WHITE PAPER

By Linda Nezerwe

Utilizing Flare Gas to Generate Power for the Oil and Gas Sector

Introduction

The Oil and Gas industry has seen high volume productions in the past few years reaching about 18 million barrels per day in 2019 in the Unites States. Crude oil refineries are a source of revenue for many governments and large corporations. It is where diesel and other types of fuel are generated. The gaseous fuel types can vary from regular pipeline natural gas to coal mine methane, to flare gas to other low energy fuels.

Natural gas that comes from oil wells is typically termed "associated gas" or flare gas. The area that has been of great concern in the past decade from both economic and environmental standpoints is how to utilize this flare gas instead of burning it. Maximizing the usage of flare gas to generate electricity would ensure that the Oil and Gas industries are helping nearby communities while protecting the environment and not just converting useful fuel to CO_2.

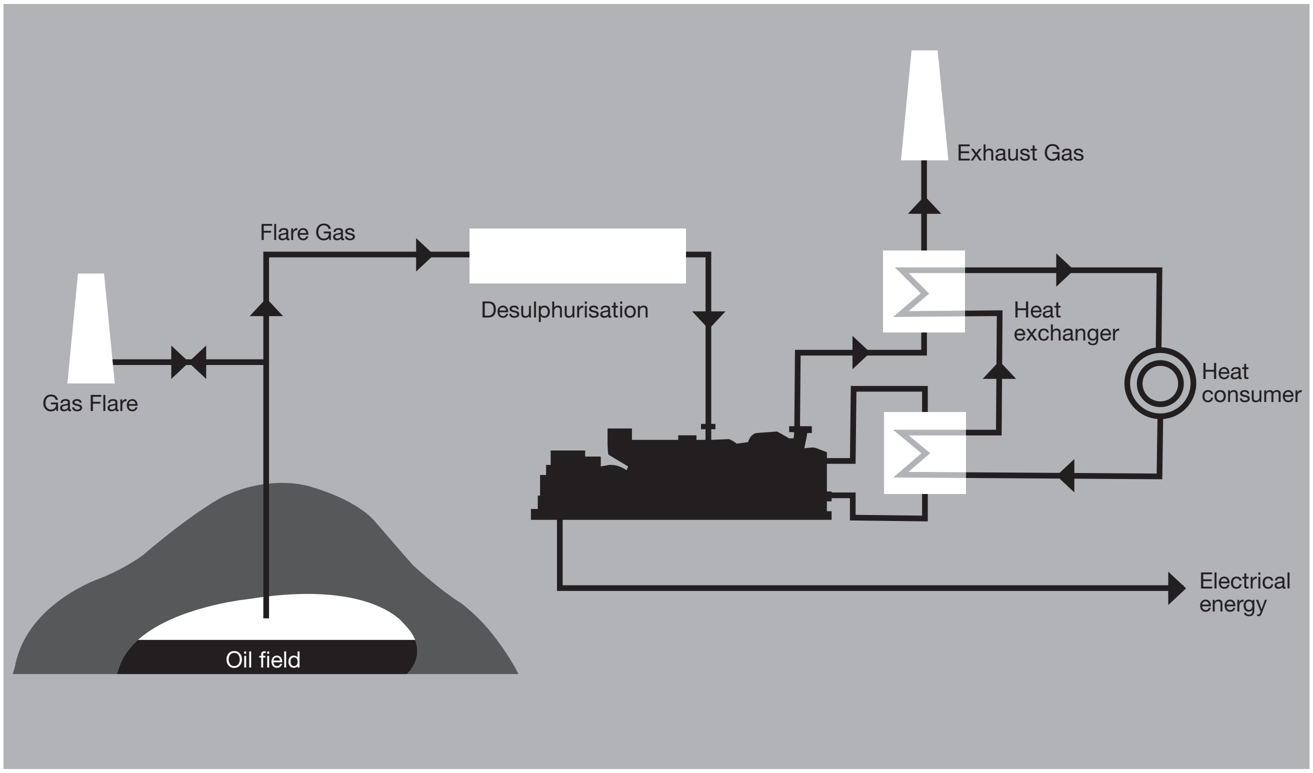

Figure 1. Generator set producing heat and electricity from flare gas

When generator set manufacturers describe features of their products, the focus is usually on the generator sets outputs such as heat and electricity. The technologies have been advancing to increase the generator's electrical and thermal efficiencies. Lean burn gas generators are one way in which manufacturers can contribute towards environmental protection, as these generator sets can use a wide variety of fuels including low energy fuels and fuels that are often unused to produce electricity for neighboring communities.

Current regulations

A gas flare is a device used in industrial plants to burn and remove excess gas from refineries. Flares are seen in chemical and natural gas processing plants with the main purpose of disposing unwanted gases. Gas flaring is also used in oil-gas production, the coal industry and landfills. Some gases that are often sent to the flare include process gases, fuel gas, steam, nitrogen and natural gas.

Sometimes, refineries use gas flares for safety reasons and to relieve gas pressure from accumulating in their systems. This practice is sometimes inevitable as plant safety comes first for all plants. Refineries will also routinely flare gas during normal oil processing operations. Routine flaring is done to reduce the unwanted gases in the normal production and as such presents an opportunity to discuss how that can be avoided.

Global concern

Gas flaring is now recognized as a major environmental problem. Globally 140 billion cubic meters of natural gas are flared annually, emitting more than 300 million tons of carbon dioxide (CO_2), a major greenhouse gas, to the environment.

Governments, development institutions, and oil companies around the world are being pressured to look at the amount of money spent in gas flaring and the damage it is causing to the environment. The World Bank has launched an initiative called Zero Routine Flaring by 2030. This means that governments and oil companies will invest in technologies that utilize the unburned fuel and find ways to protect the environment whilst benefiting financially as well.

The Global Gas Flaring Reduction Partnership (GGFRP) is a forum which seeks to generate policies and regulations to reduce gas flaring.

The quantity of unburned fuel that needs to be flared is usually known and the question is what to do with it. Flaring still provides a quick solution to get the fuel out of the facilities so they can safely continue producing gas at their desired pace. As the World Bank started to consider this problem, countries like Norway, Algeria, Canada and the United States have made a lot of progress in limiting local oil companies on how much flare gas is allowed. More and more countries are joining the movement and will be looking at all available solutions.

What to do with the unburned fuel?

As mentioned above, the major challenge remains with what to do with the excess gases from where it should go. Proposed technologies for replacing gas flaring should not add additional complexity nor add a significant cost burden to the institutions performing it. Ideally the excess gases should be utilized to create more resources to the community around.

Current technologies such as Flaring Recovery Systems (FRS) have the goal to recover some of the flare gases and introduce them back to the refineries. Although, these technologies have proven to be effective, they require a lot of upfront cost for equipment and management of the gas quality. Other companies have considered alternative methods to maximize the use of their unburned fuel while helping the neighboring communities.

This is where generator set manufacturers can play a big role by designing and manufacturing products that can utilize flare gases for electricity production. Specifically, lean burn combustion technologies are capable of combusting fuels of various energy levels and composition to produce power. Lean burn gas generator sets can produce electricity with high efficiency and very low exhaust emissions.

In times when the oil processing is not generating a lot of excess gas, the generator set can still produce electricity and heat for other facility needs using pipeline natural gas. This means electricity for houses and businesses around boosting the overall economy.

Flare gas composition

Flare gas will consist of a mixture of different gases. The composition will depend upon the source of the gas going to the flare system. Associated gases released during oil-gas production mainly contain natural gas. Natural gas is more than 90% methane (CH_4) with ethane (C_2H_6) and a small number of other hydrocarbons; inert gases such as N_2 and CO_2 may also be present. Gas flaring from refineries and other process operations will commonly contain a mixture of hydrocarbons and in some cases H_2. However, landfill gas, biogas or digester gas is a mixture of CH_4 and CO_2 along with small amounts of other inert gases. There is in fact no standard composition and it is therefore necessary to define some group of gas flaring according to the actual parameters of the gas. Changing gas composition will affect the heat transfer capabilities of the gas and affect the performance.

Table 1. Shows a list of constituents and their average percentage in flare gas from a refinery. For engine manufacturers, it is important to understand the gas composition to ensure feasibility for their products.

Gas flaring constituent	Molecular formula	Average volume %
Methane	CH_4	43.6
Ethane	C_2H_6	3.66
Propane	C_3H_8	20.3
n-Butane	C_4H_{10}	2.78
Isobutane	C_4H_{10}	14.3
n-Pentane	C_5H_{12}	0.266
Iso-pentane	C_5H_{12}	0.53
neo-Pentane	C_5H_{12}	0.017
n-Hexane	C_6H_{14}	0.635
Ethylene	C_2H_4	1.05
Propylene	C_3H_6	2.73
1-Butene	C_4H_8	0.696
Carbon monoxide	CO	0.186
Carbon dioxide	CO_2	0.713
Hydrogen Sulfide	H_2S	0.256
Hydrogen	H_2	5.54
Oxygen	O_2	0.357
Nitrogen	N_2	1.3
Water	H_2O	1.14
Total		100

Table 1. Example of refinery flare gas composition

Lean burn generator sets capabilities

The advantage of a lean burn engine lies in the combustion technology. A lean burn engine uses excess air in the combustion chamber to have lower combustion temperatures and therefore lower NOx emissions making it an environmental friendly option. The generator's high efficiency can be further improved by also capturing waste heat from the engine coolant as well as the exhaust gas for processes within the facility or to consumers near the facility. For example, the Cummins HSK78G engine is capable of operating with high or low energy density fuel with a combined heat and electrical efficiency of around 90% of the fuel input.

Precautions

Fuel quality

Most engine manufacturers have designed and tested their engines to operate on a variety of fuel compositions including low energy fuels. However, certain conditions need to be met to ensure that the state of the engine is preserved. Fuel quality is a very important factor in equipment selection and there are various ways to quantify the fuel properties. The Methane Index (MI) is one method manufacturers use to evaluate fuel quality. MI is typically reported on a scale of from 1 to 100 once inert gases have been removed and is different from the Methane (CH_4) fraction in the fuel. MI is a theoretical measure of the ability of the gas to resist auto ignition which can cause engine knocking. The higher the MI value, the more resistant the gas is to auto ignition and can guarantee stable engine performance.

Flare gases tend to have a significant quantity of long chain hydrocarbons. A high concentration of long chain hydrocarbons in the fuels tends to result in a lower MI meaning that the fuel is more likely to auto-ignite and cause engine knock. As the fuel-air charge in the combustion chamber is intended to be ignited by the spark plug at a precise point in the piston's compression stroke, engine knocking can cause severe performance issues and damage the engine. The effects of engine knocking can range from being inconsequential to completely destructive.

Contamination

The fuel going into the engine also needs to have contamination which meets the engine manufacturer limits. Proper cleaning and filtration should be done to prevent and reduce fuel contamination within acceptable limits. Flare gas that is contaminated can be harmful to the internal component of the engine but also difficult to transport.

When selecting an engine to operate on flare gas, it is important to review the fuel analysis to select an appropriate engine which can operate efficiently with the desired fuel. In addition to knowing the fuel composition, it is important to verify what contaminants are present in the fuel and at what concentrations. It is very likely that gas associated with oil fields will contain hydrogen sulfide (H_2S).

While equipment manufacturers can take steps to increase the contamination tolerance of their machines, if the concentrations of H_2S exceed the manufacturers limits it can be detrimental to engine metallurgy and oil quality. If left untreated the H_2S can damage copper based bearings or other metallic components. Additionally, H_2S becomes harmful by contacting the moisture found in the exhaust blow-by gas and forming Sulfuric Acid.

Measures that can be taken to counter the effects of H_2S:

- Clean the fuel to a level that it is well below the 20ppm (assume fuel energy greater than 36MJ/Nm^3); this can be expensive and unnecessary if the engine is built with components that can tolerate some level of H_2S contamination.
- Keep the engine warm while it is not operational, implement a crankcase sweeping after engine stops, and maintain warm oil temperatures to prevent moisture condensation. Although a fuel may have low H_2S levels the contaminated fuel can damage the engine if fumes can condense within the crankcase. One countermeasure is to implement a powered crankcase extraction system that will help sweep crankcase fumes and discharge them away from the engines after the engine has been shut down.

Cold weather operation

Due to the lower vapor pressure of the longer chain hydrocarbons present in flare gas, it is possible that these gas constituents can precipitate out as liquids in piping. This is particularly a concern if the pipework is exposed to cold ambient conditions and steps are not taken to keep fuel warm. One simple way to keep longer chain hydrocarbons from precipitating to liquids is to keep the pipe protected from the elements and where the pipe must be exposed to ambient conditions it should be heat traced and insulated. The condensed hydrocarbon liquids can be contained using drop off pots on the site to ensure that liquids do not make it to the engine.

Conclusion

Flare gas which is typically considered a waste byproduct can be a valuable source in an appropriately designed generator set. By combusting flare gas in a lean burn engine, emissions from flare gases are reduced and valuable byproducts such as electricity and heat are generated. Routine flaring can be reduced and transformed into a more environment friendly options while also helping communities around.

About the author

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Linda Nezerwe started her engineering career in the medical device industry as a Design Engineer for 2 years. She joined Cummins in January 2014 where she supported various products in the Recreational Vehicle, Commercial Mobile and Marine Markets as a Product Design Engineer.

Today, she is a Technical Specialist in the Sales Application Engineering team supporting the Cummins Distribution business. Her areas of expertise are in the Fuel and Exhaust Systems as well Emissions for both diesel and gaseous generator sets. Linda also specializes in helping the sales organization in their specification writing.

Linda attended the University of St. Thomas in Saint Paul, MN for both her Bachelors and Masters in Mechanical Engineering.

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