Pressure Swing Adsorption Recovery System

Case Study

Summary

In February 2003, construction was completed on a new polyethylene plant with the capacity to produce 320,000 metric tons per year (MTA). The Polyethylene Unit incorporates a combined partial condensation and pressure swing adsorption (PSA) recovery process that will enable the complete recovery and reuse of nitrogen gas, which is used to remove hydrocarbons from the polyethylene. Hydrocarbons, such as unreacted monomer, additives, and solvents, are recovered and recycled back into the polymerization process. Integration of this recovery system into the Polyethylene Unit provides substantial cost savings and eliminates the emissions associated with partial or no recovery of the hydrocarbons and nitrogen gas.

Benefits

- Recovery of nearly 100% of nitrogen used to degas raw polymer for reuse.
- Recovery and recycle of valuable hydrocarbons removed from raw polymer in the degassing step.
- Elimination of NO_x, CO_2, CO, and VOC emissions.

Project Overview

In the production of polyolefins such as polyethylene and polypropylene, many plants use a polymer-degassing step to remove unreacted monomer, solvents, and additives from the polyolefin before it is processed into pellets. Nitrogen is commonly used as the stripping gas in the process, producing a low-pressure vent gas stream containing nitrogen and valuable hydrocarbons. Vent gas is processed to recover a portion of the hydrocarbons, but the remaining nitrogen and hydrocarbons are disposed of through combustion either in a flare or by diluting a fuel gas stream. In some cases, natural gas or another fuel must be added to enable combustion.

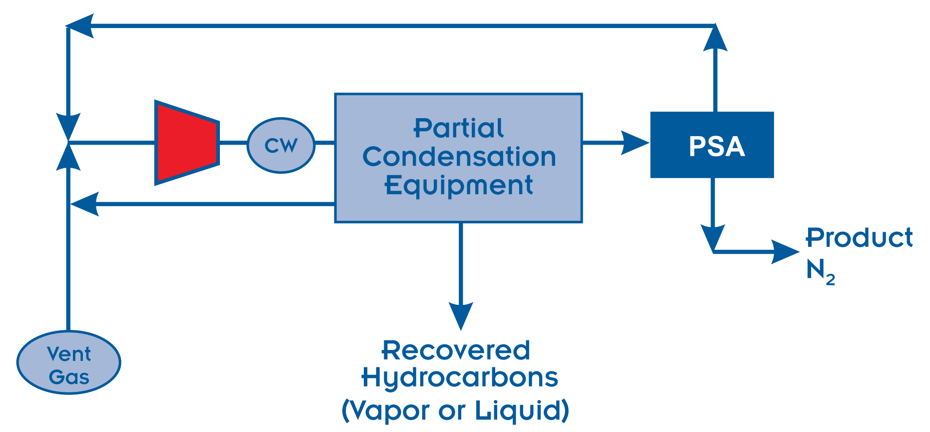
The expense of combusting vent gas can be high when considering the costs of nitrogen, lost hydrocarbons, power, and fuel. Flaring also generates volatile organic compounds (VOCs), oxides of nitrogen (NO_x), carbon monoxide (CO), and carbon dioxide (CO_2) emissions, which contribute to poor air quality. As emission regulations become stricter in Texas and throughout the United States, reducing emissions will increasingly yield economic as well as environmental benefits.

To avoid the economic and environmental impacts of flaring, the new polyethylene plant is incorporating an innovative technology developed by Air Products and Chemicals, Inc. (Air Products) to recover the nitrogen gas after it has stripped the polyethylene of unreacted monomer, solvents, and additives. The Air Products technology combines partial condensation with PSA to produce a nitrogen stream that is over 99% pure. The U.S. Department of Energy's Office of Industrial Technologies funded select portions of the product development.

How PSA Works

PSA enables improved recovery of hydrocarbons from a mixture of gases. The process has existed since the late 1970s, but improved adsorbent materials have enabled greater separation of stream components in subsequent years. The process developed by Air Products uses partial condensation to recover most of the hydrocarbons, and then applies PSA to refine the nitrogen into a nearly pure stream. The hydrocarbons are recycled back into the polymerization process (see Figure 1).

Figure 1: Polyolefin Plant Recovery Systems Flow Diagram

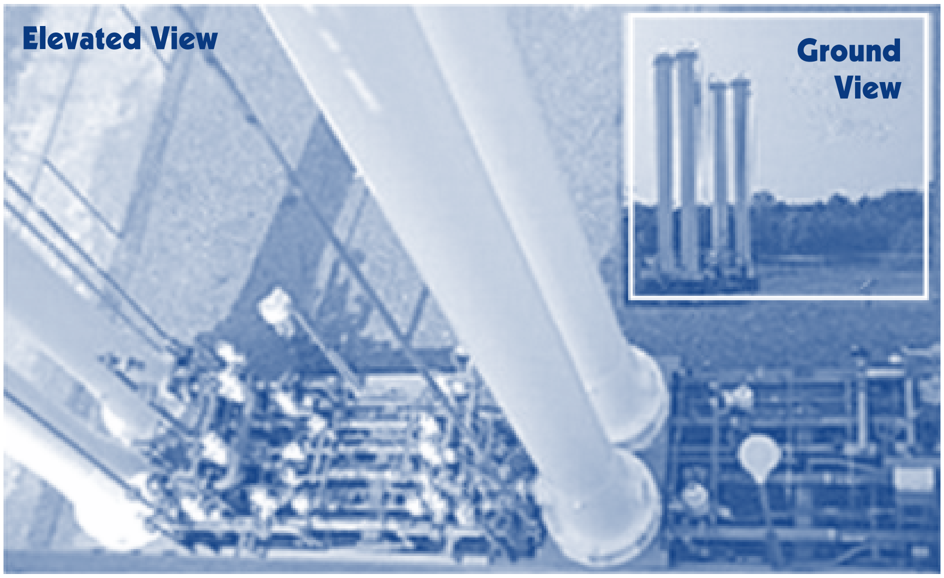


In the Partial Condensation Unit, the vent gas stream from the Polymerization Unit is compressed and partially condensed. This step can be economically carried out with or without external mechanical refrigeration. Most of the hydrocarbons are liquefied within the Condensation Unit and separated from the nitrogen gas stream. Upon exiting the Condensation Unit, they can be recycled back into the polymerization process. Lighter hydrocarbons (C_1 to C_4 compounds) are less likely to condense at the operating conditions of the Partial Condensation Unit and usually flow with the nitrogen stream into the PSA Unit.

The PSA Unit contains an adsorbent material that selectively extracts the hydrocarbons from the nitrogen stream. Nitrogen is not adsorbed, exiting the unit as a highly pure stream. When the adsorbent material in the bed becomes saturated with hydrocarbons, it is regenerated by lowering the pressure in the bed to release the hydrocarbons. The hydrocarbons are then recovered in a low-pressure tail gas and recycled back to the compressor, passing through the Partial Condensation and PSA units again. This cycle continues until the hydrocarbons condense in the Partial Condensation Unit and exit the recovery process.

Each adsorption bed operates in a cyclic mode, alternating between the adsorption and desorption phases. Multiple beds are used in staggered cycles to create a continuous-flow PSA process. The recovery process can be included in the construction of a new polyolefin plant or used to retrofit an existing plant.

Figure 2: Four-Bed Pressure Swing Adsorption Unit



Savings

The recovery process enables essentially 100% recovery of both the nitrogen and hydrocarbons. Emissions generated through flaring of the vent gas stream are eliminated, and nitrogen and hydrocarbons are recovered separately for reuse. This translates into significant cost savings and reduced environmental impacts. The only additional utilities required by the recovery process are cooling water and electric power for the compressor.

An example test case below demonstrates the benefits of incorporating the recovery system with PSA technology at a plant processing 250,000 MTA of polymer. In the No Recovery case, the vent gas stream exiting the degassing step is completely combusted. The Incomplete Recovery case involves the recovery of approximately 70% of the polypropylene in the vent gas stream. The heat content of the nitrogen and residual polypropylene gas exiting the degassing process is too low to efficiently combust in a flare; therefore, natural gas must be added for efficient combustion. The recovery system case uses the combined partial condensation and PSA technology to recover and recycle the nitrogen and hydrocarbons separately.

As shown in Table 1, the direct costs of the recovery system are significantly less than those for the No Recovery and Incomplete Recovery cases. In the new 320,000-MTA polyethylene plant, the recovery system with PSA technology is projected to recover nitrogen and hydrocarbons worth more than $18 million annually.

The typical payback period for incorporating this system into a plant is between one and two years, depending on the plant site values for recovered hydrocarbons, nitrogen, and electricity costs.

Environmental Benefits

The elimination of CO_2, NO_x, CO, and VOC emissions are especially important in an environment of increasingly stringent air quality regulations. The county and surrounding area where the new 320,000-MTA polyethylene plant is located was designated a Clean Air Act (CAA) nonattainment area after exceeding the CAA ozone limits more than three times in three years. Within the nonattainment area, the state environmental agency has put strict permitting requirements on new point-source emissions of NO_x and VOCs, which are precursors to ozone. The potential for emissions reductions in the 250,000-MTA test case is shown in Table 2.

By integrating the recovery system into the new 320,000-MTA polyethylene facility, the company both minimized emissions and facilitated the permitting process with the state environmental agency. It is estimated that the permitted emissions from the plant were reduced by 3,750 metric tons of CO_2, 1.7 metric tons of NO_x, 15 metric tons of CO, and 20 metric tons of VOC annually.

Table 1. Annual Cost of Degassing

	No Recovery	Incomplete Recovery	Recovery System with PSA
Lost Propylene ($1,000)	2,034	610	0
Purchased Nitrogen ($1,000)	366	363	2
Added Fuel to Flare ($1,000)	0	551	0
Electric Power ($1,000)	-0	136	256
Total ($1,000)	2,400	1,661	258
Cost Per Metric Ton Polypropylene	$9.60	$6.64	$1.03

Table 2. Degassing Emissions

	No Recovery	Incomplete Recovery	Recovery System with PSA
CO_2 (Metric Tons Per Year)	13,930	12,970	0
NO_x (Metric Tons Per Year)	5.6	6.2	0
CO (Metric Tons Per Year)	47.9	53.2	0
VOC (Metric Tons Per Year)	45	13.5	0

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