HYDRAULIC FRACTURE STIMULATION IN EXPLORATION AND PRODUCTION OF HYDROCARBONS

A Basic Overview

There is much information published about the process of hydraulic fracture stimulation (often called ‘fraccing’ or ‘fracking’) in scientific journals, industry and regulatory reports, magazines and newspapers, and on the web. Not all of the information contains the facts about the process, its history, its effects or non-effects, risks, and known environmental impacts. Nor does the information necessarily come from scientists, technicians or operators who have first-hand knowledge and field experience of well construction and hydraulic fracture stimulation. However, generally speaking, the best first ports of call for reliable information are the information brochures and publications generated by the relevant regulatory authorities[1], the oil companies and associated industry organisations, government science agencies such as the CSIRO, and universities.

So, what is hydraulic fracture stimulation and why is it done?

Hydraulic fracture stimulation of hydrocarbon reservoir rocks that have a structure and fabric rendering them relatively impermeable to the movement of gas and liquids is undertaken to increase their permeability. The target reservoirs which are particular geological formations, usually at significant depths (typically greater than 1km.) below the landsurface, and under great pressures, are fractured and cracked in such a way that the hydrocarbons (gas and liquids) can migrate from formerly isolated pores to the wellbore and then flow through the well (borehole) to the surface. If there are sufficient hydrocarbons in the reservoir formation, there may be commercial quantities of gas and/or oil recovered on the landsurface at the well-head.

Basically, hydraulic fracture stimulation is the process of generating permeability in the target formation by pumping (injecting), under pressure, water with a proppant (usually sand), which props open the fractures and cracks once they have been generated, and small quantities of chemicals (about 0.5% of the injected fluid) that facilitate the formation of fractures and cracks.

Secondly, how long has hydraulic fracture stimulation been used in the oil industry?

Hydraulic fracture stimulation has been used around the world for the last 65 years or so in more than 2 million oil wells to facilitate the release of hydrocarbons from relatively impermeable reservoir formations. The technology has naturally changed and developed

[1] Since we are located in South Australia, and we currently have a really good source of information from the regulatory compliance group in the Petroleum Division of The Department for Manufacturing, Industry, Trade, Resources and Energy (DMITRE), and there is very good information (see Link 1 the Chapter 11 FAQ’s) on its website.

significantly since the process was initiated (in response to declining production from formerly productive hydrocarbon reservoirs and formations). The process and its effects are continually managed, modified and improved, and monitored by the industry and its contractors and consultants, and widely scrutinised by the regulatory authorities. The outcomes, by and large, have been more focussed and effective exploration programs for hydrocarbon gases and liquids, increased production of hydrocarbons, and a low risk to the subsurface and surface environments.

It's of note that hydraulic fracture stimulation is one of the important processes used in developing geothermal energy from hot rocks at depth in the earth's crust in Australia and elsewhere. Here it facilitates the movement of water through the hot rocks between the injection and recovery wells and the generation of steam for power production.

What's the history of hydraulic fracture stimulation in South Australia?

The hydraulic facture stimulation process has been used for over 40 years to facilitate oil and gas extraction from geological formations in the deeper parts of the Cooper Basin in South Australia. There have been more than 2000 wells drilled for hydrocarbons and, since around 1970, over 700 of these have been hydraulic fracture stimulated. Unlike coal seams from which gas is extracted in eastern Australia, the primary use of hydraulic fracture stimulation in South Australia, Western Australia and Victoria has been in deep geological formations (not coal seams) 1.5 to 5 km below the surface.

What are the benefits of hydraulic fracture stimulation?

Hydraulic fracture stimulation techniques have enabled the industry world-wide to extract more gas and oil from wells than would otherwise have been possible. The average cost of production of hydrocarbons is correspondingly less than it would otherwise have been. The result is lower petrol and diesel prices, lower costs of gas for homes and businesses, and lower electricity prices for communities.

Increased production from wells, particularly as one well pad can be used for multiple wells using directional and/or horizontal drilling techniques. The industry is making use of "S" shaped drilling techniques, whereby a well bore from a well pad is deviated away from the well pad and then brought back to the vertical direction once it enters the target hydrocarbon bearing formation. This technique enables multiple wells to be drilled from the same pad and develop a much larger area 1000's of meters below the surface in the target reservoir formation. This actually means a smaller number of wells are required to meet production targets and there is correspondingly less competition for land use and less impact and disturbance on the land surface environment.

What about impacts on subsurface and surface environments?

The widely available literature, including social media and scientific discussions on professional websites such as ResearchGate and LinkedIn, however, a note of caution should be mentioned as not all sites address valid concerns, nor reference the full factual evidence about hydraulic fraccing or fracking. Some of the genuine concerns about the possible impacts of hydraulic fracture stimulation include:

- compromised integrity of well bores that could enable hydrocarbons or the components of fraccing fluids to leak out into groundwater aquifers that supply communities with water, or even degrade the quality of surface waters;
- the potential for initiation of earthquakes or other forms of seismic activity which could compromise the integrity of the hydrocarbon well, disturb or degrade groundwater aquifers, or cause destruction at the landsurface; and
- land use competition, particularly in prime agricultural areas and in or near populated community environments.

What can be verified about the complex issue of hydraulic fracture stimulation?

A. *Integrity of the well bore*
- Exploration and production wells are drilled from the landsurface to considerable depth (1.5 to 5 km below the surface) through rock layers to access the target formation containing hydrocarbons. The drillhole traverses a variety of materials, including soil and weathered rock near the landsurface, consolidated rock layers at greater depths, and one or more zones in which groundwaters are concentrated (aquifers). Drilling is carried out in such a way that the soil and rock materials, as well as water, in these various horizons are not mixed nor allowed to leak into the borehole.
- Wide-ranging discussions by technical and scientific specialists on ResearchGate indicate that the drilling of a well and hydraulic fracture stimulation (‘completion’ of the well) are two independent techniques usually carried out at different times and by different technical specialist teams. Properly constructed wells ensure that the materials traversed by the drillhole (wellbore) are sealed off from one another and the drillhole by cements or grouts that bond the rock wall to the casing pipe. The usually great depth of the target formation is also a barrier to prevent hydrocarbons and fracture stimulation fluids ‘leaking upwards’ toward the surface.
- Drilling and hydraulic fracture stimulation techniques have been developed over many years by specialised companies to ensure that any risks of a breach (leak) in the integrity of boreholes are minimised. Control techniques include monitoring systems and ‘fail safe’ sensors to ensure that pressure limits are not exceeded during fracture stimulation. Each well is constructed of an assembly of steel pipes in concentric arrangement, together with cement and grout bondings, which isolate the hydrocarbon production system from the geological and hydrological formations through which it passes. Any compromise of the integrity of the well is detected

through its monitoring and shutdown systems. Potential loss of production and regulatory oversight are a strong motivation for the E&P companies to ensure that wells are constructed and operated to the highest standards.

- There have been reports of gas (methane) in groundwaters flowing from taps in some regions overseas and this has been ascribed to contamination from fracture stimulation in nearby oil wells. However, methane does occur naturally in groundwaters in some localities, especially in hydrocarbon-rich regions. Hydrocarbons can also seep naturally from deep sources to the landsurface (over millennia), and this is widely recognised[2]. Neither of these processes involves hydraulic fracture stimulation. It is difficult for fracture stimulation fluids to contaminate aquifers because gravity stops them migrating from shale gas reservoir depths, and they would have to travel up through tightly compressed strata many hundreds (or thousands) of meters to reach an aquifer.
- Prior to undertaking any drilling, all E&P companies undertake detailed studies of the subsurface geology and hydrogeology of the regions in which they may construct exploration and/or production wells. It's sound economics to be sure of the challenges and costs before committing large sums of money in E&P. Data would normally include characteristics of the rock strata and the development and distribution of groundwater aquifers, seismic data to reveal conductive and non-conductive faults and fractures, permeability, porosity and poroelasticity of the strata, and so on.

B. Earthquakes and seismic activity induced by fracture stimulation.

- There is extensive scientific literature on this subject. Small-scale seismic activity is common around surface and underground mines, and is also known in areas where hydraulic fracture stimulation has taken place, as well as in areas of oil extraction, groundwater extraction, and geothermal energy production. The vast majority of these 'induced earthquakes' (small tremors) are too small to cause any damage[3]. It appears from the scientific studies that the energy required to generate an earthquake capable of causing damage cannot be generated by the abovementioned activities. However, the detailed geological investigations that are a necessary component of the exploration for shale gas and oil ought to indicate faults and fractures in or near the target horizon that might constitute sites of potential failure under hydraulic fracture stimulation.
- There are reports of minor seismic activity following several hydraulic fracture stimulations in northern UK. Their impact (seismic activity at around 2 to 3 on the

[2] Asphaltites such as Coorongite are local examples.

[3] Dr M Palano, National Institute of Geophysics & Volcanology, Etna Observatory, Italy. ResearchGate discussion, July 2013.

Richter scale) was assessed by the respective authorities to be low to minor, non-intrusive, and of no particular threat. The hydraulic fracture stimulation was undertaken in an area previously known for active seismic activity, and as an outcome of the investigation by the regulatory authorities drilling and hydraulic fracture stimulation was allowed to continue.

C. *Concern about the chemicals used in fracture stimulation.*

- Chemicals in fracture stimulation fluids[4] constitute about 0.5% of the material injected. The rest is water and proppant (being usually sand). The chemicals include acid (the same as used in swimming pools), surfactant (isopropanol) used in glass cleaners, antiperspirants and hair colour, friction reducers (used in hair, makeup and skin products), guar gum thickener (used in icecream, baked goods, toothpaste, sauces and salad dressings), and potassium chloride clay stabiliser (used as a salt substitute in low sodium diets).
- The chemicals are used to assist in generating the cracks and fractures in the target formation, and moving the proppant into the fractures to prop them open when the pressure is released.
- According to Dr Jeremy Boak (Colorado School of Mines, August 2013) no documented case of contamination of groundwater from fracture stimulation chemicals in Pennsylvania has withstood technical scrutiny to date.

D. *Treatment and handling of contaminated 'process water'.*

- Hydraulic fracture stimulation can generate large quantities of contaminated water at the well head (used and often recycled as part of the fraccing process). It contains the chemicals used in the hydraulic fracture stimulation process as well as hydrocarbon residues from the target formation and possibly salts from deep groundwater. From the environmental perspective, this 'process' water has to be carefully contained and processed before release or use in the surface environment. The challenge of dealing with contaminated waters in the surface environment is faced by all mining companies and many industrial companies and is strongly regulated.

E. *Land Use competition*

- There is also much discussion and concern about the disturbance generated by Exploration and Production (E&P) companies as they establish surface infrastructure

[4] Dr J Boak, Colorado School of Mines, USA (ResearchGate discussion, August 2013)

and thus interfere with, and even degrade, strongly held values of agricultural and horticultural land areas.

- Early engagement and active communication and transparency about the activities, historical performance and reputation of the E&P entity, the process and potential impact on the landsurface and existing infrastructure, and the potential partnership arrangements with the local community, are vital strategies that have the best chance of leading to cooperation between the parties.
- Coupled with a robust regulatory regime (which SA is blessed with), which has transparent regulations and a well resourced and managed regulatory oversight to ensure best industry practice of drilling operations, which includes well design, drilling operations and compliance.
- Of special note in South Australia, in the North of the State (Cooper Basin), where over 2000 wells have been drilled, of which about 700 have been fracked, there are numerous cattle stations (farms). A number of these cattle stations run their cattle within the vicinity of the oil & gas operations, and have been awarded organic beef certification. During this time (over 40 years of operations of oil & gas exploration, fracking and production) there has not been any issues about both industries co-existing within the same locality.
- In the South-East of SA, over the last 30 years approximately 120 wells have been drilled, but not fracked. Similarly to the experience in the North of the State, agriculture and the oil & gas industry have happily co-existed during this time.
- If those or new wells in the South-East are fracked, the footprint of land use by the oil & gas operations will be similar to what it is now. In summary there is no reason as to why the industries cannot happily co-exist in the future.

CONCLUDING REMARKS

It is worthwhile adding a reference to the UK experience with its rigorous inquiry into fracking by the Royal Society and the Royal Academy of Engineering specifically to do a report on hydraulic fracturing and shale gas. Professor Sir Mark Walport UK Chief Scientist gave a speech predominantly focussed on Risk and Innovation in Germany in September 2014. In reference to fracking he stated

"There are really 3 science and engineering concerns about hydraulic fracturing (fracking). The first of these is: will it cause earth tremors? The second is: will you get contamination of the water table? And the third is: will there be fugitive release of the methane gas? (In other words if you leak all the gas then you lose the advantage of it as a fossil fuel). And what the science and the engineering tells you is that this is a drilling technology and no drilling technology is completely risk-free. But if it is done well, if it is engineered well, if it is governed well, then it is as safe as any other form of drilling, recognising that there is no 'free lunch', there is nothing that is completely risk-free."

In summary, in South Australia we have the tools and the knowledge and experience base for fracking to be carried out without undue concerns regarding risk.

To do a check list as set out above by Professor Sir Mark Walport,

- Is it engineered well? – the response has to be **Yes**, since the Operators are very well experienced and the current Regulator does not issue licences to poor operators, the Regulator applies a rigorous process for Licencing and Approvals for exploration (including Environmental Assesment and Approval of Environmental Objectives), retention and production activities. The Regulator also applies a Risk assessment to achieve a risk level to conform with As Low As Reasonably Practicable (ALARP).
- Is it governed well? – the response has to be a resounding **Yes** for SA. The Regulatory regime in SA is robust through the PEGA Legislation, which to date some 700 wells have been fracked without incident.
- Will it be done well? – the response again is **Yes**, as the Operators which 'pass muster' within SA must get a licence and as stated above the SA Regulator is experienced and knowledgeable in fracking, having already overseen 700 fracks in the State. Further, the Operators operating in the South-East to date have been very experienced and to date, have carried out their operations diligently and comply with the PGEA.

Then on balance, drilling and fracking in the South-East of SA is as safe as any other form of drilling.

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Sources of information & further reading

1. South Australian regulator (DMITRE)

http://www.pir.sa.gov.au/__data/assets/pdf_file/0004/178357/Chapter_11.pdf

2. AJ Lucas involved in shale oil and gas exploration in England. Annual report re fraccing:
http://www.lucas.com.au/lucas2013onlinereport/franking-conversation/

3. Royal Society report on fraccing in the UK
Independent report by the Royal Society and Institute of Engineers in the UK re shale gas production and fraccing.
http://royalsociety.org/policy/projects/shale-gas-extraction/report/

4. Cuadrilla Resources - operator in jv with AJ Lucas in the UK re Fraccing
http://www.cuadrillaresources.com/what-we-do/hydraulic-fracturing/

5. Cuadrilla re fraccing:
The operator of the joint venture which caused the two minor earthquakes near Blackpool.
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6. British Geological Survey
Report after the two earthquakes detected near Blackpool.
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7. Australian Council of Learned Academies (ACOLA) "Engineering Energy: Unconventional Gas Production A Study of Shale Gas in Australia" Final Report.
http://www.appea.com.au/wp-content/uploads/2013/07/ACOLA-Final-Report-Engineering-Energy-June-2013.pdf

8. National Research Council. "Development of Unconventional Hydrocarbon Resources in the Appalachian Basin: Workshop Summary". Washington, DC: The National Academies Press, 2014
Contains a lot of basic information on shale gas production.

http://www.nap.edu/catalog.php?record_id=18624