UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

PERMIAN GLOBAL INC., AND
MANTICORE FUELS, LLC
Petitioners

v.

FUEL AUTOMATION STATION, LLC,
Patent Owner

Case Nos. IPR2023-01236, IPR2023-01237, & IPR2023-01238
Patent Nos. 10,815,118; 9,586,805; & 10,974,955

SUPPLEMENTAL DECLARATION OF DR. ROBERT DURHAM IN SUPPORT OF PETITIONS FOR *INTER PARTES* REVIEW

I, Robert A. Durham, Ph.D., hereby declare as follows:

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 ("IPRs") of U.S. Patent Nos. 9,586,805 (which I may abbreviate as "the '805 Patent"), 10,815,118 (which I may abbreviate as "the '118 Patent"), and 10,974,955 (which I may abbreviate as "the '955 Patent") (collectively the "Challenged Patents"). In this declaration I may refer to each of these IPRs by their patent number or IPR number (*e.g.*, "'118 IPR" or "IPR2023-01236"). This declaration supplements and updates the statements of my opinions on issues related to the unpatentability of claims of the Challenged Patents as reflected in my previous declarations submitted in these IPRs. I am being compensated at my normal hourly rate for my analysis, plus reimbursement for expenses. My compensation does not depend on the content of my opinions or the outcome of this proceeding.

II. LIST OF EXHIBITS

3. In forming my opinions, I have reviewed the Challenged Patents, its prosecution histories and references cited by the Examiner, the materials cited in the Lists of Exhibits below and in my original declarations, and the materials cited

throughout my declarations. I have also reviewed the Patent Owner's Responses ("PORs") filed in these IPRs, including the exhibits submitted therewith that relate to the opinions below. I have also reviewed the transcript of the deposition of Dr. John Rodgers taken on August 6, 2024, including the exhibits thereto that relate to the opinions below.

4. All citations to exhibits reference original page numbers found in the underlying document, and all emphases are added unless otherwise noted.

III. SECONDARY INDICIA OF NON-OBVIOUSNESS

5. The legal standards for considering secondary indicia of non-obviousness are set forth in my original declarations. I apply those standards in the opinions in this supplemental declaration.

6. Patent Owner's responses argue about significant advantages in FAS's refueling systems of hard-wired sensors.[1] However, only dependent claims 4, 6-9, and 17-18 of the '118 Patent require wired communication lines.[2] Therefore, any commercial success or praise of FAS's refueling systems attributable to an automated fueling system with wired communication lines cannot have any nexus any to the remaining claims of the '118 Patent or to any of the claims of the '805 or '955 Patents. Moreover, as discussed in my prior declaration, *Van Vliet* discloses

[1] '118 IPR POR, pages 4-6; '955 IPR POR, pages 4-6.
[2] '118 IPR EX1001.

PERMIAN GLOBAL, INC. AND MANTICORE FUELS, LLC EXHIBIT 1055, Page 3
Permian Global, Inc. et al. v. Fuel Automation Station, LLC et al.
IPR2023-01238

that the fluid tank sensors may be wired, and a POSITA would have found it obvious to route the communication lines through the hose based at least on the benefits of that arrangement.[3] Patent Owner does not dispute that *Van Vliet* discloses the elements of dependent claims 4, 6-9, and 17-18 of the '118 Patent relating to wired sensors having communication lines routed through the hoses and their alleged benefits. Therefore, any praise or commercial success of FAS's refueling systems attributable to hard-wired sensors cannot have any nexus to the Challenged Patents' claims.

7. Patent Owner's responses further argue about the significant benefits of continuous or "hot refueling" provided by FAS's refueling systems.[4] However, nothing in Challenged Claims requires or enables continuous or "hot refueling". The Challenged Patents' claims cover the claimed systems regardless of how they are used, and the claimed systems are not the only way to perform continuous or "hot refueling". To the contrary, the systems of *Van Vliet*, *AFD*, and *Frack Shack* disclose or involve continuous or "hot refueling" systems to the same extent as the Challenged Patents,[5] and the elements of the Challenged Patents' claims that Patent

---

[3] '118 IPR EX1003, ¶177 (citing EX1004, [0020]).

[4] '805 IPR POR, pages 2-3; '118 IPR POR, pages 2-4; '955 IPR POR, pages 2-3.

[5] EX1004, claim 11 ("A method of delivery of fuel to selected fuel tanks of equipment at a well site ***during fracturing of a well***…") & [0003] ("A fuel delivery system and method is presented for ***reducing the likelihood that a fuel tank of equipment at a well site during fracturing of a well will run out of fuel***."); '805 IPR EX1007 & '955 IPR EX1029, 1 ("…ensure that fuelling ***continues uninterrupted***"); EX1017 ("*Frack Shack*"), 1-2 ("[n]o slow down or stopping to refuel").

PERMIAN GLOBAL, INC. AND MANTICORE FUELS, LLC EXHIBIT 1055, Page 4
Permian Global, Inc. et al. v. Fuel Automation Station, LLC et al.
IPR2023-01238

Owner argues not disclosed in *Van Vliet* and *AFD* (*i.e.*, fluid passages in the reels, fluidly-connected reels, an aisle walkway with hose reels on each side, deploying hoses from both sides, a hose that comprises a separate tube and sleeve, a fluid register installed between the pump and manifold) are not required for and do not facilitate "hot refueling". Therefore, any praise or commercial success of FAS's systems attributable to "hot refueling" cannot have any nexus to the Challenged Patents' claims.

8. Patent Owner's responses and Dr. Rodgers' declaration discuss safety benefits associated with removing workers from a "hot zone" around fracturing pumps. PO argues that claimed inventions of the Challenged Patents were praised in the industry and commercially successful because of these benefits, for example, in the Industry Leader award given to the inventor of the Challenged Patents discussed in Dr. Rodgers' and Mr. Ortoleva's declarations.[6] However, the purportedly novel elements of the Challenged Patents' claims are not necessary to, and do not facilitate, removing workers from such areas. Indeed, as Dr. Rodgers noted, at least one automated fueling system, which would have removed workers from the "hot zone", was available from Frac Shack more than 2 years before the earliest priority date of

[6] '805 IPR EX2004, ¶¶ 65-67; '805 IPR EX2023, ¶ 5 & attached press release; '118 IPR EX2011, ¶¶ 61-63; '118 IPR EX2045, ¶ 5 & attached press release; '955 IPR EX2011, ¶¶ 62-64; '955 IPR EX2043, ¶ 5 & attached press release.

the Challenged Patents that had those benefits.[7] *Van Vliet* and *AFD* also disclosed fueling systems that provided these benefits,[8] and Patent Owner provides no evidence that the features allegedly absent from those references were necessary to or facilitated removing workers from areas around fracturing pumps. The elements of the Challenged Patents' claims that Patent Owner argues are not disclosed in *Van Vliet* and *AFD* (*i.e.*, fluid passages in the reels, fluidly-connected reels, an aisle walkway with hose reels on each side, deploying hoses from both sides, a hose that comprises a separate tube and sleeve, a fluid register installed between the pump and manifold) do not enable or facilitate removing workers from the hot zone. Therefore, any safety benefits of FAS's system associated with removing workers from a "hot zone" around fracturing pumps, as well as any praise or commercial success attributable to those benefits, cannot have nexus to the Challenged Patents' claims.

IV. SUITABILITY OF COMPONENTS IN *COXREELS* FOR REFUELING SYSTEMS

A. Dr. Rodgers' Rejection of Brass Fittings is Misplaced

9. I note, initially, that the Challenged Patents' claims do not exclude the use of brass fittings, nor do the claims require pumping diesel fuel as "the fluid".

---

[7] '805 IPR EX2004, ¶ 66; EX1017, 1-2 ("remove[s] workers from the hot zone").

[8] *See* '805 EX1007 & '955 EX1029, 2 ("AFD's innovative refuelling system ***will increase worker safety by minimizing exposure time around the hot zones*** and high pressure lines through controlled fuelling."); 'EX1004, [0002] ("Dangers to the existing way of proceeding include: extreme operating temperatures and pressures, extreme noise levels, and fire hazard from fuel and fuel vapours.").

Accordingly, any discussion regarding brass fittings or diesel fuel should not be used to exclude any particular art or combination.

10. Dr. Rodgers states that the brass-plated inlet on certain of the reels described in *Coxreels* would have promoted degradation of diesel fuel and so a POSITA would have considered those reels unsuitable for use in *Van Vliet's* systems.[9] I disagree with this assertion.

11. Initially, the references that Dr. Rodgers refers to deal with "long term storage" and high temperature and severe duty applications of diesel.[10] There is no evidence to support that the application of a fueling system meets any of those criteria. Using Dr. Rodgers' flow models, fluid velocity through the fittings (using reasonable assumptions) would be in the range of 5 ft/s (see Appendix A & B). As the flow passage through the fitting is less than 5 ft long, as shown in the dimensions of Coxreels, any portion of the diesel would only be in contact with the brass for less than one second, certainly not "long term".[11]

12. Moreover, *Van Vliet* expressly teaches using pumps 32, 34 to clear the lines of residual diesel "for example by pumping pumps 32, 34 in reverse to pull

---

[9] '805 IPR EX2004, ¶¶ 160-164; '118 IPR EX2011, ¶¶ 122-125; '955 IPR EX2011, ¶¶ 124-126.

[10] '805 IPR EX2013, page 9; '118 IPR EX2024, page 9; '955 IPR EX2023, page 9.

[11] The "problems" with long term storage are degradation of the fuel, not corrosion of the fitting. I note that degradation of the fuel, according to Dr. Rodgers' references, occurs regardless of what container the fuel is stored in or is in contact with.

flow back into the tanks 18, 20" after refueling is completed.[12] Even if small amounts of diesel remained in the hoses or fluid passages in the reel when the system is not in use, there is no evidence that such diesel would remain in contact with the brass inlet itself. Indeed, it is more likely that any diesel remaining in the hoses would fall into the lower portions of the hoses stored on the reel, as opposed to being pushed upstream into the brass inlet of the reel. Therefore, in the proposed combination of *Van Vliet* and *Coxreels*, even if diesel is used, no substantial volume of diesel would be likely to be exposed to the brass-plated inlet for any extended period of time.

13. These teachings also would not discourage a POSITA from using the reels from *Coxreels* that have brass inlets in operations at ambient temperatures (or colder) or with fluids other than diesel. As Dr. Rodgers notes, some fracturing operations are performed in cold climates,[13] and he provides no evidence of how many fracturing operations would be performed at temperatures sufficiently high to cause degradation issues. Moreover, neither *Van Vliet* nor any of the Challenged Claims, is limited to diesel,[14] and a POSITA would have known that other types of fuel could be used in fracturing equipment and thus refueled using *Van Vliet's* system, and other fluids could be used to practice the Challenged Claims. In fact, the

---

12 '805 IPR EX1004, [0028].

13 '805 IPR EX2004, ¶167; '118 IPR EX2011, ¶131; '955 IPR EX2011, ¶133.

14 EX1004, Abstract (referring to "A ***fuel*** delivery system…").

term "diesel" only applies once in each of the specifications of the '118, '805, and '955 Patents, and never in the claims.[15] Dr. Rodgers cites nothing to indicate that reels having brass-plated fluid inlets would be unsuitable for applications in environments that do not involve high temperatures or applications or for fluids other than diesel.

B. Dr. Rodgers' Assumptions about Low Temperature Inside *Van Vliet's* Trailer are Incorrect.

14. I initially note that neither the claims nor the art require or exclude operation at any temperature range. Accordingly, any discussion of temperature should not be used to disqualify any art or combination.

15. Dr. Rodgers further argues that the AFLAS seal on certain of the reels described in *Coxreels* would not be appropriate for use in temperatures below -3°C.[16] In my opinion, this would not have discouraged a POSITA from using the reels of *Coxreels* in the refueling systems of *Van Vliet*.

16. Dr. Rodgers states that locations such as North Dakota or Canada may experience these temperatures. However, many fracturing operations in which the *Van Vliet* refueling system could be used are not conducted in areas of the country that experience temperatures at or below that range most of the year. For example, in the South Texas region where many well site operations are performed,

---

[15] '118 IPR EX1001, 2:21; '805 IPR EX1001, 3:47; '955 IPR EX1001, 2:35.

[16] '805 IPR EX2004, ¶¶ 166-167; '118 IPR EX2011, ¶¶ 130-131; '955 IPR EX2011, ¶¶ 132-33.

PERMIAN GLOBAL, INC. AND MANTICORE FUELS, LLC EXHIBIT 1055, Page 9
Permian Global, Inc. et al. v. Fuel Automation Station, LLC et al.
IPR2023-01238

temperatures rarely drop below -3°C even during the winter. Both now and before the Challenged Patents were filed, many service companies would focus their operations in particulars region of the country in order to control their business costs. To the extent different equipment would be required for such cold temperatures, a service company that primarily serviced the South Texas region or a region with similar climate would not necessarily design all of their refueling units to be operable at such cold conditions since they would be so unlikely to occur in their primary service region. Therefore, a POSITA designing a refueling system of *Van Vliet* for at least certain regions would not be discouraged from using certain reels in *Coxreels* simply because they include an AFLAS seal.

17. Even in climates that experience temperatures below -3°C more regularly, a POSITA would not have expected the temperature inside the enclosed trailer of *Van Vliet* (where the reels are located) would drop below -3°C for a sufficiently long period of time to compromise the integrity of the AFLAS seal. Dr. Rodgers confirmed during his deposition that regions such as North Dakota and Canada might experience such temperatures in the winter ***outdoors***.[17] I am not aware of any evidence that the temperature inside the enclosed trailer of *Van Vliet* would have reached those temperatures, much less maintained those temperatures in a way that would impact the integrity of an AFLAS seal on the hose reels located inside

[17] Rodgers Depo. Tr., 127:22-128:4.

PERMIAN GLOBAL, INC. AND MANTICORE FUELS, LLC EXHIBIT 1055, Page 10
Permian Global, Inc. et al. v. Fuel Automation Station, LLC et al.
IPR2023-01238

the trailer. To the contrary, with pumps and other equipment giving off heat in the enclosed trailer, I would expect the temperature in the areas surrounding the reels to remain above freezing.

18. Moreover, a POSITA would know that lower temperatures impact certain properties of diesel. For example, the "cloud point"[18] of diesel is -3ºC and the "pour point"[19] of diesel is -12ºC. If a POSITA was designing a refueling system of *Van Vliet* to dispense diesel at such cold temperatures, they would already expect to have to take measures to keep the temperatures inside the trailer sufficiently high so that the temperature stays above the cloud point, to enable filtration and pumping. Those same measures would preserve the integrity of the AFLAS seal. Taking such measures to prevent degradation or freezing of fluids would have been a normal precaution when performing fracturing operations in freezing temperatures. For example, water, the most common hydraulic fracturing fluid, freezes at 0ºC, and precautions must be taken to prevent freezing of the water in the storage locations,

---

[18] *See, e.g.*, Coutinho J.A.P. *et al.*, "Cloud and pour points in fuel blends," *Fuel*, Volume 81, Issue 7, 2002, Pages 963-967, ISSN 0016-2361, https://doi.org/10.1016/S0016-2361(01)00213-7 (see Table 2, value for diesel at 100 vol%). The cloud point of a fuel is the temperature where "crystals of paraffins form in fuels".

[19] *See, e.g.*, Coutinho J.A.P. *et al.*, "Cloud and pour points in fuel blends," *Fuel*, Volume 81, Issue 7, 2002, Pages 963-967, ISSN 0016-2361, https://doi.org/10.1016/S0016-2361(01)00213-7 (see Table 2, value for diesel at 100 vol%). The pour point of a fuel is the temperature where "a crystal network develops in the fluid preventing it from flowing".

blenders, pipes, and manifolds. Taking such precautions to prevent paraffin crystals from forming in diesel fuel would be a normal and necessary course of action.

19. Finally, even if a POSITA had to design the *Van Vliet* system to withstand temperatures below -3°C inside the trailer where the reels are located, it would have been well within the skill of a POSITA to replace the AFLAS seal with a commercially-available alternative seal made of a material that could withstand those temperatures, such as the nitrile alternative disclosed in *Coxreels*.[20]

20. Therefore, in my opinion, the evidence Dr. Rodgers cites would not discourage a POSITA from using the reels of *Coxreels* in the refueling systems of *Van Vliet*.

C. Dr. Rodgers' Pressure Calculations are Based on Faulty Assumptions.

21. I initially note that the Challenged Patents' claims neither require or exclude any pressure or flow rate or any particular hose length. Accordingly, any discussion of pressure, flow rate or hose length should not be used to disqualify any art or combination. Further, none of the Challenged Patents' claims require the system described to be used in a fracturing application. It appears that Dr. Rodgers is attempting to read the specification into limitations of the claims, which I understand to be improper. Accordingly, any discussion of fracturing operations should not be used to disqualify any art or combination.

[20] '805 IPR EX1008 & '118 IPR EX1005, 1.

22. Dr. Rodgers states that he calculated the pressures required to deliver 7,500 gallons of fuel per 12 hours using the system of *Van Vliet* using certain hose reels as disclosed in *Coxreels* and concluded that they would "lead to an undesirable, unsafe operating configuration" that a POSITA would have found unacceptable.[21] I have reviewed Dr. Rodgers' analysis, including his assumptions and calculations underlying those conclusions. I respectfully disagree with his conclusions for several reasons.

23. For example, Dr. Rodgers states that a system using hoses of a 3/8" inner diameter (ID) and 700 ft length would need to pump fuel at a pressure of 440 psi in order to deliver 7,500 gallons per 12 hours.[22] I see no support for that value in Dr. Rodgers' calculations. The documentation in the Appendix to his declaration does not show that calculation, and his model (Exhibit 12 to his deposition) does not produce that value at the parameters indicated.

24. Moreover, Dr. Rodgers makes several assumptions regarding the parameters and limitations of the refueling system of *Van Vliet* as modified by *Coxreels* that are unsupported by any evidence and are inconsistent with what a POSITA would have understood about fueling systems.

---

[21] '805 IPR EX2004, ¶¶ 170-188; '118 IPR EX2011, ¶¶ 134-151; '955 IPR EX2011, ¶¶ 136-154.

[22] '805 IPR EX2004, ¶180; '118 IPR EX2011, ¶144; '955 IPR EX2011, ¶146.

25. First, Dr. Rodgers assumes that such systems would require hoses that are 700 ft long.[23] There is no evidence in *Van Vliet* or otherwise that onsite refueling systems must have hoses that long. Indeed, *AFD* disclosed that its refueling system for fracturing operations included hoses that were only 300-450 ft in length.[24] Even Dr. Rodgers seems to acknowledge that shorter hoses can be used, since both calculations "A" and "B" shown on the first page of his Appendix indicate hose lengths of only 200 ft.[25]

26. Dr. Rodgers also assumes that the hoses must have an ID of only 3/8 inches.[26] I disagree with that assumption. Even assuming that a POSITA were limited to reels of the hose capacities listed in *Coxreels*, *Coxreels* lists other reels that could accommodate hoses with larger IDs (3/4" or 1/2") of lengths within the ranges that would be acceptable for fracturing operations.[27] Of course, it also would have been well within the skill of a POSITA to design a reel substantially similar to those of *Coxreels* to accommodate even larger ID hoses (*e.g.*, 1") of lengths acceptable for fracturing operations.

---

[23] '805 IPR EX2004, ¶171; '118 IPR EX2011, ¶135; '955 IPR EX2011, ¶ 137.
[24] '805 IPR EX1007 & '955 IPR EX1029, 3.
[25] '805 IPR EX2004, Appendix A; '118 IPR EX2011, Appendix A; '955 IPR EX2011, Appendix A.
[26] '805 IPR EX2004, ¶171; '118 IPR EX2011, ¶135; '955 IPR EX2011, ¶ 137.
[27] '805 IPR EX1008 & '118 IPR EX1005, 1-2.

27. Dr. Rodgers also assumes that only 3 hoses would be used simultaneously.[28] I disagree with this assumption. His declaration cites no support for this assumption, and in his deposition Dr. Rodgers cited only his alleged discussions with the inventor on the Challenged Patents.[29] Further, this assumption is contrary to Dr. Rodgers' other testimony. Dr. Rodgers testifies that a 50% duty cycle would be "comfortable". However, a 50% duty cycle for the system of *Van Vliet* (with 10 hoses) would be at 5 hoses running simultaneously. Further, a 50% duty cycle in the system of *AFD* (with 24 hoses) would be 12 hoses running simultaneously.

28. Dr. Rodgers' assumption is also contrary to the evidence. Since the prior art refueling systems included up to 24 fuel hoses,[30] a POSITA would not expect that only 3 of them could be used to dispense fuel at any given time. In my experience, even a single field technician trained to operate these systems would have been capable of monitoring all hoses actively dispensing fuel at once, particularly with the computerized monitoring equipment that would have been available to a POSITA designing these systems in 2016.[31] For example, *Van Vliet*

---

[28] '805 IPR EX2004, ¶178 & Appendix A; '118 IPR EX2011, ¶142 & Appendix A; '955 IPR EX2011, ¶144 & Appendix A.

[29] Rodgers Depo. Tr., 146:3-148:12, 149:8-16.

[30] *See, e.g.*, '805 IPR EX1007 & '955 IPR EX1029, 3; *see also* 'EX1004, Fig. 1 (showing 10 hoses / reels).

[31] *See, e.g.*, '805 IPR EX1007 & '955 IPR EX1029, 3 ("The Control Room contains two touch screen display monitors that control and provide fuel status for each reel and the main

teaches that "*the operator* [singular] may be provided with a valve control console with individual toggles for remote operation of the valves 58, and the valve control console, or another console may include visual representations or displays showing the fuel level *in each of the tanks* 12."[32] *Van Vliet* teaches a single operator to operate and monitor at least 10 different hoses and fuel tanks, though the teachings of *Van Vliet* are not limited to just 10 hoses and tanks.

29. Further, *Van Vliet* teaches an "automatic system" where "[f]luid flow in each hose 24 is controlled *automatically* or manually in response to receiving signals representative of fuel levels in the fuel tanks."[33] In such a system the operator would only be tasked with monitoring, not controlling, the valves. To limit a system that is designed with at least 10 or 24 hoses and valves to only 3 because of some unsupported supposition that 3 is all an operator can handle strains credulity.

30. Further, *AFD* shows a single operator station with at least 23 valve / hose / fuel tank systems on a single screen (see photo below).[34]

---

tank. The color coded monitoring system allows for easy recognition of each individual reel, as well as a visual of all 24 reels at one time.").

32 EX1004, [0018] (emphasis added).

33 EX1004, [0023] (emphasis added); *see also* [0020] – [0021] & claims 8, 12, 18, 25.

34 '805 IPR EX1007 & '955 IPR EX1029, 4.

As such, a single operator could easily monitor and take action, as necessary, for as many as 23 systems at the same time. Based on my experience with designing, building and operating control systems for operations much more complicated than pumping through 23 valve, hose and tank systems, an operator could easily monitor a single screen, such as shown in *AFD*, while the system works automatically to switch fueling between the various tanks and still stay "on top" of the situation.

31. Further, the number of hoses dispensing simultaneously could be safely doubled by, for example, having just one more field technician on duty at the unit during periods when more hoses would be used.

32. Further, despite Dr. Rodgers' contention that "3" hoses are being used simultaneously, a careful examination of the calculations behind his "model" (*i.e.*, Exhibit 12) show that even that assumption is not used. In order to calculate the "total flow rate" necessary to come up with, for example, 7500 GPM, Dr. Rodgers uses a 50% "max duty cycle", which means that Dr. Rodgers assumed that only 3 hoses were available, and that those 3 hoses are only available for 50% of the time. In other words, all of the flow for a 12 hour period must flow through only 1.5 hoses. A standard calculation of GPM necessary to flow, for example, 7500 gallons over 12 hours would be the following:

$$\frac{7500\ gallons}{12\ hours * 60\ minutes/hour} = 10.4\ gpm$$

33. However, by using a 50% duty cycle, Dr. Rodgers assumes that it would take 20.8 gpm of total flow to equal 7500 gallons in a twelve-hour period. This is incorrect. It appears that Dr. Rodgers is erroneously applying a 50% duty cycle to the pumps, and only allowing the pumps to run 50% of the time, while sitting idle for 12 hours a day. Not only is there no support for such an assumption, but it is also improper. As a POSITA would have known, particularly one that is familiar with pumping operations such as hydraulic fracturing, pumps run best when run continuously. Repeatedly stopping and restarting a pump adds wear, and risks operational challenges in the starting, such as increased torque on the shaft due to inertia and pumping head, inrush into the motor (~6-7 times operating current), etc.

Additionally, lubricating oils in the pump cool, become more viscous, and settle to the reservoir (not the surfaces they are protecting) while a pump is not running. Applying Dr. Rodgers' logic to hydraulic fracturing would mean that 50% of the fracturing pumps are shut down during any fracturing operation. Not only is this unreasonable, as it would require twice the number of fracturing pumps to be on-site in order to perform the fracturing operations, it runs contrary to hydraulic fracturing where POSITAs would have wanted to reduce pump downtime (commonly referred to as non-productive time or NPT), for example, in zipper fracturing and continuous pumping fracturing.[35] Further, in my experience in oil and gas production operations, pumps run 24 hours a day (absent breakdowns), as they do in refineries, power plants, and industrial processes. Only allowing a pump to operate at a 50% duty cycle is not only unreasonable but inconsistent with practical applications of pumps across industries.

34. Dr. Rodgers also assumes that "[f]or safety purposes, pump pressure should be limited to approximately 60 psi."[36] I disagree with this assumption. Dr. Rodgers purports to adopt this 60 PSI limit in order to limit the amount of fuel that would leak out in the event of damage to the hose. However, this rationale makes

---

[35] *See, e.g.*, 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 ("when doing zipper fracturing the break in stimulation operations may only last 15 minutes as workers switch from one well to another. "It is a big change operationally for the frac crew," he said. "They go from having a huge amount of dead time in between fracs to almost no time at all.").

[36] '805 IPR EX2004, ¶177; '118 IPR EX2011, ¶141; '955 IPR EX2011, ¶143.

no sense since commonly-available fuel hoses were capable of 90-150 psi.[37] POSITAs also would have known that fuel pumps used with diesel were capable of pumping at much higher pressures.[38] I further note that the *Coxreels* reels are rated for 3,000 PSI, much higher than the hoses, or Dr. Rodgers' arbitrary limit.[39] Accordingly, there is no physical reason to restrict fuel pressure to 60 PSI. Fuel discharge pressure, and flowrate, are determined using relatively simple engineering principles, and are simply a balance of cost, power consumption, size flow and pressure. These are engineering decisions that a POSITA would have understood are made every day across all industries. *Van Vliet* also already included other safeguards such as override valves and containment pans to mitigate problems associated with spills or leaks.[40] Therefore, a POSITA would have considered maximum pressures of up to at least 80 - 135 psi (depending on the rating of the hoses) to be well within acceptable limits of the system of *Van Vliet*.[41]

35. I used a model similar to Dr. Rodgers' model to calculate the maximum pressure that would exist in the fueling system of *Van Vliet* using hoses of various

---

37 '805 IPR EX2019.

38 *See, e.g.*, Qian, Dexing, and Ridong Liao. 2015. "Theoretical analysis and mathematical modelling of a high-pressure pump in the common rail injection system for diesel engines", Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy, 229: 60-72. Pg 4 (describing pumping diesel fuel at pressures up to 160 MPa (~23,000 PSI)).

39 '805 IPR EX1008 & '118 IPR EX1005 & '955 IPR EX1015, 1-2.

40 EX1004, ¶¶ 0020, 0022-0023.

41 A 10% "safety margin" relative to pressure rating is reasonable, particularly when other provisions are made to protect equipment. For example, fracturing iron with rating of 15,000 PSI is regularly operated above 13,000 PSI, which allows for a 10% safety margin.

lengths and IDs, but assuming the use of 5 or 7 hoses simultaneously. The use of 7 hoses simultaneously in a system such as described by *Van Vliet* (10 total hoses) still allows nearly 50% "spare" hoses (3/7) and allows for the operator sufficient time to act as necessary to address problems with the automatic system. Further, in the system of *AFD*, or combinations thereof, it is my opinion that at 12-14 hoses operating simultaneously would be reasonable. I further removed Dr. Rodgers' "50% duty cycle" as such a restriction is unreasonable. In operation, I would expect the pump to operate nearly continuously (perhaps at varying loads as valves are opened or closed), so I applied a 90% duty cycle on the pump.

36. The results of my calculations are shown below and in Appendix A to this supplemental declaration.[42]

37. As a base case (Tab (1) of Appendix A, Calculation "A"), using the maximum hose length of 450 feet from *AFD* and Dr. Rodgers' assumption that the hose could only be 3/8" in diameter due to the "maximum" length of any possible fracturing site, Dr. Rodgers' model (with more reasonable assumptions about the duty cycle and number of hoses) shows a pressure drop through the hose of 77.2 PSI, significantly lower than the pressure rating of the Brent hose used as an example in

[42] *See* Appendix A, which includes the results of my calculations. Appendix B includes a version of my calculations in a "Show Formulas" view to show the underlying formulas of my calculations. EX1052 is a printout of Exhibit 12 from Dr. Rodgers' deposition that includes a "Show Formulas" view to show the underlying formulas of Dr. Rodgers' model. As shown, the formulas used in Dr. Rodgers' model are substantially the same as the ones I used in generating Appendix A & B.

my declaration.[43] Further, a 450' hose, fit on the *Coxreels* model 1125-4-450C or 1125-4-500C (or 1125-5-200-C) would have an ID not of 3/8", but ½".

REEL			CAPACITY			OPT. CAPACITY				SIZE INDEX			
MODEL	LBS	HOSE	I.D.	O.D.	FT.	I.D.	O.D.	FT.	PSI	W	H	L	
										Overall Dimensions			
1125-4-100-C	39	N	1/2"	7/8"	100	3/8"	3/4"	140'	3000	19-1/2"	18-3/4"	17-5/8"	Add to Quote
1125-4-200-C	42	N	1/2"	7/8"	200	3/8"	3/4"	300'	3000	25-1/2"	18-3/4"	17-5/8"	Add to Quote
1125-4-325-C	51	N	1/2"	7/8"	325	3/8"	3/4"	450'	3000	31-1/2"	18-3/4"	17-5/8"	Add to Quote
1125-4-450-C	55	N	1/2"	7/8"	450	3/8"	3/4"	625'	3000	37-1/2"	18-3/4"	17-5/8"	Add to Quote
1125-4-500-C	61	N	1/2"	7/8"	500	3/8"	3/4"	700'	3000	41-1/2"	18-3/4"	17-5/8"	Add to Quote
1125-5-50-C	41	N	3/4"	1-1/4"	50	1/2"	7/8"	100'	3000	20-3/4"	18-3/4"	17-5/8"	Add to Quote

38. As I testified in my deposition, any of the *Coxreels* reels would have been acceptable in the system of *Van Vliet*. Changing the hose size to ½" ID impacts the model so that the maximum pressure the hose would be exposed to would be 19.75 PSI, well below the pressure limits of available hoses.[44] The total operating pressure required in that instance would be 23.43 PSI, still below even Dr. Rodgers' unreasonable 60 PSI maximum pressure assumption.[45] Even with Dr. Rodgers' completely unreasonable 50% duty cycle for the pump, the total pressure the hose would be exposed to would be 55.4 PSI, still below the pressure limits of easily available hoses.[46] The total operating pressure required in that instance would be

[43] *See* '118 IPR EX1031; '805 IPR EX2019. The hose is also never exposed to the "total pressure" as Dr. Rodgers contends because the pressure drop through the filters, manifold, etc. has already occurred prior to fluid entering the hose.

[44] Appendix A, Tab (1), Calculation "B".

[45] Appendix A, Tab (1), Calculation "B".

[46] Appendix A, Tab (2).

62.2 PSI,[47] very close to Dr. Rodgers' 60 PSI "limit", and well below the pressure rating of, for example, the Brent hose.[48]

39. As shown in Appendix A, Tabs (2) and (3), there are numerous acceptable hose IDs and lengths that the reels of *Coxreels* would accommodate that would allow the system of *Van Vliet* incorporating such reels to deliver fuel using a 50% duty cycle at a rate of 7,500 gallons per 12 hours at total operating pressures below or near even Dr. Rodgers' arbitrary and unreasonable 60 psi limit using 7 or 10 hoses. As shown in the remaining tabs, the duty cycle could be increased to 75% or 90%, and such fluid volumes could be delivered at total operating pressures below even Dr. Rodgers' arbitrary and unreasonable 60 psi limit using 5 or 7 hoses.[49]

40. Moreover, many of the job parameters could be adjusted within acceptable ranges to meet the fuel requirements for larger fracturing jobs or reduce the maximum pressure needed to deliver the same amount of fuel. For example, the duty cycle could be increased while maintaining 7,500 gallons of total delivery.[50] Or, the number of hoses used simultaneously could be increased—either by adding additional operators to monitor a single unit or providing multiple refueling units—to further reduce the maximum pressure at which the unit operates.

---

47 Appendix A, Tab (2).
48 *See* '118 IPR EX1031; '805 IPR EX2019.
49 *See* Appendix A, Tabs (4)-(7).
50 *See* Appendix A, Tab (7).

41. Finally, the calculations in my appendix are based on delivering 7,500 gallons per 12 hours per Dr. Rodgers' assumption for a "small" fracturing job. However, fracturing jobs requiring even less fuel were routinely performed before the priority dates were Challenged Patents, and I have witnessed such smaller fracturing jobs in my experience in the field. Moreover, some fracturing operations also involve the use of "dual fuel" equipment that used some diesel in combination with another fuel such as natural gas. The document that Dr. Rodgers cites to support his fuel volume ranges confirms that such dual fuel equipment can use far less diesel than 7,500 gal/12 hours than he assumed for "small" jobs, and use nowhere near the 24,000 gal/12 hrs he assumed for "superfrac" jobs.[51] Therefore, a POSITA would have recognized that the *Van Vliet* refueling system incorporating the reels of *Coxreels* would have been more than capable of delivering sufficient fuel for those smaller fracturing jobs or fracturing jobs using dual fuel equipment even using Dr. Rodgers' arbitrary assumptions about pressure limits.

42. Conversely, a POSITA would not have assumed it was necessary to design a single refueling system of *Van Vliet* to be capable of supplying the full amount of fuel needed for a typical fracturing operation. In my opinion, it would not have been unusual to have multiple refueling units for refueling at a particular

[51] '118 IPR EX2030, pages 22-27 (Tables 11, 13, 15, 17, & 19 showing "T2 Dual Fuel" engines consuming on average only 5,454-13,241 per 12 hours (10,908-26,482 per day) and "T4 Dual Fuel" engines consuming on average only 3,225-7,981 (6,451-15,963 per day)).

fracturing job. A POSITA would have recognized that multiple of *Van Vliet*'s systems incorporating *Coxreels'* reels could be used to deliver sufficient fuel for larger fracturing jobs if needed.

V. DECLARATION

43. I hereby declare that all the statements made in this Declaration are of my own knowledge and true; that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. § 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Executed in Tulsa, OK on August 26, 2024.

Robert A. Durham

PERMIAN GLOBAL, INC. AND MANTICORE FUELS, LLC EXHIBIT 1055, Page 25
Permian Global, Inc. et al. v. Fuel Automation Station, LLC et al.
IPR2023-01238

APPENDIX A

Tab (1) Base Case

Flow Calculations

https://energy-models.com/pipe-sizing-charts-tables
https://ntrs.nasa.gov/api/citations/19660024205/downloads/19660024205.pdf

Assumptions:
1. Turbulent flow regime
2. Fluid properties

Fluid: diesel at 60 deg F	specific gravity		0.88	Schiller	Darcy-Weisbach eqn
	dyn viscosity	ft^2/s	4.31E-05	0.0054+0.396/R^0.3	dP=f L rho/2 v^2 /D
					dP = f* (L/D)(rho*v^2)/(2g)

total flow rate, gpm		11.5
max duty cycle		90%
total fuel per 12 hrs	gal	7500
Number of hoses		7
hose flow rate, gpm		1.6

	Part	ID , in.	Length (ft)	L/D	velocity, ft/s	Re (vD/nu)	f	dP (psi)	total P (psi)	Notes
A	filter	2.000			0.17	6.50E+02	0.062	3.59		dP approximation from Dr. Rodgers
1125-450	manifold to hose	1.000	6.00	72.00	0.67	1.30E+03	0.051	0.01		
1125-4-500-C	elbow	0.500		45.00	2.68	2.60E+03	0.043	0.08		
1125-5-200-C	hose	**0.375**	450	14400.00	4.77	3.46E+03	0.040	77.20	80.88	
B	filter	2.000			0.17	6.50E+02	0.062	3.59		dP approximation from Dr. Rodgers
1125-450	manifold to hose	1.000	6.00	72.00	0.67	1.30E+03	0.051	0.01		
1125-4-500-C	elbow	0.500		45.00	2.68	2.60E+03	0.043	0.08		
1125-5-200-C	hose	**0.500**	450	10800.00	2.68	2.60E+03	0.043	19.75	23.43	

Tab (2) 50% duty cycle, 7 hoses

Flow Calculations

https://energy-models.com/pipe-sizing-charts-tables
https://ntrs.nasa.gov/api/citations/19660024205/downloads/19660024205.pdf

Assumptions:
1. Turbulent flow regime
2. Fluid properties

Fluid: diesel at 60 deg F	specific gravity		0.88	Schiller	Darcy-Weisbach eqn
	dyn viscosity	ft^2/s	4.31E-05	0.0054+0.396/R^0.3	dP=f L rho/2 v^2 /D
					dP = f*(L/D)(rho*v^2)/(2g)

total flow rate, gpm		20.8
max duty cycle		50%
total fuel per 12 hrs	gal	7500
Number of hoses		7
hose flow rate, gpm		3.0

Reel	Part	ID , in.	Length (ft)	L/D	velocity, ft/s	Re (vD/nu)	f	dP (psi)	total P (psi)	Notes
A	filter	2.000			0.30	1.17E+03	0.053	6.50		dP approximation from Dr. Rodgers
	manifold to hose	1.000	6.00	72.00	1.21	2.35E+03	0.044	0.03		
	elbow	0.500		45.00	4.86	4.70E+03	0.037	0.23		
	hose	**0.750**	250	4000.00	2.16	3.13E+03	0.041	4.50	11.26	
B	filter	2.000			0.30	1.17E+03	0.053	6.50		
	manifold to hose	1.000	6.00	72.00	1.21	2.35E+03	0.044	0.03		
	elbow	0.500		45.00	4.86	4.70E+03	0.037	0.23		
	hose	**0.500**	450	10800.00	4.86	4.70E+03	0.037	55.40	62.16	
C	filter	2.000			0.30	1.17E+03	0.053	6.50		
	manifold to hose	1.000	6.00	72.00	1.21	2.35E+03	0.044	0.03		
	elbow	0.500		45.00	4.86	4.70E+03	0.037	0.23		
	hose	**0.500**	500	12000.00	4.86	4.70E+03	0.037	61.56	68.32	

Tab (3) 50% duty cycle, 10 hoses

Flow Calculations

https://energy-models.com/pipe-sizing-charts-tables
https://ntrs.nasa.gov/api/citations/19660024205/downloads/19660024205.pdf

Assumptions:
1. Turbulent flow regime
2. Fluid properties

Fluid: diesel at 60 deg F	specific gravity		0.88	Schiller	Darcy-Weisbach eqn
	dyn viscosity	ft^2/s	4.31E-05	0.0054+0.396/R^0.3	dP=f L rho/2 v^2 /D
					dP = f*(L/D)(rho*v^2)/(2g)
total flow rate, gpm			20.8		
max duty cycle			50%		
total fuel per 12 hrs		gal	7500		
Number of hoses			10		
hose flow rate, gpm			2.1		

Reel	Part	ID , in.	Length (ft)	L/D	velocity, ft/s	Re (vD/nu)	f	dP (psi)	total P (psi)	Notes
A	filter	2.000			0.21	8.22E+02	0.058	6.50		dP approximation from Dr. Rodgers
	manifold to hose	1.000	6.00	72.00	0.85	1.64E+03	0.048	0.01		
	elbow	0.500		45.00	3.40	3.29E+03	0.040	0.12		
	hose	**0.750**	250	4000.00	1.51	2.19E+03	0.045	2.42	9.06	
B	filter	2.000			0.21	8.22E+02	0.058	6.50		
	manifold to hose	1.000	6.00	72.00	0.85	1.64E+03	0.048	0.01		
	elbow	0.500		45.00	3.40	3.29E+03	0.040	0.12		
	hose	**0.500**	450	10800.00	3.40	3.29E+03	0.040	29.76	36.40	
C	filter	2.000			0.21	8.22E+02	0.058	6.50		
	manifold to hose	1.000	6.00	72.00	0.85	1.64E+03	0.048	0.01		
	elbow	0.500		45.00	3.40	3.29E+03	0.040	0.12		
	hose	**0.500**	500	12000.00	3.40	3.29E+03	0.040	33.07	39.71	

Tab (4) 75% duty cycle, 5 hose

Flow Calculations

https://energy-models.com/pipe-sizing-charts-tables
https://ntrs.nasa.gov/api/citations/19660024205/downloads/19660024205.pdf

Assumptions:
1. Turbulent flow regime
2. Fluid properties

Fluid: diesel at 60 deg F	specific gravity		0.88	Schiller	Darcy-Weisbach eqn
	dyn viscosity	ft^2/s	4.31E-05	0.0054+0.396/R^0.3	dP=f L rho/2 v^2 /D
					dP = f*(L/D)(rho*v^2)/(2g)

total flow rate, gpm		13.8
max duty cycle		75%
total fuel per 12 hrs	gal	7500
Number of hoses		5
hose flow rate, gpm		2.8

Reel	Part	ID , in.	Length (ft)	L/D	velocity, ft/s	Re (vD/nu)	f	dP (psi)	total P (psi)	Notes
A	filter	2.000			0.28	1.09E+03	0.054	4.31		dP approximation from Dr. Rodgers
	manifold to hose	1.000	6.00	72.00	1.13	2.18E+03	0.045	0.02		
	elbow	0.500		45.00	4.51	4.36E+03	0.037	0.20		
	hose	**0.750**	250	4000.00	2.00	2.91E+03	0.042	3.96	8.50	
B	filter	2.000			0.28	1.09E+03	0.054	4.31		
	manifold to hose	1.000	6.00	72.00	1.13	2.18E+03	0.045	0.02		
	elbow	0.500		45.00	4.51	4.36E+03	0.037	0.20		
	hose	**0.500**	450	10800.00	4.51	4.36E+03	0.037	48.71	53.25	
C	filter	2.000			0.28	1.09E+03	0.054	4.31		
	manifold to hose	1.000	6.00	72.00	1.13	2.18E+03	0.045	0.02		
	elbow	0.500		45.00	4.51	4.36E+03	0.037	0.20		
	hose	**0.500**	500	12000.00	4.51	4.36E+03	0.037	54.12	58.66	

Tab (5) 75% duty cycle, 7 hose

Flow Calculations

https://energy-models.com/pipe-sizing-charts-tables
https://ntrs.nasa.gov/api/citations/19660024205/downloads/19660024205.pdf

Assumptions:
1. Turbulent flow regime
2. Fluid properties

Fluid: diesel at 60 deg F	specific gravity		0.88	Schiller	Darcy-Weisbach eqn
	dyn viscosity	ft^2/s	4.31E-05	0.0054+0.396/R^0.3	dP=f L rho/2 v^2 /D
					dP = f*(L/D)(rho*v^2)/(2g)
total flow rate, gpm			13.8		
max duty cycle			75%		
total fuel per 12 hrs		gal	7500		
Number of hoses			7		
hose flow rate, gpm			2.0		

Reel	Part	ID , in.	Length (ft)	L/D	velocity, ft/s	Re (vD/nu)	f	dP (psi)	total P (psi)	Notes
A	filter	2.000			0.20	7.79E+02	0.059	4.31		dP approximation from Dr. Rodgers
	manifold to hose	1.000	6.00	72.00	0.81	1.56E+03	0.049	0.01		
	elbow	0.500		45.00	3.22	3.12E+03	0.041	0.11		
	hose	**0.750**	250	4000.00	1.43	2.08E+03	0.045	2.21	6.65	
B	filter	2.000			0.20	7.79E+02	0.059	4.31		
	manifold to hose	1.000	6.00	72.00	0.81	1.56E+03	0.049	0.01		
	elbow	0.500		45.00	3.22	3.12E+03	0.041	0.11		
	hose	**0.500**	450	10800.00	3.22	3.12E+03	0.041	27.11	31.55	
C	filter	2.000			0.20	7.79E+02	0.059	4.31		
	manifold to hose	1.000	6.00	72.00	0.81	1.56E+03	0.049	0.01		
	elbow	0.500		45.00	3.22	3.12E+03	0.041	0.11		
	hose	**0.500**	500	12000.00	3.22	3.12E+03	0.041	30.12	34.56	

Tab (6) 90% duty cycle, 5 hose

Flow Calculations

https://energy-models.com/pipe-sizing-charts-tables
https://ntrs.nasa.gov/api/citations/19660024205/downloads/19660024205.pdf

Assumptions:
1. Turbulent flow regime
2. Fluid properties

Fluid: diesel at 60 deg F	specific gravity		0.88	Schiller	Darcy-Weisbach eqn
	dyn viscosity	ft^2/s	4.31E-05	0.0054+0.396/R^0.3	dP=f L rho/2 v^2 /D
					dP = f*(L/D)(rho*v^2)/(2g)

total flow rate, gpm		11.5
max duty cycle		90%
total fuel per 12 hrs	gal	7500
Number of hoses		7
hose flow rate, gpm		1.6

Reel	Part	ID , in.	Length (ft)	L/D	velocity, ft/s	Re (vD/nu)	f	dP (psi)	total P (psi)	Notes
A	filter	2.000			0.17	6.50E+02	0.062	3.59		dP approximation from Dr. Rodgers
	manifold to hose	1.000	6.00	72.00	0.67	1.30E+03	0.051	0.01		
	elbow	0.500		45.00	2.68	2.60E+03	0.043	0.08		
	hose	**0.750**	250	4000.00	1.19	1.73E+03	0.048	1.61	5.29	
B	filter	2.000			0.17	6.50E+02	0.062	3.59		
	manifold to hose	1.000	6.00	72.00	0.67	1.30E+03	0.051	0.01		
	elbow	0.500		45.00	2.68	2.60E+03	0.043	0.08		
	hose	**0.500**	450	10800.00	2.68	2.60E+03	0.043	19.75	23.43	
C	filter	2.000			0.17	6.50E+02	0.062	3.59		
	manifold to hose	1.000	6.00	72.00	0.67	1.30E+03	0.051	0.01		
	elbow	0.500		45.00	2.68	2.60E+03	0.043	0.08		
	hose	**0.500**	500	12000.00	2.68	2.60E+03	0.043	21.94	25.63	

Tab (7) 90% duty cycle, 7 hose

Flow Calculations

https://energy-models.com/pipe-sizing-charts-tables
https://ntrs.nasa.gov/api/citations/19660024205/downloads/19660024205.pdf

Assumptions:
1. Turbulent flow regime
2. Fluid properties

Fluid: diesel at 60 deg F	specific gravity		0.88	Schiller	Darcy-Weisbach eqn
	dyn viscosity	ft^2/s	4.31E-05	0.0054+0.396/R^0.3	dP=f L rho/2 v^2 /D
					dP = f*(L/D)(rho*v^2)/(2g)

total flow rate, gpm		11.5
max duty cycle		90%
total fuel per 12 hrs	gal	7500
Number of hoses		7
hose flow rate, gpm		1.6

Reel	Part	ID , in.	Length (ft)	L/D	velocity, ft/s	Re (vD/nu)	f	dP (psi)	total P (psi)	Notes
A	filter	2.000			0.17	6.50E+02	0.062	3.59		dP approximation from Dr. Rodgers
	manifold to hose	1.000	6.00	72.00	0.67	1.30E+03	0.051	0.01		
	elbow	0.500		45.00	2.68	2.60E+03	0.043	0.08		
	hose	**0.750**	250	4000.00	1.19	1.73E+03	0.048	1.61	5.29	
B	filter	2.000			0.17	6.50E+02	0.062	3.59		
	manifold to hose	1.000	6.00	72.00	0.67	1.30E+03	0.051	0.01		
	elbow	0.500		45.00	2.68	2.60E+03	0.043	0.08		
	hose	**0.500**	450	10800.00	2.68	2.60E+03	0.043	19.75	23.43	
C	filter	2.000			0.17	6.50E+02	0.062	3.59		
	manifold to hose	1.000	6.00	72.00	0.67	1.30E+03	0.051	0.01		
	elbow	0.500		45.00	2.68	2.60E+03	0.043	0.08		
	hose	**0.500**	500	12000.00	2.68	2.60E+03	0.043	21.94	25.63	

APPENDIX B

Tab (1) Base Case

Flow Calculations

https://energy-models.com/pipe-sizing-charts-tables
https://ntrs.nasa.gov/api/citations/19660024205/downl

Assumptions:
1. Turbulent flow regime
2. Fluid properties

Fluid: diesel at 60 deg F	specific gravity		0.88	Schiller	Darcy-Weisbach eqn
	dyn viscosity	ft^2/s	=0.000004/0.0254^2/12^2	0.0054+0.396/R^0.3	dP=f L rho/2v^2/D
					dP = f*(L/D)(rho*v^2)/(2g)
total flow rate, gpm			11.6		
max duty cycle			0.9		
total fuel per 12 hrs		gal	=1000*ROUND(E11*12*60*E12/1000,1)		
Number of hoses			7		
hose flow rate, gpm			=E11/E14		

	Part	ID , in.	Length (ft)	L/D	velocity, ft/s	Re (vD/nu)	f	dP (psi)	total P (psi)	Notes
A	filter	2			=$E$15*0.1337/(PI()*C21^2/4)*12^2/60	=F21*C21/12/$E$8	=0.0054+0.396/G21^0.3	=E$11/3.2		dP approximation from Dr. Rodgers
1125-450	manifold to hose	1	6	=D22/C22*12	=$E$15*0.1337/(PI()*C22^2/4)*12^2/60	=F22*C22/12/$E$8	=0.0054+0.396/G22^0.3	=H22*E22*$E$7*62.4/2*F22^2/32.2/12^2		
1125-4-500-C	elbow	0.5		45	=$E$15*0.1337/(PI()*C23^2/4)*12^2/60	=F23*C23/12/$E$8	=0.0054+0.396/G23^0.3	=H23*E23*$E$7*62.4/2*F23^2/32.2/12^2		
1125-5-200-C	hose	**0.375**	450	=D24/C24*12	=$E$15*0.1337/(PI()*C24^2/4)*12^2/60	=F24*C24/12/$E$8	=0.0054+0.396/G24^0.3	=H24*E24*($E$7*62.4)/2*F24^2/32.2/12^2	=SUM(I21:I24)	
B	filter	2			=$E$15*0.1337/(PI()*C27^2/4)*12^2/60	=F27*C27/12/$E$8	=0.0054+0.396/G27^0.3	=E$11/3.2		dP approximation from Dr. Rodgers
1125-450	manifold to hose	1	6	=D28/C28*12	=$E$15*0.1337/(PI()*C28^2/4)*12^2/60	=F28*C28/12/$E$8	=0.0054+0.396/G28^0.3	=H28*E28*$E$7*62.4/2*F28^2/32.2/12^2		
1125-4-500-C	elbow	0.5		45	=$E$15*0.1337/(PI()*C29^2/4)*12^2/60	=F29*C29/12/$E$8	=0.0054+0.396/G29^0.3	=H29*E29*$E$7*62.4/2*F29^2/32.2/12^2		
1125-5-200-C	hose	**0.5**	450	=D30/C30*12	=$E$15*0.1337/(PI()*C30^2/4)*12^2/60	=F30*C30/12/$E$8	=0.0054+0.396/G30^0.3	=H30*E30*($E$7*62.4)/2*F30^2/32.2/12^2	=SUM(I27:I30)	

Tab (2) 50% duty cycle, 7 hoses

Flow Calculations

https://energy-models.com/pipe-sizing-ch
https://ntrs.nasa.gov/api/citations/19690(

Assumptions:
1. Turbulent flow regime
2. Fluid properties

Fluid: diesel at 60 deg F	specific gravity		0.88	Schiller	Darcy-Weisbach eqn
	dyn viscosity	ft^2/s	=0.000004/0.0254^2/12^2	0.0054+0.396/R^0.3	dP=f L rho/2 v^2/D
					dP = f*(L/D)(rho*v^2)/(2g)
total flow rate, gpm			20.8		
max duty cycle			0.5		
total fuel per 12 hrs		gal	=1000*ROUND(E11*12*60*E12/1000,1)		
Number of hoses			7		
hose flow rate, gpm			=E11/E14		

Reel	Part	ID , In.	Length (ft)	L/D	velocity, ft/s	Re (vD/nu)	f	dP (psi)	total P (psi)	Notes
A	filter	2			=$E$15*0.1337/(PI()*C21^2/4)*12^2/60	=F21*C21/12/$E$8	=0.0054+0.396/G21^0.3	=E$11/3.2		dP approximation from Dr. Rodgers
	manifold to hose	1	6	=D22/C22*12	=$E$15*0.1337/(PI()*C22^2/4)*12^2/60	=F22*C22/12/$E$8	=0.0054+0.396/G22^0.3	=H22*E22*$E$7*62.4/2*F22^2/32.2/12^2		
	elbow	0.5		45	=$E$15*0.1337/(PI()*C23^2/4)*12^2/60	=F23*C23/12/$E$8	=0.0054+0.396/G23^0.3	=H23*E23*$E$7*62.4/2*F23^2/32.2/12^2		
	hose	**0.75**	250	=D24/C24*12	=$E$15*0.1337/(PI()*C24^2/4)*12^2/60	=F24*C24/12/$E$8	=0.0054+0.396/G24^0.3	=H24*E24*($E$7*62.4)/2*F24^2/32.2/12^2	=SUM(I21:I24)	
B	filter	2			=$E$15*0.1337/(PI()*C27^2/4)*12^2/60	=F27*C27/12/$E$8	=0.0054+0.396/G27^0.3	=E$11/3.2		
	manifold to hose	1	6	=D28/C28*12	=$E$15*0.1337/(PI()*C28^2/4)*12^2/60	=F28*C28/12/$E$8	=0.0054+0.396/G28^0.3	=H28*E28*$E$7*62.4/2*F28^2/32.2/12^2		
	elbow	0.5		45	=$E$15*0.1337/(PI()*C29^2/4)*12^2/60	=F29*C29/12/$E$8	=0.0054+0.396/G29^0.3	=H29*E29*$E$7*62.4/2*F29^2/32.2/12^2		
	hose	**0.5**	450	=D30/C30*12	=$E$15*0.1337/(PI()*C30^2/4)*12^2/60	=F30*C30/12/$E$8	=0.0054+0.396/G30^0.3	=H30*E30*($E$7*62.4)/2*F30^2/32.2/12^2	=SUM(I27:I30)	
C	filter	2			=$E$15*0.1337/(PI()*C33^2/4)*12^2/60	=F33*C33/12/$E$8	=0.0054+0.396/G33^0.3	=E$11/3.2		
	manifold to hose	1	6	=D34/C34*12	=$E$15*0.1337/(PI()*C34^2/4)*12^2/60	=F34*C34/12/$E$8	=0.0054+0.396/G34^0.3	=H34*E34*$E$7*62.4/2*F34^2/32.2/12^2		
	elbow	0.5		45	=$E$15*0.1337/(PI()*C35^2/4)*12^2/60	=F35*C35/12/$E$8	=0.0054+0.396/G35^0.3	=H35*E35*$E$7*62.4/2*F35^2/32.2/12^2		
	hose	**0.5**	500	=D36/C36*12	=$E$15*0.1337/(PI()*C36^2/4)*12^2/60	=F36*C36/12/$E$8	=0.0054+0.396/G36^0.3	=H36*E36*($E$7*62.4)/2*F36^2/32.2/12^2	=SUM(I33:I36)	

Tab (3) 50% duty cycle, 10 hoses

Flow Calculations

https://energy-models.com/pipe-sizing-charts-tables
https://ntrs.nasa.gov/api/citations/19660024205/downlo

Assumptions:
1. Turbulent flow regime
2. Fluid properties

Fluid: diesel at 60 deg F	specific gravity		0.86	Schiller	Darcy-Weisbach eqn
	dyn viscosity	ft^2/s	=0.000004/0.0254^2/12^2	0.0054+0.396/R^0.3	dP=f L rho/2v^2/D
					dP = f*(L/D)(rho*v^2)/(2g)
total flow rate, gpm			20.8		
max duty cycle			0.5		
total fuel per 12 hrs		gal	=1000*ROUND(E11*12*60*E12/1000,1)		
Number of hoses			10		
hose flow rate, gpm			=E11/E14		

Reel	Part	ID , in.	Length (ft)	L/D	velocity, ft/s	Re (vD/nu)	f	dP (psi)	total P (psi)	Notes
A	filter	2			=$E$15*0.1337/(PI()*C21^2/4)*12^2/60	=F21*C21/12/$E$9	=0.0054+0.396/G21^0.3	=E$11/3.2		dP approximation from Dr. Rodgers
	manifold to hose	1	6	=D22/C22*12	=$E$15*0.1337/(PI()*C22^2/4)*12^2/60	=F22*C22/12/$E$9	=0.0054+0.396/G22^0.3	=H22*E22*$E$7*62.4/2*F22^2/32.2/12^2		
	elbow	0.5		45	=$E$15*0.1337/(PI()*C23^2/4)*12^2/60	=F23*C23/12/$E$9	=0.0054+0.396/G23^0.3	=H23*E23*$E$7*62.4/2*F23^2/32.2/12^2		
	hose	**0.75**	250	=D24/C24*12	=$E$15*0.1337/(PI()*C24^2/4)*12^2/60	=F24*C24/12/$E$9	=0.0054+0.396/G24^0.3	=H24*E24*($E$7*62.4)/2*F24^2/32.2/12^2	=SUM(I21:I24)	
B	filter	2			=$E$15*0.1337/(PI()*C27^2/4)*12^2/60	=F27*C27/12/$E$9	=0.0054+0.396/G27^0.3	=E$11/3.2		
	manifold to hose	1	6	=D28/C28*12	=$E$15*0.1337/(PI()*C28^2/4)*12^2/60	=F28*C28/12/$E$9	=0.0054+0.396/G28^0.3	=H28*E28*$E$7*62.4/2*F28^2/32.2/12^2		
	elbow	0.5		45	=$E$15*0.1337/(PI()*C29^2/4)*12^2/60	=F29*C29/12/$E$9	=0.0054+0.396/G29^0.3	=H29*E29*$E$7*62.4/2*F29^2/32.2/12^2		
	hose	**0.5**	450	=D30/C30*12	=$E$15*0.1337/(PI()*C30^2/4)*12^2/60	=F30*C30/12/$E$9	=0.0054+0.396/G30^0.3	=H30*E30*($E$7*62.4)/2*F30^2/32.2/12^2	=SUM(I27:I30)	
C	filter	2			=$E$15*0.1337/(PI()*C33^2/4)*12^2/60	=F33*C33/12/$E$9	=0.0054+0.396/G33^0.3	=E$11/3.2		
	manifold to hose	1	6	=D34/C34*12	=$E$15*0.1337/(PI()*C34^2/4)*12^2/60	=F34*C34/12/$E$9	=0.0054+0.396/G34^0.3	=H34*E34*$E$7*62.4/2*F34^2/32.2/12^2		
	elbow	0.5		45	=$E$15*0.1337/(PI()*C35^2/4)*12^2/60	=F35*C35/12/$E$9	=0.0054+0.396/G35^0.3	=H35*E35*$E$7*62.4/2*F35^2/32.2/12^2		
	hose	**0.5**	500	=D36/C36*12	=$E$15*0.1337/(PI()*C36^2/4)*12^2/60	=F36*C36/12/$E$9	=0.0054+0.396/G36^0.3	=H36*E36*($E$7*62.4)/2*F36^2/32.2/12^2	=SUM(I33:I36)	

Tab (4) 75% duty cycle, 6 hose

Flow Calculations

https://energy-models.com/pipe-sizing-charts-tables
https://ntrs.nasa.gov/api/citations/19660024205/dowl

Assumptions:
1. Turbulent flow regime
2. Fluid properties

Fluid: diesel at 60 deg F	specific gravity		0.86	Schiller	Darcy-Weisbach eqn
	dyn viscosity	ft^2/s	=0.000004/0.0254^2/12^2	0.0054+0.396/R^0.3	dP=f L rho/2v^2/D
					dP = f*(L/D)(rho*v^2)/(2g)
total flow rate, gpm			13.8		
max duty cycle			0.75		
total fuel per 12 hrs		gal	=1000*ROUND(E11*12*60*E12/1000,1)		
Number of hoses			6		
hose flow rate, gpm			=E11/E14		

Reel	Part	ID , in.	Length (ft)	L/D	velocity, ft/s	Re (vD/nu)	f	dP (psi)	total P (psi)	Notes
A	filter	2			=$E$15*0.1337/(PI()*C21^2/4)*12^2/60	=F21*C21/12/$E$8	=0.0054+0.396/G21^0.3	=E$11/3.2		dP approximation from Dr. Rodgers
	manifold to hose	1	6	=D22/C22*12	=$E$15*0.1337/(PI()*C22^2/4)*12^2/60	=F22*C22/12/$E$8	=0.0054+0.396/G22^0.3	=H22*E22*$E$7*62.4/2*F22^2/32.2/12^2		
	elbow	0.5		45	=$E$15*0.1337/(PI()*C23^2/4)*12^2/60	=F23*C23/12/$E$8	=0.0054+0.396/G23^0.3	=H23*E23*$E$7*62.4/2*F23^2/32.2/12^2		
	hose	**0.75**	250	=D24/C24*12	=$E$15*0.1337/(PI()*C24^2/4)*12^2/60	=F24*C24/12/$E$8	=0.0054+0.396/G24^0.3	=H24*E24*(($E$7*62.4)/2*F24^2/32.2/12^2	=SUM(I21:I24)	
B	filter	2			=$E$15*0.1337/(PI()*C27^2/4)*12^2/60	=F27*C27/12/$E$8	=0.0054+0.396/G27^0.3	=E$11/3.2		
	manifold to hose	1	6	=D28/C28*12	=$E$15*0.1337/(PI()*C28^2/4)*12^2/60	=F28*C28/12/$E$8	=0.0054+0.396/G28^0.3	=H28*E28*$E$7*62.4/2*F28^2/32.2/12^2		
	elbow	0.5		45	=$E$15*0.1337/(PI()*C29^2/4)*12^2/60	=F29*C29/12/$E$8	=0.0054+0.396/G29^0.3	=H29*E29*$E$7*62.4/2*F29^2/32.2/12^2		
	hose	**0.5**	450	=D30/C30*12	=$E$15*0.1337/(PI()*C30^2/4)*12^2/60	=F30*C30/12/$E$8	=0.0054+0.396/G30^0.3	=H30*E30*(($E$7*62.4)/2*F30^2/32.2/12^2	=SUM(I27:I30)	
C	filter	2			=$E$15*0.1337/(PI()*C33^2/4)*12^2/60	=F33*C33/12/$E$8	=0.0054+0.396/G33^0.3	=E$11/3.2		
	manifold to hose	1	6	=D34/C34*12	=$E$15*0.1337/(PI()*C34^2/4)*12^2/60	=F34*C34/12/$E$8	=0.0054+0.396/G34^0.3	=H34*E34*$E$7*62.4/2*F34^2/32.2/12^2		
	elbow	0.5		45	=$E$15*0.1337/(PI()*C35^2/4)*12^2/60	=F35*C35/12/$E$8	=0.0054+0.396/G35^0.3	=H35*E35*$E$7*62.4/2*F35^2/32.2/12^2		
	hose	**0.5**	500	=D36/C36*12	=$E$15*0.1337/(PI()*C36^2/4)*12^2/60	=F35*C36/12/$E$8	=0.0054+0.396/G36^0.3	=H36*E36*(($E$7*62.4)/2*F36^2/32.2/12^2	=SUM(I33:I36)	

Tab (6) 75% duty cycle, 7 hose

Flow Calculations

https://energy-models.com/pipe-sizing-charts-tables
https://ntrs.nasa.gov/api/citations/19660024205/dow

Assumptions:
1. Turbulent flow regime
2. Fluid properties

Fluid: diesel at 60 deg F	specific gravity		0.86	Schiller	Darcy-Weisbach eqn
	dyn viscosity	ft^2/s	=0.000004/0.0254^2/12^2	0.0054+0.396/R^0.3	dP=f L rho/2v^2/D
					dP = f*(L/D)(rho*v^2)/(2g)
total flow rate, gpm			13.8		
max duty cycle			0.75		
total fuel per 12 hrs		gal	=1000*ROUND(E11*12*60*E12/1000,1)		
Number of hoses			7		
hose flow rate, gpm			=E11/E14		

Reel	Part	ID , in.	Length (ft)	L/D	velocity, ft/s	Re (vD/nu)	f	dP (psi)	total P (psi)	Notes
A	filter	2			=$E$15*0.1337/(PI()*C21^2/4)*12^2/60	=F21*C21/12/$E$8	=0.0054+0.396/G21^0.3	=E$11/3.2		dP approximation from Dr. Rodgers
	manifold to hose	1	6	=D22/C22*12	=$E$15*0.1337/(PI()*C22^2/4)*12^2/60	=F22*C22/12/$E$8	=0.0054+0.396/G22^0.3	=H22*E22*$E$7*62.4/2*F22^2/32.2/12^2		
	elbow	0.5		45	=$E$15*0.1337/(PI()*C23^2/4)*12^2/60	=F23*C23/12/$E$8	=0.0054+0.396/G23^0.3	=H23*E23*$E$7*62.4/2*F23^2/32.2/12^2		
	hose	**0.75**	250	=D24/C24*12	=$E$15*0.1337/(PI()*C24^2/4)*12^2/60	=F24*C24/12/$E$8	=0.0054+0.396/G24^0.3	=H24*E24*(($E$7*62.4)/2*F24^2/32.2/12^2	=SUM(I21:I24)	
B	filter	2			=$E$15*0.1337/(PI()*C27^2/4)*12^2/60	=F27*C27/12/$E$8	=0.0054+0.396/G27^0.3	=E$11/3.2		
	manifold to hose	1	6	=D28/C28*12	=$E$15*0.1337/(PI()*C28^2/4)*12^2/60	=F28*C28/12/$E$8	=0.0054+0.396/G28^0.3	=H28*E28*$E$7*62.4/2*F28^2/32.2/12^2		
	elbow	0.5		45	=$E$15*0.1337/(PI()*C29^2/4)*12^2/60	=F29*C29/12/$E$8	=0.0054+0.396/G29^0.3	=H29*E29*$E$7*62.4/2*F29^2/32.2/12^2		
	hose	**0.5**	450	=D30/C30*12	=$E$15*0.1337/(PI()*C30^2/4)*12^2/60	=F30*C30/12/$E$8	=0.0054+0.396/G30^0.3	=H30*E30*(($E$7*62.4)/2*F30^2/32.2/12^2	=SUM(I27:I30)	
C	filter	2			=$E$15*0.1337/(PI()*C33^2/4)*12^2/60	=F33*C33/12/$E$8	=0.0054+0.396/G33^0.3	=E$11/3.2		
	manifold to hose	1	6	=D34/C34*12	=$E$15*0.1337/(PI()*C34^2/4)*12^2/60	=F34*C34/12/$E$8	=0.0054+0.396/G34^0.3	=H34*E34*$E$7*62.4/2*F34^2/32.2/12^2		
	elbow	0.5		45	=$E$15*0.1337/(PI()*C35^2/4)*12^2/60	=F35*C35/12/$E$8	=0.0054+0.396/G35^0.3	=H35*E35*$E$7*62.4/2*F35^2/32.2/12^2		
	hose	**0.5**	500	=D36/C36*12	=$E$15*0.1337/(PI()*C36^2/4)*12^2/60	=F36*C36/12/$E$8	=0.0054+0.396/G36^0.3	=H36*E36*(($E$7*62.4)/2*F36^2/32.2/12^2	=SUM(I33:I36)	

Tab (6) 90% duty cycle, 5 hose

Flow Calculations

https://energy-models.com/pipe-sizing-char
https://ntrs.nasa.gov/api/citations/19960002

Assumptions:
1. Turbulent flow regime
2. Fluid properties

Fluid: diesel at 60 deg F	specific gravity		0.88	Schiller	Darcy-Weisbach eqn
	dyn viscosity	ft^2/s	=0.000004/0.0254^2/12^2	0.0054+0.396/R^0.3	dP=fL rho/2v^2/D
					dP = f*(L/D)(rho*v^2)/(2g)
total flow rate, gpm			11.5		
max duty cycle			0.9		
total fuel per 12 hrs		gal	=1000*ROUND(E11*12*60*E12/1000,1)		
Number of hoses			7		
hose flow rate, gpm			=E11/E14		

Reel	Part	ID , in.	Length (ft)	L/D	velocity, ft/s	Re (vD/nu)	f	dP (psi)	total P (psi)	Notes
A	filter	2			=$E$15*0.1337/(PI()*C21^2/4)*12^2/60	=F21*C21/12/$E$8	=0.0054+0.396/G21^0.3	=E$11/3.2		dP approximation from Dr. Rodgers
	manifold to hose	1	6	=D22/C22*12	=$E$15*0.1337/(PI()*C22^2/4)*12^2/60	=F22*C22/12/$E$8	=0.0054+0.396/G22^0.3	=H22*E22*$E$7*62.4/2*F22^2/32.2/12^2		
	elbow	0.5		45	=$E$15*0.1337/(PI()*C23^2/4)*12^2/60	=F23*C23/12/$E$8	=0.0054+0.396/G23^0.3	=H23*E23*$E$7*62.4/2*F23^2/32.2/12^2		
	hose	**0.75**	250	=D24/C24*12	=$E$15*0.1337/(PI()*C24^2/4)*12^2/60	=F24*C24/12/$E$8	=0.0054+0.396/G24^0.3	=H24*E24*($E$7*62.4)/2*F24^2/32.2/12^2	=SUM(I21:I24)	
B	filter	2			=$E$15*0.1337/(PI()*C27^2/4)*12^2/60	=F27*C27/12/$E$8	=0.0054+0.396/G27^0.3	=E$11/3.2		
	manifold to hose	1	6	=D28/C28*12	=$E$15*0.1337/(PI()*C28^2/4)*12^2/60	=F28*C28/12/$E$8	=0.0054+0.396/G28^0.3	=H28*E28*$E$7*62.4/2*F28^2/32.2/12^2		
	elbow	0.5		45	=$E$15*0.1337/(PI()*C29^2/4)*12^2/60	=F29*C29/12/$E$8	=0.0054+0.396/G29^0.3	=H29*E29*$E$7*62.4/2*F29^2/32.2/12^2		
	hose	**0.5**	450	=D30/C30*12	=$E$15*0.1337/(PI()*C30^2/4)*12^2/60	=F30*C30/12/$E$8	=0.0054+0.396/G30^0.3	=H30*E30*($E$7*62.4)/2*F30^2/32.2/12^2	=SUM(I27:I30)	
C	filter	2			=$E$15*0.1337/(PI()*C33^2/4)*12^2/60	=F33*C33/12/$E$8	=0.0054+0.396/G33^0.3	=E$11/3.2		
	manifold to hose	1	6	=D34/C34*12	=$E$15*0.1337/(PI()*C34^2/4)*12^2/60	=F34*C34/12/$E$8	=0.0054+0.396/G34^0.3	=H34*E34*$E$7*62.4/2*F34^2/32.2/12^2		
	elbow	0.5		45	=$E$15*0.1337/(PI()*C35^2/4)*12^2/60	=F35*C35/12/$E$8	=0.0054+0.396/G35^0.3	=H35*E35*$E$7*62.4/2*F35^2/32.2/12^2		
	hose	**0.5**	500	=D36/C36*12	=$E$15*0.1337/(PI()*C36^2/4)*12^2/60	=F36*C36/12/$E$8	=0.0054+0.396/G36^0.3	=H36*E36*($E$7*62.4)/2*F36^2/32.2/12^2	=SUM(I33:I36)	

Tab (7) 90% duty cycle, 7 hose

Flow Calculations

https://energy-models.com/pipe-sizing-chart
https://ntrs.nasa.gov/api/citations/19960002/

Assumptions:
1. Turbulent flow regime
2. Fluid properties

Fluid: diesel at 60 deg F	specific gravity		0.88	Schiller	Darcy-Weisbach eqn
	dyn viscosity	ft^2/s	=0.000004/0.0254^2/12^2	0.0054+0.396/R^0.3	dP=fL rho/2v^2/D
					dP = f*(L/D)(rho*v^2)/(2g)
total flow rate, gpm			11.5		
max duty cycle			0.9		
total fuel per 12 hrs		gal	=1000*ROUND(E11*12*60*E12/1000,1)		
Number of hoses			7		
hose flow rate, gpm			=E11/E14		

Reel	Part	ID , in.	Length (ft)	L/D	velocity, ft/s	Re (vD/nu)	f	dP (psi)	total P (psi)	Notes
A	filter	2			=$E$15*0.1337/(PI()*C21^2/4)*12^2/60	=F21*C21/12/$E$8	=0.0054+0.396/G21^0.3	=E$11/3.2		dP approximation from Dr. Rodgers
	manifold to hose	1	6	=D22/C22*12	=$E$15*0.1337/(PI()*C22^2/4)*12^2/60	=F22*C22/12/$E$8	=0.0054+0.396/G22^0.3	=H22*E22*$E$7*62.4/2*F22^2/32.2/12^2		
	elbow	0.5		45	=$E$15*0.1337/(PI()*C23^2/4)*12^2/60	=F23*C23/12/$E$8	=0.0054+0.396/G23^0.3	=H23*E23*$E$7*62.4/2*F23^2/32.2/12^2		
	hose	**0.75**	250	=D24/C24*12	=$E$15*0.1337/(PI()*C24^2/4)*12^2/60	=F24*C24/12/$E$8	=0.0054+0.396/G24^0.3	=H24*E24*|$E$7*62.4/2*F24^2/32.2/12^2	=SUM(I21:I24)	
B	filter	2			=$E$15*0.1337/(PI()*C27^2/4)*12^2/60	=F27*C27/12/$E$8	=0.0054+0.396/G27^0.3	=E$11/3.2		
	manifold to hose	1	6	=D28/C28*12	=$E$15*0.1337/(PI()*C28^2/4)*12^2/60	=F28*C28/12/$E$8	=0.0054+0.396/G28^0.3	=H28*E28*$E$7*62.4/2*F28^2/32.2/12^2		
	elbow	0.5		45	=$E$15*0.1337/(PI()*C29^2/4)*12^2/60	=F29*C29/12/$E$8	=0.0054+0.396/G29^0.3	=H29*E29*$E$7*62.4/2*F29^2/32.2/12^2		
	hose	**0.5**	450	=D30/C30*12	=$E$15*0.1337/(PI()*C30^2/4)*12^2/60	=F30*C30/12/$E$8	=0.0054+0.396/G30^0.3	=H30*E30*|$E$7*62.4/2*F30^2/32.2/12^2	=SUM(I27:I30)	
C	filter	2			=$E$15*0.1337/(PI()*C33^2/4)*12^2/60	=F33*C33/12/$E$8	=0.0054+0.396/G33^0.3	=E$11/3.2		
	manifold to hose	1	6	=D34/C34*12	=$E$15*0.1337/(PI()*C34^2/4)*12^2/60	=F34*C34/12/$E$8	=0.0054+0.396/G34^0.3	=H34*E34*$E$7*62.4/2*F34^2/32.2/12^2		
	elbow	0.5		45	=$E$15*0.1337/(PI()*C35^2/4)*12^2/60	=F35*C35/12/$E$8	=0.0054+0.396/G35^0.3	=H35*E35*$E$7*62.4/2*F35^2/32.2/12^2		
	hose	**0.5**	500	=D36/C36*12	=$E$15*0.1337/(PI()*C36^2/4)*12^2/60	=F36*C36/12/$E$8	=0.0054+0.396/G36^0.3	=H36*E36*|$E$7*62.4/2*F36^2/32.2/12^2	=SUM(I33:I36)	