KEEPING CONTROL OF VAPOUR

Simon Shipley, Zeeco Europe Limited, UK, discusses the decision between two common vapour control technologies, recovery or combustion, in tank and terminal applications.

Around the globe, vapour control systems are a common sight at storage terminals handling the transfer of hydrocarbon products. Though traditionally vapour control systems were only required for gasoline distribution terminals, today the number and types of applications where vapour control systems are considered a requirement is expanding to include controlling hydrocarbon emissions from truck loading, tank storage, and ship loading operations.

Vapour handling requirements for capacities from 10 000 to 40 000 m^3/hr are not uncommon in crude oil applications. In controlling hydrocarbon emissions for crude oil applications, operators have essentially two options: either recover the hydrocarbons or destroy (combust) them.

Vapour recovery

Although there are a number of alternative vapour recovery technologies available, activated carbon adsorption vapour recovery units (VRUs) remain the preferred technology for most applications. These systems provide operators with maximum flexibility because they are capable of handling an extensive range of products and feature a wide turndown ratio capability, from 0 – 100% of the design flow and inlet concentrations.

Activated carbon VRUs are readily able to attain emission standards to 150 mg(HC)/Nm^3 in a single stage system. The lower requirements of Germany, the Netherlands, and Oman, however, require two stage systems; where the first stage is an activated carbon VRU, followed by a second stage oxidiser of either a catalytic thermal oxidiser (CTO) or regenerative thermal oxidiser (RTO) design. The two stage approach can meet the obligation that VOC emissions be recovered, often a requirement of the emissions control permit, whilst meeting the most stringent overall emissions limit through the second stage oxidation of the final few grams, that would otherwise be vented from the VRU.

Such systems are used in a wide variety of applications, including truck, rail, ship loading, and tank venting. The range of vapour flows are wide, from the smallest truck loading applications at 100 m^3/hr to the two largest vapour recovery systems in the world, using activated carbon adsorption with vapour flows of up to 40 000 m^3/hr.

Figure 1. A typical Zeeco vapour recovery unit.

Destruction or combustion?

Vapour destruction systems typically employ vapour combustion units (VCUs), which are a mix between a simple thermal oxidiser and a temperature controlled enclosed flare. Key features of VCUs include:

- Soft refractory lining to protect the combustion chamber from the heat and to handle quick swings in temperature.
- Anti-flashback burner tip and flashback protection in the upstream line via a detonation arrestor or liquid seal drum.
- Full temperature control of the combustion chamber, utilising assist gas, air assist blower, and automated external air dampers.

Destruction efficiencies for VCUs vary depending upon operating temperature, but typically range from 98 to 99.9%. For applications in which higher destruction efficiencies are required, a thermal oxidiser may be the best solution. These differ from a VCU in certain design features, and are able to attain destruction efficiencies up to 99.9999%. VCUs are able to control emissions that are not easily handled in a VRU, including methane emissions and vapours with some H_2S content. VCUs or thermal oxidisers can offer a viable solution in cases where a VRU would present particular operating problems.

There are a number of options available under each of the two primary control paths, vapour recovery or vapour combustion, when selecting a solution to manage a particular application. To select the most appropriate technology, a range of factors should be considered, including the following:

- Legislative requirements.
- Emission requirements.
- Available utilities, including electric power and assist gas.
- Equipment capital cost.
- Return on investment (ROI).

Legislative requirements

Environmental pollution legislation is – almost without exception – the driver behind most operators' decisions to install a VCU. Operators choose VCUs to meet permitting requirements and to provide cleaner local environmental emission controls and a safer working environment. Legislators often dictate whether vapour recovery technologies must be adopted or whether destruction/combustion technologies may also be considered.

Emission requirements

Legislators worldwide are demanding tighter emission control capabilities. Emission requirements have been, and will continue to be, regularly tightened, with levels in some parts of the world as low as 35 mg(HC)/Nm^3. System providers must adapt designs and continue to innovate to ensure operators can meet new regulations and demands.

While emission standards vary somewhat throughout the world, many are based on either European Union (EU) or US Environmental Protection Agency (EPA) standards. Both the US and European market areas have a well developed installed base of vapour recovery technologies. In EU countries, volatile organic compound (VOC) emissions may not exceed 35 g(HC)/Nm^3, measured in the vent of the VRU for gasoline. EU member countries have varying emission requirements, but generally require that the VOCs do not exceed either 10 or 35 g(HC)/Nm^3. A number of countries outside the EU do not exceed 150 mg(HC)/Nm^3, while in the US, the standard is usually not to exceed 35 g(HC)/1000 l or 10 g(HC)/1000 l – with the notable difference from European standards that emissions from the VRU are measured relative to the product volumes being loaded instead of in the vent line.

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

Other emissions limits may also be applicable. Permitting requirements may restrict nitrous oxide (NO_X) and sulfur oxide (SO_X) emissions as well. Fuel-bound NO_X in the inlet vapour stream is not uncommon in ship loading applications. Meeting NO_X emissions requirements is a consideration in the selection of a vapour control technology given that NO_X is naturally produced in the combustion process. NO_X developed during the combustion process is referred to as thermal NO_X, and any thermal NO_X produced would be added to fuel-bound NO_X in the inlet vapour stream. SO_X emissions may become a concern in applications where the vapour stream contains sulfur-bound compounds, i.e., H_2S and or mercaptans, commonly found in crude oil vapours.

Available utilities

Vapour recovery and vapour destruction technologies are dependent on available utilities. Both types of systems require electric power, but vapour destruction units require fuel gas as well. Electric power can become a challenge when existing feeders are not adequate for the additional load required by the vapour control system. For VRUs, the main power users are the vacuum pumps used in the regeneration process. The power required can range from the relatively low requirements of small systems, ranging from 20 to 50 kW, to the very large requirements of ship loading systems, which can reach 1 MW plus. Higher power requirements are commonly associated with VRUs, for example, currently the largest VRU in the world has a connected power requirement of 3.5 MW.

VCUs require fuel or support gas. They are used for running the pilots and acting as an assist gas during pre-heating of the stack or during the enrichment of low heating value vapours. In some terminal applications where a gas supply is not available at the terminal, this requirement can pose a challenge. In the simplest of cases, such as a small gasoline truck loading operation where the emission requirements are at the higher end of the emissions spectrum (35 g/Nm^3), a bottled propane supply may be adequate to fuel the pilots. For larger applications, in particular where emission standards are tighter, relatively large gas supplies may be required, for example, a recent ship loading application required fuel gas rates of up to 1000 Nm^3/hr. The lack of a gas supply may therefore be a factor in the selection of a vapour control technology.

Equipment capital cost

One important factor most operators consider is the capital cost of the equipment. For identical applications, a VRU typically has a capital equipment cost of 3 – 5 times that of a VCU. In moving to larger systems for marine applications, the difference in capital cost grows.

ROI

Beyond the environmental advantages VRUs offer, 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 VRU.

Vapour combustion offers no recovery, whilst adding to the overall environmental emissions footprint through the addition of CO_2 and NO_X emissions. Vapour recovery systems are not entirely emissions free since they add to the CO_2 footprint through their electric power requirements. However, in general, recovery of hydrocarbons is seen as a more positive environmental strategy compared to combustion. Recovery rates vary significantly depending on the product or mixture of products being handled. However, for gasoline truck loading applications, recovery rates of between 1 – 2 l/1000 l loaded are not uncommon. For gasoline truck loading applications where the operator is able to reclaim duties and taxes paid on the loaded product, full ROI – including operating costs – is possible within a year of installation. In cases where duties and taxes are not reclaimable, the ROI might extend up to three years.

For larger marine vapour recovery systems, a full return on the capital investment is rarely possible because of two main factors: frequency and flow rate. The frequency of loading at these types of facilities is often a few times each month, which results in the system only recovering product during these times (vs a truck loading terminal, which sometimes runs 24/7). The vapour flow rates for marine units are very large, resulting in the need for very large and costly capital equipment investment when compared to VRUs sized for truck terminals. It is common for the operating costs of a marine VRU to be covered through the value of the recovered product, even though the capital equipment cost is rarely recovered.

Conclusion

As legislative emission requirements tighten, truck, rail, ship loading, and tank operators will continue to seek more efficient ways to manage their vapour emissions. Making the decision to employ a VRU, a VCU, or a combination of technologies is typically based on a variety of factors, including regulations, available utilities, equipment capital cost, and ROI. T&T