Condensation
or adsorption
of organic solvents

Polaris

Polaris, an engineering company with headquarters in Monza, in collaboration with SIAD, leader in industrial gas production, supplies cryocondensation or activated carbon adsorption plants for the VOC recovery; these units are for the treatment and purification of gaseous emissions containing pollutants of organic or inorganic nature whereby guaranteeing compliance with the law.
The techniques proposed are of recuperative nature in compliance with the most recent ecological norms, which favour and even "suggest" this procedure, in the case of product reclaiming.
With this in mind Polaris offers, along with emission treatment units, its own technology - patented - for fractional distillation, in order to make the reuse of the reclaimed products (e.g. solvents or other organic compounds) possible and convenient, with high yield and high purity of the recovered products in spite of the complex treated mixtures.

Cryogenic condensation with liquid nitrogen

The process of cryocondensation is based on the cooling of polluted effluents at extremely low temperatures, using liquid nitrogen as energy source.
The separation of pollutants is achieved thanks to the reduction of the vapour pressure at equilibrium concentration liquid/vapour or solid/vapour obtained at lowest possible cooling temperatures.
The effluent to be purified, polluted with organic or inorganic volatile compounds, even gas, is cooled gradually, in heat exchangers of particular configuration at temperatures lower than the dew point of such compounds, which are therefore removed from the gas phase by condensation as far as is physically possible.
If their residual concentration in the effluent still results higher than the standard limits, the cooling of the gaseous flow continues until a further reduction of vapour pressure is reached.
The temperature of such chemical-physical balance may result lower than the solidification point of residual compounds that consequently need to be separated no longer as liquid but as solid.
The configuration of the heat exchanger has thus a significant role in that it must allow for a prolonged period the accumulation, on their surface, of consistent quantities of solid product, without reducing the heat exchange and containing the head losses of the system.
The unit is then regenerated using a specific defrosting circuit and left ready for a new operating cycle. If the process is a continuous one then a second condensation unit is used which is "regenerated", ready for the service and kept on stand-by.

The liquid nitrogen, evaporated inside the heat exchanger, in pressure and in countercurrent with the stream to be purified, is not contaminated and it is delivered to the distribution pipeline for inerting processes or other productive activities.

Cryogenic treatment suitability

Cryocondensation is applied, for capital and operational costs, when the concentration of pollutants exceeds a threshold of between 1.000 and 3.000 mg/Nm^3 depending on the type of pollutant and for capacities of up to some thousands of Nm^3/h.

Nevertheless, if the cryogenic treatment with liquid nitrogen is combined with adsorption on activated carbon or resins, this results excellent even in cases of effluents having relatively low concentrations and pollutant loads and this method is particularly convenient also regarding pollutants in gaseous form.

Cryogenic condensation allows for the treatment and recovery of all types of volatile organic solvents.

There are several operating units treating chlorinated solvents, especially methylene chloride.

Chlorinated products treated at low temperatures and in dry environment do not develop dioxins (as occurs in incinerator processes) and do not create hydrochloric acid which is harmful both for the plant and for the environment.

Energy consumption and safety of cryogenic treatment

Besides a minor contribution due to insulation heat losses and transient starting steps, energy consumption is subdivided as follows:

a. energy for the cooling of the incondensable fraction of the effluent from the input temperature to the treatment one;

b. energy for pollutant cooling up to condensation point;

c. energy for the gas to liquid phase change, and in part to solid phase.

Cryogenic units allow for an effective energy recovery regarding points (a) and (b), in order to reduce the liquid nitrogen consumption. Afterwards if the nitrogen gas produced, as occurs in nearly all the installations, is delivered to the nitrogen distribution pipeline, the operating costs of the unit may be minimum or even non-existent.

For what regards safety aspects, the cryogenic treatment technique is totally safe in that it is used at low temperatures and in presence of inert gas.

Along their way gas-vapour mixtures only run on surfaces at temperature lower than the ignition one and in which electrical sparks sources cannot occur due to friction or accumulation of electrostatic charges.

Adsorption on activated carbon with nitrogen regeneration

Adsorption/desorption units with activated carbon (or other adsorbent materials) of gaseous streams containing organic pollutants have been developed using a new bed regeneration technique. The adsorption phase does not change. The novelty concerns the regeneration phase of the adsorption bed. This consists in heating up the bed with nitrogen in a closed-circuit and then a vacuum desorption step in order to carry out a quantitative removal of adsorbed substances. All is combined with the contemporary use of the cryogenic energy made available from the evaporated liquid nitrogen, inside a condensation column, that is injected into the regeneration circuit.

Only a flux of very small flow rate, about 1÷2% of the treated stream, but saturated with desorbed substances, is sent to the cryocondenser within which these substances are in turn quantitatively separated and recovered.

Using the above described technique all the cryogenic energy of the gasified liquid nitrogen is recovered as well as pure nitrogen gas.

Regeneration costs are reduced thanks to a rational and efficient use of energy, by avoiding competitive heating/cooling of great nitrogen mixture flow rate and desorbed compounds, which is typical of regeneration conventional systems with nitrogen.

Thanks to the features of this new system, we can say that the regeneration efficiency is extremely high. All the streams from the treatment unit, the main treated flow and those produced during regeneration steps are discharged into the atmosphere utterly pollutant-free.

The use of hot nitrogen instead of steam avoids the formation of large masses of polluted water that then have to be purified.

The entire impact on the environment is very slight or non existent.

The presence of oxygen or water is avoided during the heating phase of adsorbent and adsorbed materials, prolonging the life of the use of adsorbents and avoiding any possible oxidation and/or hydrolysis of adsorbed compounds. The recovered product, not contaminated by other substances or by water, therefore result of better quality.

Operating advantages and safety aspects on the adsorption plant

The operating advantages offered by adsorption units are:

- "dry" regeneration, in inert circuit;
- maximum safety also in the presence of highly flammable compounds;
- compatibility with compounds that generate hydrolysis activity;
- complete elimination of water treatment costs;
- easier recovery of the organic substances condensed;
- lower running costs in comparison with other inert circuit regeneration techniques;
- compliance with the most severe emission norms;
- process may be applied on basically all substances, even on the most volatile (including gases), on which other regeneration techniques are not so effective.

Referring to safety aspects, the main causes of accidents in the adsorption units are due to oxidation-reduction reactions of the adsorbed compounds.

Activated carbons can generate activated catalysis nucleus. For the fact that the adsorption process is exothermic, it produces an heating up of the adsorbent bed and this, if not kept under control, causes an increase of temperature to such values that the catalysed reactions of adsorbed compounds are activated in correspondence with such nucleus. The oxidation creates further heat and a rise of the bed temperature. This phenomenon initially restricted to the so-called "hot spots", may gradually extend to all the bed mass.

In order to avoid the above mentioned phenomena Polaris/SIAD units have adopted the following safety measures:

- the activated carbons used are of the best possible quality and undergo specific treatment in order to have a quantitative elimination of "active nucleus";
- fluid mechanics is studied in order to optimize the homogeneity of the material and the stream to be treated, for removing the adsorption heat and avoiding localized overheating;
- at the entry the stream is thermo-conditioned in such a way as to allow for a safety precooling;
- a CO analyser continuously monitors the presence of carbon monoxide in the emission and points out, through its maximum concentration, the beginning of any oxidation phenomena which are immediately stopped by barring the entry stream on the activated carbon bed and introducing nitrogen gas for total inerting.

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SIAD IN EUROPE

SIAD S.p.A.

Headquarters
Via S. Bernardino, 92
I-24126 BERGAMO
Tel. +39 035 328111
Fax +39 035 315486
www.siad.com
siad@siad.com

AUSTRIA
SIAD Austria GmbH

Head office
Trimmelkam 111
A-5120 ST. PANTALEON
Tel. +43 (6277) 7447-0
Fax +43 (6277) 7401
siad_vtg@praxair.com

Regional office
Hofherr-Schrantz-Gasse, 4
A-1210 WIEN
Tel. +43 (1) 2719200
Fax +43 (1) 2719200-10

BULGARIA
SIAD Bulgaria OOD

Head office
4, Amsterdam str.
P. O. Box 28
BG-1528 SOFIA
Tel. +359 (2) 9785636
Fax +359 (2) 9789787
siad@siad.bg

CROATIA
MONTKEMIJA d.o.o.

Head office
Senjska cesta b.b.
HR-51222 BAKAR (RIJEKA)
Tel. +385 (51) 761466
Fax +385 (51) 761175
montkemija@montkemija.hr

CZECH REPUBLIC
SIAD Czech spol. s r.o.

Head office
č.p. 193
CZ-435 22 BRAŇANY U MOSTU
Tel. +420 476765000
Fax +420 476129286
siad@siad.cz

Regional office
Doubravínova 25
CZ-163 00 PRAHA 6
Tel. +420 235301241
Fax +420 235323828

HUNGARY
SIAD Hungary Kft

Head office
H-3527 MISKOLC, Zsigmondy u. 38
Tel. +36 (46) 412417
Fax +36 (46) 411681
siad@siad.hu

ROMANIA
SIAD Romania s.r.l.

Head office
Str. Paleologu no. 7
Ap.3 - Sect. 2
RO-023955 BUCURESTI
Tel. +40 (21) 3103658
Fax +40 (21) 3149806
siad@siad.ro

SLOVAKIA
SIAD Slovakia spol. s r.o.

Head office
Rožňavská č. 17
SK-831 04 BRATISLAVA
Tel. +421 (2) 44460347
Fax +421 (2) 44460348
siad@siad.sk

SLOVENIA
ISTRABENZ PLINI
Plini in plinske tehnologije, d.o.o.

Head office
Sermin 8/a
SLO-6000 KOPER
Tel. +386 (5) 6634600
Fax +386 (5) 6634699
istrabenzplini@s-net.net

SIAD