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Environmental and Economic Impact of Purging Gas Plant Flare System Using Nitrogen Inert Gas Instead of Fuel Gas (Case Study)

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Abstract

Within gas plant processing facilities; controlled volumes of gases are used to sweep the plant flare system as purge gases to prevent air ingress and protect the entire system from back fire events. The use of fuel gas in flare and vent headers for purging purposes results in environmental emissions as well as the losses due to burning such amount of fuel energy. Flare emissions can be in the form of COx or NOx when fuel gas burnt in the flare headers. These environmental and economic considerations encourage researches to reduce production of greenhouse gases as well as saving thermal energy. This act as driver for gas producing companies to find alternative ways to replace fuel gas purging by another safe and available sources. This paper studies the positive environment and economic impacts of using gas plant low purity nitrogen for purging flare headers. The replacement of fuel gas with nitrogen in purging the flare and atmospheric vent headers is one of the options currently being developed to reduce environmental impact. Usage of nitrogen eliminates the environmental emissions, where low purity nitrogen extracted from the plant nitrogen production unit utility systems. In case of the unavailability of the low purity nitrogen, the fuel gas purge stream will still be available to be operated as back up during upset scenarios. The study concluded that the total emissions will be saved estimated to be 23,469 Ton per year after replacing the fuel gas by nitrogen in purging; as well as saving a significant financial impact of fuel flared per year. The estimated cost saving is calculated to be 1,677,844 USD per year; given the price of the gas is 4.7 $/btu. Also the paper concluded the payback period for the replacement process of the fuel purge gas using nitrogen by 19.2 months.

Keywords: Gas Plant Flaring, Energy saving, Flare emissions reduction, Purge gas.

Introduction

Flaring Process is a high temperature combustion operation used as safe disposal for plant waste gases containing combustible constituents such as volatile organic compounds (VOCs), natural gas (methane) and carbon monoxide (CO). The waste gases are directed to designed elevated stack and burned in an ambient open flame using a special designed burner flare tip. A Portion of fuel gas called assist gases like steam or air are used to promote mixing to achieve almost complete combustion of the combustible components of waste gases. Gases flared from gas, oil plants and refineries are composed largely of inert and low molecular weight hydrocarbons with high heating value. (**U.S. EPA, 2015**). Flares typically operate with pilot flames (basically three) to provide ignition source, and by using ambient air as an oxidizing agent. Combustion considered complete if all hydrocarbons and carbon monoxide (CO) converted to carbon dioxide (CO_2) and water vapor. Incomplete combustion results in traces of hydrocarbons or CO discharged to atmosphere and converted to other non-environmental friendly organic compounds. The flaring process also produces some undesirable products including smoke, sulfur oxides (SOx), nitrogen oxides (NOx), CO which acts as undesirable potential source of ignition. Flared gases sources during gas plant operations varies; below are some examples of these sources:

- Discharged gases from pressure safety valves (PSVs) used for over pressure protection.
- Uncontrolled vent gases (Storage tanks emissions release).
- Gases resulting from process upsets and poor gas plant operation scenarios.
- Fuel gas used for purging.

The Flare Syte Flare systems safely burn flammable gases vented during planned startups, planned shutdowns, and unforeseen emergencies at refineries and petrochemical plants. A typical flare system consists of a flare header, a liquid knockout drum, a flashback seal drum, and flare pilots as shown in Fig.-1.

The Flare header is the network of pipes that runs through the plant and into the flare’s liquid knockout drum is called the flare header. It collects discharge from safety valves and control valves in the plant. Purge (or sweep) gas is introduced at a specific flowrate (specified by the flare gas system supplier) at points along the header to prevent air ingress, which could create a flammable or explosive mixture.

Liquid knockout drum is the liquid knockout drum separates entrained liquid in the gas stream to prevent it from being released into the atmosphere. The drum is located at the base of the main flare structure. A pump runs automatically when the liquid level exceeds a setpoint to safely evacuate the drums.

Flashback seal drum is the flashback seal drum helps to avoid air ingress by maintaining positive backpressure in horizontal sections of the flare header. In the event of an explosion in a vertical flare stack, the flashback seal drum prevents flames from entering the horizontal flare header. The flashback seal drum is located either inside or outside the flare stack.

Flare pilots. The flare pilots and the flare pilot burner ignition system keep the pilot burners continuously lit when the flare is in operation. In some flares, steam is injected through nozzles to ensure smokeless burning.(Center for Chemical Process Safety, 2007).

Flare Systems Purge Gas

A pre-determined and controlled amount of fuel gas or sometimes inert gas shall be flowing to the flare network piping to prevent the atmospheric air ingress, flow flashback, or back fire scenario into flare header system. This has high potential leading to an explosive mixture in the flare system. Back fire prevention is achieved through using of flare sweep or purge gas stream. Basically, purge gas refers to the gas intentionally directed into certain number of purge points distributed in the flare header system to keep forward flow of gas to the flare tip in order to prevent air oxygen buildup inside the flare header and consequent fire. Flare purge or sweep gas is typically a stream of treated fuel gas or inert gases, such as nitrogen (N_2) or (CO_2), (subject to their availability, environmental and economic considerations) used to maintain a minimum required positive pressure through the flare system.

System Process Description

In normal gas plant designs, flare system is purged by fuel gas. Low purity nitrogen coming from a nitrogen production unit will be used as main purge supply replacing fuel gas. The fuel gas shall be used only as back-up purge gas in the event of low purity nitrogen is unavailable. This is being controlled using kind of pressure sensing operated switching valves. As shown in Fig. 1, the Fuel gas or nitrogen introduced at the end of each flare header to maintain forward flow to meet the minimum flow purge to the flare stack. Fig. 1 below also depicts the two alternatives purge gas sources including fuel gas from treated gas stream, nitrogen from nitrogen production unit.

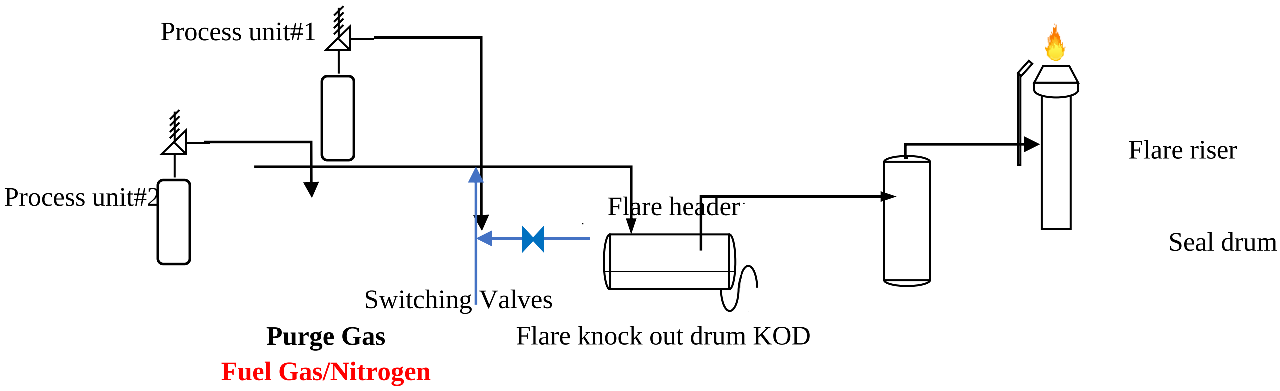

Fig. 1. Flare system process description and alternative purge gas sources

Understudying Nitrogen Generation Unit Process Description

Nitrogen system package receives dry air outlet from plant air dryer package and produce gaseous nitrogen at required purity level. The specification of dry air from the air dryer package should be as shown in Table 1 below to support healthy operation of the unit.

Table 1. Air specification for nitrogen package inlet.

Parameter	Value
Operating temperature (Min/Max) (°C)	0/60
Operating pressure (Min/Nor/Max) (barg)	8.0/8.5/9.0

The nitrogen generation package produces nitrogen with a purity of minimum 97% by volume of low purity nitrogen. The feed dry compressed air is routed to the nitrogen generation package as shown in Fig. 2 for pre-filtration section consists of two duplex filters. It removes the contaminants before the feed air enters the nitrogen membranes. Air is then heated in an electrical heater on the outlet of the filtration

Section to ensure a stable nitrogen purity at all operating conditions. The heated air directed to nitrogen purity membrane modules where the separation of nitrogen and oxygen occurs. Separation of nitrogen and oxygen occurs in the membrane separators. This permeate (oxygen enriched air) stream is vented from the membrane at atmospheric pressure (See Fig. 2 below). The selected low purity membrane

Modules are of the removable bundle type, which allows individual element replacement without the need to remove the complete membrane housing.For nitrogen generation unit acontrol valve is installed at the downstream of the membranes to maintain the pressure in membrane modules and control the purities of the residual oxygen.

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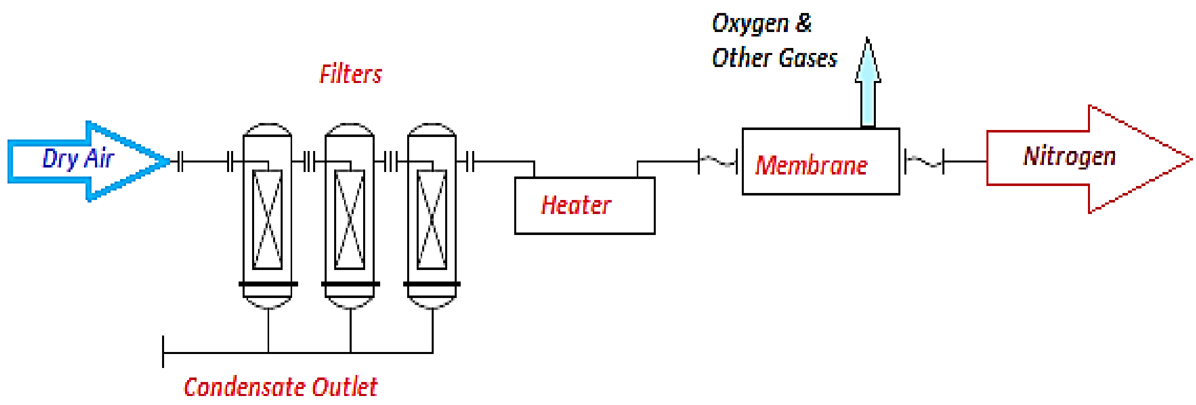

Fig. 2. Nitrogen generation unit configuration

Results and Discussion

1. Unit Design Basis and Upgrade Required

After applying the proposal, gas plant normal operation will require flare System to be continuously purged using low purity nitrogen from nitrogen production unit. The existing design conditions in shown in Table 2 shall be upgraded to cover the excess need of nitrogen supply of the flare in addition to the normal users of nitrogen in the plant such as (Storage tanks blanketing, compressor seal etc...). Low purity nitrogen will be introduced at flare header purge points to maintain forward flow to meet the minimum flow rate of flare purging which is 277.3m^3/hr (Flare package vendor requirements) to prevent air ingress. However, Low Pressure (LP) Fuel gas will be still available as back-up purge gas in the event that the low purity nitrogen is unavailable. The emergency LP Fuel gas is activated on detection of low pressure of nitrogen in the flare Knock out Drum (KOD).

Table 2. Existing and Upgrade Nitrogen Unit Design Conditions.

Parameter	**Value**	**Flare Upgrade requirement**
Design pressure; barg	20	20
Design Temperature °C	120	120
Feed Air Capacity; m^3/hr	490	970
Nitrogen Capacity m^3/hr	140	277.3
Nitrogen Purity	97%	97%
Maximum oxygen concentration	3%	3% (no combustion possibility)

A Pressure transmitter has a Low - Low alarm and trip with a set point of 0.01 barg, signaling the potential loss of the primary nitrogen purge gas. The trip signal opens a shutdown valve allowing an emergency purge of Fuel Gas into the flare KO Drum to restore the required positive pressure. Hence the operator is to monitor pressure in Flare KO Drum via pressure transmitters and ensure it is stable.

2. Environmental and Economic Impact Of Using Fuel Gas In Purging

This paper studies the techno economic impact of replacement using nitrogen instead of fuel gas for the same function of purging the flare system piping network. The study analyze and process the data of a gas plant in Alexandria, Egypt and it includes:

- Reduced amount of fuel gas purging cost and emissions.
- Excess capacity required to upgrade the nitrogen Unit.

Reduced amount of fuel gas purging and emissions

A typical data of the understudying gas plant were used to analyze the environmental and cost impact of replacing fuel gas purge by nitrogen inert. The API Compendium, 2009 Equation - 1 below was used to calculate the amount of emission due to flare gas purge. A summary of the data recorded and calculations are shown in Table 3 where the cost of flaring and emissions amount were listed.

CO_2 emissions (tons) = FC x (1/molar volume conversion) x MW(mixture) x Wt%C(mixture) x (44/12) {Equation 1}

Where:
FC = Fuel Consumed (m^3);

Molar volume conversion = 23.685 m^3/Kg conversion from molar volume to mass;
MW(Mixture) = Molecular Weight of Mixture; = 17.8 Engineering Analysis Reports
Wt%C =75% Ref. Company Engineering reports

Table 3. Understudying plant production and flare data**.**

Description	**Value**
Gas production flow rate; MMscf per day	400
Fuel gas gross heating value; btu/scf	1085.5
HP flared gases; MMscf per day	0.901
Anuual flaring rate; MMscf per year	328.87
Thermal energy loss of flared gases; MMbtu/year	356,988
Daily flared gas emissions; Ton per day	64.30
Cost of the flared gases (4.7 $/btu – agreement contract); $/year	**1,677,844**
Annual flare emissions of purge gas; Ton/year	**23,469**

Nitrogen Unit Upgrade Capacity Cost

The current capacity of the nitrogen package is 140 m3/hr which will need to be ramped up to 417.3 m^3/hr nitrogen production to meet the excess amount required for the flare new nitrogen user. Basically, a complete skid with the same capacity of the existing air and nitrogen generation package will be required to cover the needs of flare system purging. In Table4 below the cost of the upgrade capital cost of having a new skid and annual operating cost was estimated summarized below. Referring to the losses due to amount of purge fuel gas burnt in the flare on annual basis, the payback period had been calculated to be 19.2 months as shown in Table 4.

Table 4. Estimated upgrade cost for Nitrogen Package.

Item	**Value**
Nitrogen unit upgrade capital cost; $/year	**2,312,000**
Nitrogen unit operating cost; $/year	**375,000**
Total required cost (annual) $/year	**2,687,000**
Payback period; months	**19.2**

Conclusion

Gas flaring reduction and fuel gas purge replacement has a high priority as it meets the environmental and economic efficiency objectives. This paper is a case study on gas plant in Egypt with overview of reduction of flared gases by using nitrogen Inert gas for purging according to environmental and economic considerations. The capacity and design basis of the new nitrogen production unit is a key success factor of this flaring alternative solution. The upgrade cost should be clearly identified and the payback period to be calculated before applying this alternative solution. The Paper illustrated the successful possibility of using nitrogen as alternative media for purging gas plant flare system with considerable upgrade cost and reasonable payback period.

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