ENGINEERING CONTROL CONCEPTS AND GENERAL DESIGN CONSIDERATIONS

ENGINEERING CONTROL CONCEPTS

The application of control technology to air pollution problems *assumes* that a source can be reduced to a predetermined level to meet a regulation or some other target value.

- **Fact 1**: Control technology cannot be applied to an **uncontrollable** source, such as a volcano.
- **Fact 2**: Control of any air pollution requires to know the **rules and regulations** of the control agencies involved (not only the APC agency but also any agency, which may have jurisdiction over the construction, operation, and final disposal of the waste from the source).
- **Fact 3**: Control of any air pollution source requires a complete knowledge of the contaminant and the source (e.g.: thermodynamic properties, reactions involved).
- **Fact 4**: Control technology cannot be expected to control a source completely to **reduce emissions to zero**. The COST is in fact usually an exponential function of the percentage of control and therefore becomes an important consideration in the level of control required.

ENGINEERING CONTROL CONCEPTS

The control of atmospheric emissions from a process will generally take one of the three following methods/forms depending on the process, fuel, types, availability of control equipment, etc.:

1. Process change to a less polluting process or modification of operating procedures for an existing process

PREVENTION

2. Installation of control equipment between the point of pollutant generation and its release to the atmosphere. Control may consist of either removal of the pollutant or conversion to a less polluting form

TREATMENT

3. Use of tall stacks to dilute the pollutants before they came to ground

DISPERSION

ADDITIONAL CONTROL CONCEPTS

Beside the traditional CONTROL approach, based on a **command-and-control** philosophy, an additional possibility is given by the **EMISSION TRADING APPROACH**

- The "**cap and trade**" system reduces emissions by setting a limit on pollution (cap) and creating a market of emission "credits" (trade).
  Facilities can then BUY or SELL emission credits, or permitted allotments of pollutants

- In contrast to **command-and-control** environmental regulations such as best available technology (BAT), cap and trade schemes are flexible instruments regulation that allows organizations to decide how best to meet policy targets.

- Companies can decide if it is cheaper to install pollution control equipment or to simply buy someone else's credits. In theory, polluters who can reduce emissions most cheaply will do so, <u>achieving the emission reduction at the lowest cost to society</u>. Cap and trade is meant to provide the private sector with the flexibility required to ***reduce emissions while stimulating technological innovation and economic growth***.

ADDITIONAL CONTROL CONCEPTS

EMISSION TRADING APPROACH

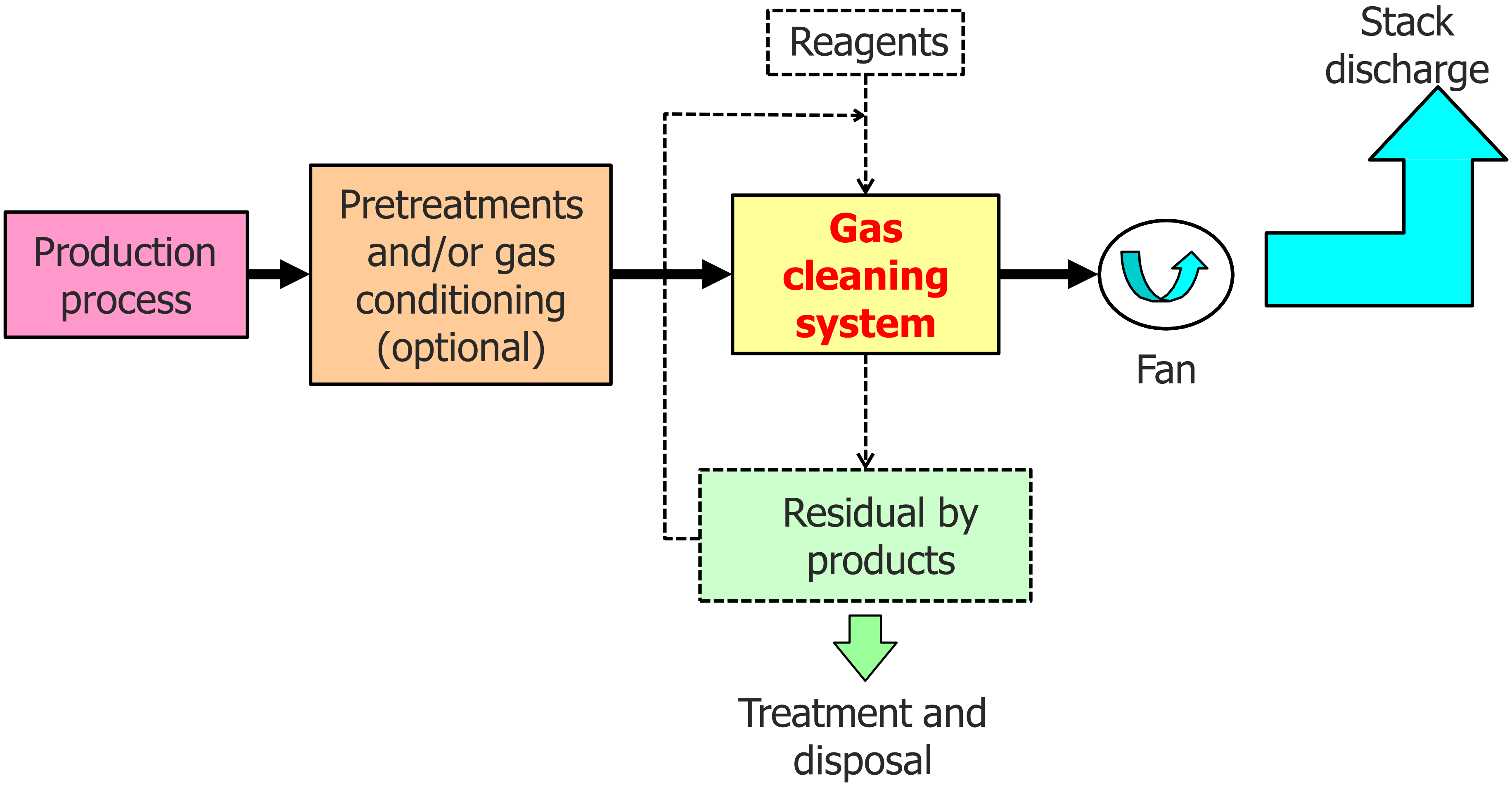
There are ACTIVE TRADING PROGRAMS for several air pollutants.

For **greenhouse gases**, permit units are often called **carbon credits.**

The largest greenhouse gases trading program are:

- European Union Emission Trading Scheme, which trades primarily in European Union Allowances (EUAs), equivalent to carbon credits;
- Californian scheme (trades in California Carbon Allowances);
- New Zealand scheme (in New Zealand Units)
- Australian scheme (in Australian Units).
- The United States has a national market to reduce acid rain and several regional markets in nitrogen oxides.

General treatment plant configuration



Production process

Pretreatments and/or gas conditioning (optional)

Reagents

Gas cleaning system

Fan

Stack discharge

Residual by products

Treatment and disposal

General design and evaluation parameters - problem definition

- Flow rates
  - gas volume flow rate Q_v (volume/time), dependent on T and P
  - pollutant mass flow rate M_i (mass/time)
- Physical parameters
  - temperature T (°C) and pressure p (atm , kPa)
  - humidity: water vapor (moisture) content ($g_{H2O}/g_{dry\ air}$, % by vol)
  - Dew point
- Pollutant content
  - mass concentrations C_i (mass/volume)
  - volume concentrations (volume/volume)
  - dependence on reference conditions of emission limits (T, P , moisture and O_2 content of flue gas)
- Removal efficiency E
  - in terms of concentrations: $E = (C_i - C_L)/C_i$ ($C_L = C_O$ from emission limits)

    applicable for pollutants removal with negligible changes in total gas flow rates (most typical situation);

    C dependence on reference conditions
  - in terms of mass flow rates: $E = (M_i - M_L)/M_i$ ($M_L = M_O$ from emission limits)
- Energy balances
- Materials
- Costs

Removal efficiency (E)

C_i, Q_i → Removal system → C_o, Q_o

$$E = (\text{inlet} - \text{outlet})/\text{inlet}$$

- general definition: in terms of pollutant mass flows M

$$E = (M_i - M_o)/M_i$$

- most common air pollutant removal situations: mass flows constant across the system (dilute streams) → evaluation with pollutant concentration C

$$E = (C_i - C_o)/C_i$$

  - both C_i and C_o measured at the same conditions (T, P, moisture and O_2 content)

Energy consumption

Energy consumptions

1. head losses for gas flow conveyance through ductworks and exhaust stack
   - ➢ Δp_1 evaluated through standard methods from fluid mechanics
2. energy required for propelling gas flow through removal devices
   - ➢ Δp_2 evaluated from specific relationships for single systems

Power required for handling gas flow

$$P_g = Q_v \cdot \Delta p \cdot 10^{-3}$$

Q_v = volume flow rate (m^3/s)
Δp = head loss = $\Delta p_1 + \Delta p_2$ (Pa, N/m^2)
P in kW

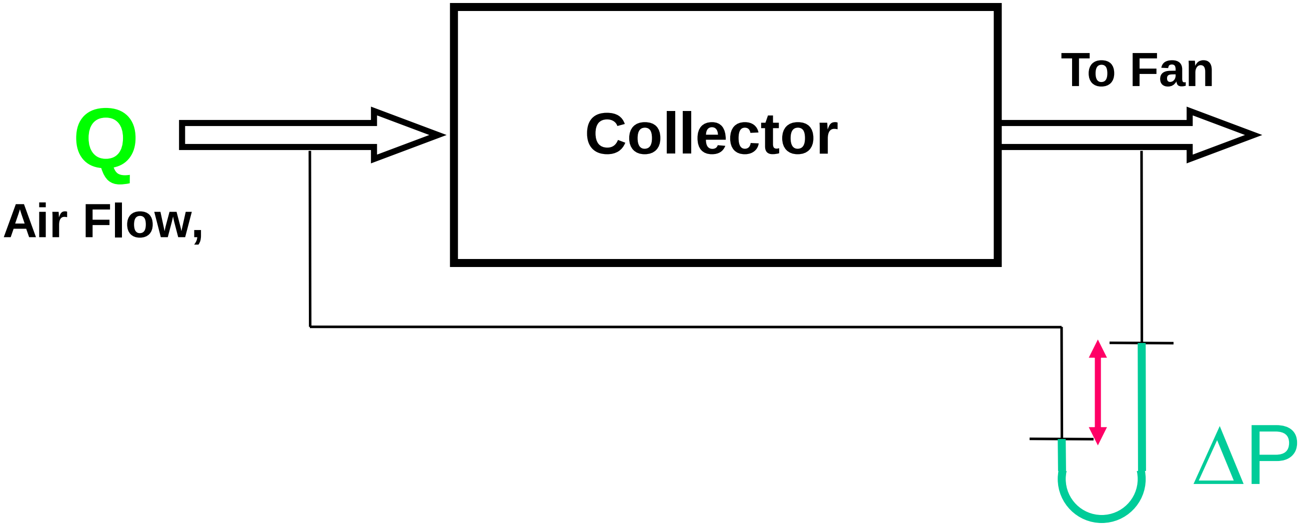
Power required by fan

$$P_f = Q_v \cdot \Delta p \cdot 10^{-3}/\eta$$

η = fan efficiency

Pressure drop, ΔP

Difference in static pressure upstream minus down-stream of the collector (*Δ**P is a** very useful Monitoring Parameter*)



Q

Air Flow,

Collector

To Fan

ΔP

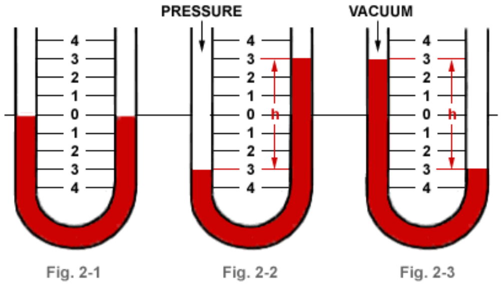


Fig. 2-1 Fig. 2-2 Fig. 2-3

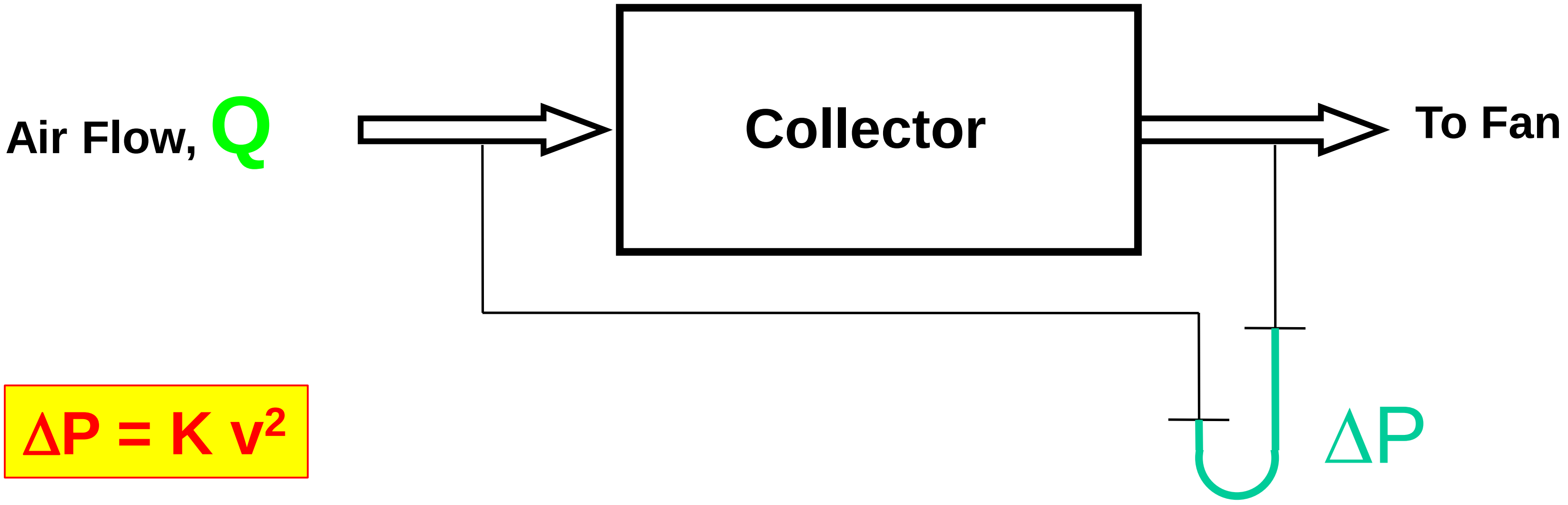
FAN POWER: **P_{el}= constant x Q x $\Sigma(\Delta P_i)$**

Pressure drop, ΔP

Two important aspects:

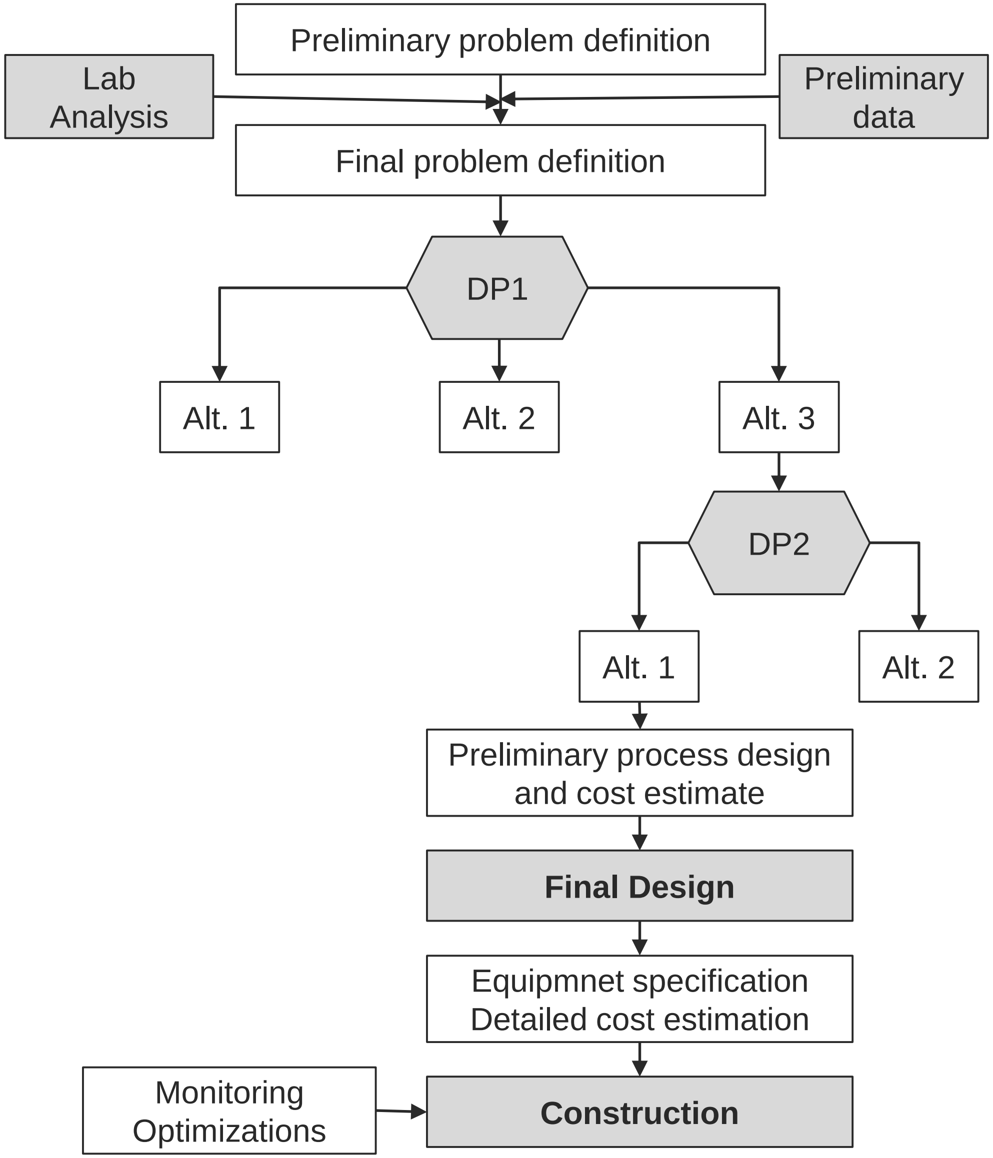
1. economical: fan annual operating cost $E_{el} = P_{el} \times t$ *(t = h/year)*
2. operative*:* continuous check! It is important monitoring the correct operation of many devices (FF; Scrubber, ESP, SCR, GAC, …)

Waste gas is drawn through the baghouse by an induced, downstream, draft fan, after which it will pass up a single stack, or to the APCD train)



$$\boxed{\Delta P = K\, v^2}$$

Steps in the design process



Preliminary material balances and air flow measures estimates the emission rates that should verified by laboratory analysis.

Final problem definition establishes the design basis for the project.

At decision point 1 (**DP1**), alternative control techniques are evaluated such as: Alt.1: electrostatic precipitations; Alt.2: filtration; Alt.3: wet scrubbing. Selection criteria include efficiency rates, energy balances, etc.

If Alternative 3 (wet scrubbing) is selected, then **DP2** will involve the selection of a type of scrubber.

At this level subproblems that lead to the selection of a type of scrubber will include pressure drop requirements, liquid recirculation rates, materials of construction, power requirements, methods for disposing of collected pollutants, etc..

The completation of all decision points leads to the final design, from which complete equipment specifications can be prepared and a project cost estimate can be developed.

Example: prevention VS control in flue gas neutralization

MSWI (municipal solid waste incinerator), or MSWIP (...Plant)

The MSWI in Padova - a 3-lines plant - can burn up-to 600 ton/waste a day. Most of the waste is MSW, but Special Wastes are also burned. The waste contains up-to 1% (w/w) of Cl, as Organic-Chlorine (bonded to organic carbon).

Assume that:

- all organic-Cl is converted to HCl(g), CO_2 and H_2O during the incineration process in the combustion chamber;

- all the HCl(g) must be chemically neutralised through addition of dry solid sodium bicarbonate $NaHCO_3$ (very fine powder diam. < 50 μm):

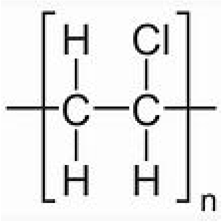
$NaHCO_3$ (s)+ HCl (g)= NaCl (s)+ H_2O (g)+ CO_2 (g) (operating temperature: about 200 ° C)

NOTE. This is an example of DRY TECHNIQUE. Solid NaCl produced in the process must be completely removed from the flue gas through a Fabric Filter (FF, or BH - baghouse) – a sort of huge “Vacuum filter”; Electrostatic Filters, ESP or EF, can also be used but have lower efficiency)

Calculate:

1. **the minimum mass of $NaHCO_3$ (sodium bicarbonate, ton/day) required (i.e. the stoichiometric mass) for complete neutralisation of HCl.** *(MW $NaHCO_3$=84; MW HCl=36.5; MW NaCl=58.4);*
2. **the mass of solid NaCl obtained by the neutralization process.**
3. **Instead of $NaHCO_3$, $Ca(OH)_2$ (calcium hydroxide or hydrated lime) can be used: do the same calculations as above!**

Example: prevention VS control in flue gas neutralization



PVC

$-CH_2-CHCl-\ (s) + 5/2\ O_2\ (g) \rightarrow 2CO_2\ (g) + H_2O\ (g) + HCl\ (g)$ $T >> 100°C$

Typically the H_2O concentration is 10% (v/v) in flue gas

Example: prevention VS control in flue gas neutralization

Cl contained in the burned waste: 1% x 600/100 = 6 ton/day
HCl produced: 6 x HCl/Cl = 6 x 36.5/35.5 = 6.17 ton/day

Mass of $NaHCO_3$ required (Stoich.): 6,17 x $NaHCO_3$/HCl = 6.17 x 84/36.5 =
= 14.20 ton/day of $NaHCO_3$(s)

mass of NaCl produced: 6.17 x NaCl/HCl = 6.17 x 58.4/36.5 = 9.89 ton/day of NaCl(s)

Note: The solid NaCl, as a fine dust, is captured by a filter (Typically a FF – Fabric filter (filtro a maniche,o filtri a tessuto); BH (from baghouse) is more common in the US.
The dust collected is a mixture of NaCl, excess of $NaHCO_3$ (*) always added in real application , small concentrations of PICs, and metals compounds --> this type of dust is always a hazardous special waste (It. Rifiuto Speciale Pericoloso) and is called "FLY ASH" (It. cenere leggera o volante)

COSTS:

- Reagents (NaHCO3, sodium bicarbonate)
- Management of fly ashes

(*) Better: Na_2CO_3. In fact at T > 140 ° C $NaHCO_3$ is converted to $NaCO_3 + CO_2 + H_2O$...)

Fly ash is the product of Air pollution Technique; Bottom ash is the product of combustion

Example: prevention VS control in flue gas neutralization

Be careful: DEACON EQUILIBRIUM

$2HCl + \frac{1}{2} O_2 = Cl_2 + H_2O$ ($\Delta H^\circ = -101.2$ kJ/mol)

The reaction of HCl with O_2 is exothermic

(In exothermic reactions, increase in temperature decreases the equilibrium constant, K)

Production of some Cl_2 in the flue gas depends on:

- temperature;
- concentrations of O_2
- concentration of H_2O

At equilibrium apply Le Chatelier principle!

For many reasons, the best thing to do is the efficient removal/chemical neutralization of HCl as soon as possibile! In the early Gas Treatment stages.!!!

HCl is also a rather corrosive gas, with nasty effects on the plant.

The Cl-Cl bond can be easily broken at T > 200 °C to give very reactive Cl

Chlorination of PIC (products of incomplete combustion, mainly organic policyclic compunds) is expected ---> PCB, PCDD, PCDF, ...

GENERAL QUESTION: Is the incineration of PVC convenient ?
PREFER MATERIAL RECOVERY WHENEVER IS POSSIBLE!

Example: prevention VS control in flue gas neutralization

MAX Cl^- concentration accepted for waste water discharged to surface waters (river, lakes, sewers) is 1200 mg/L. To clean the flue gas, in order to remove HCl we can use a WET SCRUBBER fed with aq. NaOH or plain water. HCl is efficiently transferred to the clean water. Water containing HCl must be regularly discharged.

How much water is required to comply with the chloride limit in the exercise before?

RESOLUTION

6.17 t HCl /day = 6.17×10^6 g/day

C = m / V ; V = m / C = 6.17×10^6 g/day / 1.2 g/L = 5.14×10^6 L/day = **5,140 m^3/day**

Minimum amount of water required to dilute the chloride containing solution!!!

→WE CANNOT USE THE WET TECHNIQUE ONLY;

→THE ONLY POSSIBILITY ARE TWO STEPS: 1st DRY NEUTRALIZATION; 2nd WET NEUTRALIZATION … since most HCl is removed in the first stage!

WHAT IS/ARE THE BEST TECHNIQUE?

TECHNIQUES WITH MATERIAL RECOVERY SHOULD ALWAYS BE PREFERRED.

APPLY BAT (BEST AVAILABLE TECHNIQUES → Dir. 2010/75/EU)

- *YOU MUST APPLY BAT IF THE ACTIVITY IS LISTED IN ANNEX I TO GET THE AUTHORIZATION FROM COMPETENT AUTHORITIES*
- *I SUGGEST TO REFER TO THE BAT (OR AT LEAST, to BAT CRITERIA, ALSO FOR NON INCLUDED ACTIVITIES) .*

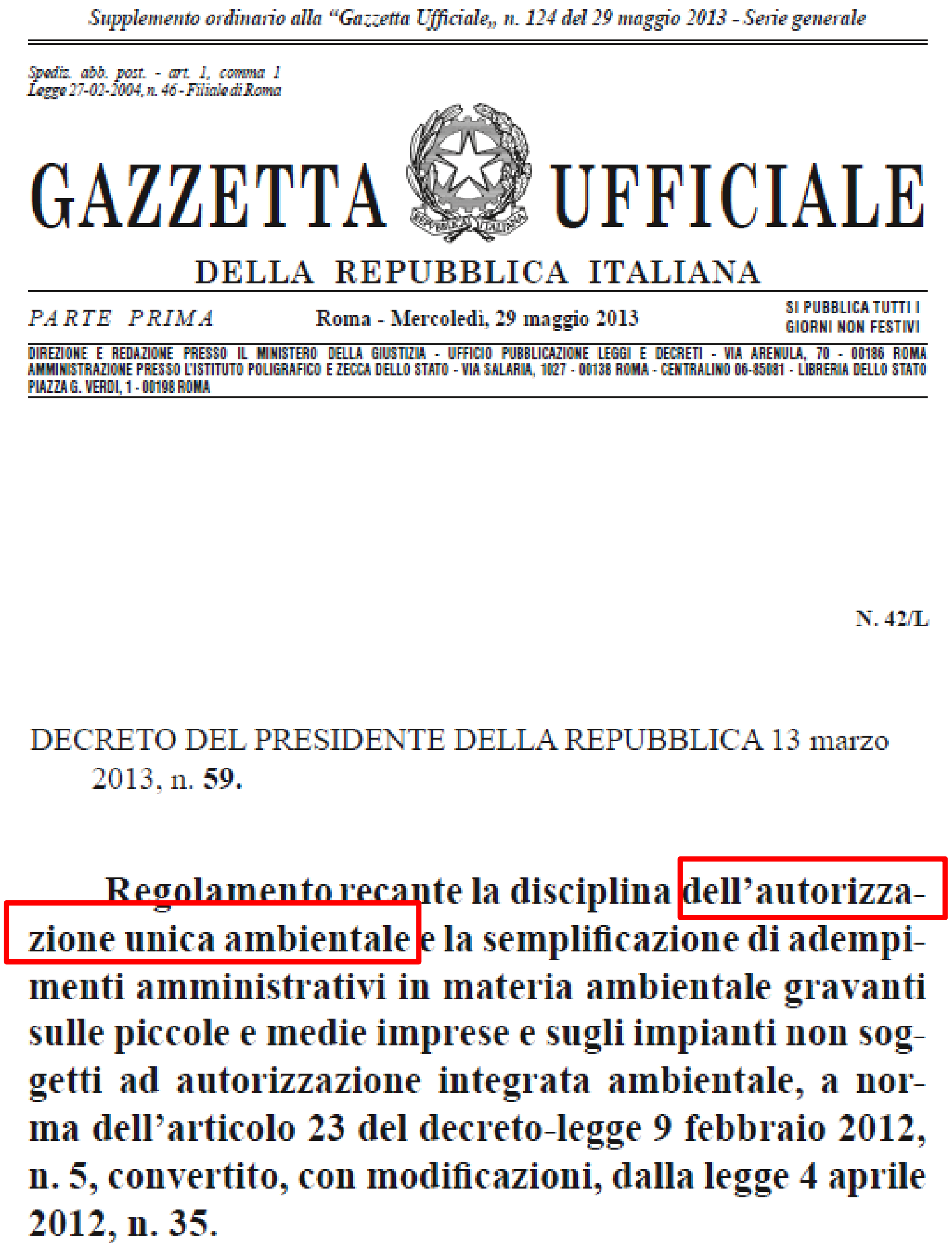
❑ ITALY, ONLY!

❑ SMALL-MEDIUM ACTIVITIES (NOT IN ANNEX I!) HAVE TO COMPLY WITH A SPECIFIC LEGISLATION FOR → AUA

AUA

→ *AN ITALIAN LAW!*

A good and useful starting point for everyone.



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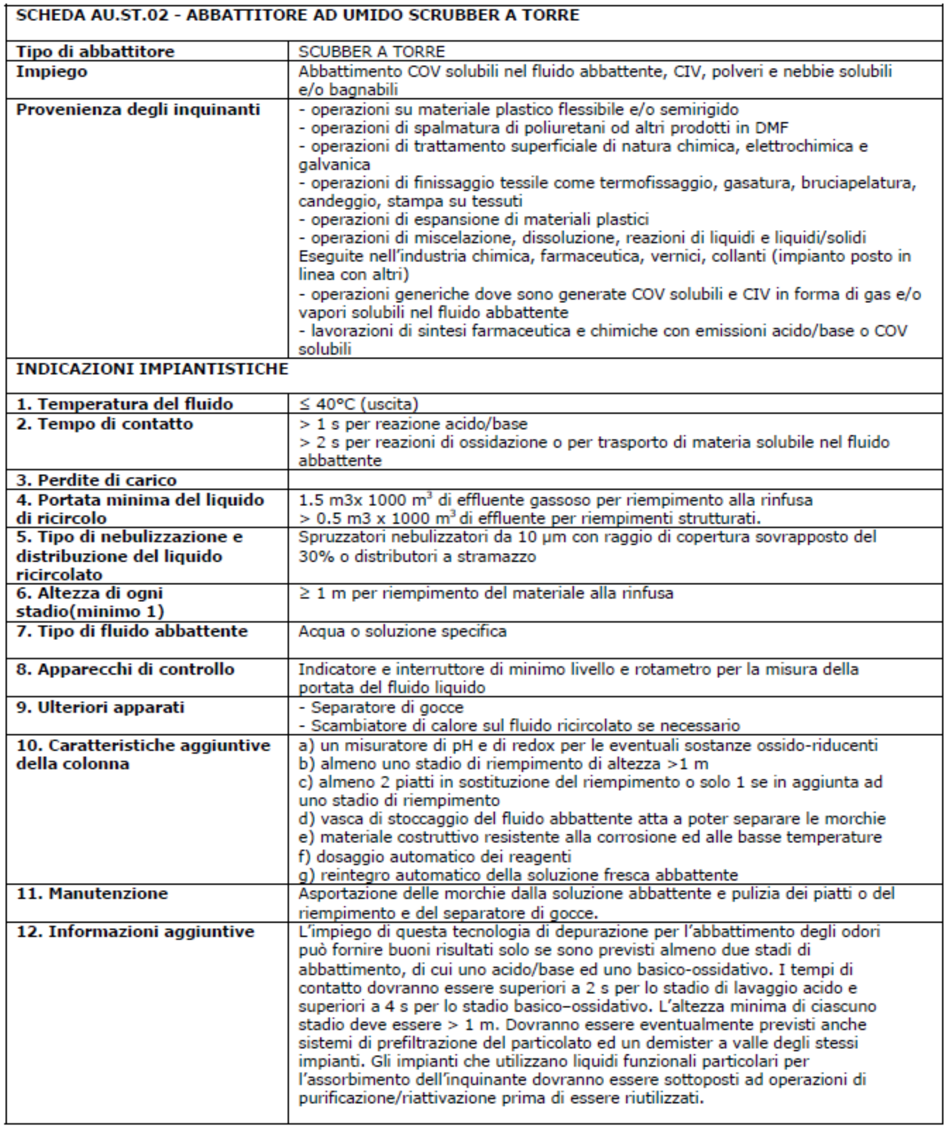
N. 42/L

DECRETO DEL PRESIDENTE DELLA REPUBBLICA 13 marzo 2013, n. **59.**

Regolamento recante la disciplina dell'autorizzazione unica ambientale e la semplificazione di adempimenti amministrativi in materia ambientale gravanti sulle piccole e medie imprese e sugli impianti non soggetti ad autorizzazione integrata ambientale, a norma dell'articolo 23 del decreto-legge 9 febbraio 2012, n. 5, convertito, con modificazioni, dalla legge 4 aprile 2012, n. 35.

PACKED WET SCRUBBER (TECHNICAL SHEETS ARE THOSE OF REGIONE LOMBARDIA - D.g.r. 30 maggio 2012)



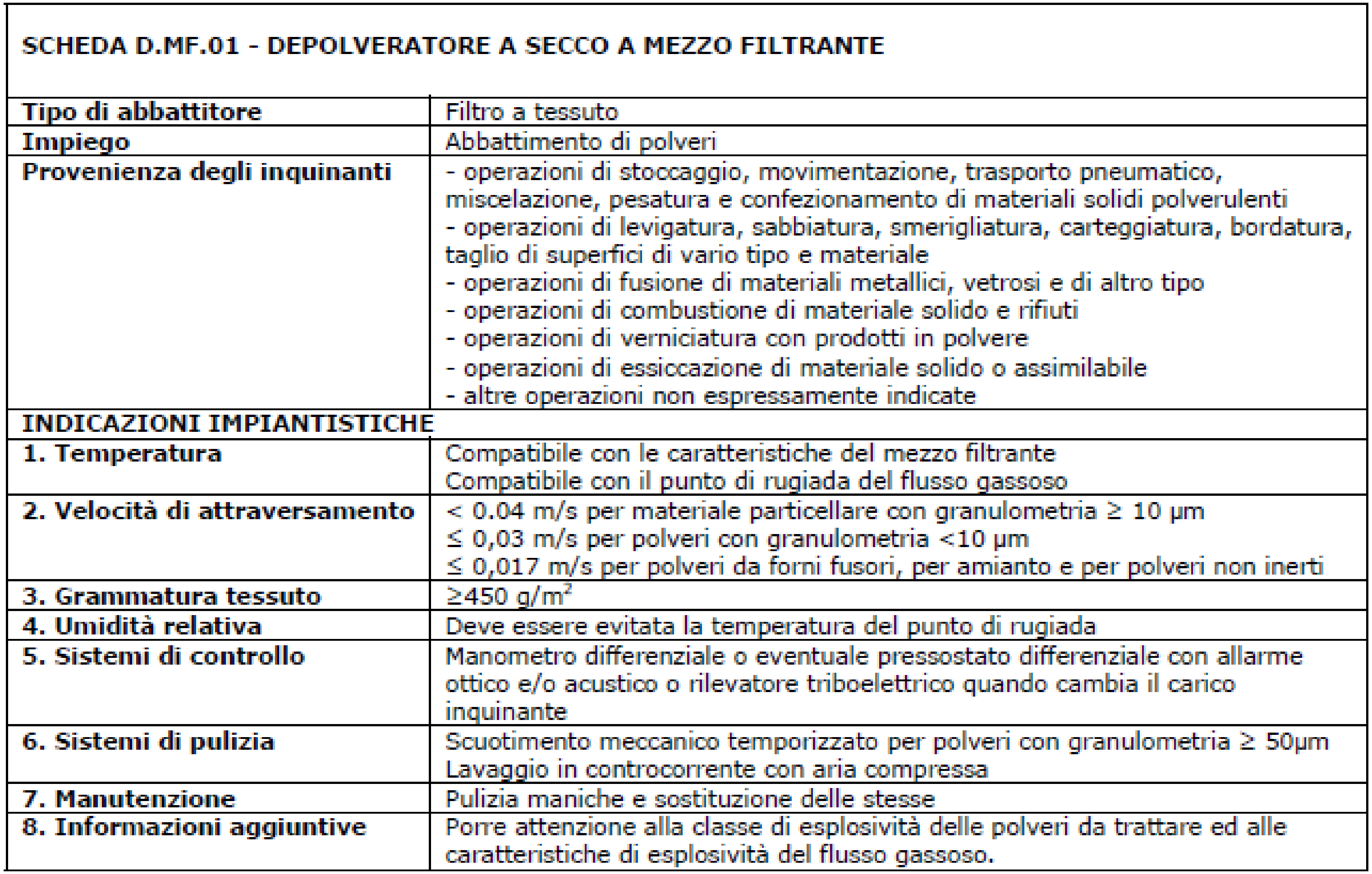
SCHEDA AU.ST.02 - ABBATTITORE AD UMIDO SCRUBBER A TORRE	
Tipo di abbattitore	SCUBBER A TORRE
Impiego	Abbattimento COV solubili nel fluido abbattente, CIV, polveri e nebbie solubili e/o bagnabili
Provenienza degli inquinanti	- operazioni su materiale plastico flessibile e/o semirigido - operazioni di spalmatura di poliuretani od altri prodotti in DMF - operazioni di trattamento superficiale di natura chimica, elettrochimica e galvanica - operazioni di finissaggio tessile come termofissaggio, gasatura, bruciapelatura, candeggio, stampa su tessuti - operazioni di espansione di materiali plastici - operazioni di miscelazione, dissoluzione, reazioni di liquidi e liquidi/solidi Eseguite nell'industria chimica, farmaceutica, vernici, collanti (impianto posto in linea con altri) - operazioni generiche dove sono generate COV solubili e CIV in forma di gas e/o vapori solubili nel fluido abbattente - lavorazioni di sintesi farmaceutica e chimiche con emissioni acido/base o COV solubili
INDICAZIONI IMPIANTISTICHE	
1. Temperatura del fluido	≤ 40°C (uscita)
2. Tempo di contatto	> 1 s per reazione acido/base > 2 s per reazioni di ossidazione o per trasporto di materia solubile nel fluido abbattente
3. Perdite di carico	
4. Portata minima del liquido di ricircolo	1.5 m3x 1000 m^3 di effluente gassoso per riempimento alla rinfusa > 0.5 m3 x 1000 m^3 di effluente per riempimenti strutturati.
5. Tipo di nebulizzazione e distribuzione del liquido ricircolato	Spruzzatori nebulizzatori da 10 µm con raggio di copertura sovrapposto del 30% o distributori a stramazzo
6. Altezza di ogni stadio(minimo 1)	≥ 1 m per riempimento del materiale alla rinfusa
7. Tipo di fluido abbattente	Acqua o soluzione specifica
8. Apparecchi di controllo	Indicatore e interruttore di minimo livello e rotametro per la misura della portata del fluido liquido
9. Ulteriori apparati	- Separatore di gocce - Scambiatore di calore sul fluido ricircolato se necessario
10. Caratteristiche aggiuntive della colonna	a) un misuratore di pH e di redox per le eventuali sostanze ossido-riducenti b) almeno uno stadio di riempimento di altezza >1 m c) almeno 2 piatti in sostituzione del riempimento o solo 1 se in aggiunta ad uno stadio di riempimento d) vasca di stoccaggio del fluido abbattente atta a poter separare le morchie e) materiale costruttivo resistente alla corrosione ed alle basse temperature f) dosaggio automatico dei reagenti g) reintegro automatico della soluzione fresca abbattente
11. Manutenzione	Asportazione delle morchie dalla soluzione abbattente e pulizia dei piatti o del riempimento e del separatore di gocce.
12. Informazioni aggiuntive	L'impiego di questa tecnologia di depurazione per l'abbattimento degli odori può fornire buoni risultati solo se sono previsti almeno due stadi di abbattimento, di cui uno acido/base ed uno basico-ossidativo. I tempi di contatto dovranno essere superiori a 2 s per lo stadio di lavaggio acido e superiori a 4 s per lo stadio basico–ossidativo. L'altezza minima di ciascuno stadio deve essere > 1 m. Dovranno essere eventualmente previsti anche sistemi di prefiltrazione del particolato ed un demister a valle degli stessi impianti. Gli impianti che utilizzano liquidi funzionali particolari per l'assorbimento dell'inquinante dovranno essere sottoposti ad operazioni di purificazione/riattivazione prima di essere riutilizzati.

CONDITIONS SET FOR AUTOMATIC APPROVAL
CONCERNING

PLANTS NOT UNDER IPPC

(NOT INCLUDED IN ANNEX 1 OF DIRECTIVE 2010/75/EU)

FABRIC FILTER (TECHNICAL SHEETS ARE THOSE OF REGIONE LOMBARDIA - D.g.r. 30 maggio 2012)



SCHEDA D.MF.01 - DEPOLVERATORE A SECCO A MEZZO FILTRANTE	
Tipo di abbattitore	Filtro a tessuto
Impiego	Abbattimento di polveri
Provenienza degli inquinanti	- operazioni di stoccaggio, movimentazione, trasporto pneumatico, miscelazione, pesatura e confezionamento di materiali solidi polverulenti - operazioni di levigatura, sabbiatura, smerigliatura, carteggiatura, bordatura, taglio di superfici di vario tipo e materiale - operazioni di fusione di materiali metallici, vetrosi e di altro tipo - operazioni di combustione di materiale solido e rifiuti - operazioni di verniciatura con prodotti in polvere - operazioni di essiccazione di materiale solido o assimilabile - altre operazioni non espressamente indicate
INDICAZIONI IMPIANTISTICHE	
1. Temperatura	Compatibile con le caratteristiche del mezzo filtrante Compatibile con il punto di rugiada del flusso gassoso
2. Velocità di attraversamento	< 0.04 m/s per materiale particellare con granulometria ≥ 10 µm ≤ 0,03 m/s per polveri con granulometria <10 µm ≤ 0,017 m/s per polveri da forni fusori, per amianto e per polveri non inerti
3. Grammatura tessuto	≥450 g/m^2
4. Umidità relativa	Deve essere evitata la temperatura del punto di rugiada
5. Sistemi di controllo	Manometro differenziale o eventuale pressostato differenziale con allarme ottico e/o acustico o rilevatore triboelettrico quando cambia il carico inquinante
6. Sistemi di pulizia	Scuotimento meccanico temporizzato per polveri con granulometria ≥ 50µm Lavaggio in controcorrente con aria compressa
7. Manutenzione	Pulizia maniche e sostituzione delle stesse
8. Informazioni aggiuntive	Porre attenzione alla classe di esplosività delle polveri da trattare ed alle caratteristiche di esplosività del flusso gassoso.

Systems general characteristics

OBJECTIVE	SYSTEM	REMARKS
Best available technology (BAT)	Fabric filter	Dry non adhesive particles. Control and potential pretreatment regulation of T and moisture (flue gas dew point).
Fine particles	Fabric filter	Dry particles. Control and potential pretreatment regulation of T and moisture (flue gas dew point).
	Electrostatic precipitator	Particles resistivity and related influencing flue gas parameters.
	Venturi scrubber	High pressure drops. Noise. Clean gas cooled and humid. Scrubbing liquid compatibility.
Coarse particles	Cyclone	Non adhesive and non erosive particles.
	Scrubbing towers	Clean gas cooling and humidity effects. Scrubbing liquid compatibility. Control and regulation of treated gas dew point.
Upstream treatment for high loaded gases	Cyclone	Non adhesive and non erosive particles.
	Scrubbing towers	Clean gas cooled and saturated with moisture. Scrubbing liquid compatibility. Control and regulation of treated gas dew point.
	Electrostatic precipitator	Particles resistivity and related influencing flue gas parameters.
Upstream treatments for temperature and moisture regulation	Scrubbing towers	Moisture and flow rate variations. Cooling and humidity increase effects. Dew point regulation and control.
	Air mixing	Mass and volume flow rate variation.
	Heat exchanging	Volume flow rate variation. Dew point regulation and control. Additional equipment.
Simultaneous removal of gaseous pollutants	Absorption towers	Solubility in scrubbing liquid solution. Clean gas cooling and humidity effects. Control and regulation of clean gas dew point.
Simultaneous removal of acid gaseous pollutants	Fabric filters with alkaline reagents injection.	Premixing with alkaline reagents (dry or semidry absorption systems).

Systems general characteristics

OBJECTIVE	SYSTEM	REMARKS
Acid gases (HCl, HF)	Scrubbing towers with water	Materials resistant to pH = 1-2. Cooled and humid clean flue gas. Acid liquid overflows.
Acid gases (SO_2, SO_3)	Scrubbing towers with alkaline solutions ($Ca(OH)_2$, $Mg(OH)_2$, $NaHCO_3$)	Liquid and saline overflows ($CaSO_3$,$CaSO_4$)
Acid gases (HCl, HF, SO_2, SO_3)	Dry and semidry systems upstream fabric filters	No liquid overflow. Solid byproducts. Excess reagent requirements. Trace volatile pollutants simultaneous removal possibilities (Hg, organics - PCDD/F, PAH) through activated carbon addition with alkaline reagent.
Nitrogen oxides (NO, NO_2)	Selective non catalytic reduction (SNCR)	Addition of reducing reagent (NH_3,urea). Temperature ≈ 950°C. Low efficiency. NH_3 slip.
Nitrogen oxides (NO, NO_2)	Selective catalytic reduction (SCR) in “high dust” location	Addition of reducing reagent (NH_3,urea). Temperature ≈ 250-350°C. High particulate loading. Absence of raw gas heating. High efficiency. Contained NH_3 ed N_2O slips.
Nitrogen oxides (NO, NO_2)	Selective catalytic reduction (SCR) in “low dust” location	Addition of reducing reagent (NH_3,urea). Temperature ≈ 350°C. High T particulate removal. Absence of raw gas heating. High efficiency. Contained NH_3 ed N_2O slips.
Nitrogen oxides (NO, NO_2)	Selective catalytic reduction (SCR) in “tail end” location	Addition of reducing reagent (NH_3,urea). Temperature ≈ 180-350°C. Clean raw flue gas (particulates removal upstream). Absence of raw gas heating with low T catalytic substrates. Catalyst fouling risks from salts formation. High efficiency. Contained NH_3 ed N_2O slips.

Systems general characteristics

OBJECTIVE	SYSTEM	REMARKS
Organics/air mixtures within self sustaining combustion range.	Enclosed flares (BAT)	Control and regulation of explosive limits.
VOC mixtures, CO. Odorous compounds. Recovery not interesting.	Thermal oxidizers	Control and regulation of explosive limits. Energy recovery through raw gas preheating (high efficiency with regenerative ceramic systems). Secondary production of acid gas pollutants for treatment of halogen, sulphur and nitrogen bearing compounds.
VOC mixtures, CO. Odorous compounds. Recovery not interesting.	Catalytic oxidizers.	Alternative option to thermal oxidation for highly diluted streams (lower heating consumption). Requirements for control of particulates raw gas content and potential deactivating elements for catalyst.
VOC mixtures, including halogenated compounds. Semivolatile pollutants mixtures (Hg, C sulphide, Br, I). Odorous pollutants. Recovery of interest.	Adsorption bed systems.	Alternative to oxidation. Evaluation of adsorption isotherms. Mixture selectivity. Potential control and regulation of raw gas content of particulates, moisture and temperature. Evaluation of stability of recovered pollutants.
VOC in highly diluted streams. Recovery not interesting.	Adsorption bed for concentrating flue gas upstream thermal or catalytic oxidizer.	See adsorption and oxidation.
Upstream treatments for temperature and moisture regulation	Scrubbing towers	Moisture and flow rate variations. Cooling and humidity increase effects. Dew point regulation and control.
	Air mixing	Mass and volume flow rate variation.
	Heat exchanging	Volume flow rate variation. Dew point regulation and control. Additional equipment.

TYPICAL COMPLEX EMISSIONS

- Coal and fuel oil power stations: particulates, SO_2, NO_x, trace toxic pollutants
- Cement kilns: particulates, NO_x
- Painting ovens: particulates, VOC
- Metal - coke foundries: particulates, SO_2, trace toxic organics (PAH)
- Steel making: particulates, SO_2 , NO_x , trace toxic organics (dioxins)
- Petroleum refineries - catalyst regeneration: particulates, CO
- Food industries: particulates, odorous compounds
- Waste incinerators: particulates, acid gases (HCl, SO_2,HF), NO_x, trace toxics (dioxins, metals)