

STUDY ON FLARING SYSTEM FOR SOUR GASES IN OIL FIELDS IN INDONESIA

by

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ABSTRACT

Many of the oil fields in East Java, Indonesia, are known to contain sulfur in amounts sufficiently high that the crude oil or the associated gases are considered sour. The sour gases have to be handled accordingly in order to prevent the workers and the surrounding communities suffering from the toxic gas.

The flaring system for disposing of the sour gases normally applied in oil fields in Indonesia has been evaluated in this study. Flare Stacks typically attempt to convert hydrogen sulfide (H_2S) in sour gas streams into sulfur dioxide (SO_2) and water. The amount of SO_2 emitted does not solely depend on the H_2S content of the gas, but also on the internal physical factors, such as flare gas flow rate, flare gas heat content, flare gas exit velocity, and external factors such as cross wind velocity.

This study focuses on the evaluation of the influence of the physical factors, especially flare gas flow rate and wind velocity, on SO_2 emission. In order to comply with the regulation the study also attempts to search the Government of Indonesia Regulations which are suitable for this purpose.

Key words : sour gas, flaring, hydrogen sulfide

I. INTRODUCTION

Flaring has been used primarily to dispose of gases in oilfields where the gas volumes are too small or the sites too remote, to make pipelining and gas processing economic. Due to government and industry commitments to reduce the amount of flaring, as well as the rising economic value of natural gas, more of the gas is now being piped to processing plants.

Flare Stacks typically attempt to convert hydrogen sulfide (H_2S) in sour gas streams into sulfur dioxide (SO_2) and water. Since most of the gas streams in question contain carbon dioxide (CO_2), a fire retardant, the result is an incomplete process and leads to no overall reduction in the toxicity of the gas stream.

At some facilities, flares have been replaced with more efficient incinerators. Previously incineration had been used primarily at smaller gas processing plants where the gas volumes or H_2S concentrations were too low to make sulfur recovery economic.

Due to a world oversupply of sulfur relative to demand, and resulting low prices, sulfur extraction has become less attractive economically. Sulfur stockpiles at gas processing plants represent an expense and a potential disposal problem. This provides an additional incentive for sour gas producers to seek alternatives such as acid gas injection.

Many of the oil fields in East Java, Indonesia, are known to contain sulfur in amounts sufficiently high so that the crude oil or the associated gases are considered sour. The sour gases have to be handled accordingly in order to prevent the workers and the surrounding communities suffering from the toxic gas. Flare Stacks typically attempt to convert hydrogen sulfide (H_2S) in sour gas streams into sulfur dioxide (SO_2) and water. The amount of SO_2 emitted does not solely depend on the H_2S content of the gas, but also on the physical factors, such as flare gas flow rate, flare gas heat content, flare gas exit velocity, cross wind velocity, etc.

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II. METHODOLOGY OF THE STUDY

A. Regulation search and interviewing

Regulation search is conducted by searching available Government of Indonesia (GOI) Regulations (*Peraturan Pemerintah*, PP), including Ministerial Decrees (*Keputusan Menteri*, *Kep. Men.*). Interviewing is conducted with Directorate General of Oil and Gas, cq. Directorate of Techniques and Environment.

B. Dispersion calculation

Using gas composition, stack parameters and atmospheric factors, calculation of SO₂ content are conducted using parameters as follows:

- Pollutant Emission Concentration
- Downwind maximum concentration of the pollutant. Equation used for the calculation is based on the formula suggested by Pasquill and modified by Gifford¹.
- Emission rate (g/s)
- Stack height (m), and
- Meteorological Parameters (Wind speed, m/s, Wind direction, and Atmospheric stability)

III. RESULTS AND DISCUSSIONS

A. Emission Standards

There is no specific regulation in Indonesia concerning the flaring of sour gases. Upon searching the available regulations, it is found that the Decree of The State Minister of Environment, (Kep. MenLH No. 129/2003²), describing Emission Standards for Oil and Gas Activities, is suitable for evaluating the flare system. It is stated in the Attachment-I of the regulation that opacity is the only parameter that has to be complied to.

Unfortunately, no other compliance parameters such as H₂S, SO₂, or NO_x, are described in the regulation.

Other regulations that can be referred to for the emission standard of those gases is Kep. MENLH No. 13/1995³ describing Emission Standards for Point Sources (Attachment VB, Emission Standard for Point Sources of Other Activities). The Attachment VB of the regulation does not explicitly describe provisions for oil and gas activity, instead other industries that are not covered by the Attachment IB (Iron and Steel Industry), Attachment IIB (Pulp and Paper Industry), Attachment IIIB (Coal Generated Power Plant), and Attachment IVB (Cement Industry). Table 1 shows the emission standard as described in the Attachment VB of the regulation.

B. Ambient Air Standards

Upon flaring the sour gas, hydrogen sulfide (H₂S) will be burned to sulfur dioxide (SO₂). In the worst case when the flare extinguishes, H₂S will be dispersed to the ambient air. This gas is heavier than air and it will be distributed downward. Since H₂S is toxic, it is worthy to refer to the existing regulation that describes the maximum concentration level of the gases (H₂S and SO₂) in the ambient air.

Table 1
Emission standard as described in Kep. MENLH No. 13/1995

No.	Parameters	Units	Threshold Limit
1	Ammonia (NH ₃)	mg/m ³	0.5
2	Chlorine (Cl ₂)	mg/m ³	10.0
3	Hydrochloric Acid (HCl)	mg/m ³	5.0
4	Hydrofluoric Acid (HF)	mg/m ³	10.0
5	Nitrogen Dioxide (NO ₂)	mg/m ³	1000
6	Opacity	%	35
7	Particulate	mg/m ³	350
8	Sulfur Dioxide (SO ₂)	mg/m ³	800
9	Total Reduced Sulfur as H ₂ S	mg/m ³	35
10	Mercury (Hg)	mg/m ³	5.0
11	Arsenic (As)	mg/m ³	8.0
12	Antimon (Sb)	mg/m ³	8.0
13	Cadmium (Cd)	mg/m ³	8.0
14	Zinc (Zn)	mg/m ³	50.0
15	Lead (Pb)	mg/m ³	12.0

Table 2
National Ambient Air Standard

No.	Parameters	Units	Exposure (hour)	Threshold Limit
1	Sulfur Dioxide (SO ₂)	ug/Nm ³	24	365
2	Carbon Monoxide (CO)	ug/Nm ³	24	10.000
3	Nitrogen Dioxide (NO ₂)	ug/Nm ³	24	150
4	O ₃ (Ozone)	ug/Nm ³	1	235
5	Hydrocarbon (HC)	ug/Nm ³	3	160
6	Particulate < 10 um (PM10)	ug/Nm ³	24	150
7	Particulate < 2.5 um (PM2.5)	ug/Nm ³	24	65
8	Total Suspended Particulate (TSP)	ug/Nm ³	24	230
9	Lead (Pb)	ug/Nm ³	24	2
10	Dustfall	ug/Nm ³	30 day	10 tons/Km ² (Settlement) 20 tons/Km ² (Industry)
11	Total Fluorides	ug/Nm ³	24	3
12	Fluor Index	ug/Nm ³	30 day	40 ug/100 cm ²
13	Chlorine & Chlorine oxide	ug/Nm ³	24	150
14	Sulphate Index	ug/Nm ³	30 day	1 mg SO ₃ /100 cm ³

Government of Indonesia Regulation PP No. 41/1999⁴ describing Air Pollution Control can be referred to for this purposes. Table 2 shows the threshold limits of the contaminant parameters. Unfortunately, the regulation does not include H₂S as the contaminant parameter. Article 58 of the regulation states that “all regulations describing air pollution control that still exist and does not controverts to this regulation and it has not been replaced by this regulation is still valid”. It is therefore, in referring to H₂S level in the ambient air, Kep. MenKLH No. 02/1988⁵ is still suitable. This Ministerial Decree states that H₂S concentration in the ambient air is allowed not to exceed 0.03 ppm (42 ug/m³). It should be noted, however, that this Kep. MenKLH No. 02/1988 is only valid for H₂S in ambient air, and not valid for evaluating emission gases since it has been replaced by Kep. MenLH No. 13/1995.

Since this study is focused on H₂S and SO₂, we attempt to summarize the regulation for these parameters. Table 3 shows the threshold concentrations of these parameters either for emission or ambient standard. It is clearly stated that for flaring activity in oil fields only opacity is the only factor to comply to.

Meanwhile, if we have to follow the provision of H₂S and SO₂ parameters for emission standards, we should refer to the Emission Standard for Point Source (Kep. MenLH No. 13/1995) that describes the threshold limit for SO₂ and H₂S, which are 800 mg/m³ and 35 mg/m³, respectively.

It has to be noted, however, that Emission Standard for Point Source described in the Kep. MenLH No. 13/1995 is only valid for waste gases, resulted from the combustion of the materials, which are ready to be emitted to the ambient air. This provision clearly can not be applied to the flare system in which the waste gas is being burned at the end of the gas stream. The gas which has been burned in the flare system is then dispersed to the atmosphere. Emission gas measurement is not possible to be conducted either at the gas stream or at the location nearest to the combustion process. For this purpose, emission gas measurement can only be carried out at certain distance from the combustion source. Once the gas has been emitted to the atmosphere, the only possibility to measure the pollutant concentration is at the ambient air as the receiving media. Therefore, provision for gas emission in flare system is worthy to refer to the

National Ambient Air Standard. Ambient standard for SO₂ refers to PP 41/1999 that requires SO₂ concentration in ambient air not to exceed 365 ug/m³, while those of H₂S concentration refers to Kep. MenKLH No. 02/1988 that requires H₂S concentration in ambient air not to exceed 42 ug/m³.

Both of the pollutant concentrations in the ambient air can be measured directly using SO₂ and H₂S analyzers with regard to the distance of the receptors to the emission source. SO₂ and H₂S concentrations in the ambient air can also be calculated using a dispersion equation model. This calculation is written in this report in Section 3.3: dispersion calculation.

C. Dispersion calculation

Dispersion calculations of the pollutants are carried out using a Gaussian plume model that incorporates source related and meteorological factors (or parameters) to estimate pollutant concentrations from continuous sources. It is assumed that the pollutant does not undergo any chemical reactions, and that no other removal processes, such as wet or dry deposition, act on the plume during its transport from the source. As mentioned in the methodology, equation used for the calculation is based on the formula suggested by Pasquill and modified by Gifford.

In such case when the flare is extinguished, the pollutant will be assumed solely as hydrogen sulfide. When the flare is activated, meaning that the waste gas can be burned, the pollutants will be a mixture of SO₂ resulting from the oxidation of H₂S and unburned H₂S. The amount of SO₂ and unburned H₂S is a func-

tion of the CO₂ content in the gas that determines the combustion efficiency.

According to the available data, the dispersion of the pollutants will be calculated using this data (Table 4).

At a standard condition (0 °C, 1 atm), mass of H₂S can be calculated using the formula below:

$$m_{H_2S} = \frac{Q_{H_2S}}{V_s} \times M_{H_2S}$$

Where:

V_s = molar volume of the gas = 22.414 m³/kmol

M_{H₂S} = molecular weight of H₂S = 34.082 kg/kmol

Hence m_{H₂S} is 1,271 kg/d, and mass of H₂S being burned is also 1,271 kg/d.

Physical factors used in the dispersion calculation are assumed to be: Effective stack height is 20 m, Wind speed is 3 m/s, and Atmospheric stability is Moderate/Stable (C class).

Determination of SO₂ emission:

Combustion rate of H₂S (combustion efficiency is considered to be 100%)

Reaction: H₂S + 3/2O₂ = SO₂ + H₂O (1 mol of H₂S produces 1 mol of SO₂)

Mol of H₂S is 37 kmol/d

Mol of SO₂ produced is 37 kmol/d

Rate of SO₂ produced is 2,390 kg/d SO₂

Hence Q_{SO₂} is 28 g/s

Table 3
Allowable Maximum Concentration of H₂S and SO₂ for emission gases and ambient air

Parameters	Concentration			
	Emission Gas		Ambient Air	
	Kep. MenLH No. 13/1995 (Attachment V B) Emission Standard for Point Source	Kep. MenLH No. 129/2003 (Attachment I) Emission Standard for Oil and Gas Exploration and Production	PP. No. 41/1999 (Attachment I) National Ambient Standard	Kep. MenKLH No. 02/1988 (Attachment III) Ambient Standard
SO ₂	800 mg/m ³	-	365 ug/m ³	-
H ₂ S	35 mg/m ³	-	-	42 ug/m ³
Opasitas (Flare Stack)	-	40%	-	-

Maximum concentration of SO₂ at certain distance

Nearest settlement to the flare	1,000	<i>m</i>
Lateral diffusion coefficient s_y	120	<i>m</i>
Vertical diffusion coefficient s_z	70	<i>m</i>
C_{max} of SO ₂ at the distance of 1 km	0.00033542	<i>g/m³</i>
	335	<i>ug/m³</i>
	0.12	<i>ppm-vol</i>
Ambient threshold limit of SO ₂ (PP.41/1999)	365	<i>ug/m³</i>
	0.13	<i>ppm-vol</i>
When flare extinguished		
Q H ₂ S	37k	<i>mol/d</i>
	1,271	<i>kg/d</i>
	14.7	<i>g/s</i>
C_{max} of H ₂ S at the distance of 1 km	0.00017844	<i>g/m³</i>
	178	<i>ug/m³</i>
	0.12	<i>ppm-vol</i>
Ambient threshold limit of H ₂ S (Kep. MNLH 02/88)	42	<i>ug/m³</i>
	0.03	<i>ppm-vol</i>
OSHA Standard for H ₂ S (Odor Threshold)	0.02	<i>ppm-vol</i>

Results of the dispersion calculation indicate that only certain value of production rate of crude oil (hence the production of associated gases to be burned) can use flare system. In this study it is found that for a production rate of crude oil at 5000 bpd (barrels per day), the SO₂ concentration in the ambient air with a distance of 1 km from the emission source is 335 ug/m³. This value can be regarded as a limit for the crude oil production rate, otherwise the SO₂ concentration in the ambient air will exceed the ambient air standard. 1 Km distance has been chosen as a distance limit, since in the populated area such as Blora and Bojonegoro Regencies the public settlements are very close to the oil fields.

D. Alternatives technologies

Alternative technologies are needed when a flare system for sour gas is not suitable, or crude oil production rate would be increased. There are two approaches that can be used to alternate direct flaring technique. This would be sulfur removal/recovery system and sub-surface injection⁶.

One of the sulfur removal or recovery unit uses Claus process, in which H₂S is oxidized to free sulfur. The elemental sulfur formed is sold to

customers and is used mainly in the manufacturing of phosphate fertilizers. Some sulfur is also used in making products such as pharmaceuticals, plastics and matches.

Environmental concern over global warming due to greenhouse gas emission has given ever rising importance to the re-injection of waste gases in oil fields; either for reutilization to Enhance Oil Recovery (EOR) or just simple disposal to a depleted reservoir to avoid atmospheric venting. Moreover, with the growing acceptance of H₂S re-injection as a feasible alternative to costly sulfur, a number of very sour gas wells can be reconsidered as exploitable to produce much needed natural gas.

Acid gas re-injection to a disposal reservoir will provide the simplification and cost reduction to make exploitation of the sour gas reserves attractive even in a low gas price scenario. Neither CO₂ nor sulfur emissions are emitted to the atmosphere. Re-injection of sour gases is very promising; nevertheless the discussion of this topic is beyond the scope of our study.

IV. CONCLUSIONS AND RECOMMENDATIONS

Upon completing the study on flaring system for sour gases some conclusions and recommendations can be made as follows:

A. Conclusions

- There are no recent Indonesian Regulations specifically regulating the flaring of sour gases. The only parameter that should be complied to is opacity as described in

Table 4
Crude oil and gas data

Parameters	Concentration	Unit
Gas Oil Ratio (GOR)	381	<i>scf/STB</i>
Q (flow rate) oil production	5	<i>bpd</i>
Q gas	1,905,000	<i>scf/d</i>
	53,944	<i>m³/d</i>
H ₂ S content	1.55	<i>%-mol</i>
$Q_{H2S} = Q_{gas} \times C_{H2S}$	836	<i>m³/d</i>

Kep. MenLH No. 129/2003), Emission Standard for Oil and Gas Exploration and Production.

- No other parameters, such as H₂S and SO₂ are described in the regulation. For a flaring system of H₂S and SO₂ emissions it is worthy to refer to ambient standard as described in Kep. MenKLH No. 02/1988 and PP. No. 41/1999, respectively, rather than emission standard as described in Kep. MenLH No. 13/1995.
- When a flaring system has to be used for emitted sour gases, especially in a populated area, only limited portion of the gas can be burned depending on the gas oil ratio (GOR) and the H₂S content, otherwise the concentration of the emission gases in the ambient air will exceed the allowable concentration.
- H₂S and SO₂ concentration in the ambient air can be measured directly using analyzers or can be calculated using a dispersion equation model.

B. Recommendation

- It is recommended to review the existing regulations for the emission of H₂S and SO₂ gases in oil field flaring systems in Indonesia.
- Re-injection is an alternative technology to a flare

system of sour gases and it is recommended to be investigated in more detail.

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