



LPG Vantage Frac

Flow Back Guide

API v1
June 2009

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ATTACHMENT I - Propane Saturation Chart

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1.0 LPG Vantage Frac Flow Back Guide

This document provides a very general guide to assist the well operator to safely and efficiently recover LPG following a fracture treatment. LPG flow behavior properties are provided along with recommendations for equipment sizing, procedure and potential hazards. Reference the Enform document, Well Testing and Fluid Handling, Industry Recommended Practice (IRP), Volume 4 – 2007, for all practices relating to flow back and fluid handling.

The LPG utilized is typically HD5 propane containing greater than 90% propane. In some cases the HD5 propane is mixed with commercial grade butane at varying quantities. All considerations provided in this flow back guide are relevant to propane-butane mixes; however the recommended separator operating conditions will differ with butane content. Note that the terms LPG and propane are used interchangeably within this text, however unless specifically identified otherwise, all information is relevant to propane.

Suitable procedures and tankage need to be in place where hydrocarbon liquids such as formation oil, condensates or oil based workover fluids are to be recovered during flow back. In particular, always ensure that high vapor pressure hydrocarbons are not placed into atmospheric tanks.

2.0 Flow Back Equipment – Closed System

Figure 1 displays a simple schematic for a closed system flow back configuration. A closed system is recommended for all LPG frac flow backs. Actual equipment and configuration used is left to the operator as it must be based upon the specific conditions and requirements for any given application. Provide, rig-in and operate all equipment within the recommendations and practices of Well Testing and Fluid Handling, Industry Recommended Practice (IRP), Volume 4 – 2007.

When specifying flow back equipment consider the following:

- 2.1 An **Emergency Shut Down (ESD) Valve** after the well head but before the optional **Sand Catcher**.
- 2.2 A **Sand Catcher** may be required to protect the choke and line heater from recovered proppant abrasion. Note that recovered LPG fluids do not move proppant as readily as conventional fracturing fluids.
- 2.3 Placement of the **Choke** before the line heater should be considered. The LPG cools with pressure drop due to vaporization which improves line heater efficiency.
- 2.4 The **Liner Heater** is used to heat returns as required to maintain the separator temperature within the gas region. Capacity requirements are presented in Section 5.0 of this document.
- 2.5 A **Separator** with steam coils may be considered in the event LPG liquids do accumulate. To avoid LPG accumulation, maintain operating conditions within vapor region, Section 3.0 of this document.
- 2.6 Collect **ALL** liquids to a **Pressure Tank** vented to the flare. LPG may be dissolved into or entrained within collected liquids. Ensure all liquids are stabilized prior to shipping or handling.

“At no time should high vapor pressure hydrocarbon returns, including LPG, be directed to the atmosphere or non-pressure tanks.”

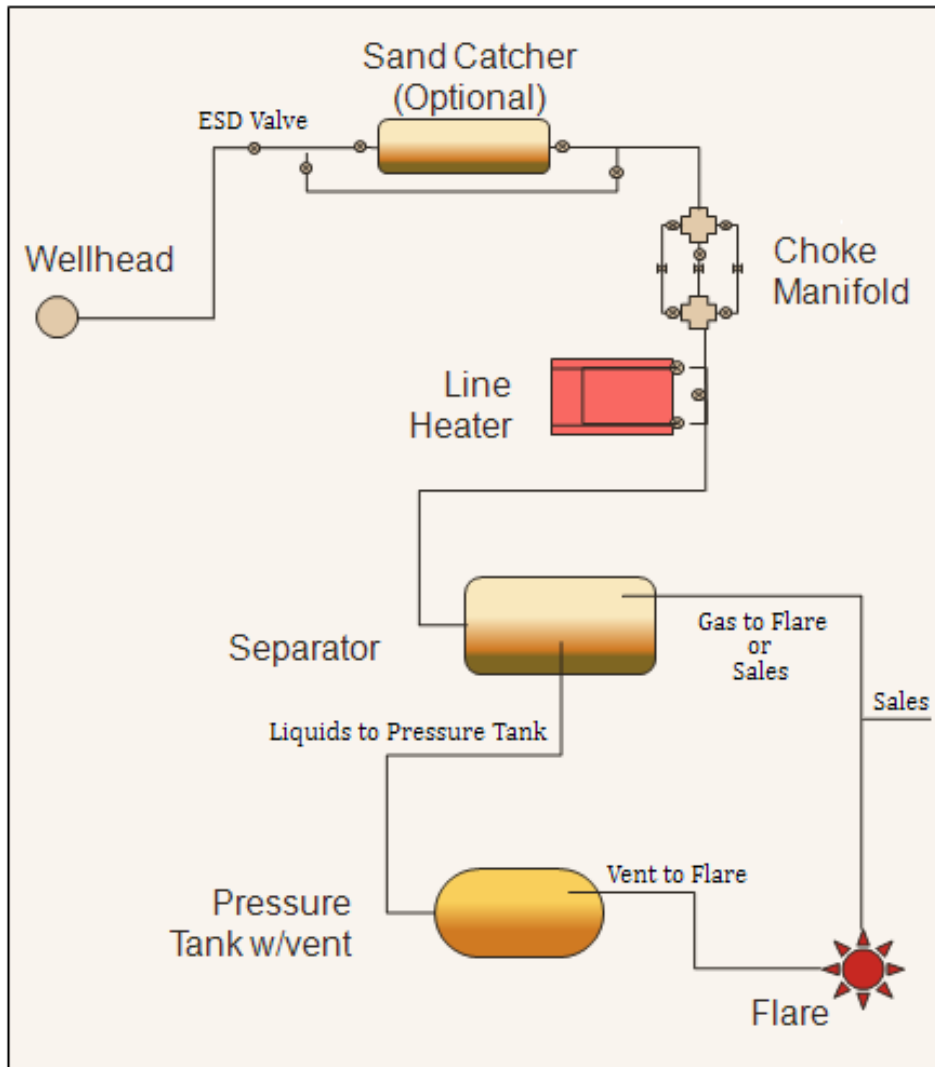


Figure 1. Closed System Flow Back Schematic

3.0 Initiating Flow and Wellbore Fluid Recovery

Initial recovery of the propane, certainly that in the wellbore, is likely to be comprised of mostly liquid propane. The intent is to flow back this liquid propane at a rate of approximately 530 gallons (12.6 barrels) liquid/hr. It is important to recognize that unless liquid propane is to be recovered to a pressurized vessel, it typically needs to be vaporized. Vaporizing propane requires considerable heat; a line heater is required to permit vaporization.

Note that the liquid propane flow needs to be brought on slowly to ensure test equipment operation is stabilized before increased flows are attempted. Particular attention needs to be paid to the separator temperatures and pressures to avoid cooling of flow equipment, potential freezing, LPG build-up in the separator and ultimately liquid LPG delivery from the separator.

Consider the following:

- 3.1 Initiate liquid recovery through a variable choke at a low choke opening. Initial choke opening is dependent upon wellhead pressure and test equipment configuration and is left to the judgment of the operator. If unsure, a smaller choke opening will ensure controlled recovery through the test equipment. Flow rates can be adjusted as equipment operating conditions stabilize and the clean up proceeds.
- 3.2 Vaporization of any LPG liquid, including propane, requires considerable heat or energy. A line heater is needed for vaporization when recovering LPG liquids. Typically a 1 - 2 MMBtu/hr line heater is used. Over specifying the needed capacity of the line heater is strongly recommended in order to ensure quick and efficient recovery. If too little heat is added prior to vaporization, the separator temperature will drop significantly and LPG liquids will accumulate. This will potentially allow liquids to the flare stack. Also, once liquids are accumulated within the separator, vaporization in separators is slow and the recovery period unnecessarily extended. As recovery proceeds, increasing quantities of reservoir fluids will be mixed with the LPG and the heat load needed for LPG vaporization will typically decrease.
- 3.3 Ensure separator pressures and temperatures are maintained well within the gas region. Separator conditions within the liquid region will result in liquid propane accumulation in the separator. Always avoid conditions that will result in propane liquids within the separator. Reference Propane Saturation Graph, Attachment I.

Example 1:

The separator is operating at a temperature of 41 °F and 102 psi. Will propane liquid accumulate in the separator?

Answer:

On the horizontal axis of the Propane Saturation Chart, find the 41 °F line. Move vertically along that line until it intersects the 102 psi line.

The intersection point is above the saturation line so that propane liquid will accumulate within the separator. Consider increasing the temperature of the flow entering the separator to at least 77 °F. Note that simply lowering the pressure in the separator will normally result in further cooling and not prove effective.

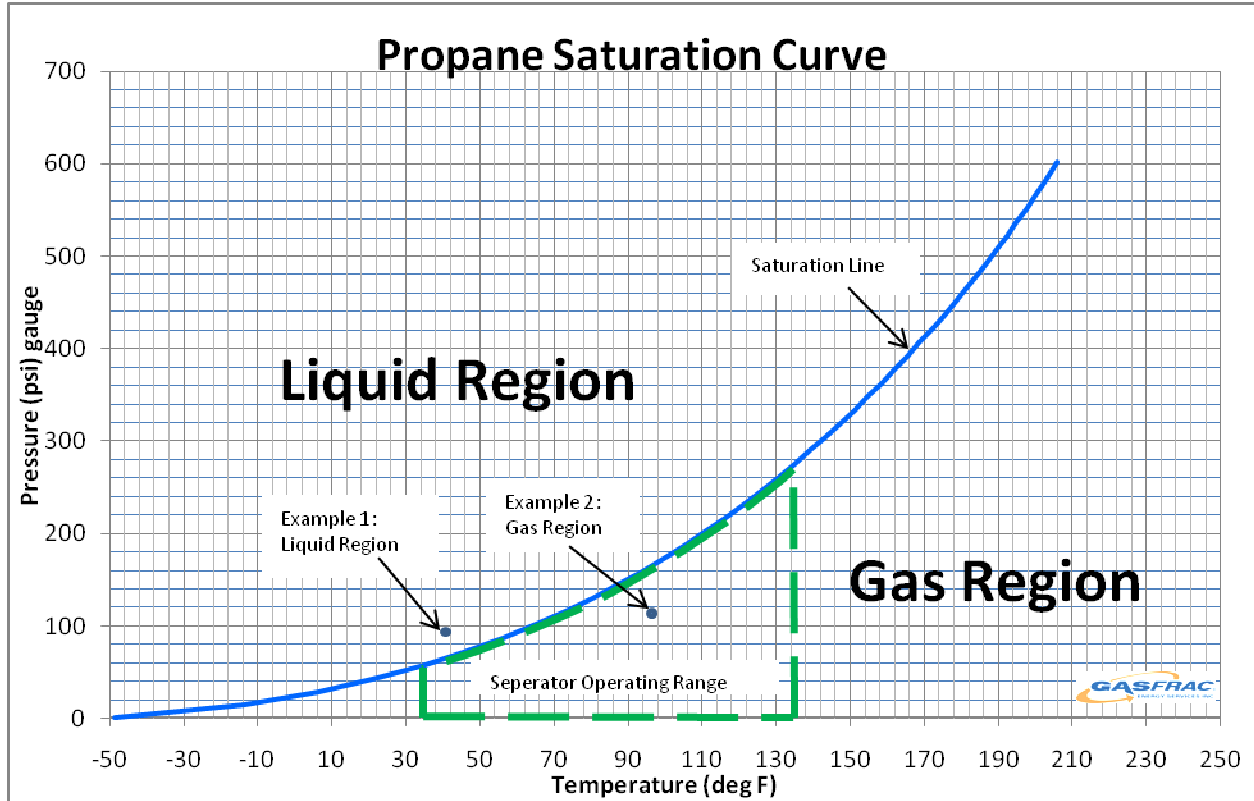
Example 2:

The separator is operating at a temperature of 95 °F and 116 psi. Will propane liquid accumulate in the separator?

Answer:

On the horizontal axis of the Propane Saturation Chart, find the 95 °F line. Move vertically along that line until it intersects the 116 psi line.

The intersection point is below the saturation line so that only propane gas will exist in the separator.



- 3.4 Manage pressure of the flow stream before and within the line heater. Placement of the choke at the wellhead may help flow conditions to stabilize prior to entering the line heater. Pressure drops after the line heater often result in vaporization with significant cooling and lower temperatures within the separator. Liquid propane accumulation may result.
- 3.5 In order to prevent freezing of accumulated water always operate the separator above 32 °F.
- 3.6 If hydrocarbon liquids are naturally produced by the reservoir, condensate or oil, ensure all liquids recovered from the separator are held in tanks suitable for the composition. Reference Well Testing and Fluid Handling, Industry Recommended Practice (IRP), Volume 4 – 2007. Pressurized tanks or a closed system should be used for flow backs, storing, producing, pumping, swabbing or killing wells with high vapor pressure hydrocarbons.

4.0 Calculating LPG Recovery

Estimating the recovered LPG is a simple process. Most often, LPG will be recovered as a vapor or gas recorded through the separator meter run.

In general the recovered LPG is determined as follows:

- 4.1 Gas flow from the separator is measured as usual with volume of gas flow recorded.
- 4.2 The content of LPG in the flow is determined through either gas chromatograph analysis or by gas density.
- 4.3 Based on LPG content of the volume of gas flow, the amount of LPG vapor is determined.
- 4.4 1 bbl of LPG liquid when vaporized creates 1530 scf of gas.
- 4.5 The LPG vapor quantity determined in 4.4 above is converted to a liquid quantity by dividing that number by the expected gas generated from the LPG at 1530 scf/bbl liquid.
- 4.6 The LPG liquid recovery for 4.5 above is then recorded and tracked as with any liquid to determine the load fluid recovery.
- 4.7 Should LPG also be recovered as a liquid in a pressurized tank, and then the calculated liquid volume from 4.6 above is added to the tank recovery volume to determine total volume recovered.

Example:

1. A frac is completed using 100 bbl of LPG. When totally vaporized the 100bbl of LPG will generate a volume of 153,000 scf of vapor or gas. If all LPG is vaporized, a cumulative LPG vapor recovery of 153,000 scf will indicate complete recovery.
2. Presuming 15 minute readings with a gas flow-meter and a gas rate of 300,000 scf/day, the gas volume for the 15 minute period is then determined at 3120 scf.

$$\begin{aligned}\text{Gas Vol} &= (300,000 \text{ scf/day}) \times (15 \text{ min}/1440 \text{ min/day}) \\ &= 3120 \text{ scf or } 3.120 \times 10^3 \text{ scf}\end{aligned}$$

3. Volumetric proportion of LPG in the flow stream is then determined at 78% over the time interval. The resulting recovery of LPG gas for the period is then 78% of the 3120 scf or 2434 scf.

$$\begin{aligned}\text{LPG Gas Vol} &= 3120 \text{ scf} \times 0.78 \\ &= 2434 \text{ scf}\end{aligned}$$

Note: Proportion of the LPG in the flow stream can be very precisely determined by a gas



chromatograph or reasonably estimated on a dry gas well by measuring the gas gravity.

4. Recognizing that 1 bbl of LPG liquid generates 1530 scf of LPG gas, the recovered LPG liquid volume for that time period is then determined at 1.59 bbl.

$$\begin{aligned} \text{LPG Liq Vol} &= (2434 \text{ scf vapor}) / (1530 \text{ scf vapor/1 bbl liquid}) \\ &= 1.59 \text{ bbl} \end{aligned}$$

5.0 Heat Requirement for LPG Vaporization

Heat for vaporization of the LPG is provided by the line heater. Additional capacity is recommended to account for variations in wellhead flowing temperature, flow rates, general heat losses and equipment inefficiencies.

Consider the following:

- 5.1 Minimum heat requirement is based on the expected LPG recovery rate and heat needed to vaporize.
- 5.2 Initial propane flow back at 528 gallons (12.57 barrels) per hour is recommended, however much higher flow back rates are applied in some instances to minimize flow back time. Accelerating flow back requires a line heater that is properly sized for the anticipated recovery rates in order to ensure complete vaporization of the LPG at all times.
- 5.3 Shutting in the well for 48 hours or more after the fracture treatment typically allows for significant mixing of the LPG with reservoir fluids. In gas reservoirs, the mixing of natural gas with LPG within the reservoir will reduce the heat requirement for vaporization. The degree of mixing achieved in the wellbore itself is difficult to predict and liquid LPG recovery from the wellbore should be anticipated.
- 5.4 Over specifying the needed capacity of the line heater is strongly recommended in order to ensure quick and efficient recovery. If too little heat is available the separator temperature will drop significantly and LPG liquids will accumulate. This will potentially allow liquids to the flare stack. Also, once liquids are within the separator, vaporization can be slow and the recovery period unnecessarily extended. Always avoid accumulation of LPG liquids in the separator.
- 5.5 As recovery proceeds, increasing quantities of reservoir gas will be recovered decreasing the heat load needed for vaporization.

Example:

At a flow back wellhead temperature of 50°F and a liquid recovery rate of 528 gallons/hour (12.5 barrels/hour), the minimum heat requirement for vaporization is determined as below.

1. Determine the energy (heat of vaporization) required to vaporize one cubic meter of propane at 50°F from Attachment II, Propane – Heat of Vaporization Volume Basis.

Enter the horizontal axis of the Propane – Heat of Vaporization chart, find the 50°F line. Move vertically along the 50°F line until it intersects the heat of vaporization curve. At the intersection move horizontally to the axis and read the value at 4965.25 Btu/ft³.

2. With a presumed flow back rate of 528 gallons/hour (12.5 barrels/hour), the heat required is 0.35 MMBtu/hr.

$$\begin{aligned}\text{Heat Req'd} &= 528 \text{ gals/hour} \times 0.1337 \text{ ft}^3/\text{gal} \\ &= 70.59 \text{ ft}^3/\text{hour} \\ &= 70.59 \text{ ft}^3/\text{hour} \times 4965.25 \text{ Btu/ft}^3 \\ &= 0.35 \text{ MMBtu/hour}\end{aligned}$$

3. Presuming recovery rates as high as 1320 gallons/hour (31.4 barrels/hour) may be desired and the well head temperature may drop as low as 41 °F during the flow, what is the heat requirement?

At 41 °F the heat of vaporization is 5153.12 Btu/ft³.

$$\begin{aligned}\text{Heat Req'd} &= 1320 \text{ gals/hour} \times 0.1337 \text{ ft}^3/\text{gal} \\ &= 176.48 \text{ ft}^3/\text{hour} \\ &= 176.48 \text{ ft}^3/\text{hour} \times 5153.12 \text{ Btu/ft}^3 \\ &= .91 \text{ MMBtu/hour}\end{aligned}$$

Given efficiencies and requirements a minimum 1 MMBtu/hr line heater is required.

6.0 General Information

General Liquefied Petroleum Gas (LPG) Properties:

Critical Pressure		615.91	psi
Critical Temperature		206.01	°F
Boiling Point at 14.7 psi		-47	°F
Freezing Point		-306.4	°F
Specific Gravity of Liquid		0.51	(water = 1.00)
Specific Gravity of Vapor		1.53	(air = 1.00)
1 ft ³ liquid	=	31.86	lbs
1 ft ³ liquid	=	272	ft ³ vapor
1 lbs	=	8.47	ft ³ vapor
1 bbl liquid	=	1530	scf

Above factors are based upon atmospheric pressure, 14.7 psi, and at ambient temperature, 59 °F, as applicable. Physical properties of LPG will vary little within the allowed HD5 composition.

LPG Composition:

Vantage Frac typically utilizes LPG provided to a specification denoted as 'HD5'. A summary of the HD5 LPG composition specification is as follows (vol. %):

Propane	C3H8	90%	minimum
Propylene		5%	maximum
Butane	C4H10	2%	maximum
Iso-Butane		1.5%	maximum
Methane	CH4	1.5%	maximum

Useful Conversions:

1 gallon = 0.1337 ft³

1 gallon = 0.02381 barrels

1 barrel = 5.61 ft³

1 ft³ = 0.1781 barrels

1 ft³ = 7.4805 gallons

1 ft³ liquid LPG = 272 ft³ vapor (14.7 psi and 59 °F)

1 bbl liquid LPG = 1530 scf (14.7 psi and 59 °F)

7.0 LPG Hazards

- LPG is approximately twice as heavy as air when in gas form, will tend to sink to the lowest possible level and will accumulate in low areas.
- LPG in liquid form can cause severe cold burns to the skin owing to its rapid vaporization.
- Vaporization can cool equipment so that it may be cold enough to cause cold burns.
- LPG forms a flammable mixture with air in concentrations of between 2% and 10%.
- LPG can be a fire and explosion hazard if stored or used incorrectly.
- Vapor/air mixtures arising from leakages may be ignited some distance from the point of escape and the flame can travel back to the source of the leak.
- At very high concentrations vapor can have an anesthetic effect and subsequently become an asphyxiant by diluting the available oxygen.
- A component that has contained LPG is normally empty but may still contain LPG vapor and be potentially dangerous.
- Refer to the Material Safety Data Sheet for LPG (Liquefied Petroleum Gas) for complete safety information.

Note:

Though liquid under moderate pressures, LPG returns are flammable gases and must be either flared, gathered into pressurized tanks or directed to a pipeline for recovery at facilities. At no time should LPG returns be directed to the atmosphere or non-pressure tanks.

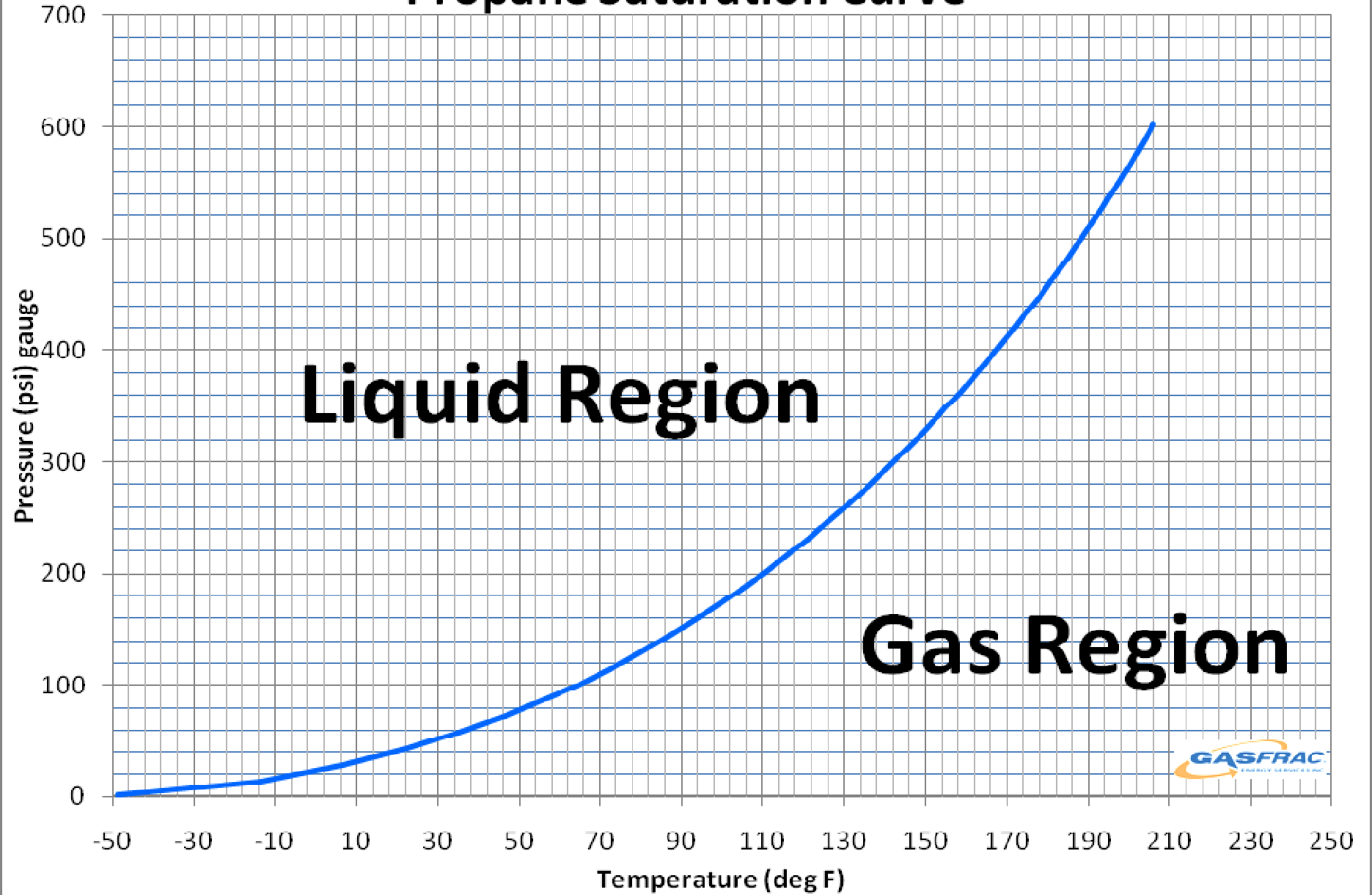
LPG flowback rates beyond capacity of surface test equipment may result in LPG liquid at the flare stack. Monitor separator outlet conditions to avoid this potentially dangerous situation.

Flammable Limits - Common flammable gas and vapors

	Explosive Limits (% by vol. In air) LEL	Explosive Limits (% by vol. In air) UEL	Flash Point °F	Vapour Density Air = 1.0	Ignition Temp. °F
Ammonia	15.0	28.0	Gas	0.58	1166
Butane	1.8	9.0	Gas	2	770
Carbon Monoxide	12.5	74.0	Gas	0.97	1058
Diesel	0.3	10.0	126	> 3.0	< 340
Ethane	3.0	12.5	Gas	1	882
Hydrogen Sulphide	4.0	45.0	Gas	1.19	500
Ethyl Alcohol	3.3	19.0	55	1.59	689
Methanol	6	7.6	61	1.1	867
Methane	5.0	15.0	Gas	0.55	1000
Propane	2.2	10.0	Gas	1.5	842
Toluene	1.3	7.0	39	3.14	995
Common Frac Oils	1.0	7.0		< 1.0	392
Gasoline	1.3	8.0	-45	3.2	> 530

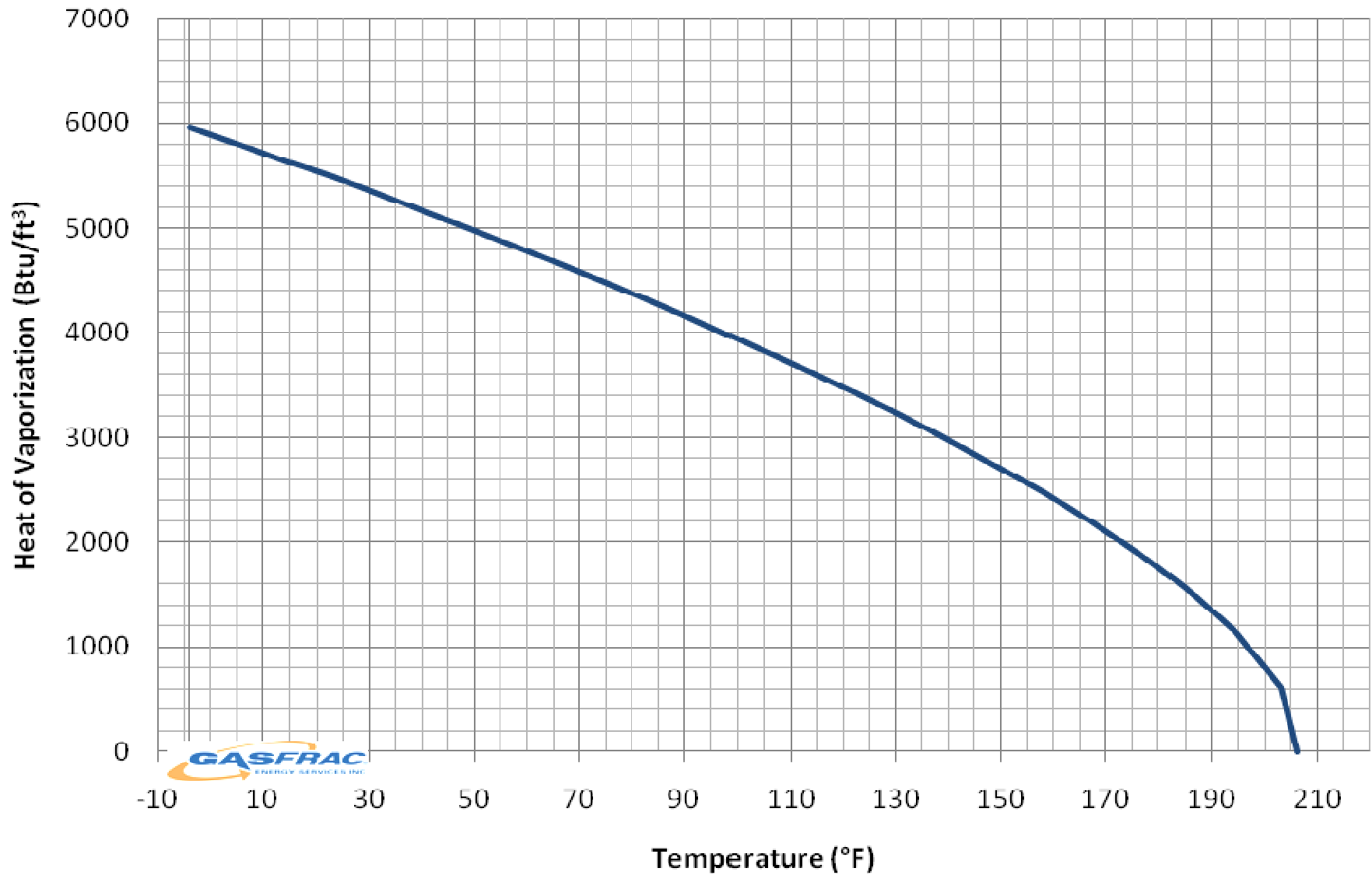
Well Testing and Fluid Handling, Industry Recommended Practice (IRP), Volume 4 – 2007

Propane Saturation Curve



ATTACHMENT I - Propane Saturation Chart

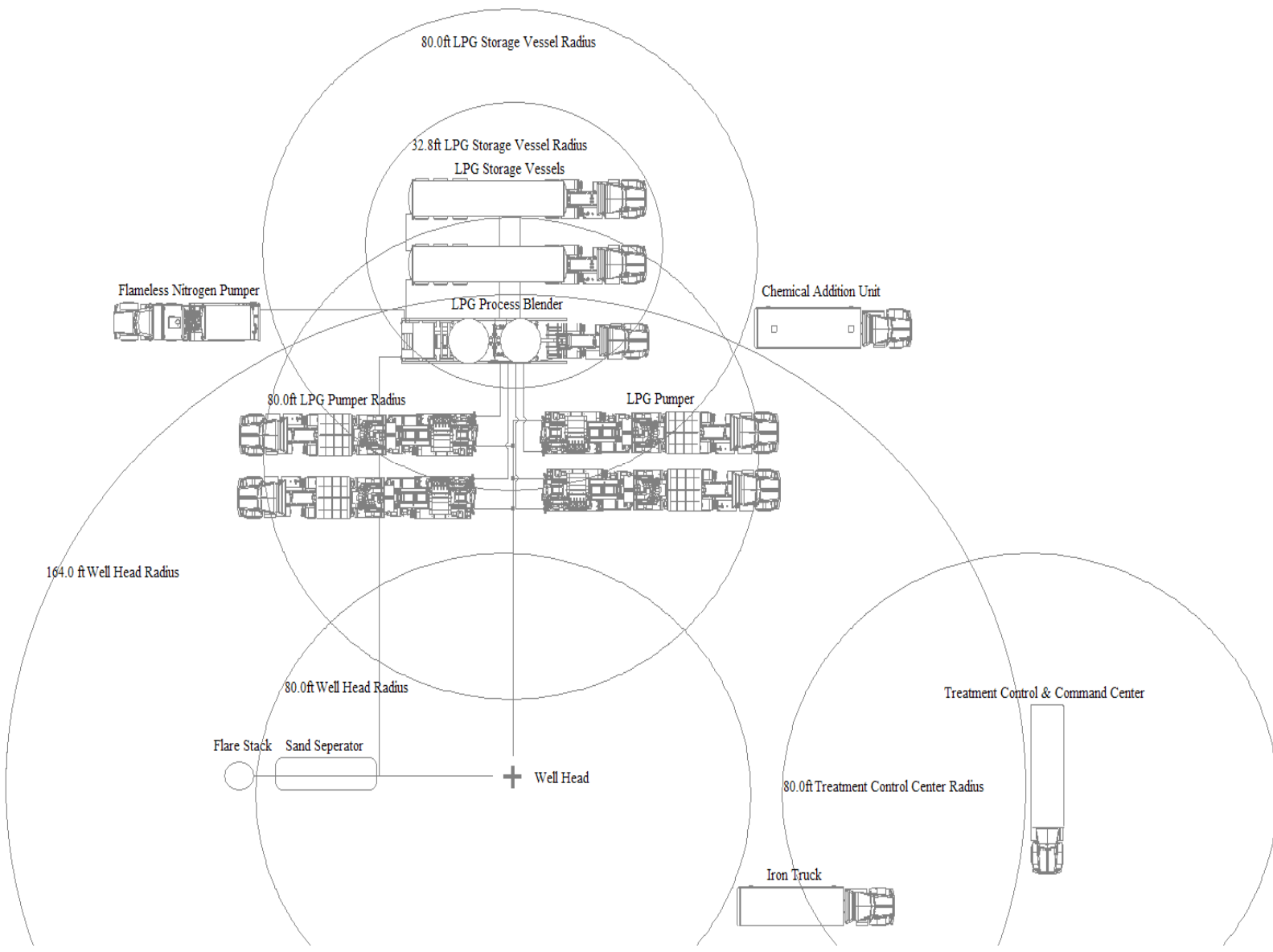
Propane - Heat of Vaporization Volume Basis



ATTACHMENT II - Propane Heat of Vaporization Chart

Gasfrac Equipment Spacing and Layout

(Not to Scale)



Distance From	LPG Storage Vessels	Nitrogen Pumper	Chemical Addition Unit	LPG Process Blender	LPG Pumper	Well Head	Control Center	Flare	Flowback Equipment
LPG Storage Vessels	--	80.0ft	80.0ft	--	32.8ft	164.0ft	164.0ft	164.0ft	80.0ft
Nitrogen Pumper	80.0ft	--	--	80.0ft	80.0ft	80.0ft	80.0ft	80.0ft	80.0ft
Chemical Addition Unit	80.0ft	--	--	80.0ft	80.0ft	80.0ft	80.0ft	80.0ft	80.0ft
LPG Process Blender	--	80.0ft	80.0ft	--	--	80.0ft	80.0ft	164.0ft	80.0ft
LPG Pumper	32.8ft	80.0ft	80.0ft	--	--	80.0ft	80.0ft	164.0ft	80.0ft
Well Head	164.0ft	80.0ft	80.0ft	80.0ft	80.0ft	--	164.0ft	164.0ft	80.0ft
Control Center	164.0ft	80.0ft	80.0ft	80.0ft	80.0ft	164.0ft	--	164.0ft	80.0ft
Flare	164.0ft	80.0ft	80.0ft	164.0ft	164.0ft	164.0ft	164.0ft	--	80.0ft
Flowback Equipment	80.0ft	80.0ft	80.0ft	80.0ft	80.0ft	80.0ft	80.0ft	80.0ft	--