

Report and Technical Protocol for the Monitoring and Regulation of Flaring from Oil Refineries in South Africa

CONTRACT: UEM-STTA-M-2006-1

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22 October 2007

TABLE OF CONTENTS

1. Introduction.....	3
1.1 Overview of the South African Oil Refining Industry.....	3
1.2 Motivation for Monitoring and Regulation of Oil Refinery Flare Emissions.....	4
1.3 Summary of Complaints of Flaring Incidents from communities in the vicinity of South African refineries	4
1.4 Objectives of this Protocol.....	5
2. Flaring Systems.....	6
2.1 General description of typical flare system.....	6
2.2 The health and environmental impacts of pollutants emitted from Refinery Flare Systems..	8
3. International Background to the Monitoring and Regulation of Oil Refinery Flare Emissions ...	8
3.1 Summary of Reports showing that flare emissions may be a significant proportion of total refinery emissions	8
3.2 Best Practices for the control of flaring and other non-stack emissions in the United States, Canada, the United Kingdom and the European Union.....	8
4. Description of Flaring Systems at South African Oil Refineries.....	10
4.1 Overview of Flaring Systems at South African refineries	10
5. PROTOCOL: Framework for Monitoring	12
5.1 Streams to be monitored	12
5.2 Technical Requirements of flare monitoring	12
5.3 Video Camera monitoring and archiving.....	13
5.4 Draft Regulation for Monitoring and Reporting Oil Refinery Flaring Emissions.....	13
5.5 Timeframes and costs of implementation	13
6. Conclusions and Recommendations	14
Appendix 1: Draft Regulation for Monitoring of Flaring at South African Petroleum Refineries.....	15

1. INTRODUCTION

1.1 Overview of the South African Oil Refining Industry

The Oil Refinery Industry is one of the major industrial sectors in South Africa. SAPIA, the South African Oil Industries Association, represents South African oil refining and marketing companies. Table 1 summarises the association between SAPIA Members and Oil Refining Operations.

Table 1: SAPIA Members in relation to Oil Refining Operations¹

Company	Refinery	Location	Type
BP Southern Africa	SAPREF	Durban/ eThekweni	Crude oil
Shell SA	SAPREF	Durban/ eThekweni	Crude oil
Engen	Enref	Durban/ eThekweni	Crude oil
Chevron	Calref	Cape Town	Crude oil
Sasol	Natref	Sasolburg	Crude oil
Sasol	Secunda	Secunda	CTL (Coal To Liquids)
PetroSA	PetroSA Refinery	Mossel Bay	GTL (Gas To Liquids)
Total	none		

The total oil industry's turnover in 2005 was R109 billion with total assets of R57 billion².

The growth in oil refining capacities is shown in Table 1 below:

Table 2: Capacity of South African Refineries²

Refineries	Capacity (bbl/day)		
	1992	1997	2005
Sapref	120 000	165 000	180 000
Enref	70 000	105 000	125 000
Calref	50 000	100 000	100 000
Natref	78 000	86 000	108 000
Sasol *	150 000	150 000	150 000
PetroSA *	45 000 [§]	45 000	45 000
Total	513 000	651 000	708 000

* Crude equivalent

§ PetroSA came on stream in 4th quarter 1992

Table 3 below shows actual refining capacity based on maximising petrol production and assumes a 92% capacity availability². The projected figures for 2012 show the expected range of demand for petroleum products based on low and high demand scenarios against anticipated 2012 refining capacity. The 2012 projections take into account the need to produce cleaner fuels but not any increases that may be made by the companies concerned in the period up to 2012. (Shortfalls may be met by planned imports.)

¹ SAPIA 2005 Annual Report, www.sapia.co.za

² SAPIA 2005 Annual Report, www.sapia.co.za

Table 3: Demand / Refining Capacity Balance

Refineries	Millions of litres							
	2005			2012				
	Refining Capacity Actual	Demand Actual	Surplus / (shortfall) Actual	Refining Capacity	Low growth demand	Low growth surplus / (shortfall)	High growth demand	High growth surplus / (shortfall)
Petrol	13 300	12 106	1 194	13 000	13 440	(440)	15 400	(2 400)
Diesel	9 000	9 091	(091)	9 300	10 090	(790)	11 570	(2 270)
Kerosene*	3 700	3 044	656	3 800	3 380	420	3 870	(70)

* Kerosene includes jet fuel and illuminating paraffin

1.2 Motivation for Monitoring and Regulation of Oil Refinery Flare Emissions

Worldwide, oil refineries are recognised as a significant, if not the major source of air pollution in areas in proximity to the refineries, with concomitant human health and environmental impacts on surrounding communities. The severity of these impacts may be mitigated through regulation, monitoring and enforcement of design and operational standards aimed at reducing emissions to an acceptable minimum. Oil refineries are complex installations involving a multiplicity of process units, storage and waste treatment facilities. Air pollutants arising from refineries are discharged via stacks, flaring operations and as fugitive emissions from multiple sources. The relative contributions to total emissions and impacts from these three broad source categories depend on both design and operational features of specific refineries. The operational control and regulation of these different source categories require significantly different approaches.

Flaring is commonly used in the oil refining and petrochemical industry to deal with emergency events and plant malfunctions. Properly used, it allows process equipment to release vapour and gases to a device (the flare) which incinerates the gases to prevent fires and explosions. Incineration also converts noxious gases to less hazardous and offensive emissions. However, evidence (US EPA) suggests that flaring is frequently used improperly i.e. in non-emergency situations. The practice may also be used to by-pass pollution control equipment.³

In the UK and US, flaring is regulated though not always adequately. In SA there are currently no regulations governing the practice of flaring, resulting in the unregulated release of SO₂, H₂S and various hydrocarbons and particulates, which are harmful to human and environmental health.

1.3 Summary of Complaints of Flaring Incidents from communities in the vicinity of South African refineries

Residents, local environmental groups, healthcare workers in the communities, and municipal and other officials including Environment Health Services in the vicinity of a number of South African refineries, have complained numerous times over the past few years about pollution emanating

³ US EPA *Enforcement Alert*, Vol 3 No. 9 (October 2000)

from these refineries. They report exposure to sulphurous odours, 'fallout' and intense heat. Exposure to these factors causes discomfort and breathing difficulties for adults and children. The incident reports provided by the refineries in response to various complaints and to criticism in the media show a disturbing list of flaring and other releases, variously ascribed to plant equipment, process and power failures, giving rise to numerous 'flaring incidents'. The reports indicate that the releases contain methane, ethane, propane, and other light hydrocarbons, CO₂, SO₂, H₂S and 'sulphur'. However, since the emissions were not sampled and analysed, the list of actual pollutants released and the concentrations in the discharged streams are essentially unknown. A smoking flare, for example, indicates the presence of particulates and products of incomplete combustion, such as elemental carbon and polycyclic aromatic hydrocarbons (PAHs). Both elemental carbon and PAHs are injurious to health. However, the refinery reports make no mention of these pollutant releases. In some cases the severity and duration of the 'flaring incidents' is disputed. In the absence of objective scientific methods of monitoring these flaring events, such disputes cannot be resolved.

Experience in the Bay Area Air Quality Management District of California (USA) is that the very process of monitoring and reporting of flare emissions motivates refineries to reduce these emissions.⁴

1.4 Objectives of this Protocol

The primary objectives of the protocol are to:

- Define a technical scheme for the monitoring of flares, tailor-made for SA refineries, taking cognisance of international standards and practices in all respects, including procedures for monitoring, prescriptions for what to monitor, prescriptions for data management, prescriptions for threshold values and events and responses to excessive flaring emissions, etc.
- Provide proposals for implementation of the proposed scheme
- Provide a budget level estimate for the implementation of the scheme

From a technical point of view, based on the protocol, the scheme should be directly implementable via regulatory instruments.

A secondary objective is capacity building and training of regulators and the collation of information on the refineries' current flaring systems.

The primary objectives will be addressed in the body of this protocol. The training objective was addressed through the two capacity-building and training workshops, based on an earlier draft of the Protocol.

A summary of the results of the questionnaires distributed to the refineries as well as information gathered through site visits is included in this report.

⁴ Alex Ezersky and Bill Guy, Proposed Regulation 12, Rule 11: Flare Monitoring at Petroleum Refineries, May 2003

2. FLARING SYSTEMS

2.1 General description of typical flare system

Flaring systems in the oil refining and petrochemical industry are used to deal with emergency events and plant malfunctions. Process equipment in danger of exceeding safe operating conditions vent gases to the flare system (or systems), which incinerates the gases prior to discharge to a flare stack. Combustion in the flare is intended to convert flammable and toxic gases to less hazardous and offensive emissions. However, combustion efficiency is invariably less than 100%, implying that a fraction (2 to 20%) of the vent gases is discharged directly to atmosphere.

The components of a typical flare system are a header, which combines flows from different sources into a single line, a knock-out drum, to remove entrained liquid droplets, a water seal, to prevent flow-back of flammable material, a flare stack and the flare tip. Combustion takes place at the flare tip, which is supplied with pilot gas to maintain a flame in anticipation of demand for gas flaring and with steam to promote air-fuel mixing and improved combustion. Alternate methods of igniting the flammable vent gas are available which eliminate the need for a constant pilot flame. Flare systems are generally designed to process hydrocarbon gas flows that have low sulphur (H₂S) content ('sweet gas'). Sulphur recovery plants (processing nearly 100% H₂S streams to elemental sulphur) usually have separate incineration systems to deal with upstream system failures; the incinerator off-gas (high in SO₂) may be combined with other streams for discharge to a high level stack. In an alternative configuration, acid gas (high H₂S, 'sour gas') may be routed to a common stack and flare tip.

South African oil refineries are designed with several different configurations, ranging from single flaring systems to multiple interlinked flaring systems. The specific configurations of local refineries will be described in a later section.

The flaring process can produce a range of pollutants: sulphur dioxide (SO₂), oxides of nitrogen (NO_x), carbon monoxide (CO), Non-Methane Hydrocarbons (NMVOC), methane (CH₄) and carbon dioxide (CO₂). Flare emissions depend on two main factors: the vent (waste) gas composition sent to the flame and the combustion efficiency. In oil refineries, hydrocarbon streams discharged via flare systems ('vent gases') may arise from any of a wide variety of process units (sources), and may include streams that contain BTEX (benzene, toluene, ethylbenzene, xylene), paraffins, hydrogen sulphide (H₂S) and hydrogen fluoride (HF), depending on the process unit origin of the streams. The combustion process, if 100% efficient, converts the hydrocarbons (HCs) to CO₂ and H₂O, and the H₂S to SO₂ and H₂O.

A widely quoted value for flare combustion efficiency is 98%. However, this figure is based on limited 1983 test data; the 1983 tests were done with pure gaseous fuels, under quiescent (windless) conditions.⁵ More recent Canadian studies^{6,7} showed that combustion efficiency is

⁵ Quoted in M.R. Johnson, O. Zastavniuk, D.J. Wilson and L.W. Kostiuk, Efficiency Measurements of Flares in a Cross Flow, *Combustion Canada 1999, Calgary Alberta, May 26-28,1999*.

⁶ M.R. Johnson, O. Zastavniuk, D.J. Wilson and L.W. Kostiuk, Efficiency Measurements of Flares in a Cross Flow, *Combustion Canada 1999, Calgary Alberta, May 26-28,1999*

strongly dependent on wind speed, vent gas exit velocity and energy density (vent gas heating value), and could be as low as 80% under adverse conditions, with wind speed, in general, having the largest influence. At high wind speeds, a dramatic decline in combustion efficiency was observed. The latter report, while valuable with respect to clarifying the relationship between the variables explored, was limited to propane and natural gas fuels, and to non-sooting combustion conditions.

“The conclusions drawn here relate to flares that emit little or no soot. Specifically, these are flare streams where the fuel is composed of methane or propane. Heavy and multi-bounded hydrocarbon fuels either in gaseous or liquid forms have a high propensity to emit soot.”⁷

Further experimental work applicable to vent gasses containing entrained liquids is underway.

The factors that influence combustion efficiency include⁸:

- the steam/fuel gas ratio,
- the (vent) gas heating value
- wind speed
- vent gas exit velocity.

Conditions thought to be required for efficient flare combustion^{4,5}:

- high gas heating value, greater than 20 MJ/m³
- low wind speed conditions, less than 10 m/sec.,
- high gas exit velocity, above 10 m/sec.

Under optimal conditions (low wind speed, high energy density, non-sooting flare, etc), flare combustion may be highly efficient, approaching 99%+ combustion efficiency. However, under more common less than optimal conditions (for example, high wind speed, less than optimal steam/ hydrocarbon ratio), flare combustion would be significantly less than 100% efficient, and may be as low as 80% under adverse conditions. Flare emissions would then consist of considerable quantities of unburnt hydrocarbons and products of incomplete combustion, and unreacted H₂S. A smoking flare indicates poor combustion conditions (insufficient air or air-fuel mixing), and/ or the presence of heavy hydrocarbon components in the vent gas, and hence the emission of particulate matter and unburnt hydrocarbons and products of incomplete combustion.

Flare systems have to be designed for a wide range of flows, ranging from the flow from a single relief valve to a ‘worst case’ maximum demand situation that may be created by a general power failure. Under the latter condition, the design maximum steam flow may not be sufficient for optimum combustion, leading to a heavily smoking flare. The control strategy used to maintain an optimum steam/ hydrocarbon ratio throughout the operating range of the flare system has a considerable influence on the combustion efficiency of the system and hence emissions during a flaring incident.

⁷ Larry Kostiuk and Matthew Johnson, UNIVERSITY OF ALBERTA FLARE RESEARCH PROJECT INTERIM REPORT, NOVEMBER 1996 – JUNE 2000

⁸ EU Emissions Inventory Guidebook: Waste Incineration, **Activity 09020**, wr090203 (1996)

2.2 The health and environmental impacts of pollutants emitted from Refinery Flare Systems

Pollutants discharged from flares may include particulate matter (PM), polycyclic aromatic hydrocarbons (PAHs), hydrogen sulphide (H₂S), sulphur dioxide (SO₂), elemental carbon, hydrofluoric acid (HF) gas, unburnt hydrocarbons, nitrogen oxides (NO_x), methane, benzene, carbon dioxide (CO₂) and carbon monoxide (CO). The impacts of flare emissions therefore include the health impacts associated with exposure to these pollutants, and the ozone forming potential (and hence indirect health impacts) associated with hydrocarbon and NO_x emissions, and the greenhouse gas effects of methane and CO₂ emissions.

3. INTERNATIONAL BACKGROUND TO THE MONITORING AND REGULATION OF OIL REFINERY FLARE EMISSIONS

3.1 Summary of Reports showing that flare emissions may be a significant proportion of total refinery emissions

A US study (for the period January 2001 to August 2002) of emissions from a number of oil refinery flare systems in the Bay Area Management District (California) concluded that, on an annual average basis, flare emissions were approximately 8 tons/day of total organic compounds (5 tons/day of non-methane organic compounds) and approximately 20 tons/day of SO_x (mainly sulphur dioxide). The daily emissions ranged from 2.5 to 55 tons/day of total organic compounds, and from 6 to 55 tons/day SO_x.⁹ Flare emissions may therefore be a significant percentage of overall volatile organic compound (VOC) and sulphur dioxide (SO₂) emissions. A smoking flare may be a significant contributor to overall particulate emissions.^{3, 4}

3.2 Best Practices for the control of flaring and other non-stack emissions in the United States, Canada, the United Kingdom and the European Union

Effective regulation of the oil refinery industry, particularly of flaring emissions, is problematic even in countries with considerable experience with the industry.

"Flare emissions are difficult to characterize and can be dependent on a number of factors such as volumetric flow, velocity, vent gas composition, energy content, combustion efficiency, and ambient wind conditions. In order to estimate emissions from flares, the District requires refineries to submit monthly reports showing vent gas flow rates and composition. Vent gas flow rates to the flare are measured by in-pipe monitors prior to combustion. These vent gas flow rates do not represent a direct measurement of emissions from flares."¹⁰

⁹ Ezersky, Alex and Lips, Harold, Characterisation of Refinery Flare Emissions: Assumptions, Assertions and AP-42, Bay Area Air Quality Management District (BAAQMD), 2003

¹⁰ Bay Area Air Quality Monitoring Quality District (BAAMQD), www.baaqmd.gov

The US EPA implemented its national refinery compliance program in 1996. During the period March 2000 to 2006, the EPA entered into 12 global settlements (legally binding 'Consent Agreements') to address areas of regulatory non-compliance with petroleum refiners that together represent more than 40 percent of the domestic (US) petroleum refining capacity. In 2004, the agency's (US EPA) Office of Enforcement and Compliance Assurance ordered an evaluation of the program. Notwithstanding the 'Consent Agreements', the evaluation¹¹ cited a number of important shortcomings, which are instructive. The evaluation report concluded that the program suffered from a lack of:

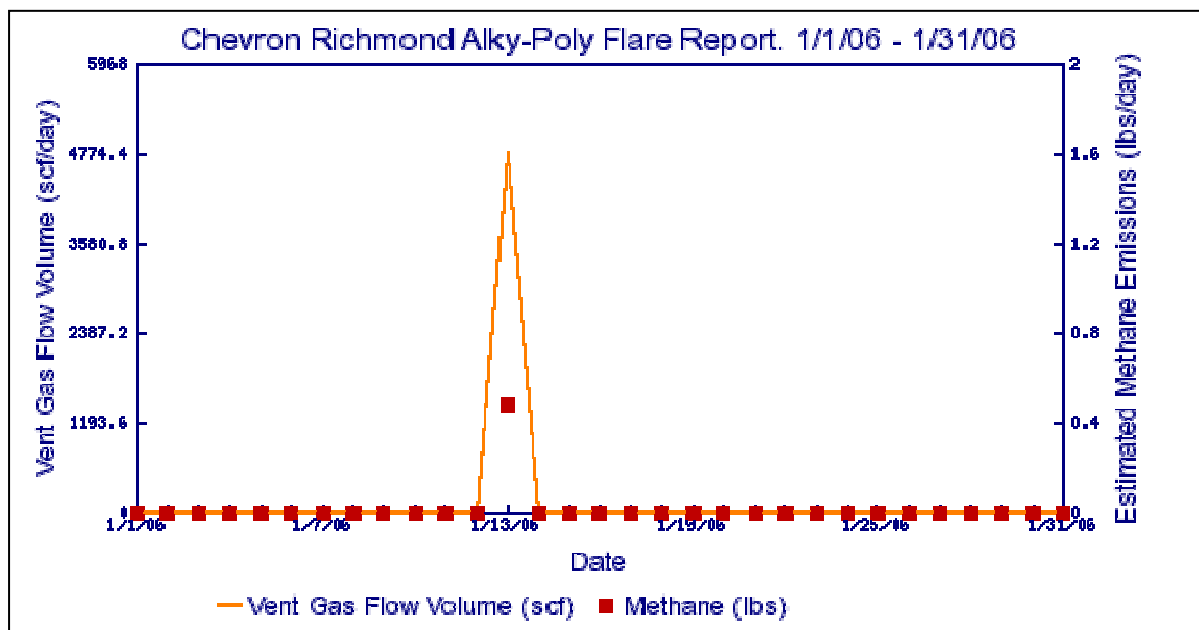
- useful and reliable information
- clear goals
- monitoring
- tracking of consent decree implementation

The evaluators also concluded that the approach taken by the EPA may have caused a delay in emissions reductions and may have compromised compliance.

In spite of this critique of the USEPA's refinery compliance programme, a perusal of several of the consent decrees and the EPA regulations pertaining to control of flaring emissions indicates that this program is a valuable source of information on possible regulatory actions that could be adopted to bring the flaring emissions from South African refineries under control.

The USEPA's Regulation 12, Rule 11 requires flare monitoring at US oil refineries. The technical and administrative provisions of this regulation provide valuable guidance for a similar regulation in SA. Figure 1 is an example of one of the publicly available outputs of the monitoring system in the BAAQMD.

Figure 1: Example of the output of a BAAQMD flare monitoring system



¹¹ USEPA Evaluation Report: EPA Needs to Improve Tracking of National Petroleum Refinery Compliance Program Progress and Impacts, Report No. 2004-P-00021 (June 22, 2004)

An Environment Canada report¹² reviews Canadian regulations (based on similar US regulations) and the efficacy of regulatory practice in controlling fugitive VOC emissions from equipment leaks, storage tanks and process sources. This review report provides guidance on possible regulatory actions in SA, and the extent of emission reduction that could be achieved through similar regulatory and enforcement actions.

The UK Guidance on Effective Flaring in the Gas, Petroleum, Petrochemical and Associated Industries¹³, although now dated (published in 1993) includes a useful technical description of flaring systems, and UK best practice at the time.

The more recent EU reference document on Best Available Techniques (BAT) in the oil refining industry¹⁴ includes a brief update on current flaring practices and provides a reference to BAT in the European oil refining industry.

4. DESCRIPTION OF FLARING SYSTEMS AT SOUTH AFRICAN OIL REFINERIES

4.1 Overview of Flaring Systems at South African refineries

At present there is a lack of (or incomplete) measurement, monitoring and reporting of the flare emissions discharged from South African refineries. The US experience⁹ implies that, in the absence of measurement and monitoring systems, there may be considerable under-reporting of the contribution of flare emissions to total refinery emissions. The absence of measuring and monitoring systems also hampers the quantitative analysis of flaring incidents. Over the past few years, numerous complaints of flaring events origination from the South Durban oil refineries, and the Calref (Chevron) refinery in Cape Town, including reports of black smoke emissions, odorous emissions, unexplained exceedences of SO₂ ambient air quality guideline values have been received. These complaints and the known adverse health effects associated with the pollutants emitted by flares emphasise the importance of introducing a program to accurately measure, monitor and report flaring emissions. This is the first and essential step to exercising regulatory control over these emissions.

The establishment of flare emission standards, with appropriate legal penalties for violating these standards, may follow the proposed regulation for monitoring and reporting these emissions.

Table 4 contains summary characteristics of the flaring systems of four South African oil refineries.

¹² Review of CCME Guidelines and Code of Practice for the Reduction of Volatile Organic Compound Emissions from Equipment Leaks, Aboveground Storage Tanks and Process Sources in the Chemical and Petroleum Refining Sectors, Environment Canada, O/Ref.: 602501, June 2003

¹³ Technical Guidance Note (Abatement): Guidance on Effective Flaring in the Gas, Petroleum, Petrochemical and Associated Industries, London HMSO, November 1993

¹⁴ Reference Document on Best Available Techniques for Mineral Oil and Gas Industries, European Commission, February 2003

Table 4: Summary data for the Flaring Systems of four South African Oil Refineries

Refinery	Nominal Refining Capacity [bbl/d]	Flowsheet(s)	Capacity [kg/h]	Maximum steam flow rate [kg/h]	'Smokeless' burning range [HC/Steam]	Flare stack height [m]	Steam/ hydrocarbon control system	Flow measurement	Composition measurement	Video monitoring (no recording)
Sapref	180 000	HC Flare 1 (low S) – FCCU	260000	25000	[0.5 – 2.5]	100	Yes	Panametrics (ultrasonic flow meter)	Sampling and Lab analysis	Yes
		HC Flare 2 (low S) – CD2/South Zone	260000	25000	[0.5 – 2.5]	100	Yes	Panametrics flow meter.	Sampling and Lab analysis	Yes
		HC Flare 3 (low S) – CD3 North Zone	260000	25000	[0.5 – 2.5]	100	Yes	Panametrics flow meter.	Sampling and Lab analysis	Yes
		Flare 4 (Ex SRU?) – H2S Flare South zone	7250	n/a		100	No	Panametrics flow meter.	Sampling and Lab analysis	Yes
		Flare 4 (Ex SRU?) - H2S Flare South zone	7250	n/a		100	No	Panametrics flow meter.	Sampling and Lab analysis	Yes
		Flare 4 (Ex SRU?) - H2S Flare South zone	7250	n/a		100	No	Panametrics flow meter.	Sampling and Lab analysis	Yes
Enref	125 000	North Flare, headers, blowdown drum, water seal, flare stack, tip	902 000	8 000	15-20%?	56	steam/ hydrocarbon ratio control	Ultrasonic mass flow meter	Currently estimated; automatic sampling system being installed	Yes
		South Flare	407 500	10 000	15-20%?	53				Yes
Calref	100 000	Sweet gas header; knock-out drums, single flare stack/ tip	Power Failure case: 122 300	22 300	58%	53	Grade mounted IR smoke detector; variable steam/ hydrocarbon ratio control; manual control based on video monitoring	GE Panametrics GF868 Ultrasonic flow meter in 36" Sweet Gas' header; MW measurement being installed	Daily (weekdays) manual sample; GC analysis	Yes
		Sour gas header, knock-out drum	Power Failure case: 5 700							
Natref	108 000	No. 1	206 000	?	?	66	Manual/ operator	Mass flow rate. Specs.?	?	?
		No. 2	103 000	?	?	66	Manual/ operator	Mass flow rate. Specs.?	?	?
		No. 3	534 000	?	?	97	steam/ hydrocarbon ratio control			

5. PROTOCOL: FRAMEWORK FOR MONITORING

5.1 Streams to be monitored

Flare emissions are unconfined and therefore cannot be directly monitored for emission rates and composition. (Remote sensing may be used to directly estimate the composition of flare emissions, but the cost of such a system for continuous emission monitoring is relatively high.) Several years' experience in the California Bay Area Air Quality Management District (BAAQMD) has demonstrated that measuring and monitoring vent gas (i.e., the stream(s) discharged to the flare stack and flare tip) flow rate and composition is a cost effective approach to monitoring flare emissions. A limitation of this approach, which should be recognised when reporting on and analysing flaring events, is that it does not provide a direct measurement of the composition of flare stack emissions. Composition has to be estimated based on assumed or estimated combustion efficiency, and literature values.

5.2 Technical Requirements of flare monitoring

Flare systems are part of a refineries' emergency pressure relief system, designed to cope with a wide range of vent gas flow rates and compositions. Demand on a flaring system may be due to a single relief valve lifting to relieve pressure in a single vessel, or a group of relief valves on a particular process unit, or refinery-wide loss of pressure control during a general power failure. Vent gas composition and flow rate are therefore inherently unpredictable. Thus mass flow rate cannot be estimated based on the measurement of flow velocity, and hence volumetric flow rate, alone. Vent gas molecular mass and gas density may vary considerably, depending on the source of the discharge. In order to measure vent gas mass flow rate continuously it is therefore necessary to simultaneously measure both velocity (or volumetric flow rate) and molecular mass. Since the flare system is integral to the refineries' emergency relief system, the flow measuring device must have a minimal pressure drop to minimise back-pressure on upstream equipment. A modern ultrasonic flow meter (such as the Panametrics GE686) satisfies all the above requirements: a wide velocity measurement range, simultaneous measurement of molecular mass and negligible pressure drop.

Vent gas composition may be established by sampling the gas manually or using an automated sampling system, and subsequent laboratory analysis of the sample(s). Continuous sampling and analysis of the vent gas is also possible, but these systems are less reliable. Vent gas flows during normal plant operations should be zero. Routine samples taken during these periods will therefore not yield useful information on vent gas composition during a flaring event. Samples therefore have to be taken as soon as the flow rate increases significantly above zero. An increase of the continuously monitored mass flow rate above a given 'threshold' value indicates that a flaring event is in progress, and may be used to initiate manual or automatic sampling of the vent gas. Flaring events typically occur without forewarning, and may be of relatively short duration. An automatic sampling system triggered by the flow rate exceeding the set 'trigger' value is therefore the preferred method of obtaining a sample. If the flaring event continues for some time (more than 15 minutes), the sampler can be programmed to take repeated aliquots of gas to obtain an integrated sample of vent gas discharged during the incident.

To avoid responding to spurious flow rate measurements, a 'trigger' value equivalent to 1000kg/h is proposed. For a 36" (0.92m) vent line, this value is about 10X the minimum detectable flow velocity of an ultrasonic flow meter, and is equal to the lower value of the range ($\pm 5\%$ accuracy) of the instrument. For smaller vent lines this value (1000kg/h) will be more than 10X the minimum detectable flow velocity and above the minimum of the instrument range. If flow rates exceed the 'trigger' value frequently it may indicate leaking relief valves (a matter that should be investigated and rectified) or that the 'trigger' value has to be reassessed.

5.3 Video Camera monitoring and archiving

The measurement of vent gas flow rate and composition would provide a valuable but incomplete record of a flaring event since it cannot provide information on the flare (i.e. the flame) combustion performance. At the same time, a flaring event is highly visible to the general public, and subject to interpretation as to whether or not it was a large flare or a smoky flare. A continuous video record provides an objective although qualitative record of combustion performance during a flaring event, at minimal cost.

5.4 Draft Regulation for Monitoring and Reporting Oil Refinery Flaring Emissions

The appended draft regulation is based on the US EPA's Regulation 12, Rule 11, adapted to the local situation. This draft encompasses the technical specifications of the proposed system and reporting requirements. The Department (DEAT) may follow the example of the BAAQMD by posting monthly summary flaring reports on a website to make the information accessible to the interested public.

Emissions from Sulphur Recovery Plant incinerators (or 'Thermal Oxidisers') that do not discharge to a flare stack but to general purpose stacks should similarly be monitored by continuously monitoring effluent gas flow rate and composition to the incinerator.

5.5 Timeframes and costs of implementation

The Draft Regulation suggests timeframes for implementation. It is possible to install the flow meter within 9 months of the regulation coming into effect. The monitoring and reporting systems should be fully operational within 18 months of the regulation coming into effect.

The installed cost applicable to each refinery is largely dependent on the configuration of each refinery and the number of systems required to ensure that all vent gas flows are measured. Indicative installed costs are: R350 000 for an ultrasonic flow meter; R200 000 for an automatic sampling system.

6. CONCLUSIONS AND RECOMMENDATIONS

The implementation of the proposed systems for monitoring and reporting flaring events at South African Oil Refineries would provide valuable objective information of the frequency, duration and magnitude of flaring events and flare emissions at oil refineries. Such data would facilitate analysis of the root causes of flaring emissions, and would assist in devising strategies for a reduction in flaring events and emissions. Monitoring data may also provide the basis for further regulatory action.

Experience in the US has shown that monitoring and reporting of flaring, **and** the availability of the resultant data to the public, induced US refineries to voluntarily take action to reduce flaring emissions. In some cases, quite dramatic reductions in emissions were achieved.

Recommendations:

1. That a regulation (see appended draft) based on the proposed scheme be adopted and promulgated as soon as possible. The public and refineries would have the opportunity to comment on the draft through the statutory notice-and-comment period.
2. That monthly flaring reports (similar to the BAAQMD practice) be placed on an appropriate website to facilitate public access to the data.
3. That the appropriate Authority for receiving and archiving the data be identified. Similarly, the Authority for implementing the regulation should be identified.
4. That the monthly reports, including any reports of Flaring Events, be used to review and evaluate refineries' flaring emissions performance on a periodic (annual) basis, and that these annual reports be used to devise regulatory strategies for reducing flaring emissions
5. In view of the considerable public interest in refinery flaring emissions, a communications strategy for disseminating the content and implications of the proposed regulation should be devised and implemented. For example, a series of public meetings and workshops could be held to explain how the monitoring system works, and to assist the public to understand and use the data available on the website. This should preferably be done once firm timelines for implementation of the scheme are available.

**APPENDIX 1: DRAFT REGULATION FOR MONITORING OF FLARING AT SOUTH AFRICAN
PETROLEUM REFINERIES**

General Description: The purpose of this regulation is to require monitoring, recording and reporting of flaring emissions emanating from South African Petroleum Refineries.

GOVERNMENT NOTICE

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM

No.R... ..200.

NATIONAL ENVIRONMENTAL MANAGEMENT ACT, 1998 (ACT 107 OF 1998)

I, , Minister of Environmental Affairs and Tourism, in terms of section 44(1) of the National Environmental Management Act 1998 (Act No.107 of 1998), hereby publish the following:

**REGULATIONS RELATING TO FLARE MONITORING AND REPORTING AT
PETROLEUM REFINERIES¹⁵**

The abovementioned Regulations shall come into effect on the ... date of publication ... thereof in the Government Gazette.

.....

MINISTER OF ENVIRONMENTAL AFFAIRS AND TOURISM

GOVERNMENT NOTICE

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM

¹⁵ Definition to include PetroSA Gas to Liquids and Sasol Coal to Liquids facilities/ processes

NATIONAL ENVIRONMENTAL MANAGEMENT ACT, 1998

REGULATIONS RELATING TO REGULATIONS RELATING TO FLARE MONITORING AND REPORTING AT **PETROLEUM REFINERIES**

The Minister of Environmental Affairs and Tourism has in terms of section 44(1) of the National Environmental Management Act 1998 (Act No.107 of 1998), made the regulations in the Schedule.

SCHEDULE

Definitions

1. In these Regulations a word or expression to which a meaning has been assigned in the Act has that meaning and, unless the context otherwise indicates: –

“Flare” means a combustion device that uses an open flame to burn combustible gases with combustion air provided by ambient air around the flame. Combustion may be steam or air assisted. Flares may be either continuous or intermittent. This term includes both ground and elevated flares;

“Flare Monitoring System” means all sampling systems, flow and composition measuring systems, transducers, transmitters, data acquisition equipment, data recording equipment, video monitoring equipment, and video recording equipment involved in flare monitoring.

“Flaring” means a high-temperature combustion process used to burn vent gases.

“Flaring Event” means a total flow of vent gas flared in any consecutive 15 minutes period that exceeds 250kg, equivalent to a flow rate of 1000kg/h for the period. If, during a flaring event, the vent gas flow rate drops below 1000kg/h and then increases above 1000kg/h within 30 minutes, that shall still be considered a single flaring event, rather than two separate events.¹⁶

“Flaring Incident” means a Flaring Event or a series of Flaring Events occurring within a 24 hour period or within subsequent contiguous non-overlapping 24 hour periods.

¹⁶ The 'trigger value' of 1000kg/h flowrate is based on the lower bound of the +-5% accuracy range of the instrument (0.3m/s), an assumed gas density of 1.5kg/Nm³ and a header line diameter of 0.92m. This figure is about 10X the minimum detectable flow rate.

"Gas" means the state of matter that has neither independent shape nor volume, but tends to expand indefinitely. For the purposes of this rule, "gas" includes aerosols and the terms "gas" and "gases" are interchangeable.

"Petroleum Refinery" means a facility that processes crude oil, coal or natural gas to finished petroleum products, and includes any associated sulphur recovery plant.

"Pilot Gas" means the gas used to maintain the presence of a flame for ignition of vent gases.

"Purge Gas" means the gas used to prevent air backflow in the flare system when there is no vent gas.

"Sulphur Recovery Plant" means a process unit that processes sulphur containing material and produces a final product of elemental sulphur.

"Thermal Oxidizer" means an enclosed or partially enclosed combustion device that is used to oxidize combustible gases, that generally comes equipped with controls for combustion chamber temperature and often with controls for air/fuel mixture, and that exhausts all combustion products through a vent, duct, or stack so that emissions can be measured directly.

"Vent Gas" means any gas directed to a flare excluding assisting air, steam or flare pilot gas, and any continuous purge gases.

Administrative Requirements

2.1 Flare Data Reporting Requirements: The owner or operator of a flare shall submit a monthly report to **...(relevant Authority)...** on or before 30 days after the end of each month for each flare subject to this regulation. Only one report is required for a staged or cascading flare system if all flares in the system serve the same header or headers. The report shall be in an approved electronic format.

Each monthly report shall include all of the following:

- a) The total volumetric flow of vent gas in normal cubic metres (Nm³), and mass flow (kg) for each hour and each day, and for the month, and the average gas molecular mass for each hour, each day and for the month.
- b) The average mass flow of steam, pilot and purge gas for each hour, each day and for of the month.
- c) For any pilot and purge gas used, the type of gas used, and the means used to determine flow
- d) Flare monitoring system downtime periods, including dates and times.
- e) The archive of images recorded for the month in accordance with Section 7.
- f) If vent gas composition is monitored using manual sampling or automated integrated sampling, total hydrocarbon content as propane by volume, methane content by volume, and, hydrogen sulfide content by volume, for each sample or integrated sample required by

Section 3. If the content of any additional compound or compounds is determined by the analysis of a sample or integrated sample, the content by volume of each additional compound.

- g) If vent gas composition is monitored by a continuous analyzer or analyzers pursuant to Section 3, average total hydrocarbon content as propane by volume, average methane content by volume, and, depending upon the analytical method used pursuant to Section 8, total reduced sulphur content by volume or hydrogen sulfide content by volume of vent gas flared for each hour of the month. If the content of any additional compound or compounds is determined by the continuous analyzer or analyzers, the average content by volume for each additional compound for each hour of the month.
- h) For each day and for the month provide calculated methane, non-methane and sulphur dioxide emissions. For the purposes of these emission calculations only, a flare control efficiency of 98 percent shall be used for hydrocarbon flares.
- i) For every flaring event, as defined, refineries are required to sample vent gas every 15 minutes for the duration of the flaring event, to obtain an integrated sample, and would be required to investigate and report on the flaring event in accordance with the reporting format. This report¹⁷ shall include (but not be limited to), a description of the flaring including:
 - i. The date and time that the Flaring Incident started and ended. To the extent that the Flaring Incident involved multiple releases either within a twenty-four (24) hour period or within subsequent, contiguous, non-overlapping twenty-four (24) hour periods, the report shall set forth the starting and ending dates and times of each release;
 - ii. An estimate of the quantities of combustion products, including but not limited to sulphur dioxide, carbon dioxide and nitrogen oxides, the quantities of unburnt hydrocarbons and H₂S and the quantities of the products of incomplete combustion such as particulate matter that were emitted, and the calculations that were used to determine these quantities;
 - iii. The steps, if any, that the refinery took to limit the duration and/or quantity of emissions associated with the Flaring Incident;
 - iv. A detailed analysis that sets forth the Root Cause and all contributing causes of the Flaring Incident, to the extent determinable
 - v. An analysis of the measures, if any, that are available to reduce the likelihood of a recurrence of a Flaring Incident resulting from the same Root Cause or contributing causes in the future. The analysis shall discuss the alternatives, if any, that are available, the probable effectiveness and cost of the alternatives, and whether or not an outside consultant should be retained to assist in the analysis. Possible design, operational, and maintenance changes shall be evaluated. If the refinery concludes that corrective action(s) is (are) required, the report shall include a description of the action(s) and, if not already completed, a schedule for its (their) implementation, including proposed commencement and completion dates. If the refinery concludes that corrective action is not required, the report shall explain the basis for that conclusion.

¹⁷ The requirement of a flaring report for every flaring event (as defined) is based on the assumption that vent flow is zero under normal refinery operating conditions. Therefore a detectable flow in the vent header implies that an abnormal operating has occurred, requiring a report. The flaring event trigger value is equivalent to at least 10X the minimum detectable flow velocity to avoid reporting of spurious events.

2.2 Flow Verification Report: Effective twelve months after adoption of this regulation and every twelve months thereafter, the owner or operator of a flare shall submit a flow verification report to (the Authority)..... for each flare subject to the regulation. The flow verification report shall be included in the corresponding monthly report required by Section 3.1 f). Only one report is required for a staged or cascading flare system if all flares in the system serve the same header or headers. The report shall compare flow as measured by the flow monitoring equipment required by Section 3 and a flow verification report for the same period or periods of time. The owner or operator shall demonstrate that the flow verification was performed using good engineering practices.

MONITORING AND RECORDS

3 Vent Gas Flow Monitoring: Effective 9 months after this regulation comes into effect, the owner or operator of a petroleum refinery shall not operate a flare unless vent gas to the flare is continuously monitored for volumetric flow by a device that meets the following requirements:

3.1 The minimum detectable velocity shall be 0.03 metres per second.

3.3 The device shall continuously measure the range of flow rates corresponding to velocities from 0.3 to 84 metres per second in the header in which the device is installed.

3.4 The device shall have a manufacturer's specified accuracy of $\pm 5\%$ over the range of 0.3 to 84 metres per second.

3.5 The device shall be installed at a location where measured volumetric flow is representative of flow to the flare or to the flare system in the case of a staged or cascading flare system consisting of more than one flare.

3.6 Effective 9 months after this regulation comes into effect, the owner or operator shall provide access to the ...(Authority)..... to verify proper installation and operation of the flare monitoring system.

3.7 Effective 18 months after this regulation comes into effect, the flow monitoring system shall be maintained to be accurate to within $\pm 20\%$ as demonstrated by a calibration report performed by an approved independent agency.

4 Vent Gas Composition Monitoring: The owner or operator of a petroleum refinery shall not operate a flare unless the following requirements are met with respect to vent gas composition monitoring:

4.1 Vent gas monitored for composition, whether by sampling, integrated sampling or continuous monitoring, shall be taken from a location at which samples are representative of vent gas composition. If flares share a common header, a sample from the header will be deemed representative of vent gas composition for all flares served by the header.

4.2 Within 12 months of this regulation coming into effect, the owner or operator shall monitor vent gas composition using one of the following methods:

4.2.1 Manual Sampling

a. If the flow rate of vent gas flared in any consecutive 15-minute period continuously exceeds 1000kg/h, a manual sample shall be taken within 15 minutes. The sampling frequency thereafter shall be one sample every three hours and shall continue until the flow rate of vent gas flared in any consecutive 15-minute period is continuously than 1000kg/h or less.

b. Samples shall be analyzed in accordance with Section 9.

4.2.2 Automated Integrated Sampling

Automated Integrated Sampling that meets the following requirements:

a. If the flow rate of vent gas flared in any consecutive 15 minute period continuously exceeds 1000kg/h, integrated sampling shall begin within 15 minutes and shall continue until the flow rate of vent gas flared in any consecutive 15 minute period is continuously 1000kg/h or less.

b. Integrated sampling shall consist of a minimum of one aliquot for each 15-minute period until the sample container is full. If sampling is still required in terms of 4.2.2a., a new sample container shall be placed in service within one hour after the previous container being filled. A sample container shall not be used for a sampling period that exceeds 24 hours.

c. Samples shall be analyzed in accordance with Section 9.

5 Pilot and Purge Gas Monitoring: The owner or operator of a petroleum refinery shall not operate a flare unless (1) volumetric flows of purge and pilot gases are monitored by flow measuring devices, or (2) other parameters are monitored so that mass flows of pilot and purge gas may be calculated based on design specifications and the parameters monitored.

6 Recordkeeping Requirements: Except as provided in Section 8 the owner or operator of a flare shall maintain records for all the information required to be monitored for a period of five years and make such records available to the ...Authority ... upon request.

7 General Monitoring Requirements: Persons responsible for monitoring subject to this rule shall comply with the following:

7.1 Periods of flare monitoring system unavailability (inoperation) greater than 24 continuous hours shall be reported by the following working day, followed by notification of resumption of monitoring. Adequate proof of expeditious repair shall be furnished to the ... Authority ... for

downtime in excess of fifteen consecutive days. Periods of inoperation of the vent gas flow monitoring required by Section 2 shall not exceed 30 days per calendar year. Periods of inoperation of vent gas composition monitoring specified in Sections 4.2.2 (integrated sampling) shall not exceed 30 days per calendar year. Periods of inoperation of video monitoring specified in Section 7 shall not exceed 30 days per calendar year.

7.2 During periods of inoperation of auto-samplers installed in terms of Section 4.2.2, persons responsible for monitoring shall take manual samples as required by Section 4.2.1. During periods of inoperation of flow monitors required by Section 3, flow shall be calculated using good engineering practices.

7.3 The person(s) responsible for monitors subject to this rule shall maintain and calibrate all required monitors and recording devices in accordance with the applicable manufacturer's specifications. In order to claim that a manufacturer's specification is not applicable, the person responsible for emissions must have, and follow, a written maintenance policy that was developed for the device in question. The written policy must explain and justify the difference between the written procedure and the manufacturer's procedure.

7.4 Data Recording System: All in-line continuous analyzer and flow monitoring data must be continuously recorded by an electronic data acquisition system capable of one-minute averages. Flow monitoring data shall be recorded as one-minute averages.

8 Video Monitoring: The owner or operator of a flare subject to this regulation shall, effective 180 days after adoption of this regulation, install and maintain equipment that records a real-time digital image of the flare and flame at a frame rate of no less than 1 frame per minute. The recorded image of the flare shall be of sufficient size, contrast, and resolution¹⁸ to be readily apparent in the overall image or frame. The image shall include an embedded date and time stamp. The equipment shall archive the images for each 24-hour period.

9 Testing, Sampling, and Analytical Methods:

9.1 Samples and integrated samples shall be analyzed using the following test methods, or latest revision, where applicable:

- a) Total hydrocarbon content and methane content of vent gas shall be determined using ASTM Method D1945-96, ASTM Method UOP 539-97, or EPA Method 18.
- b) Hydrogen sulfide content of vent gas shall be determined using ASTM Method D1945-96 or ASTM Method UOP 539-97.
- c) Any alternative method to the above methods if approved by **..the Authority.....**

¹⁸ A compressed image resolution of 160kb enables the storage of one month's data on an 8GB DVD.

9.2 If vent gas composition is monitored using continuous analyzers, the analyzers shall employ the following methods, or latest revision, where applicable:

- a) Total hydrocarbon content and methane content of vent gas shall be determined using EPA Method 25A or 25B.
- b) Total reduced sulphur content of vent gas shall be determined using ASTM Method D4468-85.
- c) Hydrogen sulfide content shall be determined using ASTM Method D4084-94.
- d) Any alternative method to the above methods if approved by **.the Authorities.....**