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SF_6 Reclamation, Where Are We?

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Introduction

The gas recycling industry maintains its lead over most of the utilities and electric equipment manufacturers with SF_6 recycling technology. Only a handful have fully embraced the concept of recovery and recycling, but most utilities are aware of the benefits of recycling SF_6 gas.

The industry was initially confused by the different technologies and terminology of recycling: low pressure, gas only, oil-free, gas, storage in bottles, gas storage in tanks, oil-less, DOT, liquid gas, cooling, ASME, high pressure, vapor gas. Over the years, several of these issues have been resolved, resulting in a better understanding of equipment, processes, and terminology.

Compact recycling carts use high-pressure, oil-less equipment to minimize the number of cart components, to reduce weight, and to ensure compact design. These carts sacrifice speed and temperature independence for compactness; they are fundamentally designed only to process small amounts of gas where speed is less important.

For larger-volume gas recycling, carts use low-pressure, assisted-cooling technology, which is not temperature dependent and ensures rapid gas recycling. High-pressure technology necessitates the use of multiple components for high flow rates, which over-complicates design and decreases reliability. Low-pressure technology gives you the necessary speed to process the large amounts of stored gas found in large breakers and bus-ducts.

A complete range of both high- and low-pressure recycling carts is available today. The range comprises mini compact carts that are lightweight and portable and require the addition of an independent storage system through large trailer-mounted carts offering pressure-coded tanks or DOT-approved cylinder storage systems. Equipment is available in many configurations.

Oil-less Compact Carts

Compact carts have developed to meet the expectations and requirements of the industry. The early models, which used high-pressure direct liquefaction, had drawbacks. The speed of recycling was slow, especially in higher ambient temperatures, and 100% gas recovery was difficult. A characteristic of high-pressure recycling technology is that all components are oil-less, except for the vacuum pump. Cooling is not employed to reduce gas temperatures. The vacuum pump is out of the SF_6 circuit to avoid oil contamination. Therefore, low base pressures, which correspond to close to 100% SF_6 recovery, were not possible.

Recently, suitable oil-less vacuum pumps, with good flow rates and acceptable base pressures, have been developed. This enables new generation carts to be 100% oil-less and recover 100% of the gas. In addition, the latest generation of these carts is fitted with a liquid SF_6 pump, which speeds up the recycling process. A popular use for this type of cart is cylinder consolidation. The process benefits from the use of a liquid pump. Gas is recovered in a reasonable amount of time: the liquid pump can fill a 115-lb. bottle in 10 minutes. This enables this type of cart to be considered as a viable piece of equipment to recycle gas from larger breakers, where the excess gas can be stored temporarily in cylinders prior to its return to the breaker.

For compact carts (for which small amounts of gas are involved), less expensive cylinders are an alternative to storage. However, as gas volumes increase, the attractiveness of cylinders as gas receivers decreases.

Compact carts have become the carts of choice in the US, as the gas volume in breakers has reduced. Large cart manufacturing continues in order to maintain the older breakers, GIS, and bus-duct systems, where stored gas volume is significant.

To complement the compact carts, a small-capacity filter/scrubber has been developed. These filters use a number of individual cartridges in series to clean the gas. Each cartridge comprises a combination of chemicals sintered together to form a cartridge. Different cartridges are available to perform different functions including drying, particulate filtration, by-product neutralization, and oil removal. Filters can be “customized” to meet any particular process requirement.

Automation

All recycling carts are now available with automatic process controls. The three main recycling functions, withdrawal, breaker evacuation, and gas return, are automatic functions. The cart set-up functions of initial evacuation and charging with SF_6 are still carried out manually due to the multiple checks of systems, connections, and functions that are carried out during set-up. Once the cart is pressurized with SF_6, recycling can be performed automatically. Manual operation is retained as a back up.

Carts measure gas moisture content, breaker vacuum, and pressure levels to control the recycling process. Safeguards are built in to prevent the system from functioning if there is a fault, leaking hose connection, or out-of-specification gas. Manual intervention is required to address and correct these faults.

Automation simplifies the process of gas recycling and ensures maintenance of gas purities and dryness levels throughout the recycling process.

Analyzers

A range of analyzing equipment is available for leak detection, including moisture measurement (hygrometers), percentage SF_6 measurement, and by-product detection. The leak detector is fully portable, is battery operated (alkaline or re-chargeable), and will detect all SF_6 leaks typically found on breaker equipment. The hygrometer is available portable or as a built-in unit to monitor dryness levels before gas is returned to the breaker.

Regenerative dryers are now commonplace on today’s carts, enabling simplified gas drying with a single pass. In the field, gas dryness can be monitored with the by-product detector. This instrument operates on a sample tube basis and checks for decomposition products and moisture content. This device is a good general-purpose detector and/or monitoring instrument, and when used regularly can create a record of the actual operation of the breaker. Routine maintenance can be scheduled depending upon the operation of the breaker.

A percentage meter is available as a portable instrument for the field. The unit will indicate the percentage of air and other decomposition-indicating contaminants contained in the gas. This unit can also be a good diagnostic tool and will help monitor the operation of the breaker and indicate when maintenance on the breaker is required.

Gas Separation

Two different systems are available for the separation of non-condensable gases from SF_6, notably air and nitrogen. One system is based on sub-cooled liquid separation. The other is based on membrane separation technology. The sub-cooled liquid separation system operates on the principle of high-pressure oil-free direct liquefaction to initially liquefy the reclaimed gas. This is followed by further liquefaction of the gas phase by sub-cooling of the gas/liquid mixture in a separation/stratification column. Non-condensable gases slowly vent through the column, in which any entrained SF_6 gas is re-liquefied and retained. This allows the non-condensables to escape to the atmosphere.

Through continuous sub-cooling of the liquid SF_6, further separation of the gases is possible. This leads to an efficient high-percentage recovery of the SF_6.

The membrane separation technology has been in use for many years in the industrial gas industry for generating nitrogen and oxygen from compressed air. The membrane comprises hollow fibers that have a perfectly circular cross section and a uniform bore through the center. They are very small; a large membrane surface area packs into a physically small space.

Specifically developed carbon membranes separate the fluoride gases, such as SF_6, CF_4 (methane), and C_2F_6 (ethane) from the air and prevent pollution of the atmosphere. Recovery rates are in excess of 99%.

Recycling carts fitted with membrane technology have dual high-efficiency coalescing filters, activated carbon filters, and a particulate filter to protect the membrane module from contamination. Recovered gas passes through the membrane regardless of its condition. This leads to very efficient “on site, one pass” recycling of the gas irrespective of its condition. Typically, membrane systems will not require service or maintenance for five years.

Membranes operate in any attitude, which makes incorporation into conventional gas cart designs extremely easy. SF_6 recycling carts will now have the ability to completely treat “used” SF_6, removing moisture, decomposition by-products, and entrained air all in the same cycle, on site, while carrying out normal breaker maintenance. This eliminates the need for centralized treatment systems and the transportation of contaminated SF_6.

Membrane technology will provide a recycling solution should mixed gases be adopted to assist in reducing the global warming effect. It will be possible to add a separation system to existing low-pressure recycling carts and recover 100% of the SF_6 from typical 80/20 mixes, or even mixes with lower concentrations of SF_6 in nitrogen.

Summary

Gas cart manufacturers are responding to the challenge made by the industry and the EPA. A full range of recycling carts and analytical equipment is developed and currently available. We are ready to realistically recycle mixed gases if the need arises. We will continue to develop equipment to meet needs as they are identified, and to improve the existing equipment to better meet the requirements of the industry.