Developing an effective crude oil vapor recovery system

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The capture and recovery of hydrocarbon vapors to reduce emissions of environmentally hazardous volatile organic compounds (VOC) is a vital concern in modern oil and gas production and transportation.

UN-ECE, US EPA, the International Maritime Organization (IMO), the EU and other bodies continue to develop (non-prescriptive) regulations and directives focused on the prevention of air pollution from shipping. Most of the larger oil companies worldwide have established clear environmental strategies for this issue with targets for VOC reductions.

In Norway, however, measures to reduce VOC emissions during the loading operations for crude oil, both offshore and onshore, have increasingly been required by the Norwegian Pollution Control Authority (SFT) and also form part of international environmental agreements.

The current SFT emission requirements for crude oil loading operations require a minimum recovery efficiency of not less than 78 percent of non-methane VOC (NMVOC). This particular recovery efficiency requirement is applicable to shuttle tankers operating in the Norwegian sector of the North Sea. The laws and regulations for onshore sites require facilities to apply for their own independent concession under which to operate.

Recovery efficiencies, rather than mass based emission rates, are commonly used for defining crude oil emission requirements because of the very wide range and complexities of crude oil compositions. Crude oils from different areas in the world, and indeed within the various sectors of oil producing areas, can vary significantly; some high in light VOC compounds others high in heavy compounds and so on.

Designing a vapor recovery system

In the design of a vapor recovery system it is essential to have a clear understanding of the product being handled. This is usually relayed in the form of a product assay, identifying the entire composition of the product being handled and thus allowing the VRU system designer to accurately determine the vapor composition, the VOC concentrations and the subsequent attainable emissions from the system. To ignore these operating parameters with such widely varying products, such as crude oil, naphtha, condensate etc., is most likely to result in erroneous VRU designs.

One case by way of example is the crude oil vapor recovery system operating at Statoil's Mongstad facility. For this system the VRU is required to recover vapors from up to four different crude oil types, with wide ranging compositions and vapor pressures, although the system can handle a much wider range of oil compositions. The resulting vapor recovery system has been designed to recover vapors resulting from each of the crude oils loaded at the terminal. However, for each of the crude oils loaded a separate recovery efficiency guarantee applies, reflecting the varying composition.

The largest crude oil VRU in the world – Statoil Mongstad.

CLA crude oil VRU system – Statoil Sture.

The Aker approach

Since its founding in 1982, Aker Solutions' subsidiary Cool Sorption has focused exclusively on VOC emissions abatement technology, and has developed into a global centre of excellence for VOC recovery systems.

For more than two decades, Carbon Bed Adsorption, or Carbon Vacuum-Regenerated Adsorption (CVA), has been the mainstay of technologies used for gasoline vapor recovery. Aker Solutions saw no reason why CVA should not have a similar position in the market for crude oil and condensate vapor recovery systems. The first crude oil vapor recovery system tests were undertaken at Frederica, Denmark, in the early 1990s. The tests were a great success and resulted in the installation of the first crude oil vapor recovery system in the mid to late 1990s.

Aker Cool Sorption's vapor recovery systems are individually designed to comply with specific safety and hazard requirements of each operator, for example, those of DNV, ABS, USCG, among others.

Following the development of the CVA system for use in the recovery of crude oil vapors, an immediate breakthrough was achieved for both land and at-sea installed systems.

In 2003, Russian oil company Lukoil ordered two large CVA units for their Vusotsk and Kaliningrad terminals. The choice was made after screening alternative technologies. In the same year as the land based Vusotsk plant was ordered, the first CVA unit for marine operation was contracted.

The Norwegian shuttle tanker M/T Navion Europa was the first to install such a unit. It has been in operation since December 2003 with a very good record. Recovery rates vary between 92 percent and 97 percent NMVOC. Several more vessels followed, including the Åsgard C Floating Storage and Offloading unit (FSO), shuttle tanker DE/T Randgrid, shuttle tanker M/T Navion Norvegia and FSO Navion Saga in the Volve oil field.

The process explained

Vapor from the cargo tanks passes through the vapor header to the recovery unit. As the vapor may, in some cases in which crude oil vapors are being processed, contain sulphurous compounds, a pre-filter (guard bed) containing a highly sulphur selective adsorbent is often installed to protect the VOC system against dimethyl sulphide, mercaptanes and H_2S upstream the VOC recovery system. The sulphur components in the vapor

Ship board crude oil VRU – Navion Norvegia – operational in the North Sea.

Åsgard C is installed aboard *M/T Jorunn Knutsen* operational in the Åsgard C field, North Sea.

are in this way removed before entering the vapor recovery system, minimising the performance and corrosive aspects of the sour gases.

The CVA system consists of activated carbon beds; operating in a cyclic mode being either adsorbing VOC'S or being regenerated. Activated carbon has an extremely large surface area and hydrocarbons are adsorbed in a very thin layer on the carbon surface. The carbon can only adsorb a certain amount of VOC hydrocarbons before reaching saturation. Consequently, the carbon is regenerated in order to restore its capacity, so hydrocarbons can be efficiently adsorbed in the following cycle. Thus, the carbon batch in the adsorber vessels (beds) will perform with sufficient capacity over the years and, typically, only needs replacement after a period of seven to 10 years.

The regeneration takes place in two stages. First, the bed is evacuated until the pressure reaches a value at which the hydrocarbons begin to desorb from the carbon surface. The bulk of the hydrocarbons are removed at this stage. In order to remove the remainder, it is necessary to introduce a small amount of purge air.

The vacuum pump used for regeneration will be either liquid seal ring or dry running type, depending on the size of the VRU, the products being handled and the machinery specifications.

The vapor, which is now very rich on hydrocarbons, passes from the vacuum pump system to the absorber column where the bulk of hydrocarbons are absorbed in a counter flow of a suitable absorbent, often gasoline or crude oil.

Through all its successes in recent years, the CVA system has proven itself time and time again as Best Available Technology (BAT), for both gasoline and crude oil vapor recovery and many other products, for example Naphtha, condensates, BTX petrochemical products.

Aker Solutions is one of the leading suppliers of crude oil vapor recovery systems. During the course of the past 10 years, over 40 systems have been supplied, a sizeable number for installation on FSO and shuttle tankers operating in various locations around the world. The most recent systems are in operation in the Al-Shaneen oilfield offshore Qatar. Each of these units is designed to recover vapors during the transfer of crude oil from the production platform to the FSO.

Developments are being made in tackling losses and associated emission problems of products in transit. Furthermore, there are debates developing considering the values, environmental effects and the consequences of the drive to reduce emissions to lower and lower levels: does it cost more environmentally, in terms of CO_2 emissions and other pollutants, to operate the vapor recovery system than there are benefits from operating the system – do we in fact use more energy to achieve the tighter emission requirements than is practically recoverable?

ABOUT THE AUTHOR AND COMPANY

Simon Shipley has been Sales and Business Development Manager with Aker Cool Sorption since 2005. A Chemical Engineer, Simon has been directly involved in the vapor recovery business since 1985, in project management, design and sales roles.

Aker Cool Sorption, a division of the oil services company Aker Solutions, is amongst the world's leading manufacturers of state-of-the-art vapor recovery systems, used to treat and recover these hazardous emissions. The company provides a broad range of vapor recovery installations for VOC systems at on-shore marine and offshore operations, including ULCC, VLCC, FSOs, shuttle tankers and large onshore marine terminals, in addition to land based distribution terminals.

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