

DECISIONS

COMMISSION IMPLEMENTING DECISION

of 9 October 2014

establishing best available techniques (BAT) conclusions, under Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions, for the refining of mineral oil and gas

(notified under document C(2014) 7155)

(Text with EEA relevance)

(2014/738/EU)

THE EUROPEAN COMMISSION,

Having regard to the Treaty on the Functioning of the European Union,

Having regard to Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) ⁽¹⁾, and in particular Article 13(5) thereof,

Whereas:

- (1) Article 13(1) of Directive 2010/75/EU requires the Commission to organise an exchange of information on industrial emissions between it and Member States, the industries concerned and non-governmental organisations promoting environmental protection in order to facilitate the drawing up of best available techniques (BAT) reference documents as defined in Article 3(11) of that Directive.
- (2) In accordance with Article 13(2) of Directive 2010/75/EU, the exchange of information is to address the performance of installations and techniques in terms of emissions, expressed as short- and long-term averages, where appropriate, and the associated reference conditions, consumption and nature of raw materials, water consumption, use of energy and generation of waste and the techniques used, associated monitoring, cross-media effects, economic and technical viability and developments therein and best available techniques and emerging techniques identified after considering the issues mentioned in points (a) and (b) of Article 13(2) of that Directive.
- (3) 'BAT conclusions' as defined in Article 3(12) of Directive 2010/75/EU are the key element of BAT reference documents and lay down the conclusions on best available techniques, their description, information to assess their applicability, the emission levels associated with the best available techniques, associated monitoring, associated consumption levels and, where appropriate, relevant site remediation measures.
- (4) In accordance with Article 14(3) of Directive 2010/75/EU, BAT conclusions are to be the reference for setting permit conditions for installations covered by Chapter II of that Directive.
- (5) Article 15(3) of Directive 2010/75/EU requires the competent authority to set emission limit values that ensure that, under normal operating conditions, emissions do not exceed the emission levels associated with the best available techniques as laid down in the decisions on BAT conclusions referred to in Article 13(5) of Directive 2010/75/EU.
- (6) Article 15(4) of Directive 2010/75/EU provides for derogations from the requirement laid down in Article 15(3) only where the costs associated with the achievement of the emission levels associated with the BAT disproportionately outweigh the environmental benefits due to the geographical location, the local environmental conditions or the technical characteristics of the installation concerned.
- (7) Article 16(1) of Directive 2010/75/EU provides that the monitoring requirements in the permit referred to in point (c) of Article 14(1) of the Directive are to be based on the conclusions on monitoring as described in the BAT conclusions.

⁽¹⁾ OJ L 334, 17.12.2010, p. 17.

- (8) In accordance with Article 21(3) of Directive 2010/75/EU, within 4 years of publication of decisions on BAT conclusions, the competent authority is to reconsider and, if necessary, update all the permit conditions and ensure that the installation complies with those permit conditions.
- (9) The Commission established a forum composed of representatives of Member States, the industries concerned and non-governmental organisations promoting environmental protection by Decision of 16 May 2011 establishing a forum for the exchange of information pursuant to Article 13 of Directive 2010/75/EU on industrial emissions ⁽¹⁾.
- (10) In accordance with Article 13(4) of Directive 2010/75/EU, the Commission obtained the opinion of the forum, established by Decision of 16 May 2011, on the proposed content of the BAT reference document for the refining of mineral oil and gas on 20 September 2013 and made it publicly available.
- (11) The measures provided for in this Decision are in accordance with the opinion of the Committee established by Article 75(1) of Directive 2010/75/EU,

HAS ADOPTED THIS DECISION:

Article 1

The BAT conclusions for the refining of mineral oil and gas, as set out in the Annex, are adopted.

Article 2

This Decision is addressed to the Member States.

Done at Brussels, 9 October 2014.

For the Commission
Janez POTOČNIK
Member of the Commission

⁽¹⁾ OJ C 146, 17.5.2011, p. 3.

ANNEX

BAT CONCLUSIONS FOR THE REFINING OF MINERAL OIL AND GAS

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SCOPE

These BAT conclusions cover certain industrial activities specified in Section 1.2 of Annex I to Directive 2010/75/EU, namely '1.2. Refining of mineral oil and gas'.

In particular, these BAT conclusions cover the following processes and activities:

Activity	Subactivities or processes included in activity
Alkylation	All alkylation processes: hydrofluoric acid (HF), sulphuric acid (H ₂ SO ₄) and solid-acid
Base oil production	Deasphalting, aromatic extraction, wax processing and lubricant oil hydrofinishing
Bitumen production	All techniques from storage to final product additives
Catalytic cracking	All types of catalytic cracking units such as fluid catalytic cracking
Catalytic reforming	Continuous, cyclic and semi-regenerative catalytic reforming
Coking	Delayed and fluid coking processes. Coke calcination
Cooling	Cooling techniques applied in refineries
Desalting	Desalting of crude oil
Combustion units for energy production	Combustion units burning refinery fuels, excluding units using only conventional or commercial fuels

Activity	Subactivities or processes included in activity
Etherification	Production of chemicals (e.g. alcohols and ethers such as MTBE, ETBE and TAME) used as motor fuels additives
Gas separation	Separation of light fractions of the crude oil e.g. refinery fuel gas (RFG), liquefied petroleum gas (LPG)
Hydrogen consuming processes	Hydrocracking, hydrorefining, hydrotreatments, hydroconversion, hydroprocessing and hydrogenation processes
Hydrogen production	Partial oxidation, steam reforming, gas heated reforming and hydrogen purification
Isomerisation	Isomerisation of hydrocarbon compounds C ₄ , C ₅ and C ₆
Natural gas plants	Natural gas (NG) processing including liquefaction of NG
Polymerisation	Polymerisation, dimerisation and condensation
Primary distillation	Atmospheric and vacuum distillation
Product treatments	Sweetening and final product treatments
Storage and handling of refinery materials	Storage, blending, loading and unloading of refinery materials
Visbreaking and other thermal conversions	Thermal treatments such as visbreaking or thermal gas oil process
Waste gas treatment	Techniques to reduce or abate emissions to air
Waste water treatment	Techniques to treat waste water prior to release
Waste management	Techniques to prevent or reduce the generation of waste

These BAT conclusions do not address the following activities or processes:

- the exploration and production of crude oil and natural gas;
- the transportation of crude oil and natural gas;
- the marketing and distribution of products.

Other reference documents which may be relevant for the activities covered by these BAT conclusions are the following:

Reference document	Subject
Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector (CWW)	Waste water management and treatment techniques
Industrial Cooling Systems (ICS)	Cooling processes
Economics and Cross-media Effects (ECM)	Economics and cross-media effects of techniques

Reference document	Subject
Emissions from Storage (EFS)	Storage, blending, loading and unloading of refinery materials
Energy Efficiency (ENE)	Energy efficiency and integrated refinery management
Large Combustion Plants (LCP)	Combustion of conventional and commercial fuels
Large Volume Inorganic Chemicals — Ammonia, Acids and Fertilisers Industries (LVIC-AAF)	Steam reforming and hydrogen purification
Large Volume Organic Chemical Industry (LVOC)	Etherification process (MTBE, ETBE and TAME production)
Waste Incineration (WI)	Waste incineration
Waste Treatment (WT)	Waste treatment
General Principles of Monitoring (MON)	Monitoring of emissions to air and water

GENERAL CONSIDERATIONS

The techniques listed and described in these BAT conclusions are neither prescriptive nor exhaustive. Other techniques may be used that ensure at least an equivalent level of environmental protection.

Unless otherwise stated, these BAT conclusions are generally applicable.

Averaging periods and reference conditions for emissions to air

Unless stated otherwise, emission levels associated with the best available techniques (BAT-AELs) for emissions to air given in these BAT conclusions refer to concentrations, expressed as mass of emitted substance per volume of waste gas under the following standard conditions: dry gas, temperature of 273,15 K, pressure of 101,3 kPa.

For continuous measurements	BAT-AELs refer to monthly average values, which are the averages of all valid hourly average values measured over a period of one month
For periodic measurements	BAT-AELs refer to the average value of three spot samples of at least 30 minutes each

For combustion units, catalytic cracking processes, and waste gas sulphur recovery units, reference conditions for oxygen are shown in Table 1.

Table 1

Reference conditions for BAT-AELs concerning emissions to air

Activities	Unit	Oxygen reference conditions
Combustion unit using liquid or gaseous fuels with the exception of gas turbines and engines	mg/Nm ³	3 % oxygen by volume
Combustion unit using solid fuels	mg/Nm ³	6 % oxygen by volume

Activities	Unit	Oxygen reference conditions
Gas turbines (including combined cycle gas turbines — CCGT) and engines	mg/Nm ³	15 % oxygen by volume
Catalytic cracking process (regenerator)	mg/Nm ³	3 % oxygen by volume
Waste gas sulphur recovery unit ⁽¹⁾	mg/Nm ³	3 % oxygen by volume

⁽¹⁾ In case of applying BAT 58.

Conversion of emissions concentration to reference oxygen level

The formula for calculating the emissions concentration at a reference oxygen level (see Table 1) is shown below.

$$E_R = \frac{21 - O_R}{21 - O_M} \times E_M$$

Where:

E_R (mg/Nm³): emissions concentration referred to the reference oxygen level O_R

O_R (vol %): reference oxygen level

E_M (mg/Nm³): emissions concentration referred to the measured oxygen level O_M

O_M (vol %): measured oxygen level.

Averaging periods and reference conditions for emissions to water

Unless stated otherwise, emission levels associated with the best available techniques (BAT-AELs) for emissions to water given in these BAT conclusions refer to values of concentration (mass of emitted substances per volume of water) expressed in mg/l.

Unless stated otherwise, the averaging periods associated with the BAT-AELs are defined as follows:

Daily average	Average over a sampling period of 24 hours taken as a flow-proportional composite sample or, provided that sufficient flow stability is demonstrated, from a time-proportional sample
Yearly/Monthly average	Average of all daily averages obtained within a year/month, weighted according to the daily flows

DEFINITIONS

For the purpose of these BAT conclusions, the following definitions apply:

Term used	Definition
Unit	A segment/subpart of the installation in which a specific processing operation is conducted
New unit	A unit first permitted on the site of the installation following the publication of these BAT conclusions or a complete replacement of a unit on the existing foundations of the installation following the publication of these BAT conclusions
Existing unit	A unit which is not a new unit

Term used	Definition
Process off-gas	The collected gas generated by a process which must be treated e.g. in an acid gas removal unit and a sulphur recovery unit (SRU)
Flue-gas	The exhaust gas exiting a unit after an oxidation step, generally combustion (e.g. regenerator, Claus unit)
Tail gas	Common name of the exhaust gas from an SRU (generally Claus process)
VOC	Volatile organic compounds as defined in Article 3(45) of Directive 2010/75/EU
NM VOC	VOC excluding methane
Diffuse VOC emissions	Non-channelled VOC emissions that are not released via specific emission points such as stacks. They can result from 'area' sources (e.g. tanks) or 'point' sources (e.g. pipe flanges)
NO _x expressed as NO ₂	The sum of nitrogen oxide (NO) and nitrogen dioxide (NO ₂) expressed as NO ₂
SO _x expressed as SO ₂	The sum of sulphur dioxide (SO ₂) and sulphur trioxide (SO ₃) expressed as SO ₂
H ₂ S	Hydrogen sulphide. Carbonyl sulphide and mercaptan are not included
Hydrogen chloride expressed as HCl	All gaseous chlorides expressed as HCl
Hydrogen fluoride expressed as HF	All gaseous fluorides expressed as HF
FCC unit	Fluid catalytic cracking: a conversion process for upgrading heavy hydrocarbons, using heat and a catalyst to break larger hydrocarbon molecules into lighter molecules
SRU	Sulphur recovery unit. See definition in Section 1.20.3
Refinery fuel	Solid, liquid or gaseous combustible material from the distillation and conversion steps of the refining of crude oil. Examples are refinery fuel gas (RFG), syngas and refinery oils, pet coke
RFG	Refinery fuel gas: off-gases from distillation or conversion units used as a fuel
Combustion unit	Unit burning refinery fuels alone or with other fuels for the production of energy at the refinery site, such as boilers (except CO boilers), furnaces, and gas turbines.
Continuous measurement	Measurement using an 'automated measuring system' (AMS) or a 'continuous emission monitoring system' (CEMS) permanently installed on site
Periodic measurement	Determination of a measurand at specified time intervals using manual or automated reference methods
Indirect monitoring of emissions to air	Estimation of the emissions concentration in the flue-gas of a pollutant obtained through an appropriate combination of measurements of surrogate parameters (such as O ₂ content, sulphur or nitrogen content in the feed/fuel), calculations and periodic stack measurements. The use of emission ratios based on S content in the fuel is one example of indirect monitoring. Another example of indirect monitoring is the use of PEMS

Term used	Definition
Predictive Emissions monitoring system (PEMS)	System to determine the emissions concentration of a pollutant based on its relationship with a number of characteristic continuously monitored process parameters (e.g. fuel-gas consumption, air/fuel ratio) and fuel or feed quality data (e.g. the sulphur content) of an emission source
Volatile liquid hydrocarbon compounds	Petroleum derivatives with a Reid vapour pressure (RVP) of more than 4 kPa, such as naphtha and aromatics
Recovery rate	Percentage of NMVOC recovered from the streams conveyed into a vapour recovery unit (VRU)

1.1. General BAT conclusions for the refining of mineral oil and gas

The process-specific BAT conclusions included in Sections 1.2 to 1.19 apply in addition to the general BAT conclusions mentioned in this section.

1.1.1. Environmental management systems

BAT 1. In order to improve the overall environmental performance of plants for the refining of mineral oil and gas, BAT is to implement and adhere to an environmental management system (EMS) that incorporates all of the following features:

- (i) commitment of the management, including senior management;
- (ii) definition of an environmental policy that includes the continuous improvement for the installation by the management;
- (iii) planning and establishing the necessary procedures, objectives and targets, in conjunction with financial planning and investment;
- (iv) implementation of the procedures paying particular attention to:
 - (a) structure and responsibility
 - (b) training, awareness and competence
 - (c) communication
 - (d) employee involvement
 - (e) documentation
 - (f) efficient process control
 - (g) maintenance programmes
 - (h) emergency preparedness and response
 - (i) safeguarding compliance with environmental legislation.
- (v) checking performance and taking corrective action, paying particular attention to:
 - (a) monitoring and measurement (see also the reference document on the General Principles of Monitoring)
 - (b) corrective and preventive action
 - (c) maintenance of records
 - (d) independent (where practicable) internal and external auditing in order to determine whether or not the EMS conforms to planned arrangements and has been properly implemented and maintained;

- (vi) review of the EMS and its continuing suitability, adequacy and effectiveness by senior management;
- (vii) following the development of cleaner technologies;
- (viii) consideration for the environmental impacts from the eventual decommissioning of the installation at the stage of designing a new plant, and throughout its operating life;
- (ix) application of sectoral benchmarking on a regular basis.

Applicability

The scope (e.g. level of detail) and nature of the EMS (e.g. standardised or non-standardised) will generally be related to the nature, scale and complexity of the installation, and the range of environmental impacts it may have.

1.1.2. Energy efficiency

BAT 2. In order to use energy efficiently, BAT is to use an appropriate combination of the techniques given below.

Technique	Description
(i) Design techniques	
a. Pinch analysis	Methodology based on a systematic calculation of thermodynamic targets for minimising energy consumption of processes. Used as a tool for the evaluation of total systems designs
b. Heat integration	Heat integration of process systems ensures that a substantial proportion of the heat required in various processes is provided by exchanging heat between streams to be heated and streams to be cooled
c. Heat and power recovery	Use of energy recovery devices e.g.: <ul style="list-style-type: none"> — waste heat boilers — expanders/power recovery in the FCC unit — use of waste heat in district heating
(ii) Process control and maintenance techniques	
a. Process optimisation	Automated controlled combustion in order to lower the fuel consumption per tonne of feed processed, often combined with heat integration for improving furnace efficiency
b. Management and reduction of steam consumption	Systematic mapping of drain valve systems in order to reduce steam consumption and optimise its use
c. Use of energy benchmark	Participation in ranking and benchmarking activities in order to achieve continuous improvement by learning from best practice
(iii) Energy-efficient production techniques	
a. Use of combined heat and power	System designed for the co-production (or the cogeneration) of heat (e.g. steam) and electric power from the same fuel
b. Integrated gasification combined cycle (IGCC)	Technique whose purpose is to produce steam, hydrogen (optional) and electric power from a variety of fuel types (e.g. heavy fuel oil or coke) with a high conversion efficiency

1.1.3. *Solid materials storage and handling*

BAT 3. In order to prevent or, where that is not practicable, to reduce dust emissions from the storage and handling of dusty materials, BAT is to use one or a combination of the techniques given below:

- (i) store bulk powder materials in enclosed silos equipped with a dust abatement system (e.g. fabric filter);
- (ii) store fine materials in enclosed containers or sealed bags;
- (iii) keep stockpiles of coarse dusty material wetted, stabilise the surface with crusting agents, or store under cover in stockpiles;
- (iv) use road cleaning vehicles.

1.1.4. *Monitoring of emissions to air and key process parameters*

BAT 4. BAT is to monitor emissions to air by using the monitoring techniques with at least the minimum frequency given below and in accordance with EN standards. If EN standards are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.

Description	Unit	Minimum frequency	Monitoring technique
(i) SO _x , NO _x , and dust emissions	Catalytic cracking	Continuous ⁽¹⁾ ⁽²⁾	Direct measurement
	Combustion units ≥ 100 MW ⁽³⁾ and calcining units	Continuous ⁽¹⁾ ⁽²⁾	Direct measurement ⁽⁴⁾
	Combustion units of 50 to 100 MW ⁽³⁾	Continuous ⁽¹⁾ ⁽²⁾	Direct measurement or indirect monitoring
	Combustion units < 50 MW ⁽³⁾	Once a year and after significant fuel changes ⁽⁵⁾	Direct measurement or indirect monitoring
	Sulphur recovery units (SRU)	Continuous for SO ₂ only	Direct measurement or indirect monitoring ⁽⁶⁾
(ii) NH ₃ emissions	All units equipped with SCR or SNCR	Continuous	Direct measurement
(iii) CO emissions	Catalytic cracking and combustion units ≥ 100 MW ⁽³⁾	Continuous	Direct measurement
	Other combustion units	Once every 6 months ⁽⁵⁾	Direct measurement
(iv) Metals emissions: Nickel (Ni), Anti- mony (Sb) ⁽⁷⁾ , Vana- dium (V)	Catalytic cracking	Once every 6 months and after significant changes to the unit ⁽⁵⁾	Direct measurement or analysis based on metals content in the catalyst fines and in the fuel
	Combustion units ⁽⁸⁾		

Description	Unit	Minimum frequency	Monitoring technique
(v) Polychlorinated dibenzodioxins/furans (PCDD/F) emissions	Catalytic reformer	Once a year or once a regeneration, whichever is longer	Direct measurement

- (¹) Continuous measurement of SO₂ emissions may be replaced by calculations based on measurements of the sulphur content of the fuel or the feed; where it can be demonstrated that this leads to an equivalent level of accuracy.
- (²) Regarding SO_x, only SO₂ is continuously measured, while SO₃ is only periodically measured (e.g. during calibration of the SO₂ monitoring system).
- (³) Refers to the total rated thermal input of all combustion units connected to the stack where emissions occur.
- (⁴) Or indirect monitoring of SO_x.
- (⁵) Monitoring frequencies may be adapted if, after a period of one year, the data series clearly demonstrate a sufficient stability.
- (⁶) SO₂ emissions measurements from SRU may be replaced by a continuous material balance or other relevant process parameter monitoring, provided appropriate measurements of SRU efficiency are based on periodic (e.g. once every 2 years) plant performance tests.
- (⁷) Antimony (Sb) is monitored only in catalytic cracking units when Sb injection is used in the process (e.g. for metals passivation).
- (⁸) With the exception of combustion units firing only gaseous fuels.

BAT 5. BAT is to monitor the relevant process parameters linked to pollutant emissions, at catalytic cracking and combustion units by using appropriate techniques and with at least the frequency given below.

Description	Minimum frequency
Monitoring of parameters linked to pollutant emissions, e.g. O ₂ content in flue-gas, N and S content in fuel or feed (¹)	Continuous for O ₂ content. For N and S content, periodic at a frequency based on significant fuel/feed changes

(¹) N and S monitoring in fuel or feed may not be necessary when continuous emission measurements of NO_x and SO₂ are carried out at the stack.

BAT 6. BAT is to monitor diffuse VOC emissions to air from the entire site by using all of the following techniques:

- (i) sniffing methods associated with correlation curves for key equipment;
- (ii) optical gas imaging techniques;
- (iii) calculations of chronic emissions based on emissions factors periodically (e.g. once every two years) validated by measurements.

The screening and quantification of site emissions by periodic campaigns with optical absorption-based techniques, such as differential absorption light detection and ranging (DIAL) or solar occultation flux (SOF) is a useful complementary technique.

Description

See Section 1.20.6.

1.1.5. Operation of waste gas treatment systems

BAT 7. In order to prevent or reduce emissions to air, BAT is to operate the acid gas removal units, sulphur recovery units and all other waste gas treatment systems with a high availability and at optimal capacity.

Description

Special procedures can be defined for other than normal operating conditions, in particular:

- (i) during start-up and shutdown operations;
- (ii) during other circumstances that could affect the proper functioning of the systems (e.g. regular and extraordinary maintenance work and cleaning operations of the units and/or of the waste gas treatment system);
- (iii) in case of insufficient waste gas flow or temperature which prevents the use of the waste gas treatment system at full capacity.

BAT 8. In order to prevent and reduce ammonia (NH₃) emissions to air when applying selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR) techniques, BAT is to maintain suitable operating conditions of the SCR or SNCR waste gas treatment systems, with the aim of limiting emissions of unreacted NH₃.

BAT-associated emission levels: See Table 2.

Table 2

BAT-associated emission levels for ammonia (NH₃) emissions to air for a combustion or process unit where SCR or SNCR techniques are used

Parameter	BAT-AEL z(monthly average) mg/Nm ³
Ammonia expressed as NH ₃	< 5 – 15 ⁽¹⁾ ⁽²⁾

⁽¹⁾ The higher end of the range is associated with higher inlet NO_x concentrations, higher NO_x reduction rates and the ageing of the catalyst.

⁽²⁾ The lower end of the range is associated with the use of the SCR technique.

BAT 9. In order to prevent and reduce emissions to air when using a sour water steam stripping unit, BAT is to route the acid off-gases from this unit to an SRU or any equivalent gas treatment system.

It is not BAT to directly incinerate the untreated sour water stripping gases.

1.1.6. *Monitoring of emissions to water*

BAT 10. BAT is to monitor emissions to water by using the monitoring techniques with at least the frequency given in Table 3) and in accordance with EN standards. If EN standards are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.

1.1.7. *Emissions to water*

BAT 11. In order to reduce water consumption and the volume of contaminated water, BAT is to use all of the techniques given below.

Technique	Description	Applicability
(i) Water stream integration	Reduction of process water produced at the unit level prior to discharge by the internal reuse of water streams from e.g. cooling, condensates, especially for use in crude desalting	Generally applicable for new units. For existing units, applicability may require a complete rebuilding of the unit or the installation

Technique	Description	Applicability
(ii) Water and drainage system for segregation of contaminated water streams	Design of an industrial site to optimise water management, where each stream is treated as appropriate, by e.g. routing generated sour water (from distillation, cracking, coking units, etc.) to appropriate pretreatment, such as a stripping unit	Generally applicable for new units. For existing units, applicability may require a complete rebuilding of the unit or the installation
(iii) Segregation of non-contaminated water streams (e.g. once-through cooling, rain water)	Design of a site in order to avoid sending non-contaminated water to general waste water treatment and to have a separate release after possible reuse for this type of stream	Generally applicable for new units. For existing units, applicability may require a complete rebuilding of the unit or the installation
(iv) Prevention of spillages and leaks	Practices that include the utilisation of special procedures and/or temporary equipment to maintain performances when necessary to manage special circumstances such as spills, loss of containment, etc.	Generally applicable

BAT 12. In order to reduce the emission load of pollutants in the waste water discharge to the receiving water body, BAT is to remove insoluble and soluble polluting substances by using all of the techniques given below.

Technique	Description	Applicability
(i) Removal of insoluble substances by recovering oil	See Section 1.21.2	Generally applicable
(ii) Removal of insoluble substances by recovering suspended solids and dispersed oil	See Section 1.21.2	Generally applicable
(iii) Removal of soluble substances including biological treatment and clarification	See Section 1.21.2	Generally applicable

BAT-associated emission levels: See Table 3.

BAT 13. When further removal of organic substances or nitrogen is needed, BAT is to use an additional treatment step as described in Section 1.21.2.

Table 3

BAT-associated emission levels for direct waste water discharges from the refining of mineral oil and gas and monitoring frequencies associated with BAT ⁽¹⁾

Parameter	Unit	BAT-AEL (yearly average)	Monitoring ⁽²⁾ frequency and analytical method (standard)
Hydrocarbon oil index (HOI)	mg/l	0,1-2,5	Daily EN 9377- 2 ⁽³⁾
Total suspended solids (TSS)	mg/l	5-25	Daily
Chemical oxygen demand (COD) ⁽⁴⁾	mg/l	30-125	Daily

Parameter	Unit	BAT-AEL (yearly average)	Monitoring ⁽²⁾ frequency and analytical method (standard)
BOD ₅	mg/l	No BAT-AEL	Weekly
Total nitrogen ⁽³⁾ , expressed as N	mg/l	1-25 ⁽⁶⁾	Daily
Lead, expressed as Pb	mg/l	0,005-0,030	Quarterly
Cadmium, expressed as Cd	mg/l	0,002-0,008	Quarterly
Nickel, expressed as Ni	mg/l	0,005-0,100	Quarterly
Mercury, expressed as Hg	mg/l	0,0001-0,001	Quarterly
Vanadium	mg/l	No BAT-AEL	Quarterly
Phenol Index	mg/l	No BAT-AEL	Monthly EN 14402
Benzene, toluene, ethyl benzene, xylene (BTEX)	mg/l	Benzene: 0,001-0,050 No BAT-AEL for T, E, X	Monthly

⁽¹⁾ Not all parameters and sampling frequencies are applicable to effluent from gas refining sites.

⁽²⁾ Refers to a flow-proportional composite sample taken over a period of 24 hours or, provided that sufficient flow stability is demonstrated, a time-proportional sample.

⁽³⁾ Moving from the current method to EN 9377-2 may require an adaptation period.

⁽⁴⁾ Where on-site correlation is available, COD may be replaced by TOC. The correlation between COD and TOC should be elaborated on a case-by-case basis. TOC monitoring would be the preferred option because it does not rely on the use of very toxic compounds.

⁽⁵⁾ Where total-nitrogen is the sum of total Kjeldahl nitrogen (TKN), nitrates and nitrites.

⁽⁶⁾ When nitrification/denitrification is used, levels below 15 mg/l can be achieved.

1.1.8. Waste generation and management

BAT 14. In order to prevent or, where that is not practicable, to reduce waste generation, BAT is to adopt and implement a waste management plan that, in order of priority, ensures that waste is prepared for reuse, recycling, recovery or disposal.

BAT 15. In order to reduce the amount of sludge to be treated or disposed of, BAT is to use one or a combination of the techniques given below.

Technique	Description	Applicability
(i) Sludge pretreatment	Prior to final treatment (e.g. in a fluidised bed incinerator), the sludges are dewatered and/or de-oiled (by e.g. centrifugal decanters or steam dryers) to reduce their volume and to recover oil from slop equipment	Generally applicable
(ii) Reuse of sludge in process units	Certain types of sludge (e.g. oily sludge) can be processed in units (e.g. coking) as part of the feed due to their oil content	Applicability is restricted to sludges that can fulfil the requirements to be processed in units with appropriate treatment

BAT 16. In order to reduce the generation of spent solid catalyst waste, BAT is to use one or a combination of the techniques given below.

Technique	Description
(i) Spent solid catalyst management	Scheduled and safe handling of the materials used as catalyst (e.g. by contractors) in order to recover or reuse them in off-site facilities. These operations depend on the type of catalyst and process
(ii) Removal of catalyst from slurry decant oil	Decanted oil sludge from process units (e.g. FCC unit) can contain significant concentrations of catalyst fines. These fines need to be separated prior to the reuse of decant oil as a feedstock

1.1.9. Noise

BAT 17. In order to prevent or reduce noise, BAT is to use one or a combination of the techniques given below:

- (i) make an environmental noise assessment and formulate a noise management plan as appropriate to the local environment;
- (ii) enclose noisy equipment/operation in a separate structure/unit;
- (iii) use embankments to screen the source of noise;
- (iv) use noise protection walls.

1.1.10. BAT conclusions for integrated refinery management

BAT 18. In order to prevent or reduce diffuse VOC emissions, BAT is to apply the techniques given below.

Technique	Description	Applicability
I. Techniques related to plant design	(i) limiting the number of potential emission sources (ii) maximising inherent process containment features (iii) selecting high integrity equipment (iv) facilitating monitoring and maintenance activities by ensuring access to potentially leaking components	Applicability may be limited for existing units
II. Techniques related to plant installation and commissioning	(i) well-defined procedures for construction and assembly (ii) robust commissioning and hand-over procedures to ensure that the plant is installed in line with the design requirements	Applicability may be limited for existing units
III. Techniques related to plant operation	Use of a risk-based leak detection and repair (LDAR) programme in order to identify leaking components, and to repair these leaks. See Section 1.20.6	Generally applicable

1.2. BAT conclusions for the alkylation process

1.2.1. Hydrofluoric acid alkylation process

BAT 19. In order to prevent hydrofluoric acid (HF) emissions to air from the hydrofluoric acid alkylation process, BAT is to use wet scrubbing with alkaline solution to treat incondensable gas streams prior to venting to flare.

Description

See Section 1.20.3.

Applicability:

The technique is generally applicable. Safety requirements, due to the hazardous nature of hydrofluoric acid, are to be considered

BAT 20. In order to reduce emissions to water from the hydrofluoric acid alkylation process, BAT is to use a combination of the techniques given below.

Technique	Description	Applicability
(i) Precipitation/Neutralisation step	Precipitation (with, e.g. calcium or aluminium-based additives) or neutralisation (where the effluent is indirectly neutralised with potassium hydroxide (KOH))	Generally applicable. Safety requirements due to the hazardous nature of hydrofluoric acid (HF) are to be considered
(ii) Separation step	The insoluble compounds produced at the first step (e.g. CaF_2 or AlF_3) are separated in e.g. a settlement basin	Generally applicable

1.2.2. Sulphuric acid alkylation process

BAT 21. In order to reduce the emissions to water from the sulphuric acid alkylation process, BAT is to reduce the use of sulphuric acid by regenerating the spent acid and to neutralise the waste water generated by this process before routing to waste water treatment.

1.3. BAT conclusions for base oil production processes

BAT 22. In order to prevent and reduce the emissions of hazardous substances to air and water from base oil production processes, BAT is to use one or a combination of the techniques given below.

Technique	Description	Applicability
(i) Closed process with a solvent recovery	Process where the solvent, after being used during base oil manufacturing (e.g. in extraction, dewaxing units), is recovered through distillation and stripping steps. See Section 1.20.7	Generally applicable
(ii) Multi-effect extraction solvent-based process	Solvent extraction process including several stages of evaporation (e.g. double or triple effect) for a lower loss of containment	Generally applicable to new units. The use of a triple effect process may be restricted to non-fouling feed stocks

Technique	Description	Applicability
(iii) Extraction unit processes using less hazardous substances	Design (new plants) or implement changes (into existing) so that the plant operates a solvent extraction process with the use of a less hazardous solvent: e.g. converting furfural or phenol extraction into the n-methylpyrrolidone (NMP) process	Generally applicable to new units. Converting existing units to another solvent-based process with different physico-chemical properties may require substantial modifications
(iv) Catalytic processes based on hydrogenation	Processes based on conversion of undesired compounds via catalytic hydrogenation similar to hydrotreatment. See Section 1.20.3 (Hydrotreatment)	Generally applicable to new units

1.4. BAT conclusions for the bitumen production process

BAT 23. In order to prevent and reduce emissions to air from the bitumen production process, BAT is to treat the gaseous overhead by using one of the techniques given below.

Technique	Description	Applicability
(i) Thermal oxidation of gaseous overhead over 800 °C	See Section 1.20.6	Generally applicable for the bitumen blowing unit
(ii) Wet scrubbing of gaseous overhead	See Section 1.20.3	Generally applicable for the bitumen blowing unit

1.5. BAT conclusions for the fluid catalytic cracking process

BAT 24. In order to prevent or reduce NO_x emissions to air from the catalytic cracking process (regenerator), BAT is to use one or a combination of the techniques given below.

I. Primary or process-related techniques, such as:

Technique	Description	Applicability
Process optimisation and use of promoters or additives		
(i) Process optimisation	Combination of operating conditions or practices aimed at reducing NO _x formation, e.g. lowering the excess oxygen in the flue-gas in full combustion mode, air staging of the CO boiler in partial combustion mode, provided that the CO boiler is appropriately designed	Generally applicable
(ii) Low-NO _x CO oxidation promoters	Use of a substance that selectively promotes the combustion of CO only and prevents the oxidation of the nitrogen that contains intermediates to NO _x ; e.g. non-platinum promoters	Applicable only in full combustion mode for the substitution of platinum-based CO promoters. Appropriate distribution of air in the regenerator may be required to obtain the maximum benefit

Technique	Description	Applicability
(iii) Specific additives for NO _x reduction	Use of specific catalytic additives for enhancing the reduction of NO by CO	Applicable only in full combustion mode in an appropriate design and with achievable oxygen excess. The applicability of copper-based NO _x reduction additives may be limited by the gas compressor capacity

II. Secondary or end-of-pipe techniques, such as:

Technique	Description	Applicability
(i) Selective catalytic reduction (SCR)	See Section 1.20.2	To avoid potential fouling downstream, additional filtering might be required upstream of the SCR. For existing units, the applicability may be limited by space availability
(ii) Selective non-catalytic reduction (SNCR)	See Section 1.20.2	For partial combustion FCCs with CO boilers, a sufficient residence time at the appropriate temperature is required. For full combustion FCCs without auxiliary boilers, additional fuel injection (e.g. hydrogen) may be required to match a lower temperature window
(iii) Low temperature oxidation	See Section 1.20.2	Need for additional scrubbing capacity. Ozone generation and the associated risk management need to be properly addressed. The applicability may be limited by the need for additional waste water treatment and related cross-media effects (e.g. nitrate emissions) and by an insufficient supply of liquid oxygen (for ozone generation). The applicability of the technique may be limited by space availability

BAT-associated emission levels: See Table 4.

Table 4

BAT-associated emission levels for NO_x emissions to air from the regenerator in the catalytic cracking process

Parameter	Type of unit/combustion mode	BAT-AEL (monthly average) mg/Nm ³
NO _x , expressed as NO ₂	New unit/all combustion mode	< 30-100
	Existing unit/full combustion mode	< 100-300 ⁽¹⁾
	Existing unit/partial combustion mode	100-400 ⁽¹⁾

⁽¹⁾ When antimony (Sb) injection is used for metal passivation, NO_x levels up to 700 mg/Nm³ may occur. The lower end of the range can be achieved by using the SCR technique.

The associated monitoring is in BAT 4.

BAT 25. In order to reduce dust and metals emissions to air from the catalytic cracking process (regenerator), BAT is to use one or a combination of the techniques given below.

I. Primary or process-related techniques, such as:

Technique	Description	Applicability
(i) Use of an attrition-resistant catalyst	Selection of catalyst substance that is able to resist abrasion and fragmentation in order to reduce dust emissions	Generally applicable provided the activity and selectivity of the catalyst are sufficient
(ii) Use of low sulphur feedstock (e.g. by feedstock selection or by hydro-treatment of feed)	Feedstock selection favours low sulphur feedstocks among the possible sources to be processed at the unit. Hydrotreatment aims at reducing the sulphur, nitrogen and metal contents of the feed. See Section 1.20.3	Requires sufficient availability of low sulphur feedstocks, hydrogen production and hydrogen sulphide (H ₂ S) treatment capacity (e.g. amine and Claus units)

II. Secondary or end-of-pipe techniques, such as:

Technique	Description	Applicability
(i) Electrostatic precipitator (ESP)	See Section 1.20.1	For existing units, the applicability may be limited by space availability
(ii) Multistage cyclone separators	See Section 1.20.1	Generally applicable
(iii) Third stage blowback filter	See Section 1.20.1	Applicability may be restricted
(iv) Wet scrubbing	See Section 1.20.3	The applicability may be limited in arid areas and in the case where the by-products from treatment (including e.g. waste water with high level of salts) cannot be reused or appropriately disposed of. For existing units, the applicability may be limited by space availability

BAT-associated emission levels: See Table 5.

Table 5

BAT-associated emission levels for dust emissions to air from the regenerator in the catalytic cracking process

Parameter	Type of unit	BAT-AEL (monthly average) ⁽¹⁾ mg/Nm ³
Dust	New unit	10-25
	Existing unit	10-50 ⁽²⁾

⁽¹⁾ Soot blowing in CO boiler and through the gas cooler is excluded.

⁽²⁾ The lower end of the range can be achieved with a 4-field ESP.

The associated monitoring is in BAT 4.

BAT 26. In order to prevent or reduce SO_x emissions to air from the catalytic cracking process (regenerator), BAT is to use one or a combination of the techniques given below.

I. Primary or process-related techniques, such as:

Technique	Description	Applicability
(i) Use of SO _x reducing catalyst additives	Use of a substance that transfers the sulphur associated with coke from the regenerator back to the reactor. See description in 1.20.3	Applicability may be restricted by regenerator conditions design. Requires appropriate hydrogen sulphide abatement capacity (e.g. SRU)
(ii) Use of low sulphur feedstock (e.g. by feedstock selection or by hydro-treatment of the feed)	Feedstock selection favours low sulphur feedstocks among the possible sources to be processed at the unit. Hydrotreatment aims at reducing the sulphur, nitrogen and metal contents of the feed. See description in 1.20.3	Requires sufficient availability of low sulphur feedstocks, hydrogen production and hydrogen sulphide (H ₂ S) treatment capacity (e.g. amine and Claus units)

II. Secondary or end-of-pipe techniques, such as:

Techniques	Description	Applicability
(i) Non-regenerative scrubbing	Wet scrubbing or seawater scrubbing. See Section 1.20.3	The applicability may be limited in arid areas and in the case where the by-products from treatment (including e.g. waste water with high level of salts) cannot be reused or appropriately disposed of. For existing units, the applicability may be limited by space availability
(ii) Regenerative scrubbing	Use of a specific SO _x absorbing reagent (e.g. absorbing solution) which generally enables the recovery of sulphur as a by-product during a regenerating cycle where the reagent is reused. See Section 1.20.3	The applicability is limited to the case where regenerated by-products can be sold. For existing units, the applicability may be limited by the existing sulphur recovery capacity as well as by space availability

BAT-associated emission levels: See Table 6.

Table 6

BAT-associated emission levels for SO₂ emissions to air from the regenerator in the catalytic cracking process

Parameter	Type of units/mode	BAT-AEL (monthly average) mg/Nm ³
SO ₂	New units	≤ 300
	Existing units/full combustion	< 100-800 ⁽¹⁾
	Existing units/partial combustion	100-1 200 ⁽¹⁾

⁽¹⁾ Where selection of low sulphur (e.g. < 0,5 % w/w) feed (or hydrotreatment) and/or scrubbing is applicable, for all combustion modes: the upper end of the BAT-AEL range is ≤ 600 mg/Nm³.

The associated monitoring is in BAT 4.

BAT 27. In order to reduce carbon monoxide (CO) emissions to air from the catalytic cracking process (regenerator), BAT is to use one or a combination of the techniques given below.

Technique	Description	Applicability
(i) Combustion operation control	See Section 1.20.5	Generally applicable
(ii) Catalysts with carbon monoxide (CO) oxidation promoters	See Section 1.20.5	Generally applicable only for full combustion mode
(iii) Carbon monoxide (CO) boiler	See Section 1.20.5	Generally applicable only for partial combustion mode

BAT-associated emission levels: See Table 7.

Table 7

BAT-associated emission levels for carbon monoxide emissions to air from the regenerator in the catalytic cracking process for partial combustion mode

Parameter	Combustion mode	BAT-AEL (monthly average) mg/Nm ³
Carbon monoxide, expressed as CO	Partial combustion mode	≤ 100 ⁽¹⁾

⁽¹⁾ May not be achievable when not operating the CO boiler at full load.

The associated monitoring is in BAT 4.

1.6. BAT conclusions for the catalytic reforming process

BAT 28. In order to reduce emissions of polychlorinated dibenzodioxins/furans (PCDD/F) to air from the catalytic reforming unit, BAT is to use one or a combination of the techniques given below.

Technique	Description	Applicability
(i) Choice of the catalyst promoter	Use of catalyst promoter in order to minimise polychlorinated dibenzodioxins/furans (PCDD/F) formation during regeneration. See Section 1.20.7	Generally applicable
(ii) Treatment of the regeneration flue-gas		
a. Regeneration gas recycling loop with adsorption bed	Waste gas from the regeneration step is treated to remove chlorinated compounds (e.g. dioxins)	Generally applicable to new units. For existing units the applicability may depend on the current regeneration unit design
b. Wet scrubbing	See Section 1.20.3	Not applicable to semi-regenerative reformers
c. Electrostatic precipitator (ESP)	See Section 1.20.1	Not applicable to semi-regenerative reformers

1.7. BAT conclusions for the coking processes

BAT 29. In order to reduce emissions to air from the coking production processes, BAT is to use one or a combination of the techniques given below:

Primary or process-related techniques, such as:

Technique	Description	Applicability
(i) Collection and recycling of coke fines	Systematic collection and recycling of coke fines generated during the whole coking process (drilling, handling, crushing, cooling, etc.)	Generally applicable
(ii) Handling and storage of coke according to BAT 3	See BAT 3	Generally applicable
(iii) Use of a closed blow-down system	Arrestment system for pressure relief from the coke drums	Generally applicable
(iv) Recovery of gas (including the venting prior to the drum being opened to atmosphere) as a component of refinery fuel gas (RFG)	Carrying venting from the coke drum to the gas compressor to recover as RFG, rather than flaring. For the flexicoking process, a conversion step (to convert the carbonyl sulphide (COS) into H ₂ S) is needed prior to treating the gas from the coking unit	For existing units, the applicability of the techniques may be limited by space availability

BAT 30. In order to reduce NO_x emissions to air from the calcining of green coke process, BAT is to use selective non-catalytic reduction (SNCR).

Description

See Section 1.20.2.

Applicability

The applicability of the SNCR technique (especially with respect to residence time and temperature window) may be restricted due to the specificity of the calcining process.

BAT 31. In order to reduce SO_x emissions to air from the calcining of green coke process, BAT is to use one or a combination of the techniques given below.

Technique	Description	Applicability
(i) Non-regenerative scrubbing	Wet scrubbing or seawater scrubbing. See Section 1.20.3	The applicability may be limited in arid areas and in the case where the by-products from treatment (including e.g. waste water with high level of salts) cannot be reused or appropriately disposed of. For existing units, the applicability may be limited by space availability
(ii) Regenerative scrubbing	Use of a specific SO _x absorbing reagent (e.g. absorbing solution) which generally enables the recovery of sulphur as a by-product during a regenerating cycle where the reagent is reused. See Section 1.20.3	The applicability is limited to the case where regenerated by-products can be sold. For existing units, the applicability may be limited by the existing sulphur recovery capacity as well as by space availability

BAT 32. In order to reduce dust emissions to air from the calcining of green coke process, BAT is to use a combination of the techniques given below.

Technique	Description	Applicability
(i) Electrostatic precipitator (ESP)	See Section 1.20.1	For existing units, the applicability may be limited by space availability. For graphite and anode coke calcining production, the applicability may be restricted due to the high resistivity of the coke particles
(ii) Multistage cyclone separators	See Section 1.20.1	Generally applicable

BAT-associated emission levels: See Table 8

Table 8

BAT-associated emission levels for dust emissions to air from a unit for the calcining of green coke

Parameter	BAT-AEL (monthly average) mg/Nm ³
Dust	10-50 ⁽¹⁾ ⁽²⁾

⁽¹⁾ The lower end of the range can be achieved with a 4-field ESP.

⁽²⁾ When an ESP is not applicable, values of up to 150 mg/Nm³ may occur.

The associated monitoring is in BAT 4.

1.8. BAT conclusions for the desalting process

BAT 33. In order to reduce water consumption and emissions to water from the desalting process, BAT is to use one or a combination of the techniques given below.

Technique	Description	Applicability
(i) Recycling water and optimisation of the desalting process	An ensemble of good desalting practices aiming at increasing the efficiency of the desalter and reducing wash water usage e.g. using low shear mixing devices, low water pressure. It includes the management of key parameters for washing (e.g. good mixing) and separation (e.g. pH, density, viscosity, electric field potential for coalescence) steps	Generally applicable
(ii) Multistage desalter	Multistage desalters operate with water addition and dehydration, repeated through two stages or more for achieving a better efficiency in the separation and therefore less corrosion in further processes	Applicable for new units
(iii) Additional separation step	An additional enhanced oil/water and solid/water separation designed for reducing the charge of oil to the waste water treatment plant and recycling it to the process. This includes, e.g. settling drum, the use of optimum interface level controllers	Generally applicable

1.9. BAT conclusions for the combustion units

BAT 34. In order to prevent or reduce NO_x emissions to air from the combustion units, BAT is to use one or a combination of the techniques given below.

I. Primary or process-related techniques, such as:

Technique	Description	Applicability
(i) Selection or treatment of fuel		
(a) Use of gas to replace liquid fuel	Gas generally contains less nitrogen than liquid and its combustion leads to a lower level of NO _x emissions. See Section 1.20.3	The applicability may be limited by the constraints associated with the availability of low sulphur gas fuels, which may be impacted by the energy policy of the Member State
(b) Use of low nitrogen refinery fuel oil (RFO) e.g. by RFO selection or by hydrotreatment of RFO	Refinery fuel oil selection favours low nitrogen liquid fuels among the possible sources to be used at the unit. Hydrotreatment aims at reducing the sulphur, nitrogen and metal contents of the fuel. See Section 1.20.3	Applicability is limited by the availability of low nitrogen liquid fuels, hydrogen production and hydrogen sulphide (H ₂ S) treatment capacity (e.g. amine and Claus units)

Technique	Description	Applicability
(ii) Combustion modifications		
(a) Staged combustion: — air staging — fuel staging	See Section 1.20.2	Fuel staging for mixed or liquid firing may require a specific burner design
(b) Optimisation of combustion	See Section 1.20.2	Generally applicable
(c) Flue-gas recirculation	See Section 1.20.2	Applicable through the use of specific burners with internal recirculation of the flue-gas. The applicability may be restricted to retrofitting external flue-gas recirculation to units with a forced/induced draught mode of operation
(d) Diluent injection	See Section 1.20.2	Generally applicable for gas turbines where appropriate inert diluents are available
(e) Use of low-NO _x burners (LNB)	See Section 1.20.2	Generally applicable for new units taking into account, the fuel-specific limitation (e.g. for heavy oil). For existing units, applicability may be restricted by the complexity caused by site-specific conditions e.g. furnaces design, surrounding devices. In very specific cases, substantial modifications may be required. The applicability may be restricted for furnaces in the delayed coking process, due to possible coke generation in the furnaces. In gas turbines, the applicability is restricted to low hydrogen content fuels (generally < 10 %)

II. Secondary or end-of-pipe techniques, such as:

Technique	Description	Applicability
(i) Selective catalytic reduction (SCR)	See Section 1.20.2	Generally applicable for new units. For existing units, the applicability may be constrained due to the requirements for significant space and optimal reactant injection
(ii) Selective non-catalytic reduction (SNCR)	See Section 1.20.2	Generally applicable for new units. For existing units, the applicability may be constrained by the requirement for the temperature window and the residence time to be reached by reactant injection

Technique	Description	Applicability
(iii) Low temperature oxidation	See Section 1.20.2	The applicability may be limited by the need for additional scrubbing capacity and by the fact that ozone generation and the associated risk management need to be properly addressed. The applicability may be limited by the need for additional waste water treatment and related cross-media effects (e.g. nitrate emissions) and by an insufficient supply of liquid oxygen (for ozone generation). For existing units, the applicability of the technique may be limited by space availability
(iv) SNO _x combined technique	See Section 1.20.4	Applicable only for high flue-gas (e.g. > 800 000 Nm ³ /h) flow and when combined NO _x and SO _x abatement is needed

BAT-associated emission levels: See Table 9, Table 10 and Table 11.

Table 9

BAT-associated emission levels for NO_x emissions to air from a gas turbine

Parameter	Type of equipment	BAT-AEL ⁽¹⁾ (monthly average) mg/Nm ³ at 15 % O ₂
NO _x expressed as NO ₂	Gas turbine (including combined cycle gas turbine — CCGT) and integrated gasification combined cycle turbine (IGCC)	40-120 (existing turbine)
		20-50 (new turbine) ⁽²⁾

⁽¹⁾ BAT-AEL refers to combined emissions from the gas turbine and the supplementary firing recovery boiler, where present.

⁽²⁾ For fuel with high H₂ content (i.e. above 10 %), the upper end of the range is 75 mg/Nm³.

The associated monitoring is in BAT 4.

Table 10

BAT-associated emission levels for NO_x emissions to air from a gas-fired combustion unit, with the exception of gas turbines

Parameter	Type of combustion	BAT-AEL (monthly average) mg/Nm ³
NO _x expressed as NO ₂	Gas firing	30-150 for existing unit ⁽¹⁾
		30-100 for new unit

⁽¹⁾ For an existing unit using high air pre-heat (i.e. > 200 °C) or with H₂ content in the fuel gas higher than 50 %, the upper end of the BAT-AEL range is 200 mg/Nm³.

The associated monitoring is in BAT 4.

Table 11

BAT-associated emission levels for NO_x emissions to air from a multi-fuel fired combustion unit with the exception of gas turbines

Parameter	Type of combustion	BAT-AEL (monthly average) mg/Nm ³
NO _x expressed as NO ₂	Multi-fuel fired combustion unit	30-300 for existing unit ⁽¹⁾ ⁽²⁾

⁽¹⁾ For existing units < 100 MW firing fuel oil with a nitrogen content higher than 0,5 % (w/w) or with liquid firing > 50 % or using air preheating, values up to 450 mg/Nm³ may occur.

⁽²⁾ The lower end of the range can be achieved by using the SCR technique.

The associated monitoring is in BAT 4.

BAT 35. In order to prevent or reduce dust and metal emissions to air from the combustion units, BAT is to use one or a combination of the techniques given below.

I. Primary or process-related techniques, such as:

Technique	Description	Applicability
(i) Selection or treatment of fuel		
(a) Use of gas to replace liquid fuel	Gas instead of liquid combustion leads to lower level of dust emissions See Section 1.20.3	The applicability may be limited by the constraints associated with the availability of low sulphur fuels such as natural gas, which may be impacted by the energy policy of the Member State
(b) Use of low sulphur refinery fuel oil (RFO) e.g. by RFO selection or by hydrotreatment of RFO	Refinery fuel oil selection favours low sulphur liquid fuels among the possible sources to be used at the unit. Hydrotreatment aims at reducing the sulphur, nitrogen and metal contents of the fuel. See Section 1.20.3	The applicability may be limited by the availability of low sulphur liquid fuels, hydrogen production and the hydrogen sulphide (H ₂ S) treatment capacity (e.g. amine and Claus units)
(ii) Combustion modifications		
(a) Optimisation of combustion	See Section 1.20.2	Generally applicable to all types of combustion
(b) Atomisation of liquid fuel	Use of high pressure to reduce the droplet size of liquid fuel. Recent optimal burner designs generally include steam atomisation	Generally applicable to liquid fuel firing

II. Secondary or end-of-pipe techniques, such as:

Technique	Description	Applicability
(i) Electrostatic precipitator (ESP)	See Section 1.20.1	For existing units, the applicability may be limited by space availability
(ii) Third stage blowback filter	See Section 1.20.1	Generally applicable
(iii) Wet scrubbing	See Section 1.20.3	The applicability may be limited in arid areas and in the case where the by-products from treatment (including e.g. waste water with a high level of salt) cannot be reused or appropriately disposed of. For existing units, the applicability of the technique may be limited by space availability
(iv) Centrifugal washers	See Section 1.20.1	Generally applicable

BAT-associated emission levels: See Table 12.

Table 12

BAT-associated emission levels for dust emissions to air from a multi-fuel fired combustion unit with the exception of gas turbines

Parameter	Type of combustion	BAT-AEL (monthly average) mg/Nm ³
Dust	Multi-fuel firing	5-50 for existing unit ⁽¹⁾ ⁽²⁾
		5-25 for new unit < 50 MW

⁽¹⁾ The lower end of the range is achievable for units with the use of end-of-pipe techniques.

⁽²⁾ The upper end of the range refers to the use of a high percentage of oil burning and where only primary techniques are applicable.

The associated monitoring is in BAT 4.

BAT 36. In order to prevent or reduce SO_x emissions to air from the combustion units, BAT is to use one or a combination of the techniques given below.

I. Primary or process-related techniques based on a selection or a treatment of the fuel, such as:

Technique	Description	Applicability
(i) Use of gas to replace liquid fuel	See Section 1.20.3	The applicability may be limited by the constraints associated with the availability of low sulphur fuels such as natural gas, which may be impacted by the energy policy of the Member State

Technique	Description	Applicability
(ii) Treatment of refinery fuel gas (RFG)	Residual H ₂ S concentration in RFG depends on the treatment process parameter, e.g. the amine-scrubbing pressure. See Section 1.20.3	For low calorific gas containing carbonyl sulphide (COS) e.g. from coking units, a converter may be required prior to H ₂ S removal
(iii) Use of low sulphur refinery fuel oil (RFO) e.g. by RFO selection or by hydrotreatment of RFO	Refinery fuel oil selection favours low sulphur liquid fuels among the possible sources to be used at the unit. Hydrotreatment aims at reducing the sulphur, nitrogen and metal contents of the fuel. See Section 1.20.3	The applicability is limited by the availability of low sulphur liquid fuels, hydrogen production and the hydrogen sulphide (H ₂ S) treatment capacity (e.g. amine and Claus units)

II. Secondary or end-of-pipe techniques:

Technique	Description	Applicability
(i) Non-regenerative scrubbing	Wet scrubbing or seawater scrubbing. See Section 1.20.3	The applicability may be limited in arid areas and in the case where the by-products from treatment (including e.g. waste water with high level of salts) cannot be reused or appropriately disposed of. For existing units, the applicability of the technique may be limited by space availability
(ii) Regenerative scrubbing	Use of a specific SO _x absorbing reagent (e.g. absorbing solution) which generally enables the recovery of sulphur as a by-product during a regenerating cycle where the reagent is reused. See Section 1.20.3	The applicability is limited to the case where regenerated by-products can be sold. Retrofitting to existing units may be limited by the existing sulphur recovery capacity. For existing units, the applicability of the technique may be limited by space availability
(iii) SNO _x combined technique	See Section 1.20.4	Applicable only for high flue-gas (e.g. > 800 000 Nm ³ /h) flow and when combined NO _x and SO _x abatement is required

Table 13

BAT-associated emission levels for SO₂ emissions to air from a combustion unit firing refinery fuel gas (RFG), with the exception of gas turbines

Parameter	BAT-AEL (monthly average) mg/Nm ³
SO ₂	5-35 ⁽¹⁾

⁽¹⁾ In the specific configuration of RFG treatment with a low scrubber operative pressure and with a refinery fuel gas with an H/C molar ratio above 5, the upper end of the BAT-AEL range can be as high as 45 mg/Nm³.

The associated monitoring is in BAT 4.

Table 14

BAT-associated emission levels for SO₂ emissions to air from multi-fuel fired combustion units, with the exception of gas turbines and stationary gas engines

This BAT-AEL refers to the weighted average emissions from existing multi-fuel fired combustion units within the refinery, with the exception of gas turbines and stationary gas engines.

Parameter	BAT-AEL (monthly average) mg/Nm ³
SO ₂	35-600

The associated monitoring is in BAT 4.

BAT 37. In order to reduce carbon monoxide (CO) emissions to air from the combustion units, BAT is to use a combustion operation control.

Description

See Section 1.20.5.

BAT-associated emission levels: See Table 15.

Table 15

BAT-associated emission levels for carbon monoxide emissions to air from a combustion unit

Parameter	BAT-AEL (monthly average) mg/Nm ³
Carbon monoxide, expressed as CO	≤ 100

The associated monitoring is in BAT 4.

1.10. BAT conclusions for the etherification process

BAT 38. In order to reduce emissions to air from the etherification process, BAT is to ensure the appropriate treatment of process off-gases by routing them to the refinery fuel gas system.

BAT 39. In order to prevent upset of the biotreatment, BAT is to use a storage tank and an appropriate unit production plan management to control the toxic components dissolved content (e.g. methanol, formic acid, ethers) of the waste water stream prior to final treatment.

1.11. BAT conclusions for the isomerisation process

BAT 40. In order to reduce emissions to air of chlorinated compounds, BAT is to optimise the use of chlorinated organic compounds used to maintain catalyst activity when such a process is in place or to use non-chlorinated catalytic systems.

1.12. BAT conclusions for the natural gas refinery

BAT 41. In order to reduce sulphur dioxide emissions to air from the natural gas plant, BAT is to apply BAT 54.

BAT 42. In order to reduce nitrogen oxides (NO_x) emissions to air from the natural gas plant, BAT is to apply BAT 34

BAT 43. In order to prevent emissions of mercury when present in raw natural gas, BAT is to remove the mercury and recover the mercury-containing sludge for waste disposal.

1.13. BAT conclusions for the distillation process

BAT 44. In order to prevent or reduce waste water flow generation from the distillation process, BAT is to use liquid ring vacuum pumps or surface condensers.

Applicability

May not be applicable in some retrofit cases. For new units, vacuum pumps, either in or not in combination with steam ejectors, may be needed to achieve a high vacuum (10 mm Hg). Also, a spare should be available in case the vacuum pump fails.

BAT 45. In order to prevent or reduce water pollution from the distillation process, BAT is to route sour water to the stripping unit.

BAT 46. In order to prevent or reduce emissions to air from distillation units, BAT is to ensure the appropriate treatment of process off-gases, especially incondensable off-gases, by acid gas removal prior to further use.

Applicability

Generally applicable for crude and vacuum distillation units. May not be applicable for stand-alone lubricant and bitumen refineries with emissions of less than 1 t/d of sulphur compounds. In specific refinery configurations, applicability may be restricted, due to the need for e.g. large piping, compressors or additional amine treating capacity.

1.14. BAT conclusions for the products treatment process

BAT 47. In order to reduce emissions to air from the products treatment process, BAT is to ensure the appropriate disposal of off-gases, especially odorous spent air from sweetening units, by routing them to destruction, e.g. by incineration.

Applicability

Generally applicable to products treatment processes where the gas streams can be safely processed to the destruction units. May not be applicable to sweetening units, due to safety reasons.

BAT 48. In order to reduce waste and waste water generation when a products treatment process using caustic is in place, BAT is to use cascading caustic solution and a global management of spent caustic, including recycling after appropriate treatment, e.g. by stripping.

1.15. **BAT conclusions for storage and handling processes**

BAT 49. In order to reduce VOC emissions to air from the storage of volatile liquid hydrocarbon compounds, BAT is to use floating roof storage tanks equipped with high efficiency seals or a fixed roof tank connected to a vapour recovery system.

Description

High efficiency seals are specific devices for limiting losses of vapour, e.g. improved primary seals, additional multiple (secondary or tertiary) seals (according to quantity emitted).

Applicability

The applicability of high efficiency seals may be restricted for retrofitting tertiary seals in existing tanks.

BAT 50. In order to reduce VOC emissions to air from the storage of volatile liquid hydrocarbon compounds, BAT is to use one or a combination of the techniques given below.

Technique	Description	Applicability
(i) Manual crude oil tank cleaning	Oil tank cleaning is performed by workers entering the tank and removing sludge manually	Generally applicable
(ii) Use of a closed-loop system	For internal inspections, tanks are periodically emptied, cleaned and rendered gas-free. This cleaning includes dissolving the tank bottom. Closed-loop systems that can be combined with end-of-pipe mobile abatement techniques prevent or reduce VOC emissions	The applicability may be limited by e.g. the type of residues, tank roof construction or tank materials

BAT 51. In order to prevent or reduce emissions to soil and groundwater from the storage of liquid hydrocarbon compounds, BAT is to use one or a combination of the techniques given below.

Technique	Description	Applicability
(i) Maintenance programme including corrosion monitoring, prevention and control	A management system including leak detection and operational controls to prevent overfilling, inventory control and risk-based inspection procedures on tanks at intervals to prove their integrity, and maintenance to improve tank containment. It also includes a system response to spill consequences to act before spills can reach the groundwater. To be especially reinforced during maintenance periods	Generally applicable
(ii) Double bottomed tanks	A second impervious bottom that provides a measure of protection against releases from the first material	Generally applicable for new tanks and after overhaul of existing tanks ⁽¹⁾
(iii) Impervious membrane liners	A continuous leak barrier under the entire bottom surface of the tank	Generally applicable for new tanks and after an overhaul of existing tanks ⁽¹⁾

Technique	Description	Applicability
(iv) Sufficient tank farm bund containment	A tank farm bund is designed to contain large spills potentially caused by a shell rupture or overfilling (for both environmental and safety reasons). Size and associated building rules are generally defined by local regulations	Generally applicable

(¹) Techniques ii and iii may not be generally applicable where tanks are dedicated to products that require heat for liquid handling (e.g. bitumen), and where no leak is likely because of solidification.

BAT 52. In order to prevent or reduce VOC emissions to air from loading and unloading operations of volatile liquid hydrocarbon compounds, BAT is to use one or a combination of the techniques given below to achieve a recovery rate of at least 95 %.

Technique	Description	Applicability (¹)
Vapour recovery by: (i) Condensation (ii) Absorption (iii) Adsorption (iv) Membrane separation (v) Hybrid systems	See Section 1.20.6	Generally applicable to loading/unloading operations where annual throughput is > 5 000 m ³ /yr. Not applicable to loading/unloading operations for sea-going vessels with an annual throughput < 1 million m ³ /yr

(¹) A vapour destruction unit (e.g. by incineration) may be substituted for a vapour recovery unit, if vapour recovery is unsafe or technically impossible because of the volume of return vapour.

BAT-associated emission levels: See Table 16.

Table 16

BAT-associated emission levels for non-methane VOC and benzene emissions to air from loading and unloading operations of volatile liquid hydrocarbon compounds

Parameter	BAT-AEL (hourly average) (¹)
NMVOC	0,15-10 g/Nm ³ (²) (³)
Benzene (³)	< 1 mg/Nm ³

(¹) Hourly values in continuous operation expressed and measured according to European Parliament and Council Directive 94/63/EC (OJ L 365, 31.12.1994, p. 24).

(²) Lower value achievable with two-stage hybrid systems. Upper value achievable with single-stage adsorption or membrane system.

(³) Benzene monitoring may not be necessary where emissions of NMVOC are at the lower end of the range.

1.16. **BAT conclusions for visbreaking and other thermal processes**

BAT 53. In order to reduce emissions to water from visbreaking and other thermal processes, BAT is to ensure the appropriate treatment of waste water streams by applying the techniques of BAT 11.

1.17. **BAT conclusions for waste gas sulphur treatment**

BAT 54. In order to reduce sulphur emissions to air from off-gases containing hydrogen sulphides (H₂S), BAT is to use all of the techniques given below.

Technique	Description	Applicability ⁽¹⁾
(i) Acid gas removal e.g. by amine treating	See Section 1.20.3	Generally applicable
(ii) Sulphur recovery unit (SRU), e.g. by Claus process	See Section 1.20.3	Generally applicable
(iii) Tail gas treatment unit (TGTU)	See Section 1.20.3	For retrofitting existing SRU, the applicability may be limited by the SRU size and configuration of the units and the type of sulphur recovery process already in place

⁽¹⁾ May not be applicable for stand-alone lubricant or bitumen refineries with a release of sulphur compounds of less than 1 t/d

BAT-associated environmental performance levels (BAT-AEPL): See Table 17.

Table 17

BAT-associated environmental performance levels for a waste gas sulphur (H₂S) recovery system

	BAT-associated environmental performance level (monthly average)
Acid gas removal	Achieve hydrogen sulphides (H ₂ S) removal in the treated RFG in order to meet gas firing BAT-AEL for BAT 36
Sulphur recovery efficiency ⁽¹⁾	New unit: 99,5 – > 99,9 %
	Existing unit: ≥ 98,5 %

⁽¹⁾ Sulphur recovery efficiency is calculated over the whole treatment chain (including SRU and TGTU) as the fraction of sulphur in the feed that is recovered in the sulphur stream routed to the collection pits.
When the applied technique does not include a recovery of sulphur (e.g. seawater scrubber), it refers to the sulphur removal efficiency, as the % of sulphur removed by the whole treatment chain.

The associated monitoring is described in BAT 4.

1.18. **BAT conclusions for flares**

BAT 55. In order to prevent emissions to air from flares, BAT is to use flaring only for safety reasons or for non-routine operational conditions (e.g. start-ups, shutdown).

BAT 56. In order to reduce emissions to air from flares when flaring is unavoidable, BAT is to use the techniques given below.

Technique	Description	Applicability
(i) Correct plant design	See Section 1.20.7	Applicable to new units. Flare gas recovery system may be retrofitted in existing units
(ii) Plant management	See Section 1.20.7	Generally applicable
(iii) Correct flaring devices design	See Section 1.20.7	Applicable to new units
(iv) Monitoring and reporting	See Section 1.20.7	Generally applicable

1.19. BAT conclusions for integrated emission management

BAT 57. In order to achieve an overall reduction of NO_x emissions to air from combustion units and fluid catalytic cracking (FCC) units, BAT is to use an integrated emission management technique as an alternative to applying BAT 24 and BAT 34.

Description

The technique consists of managing NO_x emissions from several or all combustion units and FCC units on a refinery site in an integrated manner, by implementing and operating the most appropriate combination of BAT across the different units concerned and monitoring the effectiveness thereof, in such a way that the resulting total emissions are equal to or lower than the emissions that would be achieved through a unit-by-unit application of the BAT-AELs referred to in BAT 24 and BAT 34.

This technique is especially suitable to oil refining sites:

- with a recognised site complexity, multiplicity of combustion and process units interlinked in terms of their feedstock and energy supply;
- with frequent process adjustments required in function of the quality of the crude received;
- with a technical necessity to use a part of process residues as internal fuels, causing frequent adjustments of the fuel mix according to process requirements.

BAT-associated emission levels: See Table 18.

In addition, for each new combustion unit or new FCC unit included in the integrated emission management system, the BAT-AELs set out under BAT 24 and BAT 34 remain applicable.

Table 18

BAT-associated emission levels for NO_x emissions to air when applying BAT 57

The BAT-AEL for NO_x emissions from the units concerned by BAT 57, expressed in mg/Nm³ as a monthly average value, is equal to or less than the weighted average of the NO_x concentrations (expressed in mg/Nm³ as a monthly average) that would be achieved by applying in practice at each of those units techniques that would enable the units concerned to meet the following:

- (a) for catalytic cracking process (regenerator) units: the BAT-AEL range set out in Table 4 (BAT 24);
- (b) for combustion units burning refinery fuels alone or simultaneously with other fuels: the BAT-AEL ranges set out in Tables 9, 10 and 11 (BAT 34).

This BAT-AEL is expressed by the following formula:

$$\frac{\sum [(flue\ gas\ flow\ rate\ of\ the\ unit\ concerned) \times (NO_x\ concentration\ that\ would\ be\ achieved\ for\ that\ unit)]}{\sum (flue\ gas\ flow\ rate\ of\ all\ units\ concerned)}$$

Notes:

1. The applicable reference conditions for oxygen are those specified in Table 1.
2. The weighing of the emission levels of the individual units is done on the basis of the flue-gas flow rate of the unit concerned, expressed as a monthly average value (Nm³/hour), which is representative for the normal operation of that unit within the refinery installation (applying the reference conditions under Note 1).
3. In case of substantial and structural fuel changes which are affecting the applicable BAT-AEL for a unit or other substantial and structural changes in the nature or functioning of the units concerned, or in case of their replacement or extension or the addition of combustion units or FCC units, the BAT-AEL defined in Table 18 needs to be adjusted accordingly.

Monitoring associated with BAT 57

BAT for monitoring emissions of NO_x under an integrated emission management technique is as in BAT 4, complemented with the following:

- a monitoring plan including a description of the processes monitored, a list of the emission sources and source streams (products, waste gases) monitored for each process and a description of the methodology (calculations, measurements) used and the underlying assumptions and associated level of confidence;
- continuous monitoring of the flue-gas flow rates of the units concerned, either through direct measurement or by an equivalent method;
- a data management system for collecting, processing and reporting all monitoring data needed to determine the emissions from the sources covered by the integrated emission management technique.

BAT 58. In order to achieve an overall reduction of SO₂ emissions to air from combustion units, fluid catalytic cracking (FCC) units and waste gas sulphur recovery units, BAT is to use an integrated emission management technique as an alternative to applying BAT 26, BAT 36 and BAT 54.

Description

The technique consists of managing SO₂ emissions from several or all combustion units, FCC units and waste gas sulphur recovery units on a refinery site in an integrated manner, by implementing and operating the most appropriate combination of BAT across the different units concerned and monitoring the effectiveness thereof, in such a way that the resulting total emissions are equal to or lower than the emissions that would be achieved through a unit-by-unit application of the BAT-AELs referred to in BAT 26 and BAT 36 as well as the BAT-AEPL set out under BAT 54.

This technique is especially suitable to oil refining sites:

- with a recognised site complexity, multiplicity of combustion and process units interlinked in terms of their feedstock and energy supply;
- with frequent process adjustments required in function of the quality of the crude received;
- with a technical necessity to use a part of process residues as internal fuels, causing frequent adjustments of the fuel mix according to process requirements.

BAT associated emission level: See Table 19.

In addition, for each new combustion unit, new FCC unit or new waste gas sulphur recovery unit included in the integrated emission management system, the BAT-AELs set out under BAT 26 and BAT 36 and the BAT-AEPL set out under BAT 54 remain applicable.

Table 19

BAT-associated emission levels for SO₂ emissions to air when applying BAT 58

The BAT-AEL for SO₂ emissions from the units concerned by BAT 58, expressed in mg/Nm³ as a monthly average value, is equal to or less than the weighted average of the SO₂ concentrations (expressed in mg/Nm³ as a monthly average) that would be achieved by applying in practice at each of those units techniques that would enable the units concerned to meet the following:

- (a) for catalytic cracking process (regenerator) units: the BAT-AEL ranges set out in Table 6 (BAT 26);
- (b) for combustion units burning refinery fuels alone or simultaneously with other fuels: the BAT-AEL ranges set out in Table 13 and in Table 14 (BAT 36); and
- (c) for waste gas sulphur recovery units: the BAT-AEPL ranges set out in Table 17 (BAT 54).

This BAT-AEL is expressed by the following formula:

$$\frac{\Sigma [(\text{flue gas flow rate of the unit concerned}) \times (\text{SO}_2 \text{ concentration that would be achieved for that unit})]}{\Sigma (\text{flue gas flow rate of all units concerned})}$$

Notes:

1. The applicable reference conditions for oxygen are those specified in Table 1.
2. The weighing of the emission levels of the individual units is done on the basis of the flue-gas flow rate of the unit concerned, expressed as the monthly average value (Nm³/hour), which is representative for the normal operation of that unit within the refinery installation (applying the reference conditions under Note 1).
3. In case of substantial and structural fuel changes which are affecting the applicable BAT-AEL for a unit or other substantial and structural changes in the nature or functioning of the units concerned, or in case of their replacement, extension or the addition of combustion, FCC, or waste gas sulphur recovery units, the BAT-AEL defined in Table 19 needs to be adjusted accordingly.

Monitoring associated with BAT 58

BAT for monitoring emissions of SO₂ under an integrated emission management approach is as in BAT 4, complemented with the following:

- a monitoring plan including a description of the processes monitored, a list of the emission sources and source streams (products, waste gases) monitored for each process and a description of the methodology (calculations, measurements) used and the underlying assumptions and associated level of confidence;
- continuous monitoring of the flue-gas flow rates of the units concerned, either through direct measurement or by an equivalent method;
- a data management system for collecting, processing and reporting all monitoring data needed to determine the emissions from the sources covered by the integrated emission management technique.

GLOSSARY

1.20. **Description of techniques for the prevention and control of emissions to air**1.20.1. *Dust*

Technique	Description
Electrostatic precipitator (ESP)	Electrostatic precipitators operate such that particles are charged and separated under the influence of an electrical field. Electrostatic precipitators are capable of operating under a wide range of conditions.

Technique	Description
	<p>Abatement efficiency may depend on the number of fields, residence time (size), catalyst properties and upstream particles removal devices.</p> <p>At FCC units, 3-field ESPs and 4-field ESPs are commonly used.</p> <p>ESPs may be used on a dry mode or with ammonia injection to improve the particle collection.</p> <p>For the calcining of green coke, the ESP capture efficiency may be reduced due to the difficulty for coke particles to be electrically charged</p>
Multistage cyclone separators	Cyclonic collection device or system installed following the two stages of cyclones. Generally known as a third stage separator, common configuration consists of a single vessel containing many conventional cyclones or improved swirl-tube technology. For FCC, performance mainly depends on the particle concentration and size distribution of the catalyst fines downstream of the regenerator internal cyclones
Centrifugal washers	Centrifugal washers combine the cyclone principle and an intensive contact with water e.g. venturi washer
Third stage blowback filter	Reverse flow (blowback) ceramic or sintered metal filters where, after retention at the surface as a cake, the solids are dislodged by initiating a reverse flow. The dislodged solids are then purged from the filter system

1.20.2. Nitrogen oxides (NO_x)

Technique	Description
Combustion modifications	
Staged combustion	<ul style="list-style-type: none"> — Air staging — involves substoichiometric firing in a first step and the subsequent addition of the remaining air or oxygen into the furnace to complete combustion — Fuel staging — a low impulse primary flame is developed in the port neck; a secondary flame covers the root of the primary flame reducing its core temperature
Flue-gas recirculation	<p>Reinjection of waste gas from the furnace into the flame to reduce the oxygen content and therefore the temperature of the flame.</p> <p>Special burners using the internal recirculation of combustion gases to cool the root of the flames and reduce the oxygen content in the hottest part of the flames</p>
Use of low-NO _x burners (LNB)	The technique (including ultra-low-NO _x burners) is based on the principles of reducing peak flame temperatures, delaying but completing the combustion and increasing the heat transfer (increased emissivity of the flame). It may be associated with a modified design of the furnace combustion chamber. The design of ultra-low-NO _x burners (ULNB) includes combustion staging (air/fuel) and flue-gas recirculation. Dry low-NO _x burners (DLNB) are used for gas turbines
Optimisation of combustion	Based on permanent monitoring of appropriate combustion parameters (e.g. O ₂ , CO content, fuel to air (or oxygen) ratio, unburnt components), the technique uses control technology for achieving the best combustion conditions

Technique	Description
Diluent injection	Inert diluents, e.g. flue-gas, steam, water, nitrogen added to combustion equipment reduce the flame temperature and consequently the concentration of NO _x in the flue-gases
Selective catalytic reduction (SCR)	The technique is based on the reduction of NO _x to nitrogen in a catalytic bed by reaction with ammonia (in general aqueous solution) at an optimum operating temperature of around 300-450 °C. One or two layers of catalyst may be applied. A higher NO _x reduction is achieved with the use of higher amounts of catalyst (two layers)
Selective non-catalytic reduction (SNCR)	The technique is based on the reduction of NO _x to nitrogen by reaction with ammonia or urea at a high temperature. The operating temperature window must be maintained between 900 °C and 1 050 °C for optimal reaction
Low temperature NO _x oxidation	The low temperature oxidation process injects ozone into a flue-gas stream at optimal temperatures below 150 °C, to oxidise insoluble NO and NO ₂ to highly soluble N ₂ O ₅ . The N ₂ O ₅ is removed in a wet scrubber by forming dilute nitric acid waste water that can be used in plant processes or neutralised for release and may need additional nitrogen removal

1.20.3. Sulphur oxides (SO_x)

Technique	Description
Treatment of refinery fuel gas (RFG)	Some refinery fuel gases may be sulphur-free at source (e.g. from catalytic reforming and isomerisation processes) but most other processes produce sulphur-containing gases (e.g. off-gases from the visbreaker, hydrotreater or catalytic cracking units). These gas streams require an appropriate treatment for gas desulphurisation (e.g. by acid gas removal — see below — to remove H ₂ S) before being released to the refinery fuel gas system
Refinery fuel oil (RFO) desulphurisation by hydrotreatment	In addition to selection of low-sulphur crude, fuel desulphurisation is achieved by the hydrotreatment process (see below) where hydrogenation reactions take place and lead to a reduction in sulphur content
Use of gas to replace liquid fuel	Decrease the use of liquid refinery fuel (generally heavy fuel oil containing sulphur, nitrogen, metals, etc.) by replacing it with on-site Liquefied Petroleum Gas (LPG) or refinery fuel gas (RFG) or by externally supplied gaseous fuel (e.g. natural gas) with a low level of sulphur and other undesirable substances. At the individual combustion unit level, under multi-fuel firing, a minimum level of liquid firing is necessary to ensure flame stability
Use of SO _x reducing catalysts additives	Use of a substance (e.g. metallic oxides catalyst) that transfers the sulphur associated with coke from the regenerator back to the reactor. It operates most efficiently in full combustion mode rather than in deep partial-combustion mode. NB: SO _x reducing catalysts additives might have a detrimental effect on dust emissions by increasing catalyst losses due to attrition, and on NO _x emissions by participating in CO promotion, together with the oxidation of SO ₂ to SO ₃

Technique	Description
Hydrotreatment	Based on hydrogenation reactions, hydrotreatment aims mainly at producing low-sulphur fuels (e.g. 10 ppm gasoline and diesel) and optimising the process configuration (heavy residue conversion and middle distillate production). It reduces the sulphur, nitrogen and metal content of the feed. As hydrogen is required, sufficient production capacity is needed. As the technique transfer sulphur from the feed to hydrogen sulphide (H ₂ S) in the process gas, treatment capacity (e.g. amine and Claus units) is also a possible bottleneck
Acid gas removal e.g. by amine treating	Separation of acid gas (mainly hydrogen sulphide) from the fuel gases by dissolving it in a chemical solvent (absorption). The commonly used solvents are amines. This is generally the first step treatment needed before elemental sulphur can be recovered in the SRU
Sulphur recovery unit (SRU)	Specific unit that generally consists of a Claus process for sulphur removal of hydrogen sulphide (H ₂ S)-rich gas streams from amine treating units and sour water strippers. SRU is generally followed by a tail gas treatment unit (TGTU) for remaining H ₂ S removal
Tail gas treatment unit (TGTU)	A family of techniques, additional to the SRU in order to enhance the removal of sulphur compounds. They can be divided into four categories according to the principles applied: <ul style="list-style-type: none"> — direct oxidation to sulphur — continuation of the Claus reaction (sub-dewpoint conditions) — oxidation to SO₂ and recovering sulphur from SO₂ — reduction to H₂S and recovery of sulphur from this H₂S (e.g. amine process)
Wet scrubbing	In the wet scrubbing process, gaseous compounds are dissolved in a suitable liquid (water or alkaline solution). Simultaneous removal of solid and gaseous compounds may be achieved. Downstream of the wet scrubber, the flue-gases are saturated with water and a separation of the droplets is required before discharging the flue-gases. The resulting liquid has to be treated by a waste water process and the insoluble matter is collected by sedimentation or filtration According to the type of scrubbing solution, it can be: <ul style="list-style-type: none"> — a non-regenerative technique (e.g. sodium or magnesium-based) — a regenerative technique (e.g. amine or soda solution) According to the contact method, the various techniques may require e.g.: <ul style="list-style-type: none"> — Venturi using the energy from inlet gas by spraying it with the liquid — packed towers, plate towers, spray chambers. Where scrubbers are mainly intended for SO _x removal, a suitable design is needed to also efficiently remove dust. The typical indicative SO _x removal efficiency is in the range 85-98 %.
Non-regenerative scrubbing	Sodium or magnesium-based solution is used as alkaline reagent to absorb SO _x generally as sulphates. Techniques are based on e.g.: <ul style="list-style-type: none"> — wet limestone — aqueous ammonia — seawater (see infra)

Technique	Description
Seawater scrubbing	A specific type of non-regenerative scrubbing using the alkalinity of the seawater as solvent. Generally requires an upstream abatement of dust
Regenerative scrubbing	Use of specific SO _x absorbing reagent (e.g. absorbing solution) that generally enables the recovery of sulphur as a by-product during a regenerating cycle where the reagent is reused

1.20.4. *Combined techniques (SO_x, NO_x and dust)*

Technique	Description
Wet scrubbing	See Section 1.20.3
SNO _x combined technique	<p>Combined technique to remove SO_x, NO_x and dust where a first dust removal stage (ESP) takes place followed by some specific catalytic processes. The sulphur compounds are recovered as commercial-grade concentrated sulphuric acid, while NO_x is reduced to N₂.</p> <p>Overall SO_x removal is in the range: 94-96,6 %.</p> <p>Overall NO_x removal is in the range: 87-90 %</p>

1.20.5. *Carbon monoxide (CO)*

Technique	Description
Combustion operation control	The increase in CO emissions due to the application of combustion modifications (primary techniques) for the reduction of NO _x emissions can be limited by a careful control of the operational parameters
Catalysts with carbon monoxide (CO) oxidation promoters	Use of a substance which selectively promotes the oxidation of CO into CO ₂ (combustion)
Carbon monoxide (CO) boiler	<p>Specific post-combustion device where CO present in the flue-gas is consumed downstream of the catalyst regenerator to recover the energy</p> <p>It is usually used only with partial-combustion FCC units</p>

1.20.6. *Volatile organic compounds (VOC)*

Technique	Description
Vapour recovery	<p>Volatile organic compounds emissions from loading and unloading operations of most volatile products, especially crude oil and lighter products, can be abated by various techniques e.g.:</p> <ul style="list-style-type: none"> — Absorption: the vapour molecules dissolve in a suitable absorption liquid (e.g. glycols or mineral oil fractions such as kerosene or reformat). The loaded scrubbing solution is desorbed by reheating in a further step. The desorbed gases must either be condensed, further processed, and incinerated or re-absorbed in an appropriate stream (e.g. of the product being recovered)

	<ul style="list-style-type: none"> — Adsorption: the vapour molecules are retained by activate sites on the surface of adsorbent solid materials, e.g. activated carbon (AC) or zeolite. The adsorbent is periodically regenerated. The resulting desorbate is then absorbed in a circulating stream of the product being recovered in a down-stream wash column. Residual gas from wash column is sent to further treatment — Membrane gas separation: the vapour molecules are processed through selective membranes to separate the vapour/air mixture into a hydrocarbon-enriched phase (permeate), which is subsequently condensed or absorbed, and a hydrocarbon-depleted phase (retentate). — Two-stage refrigeration/condensation: by cooling of the vapour/gas mixture the vapour molecules condense and are separated as a liquid. As the humidity leads to the icing-up of the heat exchanger, a two-stage condensation process providing for alternate operation is required. — Hybrid systems: combinations of available techniques <p>NB Absorption and adsorption processes cannot notably reduce methane emissions.</p>
Vapour destruction	<p>Destruction of VOCs can be achieved through e.g. thermal oxidation (incineration) or catalytic oxidation when recovery is not easily feasible. Safety requirements (e.g. flame arrestors) are needed to prevent explosion.</p> <p>Thermal oxidation occurs typically in single chamber, refractory-lined oxidisers equipped with gas burner and a stack. If gasoline is present, heat exchanger efficiency is limited and preheat temperatures are maintained below 180 °C to reduce ignition risk. Operating temperatures range from 760 °C to 870 °C and residence times are typically 1 second. When a specific incinerator is not available for this purpose, an existing furnace may be used to provide the required temperature and residence times.</p> <p>Catalytic oxidation requires a catalyst to accelerate the rate of oxidation by adsorbing the oxygen and the VOCs on its surface The catalyst enables the oxidation reaction to occur at lower temperature than required by thermal oxidation: typically ranging from 320 °C to 540 °C. A first preheating step (electrically or with gas) takes place to reach a temperature necessary to initiate the VOCs catalytic oxidation. An oxidation step occurs when the air is passed through a bed of solid catalysts</p>
LDAR (leak detection and repair) programme	<p>An LDAR (leak detection and repair) programme is a structured approach to reduce fugitive VOC emissions by detection and subsequent repair or replacement of leaking components. Currently, sniffing (described by EN 15446) and optical gas imaging methods are available for the identification of the leaks.</p> <p>Sniffing method: The first step is the detection using hand-held VOC analysers measuring the concentration adjacent to the equipment (e.g. by using flame ionisation or photo-ionisation). The second step consists of bagging the component to carry out a direct measurement at the source of emission. This second step is sometimes replaced by mathematical correlation curves derived from statistical results obtained from a large number of previous measurements made on similar components.</p> <p>Optical gas imaging methods: Optical imaging uses small lightweight hand-held cameras which enable the visualisation of gas leaks in real time, so that they appear as 'smoke' on a video recorder together with the normal image of the component concerned to easily and rapidly locate significant VOC leaks. Active systems produce an image with a back-scattered infrared laser light reflected on the component and its surroundings. Passive systems are based on the natural infrared radiation of the equipment and its surroundings</p>

VOC diffuse emissions monitoring	<p>Full screening and quantification of site emissions can be undertaken with an appropriate combination of complementary methods, e.g. Solar occultation flux (SOF) or differential absorption lidar (DIAL) campaigns. These results can be used for trend evaluation in time, cross checking and updating/validation of the ongoing LDAR programme.</p> <p>Solar occultation flux (SOF): The technique is based on the recording and spectrometric Fourier Transform analysis of a broadband infrared or ultraviolet/visible sunlight spectrum along a given geographical itinerary, crossing the wind direction and cutting through VOC plumes.</p> <p>Differential absorption LIDAR (DIAL): DIAL is a laser-based technique using differential adsorption LIDAR (light detection and ranging) which is the optical analogue of sonic radio wave-based RADAR. The technique relies on the back-scattering of laser beam pulses by atmospheric aerosols, and the analysis of spectral properties of the returned light collected with a telescope</p>
High-integrity equipment	<p>High-integrity equipment includes e.g.:</p> <ul style="list-style-type: none"> — valves with double packing seals — magnetically driven pumps/compressors/agitators — pumps/compressors/agitators fitted with mechanical seals instead of packing — high-integrity gaskets (such as spiral wound, ring joints) for critical applications

1.20.7. Other techniques

Technique	Description
Techniques to prevent or reduce emissions from flaring	<p>Correct plant design: includes sufficient flare gas recovery system capacity, the use of high-integrity relief valves and other measures to use flaring only as a safety system for other than normal operations (start-up, shutdown, emergency).</p> <p>Plant management: includes organisational and control measures to reduce flaring events by balancing RFG system, using advanced process control, etc.</p> <p>Flaring devices design: includes height, pressure, assistance by steam, air or gas, type of flare tips, etc. It aims at enabling smokeless and reliable operations and ensuring an efficient combustion of excess gases when flaring from non-routine operations.</p> <p>Monitoring and reporting: Continuous monitoring (measurements of gas flow and estimations of other parameters) of gas sent to flaring and associated parameters of combustion (e.g. flow gas mixture and heat content, ratio of assistance, velocity, purge gas flow rate, pollutant emissions). Reporting of flaring events makes it possible to use flaring ratio as a requirement included in the EMS and to prevent future events. Visual remote monitoring of the flare can also be carried out by using colour TV monitors during flare events</p>
Choice of the catalyst promoter to avoid dioxins formation	<p>During the regeneration of the reformer catalyst, organic chloride is generally needed for effective reforming catalyst performance (to re-establish the proper chloride balance in the catalyst and to assure the correct dispersion of the metals). The choice of the appropriate chlorinated compound will have an influence on the possibility of emissions of dioxins and furans</p>

Solvent recovery for base oil production processes	<p>The solvent recovery unit consists of a distillation step where the solvents are recovered from the oil stream and a stripping step (with steam or an inert gas) in a fractionator.</p> <p>The solvents used may be a mixture (DiMe) of 1,2-dichloroethane (DCE) and dichloromethane (DCM).</p> <p>In wax-processing units, solvent recovery (e.g. for DCE) is carried out using two systems: one for the deoiled wax and another one for the soft wax. Both consist of heat-integrated flashdrums and a vacuum stripper. Streams from the dewaxed oil and waxes product are stripped for removal of traces of solvents</p>
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1.21. Description of techniques for the prevention and control of emissions to water

1.21.1. Waste water pretreatment

Pretreatment of sour water streams before reuse or treatment	Send generated sour water (e.g. from distillation, cracking, coking units) to appropriate pretreatment (e.g. stripper unit)
Pretreatment of other waste water streams prior to treatment	To maintain treatment performance, appropriate pretreatment may be required

1.21.2. Waste water treatment

Removal of insoluble substances by recovering oil.	<p>These techniques generally include:</p> <ul style="list-style-type: none"> — API Separators (APIs) — Corrugated Plate Interceptors (CPIs) — Parallel Plate Interceptors (PPIs) — Tilted Plate Interceptors (TPIs) — Buffer and/or equalisation tanks
Removal of insoluble substances by recovering suspended solid and dispersed oil	<p>These techniques generally include:</p> <ul style="list-style-type: none"> — Dissolved Gas Flotation (DGF) — Induced Gas Flotation (IGF) — Sand Filtration
Removal of soluble substances including biological treatment and clarification	<p>Biological treatment techniques may include:</p> <ul style="list-style-type: none"> — Fixed bed systems — Suspended bed systems. <p>One of the most commonly used suspended bed system in refineries WWTP is the activated sludge process. Fixed bed systems may include a biofilter or trickling filter</p>
Additional treatment step	A specific waste water treatment intended to complement the previous treatment steps e.g. for further reducing nitrogen or carbon compounds. Generally used where specific local requirements for water preservation exist.