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Study on External Costs of Flare Gases Using Asian Development Bank Method

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One of the safest pressure relieving systems in oil and gas refineries as well as petrochemical complexes, is the flare gases network using the flare stack as last component of network. Burning this gas mixture in flare stack causes environmental problems such as air and noise pollution and also is Non-economical. Iran, with production of 10.3 10^{12} m^3 of flare gases - is ranked as 3rd place in the world on 2008, therefore flare gas recovery seems more valuable and economical in Iran. In this paper a step by step approach and calculations for flare gas recovery benefits of Tabriz refinery is discussed first, then Asian Development Bank method is reviewed and used for calculating external costs. The method contains data gathering of flare gases composition and conditions, simulating of data and calculating financial benefits for the case study by available equations. For external cost calculation; CO_2, SO_2 and NO_x yearly emissions are calculated for Tabriz Refinery, then economical benefits of preventing pollution emissions are calculated using Asian Development Bank method.
Calculation shows 23.2 M USD gains each year in the case of preventing flare gases emission in Tabriz refinery.

1. Introduction

Even in most advanced countries only a decade has passed from flare gas recovery modern technology, thus the method is of new methods for application in refineries wastes. Of such countries active in flare gas recovery are USA, Italy, the Netherlands, and Switzerland. To recover flare gas, flare gas after collecting from header and flare knock-out drum, passes through a compressor. The compressor design and selection is the main part of plan. After gas compression based on refinery structure or related unit, the gases used as a feed or fuel. If required, to reach entrance gas temperature to flare gas recovery unit and external gas temperature from this unit to an optional temperature, thermal transformers are used. Figure1 shows a general view of a flare gas recovery unit.

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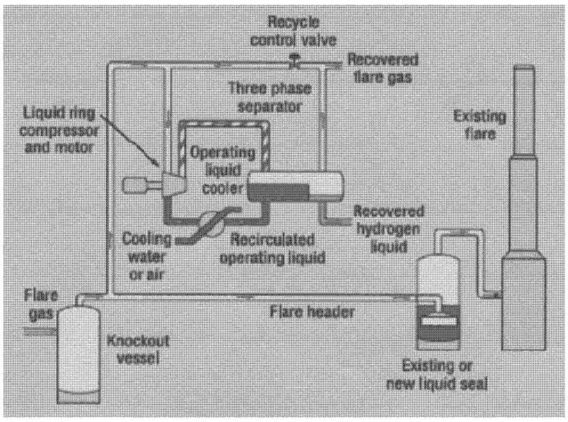

Fig. 1: A view of a Flare Gas Recovery Unit (Fisher and Brennan, 2002)

To compress gases and to design flare gas recovery unit, in general, liquid ring compressors and or reciprocating compressors are used. Advantage of first type is that gas is dried during compression by heat transfer of gas through water inside compressor (usually water). It is possible to use amine instead of water in such compressor to separate hydrogen sulphide from flare gases (Peterson and Tuttle, 2007). Reciprocating compressors are purchased easily than the first type, also spare parts provision, repair and maintenance is much easier. If using reciprocating compressors explosion will appear if temperature exceeds over allowable limit.

2. Pollution of Flares

As it was already mentioned, each industrial unit and refinery based on type of manufactured products and waste materials and also industrial and chemical processes, may create pollution. These pollutants may result in polluting weather, air, soil and may cause a serious damage to human and ecosystem. Table 1 shows health effects of flares pollution. Besides burning gases in flare will create smoke in which sometimes it causes problem for vision and decreases radius of vision in which it is one of the potential dangers may causes aerial incidents, flare may produce unpleasant smell as a result of burning gases and circulating aromatic materials and sulphur dioxide is bothersome at residential and administrative places which are located around of refineries. Beside annoying sound of flares they do not have beautiful appearance and cause visual pollution. Burning gases in refineries will result in fundamental damages to environment in which some of the most important of them include:

1- Environmental pollution specially air pollution

Mentioned items -especially second one - are causes of the worst problem of humanity in 20th century: climate changes. Greenhouse gas emissions have increased by approximately 27.38 % between 1990 and 2007. (Crilly and Zhelev, 2009)

Table 1: Pollutants of flare and their health effect (Andalib Moghadam, 2007)

Chemical Name	Health Effect
Ozone in Land(O_3)	In low densities eye will stimulate and in high densities especially children and adults it will cause respiratory problems.
Sulphide Hydrogen(H_2S)	In low densities it will effect on eye and nose which result in insomnia and headache.
Dioxide Nitrogen	It will effect on depth of lung and respiratory pipes and aggravates symptoms of asthma. In high densities it will result in meta haemoglobins which prevents from absorption of oxygen by blood.
Particles Matter(PM)	There is this believe that it will result in cancer and heart attack.
Dioxide of Sulphur	It will stimulate respiratory system and as a result aggravating asthma and bronchitis.
Alkanes Including Methane, Ethane, Propane	In low densities it will result in swelling, itching and inflammation and in high densities it will result in eczema and acute lung swelling.
Alkenes Including Ethylene, Propylene	It will result in weakness, nausea and vomit.
Aromatics Including Benzene, Toluene, Zaylin	It is poisonous and carcinogenic. It influences on nerve system and in low densities it will result in blood abnormalities and also it will stimulate skin and result in depression.

3. Approximation of flares external cost

3.1 General

An external cost, also known as an externality, arises when the social or economic activities of one group of persons have an impact on another group and when that impact is not fully accounted, or compensated for, by the first group. (Busquin, 2003) Since external costs are raised and introduced at economical topics as a factor for defeat of market, thus at first the concept of external effects in economy shall be specified and then the procedure of valuing and its different types at environmental and economical concepts shall be studied then the best method shall be extracted, so that we will be able to observe monetary value on environment and damages as a result of environmental pollution. For calculating flares external costs, air pollution as a major and most harmful effect of flare will be discussed.

Air pollution, as a result of flaring, shall be studied in two categories:

1-In first category environmental damages causes by air pollution will categorize under monetary values.

2- In second one medical cost of acute diseases as a result of air pollution will categorize under monetary value

Then according to type of incurred damage as a result of discharging pollution by flaring, the external costs will be calculated.

For environmental valuing of flaring, industrial and technical aspect of air pollution have main status. Medical costs and also coefficients of distributing pollution of industries will be shown as logical relations.

Many different methods have been developed for calculating external costs which we can categorize them as below: (Abaspour, 2007)

1-The physical linkage approach
2-A.E.M. (Averting Expenditure Method)
3- T.C.M. (Travel Cost Method)
4- H.P.A. (Hedonic Price Estimate)
5- C.V.M. (Contingent Valuation Method)

3.2 Asian development bank method

Asian development bank - in 1996 -introduced a method for calculating external costs. In this method - which is used in this paper - the external cost data of a developed country is settled and referenced for calculation. (Abaspour, 2007) Then a coefficient will be calculated according to Formula 1:

$$Asian\ \ Development\ Bank\ Method\ Coefficient = \frac{GDP_{(PPD)_1}}{GDP_{(PPD)_2}} \quad (1)$$

Which:

$GDP_{(PPD)1}$: Gross Domestic Production for a referenced country
$GDP_{(PPD)2}$: Gross Domestic Production for a subject country

After calculating Asian development bank coefficient and multiplying it in pollution cost of referenced country; contaminant cost for subject country is calculated as a result. (Abaspour, 2007).

4. Case Study

Tabriz oil refinery flaring system is used as a case study. In Tabriz Refinery, flare gases run to flare towers with 1 bar pressure, 635 kg/h flow, 90°C and the following composition percentage:

Table 2: Tabriz oil refinery component composition (Younessi Sinaki et al., 2010)

Chemical Name	Component Composition Percentage
H_2	0.43
C_1	0.1
C_2	0.3
C_3	0.02
C_4	0.1
C_5	0.0
H_2S	0.05

Inlet feed of Tabriz oil refinery is 110,000 bbl/d, which is approximately: 14,600,000 m^3/y.

$$Inlet\ Feed\ Flow\ Rate = 110{,}000[\frac{bbl}{d}] * 363.63[\frac{l}{bbl}] * 365[\frac{d}{y}] * 0.001[\frac{m^3}{l}] = 14{,}599{,}745 m^3 \quad (2)$$

Air contaminates of flares are SO_2, CO_2 and No_x, (EPA, 1998) studies shows that for each m^3 of inlet feed for oil refineries, mentioned contaminant can be calculated as below Table:

Table 3: Contaminant quantity per each m^3 of inlet feed for oil refineries (Deslauriers, 1996)

Contaminant Name	*Grams of contaminant per each m^3 of Inlet Feed*
SO_2	0.077
CO_2	0.012
NO_x	0.054

As discussed before for using Asian Development Bank method we have to use a referenced country data and calculated information, using USA calculated data, air contaminant external cost have been calculated according to Table 4.

Table 4: Calculated Air contaminant external cost (The World Energy Council, 1996)

Contaminant Name	External Cost ($/g) of contaminant
SO_2	12.5
CO_2	0.02
NO_x	4.8

Last step for our calculation is using Asian development method as formula1; the result is appearing as formula 3:

Asian Development Bank Coefficient= 1.05/0.8=1.3 (3)

We have used USA available information as a referenced country, for Tabriz oil refinery, case study; we can calculate contaminant and pollution production and their cost as Table 5, then we can summarized cost and multiply it at Asian development Bank coefficient (1.3).

Total Contaminant Price=
*14,052,254+3,503+3,784,253=17,840,011 $/y *1.3=23,192,015 $/y*

Table 5: Calculated contaminant for one year production of Tabriz Refinery

Contaminant Name	kg of contaminent/m^3 of Inlet Feed	Contaminant Production (kg/y)	External Cost ($/g) of contaminant	Gain Profit ($/y)
SO_2	0.077	1,124,180	$12.5*10^{-3}$	14,052,254
CO_2	0.012	175,197	$0.02*10^{-3}$	3,503
NO_x	0.054	788,386	$4.8*10^{-3}$	3,784,253

5. Conclusion

By burning 10.3 billion m^3 of flare gases in the year 2008, Iran was regarded as third country polluting environment (The World Bank International Finance Corporation, 2008). Recycling these gases (FGR) and using them as raw material of other units or using their heat energy is the least activity can be done by any country. Studying FGR method shows US$ 105,000 gain for each year in the case of using flares gases as feed instead of burning them. (Younessi Sinaki et al., 2010)

As it has been described, Asian Development Bank Method shows prevention of pollutant emission has greater impact in comparison of flare gases energy recovery.

In other hand environmental protocols -Kyoto protocol for example-has restricted pollutant emissions. Considering 13th place of Iran in greenhouse gases emission (Oak Ridge National Laboratory, 2011), recovering flare gases - FGR unit- to use energy and environmental benefits simultaneously is proposed as the best solution.

References

Abbaspour, 2007, Energy, Environment and sustainable Development, Sharif University of Technology Press, Tehran, Iran. Ed.1

Andalib Moghadam S.H., 2007, Flares and their environmental effects, 1st Professional Iranian environmental conference, Environmental department of Tehran University, Tehran, Iran, Paper No.51, 76 – 82

Busquin P., 2003, External Costs Research results on socio-environmental damages due to electricity and transport. Directorate-General for Research, Information and Communication Unit, EC Brussels, Belgium.

Crilly D. and Zhelev T., 2009, Expanded Emissions and Energy Targeting: A Further Application of CO2 Emissions Pinch Analysis (CEPA) to the Irish Electricity Generation Sector, Chemical Engineering Transactions, 18, 75-81.

Deslauriers M., 1996, Waste Incineration Flaring In Oil Refinery, Environment Canada Criteria Air Contaminants, Division Pollution Data Branch.

EPA AP-42, 1998, Completion of Air Pollution Emission Factors, Vol.1: Stationary Point and Area Sources, Fifth Edition.

Fisher P. and Brennan D., 2002, Minimize Flaring With Flare Gas Recovery, Hydrocarbon Processing, June 2002, 83-85.

Oak Ridge National Laboratory, 2011 <www.ornl.gov> accessed 23.02.2011

Peterson J., Tuttle N., Cooper H. and Baukal C., 2007, Minimize Facility Flaring, Hydrocarbon Processing, 111–115.

The World Bank International Finance Corporation, 2010, <go.worldbank.org> accessed 23.02.2011

The World Energy Council, 2011 < www.worldenergy.org > accessed 23.02.2011

Younessi Sinaki S., Omidkhah M.R. and Tarighaleslami A.H., 2010, Study on flare gas recovery (FGR) to minimize waste and economical benefits, 17th regional symposium on chemical engineering, Bangkok, Thailand, ISBN: 978-974-466-513-3