Flare Gas Recovery from an Existing Oil Plant using Gas Compressors

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Abstract
Global warming is nowadays one of the main and important issues. As the increase in the concentration of carbon dioxide and other greenhouse gases in the atmosphere as a result of the combustion of these gases causes such phenomena. Therefore, oil and gas plants need to be constantly reviewed over time to maintain high performance and operability, especially while changing feed composition and rate to meet standard product specifications. The aim of this study is to study the effect of flare gases recovery using gas compressors on the economic and environmental performance of an existing oilfield plant. A commercial simulation program aspen HYSYS Version 11 was used. The Kalabsha Central Processing Facility (KCPF) in the Western Desert of Egypt is the studied plant. This plant handles 30 million standard cubic feet per day (MMSCFD) from free water knock out drum and 1.6 MMSCFD of gases from heaters. 20 MMSCFD from gas is charged to the gas pipeline and 10 MMSCFD is sent to the flare with the 1.6 MMSCFD. It is proposed to install gas compressors to capture the gases from the free water knock out drum and heaters before sending them to the flare. Such technology can be used as a guide in upgrading existing and new oil and gas plants to reduce gas flaring. In addition, environmental protection also adds more economic profits from burning the recovered gas besides increasing the life of the flare equipment.

Keywords: Flare gas, compression, global warming, gas pipeline,

1. Introduction

Flaring is defined as an oxidation process used to burn gases from industrial operations. Flaring acts as a safety device to protect facilities from over pressuring. Besides flare system function when hydrocarbon gases such as methane build up by preventing explosion during emergency or maintenance [1]. However, flaring has local environmental impacts as well as producing gas emissions which have the potential to contribute to global warming [2,3].

A considerable increase in temperature of earth which cause global warming since of the mid of 20th century was recorded. This due to increase in carbon dioxide emission as a result of high fossil fuel consumption. And consequently, increase in average of greenhouse concentration in atmosphere. The main greenhouse gases are methane, carbon dioxide, nitrous oxide (N_2O) and three fluorinated industrial gas (HFCs, PFCs) which produced depending on the gas flared type [4]. The most dangerous of these gases is methane which has 23 times more global warming potencial than that of CO_2 [4-6].

Emergency gas flaring occurs in the event of value breaking, fire when huge volume of gas burned in short span of time with high velocity or in case of compressor failures. Where process flaring occurs usually at lower rate to remove waste gases from the production stream.

Flaring emission is both a concern to the government and environmental potential. Since environmental associated with gas flaring have a considerable impact on health risk including cancer, deformities in children, lung damage and many more health problems have been reported [7]. Also due to the global warming and changes in temperature of the atmosphere effects on crops stunted growth beside the soils lose their fertility and capacity for sustainable agriculture due to acidification of the soil by various acid gases emission from flaring. In addition, acid rain accelerates the decay of building material and pants [8-10].in spite of this flare gas represent a valuable source of energy since more than 90% of flared gas composed of methane, ethane, CO_2, N_2 and a few of other hydrocarbons. So, the preservation of the environment is important goal for sustainable development and poverty reduction [11-13]. Therefore, limiting or reducing greenhouse gas emissions presents on enormous challenges to gas and oil industry which considered the major sectors cause global warming. There are large number of government and industry commitments aim to eliminate flaring by 2030 [14]. Many steps may be used to reduce the flare losses by proper operation and maintenance eliminating leaking value better control of streams and more [15].

There are many techniques used to reduce and recover flare gases such as collection, compression and injection into oil reservoirs to improve oil recovery, electricity generation, LPG production, LNG , natural gas hydrates, gas to ethylene and methanol ammonia production, gas-to-liquids and compression by ejectors or compressors and injected into the pipeline.

Collection, compression, and injection are generally used to maintain the presence of gas for future use and increase the efficiency of oil production in enhancing oil recovery. This is commonly used for industries that have a small gas capacity.

Another important method to use these gases is to generate electricity via a gas power plant. It is a very efficient cycle of using gaseous fuels to generate mechanical power or electricity. It consists of a compressor, a combustion chamber, a gas turbine, and a generator, as well as a gas turbine to generate electricity [16]. The gas produced will be used as a power plant to meet the electricity needs of both the industry itself and the household.

Liquefied petroleum gas (LPG) technology is widely used because of the ease of storage and transportation of local markets.

The volume of liquefied natural gas (LNG) is 1/600th of the volume of natural gas in the gaseous state. LNG is the most economical method for oil/gas production field which has a large volume of gas production and there is a major obstacle to reach consumers in the market. The lower volume of LNG compared to natural gas makes it more cost-effective to transport it over long distances where transporting natural gas through pipelines is not feasible or economical. Compressed natural gas (CNG) is almost identical to liquefied natural gas, but compression does not occur before the liquid phase. Therefore, gas-to-gas regasification is not required. The volume generated is also greater than 1/1200 the volume of the gas at room temperature.

The natural gas hydrate (NGH) method hydrates the gas to crystallize and stabilize at -200 °C. This method is also possible in the recovery of associated gas with a higher economic value than LNG.

The gas-to-ethylene (GTE) and ammonia-methanol production methods use flare gases and convert them into methanol products as DME (dimethyl ether) and olefin (ethylene and propylene) used in reactors with conventional catalyst production systems. Methane can also be converted into ammonia as a raw material for fertilizer production. Ethylene is commonly used in the production of low-density polyethylene (LDPE) and high-density polyethylene (HDPE).

Gas to liquid (GTL) technology converts flaring gases into longer-chain hydrocarbons such as gasoline or diesel fuel. These gases are converted into liquid either directly or by synthetic gas as an intermediate step by using the Fischer Tropsch or Mobil processes. Using gas-to-liquid enables plants to convert gases products to more valuable liquid products. In the Fischer Tropsch method, partial oxidation of flare gases is done leading to the formation of synthetic gas which is chemically reacted over an iron or cobalt catalyst producing liquid hydrocarbons and other by-products [11]. In the Mobil process, the flare gases are converted to synthetic gases, then to methanol, and finally polymerized into alkanes over a zeolite catalyst [17,18].

Flare gas recovery using ejector or compressor collects and pressurizes flaring gases to be used as a fuel heater, re-boiler to run burners. Thus, saving on the amount of sweet gas required for operating these devices. Ejector works on Bernoulli’s principle which states that if no work done the total energy of the system which is the summation of potential, kinetic and pressure energy remains constant at all points along the streamline. Therefore, an increase kinetic energy results in a decrease in pressure and vice versa. Bernoulli’s principle used in compression of flare gas to an intermediate pressure with the help of high-pressure motive fluid which may be either liquid or gas [19]. Ejector is a cost-effective device [20]. Multi stage ejectors can be used if the exit pressure of the mixture after recovery is less than the required for transportation pipelines can be used. The discharge of the first ejector serves as driving fluid for the next ejector and the process is repeated until the desired pressure rise is achieved [21]. On the other hand, flare gas recovery using compressor compresses flaring gases to the required pressure for transportation into a pipeline. Rahimpour et al. [18] concluded that the compression and injection into pipelines is a very effective and economical way of flare gas recovery as compared to others. The use of compressors is more cost than the ejector because of higher initial, operation and maintenance cost, higher space and power consumption and a low rate of return with a payback period of few years whereas the ejector is more simple, reliable and has high rate of return with a short payback period [22].

In this paper, the flaring gas compression technique was applied using compressor in an existing oilfield plant. The resulting compressed gas is injected into the pipeline. This plant produces 30 million standard cubic feet per day of associated gas with oil. Of this amount, 20 MMSCFD is compressed and injected into the pipeline and the remaining 10 MMSCFD is sent to flare. In this work, a new compression system is proposed to capture these flaring gases. Also, an economic study of the proposed pressure system was made to calculate the capital cost and the return on the equipment.

2. Case study

In this work, Kalabsha Central Processing Facility (KCPF) plant located in Egypt was used as a case study. This plant is designed to handle 50,000-barrel oil, 30 MMSCF, and 120,000-barrel water per day. Crude oil contains salts in addition to other impurities as a result of the presence of the formation of water. Salts have a corrosive effect on pipelines and facilities material. Therefore, it is essential to reduce the salts and water content to meet a standard specification before being shipped into pipelines to a terminal point. The feed from different wells flows through oil flow lines to Free Water Knock-Out Drum (FWKOD) system installed upstream inlet separators in order to improve the performance of the facility and provide bulk gas and water separation. FWKOD consists of 3 vessels designed and installed to handle the following flowrates 30 MMSCFD gas, 120,000-barrel water per day, and 50,000-barrel oil per day. The facility consists of 6 processing trains. The fluid from producing wells is received at the production manifold which has the main function to distribute the inlet flow to 6 processing trains. Each train consists of a water bath heater, separator, and heater treater. The oil outlet from the 6 heater treaters is pumped with oil feed pumps to 2 desalters to remove salt content to meet standard company specifications. Oil outlet from desalters is directed to be flashed at a slightly higher pressure than atmospheric pressure in the gas boot then to storage tank. After that oil stays at the storage tank for some retention time, it is allowed to settle out free water to meet water content standard specifications. The oil is shipped through 2 pipelines of 110 km length with 6 and 12 inches in diameter respectively. Gases exist the free water knock out drum is directed to gas compression for compression and shipping in the gas pipeline. 20 MSCFD gases are directed to existing three stages gas compressor trains A & B with a capacity of 10 MMSCFD each for compression and injection into a gas pipeline respectively. Excess gases will be directed to a flare system for burning as there is no compressor is installed to ship these gas quantities. Gas compressor have been installed to capture flared gases from separators and free water knock out drum. Gases outlet from separators or heater treater have 2 ways one way to flare system for burning, the second way to gas compressors for compression and injection into gas shipping pipelines.

Currently, A & B gas compression systems have 10 MMSCFD per unit. Each compression system consists of three-stage positive displacement compressors that are used to capture associated gas from the free water knock out drum before sending it to the flare system for safe combustion. Associated gas currently has a volume of 30 million standard cubic feet per day. 10 MMSCFD gas is compressed by A & B gas compression systems and shipped to gas shipping pipelines to final gas stations. The remaining 10 MMSCFD is usually sent to flare for combustion. Each gas compression system facility includes the following systems: -

1-Fuel gas condition skid
2-Instrument air distribution header and surge vessel,
3- Compressor open drain sump, collection header
4- Closed drain collection header
5- Methanol injection system
6- Flare header
7- Purge gas pipeline
8- The main gas pipeline

The gas shipping pipeline is 8 inches in diameter and 33 km long, which is a pipeline used to transport associated gas produced from Free Water Knock out drum after being compressed in A & B gas compression systems to the downstream gas station. Operating conditions for pipelines are 30 MMSCFD, delivery pressure 32 bar, inlet pressure 72.5 bar.

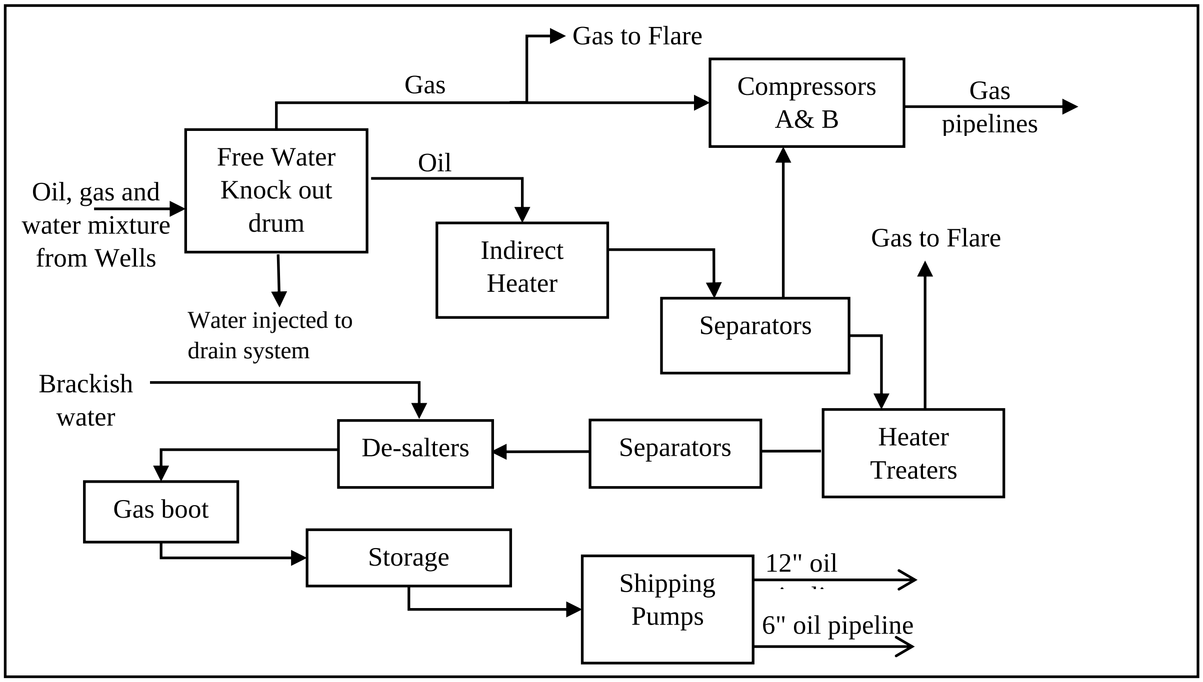

Figure 1: Case study block flow diagram

3. The proposed modification

The purpose of this study is to collect the gases sent to the flaring system which are burned by compressing these gases and injecting them into the gas shipping pipeline. These gases represent a great economic value, therefore, by extracting them, you will add a profitable return, in addition, they will reduce the heat radiation and increase the life of the flare tip. In this paper, gas compression systems were installed to recover gases sent to the flare system for combustion as there are currently 11.6 MMSCFDs sent to the flare system for combustion. 10 MMSCFD of these gases exits from the Free Water Knock out drum while 1.6 MMSCFD exits from the heater treatment in the crude oil processing unit as shown in Figure 2. These amounts of gas can be recovered and injected into the gas shipping pipeline as the infrastructure is in place. The recovered gases can be used as fuel to power turbines.

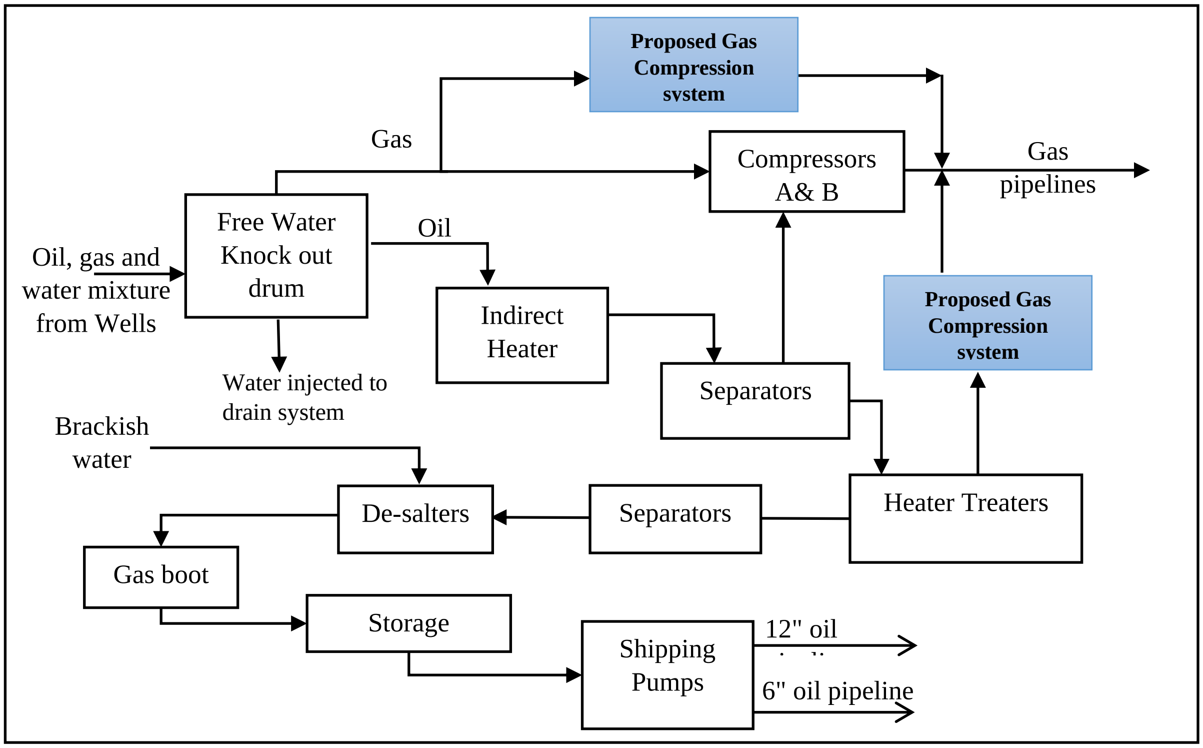

Figure 2: KCPF Block Flow Diagram with proposed gas compressor modification

4. Results and discussion

Flare gas can be used as a source of energy in fuel gas, electricity generation, gas to liquid conversion process or can be shipped in the pipeline if the infrastructure and market existing. Burning gas in the flare system have several environmental and human harmful impacts. The commercially software ASPEN HYSYS version 11 is used to model the oil plant under this study. Ping- Robeson equation of state has been used as it is suitable in this case.

The present work proposed two new compression systems to the studied case study to use waste gases disposed to flare system as these gases have economic value. Installation of new gas compression systems will capture 11.6 MMSCFD which is burning on the flare. The operating conditions and composition of feed stream exits from Free water Knock out drum are shown in Tables 1 and 2 respectively. Figure: 3 show the simulated process flow diagram of the plant under study.

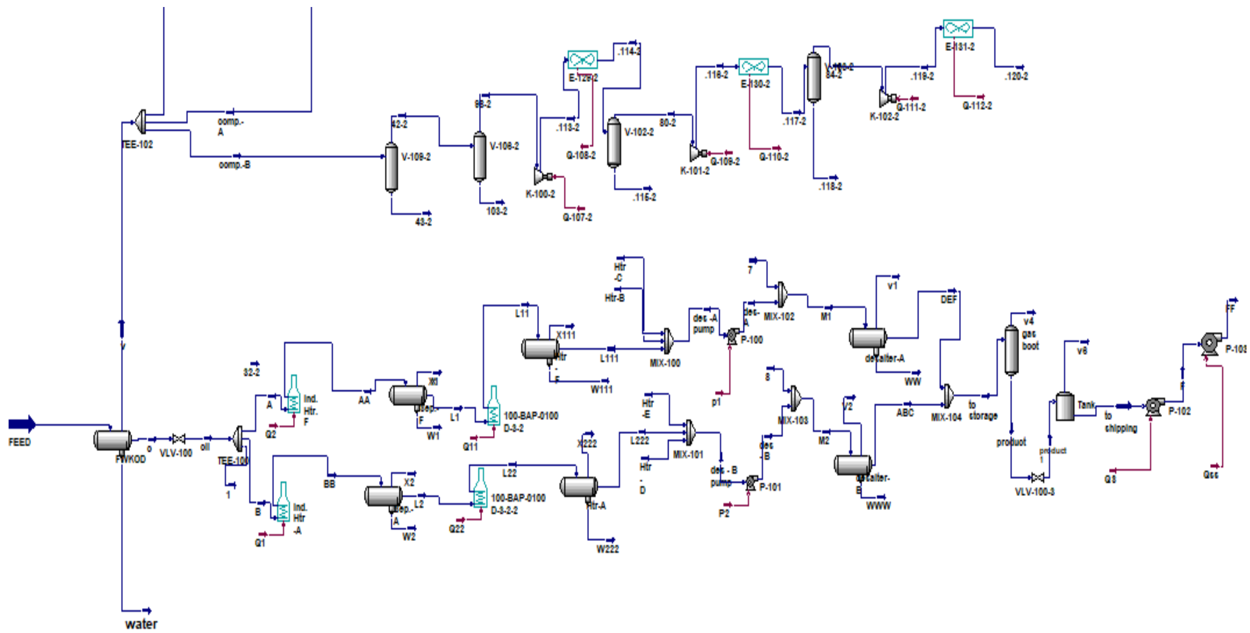

Figure 3: KCPF simulated process flow diagram

Table 1: Feed stream conditions to proposed gas compressor

Feed Condition	
Temperature [°F]	120.00
Pressure [psig]	90
Flow Rate [MMSCFD]	10.16

Table 2: Feed stream compositions to proposed gas compressor

Composition	**Mole fraction**
H2O	0.02
H2S	0.00
CO2	0.04
Nitrogen	0.00
Methane	0.65
Ethane	0.19
Propane	0.06
i-Butane	0.01
n-Butane	0.01
i-Pentane	0.01
n-Pentane	0.01
n-Hexane	0.01
Mcyclopentan	0.00

The results achieved from this work are the recovery of 10 million standard cubic feet of gas from the Free Water Knock out drum normally sent to the flare system. These gases represent 1900 barrels of oil equivalent per day (1 million cubic feet = 190 barrels of oil). On the other hand, extracting 1.6 million standard cubic feet of gases out of the heater treater and sent to the flare system for burning is equivalent to 304 barrels of oil equivalent per day. The total gas captured is 11.6 million cubic feet per day (2,204 barrels per day of gases sent to the flaring to burn). This can yield a return of $154,280 per day ($2204 * $70). The capital and operating cost of the two compression systems is obtained from the economic analyzer of ASEN HYSYS program Version 11. The economic evaluation unit develops both capital and utility costs. The following costs have been considered for capital and operating costs:

A. Direct field costs referring to materials, manpower costs for equipment, piping, civil, structural steel, instrumentation and control, electrical equipment, insulation materials, and paints.
B. Indirect costs like engineering, supervision, start-up, commissioning, construction expenses, fringe benefits, encumbrances, insurance, scaffolding, equipment rental, field service, temporary constructions, etc.
C. Indirect non-field costs as shown below:
- Shipping, taxes, permits and engineering (basic engineering, detail engineering, procurement of materials)
- Emergency (unexpected event allowances)
- Cost of other projects such as general and administrative expenses, contract fees, and home office expenses.

The calculated total capital and operating costs obtained by HYSYS economic module are USD and USD/Year respectively. So, the total capital investment can be calculated as in the following equations

Total capital investment = total capital cost + total operating cost
Proposed gas compression system for heater treater = 4,867440 + 1,595030 = $ 6,462470
proposed gas compression system for FWKOD = 8,339610 + 2,885290 = $ 11,224900
Total capital investment = 6,462470 + 11,224900 = $ 17,687370

Return on investment (ROI) = $\frac{\text{total annual income increment} - \text{annual increase in operating cost}}{\text{total capital investment}}$

$$= \frac{154280 \times 365\ day - 4480320}{17{,}687370} = 2.9$$

Payback period = $\frac{1}{ROI}$ = 0.344 Year

It is clear that the modified plant will have a reasonable ROI and payout period. In addition, other results can be obtained from this project which are as follows:

- Reduce emissions of flaring gases, ash and greenhouse gases
- Reducing the heat rate, as there are 11.6 million standard cubic feet of gases that will not be burned by the flames
- Compliance with environmental regulations

- Increase the life of the flare tip

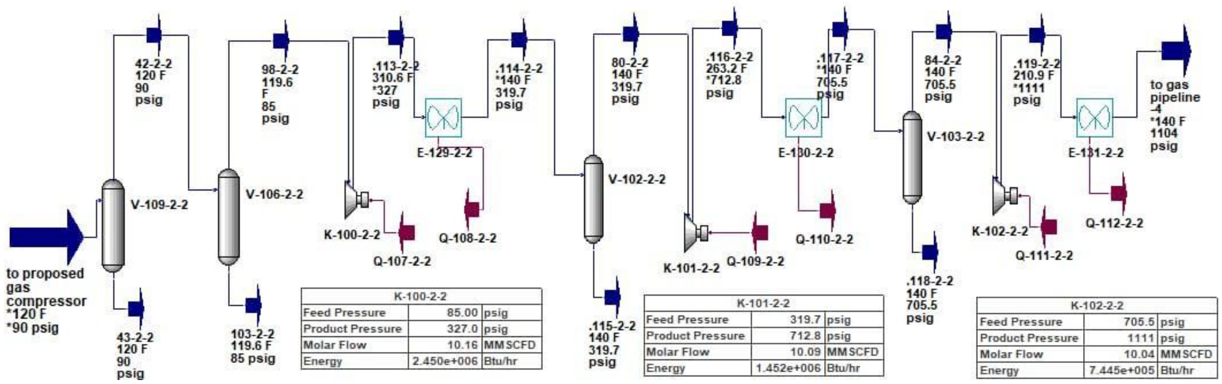

Figure 4: Simulated process flow diagram with a proposed gas compression train to recover heater treaters outlet gases

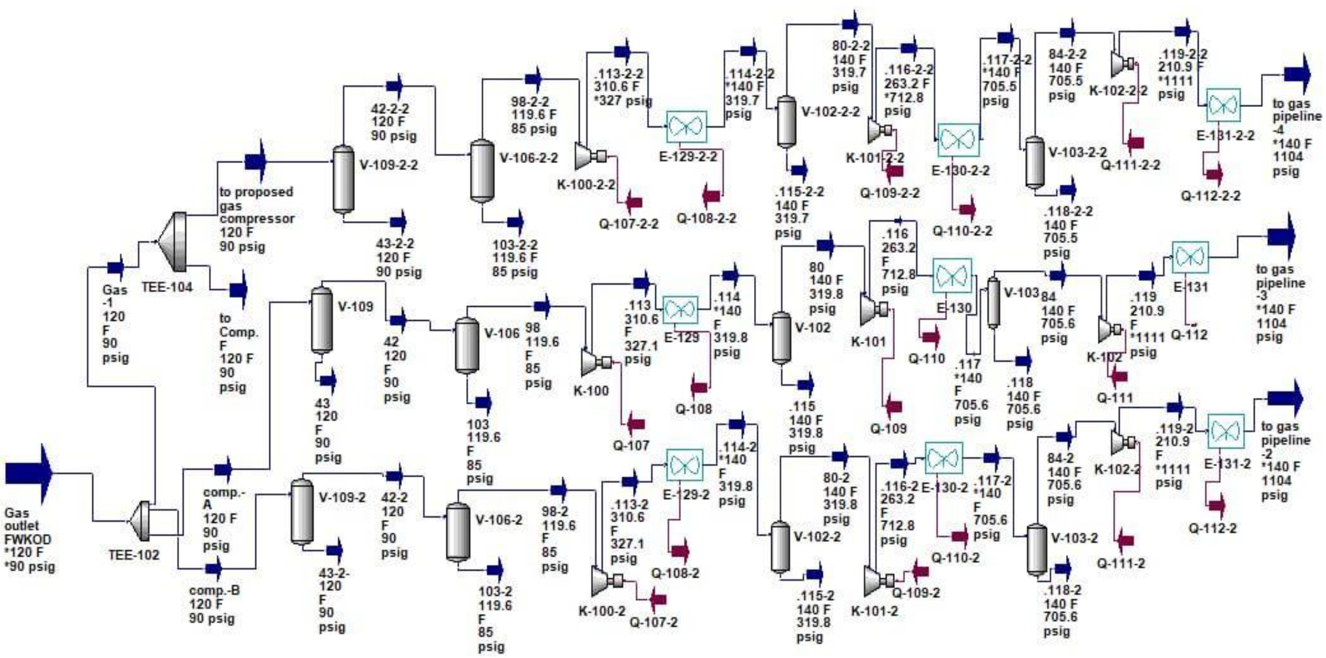

Figure 5: Simulated process flow diagram with a proposed gas compression train to recover FWKOD outlet gases

Flare gas recovery system has been installed based primarily on economics, where the payback on the equipment was short enough to justify the capital cost.

5. Conclusions

flare gases can be used as fuel for heaters, turbines, household uses and electricity generation. There are several techniques used to recover flare gases. Among these technologies, for example, is the process of converting these gases into a liquid (LNG) and installing a gas compressor to compress the gases and then shipping to pipelines if the infrastructure is present. Combustion gas recovery will reduce greenhouse gas emissions and pollutants to the environment. Oil facilities require constant upgrading to improve performance, reduce operating costs, improve process safety, generate more corporate profits, or maintain a healthy environment. In this work, two new gas compression systems were installed to recover the gases sent to the flare daily for combustion. The installation of these two gas pressure systems will achieve the following:

- ✓ Extraction of 11.6 million standard cubic feet of gases sent to the flare to be burned. This amount of gases is equivalent to 2,204 barrels of oil per day.
- ✓ Depending on the price of oil (1 barrel of oil = $70), $154,240 will be earned per day.
- ✓ Reducing heat radiation, pollutants and greenhouse gases that affect human health.
- ✓ Absorbing gases from the flare will reduce the back pressure on the flare head.

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