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Review Article

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LP Fracturing: a review on waterless fracturing technology in unconventional reservoir

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Abstract Hydraulic fracturing is the method used for the stimulation of unconventional reservoirs. This method uses large quantities of water with proppants and other chemicals. Hydraulic fracturing can cause severe problems with formation even after creating fracture for production such as clay swelling, water clogging, environmental issues also happen due to discharge of large quantities of water with chemicals. Because of these issues and economic constraints new technology is being developed which is waterless fracturing methods.In this review paper we considered liquid propane and gathered various advantageous properties of liquid propane from various literature reviews.

Keywords Liquid Propane, Unconventional reservoirs, Fracturing techniques, waterless fracturing

Introduction

Unconventional reservoirs provide the world's energy demand. Shale gas reservoirs are internationally recognized as an important unconventional resource. The shale reservoir is considered unconventional due to the ultra-low permeability and low porosity which reasons a negative impact on the economic production of fossil fuels. Due to its ultra-low permeability, it effectively affects the migration of reservoir fluids, so there are stimulation methods such as fracturing is done to effectively increase the permeability in unconventional tight reservoirs. Currently, hydraulic fracturing is the technique used for the stimulation of reservoirs. The method of hydraulic fracturing is being applied for the development of reservoirs that have the permeability of micro-and nano-Darcy. Hydraulic fracturing involves injecting highly pressurized fracturing fluids (water with chemical additives) at specific flow rates into the formation creating fractures.

More than 90% of gas wells and 70% of oil wells drilled in recent years have been hydraulically fractured. Hydraulic fracturing is typically comprised of 98–99% water and proppant, with 1–2% chemical additives [1]. The dependence on hydraulic fracturing has demerits such as the water used for the fracturing can cause formation damage mainly clay swelling in shale reservoirs which can cause effective permeability reduction at pore throats. Another reason is the requirement of huge quantities of water which causes stress on local water resources. The typical amount of water used for hydraulic fracturing is 4 million gallons per well. The third reason is the impact on the environment due to the hydraulic fracturing method that uses numerous chemicals which can cause many disastrous impacts on freshwater resources and the environment.

During the past several decades some waterless fracturing methods were tested and developed both in laboratories and in fields, some of the waterless fracturing methods include explosive and propellant fracturing, oil-based and CO_2 energized oil fracturing, gelled alcohol, and LPG fracturing, gas fracturing, cryogenic fracturing using liquid nitrogen (LN_2) and liquid/supercritical CO_2 fracturing [2].

Liquid Propane fracturing- waterless fracturing technology

LPG fracturing is a method in which propane is made into a gel and it is injected into the formation in order to fracture the formation and transport the proppant to the fracture (figure 1). The propane fracturing technique is a green technology which neither uses water or other chemicals that are used in traditional hydraulic fracturing [3]. Propane based gel has low viscosity and low surface tension compared to water [4]. The gelled propane is injected into the formation in the liquid state, the high injection pressure causes the occurrence of micro-fractures within the formation. After the creation of sufficient fracture length and evenly distribution of proppants within the fractures due to decrease in pressure and increase in temperature the gelled propane turns back into vapor and move to the surface through given tubing. That technique was developed and applied for conventional reservoirs but after a detailed study of properties, it's been applied to unconventional reservoirs. LPG fracturing is considered as a rare method in the industry which can deliver good benefits in both economic and environmental consideration. For formation temperatures, up to 96°C propane can be injected but if the temperature of the formation is more, then it is mixed with butane to do the fracturing.

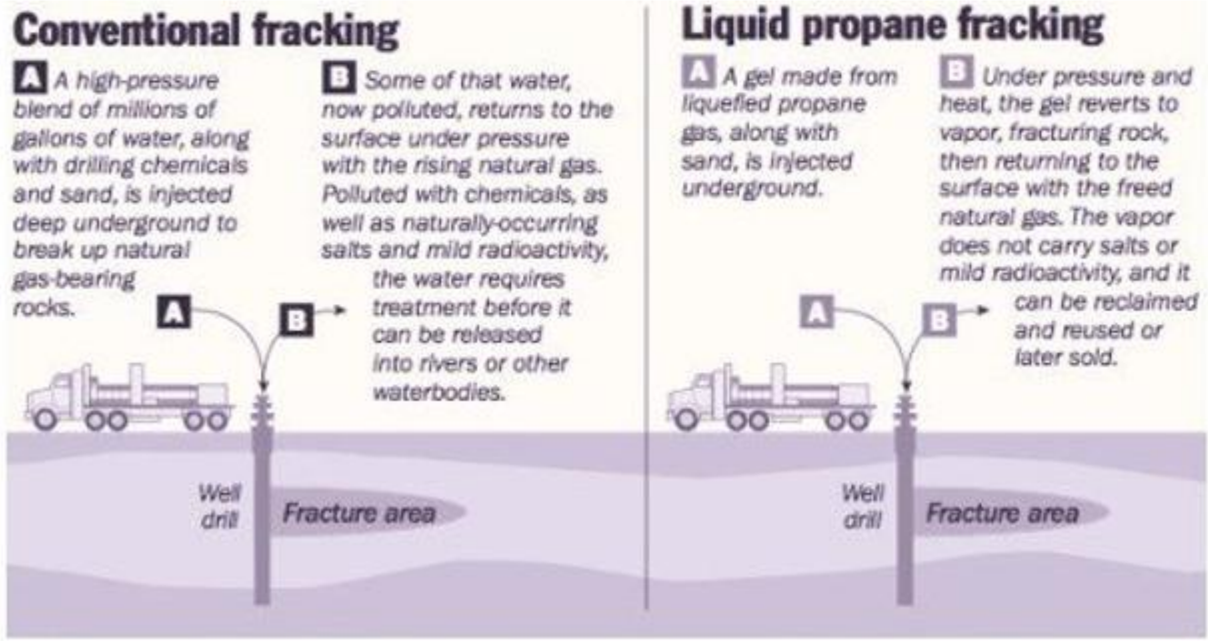

Figure 1: Hydraulic fracturing and liquid propane fracturing representation

The main advantage of LPG fracturing is that it can be used in a low permeable reservoir which helps in consistent enhancement of well productivity, because in hydraulic fracturing many problems may occur later on in life. Normally the LPG gas from the well is flared due to the limitations in storing capacity at surface facilities which also causes GHG during flaring, consumption of these LPG gas can be beneficial. LPG also has a predictable and consistent viscosity which makes it a better carrier of proppants to formations and propane liquid has specific gravity half of water which makes it easier to be transported to fracturing sites compared to traditional fracturing with base fluid as water. Besides LPG is less reactive to the formation which minimizes formation damage and less likely to mobilize any constituents from the formation.

Table 1: Comparison of properties LPG vs. Water

Performance	Water	LPG
Viscosity	0.66mPa	0.08 mPa
Relative density	1.02	0.51
Surface tension	72×10-8N/cm	7.6×10-8N/cm
Reaction possibility in clay / salt	Yes	No

Various properties of LPG fracturing

LPG must be preserved in the liquid state throughout the fracturing process so that it can be efficient in carrying proppant. LPG vapor and liquid phases are in the 100 % propane liquid-vapor saturation. Above saturation line propane exist as a liquid, so the minimum storing pressure is 125 psi and temperature required is 70 ^{o}C. Figure 2 shows the phases of propane under different temperature and pressure.

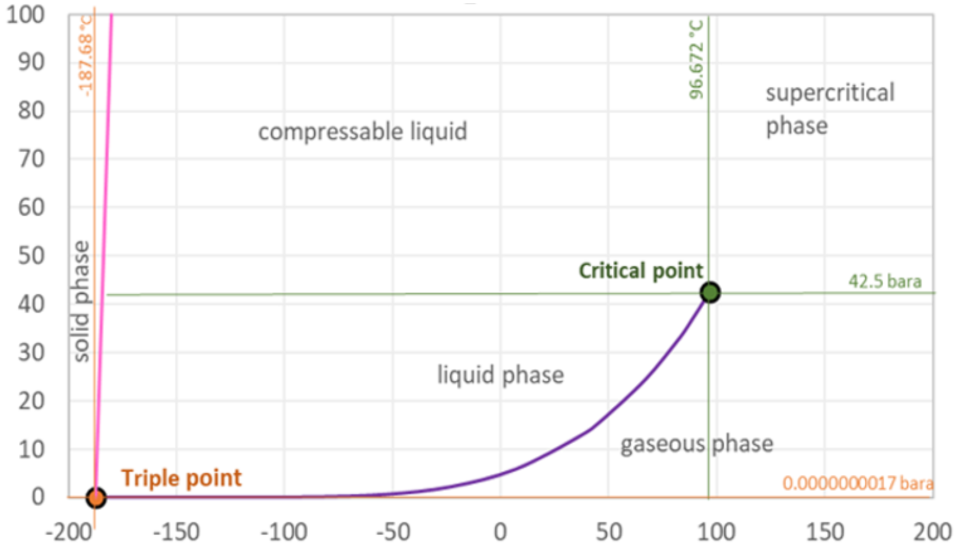

Figure 2: Propane phase diagram (pressure Vs. Temperature)

The density of propane liquid is 0.493 g/cm³ at 25 °C (77 °F). Liquefaction of LPG is done under pressure of 177 psi at 37.8°C (100°F). Density of liquid propane is marginally less than 60% that of water at -40°C. Figure 2 shows the viscosity of the methanol fluid (40%), water, propane, and butane in various temperature ranges. Compared with other fluids, propane and butane are both at a lower level, especially in a lower temperature environment (0.0~50°C). The viscosity of LPG is lower than that of water and 40% methanol fluid. The fracture creation and proppant carrying capacity may be affected by the viscosity of the fracturing fluid. Lower viscosity, density and surface tension of the fluid, which helps in lesser energy consumption during the process [5].

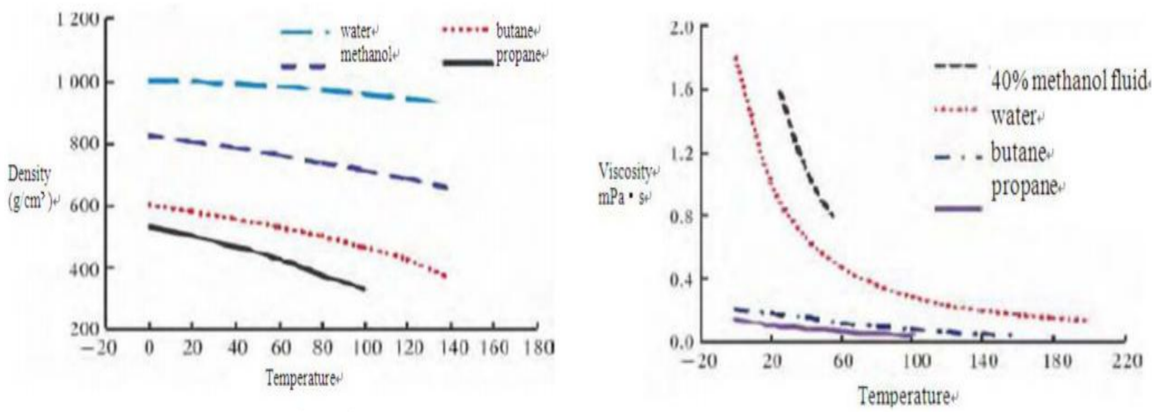

Figure 3a, b: Densities and Viscosities of various fluids

Fracture length

Soni [6] explained that intraditional water fracturing, the long fracture length is limited due to blockage and clay swelling caused by water in pores but in LPG fracturing the propped fracture length is almost equal to the effective fracture length. Effective fracture length is more which means a higher amount of hydrocarbons can be mobilized compared to traditional fracturing. The comparison of effective fracture length in LPG and hydraulic fracturing is shown in figure 4.

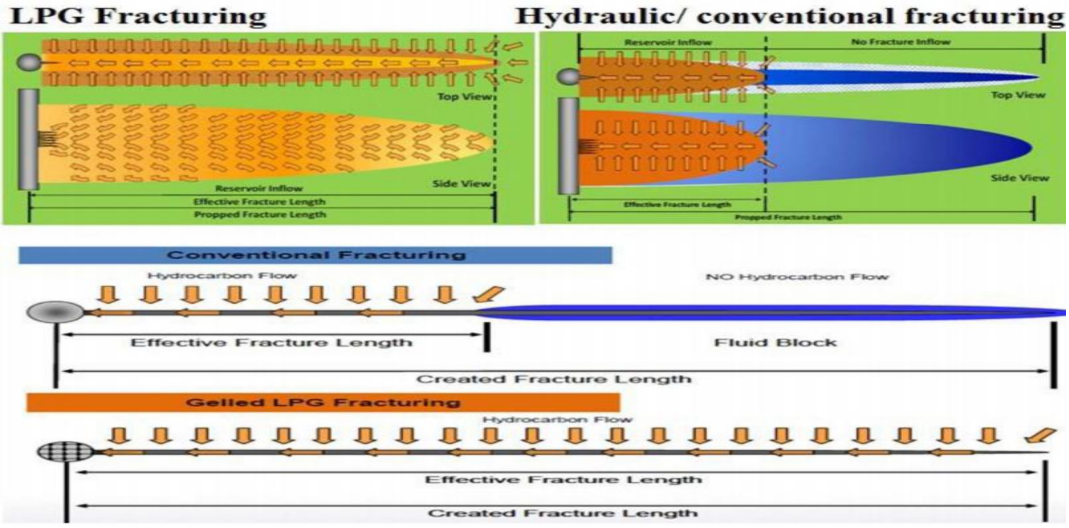

Figure 4: Comparison of effective fracture length in LPG and hydraulic fracturing

Fluid recovery

The clean-up of fracturing fluid depends upon the surface tension of fluid from the vertical length of tubing to the wellhead. The fluid from formation to wellbore the low surface tension of LPG reduces the pressure needed to mobilize the fluid. Specific-gravity of liquid propane is half that of water hence, better cleanup is achieved with gas fracturing [7]. LPG flow back is economically viable that it can be sold or it can be reused again through separator for separation of LPG from the mixture. When LPG is not desirable, it can be flared but it produces GHG emissions. The recovery of fracturing fluid can be measured using gas chromatography. It has been practically found that 90% of fluid has been recovered during application [7].

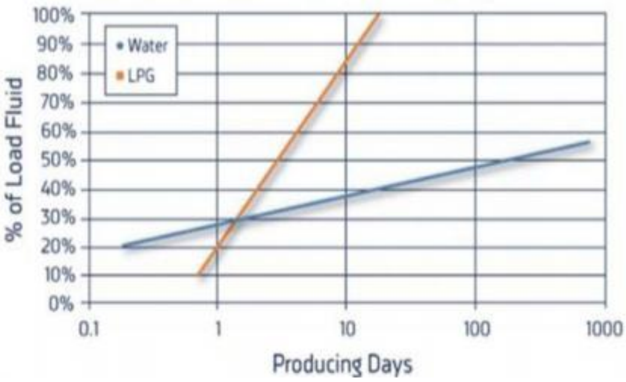

Figure 5: Comparison of fracture fluid recovery LPG and hydraulic fracturing

Proppant settling

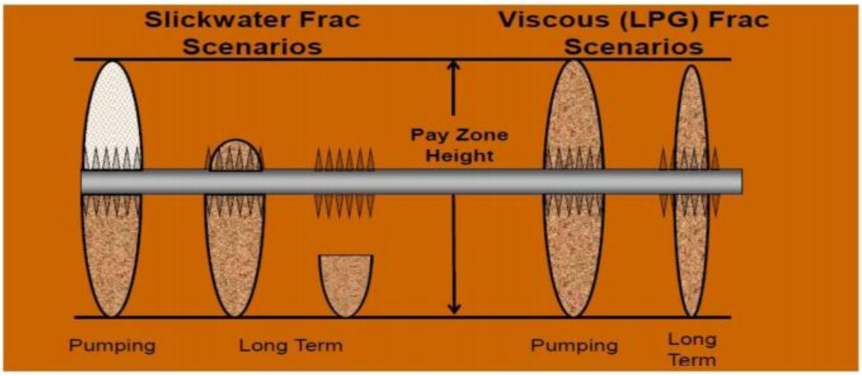

Figure 6: Proppant settling comparison

In liquid propane fracturing, the proppant gets settled properly compared to water fracturing. In hydraulic fracturing cross-linkers and linear gels are used to mitigate issues that occur during proppant settling. Due to the various properties of propane liquid, it can handle the proppant in suspended form and it can effectively transport the proppant into the fracture. As shown in figure 6 the proppant settling in LP fracturing is more effective than in water fracturing. In LPG fracturing it is justified from the laboratory and field examples that the proppants get properly settled compared to water fracturing [3]. In LPG, the pressing pressure drop after the suspension of injection in the fracturing cycle is combined with the normally higher temperature of the reservoir to impact a difference in the actual state from fluid to gas. This doesn't influence unfavorably the relative permeability to gas through the fractures and the lattice, and it also improves the unusual progression of fluid hydrocarbons towards the production well through the reduction of their viscosity [8].

Methodology- Field Setup

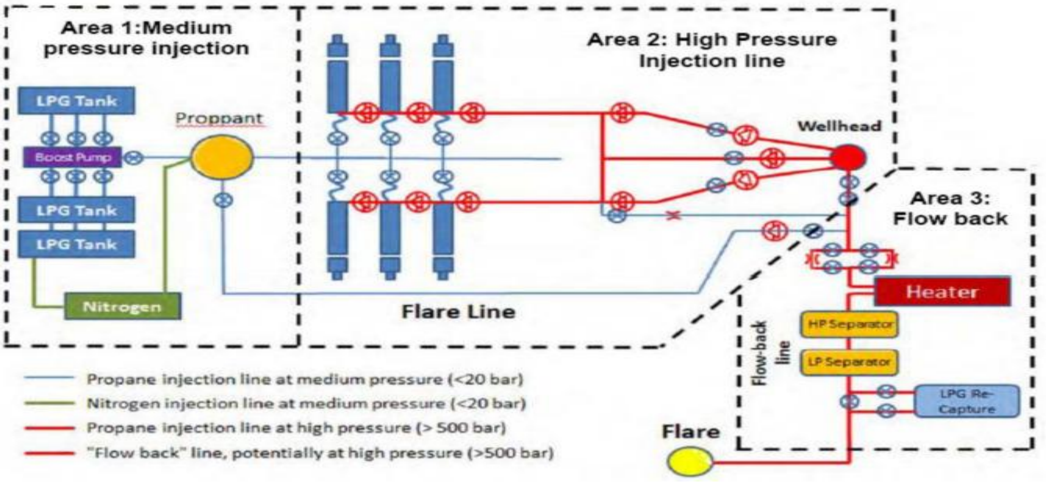

Figure 7: Propane fracturing setup

LPG fracturing system is mainly composed of a high-pressure pump, a storage system, a controller, a proppant supply source, a gelling agent supply source, and ground high-pressure pipes[3]. During the oilfield construction process, fracturing trucks are used to provide pressure to the LPG fracturing fluid, to make the down hole pressure higher than the formation breakdown pressure and create cracks. The storage system is mainly used to store LPG and inert gas (mainly nitrogen). The inert gas is used to purify LPG system components and prevent them from exploding, pushing the mixed gas from the storage tank to pipes. LPG is so dangerous that wellheads and ground pipes have to be controlled off the worksite. Operators must control the whole construction process in safe zones. The proppant supply source and the gelling agent supply source mainly provide proppants and gelling agents. Ground high-pressure pipes are used to connect every system on the ground to pumps and provide channels [5]. The sections of a propane fracturing setup as detailed below:

AREA 1- Medium pressure injection line. It consists of the LPG tanks, boost pumps, nitrogen gas feed, and proppant/proppant blender. This area is running at medium pressure.

AREA 2- Liquid propane injection line at high pressure. It covers more area than Area 1, and contains a series of high-pressure compressors and high-pressure injection line that flows to well or to the flare.

AREA 3- Recovery line/ flow back. This area processes all of the fluids produced from the well including the recovered propane liquid and the separation process. This line also serves as a blow down system.

Storage Tank: The storage tanks are used collect the Liquid propane under respective temperature and pressure and it is directed to the specialized proppant blenders. For safety purposes, nitrogen formed blanket is used for all storage tanks [9].

Proppant Blender: This is pressurized with the nitrogen to purge and proppant is preloaded. A controller is installed which measures the proppant mixed into the gelled LPG, creating LPG proppant loaded slurry to stimulate the reservoir.

Pumping Units: These are the high-pressure pumping units that pump the slurry down the hole at specified surface pressures. Propane fracking needs specialized equipment (to perform the operation under the pressures and low temperatures to keep it in a liquid state) and safety systems (as propane is flammable and in order to handle emergency situations) [9].

Lower Explosive Limit (LEL) Monitoring Array or infrared imaging is used for Leak Detection on Location. Infrared imaging easily identifies leaks too small for humans to detect and much sooner than LEL's. Infrared monitoring was used by GAS FRAC Energies Company.

Table 2: Advantages and disadvantages of LPG fracturing

Advantages of LPG fracturing	Disadvantages of LPG fracturing
1. Lower density viscosity and surface tension of the fluid helps in lower energy consumption	1. LPG is denser than air which can accumulate at lower points which may cause a threat to humans and animals
2. Only lesser amounts of chemicals are added (depending on reservoir characteristics)	2. Flaring produces CO2 emission to the atmosphere
3. Normally full compatibility with the reservoir as LPG is soluble	3. Explosive nature due to leakage in tankers, flow lines, etc.
4. No fluid loss compared to traditional fracturing which makes 100 percent recovery of injected LPG	4. It must be stored in a pressurized tank all the time which makes it costly.
5. Fast well intervention to stimulate well	5. The investment cost is higher due to the reason that after each fracturing job the gas should be liquefied again for future fracturing jobs
6. The environment-friendly and recyclable fluid makes commercially viable	
7. Till now no geologic or geochemical limitation found out with the application of this technology	
8. No need for extra handling facilities	
9. Reduced cost due to efficient and fast clean up	

Conclusion

Propane-based LPG at first can cost 20-40 percent more than water fracturing. With conventional fluids which show high capillary pressure in reservoir, liquid propane can take out phase trapping/catching. In reservoir zones under pressure, liquid propane during cleanup will lessen the hydrostatic head, increase the mobility of fracture fluid and in this way advance recuperation of the fracking liquid. For reservoirs of lower permeability that need long compelling fracture lengths to accomplish economical production, liquid propane can acquire maximum effective fracture lengths and enhanced production. When liquid propane is utilized as the fracturing fluid, there is no prerequisite to flow back & cleanup between fracturing stages. Because of 100% formation compatible multiple fracture treatments can be finished without fracture clean up between treatments. Broadened shut-ins streamline and accelerated clean up without weakness to the formation given liquid propane capability to either blend totally with NG (natural gas) causing the liquid propane to become a gas or 100% miscible into crude oils bringing about a low viscosity of oil. The best reservoir parameters for application of liquid propane fracturing are water saturation (S_w) at or below irreducible saturation. It can be applied to water sensitive formations and also formations with clay issues and fine grain reservoirs. All lithologies with reservoir temperature ranging from 60^0F to 306^0F and effective fracture length critical can be good candidate for LPG fracturing. From various literature reviews and applications in the fields, it can be established that fracturing with liquid propane can be a dependable and operative waterless technology due to the ease of availability and various properties that can increase the well productivity with very limited environmental concerns.

Reference

[1]. "Waterless fracturing technologies for unconventional reservoirs-opportunities for liquid nitrogen Lei

Wang," pp. 1–37.

[2]. K. Wilk, "Experimental and Simulation Studies of Energized Fracturing Fluid E ffi ciency in Tight Gas Formations," 2019.

[3]. N. Kumar, S. Rajput, and K. G. Gautham, "SPE-185441-MS Propane Fracturing : A Waterless Approach , Safety Considerations and Its Prospects in India Propane Fracturing / LPG Fracturing," 2017.

[4]. L. Gandossi, State of the art report on waterless stimulation techniques for shale formations. 2016.

[5]. F. Jin, Z. Shunyuan, L. Bingshan, C. Chen, C. Drilling, and M. Kedi, "SPE-185500-MS Green Fracturing Technology of Shale Gas : LPG Waterless Fracturing Technology and its Feasibility in China Main Research Routes and Outcomes," 2017.

[6]. T. M. Soni, "LPG-Based Fracturing : An Alternate Fracturing Technique in Shale," 2014.

[7]. N. Brunswick, D. Leblanc, E. Petroleum, T. Martel, D. Graves, and C. Resources, "Application of Propane (LPG) Based Hydraulic Fracturing in the McCully Gas SPE 144093 Application of Propane (LPG) Based Hydraulic Fracturing In The McCully Gas Field , New Brunswick , Canada," no. February, 2018, doi: 10.2118/144093-MS.

[8]. R. Work, "Literature Review and Analysis of Waterless Fracturing Methods," 2017.

[9]. M. A. Soomro, E. C. De Nantes, and A. S. Shaikh, "LP Gas Frack : An Energy Breakthrough," no. January 2019, 2016.