POLARIS ADSORPTION TECHNOLOGY

FOR VOC RECOVERY

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Polaris s.r.l.
Via Zucchi, 1
20052 MONZA (MI), Italy
tel. +39 039 327783
fax +39 039 2311487
e-mail polaris@polarisengineering.com

INTRODUCTION

The adsorption technique, using beds of materials like activated carbon, macroporous polymers and zeolites, is largely adopted for the recovery of volatile organic compounds (raw materials, products, solvents, fuels etc.) to be directly reused or re-worked (fractionated and/or purified) for reuse, as well as for the abatement of pollutants (in form of VOC, gases, odours etc.) coming from production processes and accessory activities, also as a guard or finishing step after final treatment facilities.

Adsorption has been very well studied and developed, and is considered a highly efficient technology for the above separations, simple and almost reliable running the above recovery and effluent treatment processes. Therefore, it has been included in the list of the Best Available Techniques in waste gas treatment, prepared by the Commission of the European Community, even more appreciated because it is a recuperative technology which complies with the spirit of the most recent approach to the ecology problems. The entailed problems, due to the nature of the compounds to be adsorbed (e.g. risk of fire because of their reactivity in presence of the catalytic sites of active carbon), and to the possible presence of particulates and excess water in the streams entering the adsorption beds, are known, and adequate measures can be provided to solve the problems in the most of cases.

The adsorption processes can be run on fixed beds, fluidised beds, continuous-moving beds, or according to the pressure-swing adsorption/desorption method. The most widely diffused is fixed–bed adsorption, more flexible in the use.
To regenerate a bed of adsorbent, in particular active carbon and macroporous polymers, the following methods can be applied, using several heat sources:

- steam, the most common, at different conditions of temperature, pressure, saturation degree;
- embedded heaters or microwaves, at different temperature levels;
- hot gases, inert in particular, for safety reasons, at different temperature levels.

In alternative, vacuum regeneration can be used for desorption.

The use of steam appears very effective for supplying the thermal energy by convection to the adsorbed compounds, but entails, in the most of cases, the formation of huge amounts of polluted water to be treated, or the increase of difficulties in the downstream separation processes for recovery of products (water can produce azeotropes with solvents and other VOC and cause hydrolysis of several compounds).

Using embedded heaters or microwaves, the difficulty consists on the heat transfer through the bed, very poor and not homogeneous because of the minimum thermal conductivity of the adsorbent materials. Therefore, the removal of adsorbates is time-consuming and not effective in the most of cases, because a high, risky level of regeneration temperature must be avoided.

In the vacuum regeneration, a quiet technique in itself, where the energy for desorption of the adsorbed compounds is supplied by the bed material thermal capacity, a similar restriction to the use occurs when a high level of cleaning of adsorbents is required, in front of very severe treatment of polluted emissions. Combined with embedded heaters, the performance is improved, but the risk of process increases. No side-effect on environment is produced.

Following the conventional procedure for thermal regeneration, hot gases are passed through the bed of the adsorbent, to desorb products, in closed loop with a cooler (for separating the desorbed materials) and a heater (for supplying further energy to the bed). In detail: hot gas is the source of heat to increase the temperature of the bed and allow the adsorbate outdo the adsorption bonds; the source of cooling is needed to reach the dew point and get condensation of compounds passed in vapour phase. Heating by convection is effective, but not always enough to get a quantitative removal of the adsorbed compounds, working at the usual heating temperatures, because of the limiting effect of the strong adsorption bonds. Cooling at relatively high temperatures, as usual, means that the stream recycled to the adsorption bed contains a lot of residual desorbate, so the bed cannot be perfectly cleaned. This limitation is particularly evident when the highest level of efficiency in the pollutant separation processes is required, facing the most restrictive concentration limits prescribed by the law, therefore a very clean bed after regeneration is needed. When hot nitrogen is used, at the initial step, it is purged inside the circuit to get a inert atmosphere, the cooling energy released for evaporating liquid nitrogen is waste. Later, when a high flow-rate in the loop is required to perform the desorption, huge quantities of heating (by steam or hot dowtherm) and cooling energy (by brine) are contemporaneously supplied, but the use of the latter is inefficient (because of the contemporaneousness) and almost ineffective (because of the thermal level, not adequate for a full regeneration of the bed). However, no further impact on the environment is usually entailed by the use of hot inert gas.

Following the above considerations, the adsorption technique, using, for desorption, hot nitrogen in closed loop, or the vacuum regeneration carefully applied, should be recommended, from the ecology and safety point of view, but a further effort is required to remove some limitation or deficiency in the use. This approach complies with the trend of the directives issued by the national governments and by the World Organizations and Committees in matter of environmental protection, which put enhanced emphasis on the prevention and reduction of the overall impact on the ambient owing to the production processes and auxiliary activities, here including the wastewater and waste gas treatment plants. Based on the above directives, the residual concentration of the most dangerous pollutants must be kept in the limits of few mg or fraction of mg per Nm3 of the cleaned final effluent to atmosphere.

Polaris has developed and enhanced the thermal regeneration, with hot nitrogen for obvious safety and process reasons, finding a new method for which the patent application has been introduced .

DESCRIPTION OF THE POLARIS SYSTEM

The Polaris approach is to provide an integrated adsorption-desorption system, with enhanced features, for the recovery of volatile organic compounds (raw materials, products, solvent, fuels etc.) or for the abatement of pollutants (VOC, gases, odours etc.), particularly suitable for fixed-beds adsorbers. The method introduces substantial improvements in the desorption of compounds from the bed.

The **adsorption** step is implemented with a conventional approach, passing the stream to be treated through the adsorption bed after a preliminary partial separation of the moisture contained in the stream. This is very important to avoid any trouble, coming from the water presence, in the following steps.

The **desorption** starts with the injection through the bed of gas nitrogen, evaporated on purpose from liquid, for purging oxygen from vessel and circuit. The purging stream is treated, to separate the volatile compounds before discharging to atmosphere, in a cryogenic condenser using the energy of brine for pre-condensation, and the cryogenic energy recovered from the nitrogen evaporation for finishing the separation.
After this first inertisation phase, continuing purge, the adsorption bed is heated at high temperature, by circulating, in closed loop with a heat exchanger, the stream of nitrogen and vapours of desorbate compounds. In the above cryogenic condenser **only** the saturated overflow from the loop is treated, previously pre-cooled, by using liquid nitrogen which is evaporated and recovered in pressure.
When the bed reaches the required desorption temperature, the nitrogen purge is stopped, and the hot adsorption bed is put under vacuum with a pump, to allow the desorption of compounds. The resulting sucked stream is treated into the cryogenic condenser, then it can be discharged to atmosphere or to the other adsorption bed in parallel (depending on cases).
The desorption is stopped when the bed is sufficiently free of VOC. At this moment the bed is cooled in closed loop using cooling water in a cooler.

In the above operations

- all cryogenic energy from liquid nitrogen is recovered, as well as the formed gas;
- all the desorbed compounds are recovered, not contaminated by any added material or moisture;
- all streams from treatment are discharged to the atmosphere absolutely free of pollutants;

- heating of adsorbent and adsorbate in presence of oxygen and water is avoided, thus increasing the service life of adsorbent and avoiding the possible oxidation and/or hydrolysis of adsorbate.

Thanks to the features of the new system

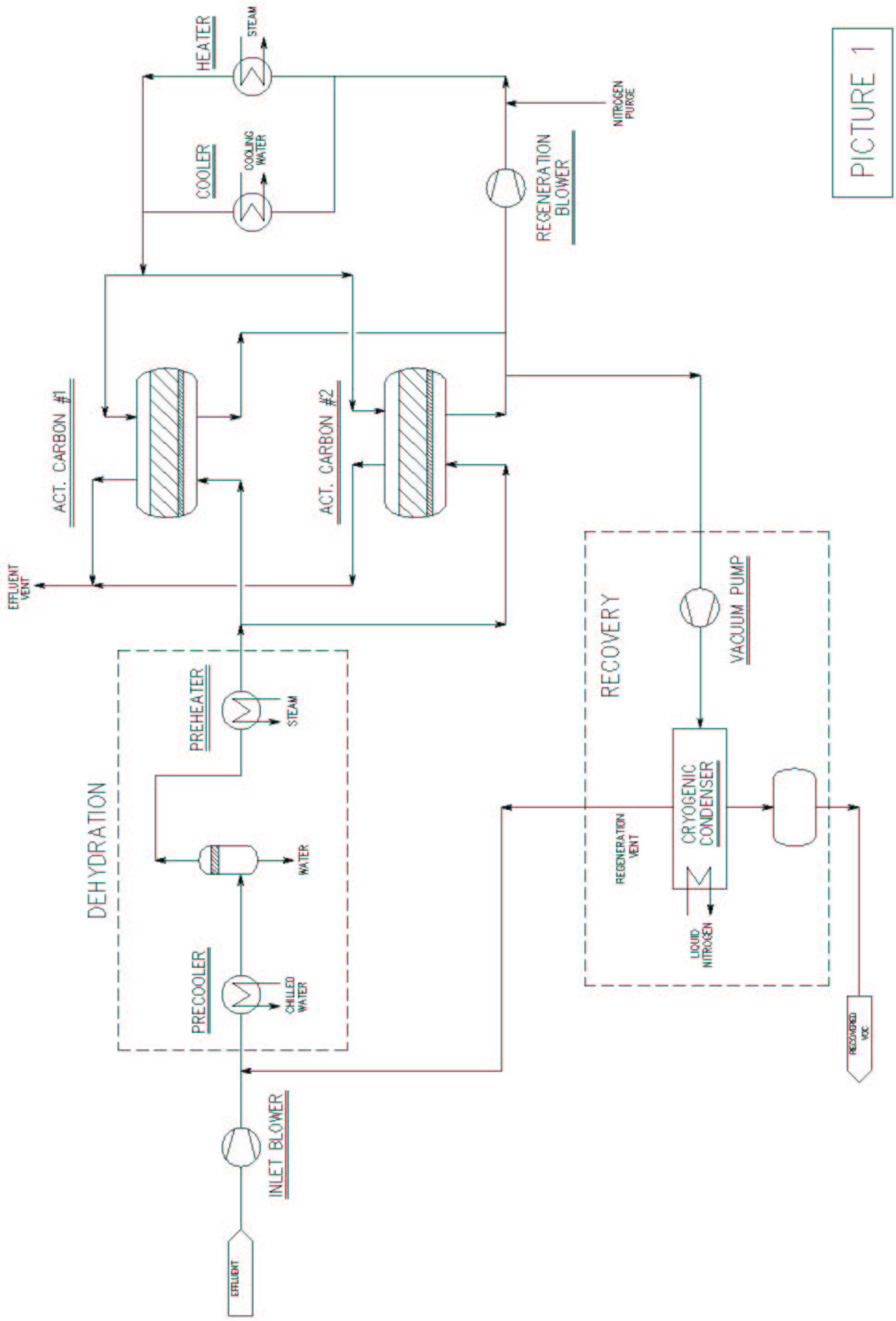
- the effectiveness of regeneration is complete;
- the quality of recovered products improved;
- the downstream environmental impact is minimised;
- the running costs are contained thanks to a rational and efficient use of energy, avoiding the competitive cooling-heating of the huge flow-rate of nitrogen-desorbate mixture in the loop;
- the reliability of the system is guaranteed, and the duration of the total operational cycle, step of adsorption plus step of bed regeneration, is kept inside the usual times of the existing adsorption technologies.

Finally, by virtue of the method, it is also easier to use for adsorption the macroporous polymers, which are sensitive to the effect of quite high temperature levels during regeneration, in particular in presence of oxygen. By using said polymers, the energy consumption for regeneration (heating and cooling) is reduced thanks to the weaker bonds of adsorption in comparison with the activated carbon's ones.

In accordance with another application of the system, during the above mentioned regeneration of a bed which has been used for the adsorption of a mixture of different vapours, also gases, it is possible to get, desorbing the products, the contemporaneous fractionation of the different components in the same facility, by using an internal reflux column as cryogenic condenser.

Pict. 1 shows a schematic diagram of the adsorption-regeneration process developed by Polaris.

Pict. 2 shows an industrial application of the technology.


HEATER
STEAM
COOLER
COOLING WATER
NITROGEN PURGE
REGENERATION BLOWER
ACT. CARBON #1
ACT. CARBON #2
EFFLUENT VENT
DEHYDRATION
PRECOOLER
CHILLED WATER
WATER
PREHEATER
STEAM
RECOVERY
VACUUM PUMP
CRYOGENIC CONDENSER
REGENERATION VENT
LIQUID NITROGEN
RECOVERED VOC
INLET BLOWER
EFFLUENT

PICTURE 1

PICTURE 2