Vapour recovery developments in emission standards and applications

Throughout the world today, vapour recovery systems are a common sight at distribution terminals handling the transfer of products ranging from petrol to aromatics, such as benzene and xylene, and increasingly, crude oil. Some of the largest vapour recovery units in the world are used in crude oil transfer operations. Vapour handling capacities between 10,000m^3/hr and 40,000m^3/hr are not uncommon in crude oil applications.

Activated carbon vapour recovery units remain the preferred technology, often referred to as the best available technology (BAT), in many of these applications. These systems provide operators with maximum flexibility because they are capable of handling an extensive range of product and feature a wide turn down ratio capability, from 0% to 100% of the design flow and inlet concentrations.

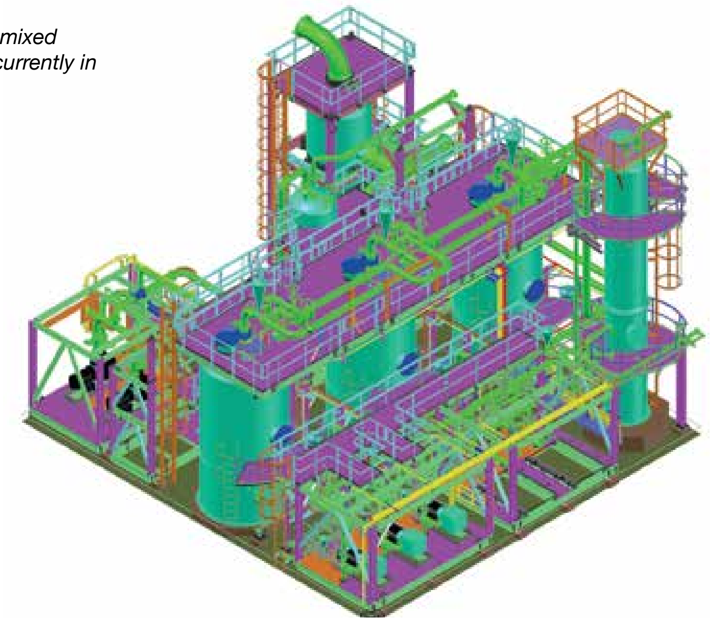
Traditionally, vapour recovery systems were only considered a requirement for petrol distribution terminals. Now, however, the number and types of applications where vapour recovery units are considered a requirement is expanding across the globe to include controlling emissions from truck loading, tank storage, and ship loading operations over a range of product. With these developments comes an ever-increasing demand for higher levels of both system complexity and overall capacity as vapour recovery units are tied into existing terminal infrastructures.

In addition, legislators worldwide are demanding more emission control capability from the operators and system designers. Today and into the future emission demands are and will continue to be regularly tightened, with requirements in some parts of the world as low as 35mg(HC)/Nm^3. Naturally, system providers must adapt designs to meet these new regulations and demands.

Environmental pollution legislation is – almost without exception – the driver behind the decision to install a vapour recovery unit to meet the permitting requirements and that of providing cleaner local environmental emission controls and safer working environments. Beyond the environmental and safety advantages, the potential economic benefit from the recovery of a highly valuable product cannot be ignored as an additional positive outcome in any operating analysis regarding the installation of a vapour recovery unit. For example, in gasoline truck loading applications where the operator is able to reclaim duties and taxes paid on the load product, full return on investment when including the operational costs is possible within a year of installation. In cases where duties and taxes are not reclaimable, the return on investment might extend to between two and three years.

For larger marine vapour recovery systems a full return on the capital investment is often not possible, although it is common for the operating costs of the systems to be covered through the value of the recovered product.

3D model of mixed xylene VRU currently in construction



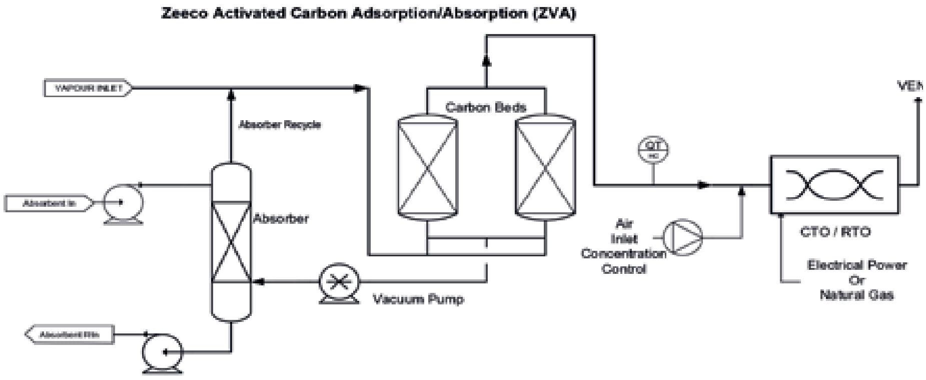
Emission requirements

Emission standards vary somewhat throughout the world, although many are typically based on either European or US EPA standards. Both the US and European market areas have well-developed vapour recovery installed bases. In the EU countries, the minimum requirements are that VOC emissions do not exceed 35g(HC)/Nm^3 measured in the vent of the vapour recovery unit[1] for petrol. Member countries have varying emission requirements, but generally require the VOCs do not exceed either 10g(HC)/Nm^3 or 35g(HC)/Nm^3. A number of countries outside of the EU use the requirement of not to exceed 150mg(HC)/Nm^3., while in the US the standard is usually not to exceed 35g(HC)/1000ltr or 10g(HC)/1000ltr – with the notable difference from European standards that the emissions from the vapour recovery unit are measured relative to the product volumes being loaded.

Currently Germany and the Netherlands require the lowest emissions applicable to VOCs at 50mg(HC)/Nm^3, while Oman has enacted the most extreme emission requirement overall at 35mg(HC)/Nm^3 .

Activated carbon vapour recovery units are readily able to attain emission standards down to 150mg(HC)/Nm^3 in a single-stage system. The lower requirements of Germany, The Netherlands, and Oman, however, require a two-stage system, where the first stage is an activated carbon vapour recovery unit, followed by a second-stage oxidiser of either Catalytic Thermal Oxidiser (CTO) or Regenerative Thermal Oxidiser (RTO design. The two-stage approach can meet the obligation that VOC emissions are recovered, often a requirement of the emissions control permit, whilst attaining the most stringent emissions limit through the oxidation of the final few grams vented from the vapour recovery unit.

In balancing the overall emissions from a vapour recovery unit and the emissions arising from the generation of the power to run the vapour recovery unit, the optimum vapour recovery unit



Two stage vapour recovery system

emission is approximately 1g(HC)/Nm^3, below which, more fuel would be used to run the vapour recovery unit than VOCs recovered from operating the system. This figure is of course very subjective dependent on factors including the product loaded and the utilisation of the vapour recovery system, amongst others.

Whereas in the '70s and '80s the vast majority of the vapour recovery units installed were at petrol distribution terminals, today there is are significant interest and intent from ship/marine loading applications and tank out-breathing applications. This growing market is a result of emissions control legislation, with a particular focus within the areas of the EU and the Middle East. Loading rates in these applications are significantly higher than truck loading terminals, varying from 800m^3/hr to 2000m^3/hr at the low end to 10,000m^3/hr to over 40,000m^3/hr at the high end. The most commonly arising volumes fall between 5000m^3/hr to 6000m^3/hr.

The range of products in ship loading applications is much wider, with crude oil, naphtha, condensates, and aromatics including gasoline and xylenes forming a sizeable proportion of the applications. Crude oil comes with a number of challenges; the vapour composition varies on a case by case application and in some cases on a load by load basis, dependent on the oil's source and resulting assay. In addition, any trace of hydrogen sulphide (H_2S) adds an additional complexity to the vapour recovery system since it is normally removed from the vapour stream prior to the vapour recovery unit. At the point of initial design the H_2S concentration in the vapour phase is often not known, although it might be well documented in the assay for the crude oil itself. Whereas it is always preferable to have actual vapour composition data from the loading operation, approximations can be drawn from the understanding that each 1ppm(m) H_2S in the crude oil can lead to H_2S concentrations in the vapour phase of 100ppm(v), or higher.

Loading dynamics, from the vapour recovery unit designer's perspective, also vary significantly for a ship loading application when compared with a truck loading system. A good understanding of these variances is necessary to avoid either over-designing or under-designing the vapour control systems.

Displaced vapours will typically be comprised of the VOCs in an inert atmosphere or, in some cases, normal air. The atmosphere in a ship's hold can be very stratified with layers directly above the product being loaded having relatively high VOC concentrations, and layers further away from the product surface showing reduced concentrations as one travels up through the hold. During loading operations, this results in a relatively lean VOC concentration flow from a vessel which gradually increases as the liquid level rises. The maximum concentrations commonly occur as the product flows are reduced during the topping off of the vessel.

During product loading there is a natural degree of atmospheric disturbance in the vessel. A secondary effect of the loading operation and this disturbance is vapour growth. Simply put, the resulting vapour flow from the loading the vessel exceeds the actual product loading rate. This difference between the vapour flow rate and the product fill rate is referred to as the growth rate.

Tank out-breathing is another application employing vapour recovery units in increasing numbers. Tank venting can result in large emission flow rates from the tanks and resultant product losses. Often tanks are fitted with floating roofs, but when they are not, the inclusion of a vapour recovery unit is often the preferred means of controlling emissions. Vapour flow dynamics are again relatively complex and different from either truck or ship loading operations. In determining the design basis for the vapour recovery unit, consider:

- the maximum fill rate of the tanks,
- thermal growth rates, or the vapours displaced through the warming of the vapour spaces as a result of solar gain, and
- draw-out vapour growth, resulting from the growth in the vapour volume as a result of the re-saturation of the tank ullage following the withdrawal of product from the tank.

The vapour flow should be considered against a design basis hydrocarbon concentration, which should be assumed to be saturated for tank breathing designs.

As emissions control legislation tightens and the range of vapour recovery applications widen, understanding the extensive requirements of a well-designed, efficient, and effective vapour recovery system requires an experienced engineering team.

For more information:

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Reference:

1 European Parliament and Council Directive 94/63/EC of 20 December 1994