID (inch)	Hose OD (mm)		Carbon Steel		Ferrule ID (inch)	Ferrule Wall Thickness (mm)	Ferrule Overall Length (mm)
	From	To	Heavy Duty (HD) Part No.	Price $			
4	114.70	115.90	CF400-6CSHD	81.80	4.625	3.05	102
	116.30	117.50	CF400-7CSHD	97.11	4.688	3.05	102
	117.90	119.10	CF400-8CSHD	97.11	4.750	3.05	102
	119.45	120.65	CF400-9CSHD	97.11	4.813	3.05	102
	121.00	122.25	CF400-10CSHD	97.11	4.875	3.05	102
	122.60	123.80	CF400-11CSHD	49.29	4.938	3.05	102
	124.20	125.40	CF400-12CSHD	68.10	5.000	3.05	102
	125.80	127.00	CF400-13CSHD	236.67	5.063	3.05	102
	127.40	128.60	CF400-14CSHD	69.21	5.125	3.05	102
	129.00	130.20	CF400-15CSHD	62.49	5.188	3.05	102
	130.60	131.80	CF400-16CSHD	81.80	5.250	3.05	102



[338] Ex. 1009 (*Dixon-Australia*), pg. 149; Ex. 1012 (*Dixon-U.S.*), pg. 78.
[339] Ex. 1009 (*Dixon-Australia*), pg. 149; Ex. 1012 (*Dixon-U.S.*), pg. 78.
[340] Ex. 1009 (*Dixon-Australia*), pg. 150-151 (showing the crimp ferrules that would be used with the shanks disclosed on pg. 149; Ex. 1012 (*Dixon-U.S.*), pg. 118 .

Ex. 1009 (*Dixon-Australia*) pg. 150-151 (excerpted); Ex. 1012 (*Dixon-U.S.*), pgs. 78-81.

325. The shank end includes an opening to receive the hose. A POSITA would have recognized, from at least the description in *Dixon,* that the shank (barb) end comprises both the shank interior to and a ferrule around (exterior to) a portion of the hose and that the ferrule is then crimped (squeezed or smashed) over the hose in order for the hose to engage the ribs or barbs of the shank. The shank end accordingly comprises a shank that is inserted into the hose and a ferrule that is crimped over the hose to engage the barbs/ridges on the shank end. The combination of the ferrule and the ribs or barbs on the shank makes the shank end securable to the hose, such as when the ferrule is crimped.

326. The shank end includes an opening to receive the hose. A POSITA would have understood that when the ferrule is fitted around the shank end before insertion of the shank into the hose, the ferrule would comprise an opening to receive the hose. The shank would be inserted into the hose, and the ferrule would surround the hose. This is consistent with the '420 Patent, which describes "an end of the hose may be inserted into the shank end 212 and crimped, thereby joining the hose to the fitting 200."[341]

[341] Ex. 1001 ('420 Patent), at 5:28-30.

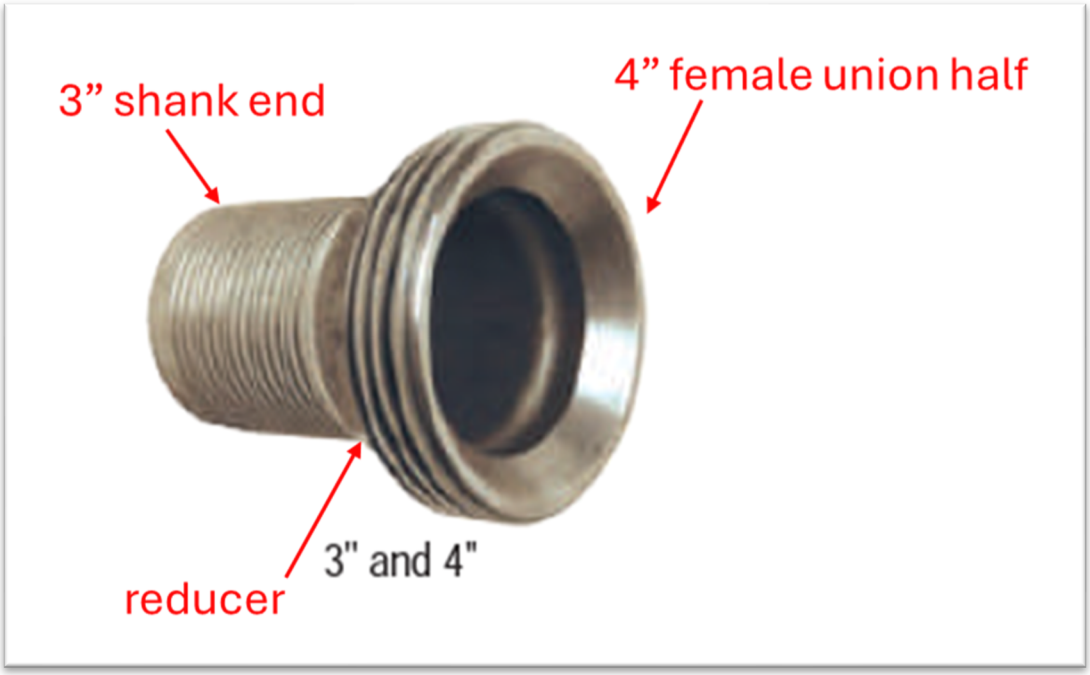
327. Accordingly, limitation 11[i] is disclosed and would have been obvious to a POSITA over the combined teachings of *Cicci, Coli, Dixon* and *Liu.*

11. 11[j]: "a reducer positioned between the union and the shank end, the reducer being welded to the respective union and shank end at each end, the reducer having an increasing diameter along its axial length, the reducer extending at least partially into the union."

328. *Dixon* discloses a reducer positioned between the union and the shank end, and the reducer extending at least partially into the union, for the reasons that I discuss above with respect to limitation 1[g] and Claims 3-4.

329. *Dixon* shows an example of a fitting with a 3" shank end and a 4" union end as shown below.[342]

[342] Ex. 1009 (*Dixon-Australia*), pg. 149; Ex. 1012 (*Dixon-U.S.*), pg. 78 excerpted and annotated.



Ex. 1009 (*Dixon-Australia*), pg. 149; Ex. 1012 (*Dixon-U.S.*), pg. 78 excerpted and annotated.

As shown by *Dixon*, there is (and would need to be) a reducer in the claimed location to enable the connection of the disparate-sized parts, and to allow for smooth transition of the fluid flow.

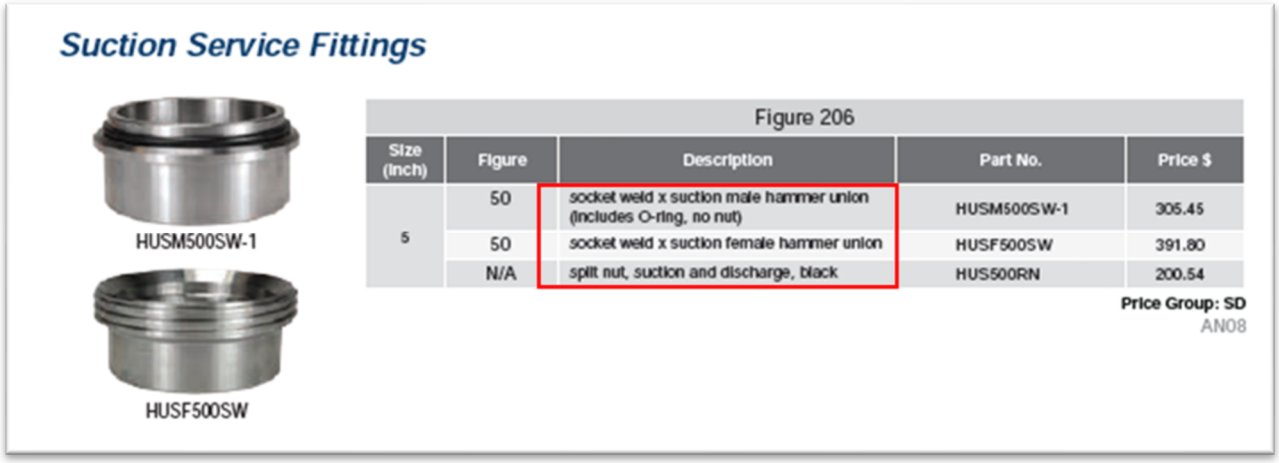
330. *Dixon* discloses that its reducer has an increasing diameter along its axial length, consistent with the well-known construction of reducers. In both examples, the reducer has an increasing diameter along its axial length, as this is a known method for constructing a reducer (see, e.g., Ex. 1009 (*Dixon-Australia*), pp. 359, 360, 460, 469 & Ex. 1012 (*Dixon-U.S.*), pp. 575, 592, 608, 613, 628), each of which shows a reducer with an increasing diameter along its axial length.

331. It would have been obvious to weld the reducer to the respective union and shank end at each end. *Dixon* teaches individual components of "socket weld" hammer unions and reducers. A POSITA would have found it obvious to take *Dixon*'s socket weld unions[343] and combine them with *Dixon*'s teachings of weld reducers,[344] and weld them together to form a reducing fitting, like the "frac fittings" disclosed by *Dixon*. This would have been combined with *Dixon*'s hose shank[345] to create a fitting that would have enabled a smaller hose size for the flow parameters and calculations discussed above.

332. A POSITA would have understood that the integral fittings shown in *Dixon*, for example, would have been either machined as a single part or welded together from the various individual components, each of which is taught by *Dixon.* Based on *Dixon*'s "socket weld" and "weld" fittings, it would have been obvious to weld the parts together. Thus, welding is one of only a limited number of connection options to create an integral frac fitting. Accordingly, there was a finite number of ways to construct the "Frac Fittings" disclosed by *Dixon*, and it would have been obvious to construct the part by welding known parts together.

[343] Ex. 1009 (*Dixon-Australia*), pg. 150; Ex. 1012 (*Dixon-U.S.*), pg. 79.
[344] Ex. 1009 (*Dixon-Australia*), pg. 359; Ex. 1012 (*Dixon-U.S.*), pg. 613.
[345] Ex. 1009 (*Dixon-Australia*), pg. 85, 91-96, 98-100; Ex. 1012 (*Dixon-U.S.*), pgs. 33-34, 67, 71, 74, 101, 104-106, 109-110.

333. For example, *Dixon* further teaches individual components of "socket weld" hammer unions and reducers. A POSITA would have found it obvious to apply the teachings of socket weld unions, as taught on page 150 of *Dixon* specifically for frac systems, and combine them with the teachings of weld reducers, as taught on page 359 of *Dixon* and weld such reducers and unions together to form a reducing fitting, such as the "frac fittings" disclosed by *Dixon*.[346]



Ex. 1009 (*Dixon-Australia*) pg. 150; Ex. 1012 (*Dixon-U.S.*), pg. 79 (excerpted and annotated)

334. This would have been combined with the teaching of a hose shank, taught in numerous places in *Dixon,*[347] which would be similarly welded together to

[346]Ex. 1009 (*Dixon-Australia*), pg. 150 (excerpted and annotated). I am relying on the teachings of *Dixon* that socket weld hammer unions and weld reducers were known, not specifically on the particular parts sold by Dixon.
[347] *See, e.g.,* Ex. 1009 (*Dixon-Australia*), pgs. 85, 91–96, 98–100 and many others.

create a fitting as claimed. A POSITA would be motivated to make the combination to connect between a hose with a smaller diameter and a coupling with a larger diameter for the reasons described above regarding limitation 1[f] and 1[g], which are incorporated herein by reference.

335. Accordingly, the combined teachings of *Cicci, Coli, Dixon* and *Liu* would have rendered limitation 11[j] obvious to a POSITA.

L. DEPENDENT CLAIM 12: "12. THE SYSTEM OF CLAIM 11, WHEREIN THE THIRD DIAMETER IS APPROXIMATELY 5 INCHES AND THE SECOND DIAMETER IS APPROXIMATELY 6 INCHES."

336. The limitations of Claim 12 are the same as those in Claim 2 and would have been obvious to a POSITA for the same reasons as those discussed above in Section XIII.C.

M. DEPENDENT CLAIM 13: "13.THE SYSTEM OF CLAIM 11, WHEREIN AT LEAST A PORTION OF THE REDUCER EXTENDS INTO A GROOVE FORMED IN THE UNION, THE UNION EXTENDING FARTHER LATERALLY THAN THE REDUCER."

337. The limitations of Claim 13 are the same as those in Claim 4 and would have been obvious to a POSITA for the same reasons as those discussed above in Section XIII.E.

N. DEPENDENT CLAIM 14: "14. THE SYSTEM OF CLAIM 11, WHEREIN EACH FITTING OF THE PAIR OF FITTINGS IS FORMED AS AN INTEGRAL PIECE WITH AT LEAST ONE RIGID COUPLING BETWEEN AT LEAST ONE OF THE UNION, THE SHANK END, AND THE REDUCER."

338. The limitations of Claim 14 are the same as those in Claim 5 and would have been obvious to a POSITA for the same reasons as those discussed above in Section XIII.F.

O. DEPENDENT CLAIM 15: "15. THE SYSTEM OF CLAIM 11, WHEREIN THE THIRD DIAMETER IS PARTICULARLY SELECTED BASED AT LEAST IN PART ON A THRESHOLD, THE THRESHOLD CORRESPONDING TO A DROP OUT RATE FOR THE SLURRY."

339. The limitations of Claim 15 are the same as those in Claim 6 and would have been obvious to a POSITA for the same reasons as those discussed above in Section XIII.G.

P. DEPENDENT CLAIM 16: "16. THE SYSTEM OF CLAIM 11, WHEREIN THE THIRD DIAMETER IS PARTICULARLY SELECTED BASED AT LEAST IN PART ON A PRESSURE DROP RATE, A DAMAGE ACCUMULATION RATE, OR A SUGGESTED FLOW RATE."

340. The limitations of Claim 16 are the same as those in Claim 7 and would have been obvious to a POSITA for the same reasons as those discussed above in Section XIII.H

Q. DEPENDENT CLAIM 18

341. It is my opinion that the combination of *Cicci, Coli, Liu,* and *Dixon* would have rendered Claim 18 obvious. The combined teachings of *Cicci, Coli, Liu* and *Dixon* disclose, or at least suggest, each and every limitation of Claim 18, as discussed in the sections below.

1. 18[a]: "18. The system of claim 11, further comprising: a plurality of electric powered multi-plunger hydraulic fracturing pumps, each electric powered multi-plunger hydraulic fracturing pump receiving fluid from the fluid source;"

342. The limitations of Limitation 18[a] are the same as those in Limitation 9[a] and would have been obvious to a POSITA for the same reasons as those discussed above in Section XIII.I.1.

2. 18[b]: "a plurality of hoses having the third diameter; and"

343. The limitations of Limitation 18[b] are the same as those in Limitation 9[b] and would have been obvious to a POSITA for the same reasons as those discussed above in Section XIII.I.2.

3. 18[c]: "a plurality of fittings between respective hoses of the plurality of the hoses and respective electric powered multi-plunger hydraulic fracturing pumps of the plurality of electric powered multi-plunger hydraulic fracturing pumps, each of the electric powered multi-plunger hydraulic fracturing pumps having a connection having the second diameter."

344. The limitations of Limitation 18[c] are the same as those in Limitation 9[c] and would have been obvious to a POSITA for the same reasons as those discussed above in Section XIII.I.3.

R. DEPENDENT CLAIM 19: "19. THE SYSTEM OF CLAIM 11, FURTHER COMPRISING: A DISTRIBUTION SYSTEM, POSITIONED BETWEEN THE WELL AND THE ELECTRIC POWERED MULTI-PLUNGER HYDRAULIC FRACTURING PUMP, THE DISTRIBUTION SYSTEM COLLECTING THE SLURRY FROM ELECTRIC POWERED MULTI-PLUNGER HYDRAULIC FRACTURING PUMP FOR INJECTION INTO THE SUBTERRANEAN FORMATION."

345. The limitations of Claim 19 are the same as those in Claim 10 and would have been obvious to a POSITA for the same reasons as those discussed above in Section XIII.J.

XIV. GROUND 2: THE COMBINATION OF *CICCI, COLI, DIXON, LIU* AND *GARDNER-DENVER* RENDERS CLAIMS 1-19 OBVIOUS

346. It is my opinion that the combination of *Cicci, Coli, Dixon, Liu* and *Gardner-Denver* renders claims 1-19 of the '420 Patent obvious.

A. MOTIVATION TO COMBINE

347. The reasons to combine *Cicci, Coli, Dixon*, and *Liu* are the same as those described above in Section XIII.A, which are incorporated herein by reference. Nothing in *Gardner-Denver* teaches away from such a combination. To the extent that the Board finds that the teachings of *Gardner-Denver* would not have been included in the teachings of *Coli*, a POSITA would have been motivated to combine the teachings of *Gardner-Denver* with the system of *Cicci/Coli/Dixon*/*Liu.*

348. *Gardner-Denver* is analogous art to the '420 Patent because it is in the same field of endeavor regarding hydraulic fracturing systems.[348] For example, *Gardner-Denver* discloses pumps "for various applications such as oil and gas well fracturing."[349]

349. Initially, *Coli* contains an express motivation to combine the references. *Coli* teaches that "[a] suitable pump [for *Coli's* fracturing system] is a quintiplex [quintuplex] or triplex plunger style pump, for example, the SWGS-2500 Well Service Pump sold by Gardner Denver, Inc."[350] A POSITA incorporating the teachings of *Coli* would have been motivated to find information about the Garner

[348] Ex. 1001 ('420 Patent), at 1:7-19, Abstract.
[349] Ex. 1010 (*Gardner-Denver*), pg. 9.
[350] Ex. 1006 (*Coli*), [0046]. I understand the Gardner Denver "SWGS-2500" well service pump to be a GD-2500Q power end with a "Super GWS Fluid End", and that "SWGS" is a typo in *Coli* and should be "SGWS".

Denver (GD) SGWS-2500 pump, such as the information contained in *Gardner-Denver*.

350. A POSITA would have been motivated to look to *Gardner-Denver* for the implementation details of incorporating, and the operating parameters of, the Gardner-Denver pump expressly disclosed in *Coli*. For example, *Gardner-Denver* discloses the interaction between plunger size, speed, flow rate (GPM) and PSI which would be expected from a GD SGWS-2500 pump, as shown in the figure below.[351]

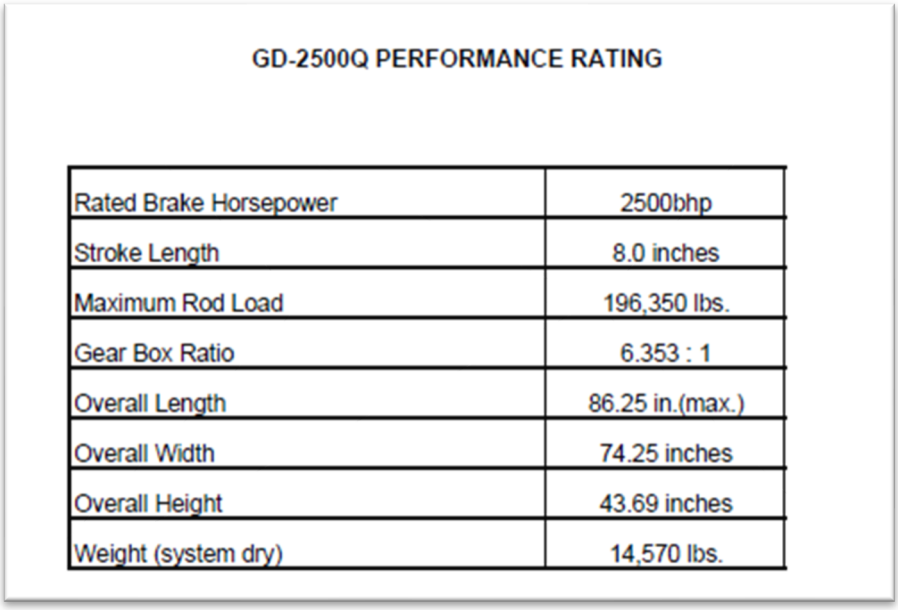
[351] Ex. 1010 (*Gardner-Denver*), pg. 20 of the PDF excerpted.

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. 1010 (*Gardner-Denver*), pg. 20 of the PDF (excerpted)

Gardner-Denver also discloses the Performance Ratings of the GD-2500Q power end as shown in the figure below.[352]

[352] Ex. 1010 (*Gardner-Denver*), pg. 20 of the PDF excerpted.



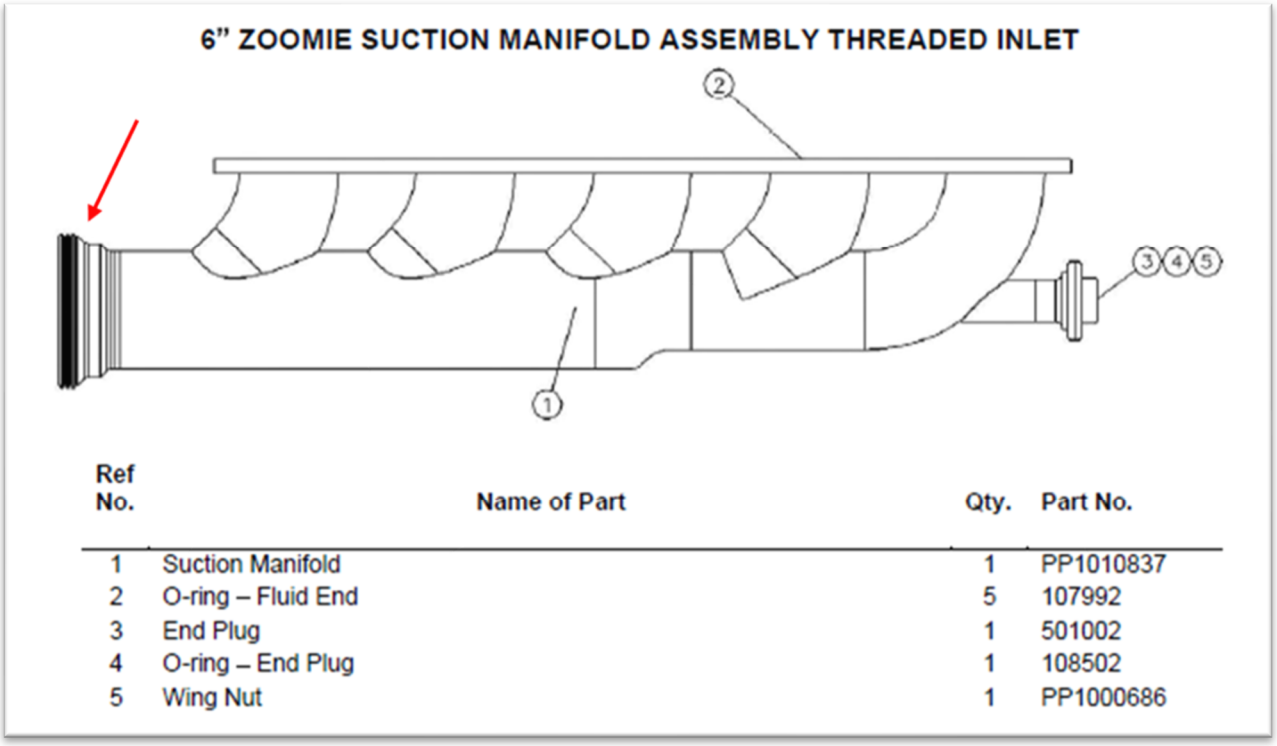
GD-2500Q PERFORMANCE RATING

Rated Brake Horsepower	2500bhp
Stroke Length	8.0 inches
Maximum Rod Load	196,350 lbs.
Gear Box Ratio	6.353 : 1
Overall Length	86.25 in.(max.)
Overall Width	74.25 inches
Overall Height	43.69 inches
Weight (system dry)	14,570 lbs.

Ex. 1010 (*Gardner-Denver*), pg. 20 of the PDF excerpted

351. Furthermore, *Gardner-Denver* offers a range of suction manifolds with various connection types, including Victaulic and threaded inlets (hammer unions), as well as fixed sizes, such as 6" and 8" inlet connections.[353] For example, the "6" Zoomie Suction Manifold Assembly Threaded Inlet" shows an inlet that is recognizable to a POSITA as a hammer union end (red arrow in the figure below) connected to a suction manifold.[354] A POSITA would have understood this to be a 6" threaded inlet (hammer union half).

[353] Ex. 1010 (*Gardner-Denver*), pgs. 76-79 of the PDF.
[354] Ex. 1010 (*Gardner-Denver*), pg. 77 of the PDF.



6" ZOOMIE SUCTION MANIFOLD ASSEMBLY THREADED INLET

Ref No.	Name of Part	Qty.	Part No.
1	Suction Manifold	1	PP1010837
2	O-ring – Fluid End	5	107992
3	End Plug	1	501002
4	O-ring – End Plug	1	108502
5	Wing Nut	1	PP1000686

Ex. 1010 (*Gardner-Denver*), pg. 77 of the PDF

352. A POSITA would have found such information, and the rest of the information in *Gardner-Denver,* helpful in understanding *Coli's* teachings regarding applicable fracturing pumps, their characteristics, and the connections. A POSITA would have found the operating data to be valuable in evaluating, for example, how many pumps would be necessary to pump the fracturing fluid at the suggested rate and pressure. Furthermore, a POSITA would have found the connection data disclosed by *Coli* valuable in understanding what kind of fittings would have been appropriate to connect to an applicable pump, such as the SGWS-2500.

353. A POSITA would have had a reasonable expectation of success in combining the teachings of *Gardner-Denver* with *Cicci*/*Coli/Dixon/Liu* combination as it is merely the use of applying a known technique (the teachings of the characteristics of an applicable pump) to a known device (the fracturing system of *Cicci/Coli/Dixon/Liu*) ready for improvement (the practical design of the system) to yield predictable results (a system constructed with an applicable pump, for example a GD SGWS-2500).

B. INDEPENDENT CLAIM 1

354. It is my opinion that the combination of *Cicci, Coli, Dixon, Liu* and *Gardner-Denver* would have rendered Claim 1 obvious. The combined teachings of *Cicci, Coli, Dixon, Liu* and *Gardner-Denver* disclose, or at least suggest, each and every limitation of Claim 1, as discussed in the sections below.

1. Limitations 1[p] – 1[e]

355. Limitations 1[p] – 1[e] are disclosed and/or rendered obvious by the combination of *Cicci, Coli, Liu, Dixon* and *Gardner-Denver* for the same reasons as those discussed above regarding Ground 1 in Sections XIII.B.1-6.

2. Limitation 1[f]

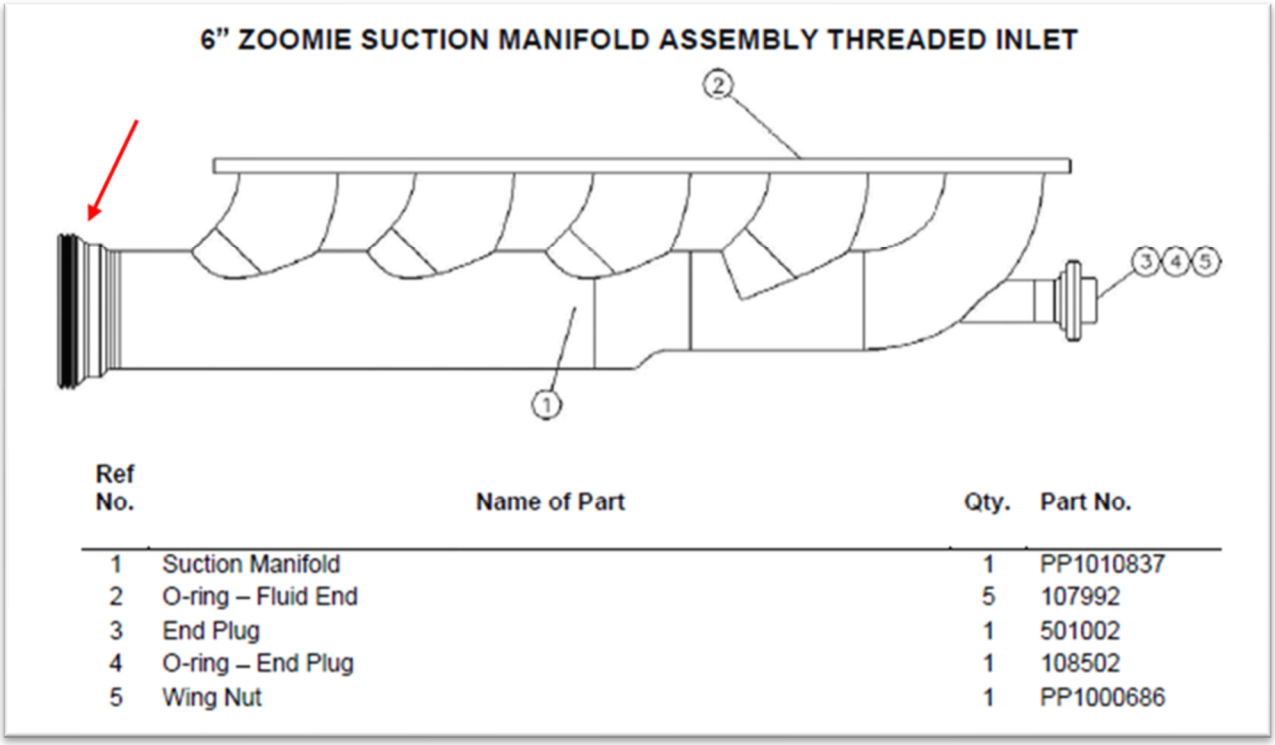
356. The discussion of the disclosure and teachings of *Cicci*, *Coli*, *Dixon*, and *Liu* included regarding Ground 1 above is incorporated herein by reference.

Gardner-Denver discloses that commercially available fracturing pumps, for example, the Gardner Denver SGWS-2500 referenced by Coli, have 6" or 8" headers, as described more fully below regarding Claim 2. This would have motivated a POSITA to combine well-known, commercially available components, designed for fracturing systems, to allow for a smaller hose size, thereby increasing velocity, rather than returning to the manufacturer and obtaining custom inlet headers for the fracturing pumps.

357. Accordingly, Limitation 1[f] would have been obvious to a POSITA based on the combined teachings of *Cicci, Coli, Dixon, Liu* and *Gardner-Denver*.

3. Limitation 1[g]

358. The discussion of the disclosure and teachings of *Cicci*, *Coli*, *Dixon*, and *Liu* included regarding Ground 1 above is incorporated herein by reference. The addition of *Gardner-Denver* would have further rendered obvious limitation 1[g]. a POSITA would have understood from Gardner-Denver that the other half (female half) of the hammer union would have been attached to the pump:



Ref No.	Name of Part	Qty.	Part No.
1	Suction Manifold	1	PP1010837
2	O-ring – Fluid End	5	107992
3	End Plug	1	501002
4	O-ring – End Plug	1	108502
5	Wing Nut	1	PP1000686

EX1010 (Gardner-Denver), pg. 77.

C. DEPENDENT CLAIM 2: "2. THE SYSTEM OF CLAIM 1, WHEREIN THE THIRD DIAMETER IS APPROXIMATELY 5 INCHES AND THE SECOND DIAMETER IS APPROXIMATELY 6 INCHES."

359. Claim 2 depends from Claim 1. In addition to the teachings regarding Claim 1 as discussed above and incorporated herein by reference, the combination of *Cicci, Coli, Dixon, Liu* and *Gardner-Denver* would have rendered the additional limitations of Claim 2 obvious.

360. A third (hose) diameter of approximately 5 inches and a second diameter (end for connection to pump) of approximately 6 inches would have been obvious to a POSITA in view of, at least, the teachings of *Cicci. Cicci* discloses that

"each of the plurality of flexible hoses have an inner diameter of from one inch to eight inches."[355] Accordingly, *Cicci* discloses a range of acceptable flexible hose diameters, including 5 inches. It would have been obvious to a POSITA to use a diameter between 1 and 8 inches, including 5 inches. It would have been obvious to a POSITA and a POSITA would have been motivated to use a hose with a diameter of 5 inches when the flow calculations, such as those discussed above regarding Claim 1, indicate that 5 inches is an appropriate size.

361. A POSITA would have further found it obvious for the third diameter to be approximately five inches because it would have been obvious to use a 5-inch hose in light of *Dixon* and *Cicci*'s disclosures. *Dixon* discloses "Suction Service Fittings" for hydraulic fracturing that have a 5" diameter.[356] A POSITA would have found it obvious to use a 5-inch hose based on *Dixon*'s teaching and *Cicci*'s disclosure of hose diameters between 1 and 8 inches.

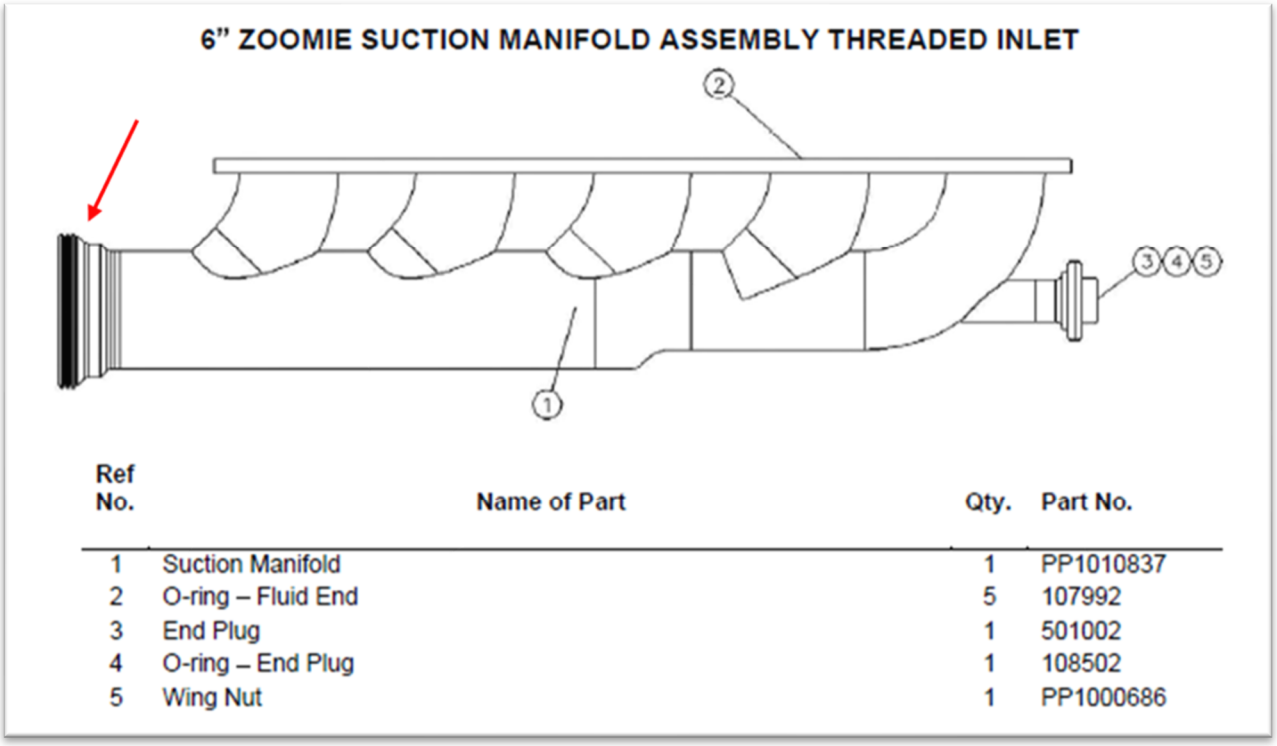
362. A POSITA would have been motivated to use a 5-inch hose when the flow velocity calculations, such as those discussed above regarding Claim 1, indicate that 5 inches is an appropriate hose diameter size to keep velocity in the proper range

[355] Ex. 1004 (*Cicci*), 1:64-65, Claim 7; Ex. 1005 (*Cicci Provisional*) [4].
[356] Ex. 1009 (*Dixon-Australia*), pg. 150; Ex. 1012 (*Dixon-U.S.*), pg. 79.

to avoid a bed of slurry deposited in the hose, and thus avoid drop-out, as discussed above in Claim 1.

363. It would have been obvious to a POSITA for the second diameter to be approximately 6 inches in light of the additional disclosure of *Gardner-Denver*. For example, *Coli* discloses a "SWGS-2500 Well Service Pump sold by Gardner Denver, Inc."[357] It would have been obvious to a POSITA to use a fitting diameter that is consistent with this disclosure. A POSITA would have understood that this disclosure of Coli refers to 6" inlet connections with both threaded (for hammer union) and Victaulic style inlet connections, as discussed below.[358] *Gardner-Denver* discloses suction manifolds with various connection types, including Victaulic and threaded inlets (for hammer unions) and fixed sizes, such as 6" and 8" connections.[359] For example, the "6" Zoomie Suction Manifold Assembly Threaded Inlet" shows an inlet that is recognizable to a POSITA as a hammer union female end (red arrow) connected to suction manifold.[360] A POSITA would have understood this to be a 6" threaded inlet.

[357] Ex. 1006 (*Coli*), [0046].
[358] Ex. 1010 (*Gardner-Denver*), pgs. 76-79.
[359] Ex. 1010 (*Gardner-Denver*), pgs. 76-79.
[360] Ex. 1010 (*Gardner-Denver*), pg. 77 of the PDF.

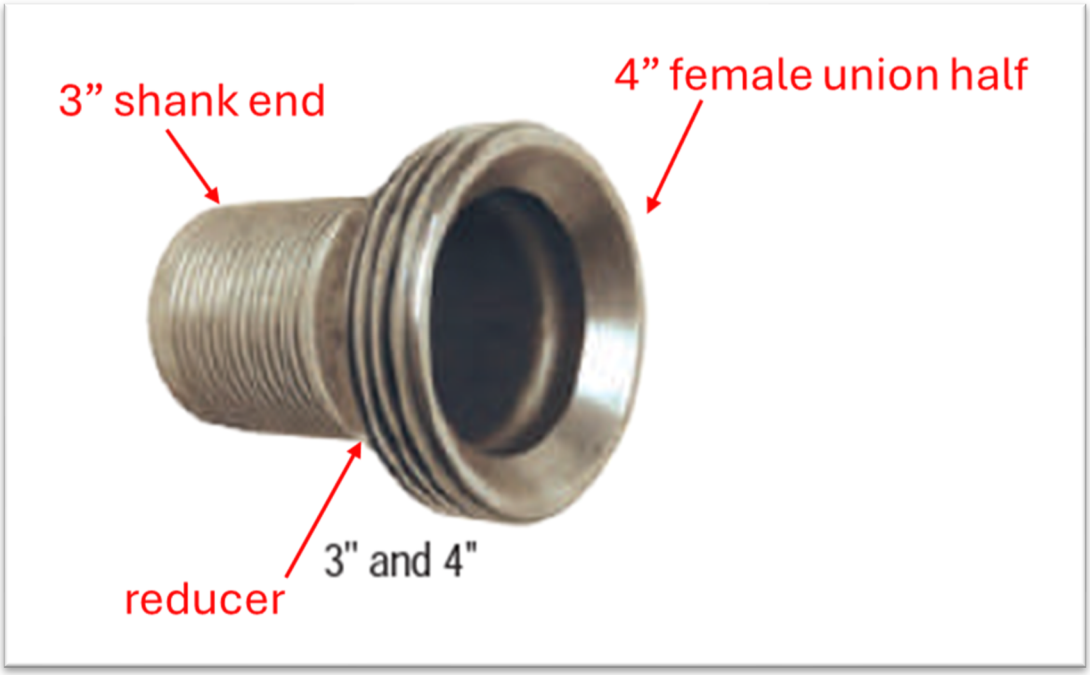


6" ZOOMIE SUCTION MANIFOLD ASSEMBLY THREADED INLET

Ref No.	Name of Part	Qty.	Part No.
1	Suction Manifold	1	PP1010837
2	O-ring – Fluid End	5	107992
3	End Plug	1	501002
4	O-ring – End Plug	1	108502
5	Wing Nut	1	PP1000686

A hammer union female end from *Dixon* is shown for comparison.[361]

[361] Ex. 1009 (*Dixon-Australia*), pg. 149; Ex. 1012 (*Dixon-U.S.*), pg. 78 annotated.



Ex. 1009 (*Dixon-Australia*) pg. 149; Ex. 1012 (*Dixon-U.S.*), pg. 78 annotated

364. Other connections and sizes include 6” Victaulic, 8” threaded (hammer union) and 8” Victaulic.[362] Accordingly, *Gardner-Denver*, which contains information about the GD-2500 pump specifically referenced by *Coli,* discloses a 6” suction end (2nd diameter) for connection to the pump. Moreover, it would have been obvious to use a 6” hammer union to connect to the 6” inlet manifold disclosed by *Coli* as hammer unions were well known long before the ’420 Patent, as discussed above.

[362] Ex. 1010 (*Gardner-Denver*), pgs. 64-79 of the PDF.

365. Further still, the ’420 Patent admits that “6"” (0.1524 m) components, such as but not limited to hammer unions, were “standard” even before the ’420 Patent.

366. Therefore, the combined teachings of *Cicci, Coli, Dixon, Liu* and *Gardner-Denver* would have rendered Claim 2 obvious to a POSITA.

D. DEPENDENT CLAIM 8: “8. THE SYSTEM OF CLAIM 1, WHEREIN THE THIRD DIAMETER IS ASSOCIATED WITH A SECOND THRESHOLD, CORRESPONDING TO A MAXIMUM SUGGESTED FLOW RATE, AN OPERATING WINDOW FOR THE ELECTRIC POWERED MULTI-PLUNGER HYDRAULIC FRACTURING PUMP EXCEEDING THE MAXIMUM SUGGESTED FLOW RATE.”

367. Claim 8 depends from Claim 1. In addition to the teachings regarding Claim 1 as discussed above and incorporated herein by reference, the combination of *Cicci, Coli, Dixon, Liu* and *Gardner-Denver* would have rendered the additional limitations of Claim 8 obvious.

368. As discussed above, *Liu* teaches that pressure drop and a damage accumulation rate (e.g., wear or abrasion on the hose) would have impacted the selection of a third diameter. Pressure drop and wear are both directly related to velocity. Velocity (V), in turn, is related to both flowrate (Q) and diameter (D) of the hose as shown in the equation below.

$$V = \frac{Q}{A} = \frac{4Q}{\pi D^2}$$

369. The third diameter would have been selected based on an upper limit on velocity, above which pressure drop and/or wear would have been unacceptable.

370. In a similar manner, for any given diameter of hose, there is a maximum flowrate (Q) above which velocity would be too high, leading to unacceptable pressure drop or wear. Accordingly, it would have been obvious to a POSITA that for any given third diameter, there is a second threshold that corresponds to a maximum suggested flowrate which would limit pressure drop and wear to acceptable levels. The third diameter is therefore associated with this second threshold.

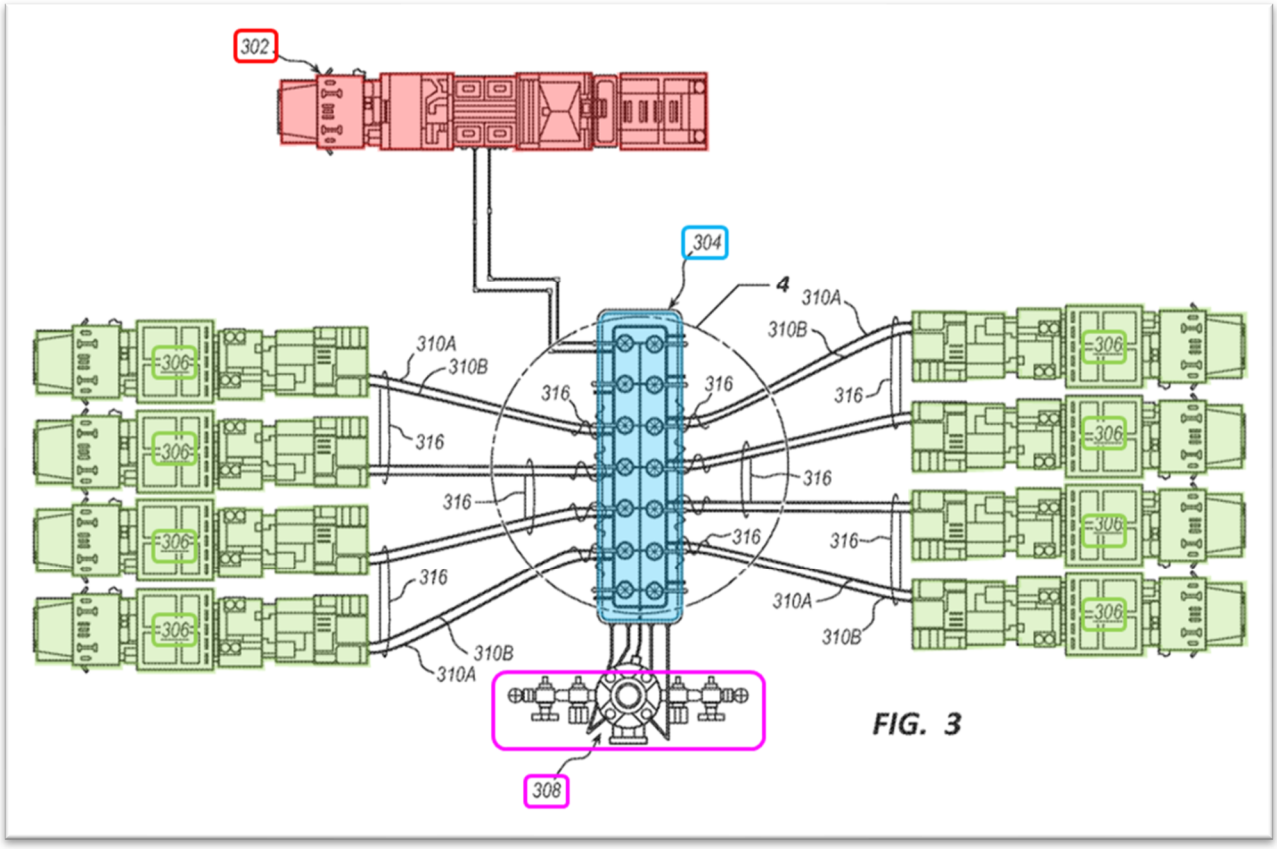
371. *Coli* teaches "[c]onventional blenders powered by a diesel hydraulic system are typically housed on a forty-five foot tractor trailer and are capable of approximately 100 bbl/min. In contrast, the dual configuration of blender module 40 having first blender unit 47a and second blender unit 47b can provide a total output capability of 240 bbl/min in the same physical footprint as a conventional blender."[363] As the fluid supplied by the blender would have the same rate as the fluid entering the wellbore, *Coli* at least suggests a range of maximum flow rates for

[363] Ex. 1006 (*Coli*), [0060].

the entire system between 100 bbl/min and 240 bbl/min (4200 GPM to 10,080 GPM).[364] This total would be divided by the total number of pumps available in the system to provide the flowrate required by each pump.

372. It would have been well-known to a POSITA to select the proper number of pumps to perform the fracturing job according to the fracturing design. For example, *Cicci* shows a system with eight pump trailers 306 (highlighted in green in the figure below), but discloses "one or more pumps 306"[365] and "a plurality of pumps,"[366] disclosing to a POSITA the use of any number of pumps.

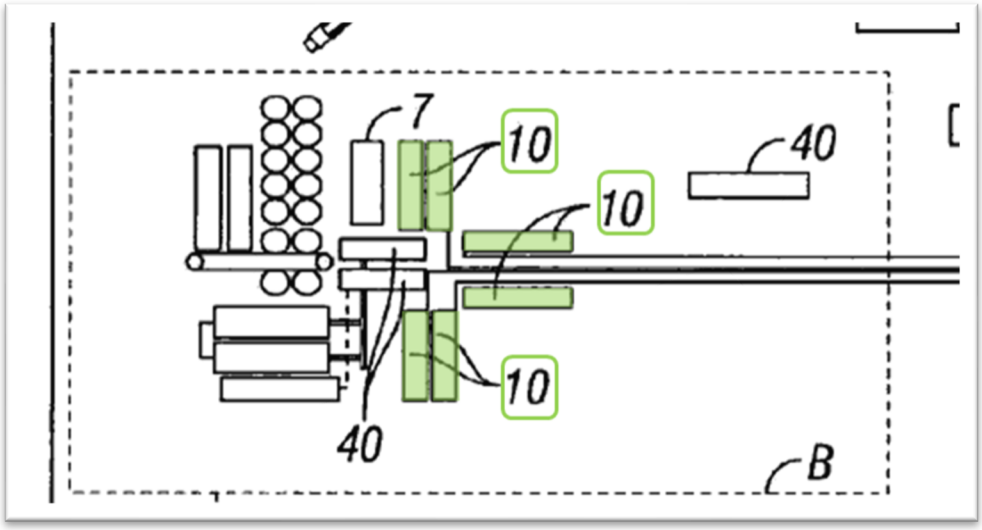
[364] Bbl stands for "barrel" which is a standard oilfield term used to represent 42 gallons.
[365] *See, e.g.,* Ex. 1004 (*Cicci*), 5:15–17; Ex. 1005 (*Cicci Provisional*), [23].
[366] Ex. 1004 (*Cicci*), 1:25-26; Ex. 1005 (*Cicci Provisional*), [2].



Ex. 1004 (*Cicci*), Fig. 3; Ex. 1005 (*Cicci Provisional*), Fig. 3 annotated.

373. *Coli* discloses a different number of pumps. *Coli* teaches the use of six "fracturing trailers 10" (highlighted in the figure below in green).[367]

[367] Ex. 1006 (*Coli*), Fig. 2 (excerpted and annotated).



Ex. 1006 (*Coli*), Fig. 2 (excerpted and annotated)

374. *Coli* also teaches that each fracturing trailer 10 (annotated in magenta in the figure below) contains as many as four fracturing modules, with each fracturing module 20 (annotated in red) containing a pump 22 (annotated in blue) and a motor 21 (annotated in green).[368] *Coli* also discloses "a plurality of electric motors 21 and pumps 22 can be transported on a single trailer 10",[369] as shown in Fig. 3 of *Coli*, annotated below.

[368] Ex. 1006 (*Coli*), Fig 3 (annotated). See also Section XIII.B.2 above.
[369] Ex. 1006 (*Coli*), [0040].

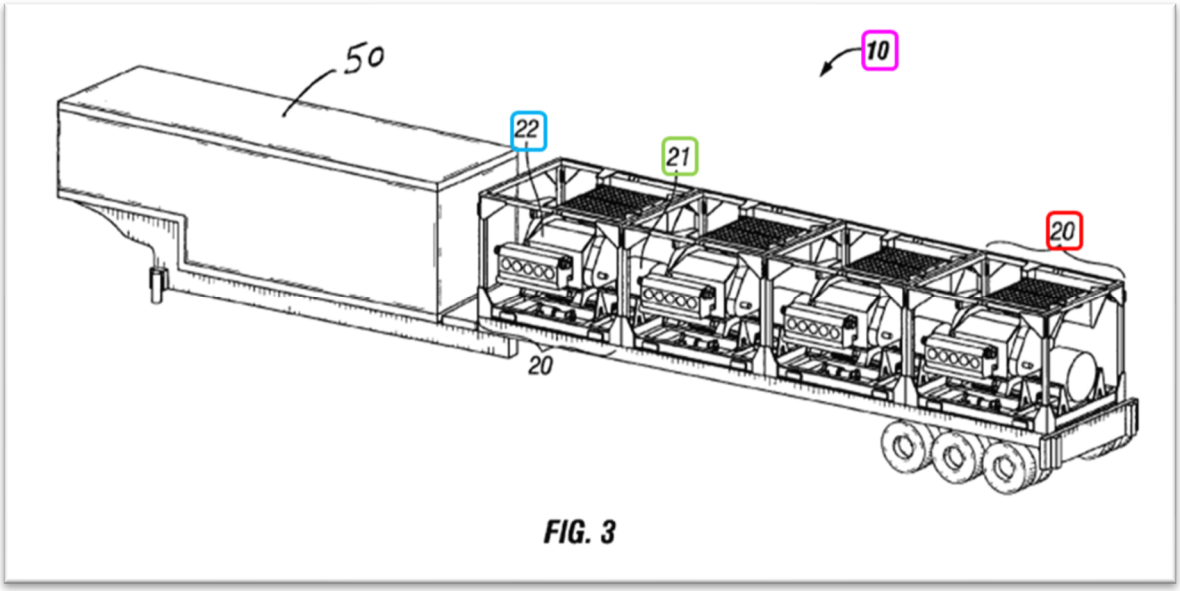


FIG. 3

Ex. 1006 (*Coli*), Fig 3 (annotated).

375. Accordingly, *Coli* discloses at least 24 pumps. *Coli* also discloses "providing one or more electric fracturing modules at the site, each electric fracturing module comprising an electric motor and a coupled fluid pump"[370] at least suggesting any number of pumps. As I discuss above, the pumps are electric-powered multi-plunger hydraulic fracturing pumps.

376. *Gardner-Denver*, which contains information regarding the GD-2500 pump specifically referenced by *Coli* as suitable for hydraulic fracturing, teaches that the "operating window" for each pump is between 191 GPM (4.5 BPM, red box in figure below) and 2,044 GPM (48.66 BPM), depending on the design, speed and

[370] Ex. 1006 (*Coli*), [0009].

specific well conditions.[371] For the conditions specified in *Cicci* ("5,000 PSI to 15,000 PSI or more"),[372] the range of each pump is 191 GPM (4.5 BPM, annotated in the figure below in red) to 734 GPM (17.5 BPM, annotated in blue).[373]

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. 1010 (*Gardner-Denver*) pg. 20 of the PDF (excerpted and annotated)

377. Using the teachings of *Coli* of a potential range of maximum flow rates (100 bbl/min to 240 bbl/min), in the system of *Cicci*, with 8 pumps, would require a maximum flow rate between 12.5 bbl/min (525 GPM) and 30 bbl/min (1,260 GPM)

[371] Ex. 1010 (*Gardner-Denver*), pg. 20 of the PDF (excerpted and annotated).
[372] Ex. 1004 (*Cicci*) 5:23-25; Ex. 1005 (*Cicci Provisional*) [23].
[373] Ex. 1010 (*Gardner-Denver*), pg. 20 of the PDF (excerpted and annotated)

per pump respectively. However, in the system of *Coli* with as many as 24 pumps, each pump would require a maximum flow rate between 4.2 bpm (175 GPM) and 10 bbl/min (420 GPM). A POSITA would have understood to select (or at least operate) the proper number of pumps (at least between 8 and 24, but actually any number based on the "one or more" disclosure of both *Cicci* and *Coli)* so that the maximum flow rate, as determined by the pressure drop and damage accumulation considerations discussed above, for each pump falls within the operating window of the pumps, as shown by *Gardner-Denver.* Accordingly, the combined teachings of *Coli* and *Cicci* render a maximum suggested flow rate, an operating window for the electric powered multi-plunger hydraulic fracturing pump exceeding the maximum suggested flow rate as claimed.

378. In this manner, the fracturing job would be accomplished with the minimum number of pumps, which would be a benefit to a POSITA in reducing capital expenditures and, potentially, operating costs (for example, lower fuel or electricity consumption). It would have been obvious to a POSITA, then, that the operating window of the pump would exceed the maximum flowrate determined by the size of the pipe, based on pressure drop and/or wear (damage accumulation).

379. Further, as there are a finite number of sizes of piping systems available (such as the ~4" – ~8" sizes shown in *Dixon*'s "frac hose" disclosure), and the

operating window for pumps is so large (e.g., 4.5 BPM – 48.66 BPM shown in *Gardner-Denver*), it would have been obvious that the operating window of the pump would, in some cases, exceed the second threshold determined by a maximum suggested velocity, and the associated maximum suggested flowrate.

380. As discussed above regarding limitations 1[f], Claim 6, and Claim 7, the selection of hose size (and accordingly, third diameter) is a standard engineering problem with standard trade-offs. It is simply an optimization of the slurry flow system. Accordingly, a POSITA would recognize a variety of desired "suggested" flow rates throughout the fracturing operation, such as a minimum flow rate and a maximum flow rate, as disclosed by *Coli*, and select the third diameter (hose diameter) based on those flow rates. Because the maximum suggested flowrate depends on the selected third diameter, the second threshold, corresponding to a maximum suggested flowrate, is associated with the third diameter.

381. Accordingly, the combined teachings of *Cicci, Coli, Dixon* and *Liu* and *Gardner-Denver* would have rendered Claim 8 obvious to a POSITA.

E. DEPENDENT CLAIMS 3-7, 9-10

382. Dependent Claims 3-7, 9-10 are disclosed and/or rendered obvious by the combination of *Cicci, Coli, Dixon, Liu* and *Gardner-Denver* for the same reasons as those discussed above regarding Ground 1 in Sections XIII.C – XIII.J.

F. INDEPENDENT CLAIM 11

383. It is my opinion that the combination of *Cicci, Coli, Liu, Dixon* and *Gardner* would have rendered Claim 1 obvious. The combined teachings of *Cicci, Coli, Liu, Dixon* and *Gardner-Denver* disclose, or at least suggest, each and every limitation of Claim 1, as discussed in the sections below.

1. Limitations 11[p] – 1[e], 11[g], 11[i]

384. Limitations 11[p] – 1[e], 11[g], and 11[i] are disclosed and/or rendered obvious by the combination of *Cicci, Coli, Liu, Dixon* and *Gardner* for the same reasons as those discussed above regarding Ground 1 in Sections XIII.K.1-6, XIII.K.8, and XIII.K.10.

2. Limitation 11[f]

385. This claim limitation is the same as Limitation 1[f] and would have been obvious to a POSITA for the same reasons as those discussed in Section XIV.B.2 above.

3. Limitation 11[h]

386. Limitation 11[h] is disclosed and/or rendered obvious by the combination of *Cicci, Coli, Liu, Dixon* for the same reasons as those discussed above regarding Ground 1 in Section XIII.K.9. The addition of *Gardner-Denver*

additionally renders this claim obvious for the reasons explained with respect to Limitation 1[g], as discussed above in Section XIV.B.3.

G. DEPENDENT CLAIMS 13-16, 18-19

387. Dependent Claims 13-16, 18-19 are disclosed and/or rendered obvious by the combination of *Cicci, Coli, Liu, Dixon* and *Gardner-Denver* for the same reasons as those discussed above regarding Ground 1 in Sections XIII.M – XIII.R.

H. DEPENDENT CLAIM 12: "12. THE SYSTEM OF CLAIM 11, WHEREIN THE THIRD DIAMETER IS APPROXIMATELY 5 INCHES AND THE SECOND DIAMETER IS APPROXIMATELY 6 INCHES."

388. The limitations of Claim 12 are the same as those in Claim 2 and would have been obvious to a POSITA for the same reasons as those discussed above in Section XIV.C.

I. DEPENDENT CLAIM 17: "17. THE SYSTEM OF CLAIM 11, WHEREIN THE THIRD DIAMETER IS ASSOCIATED WITH A SECOND THRESHOLD, CORRESPONDING TO A MAXIMUM SUGGESTED FLOW RATE, AN OPERATING WINDOW FOR THE ELECTRIC POWERED MULTI-PLUNGER HYDRAULIC FRACTURING PUMP EXCEEDING THE MAXIMUM SUGGESTED FLOW RATE."

389. The limitations of Claim 17 are the same as those in Claim 8 and would have been obvious to a POSITA for the same reasons as those discussed above in Section XIV.D.

XV. GROUNDS 3A AND 3B: THE COMBINATION OF *CICCI, COLI, DIXON, LIU*, AND *KAJARIA*, WITH OR WITHOUT *GARDNER-DENVER* RENDERS CLAIM 20 OBVIOUS

390. It is my opinion that the combination of *Cicci, Coli, Dixon, Liu* and *Kajaria*, with or without *Gardner-Denver*, renders Claim 20 of the '420 Patent obvious.

A. MOTIVATION TO COMBINE

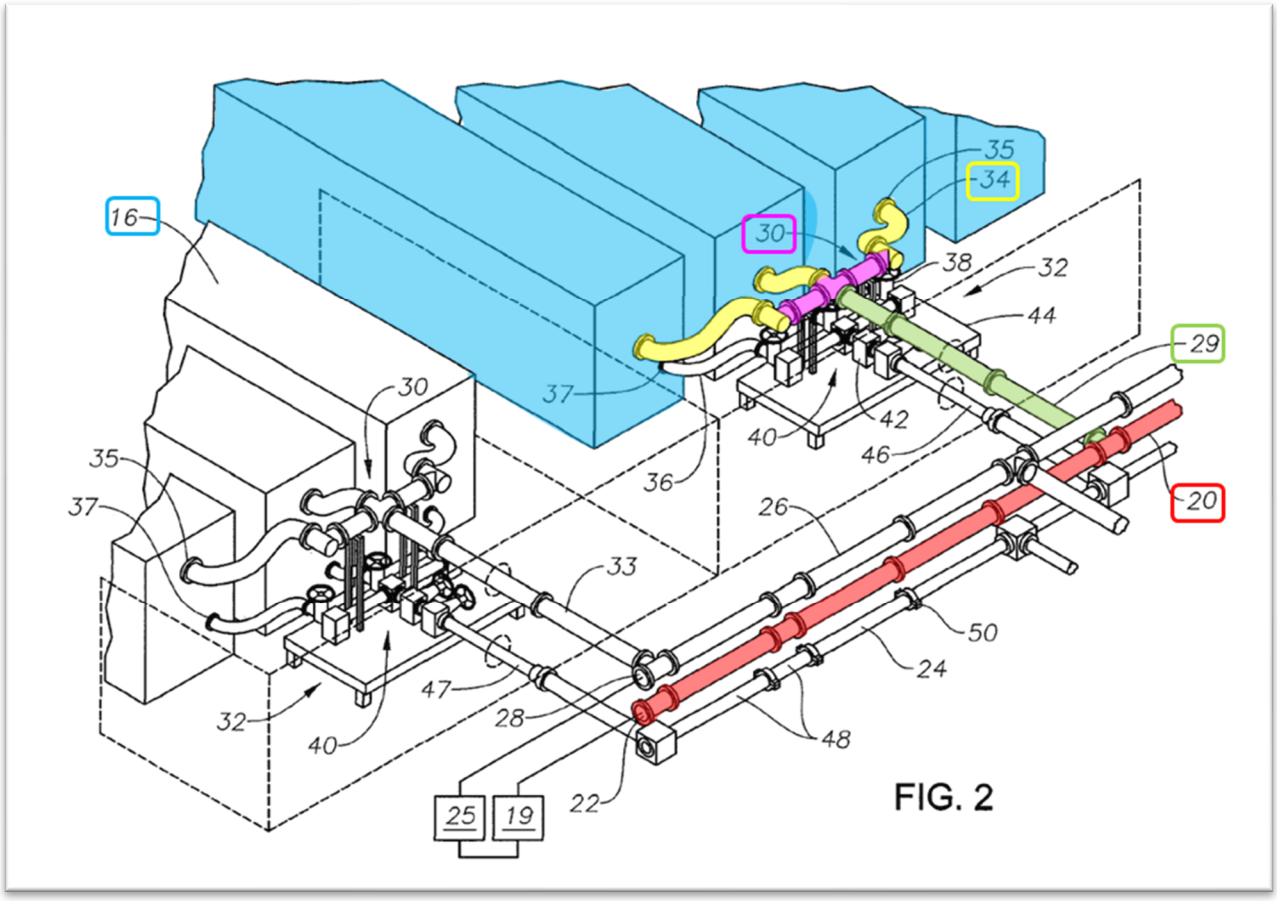
391. As I discuss above in Grounds 1 and 2, incorporated here by reference, a POSITA would have been motivated to combine *Cicci*, *Coli*, *Dixon*, and *Liu*, and *Gardner-Denver*. A POSITA would have been motivated to combine the teachings of *Kajaria* with those of *Cicci, Coli, Dixon,* and *Liu*, with or without *Gardner-Denver*, to arrive at the claimed invention, and would have had a reasonable expectation of success in doing so.

392. *Kajaria*, like *Cicci* and *Coli* teaches a hydraulic fracturing system. *Kajaria* discloses that "in oilfield operations, fluids are pumped into a wellbore extending through a geologic formation. Hydraulic fracturing is an example of an oilfield operation in which fluids are pumped into a wellbore at a sufficient pressure to fracture the geologic formation. Fracturing the geologic formation provides a conductive path for hydrocarbons captured in the geologic formation to reach the wellbore, and thereby facilitates recovery of the hydrocarbons through the

wellbore."[374] *Kajaria* further discloses that "[i]n general, the equipment used in hydraulic fracturing includes a tank or other source of low-pressure fracturing fluid, a slurry blender, a plurality of high-pressure, high volume fracturing pumps, and various hoses and pipelines to direct the flow of the fracturing fluid to the wellbore."[375] Further, *Kajaria* teaches that "slurry is conveyed to the pump trucks 16 [highlighted in Fig 2 in blue] by way of a slurry pipeline or first low-pressure pipeline 20 [highlighted in red]."[376] Accordingly, like *Cicci*, *Kajaria* discloses a fluid source in the form of a low-pressure pipeline 20.

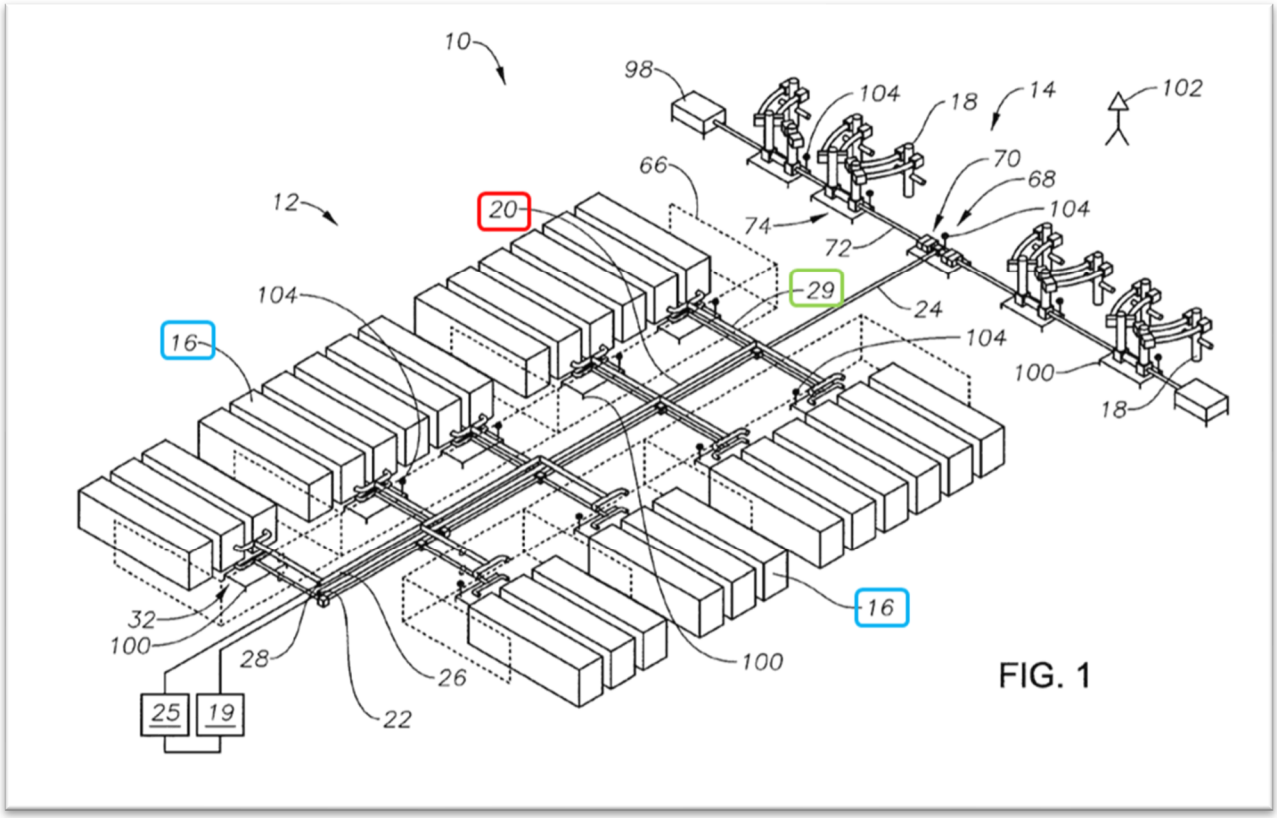
393. *Kajaria* further discloses "the slurry travels from first low-pressure pipeline 20 to truck slurry supply branch 29 [highlighted in Fig 2 in green]. Truck slurry supply branch 29 is in fluid communication with a distribution junction 30 [highlighted in magenta]".[377] Further still, *Kajaria* teaches that "distribution junction 30 is in fluid communication with multiple truck connection lines 34 [highlighted in Fig 2 in yellow] and divides the slurry flowing in truck slurry supply branch 29 between the truck connection lines 34. Truck connection line 34 may be, for example, either a flexible flow line or a rigid pipeline."[378]

[374] Ex. 1008 (*Kajaria*), 1:19-26.
[375] Ex. 1008 (*Kajaria*), 1:27-31.
[376] Ex. 1008 (*Kajaria*), 4:16-18.
[377] Ex. 1008 (*Kajaria*), 4:31-33.
[378] Ex. 1008 (*Kajaria*), 4:37-45.

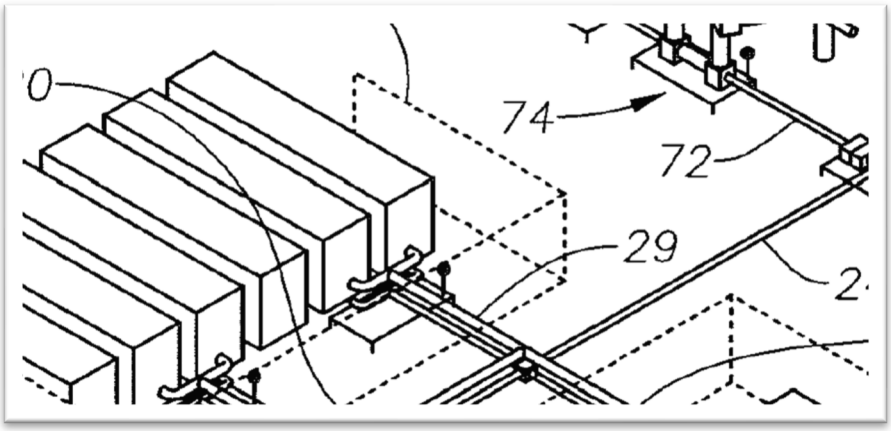


Ex. 1008 (*Kajaria*) Fig. 2 annotated

394. Accordingly, *Kajaria* is analogous art to the '420 Patent because it is in the same field of endeavor regarding hydraulic fracturing systems. Additionally, *Kajaria* discloses connecting to the inlet of a plurality of pumps from a single line connected to the fluid source 20. Although Fig. 2 shows the connection to three pump inlets, other examples are also disclosed, including the connection to two pump inlets from a single line.



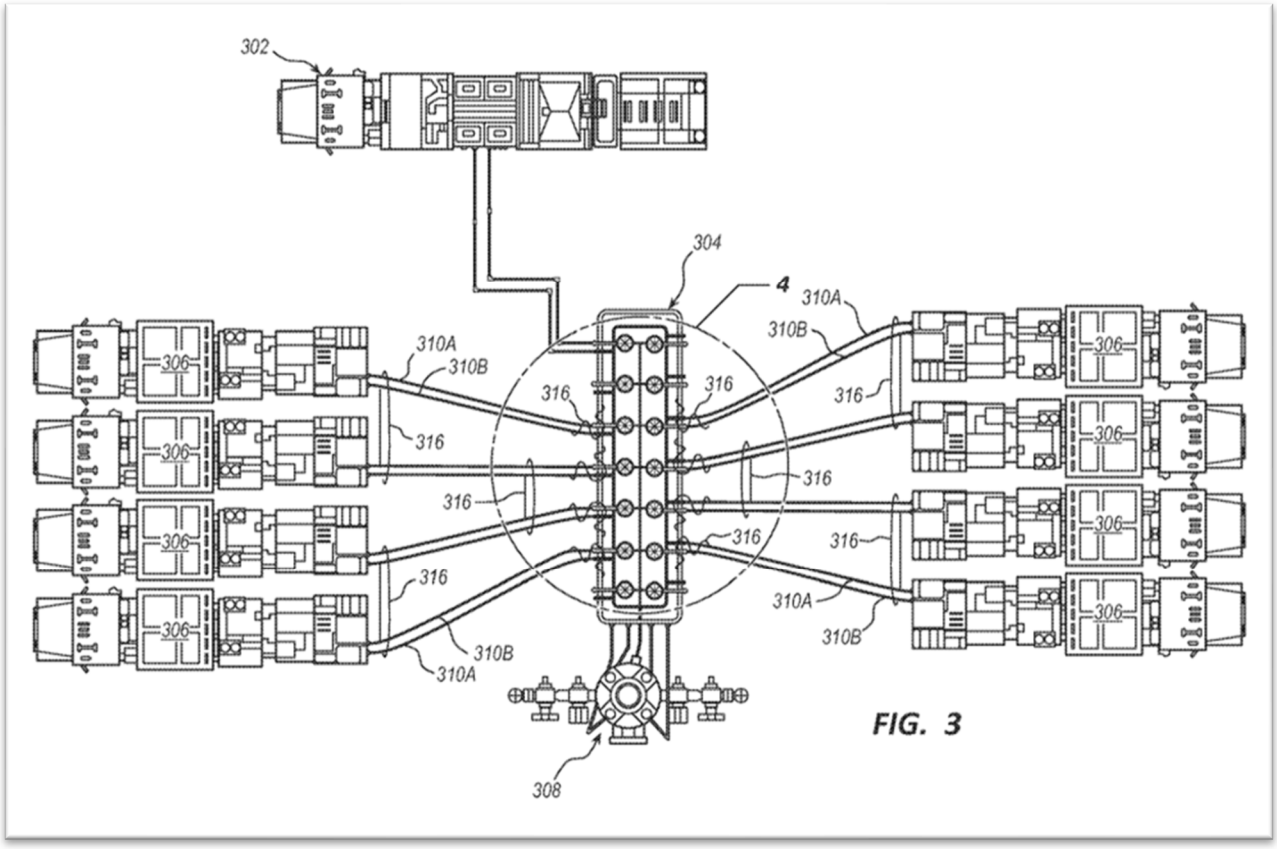
Ex. 1008 (*Kajaria*), Fig. 1 (annotated)



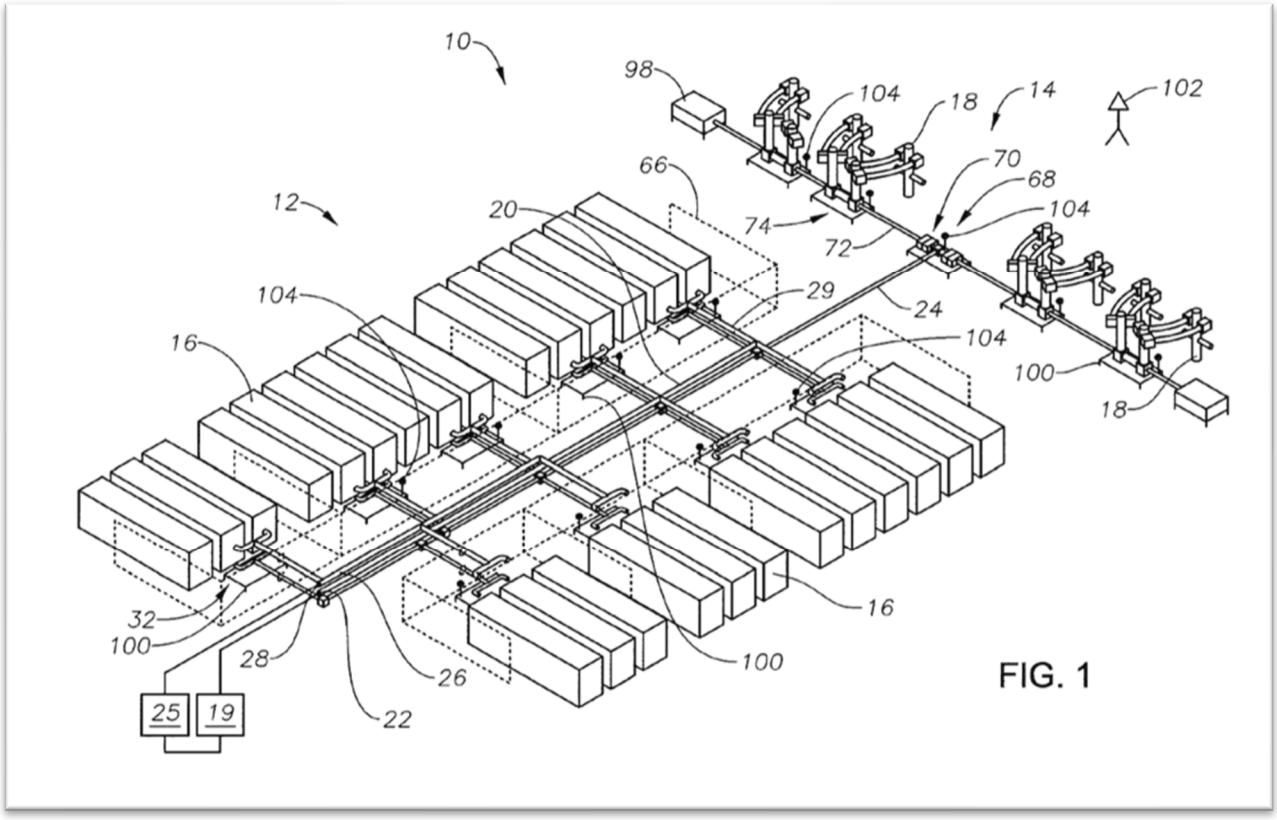
Ex. 1008 (*Kajaria*), Fig. 1 (detail)

395. A POSITA would have been motivated to incorporate *Kajaria*'s teachings of feeding multiple pumps from a single flow line into the teachings of a hose connecting a fluid source to a pump from *Cicci* to gain the benefits of ease of assembly, reduced clutter, fewer manifold connections, fewer lines, and reduced chance of forming a proppant bed in the line.

396. For example, a POSITA would also have understood, by comparing, for example, Fig. 3 of *Cicci*, with Fig. 1 of *Kajaria*, that, for the same number of pumps, *Kajaria's* site would have been less cluttered (fewer lines between the pumps and the manifold), and would have required fewer connections that need to be made up at the fluid source end (manifold or missile). For example, the *Kajaria* system would only require one suction connection at the manifold for every two (or three) pumps. In contrast, the *Cicci* system would have required one suction connection at the manifold for each pump.



Ex. 1004 (*Cicci*), Fig. 3; Ex. 1005 (*Cicci Provisional*), Fig. 3



Ex. 1008 (*Kajaria*), Fig. 1

397. A POSITA further would have understood that such a modification would have reduced the likelihood of forming a proppant bed in the line. For example, a POSITA would have recognized that the slurry flow into the single suction line would be the sum of the flows of the two individual pumps. This would increase the flow rate through the line, which would increase the velocity and reduce the likelihood of forming a proppant bed in the line, particularly during low-flow conditions, as discussed above in Ground 1.

398. A POSITA would have had a reasonable expectation of success in the combination as it is simply applying a known technique (feeding the suction of two pumps from a single line connecting to the manifold) to a known system (the system of *Cicci/Coli/Liu/Dixon*, with or without *Gardner-Denver*) ready for improvement to yield predictable results (a system with easier assembly, reduced clutter, fewer manifold connections, fewer lines, and reduced chance of forming a proppant bed in the line). This is further confirmed by *Kajaria*'s teaching that its system is "readily configured and assembled at a well site" due to its modularity.[379]

B. DEPENDENT CLAIM 20: "20. THE SYSTEM OF CLAIM 11, FURTHER COMPRISING: A THIRD FITTING POSITIONED ON A THIRD END OF THE HOSE FOR COUPLING TO A SECOND ELECTRIC POWERED MULTI-PLUNGER HYDRAULIC FRACTURING PUMP, HAVING THE SECOND DIAMETER."

399. Claim 20 depends from Claim 11. In addition to the teachings regarding Claim 11 as discussed above in Section XIII.K and Section XIV.F, and incorporated herein by reference, the combination of *Cicci, Coli, Liu, Dixon* and *Kajaria* would have rendered the additional limitations of Claim 20 obvious.

400. The limitations of Claim 20 are directed toward using the flexible lines and fitting discussed in Claim 11 to feed two pumps from the same suction line connected to the fluid source. *Kajaria* discloses a third end of the hose for coupling

[379] Ex. 1008 (*Kajaria*), Abstract.

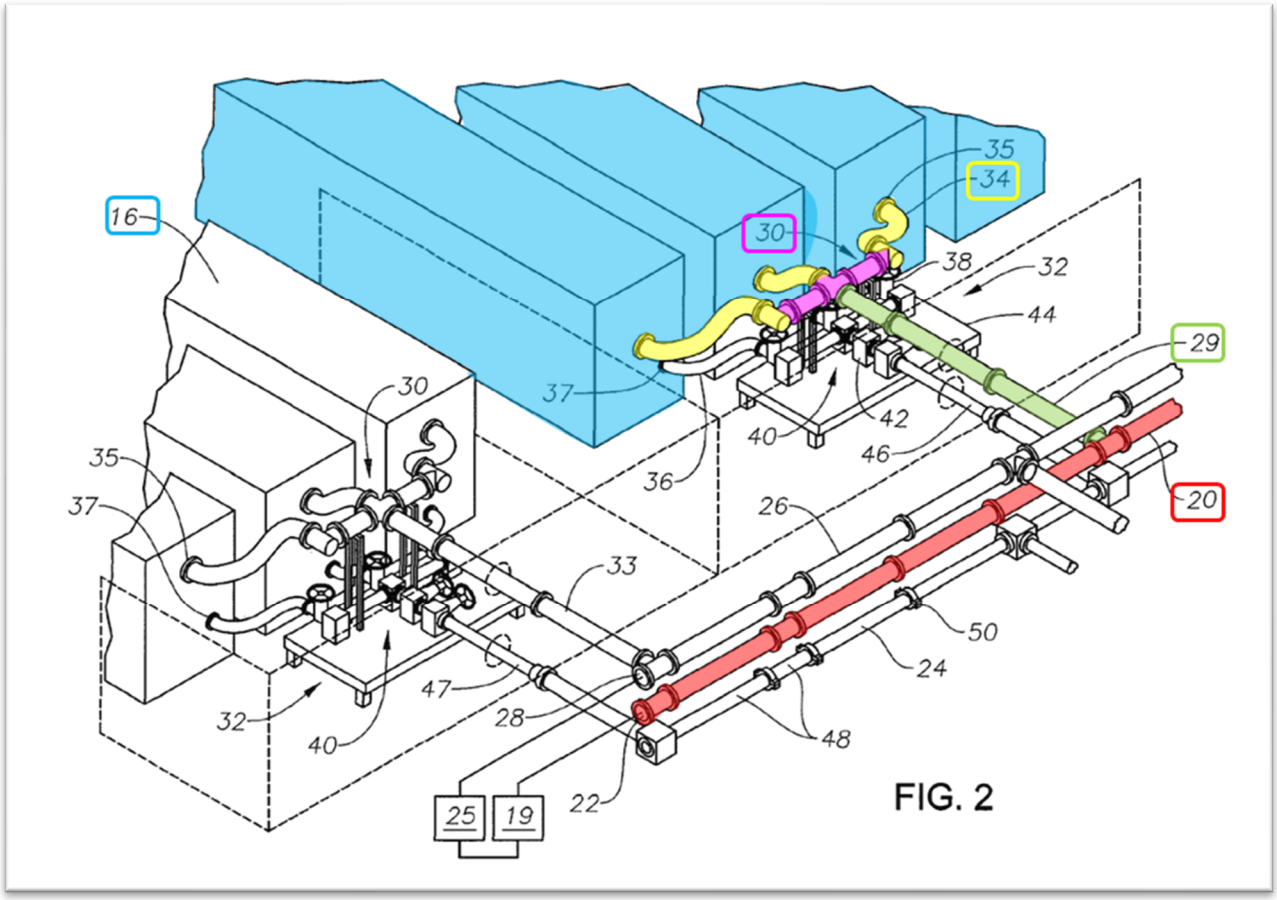
to a second electric powered multi-plunger hydraulic fracturing pump. *Kajaria* discloses using a single flow line to feed two pumps from the same suction line, which is connected to the fluid source. *Kajaria* teaches that "[i]n general, the equipment used in hydraulic fracturing includes a tank or other source of low-pressure fracturing fluid, a slurry blender, a plurality of high-pressure, high volume fracturing pumps, and various hoses and pipelines to direct the flow of the fracturing fluid to the wellbore."[380]

401. Further, *Kajaria* teaches that "slurry is conveyed to the pump trucks 16 [highlighted in Fig. 2 in blue] by way of a slurry pipeline or first low-pressure pipeline 20 [highlighted in red]."[381] Accordingly, like *Cicci*, *Kajaria* discloses a fluid source in the form of a low-pressure pipeline 20.

402. *Kajaria* further discloses "the slurry travels from first low-pressure pipeline 20 to truck slurry supply branch 29 [highlighted in Fig 2 in green]. Truck slurry supply branch 29 is in fluid communication with a distribution junction 30 [highlighted in magenta]".[382] Further still, *Kajaria* teaches that "distribution junction 30 is in fluid communication with multiple truck connection lines 34 [highlighted in yellow] and divides the slurry flowing in truck slurry supply branch 29 between the

[380] Ex. 1008 (*Kajaria*), 1:27-31.
[381] Ex. 1008 (*Kajaria*), 4:16-18.
[382] Ex. 1008 (*Kajaria*), 4:31-33.

truck connection lines 34. Truck connection line 34 may be, for example, either a flexible flow line or a rigid pipeline."[383]

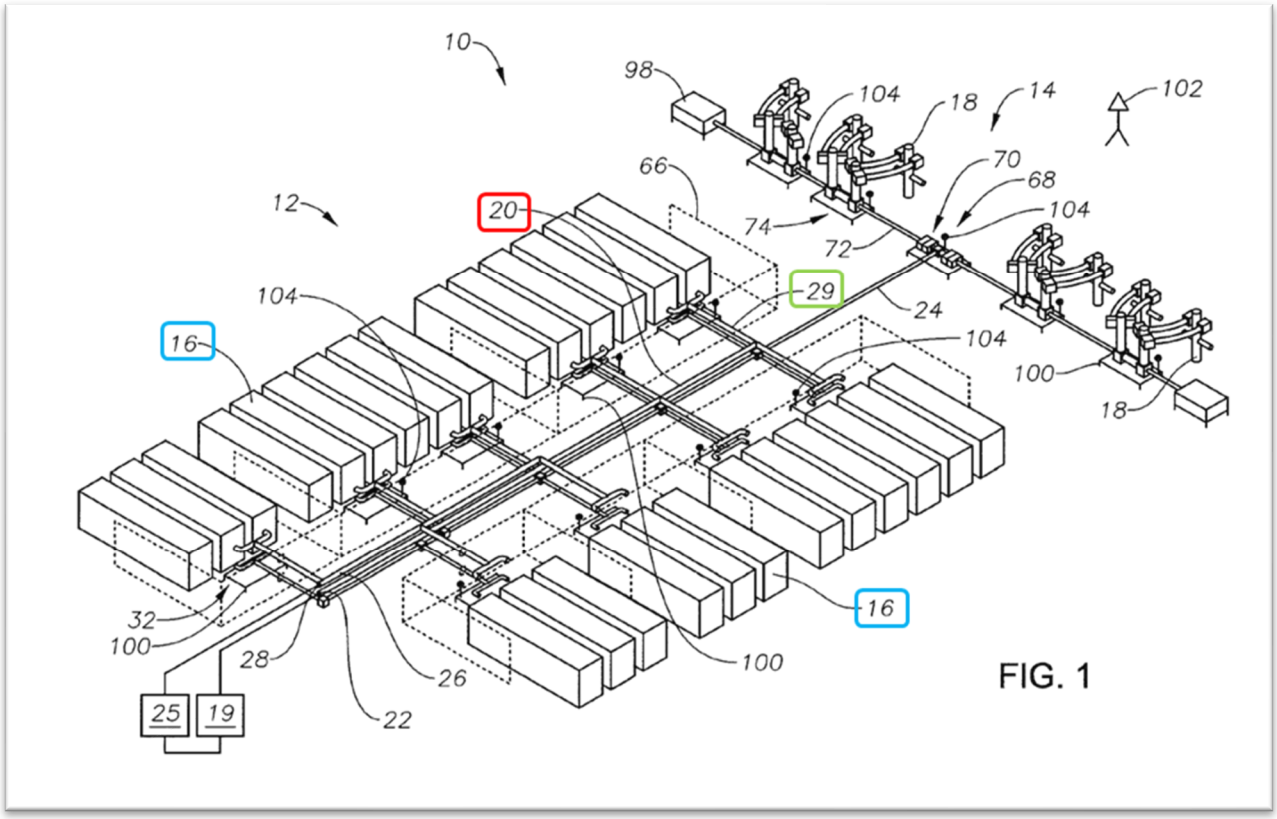


Ex. 1008 (*Kajaria*), Fig. 2 annotated

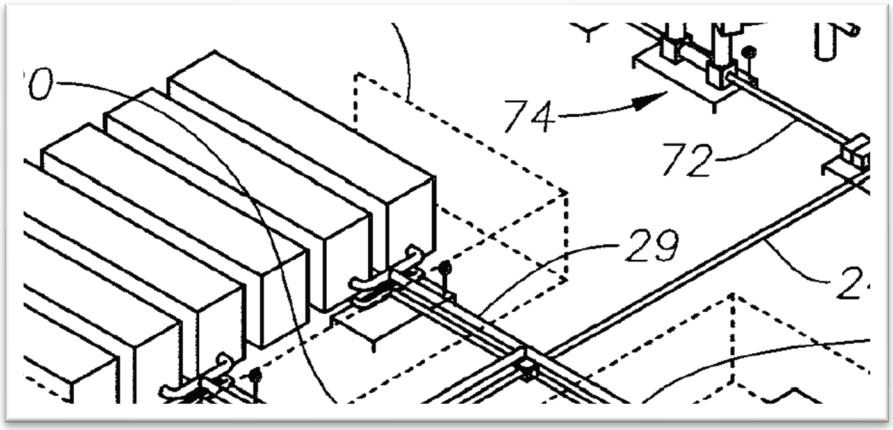
403. Accordingly, *Kajaria* discloses a third end of the hose for coupling to a second electric powered multi-plunger hydraulic fracturing pump by connecting to the inlet of a plurality of pumps from a single line connected to the fluid source 20.

[383] Ex. 1008 (*Kajaria*), 4:40-45.

Although Fig. 2 shows the connection to three pump inlets, other examples are also disclosed, including the connection to two pump inlets from a single line.



Ex. 1008 (*Kajaria*) Fig. 1 (annotated)



Ex. 1008 (*Kajaria*) Fig. 1 (detail)

404. *Cicci* in combination with *Kajaria* thus discloses a third fitting positioned on the third end of the hose for coupling to an electric-powered multi-plunger hydraulic fracturing pump for the same reasons discussed above. It would have been obvious to a POSITA to use a third fitting positioned on the third end of the hose for the same reasons the POSITA would have used the second fitting of the pair of fittings on the second end to couple to the electric-powered multi-plunger hydraulic fracturing pump recited in Claim 11.

405. The third fitting, and the connection to the second electric-powered multi-plunger hydraulic fracturing pump would have the second diameter for the same reasons that I discuss above with respect to limitation 1[d]. It further would have been obvious to a POSITA for the second pump and third fitting to have the same diameter as the first pump and fitting, respectively, recited in Claim 11, to allow for interchangeability and standard sizing of pump parts, materials, and connections. A POSITA would have had a reasonable expectation of success in using the second diameter, because it is the diameter already used for the first pump and for the same reasons with respect to the first pump.

406. A POSITA would have incorporated *Kajaria's* teachings of feeding multiple pumps from a single flow line into the teachings of a hose connecting a

fluid source to a pump from *Cicci* in order to gain the benefits of reduced clutter and ease of cleanup disclosed by *Kajaria.*

407. Accordingly, the combined teachings of *Cicci, Coli, Liu, Dixon* and *Kajaria* render Claim 20 obvious.

XVI. GROUND 4: THE COMBINATION OF *CICCI, COLI, DIXON, LIU, GARDNER-DENVER* AND *ANSI 6.1* RENDERS CLAIMs 8 AND 17 OBVIOUS

A. MOTIVATION TO COMBINE

408. The motivation for a POSITA to combine *Cicci, Coli, Dixon,* and *Liu* is the same as that discussed above in Section XIII.A. The motivation for a POSITA to combine *Cicci*/*Coli*/*Dixon*/*Liu*/*Gardner-Denver* is the same as that discussed above in Section XIV.A. Nothing in *ANSI/HI 6.1* teaches away from the combination.

409. A POSITA would have been further motivated to combine the teachings of *ANSI/HI 6.1* with the combination of *Cicci*, *Coli*, *Dixon, Liu* and *Gardner-Denver* and would have had a reasonable expectation of success in doing so. *ANSI/HI 6.1* is analogous art to the ’420 Patent because it is directed to the same field of endeavor as the ’420 Patent of hydraulic fracturing systems, as it describes operations of plunger pumps commonly used in hydraulic fracturing, as I explain

further below.[384] *ANSI/HI 6.1* also would have been reasonably pertinent to the problem with which the '420 Patent is concerned—fluid flow rates for fracturing operations[385]—as *ANSI/HI 6.1* relates to sizing hydraulic pumps and piping to maintain sufficient fluid velocity or flow.[386] ANSI/HI 6.1 is a standard approved by the American Natural Standard when consensus is established.[387]

410. *ANSI/HI 6.1* is the "American National Standard for Reciprocating Power Pumps" and is published by the American National Standards Institute (ANSI) and developed by the Hydraulic Institute.[388] *ANSI/HI 6.1* describes that "Approval of an American National Standard requires verification by ANSI that the requirements for due process, consensus and other criteria for approval have been met by the standards developer."[389] Further, *ANSI/HI 6.1* discloses that "Consensus

[384] Ex. 1011 (*ANSI/HI 6.1*), pg. 66.
[385] For example, the '420 Patent describes "problems with flow rates, as flow rates that drop below a threshold may experience drop out of particulates, leading to blockages and other problems at the well site." Ex. 1001 ('420 Patent), at 1:49-55. Similarly, during prosecution of the application that led to the '420 Patent, the applicant distinguished prior art by arguing that it did not "identify the problem associated with efficient fluid flow rates for fracturing operations." Ex. 1056 ('162 Patent File History), pg. 433 (Sept. 29, 2020, Response to Nonfinal Rejection, pg. 8)
[386] Ex. 1011 (*ANSI/HI 6.1*), pg. 66.
[387] Ex. 1011 (*ANSI/HI 6.1*), pg. 3.
[388] Ex. 1011 (*ANSI/HI 6.1*), Cover
[389] Ex. 1011 (*ANSI/HI 6.1*), pg. ii.

is established when, in the judgement of the ANSI Board of Standards Review, substantial agreement has been reached by directly and materially affected interests [] Consensus requires that all view and objections be considered, and that a concerted effort be made toward their resolution."[390]

411. *ANSI/HI 6.1* teaches that the "purpose and aims of the Hydraulic Institute" includes "develop and publish standards for pumps" and "to collect and disseminate information of value to its members and to the public".[391] Further, *ANSI/HI 6.1* that "Hydraulic Institute Standards are adopted in the public interest and are designed to help eliminate misunderstandings between the manufacturer, the purchaser and/or the user and to assist the purchaser in selecting and obtaining the proper product for a particular need."[392] Further, *ANSI/HI 6.1* describes that "An Institute Standard defines the product, material, process or procedure with reference one or more of the following: nomenclature, composition, construction, dimensions, tolerances, safety, operating characteristics, performance, quality, rating, testing and service for which designed."[393] Further, *ANSI/HI 6.1* describes, in the Scope of *ANSI/HI 6.1*, that "[t]he standard applies to reciprocating power pumps. It includes

[390] Ex. 1011 (*ANSI/HI 6.1*), pg. ii.
[391] Ex. 1011 (*ANSI/HI 6.1*), pg vi.
[392] Ex. 1011 (*ANSI/HI 6.1*), pg vi.
[393] Ex. 1011 (*ANSI/HI 6.1*), pg vi.

types and nomenclature; definitions; design and application; and installation, operation and maintenance."[394] A POSITA would have recognized, from these disclosures, that *ANSI/HI 6.1* represented industry consensus for definitions; design and application; and installation, operation and maintenance of reciprocating power pumps.

412. *ANSI/HI 6.1* further teaches that "[a] reciprocating power pump is one driven by power from an outside source applied to the crankshaft of the pump. [] There are several variations and types of reciprocating power pumps,"[395] which are shown in Figure 6.1.

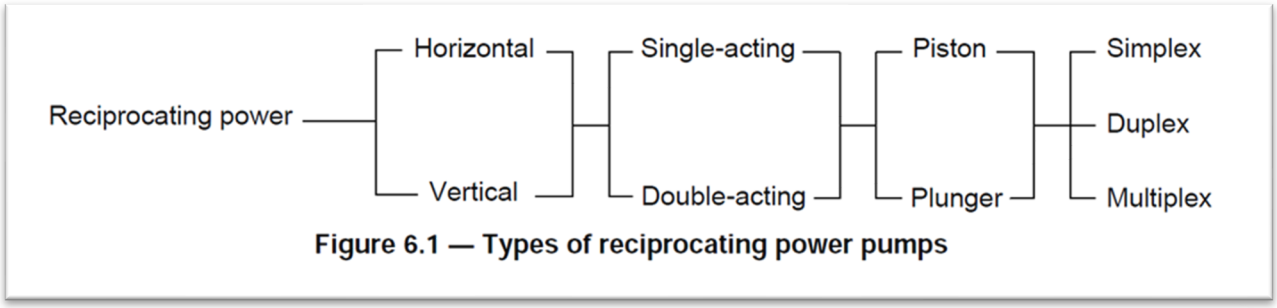


Figure 6.1 — Types of reciprocating power pumps

Ex. 1011 (*ANSI/HI 6.1*) Figure 6.1

Accordingly, a POSITA would have understood that the teachings in *ANSI/HI 6.1* are directed towards the type of pumps used for hydraulic fracturing in the system of *Cicci/Coli,* as described above in Sections XIII.A. and XIII.B.2, which is

[394] Ex. 1011 (*ANSI/HI 6.1*), pg vi.
[395] Ex. 1011 (*ANSI/HI 6.1*), pg 1.

incorporated herein by reference. For example, *Coli* discloses that pumps for hydraulic fracturing "can be a triplex or quintuplex plunger style fluid pump,"[396] which is one of the types of reciprocating pumps for which disclosure is made in *ANSI/HI 6.1*. Accordingly, a POSITA would have found the information contained in *ANSI/HI 6.1* useful in applying reciprocating pumps in the system of *Cicci/Coli/Dixon/Liu/Gardner-Denver* and would have looked to *ANSI/HI 6.1* for implementation details for the multi-plunger hydraulic fracturing pump in the hydraulic fracturing system of the *Cicci/Coli/Dixon/Liu/Gardner-Denver* combination.

413. Further, *ANSI/HI 6.1* describes the use of reciprocating power pumps to pump slurry, such as would have been used in the system of *Cicci/Coli/Dixon/Liu/Gardner-Denver*. As discussed above in Section XIII.B.3 and XIII.A, which are each incorporated herein by reference, the system of *Cicci/Coli/Dixon/Liu/Gardner-Denver*, incorporates a slurry comprised of proppant and water to perform hydraulic fracturing. Like the combination of *Cicci/Coli/Dixon/Liu/Gardner-Denver, ANSI/HI 6.1* discloses that "[r]eciprocating pumps are used to handle slurries for in-plant process and pipeline applications."[397]

[396] Ex. 1006 (*Coli*) ¶[0011]; *see also* Ex. 1006 (*Coli*), [0015], [0035], [0046], [0050], Claim 6, Claim 7, Claim 27.
[397] Ex. 1011 (*ANSI/HI 6.1*), pg. 66.

A POSITA would have recognized that "in-plant" applications would include a hydraulic fracturing plant, such as the system of *Cicci/Coli/Dixon/Liu/Gardner-Denver*.

414. Like *Liu*, which discloses that slurry velocities should be maintained between a minimum velocity (high enough to prevent solid dropout) and a maximum velocity (low enough to prevent unacceptable pressure drop or wear), as discussed above in Sections XIII.B.7, XIII.G-H, and XIV.D, and incorporated herein by reference, *ANSI/HI* teaches that "hydraulic passages should be sized to that the lowest velocity of the liquid will be within operating carrying velocity of 1.2 to 1.8 m/s (4 to 6 ft/s) as an average. The highest velocity should be below that which causes excessive erosion. Typical average operating velocities through a reciprocating slurry pump's passages are 1.8 to 3.6 m/s (6 to 12 ft/s)."[398] A POSITA would have been motivated to apply these teachings to the hydraulic passages of the hoses in the system of *Cicci/Coli/Dixon/Liu* to obtain the benefits of avoiding such excessive erosion, which would damage the pipe and equipment. A POSITA would have had a reasonable expectation of success in doing so at least because the same slurry passes through the passages of the pump and the hoses, and the same scientific principle, as described by *Liu*, apply.

[398] Ex. 1011 (*ANSI/HI 6.1*), pg. 66.

415. *Liu* discloses wear (abrasion) at high velocities, as I discuss above. A POSITA would have been motivated to look to *ANSI/HI 6.1* for implementation details of how to avoid damaging erosion. For example, *ANSI/HI 6.1* teaches that the "critical carrying velocity" is "the mean velocity of the specific slurry in a particular conduit, above which the solids phase remains in suspension and below which solid-liquid separation occurs."[399] Accordingly, *ANSI/HI 6.1*'s teachings are complimentary to those in *Liu*. Further a POSITA would have understood that the "excessive erosion" that *ANSI/HI 6.1* teaches to avoid is the same wear (abrasion) that *Liu* teaches occurs with high velocity slurries. Accordingly, *ANSI/HI 6.1* and *Liu*'s teachings are complimentary.

416. Accordingly, while *Liu* describes the scientific principles which would enable a POSITA to apply the pumps and hoses successfully, *ANSI/HI 6.1* provides real-world examples of numbers which should be used while applying those principles. Accordingly, a POSITA would have been motivated to apply the limits on velocity of the slurry described by *ANSI/HI 6.1* when applying those principles described in *Liu* to the practical application of those principles in the system of *Cicci/Coli/Dixon/Liu/Gardner-Denver.* A POSITA accordingly would have been motivated to look to *ANSI/HI 6.1* for implementation details.

[399] Ex. 1011 (*ANSI/HI 6.1*), pg. 34.

417. A POSITA would have had a reasonable expectation of success in applying the teachings of *ANSI/HI 6.1* to the system of *Cicci/Coli/Dixon/Liu/Gardner-Denver* at least because the combination merely applies a known technique (practical limits on slurry velocity) to a known system (the hydraulic fracturing system of *Cicci/Coli/Dixon/Liu/Gardner-Denver*) ready for improvement (the practical application of *Liu's* scientific principles) to yield predictable results (a system which minimizes proppant drop out and wear/abrasion/erosion).

B. DEPENDENT CLAIM 8: "8. THE SYSTEM OF CLAIM 1, WHEREIN THE THIRD DIAMETER IS ASSOCIATED WITH A SECOND THRESHOLD, CORRESPONDING TO A MAXIMUM SUGGESTED FLOW RATE, AN OPERATING WINDOW FOR THE ELECTRIC POWERED MULTI-PLUNGER HYDRAULIC FRACTURING PUMP EXCEEDING THE MAXIMUM SUGGESTED FLOW RATE."

418. Claim 8 would have been obvious to a POSITA based on the combined teachings of *Cicci, Coli, Dixon, Liu* and *Gardner-Denver* as discussed above in Section XIV.D, incorporated herein by reference. *ANSI/HI 6.1* provides further evidence that Claim 8 would have been obvious to a POSITA.

419. *Liu* teaches, as discussed in Sections XIII.B.8, XIII.G, XIII.H, and XIV.D, that velocity of a slurry should be held between a minimum velocity, to preventing slurry dropout, and a maximum velocity, to prevent unacceptable pressure drop and wear (abrasion). *Liu* further teaches that the velocity (V) of a fluid,

is related to both flowrate (Q) and diameter (D) of the hose as shown in the equation below.

$$V = \frac{Q}{A} = \frac{4Q}{\pi D^2}$$

420. While *Liu* contains these known scientific principles, *ANSI/HI 6.1* provides real-world velocities useful for applying these principles. For example, *ANSI/HI 6.1* teaches that, when pumping a slurry, "hydraulic passages should be sized to that the lowest velocity of the liquid will be above the critical carrying velocity of 1.2 to 1.8 m/s (4 to 6 ft/s) as an average. The highest velocity should be below that which causes excessive erosion. Typical average operating velocities through a reciprocating slurry pump's passages are 1.8 to 3.6 m/s (6 to 12 ft/s)."[400] A POSITA would have recognized that the same principles would have applied to the hydraulic passages of the hoses in the system of *Cicci/Coli/Dixon/Liu/Gardner-Denver*, particularly in light of the abrasion teachings of *Liu*. A POSITA would have been motivated to apply these teachings to the hoses to obtain the benefits of avoiding excessive erosion, would damage the pipe and equipment. It would have been obvious to a POSITA to apply such teachings to the hoses, at least because the

[400] Ex. 1011 (*ANSI/HI 6.1*), pg. 66.

same slurry passes through the passages of the pump and the hoses, and the same scientific principle, as describe by *Liu*, would apply.

421. *ANSI/HI 6.1* further teaches that the "Critical carrying velocity" is "the mean velocity of the specific slurry in a particular conduit [e.g., hose], above which the solids phase remains in suspension and below which solid-liquid separation occurs."[401] Accordingly, *ANSI/HI 6.1*'s teachings are complimentary to those in *Liu*. Further a POSITA would have understood that the "excessive erosion" that *ANSI/HI 6.1* teaches to avoid is the same wear (abrasion) that *Liu* teaches occurs with high velocity slurries.

422. A POSITA, then, would have understood, based on the combined teachings of *Cicci/Coli/Dixon/Liu/Gardner-Denver* and *ANSI/HI 6.1*, that velocities of the slurry in the hydraulic fracturing system should be maintained between 1.8 to 3.6 m/s (6 to 12 ft/s) to minimize slurry drop out and to minimize wear/abrasion/erosion. For any given diameter of hose, there is a maximum flow rate above which velocity would exceed 12 ft/s, leading to unacceptable pressure drop or wear. Further, for any given diameter of hose, there is a minimum flow rate below which velocity would be below 6 ft/s, leading to unacceptable slurry drop-out. Accordingly, it would have been obvious to a POSITA that for any given third

[401] Ex. 1011 (*ANSI/HI 6.1*), pg. 34.

diameter, there is a second threshold associated with that third diameter that corresponds to a maximum suggested flow rate, which would limit pressure drop and wear to acceptable levels.

423. Applying *Liu*'s formula, described above, it would have been obvious to a POSITA to calculate example minimum and maximum flowrates which would apply the limits of *ANSI/HI 6.1* with various hose sizes which would have been obvious to use, as described above in Sections XIII.B-C and XIII.F-G, and incorporated herein by reference (e.g., hose sizes smaller than the diameter of standard fracturing pump connections, 6"). These minimum and maximum flowrates are contained in the table below.

Diameter of Hose (inches)	Minimum Flowrate (BPM)	Maximum Flow Rate (BPM)
3	3.15	6.29
4	5.60	11.19
5	8.74	17.49

424. As discussed above in Section XIV.D, *Gardner-Denver* describes that its pump has a range of operations, teaches that the "operating window" for each pump is between 191 GPM (4.5 BPM, red box in the figure below) and 2,044 GPM (48.66 BPM) depending on the design, speed and specific well conditions.[402] For the

[402] Ex. 1010 (*Gardner-Denver*), pg. 20 of the PDF excerpted and annotated.

conditions specified in *Cicci* ("5,000 PSI to 15,000 PSI or more"),[403] the range of each pump is 191 GPM (4.5 BPM, annotated in red) to 734 GPM (17.5 BPM, annotated in blue).

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. 1010 (*Gardner-Denver*) pg. 20 of the PDF excerpted and annotated.

A comparison of the operating range of the *Gardner-Denver* pump with the practical maximum flowrate thresholds described by *ANSI/HI 6.1*, applying the principles of *Liu* shows that the operating range exceeds the maximum flowrate threshold of the hose sizes which would have been obvious to a POSITA to use in the system of *Cicci/Coli/Dixon/Liu/Gardner-Denver.*

[403] Ex. 1004 (*Cicci*) 2:39-42; Ex. 1005 (*Cicci Provisional*) [12].

425. Accordingly, the combination of *Cicci/Coli/Dixon/Liu*/*Gardner-Denver* and *ANSI/HI 6.1* teaches wherein the first diameter is associated with a second threshold, corresponding to a maximum suggested flow rate, an operating window for the electric powered pump exceeding the maximum suggested flow rate. Thus, Claim 8 would have been obvious to a POSITA based on the combined teachings of *Cicci/Coli/Dixon/Liu*/*Gardner-Denver* and *ANSI/HI 6.1*.

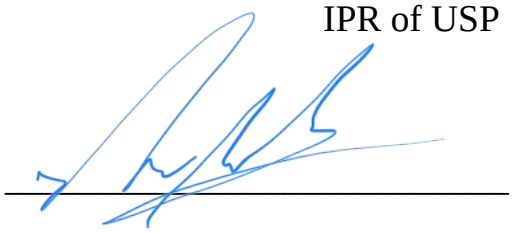
C. DEPENDENT CLAIM 17: "17. THE SYSTEM OF CLAIM 11, WHEREIN THE THIRD DIAMETER IS ASSOCIATED WITH A SECOND THRESHOLD, CORRESPONDING TO A MAXIMUM SUGGESTED FLOW RATE, AN OPERATING WINDOW FOR THE ELECTRIC POWERED MULTI-PLUNGER HYDRAULIC FRACTURING PUMP EXCEEDING THE MAXIMUM SUGGESTED FLOW RATE."

426. The limitations of Claim 17 are the same as those in Claim 8 and would have been obvious to a POSITA for the same reasons as those discussed above in Section XVI.B.

XVII. CONCLUSION

427. 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 September 30, 2025.



Dr. Robert A. Durham