Refineries
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REFINERIES

Source: Oil & Gas Refining Journal, reviewed by TWG
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Cartography: template by IPTS-GIS analyst
Delivered oil products to Swedish market

Petrol and diesel fuel with bio fuel content
5 Swedish refineries

- Preem Lysekil (11.5 Mton)
- Preem Gothenburg (6 Mton)
- St 1 (former Shell) Gothenburg (5 Mton)
- Nynas, Nynäshamn (1.5 Mton)
- Nynäs, Gothenburg (0.7 Mton)

- Refineries have had individual, integrated permits with individual conditions since 1969
Typical refinery operations

- Coking
- Vacuum Distillation
- Catalytic Cracking
- Atmospheric distillation
- Catalytic Reforming
- Catalytic Hydrocracking
- Catalytic Hydrotreatment

- Alkylation
- Isomerisation
- Hydrogen Production
- Sulphur recovery
How to compare Refineries
Large and small Refineries
Simple and complex Refineries

• Through put
• Crude Distillation capacity
• 0,5-23 Mtonnes/year, (Europe)
• Average 8 Mtonnes/year (Europe)
Figure 10.1: Scheme 1: Hydroskimming + isomerisation unit
Figure 10.2: Scheme 2: Catcracker configuration
Figure 10.3: Scheme 3: Hydrocracker configuration
Figure 10.4: Scheme 4: Complex refinery with hydroconversion and IGCC
Preem Lysekil - 11,4 Mton Crude /year

• Crude Destillation
• Vacuum Destillation
• Desulphurisation (SynSat, MHC, Iso Cracking reactor)
• Catalytic Reformer
• Thermal and Catalytic Cracker
• Sulphur recovery (3 Claus + TGTU)
• Isomerisation
• Polymerisation
• Hydrogen gas production
• Boilers
Nelson complexity index (EU15)

Figure 1.3: Nelson complexity index of European refineries per country (average 6.1)
Emissions to air

- Air emissions related to energy
- How to be energy efficient
- How to measure energy efficiency
Action in order to improve energy efficiency - examples

• Installation of waste heat boilers in furnaces

• Expanded heat exchanger area in heat exchangers where cold streams are preheated by warm product streams from process
Action in order to improve energy efficiency - Examples

- Direct feed of “semi products” to processes without cooling/storage
- Balancing of vapour and fuel gas systems
- Effective combustion processes
- High efficiency on pumps and compressors
- Make use of waste heat
How to measure energy efficiency

- MJ/tonnes of crude
- Tonnes CO2/tonnes of crude (related to complexity)
- Energy Efficiency Index
EU 15 Refineries CO₂/tonne
EII- Energy Intensity Index
A energy efficiency benchmark

EII = “real energy use” /”theoretical energy use”

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<tr>
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<tbody>
<tr>
<td>Nr. of refineries</td>
<td>84</td>
<td>75</td>
<td>68</td>
<td>72</td>
</tr>
<tr>
<td>EII Preem (L)</td>
<td>70</td>
<td>59</td>
<td>59</td>
<td>65</td>
</tr>
<tr>
<td>Ranking Preem (L)</td>
<td>7</td>
<td>2</td>
<td>2</td>
<td>4</td>
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<tr>
<td>EII Average WE</td>
<td>87</td>
<td>83</td>
<td>81</td>
<td>81</td>
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<tr>
<td>Interval WE</td>
<td>58-124</td>
<td>55-106</td>
<td>58-105</td>
<td>54-101</td>
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</tbody>
</table>

2008: interval 65-120 in IED BREF    World average 92

2015 Preem (L) EII 78
Air Emissions

• SO$_2$
• NO$_x$
• Particles
• VOC
• Smell
Sulphur emissions

- Furnaces and boilers
- Catalytic cracker
- Sulphur Recovery
- Flaring
Fuel for furnaces and boilers

- Energy efficient plants need less fuel - can use refinery gas (low sulphur content <50 ppm (vol))
- Minimize the use of oil as fuel and limit the S content in the oil
- If not use end of pipe (cleaning)
Sulphur recovery plants

- Claus unit – (95%)
- Claus + Tail Gas Treatment Unit (99.9 %)
- Flaring from SRU included

- Avoid unnecessary flaring
### SO₂ emissions – Swedish Refineries 2004
*(red figures 2008) (green figures 2014)*

<table>
<thead>
<tr>
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<th>Preem (L)</th>
<th>Preem (G)</th>
<th>ST 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Crude, Mtonnes</strong></td>
<td>10 (10) (11)</td>
<td>6 (5,4) 4,6</td>
<td>4 (4) (3,5)</td>
</tr>
<tr>
<td><strong>SO₂ (fuel), tonnes</strong></td>
<td>210 (106)</td>
<td>260 (178)</td>
<td>286 (28)</td>
</tr>
<tr>
<td><strong>Share of refinery gas and other gas %</strong></td>
<td>84 (89)</td>
<td>91 (94) (99)</td>
<td>91 (99,8) (99,5)</td>
</tr>
<tr>
<td><strong>SO₂ (SRU), tonnes</strong></td>
<td>490 (238)</td>
<td>60 (4)</td>
<td>140 (72)</td>
</tr>
<tr>
<td><strong>SRU, Efficiency, %</strong></td>
<td>99,7 (99,9) (99,9)</td>
<td>99,0 (99,9) (98,8)</td>
<td>99,6 (99,8) (99,6)</td>
</tr>
<tr>
<td><strong>SO₂, TOTAL</strong></td>
<td>700 (344) (411)</td>
<td>320 (162) (120)</td>
<td>426 (100) (62)</td>
</tr>
</tbody>
</table>
Figure 18 European Refinery SO₂ Emissions, 2003

Refinery-Wide SO₂ Emissions

SO₂ (kg/tonne crude oil processed)

Nelson Complexity Index

90 percentile

50 percentile

(1) 2003, or the most recent year for which a refinery's data was available.
Nitrogen oxides

- Furnaces and boilers
- Fluid catalytic cracker
Reduction of NOx from furnaces and boilers

• Choice of fuel  (typically 60-70 % lower emissions from gas than oil)
• Low NOx burners, gas fuel 15-35 mg/MJ, 50-130 mg/m3), oil fuel 100 mg/MJ, 300 g/m3
• SNCR  (50 % reduction)
• SCR    (appr. 90 % reduction)
### NOx emissions - Swedish Refineries

#### 2004 (2011)(2014)

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<th>Preem (G)</th>
<th>St 1</th>
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<tbody>
<tr>
<td>Crude, Mtonnes</td>
<td>10 (10) (11)</td>
<td>6 (5) (4.6)</td>
<td>4 (4) (3.5)</td>
</tr>
<tr>
<td>NOx (total), tonnes</td>
<td>690 (550) (614)</td>
<td>340 (382) (196)</td>
<td>413 (315) (270)</td>
</tr>
<tr>
<td>NOx mg/m³</td>
<td>150 (120)</td>
<td>150</td>
<td>150-200</td>
</tr>
<tr>
<td>NOx tonnes/Mtonnes of crude</td>
<td>69 (55) (56)</td>
<td>63 (76) (43)</td>
<td>103 (90) (77)</td>
</tr>
</tbody>
</table>

**Measures** – refinery gas, natural gas, minimize oil, low-nox-burners, SCR
Figure 29 European Refinery NOx Emissions, 2003

Refinery-Wide NOx Emissions

N0x (kg/tonne crude oil processed)

Nelson Complexity Index

(1) 2003, or the most recent year for which a refinery’s data was available.
VOC – emission sources

• Process area
• Storage area for crude and products
• Waste Water Treatment Plant
• Harbours
• Dispatch Stations (truck and rail way)
VOC - Composition

- Alkanes (80-90 %), (C2-C7)
- Alkenes (5-15 %), (C2-C6)
- Aromatics (3-5 %), (C6-C8)
• Thousand of potential leaking sources
• Sources spread over a very large area some of them high above ground
• Some potential leaking points are tight when installed but will leak eventually

Is this a major problem?
- how to find out (calculations or monitoring)

How to keep emissions low?
- choice of equipment
- leak detection and repair (LDAR)

Are we successful? Assess
- monitoring
Measures to reduce VOC-process area- examples

• Tight equipment (live-loading valves, bellow seal valves, seal less pumps, Pumps with double mechanical seals)

• Minimize flanges

• Compressor vents connected to the flare
Leak detection and repair

- At a Swedish refinery 100,000 potential leaking points are leak tested twice a year. If leaks are found (def) action must be taken in order to stop leak
IR Camera
a complement to sniffer

• Possible to search for leaks in difficult positions
• Easy to handle
• Need to define a leak
Measures to reduce VOC-Tanks and WWTU

- Floating roofs (inner and outer floating roofs, primary and secondary seals)
- Floating roofs on equalizing tanks before API separators
- Floating decks on API separators
Are the measures good enough?
How to estimate total VOC emission

- Calculations (API, EPA, Concawe)
- Monitoring (Trace gas, DIAL, SOF)
Programme for VOC mitigation

• Monitoring
The Solar Occultation Flux method (SOF)
SOF (Solar Occultation Flux) method

Cross section of a flue gas plume blowing towards the observer

Gas column

Flux = Accumulated gas column * windspeed
SOF method – Gothenburg harbour
Leakage search / screening
Total emission – 3910 tonnes /year
Conditions in a permit

• The operator shall with a suitable detection equipment recurrently (regularly) trace leaks from valves, flanges, pumps and other process equipment within process area and tank area. The leak detection shall also be carried out on floating roofs, storage caverns, waste water treatment plant and areas for loading of products.

• The operator shall, in consultation with the inspection authority, carry out necessary repairs, exchange or improvement of equipment and other that is needed.

• The leak search shall also include smelly substances.
• The operator shall continuously take measures to reduce VOC emissions from the plant. In order to do this the operator shall establish a plan for this work and present it to the inspection authority.

• The plan shall be revised every year. From the plan it shall be clear what measures will be taken the coming year.
Discharge into water
Typical emission parameters

• Oil (total extractable hydrocarbons)
• COD
• BOD
• Particles
• Phenols, metals
• Nutrients (total N and total P)
Discharge into water - measures to reduce impact

- Minimize use of water, reuse water
- Segregate pure surface water from Waste Water
- Effective desalter
- Equalizing Tank before API separator
- Biological treatment with pre-treatment
- Separate cooling water and keep clean
<table>
<thead>
<tr>
<th>Parameter</th>
<th>mg/l, (monthly)</th>
<th>g/tonne crude (yearly)</th>
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<tbody>
<tr>
<td>Total hydrocarbon</td>
<td>0,05-1,5</td>
<td>0,01-0,75</td>
</tr>
<tr>
<td>BOD</td>
<td>2-20</td>
<td>0,5-11</td>
</tr>
<tr>
<td>COD</td>
<td>30-125</td>
<td>3-70</td>
</tr>
<tr>
<td>Total N</td>
<td>1,5-25</td>
<td>0,5-15</td>
</tr>
<tr>
<td>Susp. solids</td>
<td>2-50</td>
<td>1-25</td>
</tr>
<tr>
<td>Total metals</td>
<td>&lt;0,1-4</td>
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</table>
Total discharge of oil from all of the refinery industry 6 ton/year
Waste water treatment plant - PREEM (L)