POZP 8 EN

**Incineration**

• Combustion
• Flares
• Combustion units
• Catalytic VOC oxidation
• Incineration of Hazard materials
• Vent gas cleaning
• Summary
Thermal Oxidation

Description
Thermal oxidation is the oxidation process of combustible gases and odorants in a waste gas stream, by heating a mixture of contaminants with air or oxygen above its auto-ignition point in a furnace and maintaining it at high temperature for sufficient time to complete combustion to carbon dioxide and water.

Time, temperature (about 200–400 °C above auto-ignition), turbulence (for mixing) and the availability of oxygen all affect the rate and efficiency of the combustion process. These factors provide the basic design parameters for VOC oxidation systems.

When halogenated VOC are present, special conditions might be needed to suppress the generation (or de-novo synthesis) of dioxins, though normally there is only a negligible dioxin formation with the combustion of gaseous waste streams:

- residence time ≥1 s
- temperature ≥1100 °C
- oxygen content >3 %
- quenching of flue gas after incinerator to rush through the ‘recombination window’ of dioxins.
Application

Thermal oxidisers are used to reduce emissions from almost all VOC sources, including reactor vents, distillation vents, solvent operations and operations performed in ovens, dryers and kilns.

They can handle minor fluctuations in flow, but excess fluctuations require the use of a flare.

Their fuel consumption can be high, when low-loaded waste gases are fed, so thermal units are best suited for smaller process applications with moderate-to-high VOC loadings.

Thermal oxidisers are used to control VOC from a wide variety of industrial processes, e.g.:

- storing and loading / unloading of petroleum products and other volatile organic liquids
- vessel cleaning (rail tank cars, road tankers, barges)
- process vents in the synthetic organic chemicals manufacturing industry
- paint manufacturing
- rubber products and polymer manufacturing
- flexible vinyl and urethane coating
- hazardous waste treatment storage and disposal facilities.
Several types of thermal oxidisers are operated:

The straight thermal oxidiser, comprised of a combustion chamber and not including any heat recovery of exhaust air.

The regenerative thermal oxidiser, following the steps:
- Exhaust gas stream entering the oxidiser through the common inlet and passing into a regenerative chamber through a butterfly valve.
- Then passing through a ceramic heat exchange matrix, which raises the gas temperature near to oxidation temperature.
- Then entering the combustion chamber, which is maintained at about 800 °C by burners, the released heat decreasing the fuel consumption of the burners.
- Then leaving the combustion chamber through a second ceramic heat exchanger matrix, transferring its thermal energy to be re-used for preheating the next cycle.
- The clean gas stream released through an outlet valve to discharge.

Due to the relatively high combustion space temperature, the large excess of air and small influence of flame, only small amounts of carbon monoxide and NOx are formed.

This system is particularly suitable for waste gas streams of comparatively high flow rates (up to 200 Nm³/s). 90–97 % heat recovery (waste gas preheating) is generally achieved.
Conditions of combustion

- The mixing section
  Good mixing can be achieved by:
  - natural diffusion between turbulent streams
  - impingement of gas streams at an angle
  - changes in direction of flow, round corners or past baffles.
- The combustion chamber
  Conditions for dimensioning the combustion chamber are:
  - its diameter must allow turbulent flow
  - it has to be large enough to take the flame without quenching
  - its length is determined by the length of the flame plus the length needed to achieve mixing
  - it must be resistant to temperature and corrosion
  - it must withstand frequent expansion and contraction.
- Waste gas pretreatment
  When pretreatment is necessary before entering the thermal oxidiser:
  - condensing out water vapour from a wet waste gas
  - removal of solid and liquid contaminants
  - concentration (e.g. by GAC or zeolite adsorption and subsequent desorption) to reduce the total gas volume to be treated by the oxidiser
  - preheating, which reduces fuel requirements.
- Safety equipment
  Necessary safety devices are:
  - protection against flame flashback by devices, e.g. parallel plate flame arrestors, multiple screen flame arrestors, and/or water seals
  - burner purge period on start up of the thermal oxidiser
  - shut off flows in the event of flame failure
  - limiting of peak temperatures.
<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>• High and constant performance</td>
<td>• Emission of carbon monoxide and nitrogen oxides</td>
</tr>
<tr>
<td>• Simple principle</td>
<td>• Risk of dioxin formation, when chlorinated compounds are incinerated</td>
</tr>
<tr>
<td>• Reliable in operation</td>
<td>• Flue gas treatment necessary for VOC's containing sulphur and/or halides</td>
</tr>
<tr>
<td>• Recuperative and regenerative oxidation have a high thermal efficiency,</td>
<td>• Additional fuel needed, at least for start-up operation VOC concentration</td>
</tr>
<tr>
<td>with the effect of lower extra fuel consumption and hence lower carbon</td>
<td>below auto-ignition point</td>
</tr>
<tr>
<td>dioxide emission</td>
<td></td>
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<tr>
<td>• Process integration of waste heat or steam generation is possible</td>
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</table>
Flaring

Description
Flaring is a high-temperature oxidation process used to burn combustible components of waste gases from industrial operations. There are two types of flares:
- elevated flares
- ground flares.

**Elevated flares**, the more common type, have larger capacities than ground flares. In elevated flares, a waste gas stream is fed through a stack anywhere from 10 to over 100 metres tall and is combusted at the tip of the stack. The flame is exposed to atmospheric disturbances (wind, precipitation). Elevated flares are generally designed for large capacities (hundreds of tonnes per hour) and are more suitable to large variations of gas flow.
Flares
Flares
- gas collection header and piping for collecting gases from processing units
- knockout drum (disentrainment drum) to remove and store condensables and entrained liquids
- proprietary seal, water seal or purge gas supply to prevent flash-back
- single- or multiple-burner unit and a flare stack
- gas pilots and an ignitor to ignite the mixture of waste gas and air
- if required, provision for external momentum force (steam injection or forced air) for smokeless flaring.

Natural gas, fuel gas, inert gas or nitrogen can be used as purge gas.
Ground flares

- In **ground flares**, combustion takes place at ground level. They vary in complexity and may
- consist either of conventional flare burners discharging horizontally with no enclosures or of
- multiple burners in refractory-lined steel enclosures. They are designed for smaller capacities
- (tens of tonnes per hour) and handle the base load of combustible gases generated by all the
- point sources connected to the flare system during normal operation. This includes mainly
- leaking safety valves and any start-up and shutdown processes
Application

Flares are widely used in the oil, gas and petrochemical industry to safely dispose of surplus combustible gases and vapours when there is no opportunity to use or recycle them. VOC from vents, pumps and compressors are collected and routed to a flare system.

A significant function of flares is to prevent the unwanted occurrence of larger amounts of inflammable gases as a safety measure or under emergency conditions.

Technically, all points in a chemical plant with a potential safety release of combustible gases are connected to a flare system.

Flares are normally not, however, regularly used as a continuous measure. They can also be used to burn waste gases generated by sewage / sludge digesters.

Whereas elevated flares are normally used as emergency and relief gas flaring, ground flares are more often employed as routine flaring, provided that the waste gas does not contain toxic constituents.

Ground flares cannot - in contrast to elevated flares – handle large fluctuations in gas flow. When these fluctuations can occur, combination with an elevated flare is required.
Combustion unit
burner – chamber – steam kettle

Conditions of thermal oxidation
- Temperature 800-1200°C
- Residence time in chamber 0.3 – 2 s
- Capacity 1000 – 30000 m³/h
Regeneration of active carbon sorbent

Adsorption on powdered active carbon suspended in liquid
Example LURGI.
Adsorption and regeneration of active carbon (Lurgi)
Catalytic VOC Oxidation

**Application**
Catalytic oxidation is used to reduce emissions from a variety of stationary sources.

The main emission source is VOC from solvent evaporation, and catalytic oxidation is widely used by many industry sectors in this category. Examples from the chemical and related sectors are:

- petrol bulk loading stations
- process vents in the synthetic organic chemical manufacturing industry
- rubber products and polymer manufacturing
- polythene, polystyrene and polyester resin manufacturing.

Catalytic oxidation is most suited to systems with lower exhaust volumes, when there is little variation in the type and concentration of VOC, and where catalyst poisons or other fouling contaminants are not present.

Other components to abate are carbon monoxide and – to a certain degree – particulates, though the latter require special operational devices.
Figure 3.69: Regenerative Catalytic Oxidiser
1) Exhaust inlet, 2) Bed of ceramic heat-sink material, 3) Catalyst layer, 4) Combustion chamber, 5) Exit layer of catalyst, 6) Regenerative chamber, 7) Outlet manifold, 8) Transition duct
Catalytic cleaning of vent gas

- Catalytic oxidation of VOC and reduction of NOx
- Gasoline tanks
- Venting of production hals
- Rubber and polymer processing
- Production of polyethylene, polystyrene and polyester resins

SCR Topsoe DENOX
capacity: 117 000 Nm3/h

imise: TCDD (2,3,7,8-tetra chloro dibenzo dioxin) max 0,1 ng/Nm3 ,
NOx (NO2) max. 45 mg/Nm3

Reactor
2x 500 mm catalyst bed Topsoe DNX (11,7 m3) 85% conversion NOx
 reduction of NOx by amonia or urea:
NO + NH3 + 0,25 O2 = N2 + 1,5 H2O
1x 500 mm catalyst bed . Topsoe CKM73 (5,85 m3) 97% conversion dioxins
Oxidation 300-450°C

CO: CO + 0,5 O2 = CO2
VOC (benzene) C6H6 + 7,5 O2 = 6 CO2 + 3 H2O
TCDD (dioxine) C12H4O2Cl4 + 11 O2 = 12 CO2 + 4HCl
Topsoe Denox process
Topsoe catalytic unit
Waste incineration

• incoming waste reception
• storage of waste and raw materials
• pretreatment of waste (where required, on-site or off-site)
• loading of waste into the process
• thermal treatment of the waste
• energy recovery (e.g. boiler) and conversion
• flue-gas cleaning
• flue-gas cleaning residue management (from flue-gas treatment)
• flue-gas discharge
• emissions monitoring and control
• waste water control and treatment (e.g. from site drainage, flue-gas treatment, storage)
• ash/bottom ash management and treatment (arising from the combustion stage)
• solid residue discharge/disposal.
Wet FGT system with several unit operations
# Thermal operation

<table>
<thead>
<tr>
<th></th>
<th>Pyrolysis</th>
<th>Gasification</th>
<th>Combustion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reaction temperature (°C)</strong></td>
<td>250 – 700</td>
<td>500 – 1600</td>
<td>800 - 1450</td>
</tr>
<tr>
<td><strong>Pressure (bar)</strong></td>
<td>1</td>
<td>1 – 45</td>
<td>1</td>
</tr>
<tr>
<td><strong>Atmosphere</strong></td>
<td>Inert/nitrogen</td>
<td>Gasification agent: O₂, H₂O</td>
<td>Air</td>
</tr>
<tr>
<td><strong>Stoichiometric ratio</strong></td>
<td>0</td>
<td>&lt;1</td>
<td>&gt;1</td>
</tr>
<tr>
<td><strong>Products from the process</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gas phase:</strong></td>
<td>H₂, CO, H₂O, N₂</td>
<td>H₂, CO, CO₂, CH₄, H₂O, N₂</td>
<td>CO₂, H₂O, O₂, N₂</td>
</tr>
<tr>
<td><strong>Solid phase:</strong></td>
<td>Ash, coke</td>
<td>Slag, ash</td>
<td>Ash, slag</td>
</tr>
<tr>
<td><strong>Liquid phase:</strong></td>
<td>Pyrolysis oil and water</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2.1: Typical reaction conditions and products from pyrolysis, gasification and incineration processes
Drum kiln with post-combustion chamber for hazardous waste incineration

For the incineration of hazardous waste, a combination of drum-type kilns and post-combustion chambers has proven successful, as this combination can treat solid, pasty, liquid, and gaseous wastes uniformly. Drum-type kilns between 10 and 15 metres in length, and with a length to diameter ratio usually in the range of 3 to 6, and with an inner diameter between one and five metres are usually deployed for hazardous waste incineration. Some drum-type kilns have throughputs of up to 70000 tonnes/yr each. In correlation to the average heat value of the waste, where heat recovery is carried out steam generation increases correspondingly. Drum-type kiln plants are highly flexible in terms of waste input characteristics. The following range is usual in the composition of the waste input menu:

- solid wastes: 10 – 70 %
- liquid wastes: 25 – 70 %
- pasty wastes: 5 – 30 %
- barrels: up to 15 %.
1 Nitrogen sluice
2 Shredder
3 Mixing tanks
4 Sieve
5 Liquid discharge
6 Separation of metal and plastic

1 Sluice for crane waste
2 Sluice for drums
3 Crushing chamber
4 Discharge screws
5 Waste pump

Figure 2.2: Example of some hazardous waste pretreatment systems used at some merchant HWI
Combustion part

Figure 2.10: Drum-type kiln with post-combustion chamber
Drum-type kiln incineration plant with an incineration capacity of 45000 tonnes/yr

Figure 2.11: Example of a drum-type kiln plant for hazardous waste incineration
Source [1, UBA, 2001]
Hazardous waste incineration

• drum-type kiln with post combustion chamber (Minimum residence times in excess of two seconds are the basic requirement of EC Directive 2000/76/EC.)
• waste heat boiler for steam generation
• multi-step flue-gas cleaning.

There is, in addition, the infrastructure for the storage, feed system, and disposal for the waste and waste waters (from wet gas scrubbing) produced during incineration.
Summary

• Thermal oxidation to H₂O a CO₂ (ash and slag)
• Flares – combustion of VOC in vent gas, liquids – accidental source
• Combustion units with heat regeneration – thermal oxidation of desorbed VOC – constant source
• Incineration of municipal and hazardous wastes
  – Solid and liquid wastes
  – Combustion part: 950°C, 2 s residence time
  – Flue-gas cleaning – dry, wet, catalytic
  – Infrastructure for waste water and solid wastes disposal
• Catalytic incineration of VOC
  – Minimalization of NOx and dioxins