NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Fracturing Fluid Manufacturing

Reference Flow: 1 m^3 of Fracturing Fluid

Brief Description: This unit process quantifies water and chemical inputs used in the production of fracturing fluid.

Section I: Meta Data

Geographical Coverage: United States **Region:** N/A

Year Data Best Represents: 2008

Process Type: Manufacturing Process (MP)

Process Scope: Gate-to-Gate Process (GG)

Allocation Applied: No

Completeness: Individual Relevant Flows Recorded

Flows Aggregated in Data Set:

☐ Process ☐ Energy Use ☐ Energy P&D
☐ Material P&D

Relevant Output Flows Included in Data Set:

Releases to Air:	☐ Greenhouse Gases	☐ Criteria Air	☐ Other
Releases to Water:	☐ Inorganic	☐ Organic Emissions	☐ Other
Water Usage:	☐ Water Consumption	☐ Water Demand (throughput)	
Releases to Soil:	☐ Inorganic Releases	☐ Organic Releases	☐ Other

Adjustable Process Parameters:

Wateruse_g	*[kg/m3] Groundwater use for fracturing fluid production per m3 of fracturing fluid produced.*
Wateruse_s	*[kg/m3] Surface water use for fracturing fluid production per m3 of fracturing fluid produced.*

Friction_Reduce	*[kg/m3] Friction reducer use for fracturing fluid production per m3 of fracturing fluid produced.*
Acid	*[kg/m3] Acid use for fracturing fluid production per m3 of fracturing fluid produced.*
Biocide	*[kg/m3] Biocide use for fracturing fluid production per m3 of fracturing fluid produced.*
Corrosion_Inhib	*[kg/m3] Corrosion inhibitor use for fracturing fluid production per m3 of fracturing fluid produced.*
Fe_Control	*[kg/m3] Iron control use for fracturing fluid production per m3 of fracturing fluid produced.*
Crosslinker	*[kg/m3] Crosslinker use for fracturing fluid production per m3 of fracturing fluid produced.*
Breaker	*[kg/m3] Breaker use for fracturing fluid production per m3 of fracturing fluid produced.*
pH_Adjust_Agent	*[kg/m3] pH adjusting agent use for fracturing fluid production per m3 of fracturing fluid produced.*
Scale_Inhibit	*[kg/m3] Scale inhibitor use for fracturing fluid production per m3 of fracturing fluid produced.*
Gel_Agent	*[kg/m3] Gelling agent use for fracturing fluid production per m3 of fracturing fluid produced.*
KCL	*[kg/m3] KCL use for fracturing fluid production per m3 of fracturing fluid produced.*
Surfactant	*[kg/m3] Surfactant use for fracturing fluid production per m3 of fracturing fluid produced.*
Sand	*[kg/m3] Sand use for fracturing fluid production per m3 of fracturing fluid produced.*

Tracked Input Flows:

Water (ground water)	*[Resource]*
Water (surface water)	*[Resource]*
Friction reducer	*[Resource]*
Acid	*[Resource]*
Biocide	*[Resource]*
Corrosion inhibitor	*[Resource]*
Iron Control	*[Resource]*
Crosslinker	*[Resource]*
Breaker	*[Resource]*
pH Adjusting Agent	*[Resource]*
Scale inhibitor	*[Resource]*
Gelling Agent	*[Resource]*
KCl	*[Resource]*
Surfactant	*[Resource]*
Sand	*[Resource]*

Tracked Output Flows:

Fracturing Fluid	*Reference flow*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage1_C_Fracturing_Fluid_Manufacture_2015.01.xlsx*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

This unit process provides a summary of relevant input and output flows associated with the production of fracturing fluid. There is significant uncertainty regarding the type and volume of chemicals used in this process as mixtures will vary from region to region, and even from well to well. Inputs to this process are generalized by input type (e.g. acid, biocide, surfactant). This unit process represents the manufacturing of a generic fracturing fluid. The calculations

presented for this unit process are based on the reference flow of1 m^3 of Fracturing Fluid as described below and shown in **Figure 1**.

This unit process is used under Life Cycle (LC) Stage #1 in support of the extraction of natural gas. This unit process is combined with a separate hydraulic fracture completion unit process.

Boundary and Description

Fracturing fluid is an input to hydraulic fracturing (hydrofracking), which is used for recovering natural gas from tight reservoirs such as Barnett Shale. The majority of fracturing fluid by volume is water, which comprises 60% groundwater and 40% surface water (TWDB 2007). Sand, usually silica, and a variety of chemical additives make up the remaining volume of fracturing fluid. Chemical additives vary depending on the conditions of the well being fractured. Typical fracture treatments use low concentrations of these additive chemicals, with the number of additives usually falling between 3 and 12 chemicals. Each of these chemicals performs a specific, engineered purpose based on the well location, so there is no universal formula for the volume of each additive. It is also important to note that many of the suppliers of these additives have developed multiple compounds that perform the same function but are optimized for different well environments. For the purposes of this unit process, mass percentages of additives used in the fracturing treatment of a Marcellus Shale horizontal well (ALL 2009) were used to generate an approximate make-up of fracturing fluid. These percentages only specify the type of additive, based on its function, not the compound used. A list of compounds commonly used to perform these functions was included in the referenced document and adapted in the table below (**Table 1**). Given the broad scope of this unit process, the density of the first compound listed for each function was used in combination with the mass percentage to calculate the approximate mass of each compound input into 1 m^3 of fracturing fluid.

Table 1: Fracturing fluid additives, main compounds, and their function.

Additive Type	Main Compound(s)	Volume (m3 per m^3 of fluid produced)	Density (g/cm3)	Mass (kg)	Function
Diluted Acid (15%)	Hydrochloric acid or muriatic acid	0.115%	1.16E+00	9.93E-01	Help dissolve minerals and initiate cracks in the rock
Biocide	Glutaraldehyde	0.001%	7.20E-01	9.03E-03	Eliminates bacteria in the water that produce corrosive byproducts
Breaker	Ammonium persulfate	0.016%	1.98E+00	8.13E-02	Allows a delayed break down of the gel polymer chains
Corrosion Inhibitor	N,n-dimethyl formamide	0.009%	9.45E+00	9.03E-03	Prevents the corrosion of the pipe
Crosslinker	Borate salts	0.009%	1.71E+00	5.42E-02	Maintains fluid viscosity as temperature increases
Friction Reducer	Polyacrylamide	0.082%	1.13E+00	7.23E-01	Minimizes friction between the fluid and the pipe
	Mineral oil		8.38E-01		
Gel	Guar gum	0.018%	4.00E-01	4.52E-01	Thickens the water in order to suspend the sand
	Hydroxyethyl cellulose		6.00E-01		
Iron Control	Citric acid	0.006%	1.67E+00	3.61E-02	Prevents precipitation of metal oxides
KCl	Potassium chloride	0.089%	1.98E+00	4.52E-01	Creates a brine carrier fluid
Oxygen Scavenger	Ammonium bisulfite		2.03E+00		Removes oxygen from the water to protect the pipe from corrosion
pH Adjusting Agent	Sodium carbonate	0.025%	2.54E+00	9.93E-02	Maintains the effectiveness of other components, such as crosslinkers
	Potassium carbonate		2.29E+00		

Proppant	Silica, quartz sand	17.783%	2.20E+00	8.08E+01	Allows the fractures to remain open so the gas can escape
Scale Inhibitor	Ethylene glycol	0.040%	1.11E+00	3.61E-01	Prevents scale deposits in the pipe
Surfactant	Isopropanol	0.057%	7.85E-01	7.23E-01	Used to increase the viscosity of the fracture fluid
Note: The specific type and volume of compound used in a fracturing fluid will vary depending on company preference, source water and site-specific characteristics of the target formation. The compounds above are representative of the major compounds used in hydraulic fracturing of gas shales.					

Figure 1 provides an overview of the boundary of this unit process. As shown, groundwater and surface water inputs to the unit process are considered. However, these water sources are assumed to carry negligible environmental and energy burdens; upstream emissions and energy requirements associated with groundwater and surface water acquisition and delivery are assumed to be negligible. Within the system boundary, water, sand, and the additives listed above are the inputs in support of fracturing fluid manufacturing.

Figure 1: Unit Process Scope and Boundary

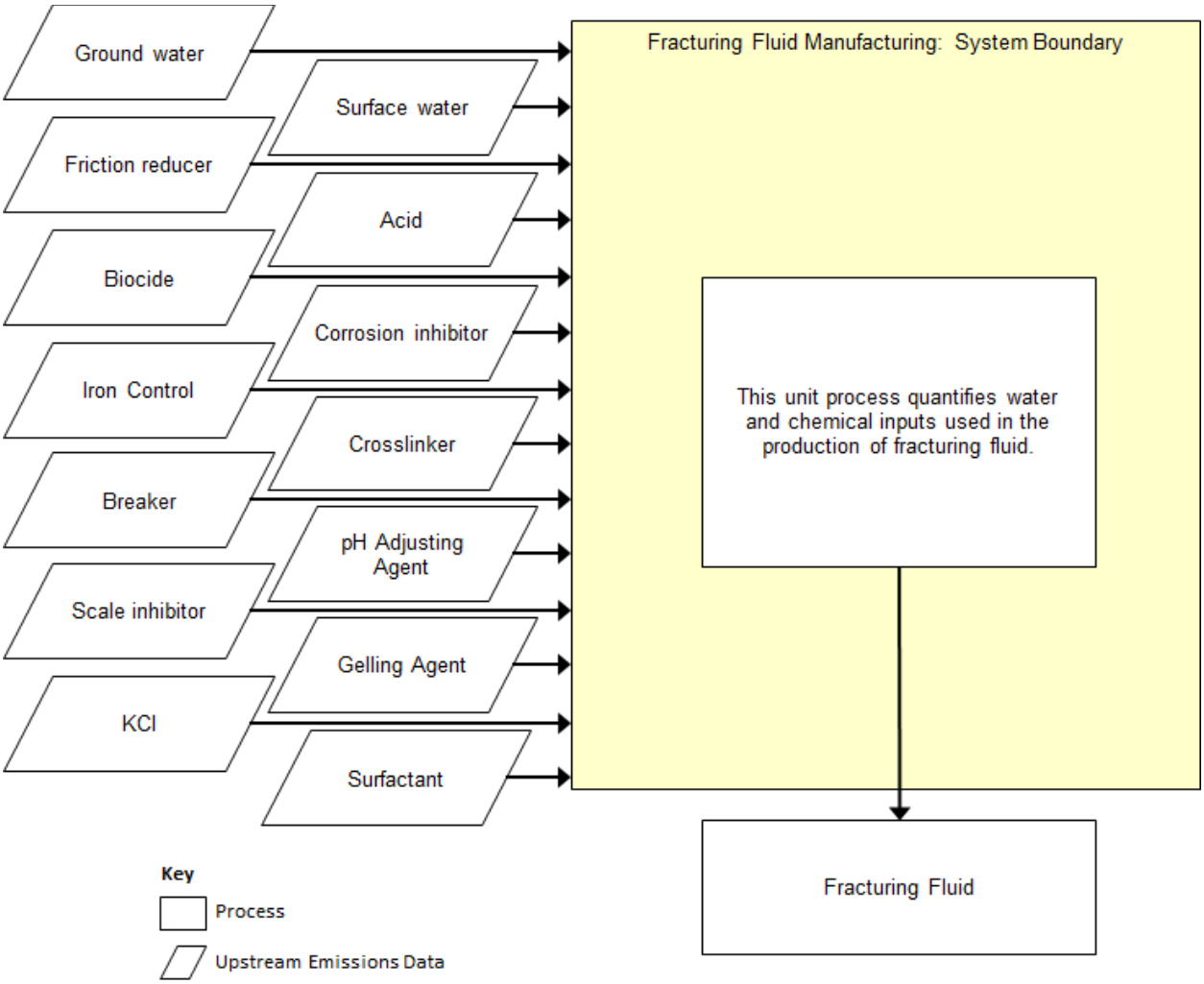

Table 2: Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Water (ground water) [Water]	4.91E+02	kg
Water (surface water) [Water]	3.27E+02	kg
Friction reducer	**7.23E-01**	**kg**
Acid	**9.93E-01**	**kg**
Biocide	**9.03E-03**	**kg**
Corrosion inhibitor	**9.03E-03**	**kg**
Iron Control	**3.61E-02**	**kg**
Crosslinker	**5.42E-02**	**kg**
Breaker	**8.13E-02**	**kg**
pH Adjusting Agent	**9.93E-02**	**kg**
Scale inhibitor	**3.61E-01**	**kg**
Gelling Agent	**4.52E-01**	**kg**
KCl	**4.52E-01**	**kg**
Surfactant	**7.23E-01**	**kg**
Sand	**8.08E+01**	**kg**
Outputs		
Fracturing Fluid	**1.00E+00**	**m^3**

* **Bold face** clarifies that the value shown *does not* include upstream environmental flows.

Embedded Unit Processes

None.

References

TWDB 2007 — Texas Water Development Board. 2007. Northern Trinity/Woodbine GAM Assessment of Groundwater Use in the Northern Trinity Aquifer Due to Urban Growth and Barnett Shale Development. http://rio.twdb.state.tx.us/RWPG/rpgm_rpts/0604830613_BarnetShale.pdf (Accessed May 14, 2010).

ALL 2009 — Ground Water Protection Council and ALL Consulting. (2009) MODERN SHALE GAS DEVELOPMENT IN THE UNITED STATES: A PRIMER. http://www.all-llc.com/publicdownloads/ShaleGasPrimer2009.pdf (Accessed 2/23/2015)

Section III: Document Control Information

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