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Vapor Recovery from Condensate Storage Tanks Using Gas Ejector Technology

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Abstract

This paper demonstrates a method of recovering the low pressure vapor from the condensate tanks in the Bibiyana gas field. This method uses a gas ejector as a device to compress the low pressure natural gas from the condensate tanks to an intermediate pressure, which would then be fed into the intermediated stage of the existing vapor recovery unit. Thus the natural gas will be saved which would have been otherwise flared. The amount of tank vapor is estimated by different methods, which shows a significant amount of gas is now being flared. Flaring of gas is a problem which entails both economic loss and environmental concerns. It is estimated that, on the average 190 MSCFD tank vapor can be recovered using the proposed method involving a gas ejector. Thus yearly saving would be about 68 MMSCF of natural gas. The equivalent heat energy saving is about $74.55X10^9$ BTU. In terms of greenhouse gas emissions, this project will reduce about 1,112 tons of CO_2 emissions per year in the gas plant locality.

1. Introduction

The Bibiyana gas field is located in the north-eastern corner of Bangladesh, about 150 km from Dhaka. Discovered in 1998, the field is one of the most significant natural gas fields in Bangladesh, both in terms of quality and size of the reserve. It started production in March 2007. With the 12 producing wells, it currently produces more than 750 MMSCFD of natural gas and approximately 3,500 BPD of condensate.

There are 6 condensate storage tanks in the Bibiyana field. At first the condensate from the four High-Pressure Inlet Separators is sent for first stage stabilization. This is accomplished in the two Flash Gas Separators which operate at 100 psig. Next the partially stabilized condensate is sent to the two Low pressure separators operating at 35 psig. Finally it is sent to the condensate storage tanks for stabilization at atmospheric pressure. There is a mechanical Vapor Recovery Unit (VRU) in Bibiyana to collect vapor from Flash gas separators, LP gas separators and LP gas boots. The VRU consists of a 3 stage reciprocating Vapor Recovery Compressor. The VRU however, cannot recover vapor from the storage tanks because of low pressure of vapor (nearly atmospheric). The tank vapor is therefore regularly flared through the Low Pressure Flare line. Thus valuable resource with good heating value is being lost every day.

This paper demonstrates the use of an alternative method for recovering condensate tank vapors that is otherwise typically flared. This method uses a 'Gas Ejector' type pump.

2. Ejector Technology

Gas ejector is a device which works on the principle of entrainment. It has no moving parts. It provides almost maintenance free operation and has no operating cost. According to Bernoulli's equation, if no work is done on or by a flowing frictionless fluid, its energy due to pressure and velocity remains constant at all points along the streamline. As a result an increase of velocity is always accompanied by a decrease in pressure. This principle can be used to collect a low pressure gas stream with a high pressure gas stream (called the 'motive' gas) for entrainment and compression to an intermediate pressure.

Figure 1 shows the working principle of a gas ejector device. It consists of a nozzle and a venturi tube. The nozzle receives the motive fluid from a high pressure source. As the motive fluid passes through the nozzle, velocity increases and pressure decreases. This causes suction effect around the nozzle. Low pressure gas around the nozzle is drawn into the motive stream and mixed with it. The venturi tube consists of piping whose diameter narrows at the throat and then widens at its terminal end. This increased diameter at the terminal end causes the velocity of the mixed fluid to decrease and the pressure to increase. Thus the fluid mixture is delivered at an intermediate pressure. [1]

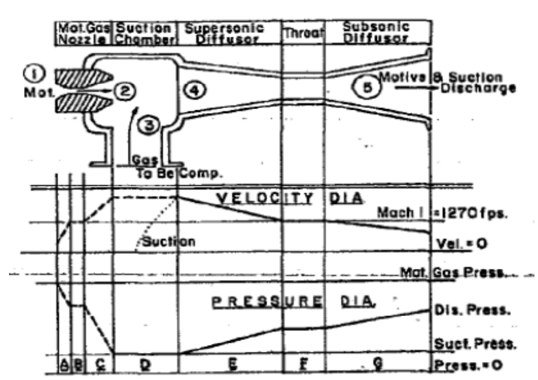

Fig. 1: Velocity-Pressure profiles in a Gas Ejector

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Gas ejector is a viable technology and it has been applied to recover low pressure gas in different oil and gas fields in the world. Figure 2 shows the schematic of a flare gas recovery system using this technique.

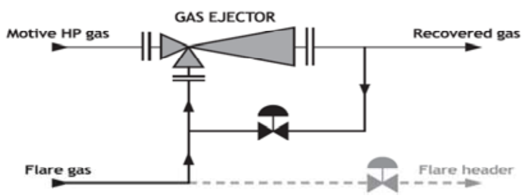

Fig. 2: Flare gas recovery system

3. Condensate Tank Vapor Estimation

Significant amount of vapor is produced in the storage tanks due to: i) shrinkage/flashing, ii) standing, and iii) working effects. Flash or shrinkage effect occurs when condensate is transferred from a gas–oil separator at higher pressure to a low pressure storage tank. Upon injection of the oil into the storage tanks, lower molecular weight hydrocarbons dissolved in the crude oil come out of the solution. Standing effects occur due to the daily and seasonal temperature and barometric pressure changes. Working effect occurs when crude level changes during production and shipping and when crude in tank is agitated. The volume of gas vapor coming off a storage tank depends on crude oil properties. Lighter crude oils (API gravity>36°) yield more vapors than heavier oils. Bibiyana condensate API gravity is 43.4° at 60^0F, which is considered as lighter crude oil.
Three different methods were used to estimate the quantity of vapor emissions from condensate tanks, as presented in the next section.

3.1 Flash Calculations

The condensate properties used for calculation are shown in Table 1.
Table 1. Condensate properties

Location	Pressure Changes	Shrinkage Volume
HP to Flash Sep.	1250 to 100 psi	9.4
Flash to LP Sep.	100 to 35 psi	0.8
LP Sep to Tank	35 psi to ambient pressure	1.0
Condensate Specific Gravity: 0.809034 at 60^0 F		
Condensate API Gravity: 43.4 at 60^0 F		
Gas Specific Gravity: 0.61028		
Gross Heating value of Gas: 1075 BTU/SCF		
Average condensate production: 3500 BBLD		

The conversion factor of gas volume to liquid amount is given by the following correlation [2]:

3178 (MMSCFD)* Specific Gravity of Gas
= 14.6 (BBLD)* Specific Gravity of Condensate

Using the values from Table 1, it is reorganized:

MMSCF = 0.00609 * Number of BBL (1)

Let,
Total Condensate Production A (= 3500)
Condensate from LP Gas Separator L
Condensate from Flash Gas Separator F
Condensate from HP Separator H

From simple mass balance,
A = Condensate from LP gas separator - Shrinkage volume at Condensate tank
= L - 0.01L [cond. shrinkage volume 1%]
= 0.99L , or L = A/0.99

Thus condensate shrinkage at storage tank = 0.01L
= 0.010101A BBL = 0.010101A X 3500 BBLD
= 35.45 BBLD

This amount of liquid is vaporized from the storage tanks. Using Eq. (1), the equivalent volume of gas is 215.8 MSCFD.

3.2 API Chart

The chart shown in Fig.3 can be used to estimate the Gas-Oil Ratio (GOR) in crude oil/condensate as a function of vessel pressure, and API gravity.

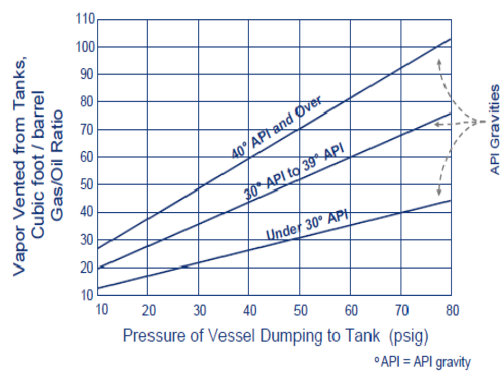

Fig. 3: API Chart for estimating GOR

For API gravity is 43.4, and upstream pressure of 35 psig, the GOR is found as 57 SCF/BBL.
Thus vapor from tanks = 57X 3500
= 199.5 MSCFD.

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3.3 HYSYS Simulation

HYSYS simulation tool was used to find the vapor streams from condensate storage tanks due to flashing and pressure drop between LP gas separators and condensate tanks. Peng-Robinson correlations were used for simulation. The result showed the amount of vapor to be 157 MSCFD. Results from the above three techniques are summarized in Table 2.

Table 2. Amount of vapor from condensate tanks

Calc. Method	Estimated Gas (MSCFD)
Flash calculations	215
API Chart	199
HYSYS Simulation	157

It shows that the flash calculation yields the highest value, while simulation result is most conservative. The average value of 190 MSCFD is used for subsequent calculations and system design.

4. System Design

For the sake of simplicity in designing an ejector, the following assumptions were considered:

- Flow is frictionless (viscosity = 0).
- Expansion in the nozzle and compression in the diffuser are isentropic, with k (ratio of specific heats) remaining constant.
- Motive and suction fluid properties are the same.
- Mixture occurs at constant pressure and is adiabatic.
- Total enthalpy of the final mixture equals the weighted average of the initial components.

4.1. Key Design Parameters

The compression ratio ($P_{Out}/P_{Suction}$) and the entrainment ratio (W_m/W_s) are key parameters in designing an ejector.

$$\text{Compression ratio} = \frac{Discharge\ gas\ pressure}{Suction\ gas\ pressure} = \frac{(90+14.7)PSIA}{(0.6+14.4)PSIA} = 6.8$$

$$\text{Entrainment ratio} = \frac{Motive\ gas\ flowrate}{Suction\ gas\ flowrate} = \frac{(440\sim590)MSCFD}{(155\sim215)\ MSCFD} = 2.8$$

Motive gas volume should be about 3 times greater than the suction volume to be picked up, depending on pressure [3]. The motive gas pressure is taken at 750 psig. The advantage is that, the higher the pressure of the motive gas, the more beneficial would the ejector be in generating the required level of boost for the lower pressure gas, using a minimum amount of higher pressure gas. In this project, entrainment ratio is estimated to be approximately 2.8 times that would support the optimum ejector operations. Compression ratio is about 6.8 with low suction pressure. Therefore it is possible to achieve high compression ratio with a supersonic nozzle for ejector. Table 3 shows the design parameters.

Table 3. Ejector design parameters

Parameters		Unit	Values
Suction Gas	Flow Rate	MSCFD	155-215
	Pressure	PSIG	0.4-0.6
	Temperature	^{0}F	80-85
	C_p/C_v		1.283
Motive Gas	Flow Rate	MSCFD	440-590
	Pressure	PSIG	750
	Temperature	^{0}F	80-95
	C_p/C_v		1.629
Discharge	Pressure	PSIG	90-100

The Ejector, low pressure and high pressure sources, and connections are shown in Fig. 4.

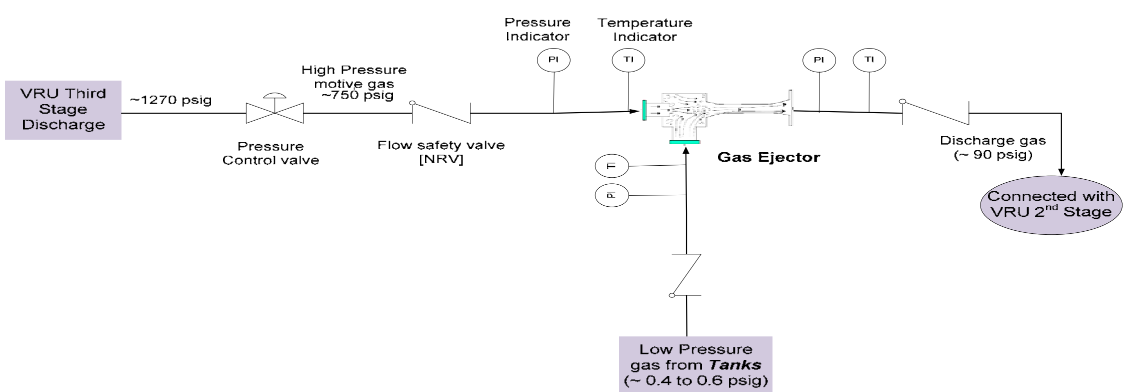

Fig. 4: Schematic view of Gas Ejector set up

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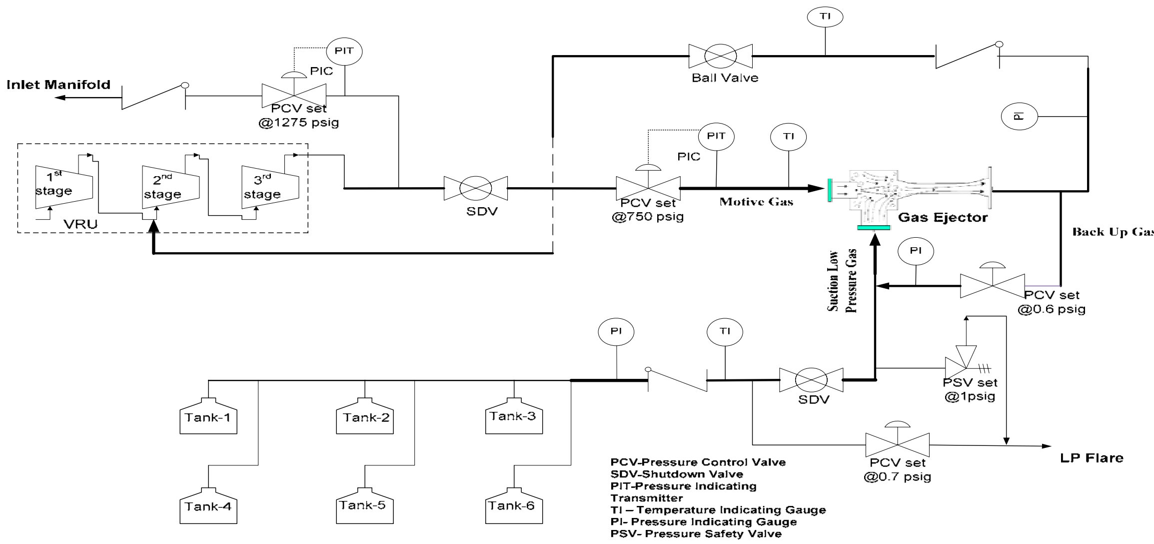

Fig.5: Gas Ejector Installation and Operations philosophy

4.2 Gas Ejector Operations and Control Philosophy

Referring to Fig. 5, the source gas will come from the condensate tanks through a common header. Gas feed into the ejector suction side is at operating pressure range of 0.4 to 0.6 psig, and the flow rate range is 155 to 215 MSCFD. Present safety system of tank will not be interrupted by installing an ejector. Only flared gas will be feed into ejector. The high pressure gas will come from the third stage of VRU, first priority to use as motive gas for ejector and the remaining gas will be feed into inlet manifold (upstream of high pressure separator). VRU discharge pressure is approx. 1265-1270 psig, whereas motive pressure for ejector would be about 750 psig (pressure step down by pressure regulator) and gas flow rate is controlled depending on suction gas; Motive flow rate range would be approximately 440 to 590 MSCFD, considering flow rate is on average 530 MSCFD.

The discharge of ejector will be fed into VRU second stage; presently VRU second stage handles only about 811 MSCFD as against the total capacity of 1670 MSCFD. Considering maximum recovery from tank, the second stage will handle totally 1065 MSCFD (64% of mentioned capacity). Ejector discharge pressure would be about 90 psig and flow rate is the summation of suction and motive flow. For steady flow at suction low pressure side, a simple control system is used to recycle make-up gas from the discharge of the ejector, if required.

Regarding the control and safety considerations, the ejector system piping will be equipped with flow control valves and check valves (to prevent any back flow). A pressure safety valve (PSV) is located on the suction piping set to 1 psig. All piping connections have pressure and temperature indicators to show real-time data. Gas Ejector installation will not eliminate the LP flare system rather it will minimize tank flare. Then LP flare will burn only purge and pilot gas necessary for safe operation of the plant.

5. Environmental and Economical Benefits

Flaring of gas involves both economic losses and environmental pollution. Gas flaring mainly emits CO_2, CO and other greenhouse gases (GHG) in the atmosphere, which in turn contributes to global warming.

5.1. Estimation of CO_2 from Flaring

To calculate CO_2 emissions, the volume of flaring gas is converted into BTU, and then multiplied by an emission coefficient of 14.92 million metric tons of CO_2 per quadrillion BTU. [4]

The estimated average volume of flaring gas from condensate tanks is 190 MSCFD, and considering gross heating value of the gas is 1075 BTU/SCF, it is calculated as follows:

Amount of heat content of flared gas,

$$= (190*1000*1075) \text{ BTU/day}$$
$$= 74.55\text{X}10^9 \text{ BTU/year}$$

Using the emission factor, total CO_2 emission is about 1,112 tons per year. By capturing Tank hydrocarbon vapors, gas ejector reduces flaring and CO_2 emissions in gas plant locality. This ensures a cleaner environment (cleaner air) for on-site personnel who get benefit from a safer working environment.

5.2. Economical Concerns

By implementing the system proposed, it will be possible to recover on average 190 MSCFD of gas. Thus 68 MMSCF will be saved per year. Price of this gas is about $208,050, assuming minimal or standard sales gas price of $ 3/MCF. The heat content of this recovered vapor is actually higher than the standard sales gas.

According to ejector manufacturer and suppliers of other equipments and piping cost, the total project cost (all equipments and installation) was estimated and found to be approximately $119,900. Thus the payback period is only 7 months. Operating and maintenance costs are very low because an ejector has no moving parts.

6. Conclusions

A simple design based on gas ejector principle is proposed to recover low pressure vapor from the condensate storage tanks. This design is easily implementable, with minimal intrusion of the existing system. Environmental and economical benefits justify its application. Proper implementation of the design should result into the following:

- ***Volume of gas collected:*** *157 to 215 MSCFD with an average 190 MSCFD, i.e., 68 MMSCF per year.*
- ***Potential value of gas recovered:*** *$208,050 per year, based on $3/MSCF*
- ***Payback Period:*** *7 Months*
- ***Net Heat Energy Saving:*** 74.55×10^9 *BTU/year*
- ***Flare CO_2 eliminated:*** *1,112 tons/year (locally)*

Nomenclature

BBLD	Barrels per Day
BTU	British Thermal Unit
HP	High Pressure
LP	Low Pressure
MSCFD	Thousand Standard Cubic Feet per Day
MMSCFD	Million Standard Cubic Feet per Day

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