

## **All eyes on Norway**

**As the world's leading generator of cargo vapour emissions from offshore tanker loading operations and home to many of the leading tanker companies, it is not surprising that Norway is the originator of most of the new technologies for controlling escapes of volatile organic compounds**

The Norwegian authorities have set an initial requirement that 40 per cent of offshore oil loading and storage operations must be free of volatile organic compound (VOC) emissions by December 31, 2003. The long-term goal is that 95 per cent of offshore oil will be loaded and stored without VOC emissions by December 31, 2006.

Industry gave full backing to the initiative this past June when the 23 energy companies which are licensees in the Norwegian oil fields signed a cooperative agreement to ensure that the targets set by the Norwegian Pollution Control Authority are met.

To meet the end-2003 deadline vapour recovery plants will be installed on eight shuttle tankers. In addition, Statoil has commissioned new plants for recovering VOC emissions on its Norne and Asgard A floating oil storage and production (FPSO) vessels in the North Sea.

### **Kvaerner technology**

Five of the eight shuttle tankers are being fitted with vapour recovery systems built to a design initially developed by Kvaerner Process Systems (KPS), the ships being Borgia, Knock Ann, Juanita, Navion Anglia and Navion Oceania.

The KPS technology was first acquired by Hitec Marine AS and, in September 2002, by Advanced Production and Loading AS (APL) when it took over Hitec. Based in Arendal, Norway, APL was established in 1993 to develop and commercialise the submerged turret loading (STL) and submerged turret production (STP) techniques for offshore transfers of oil. APL is part of the Statoil group.

The APL vapour recovery technology is based on the direct absorption of the VOCs in crude oil through a packed column. Developed over the past decade, the approach was first tested and proven when a plant was installed on the shuttle tanker Anna Knutsen in 1998.

During loading of the shuttle tanker, a side stream of the loading oil, typically 5 to 10 per cent of the total volume being loaded, is routed to the VOC recovery unit. The side stream is pressurised to 7-10 bars before the oil enters the absorption column for counter-current absorption with the VOC gases from the storage tanks.

Prior to entering the column, the emitted gas from the tanks is compressed. A bypass line is installed for safety purposes in the event that the gas flow exceeds the compressor capacity. In the absorption column VOC is absorbed in the crude oil under pressure. The remaining gas is sent to the riser, while the oil is returned to the crude oil loading line.

### **KPS back with CSA**

Ironically, although Kvaerner Process Systems has sold its absorption technology, it is still involved with vapour recovery engineering. The link comes about as a result of the purchase of Cool Sorption AS (CSA) of Denmark by Aker of Norway. When Kvaerner and Aker merged their activities earlier this year, CSA was made a full subsidiary of Kvaerner Process Systems.

CSA has delivered 140 shore-based vapour recovery plants over the past 20 years, most of which are for the control of gasoline vapours. In 1996 the company delivered a vapour recovery unit for the Sture crude oil loading terminal on Norway's west

coast. Based on a two-stage cold liquid absorption process developed by CSA, this was the world's first such crude oil unit and remains the largest. CSA is now taking its expertise to the ship, having just signed a contract with Navion for the delivery of a vapour recovery unit for the Heidrun field. This will be installed on the tanker Navion Europa and will be based on the carbon bed absorption system. It will be the first application of this technology on crude oil vapours. "We believe our pressure swing, carbon bed absorption system, combined with an upstream absorber, provides the most competitive solution," explains Tomm Lund, vice president business development at CSA. "It provides recovery rates in excess of 90 per cent, requires only 50 per cent of the energy needed to operate pressurised absorption, has low maintenance costs and a high degree of reliability, does not need a deckhouse and is easy to operate."

### **Knutsen minimises vapours**

Knutsen OAS, a leading operator of shuttle tankers on the Norwegian Shelf, has developed another new method for reducing VOC emissions from tankers during loading operations which is claimed to be a much simpler and less costly alternative than the competing systems.

"We investigated North Sea tanker loading procedures extensively and concluded that the way this operation is currently carried out is conducive to generating the maximum possible volume of VOCs," points out Per Lothe, project manager at Knutsen.

"We decided that the optimum approach was to reduce the generation of VOC vapours in the first place rather than attempt to control and remove all the VOCs that current loading operations give rise to. We have accomplished this with a system that requires no power. Thus, there are no operating costs and no production of harmful combustion emissions such as carbon dioxide and nitrogen oxides."

### **All in the drop**

Knutsen OAS has achieved this by designing a large-diameter drop pipe to control the introduction of the oil being loaded from the platform into the cargo tanks. Use of such an arrangement helps minimise pressure buildup, and hence VOC generation, in the cargo.

The shipowner installed the Knutsen Volatile Organic Compound (KVOC) system on the Ragnhild Knutsen in April 2002, since which time all loading operations have been carried out using the new technology. The specially designed, single, central drop pipe on the tanker is 2.5 metres in diameter. From the bottom of the pipe the oil is distributed along the bottom of the ship and introduced into each cargo tank.

"When high vapour pressure crude oils are loaded, KVOC enables a reduction in VOC emissions of 65-80 per cent compared to the volume generated during a normal loading operation," continues Lothe. "When low vapour pressure oils are loaded, the reduction is in the range 85-95 per cent. Also, if hydrogen sulphides are present in the oil, reductions of 80-90 per cent in emissions of this harmful product are possible using KVOC."

KVOC installations are said to represent only 15 per cent of the investment cost of some of the high-tech alternative shipboard systems for treating VOC emissions generated during tanker loading operations. Such recovered vapours are either reintroduced back into the crude oil cargo or directed to the engine room for use as fuel for the ship propulsion system.

### **Preparing for the market**

"We are now compiling all the test data from our Ragnhild Knutsen pilot project for submission to the Norwegian authorities who have set rigorous standards governing the future release of VOC emissions," comments Lothe. "We are confident that KVOC will meet the necessary standards and an official announcement on the

performance of our system in complying with the requirements is expected either later in 2002 or early next year.

"The use of KVOOC is as equally applicable when tankers are loading at shore terminals as at offshore facilities. The system can be installed on any tanker over a period of 8 to 12 weeks and it is only necessary for the ship to be offhire for less than one week if a system is to be retrofitted onboard an existing tanker."

As part of the current data review process, Knutsen OAS is also discussing how best to market their technology to the global tanker industry. "Whatever way we eventually choose to promote the application of KVOOC on an industry-wide basis, we are confident that we have a good product which will be very much in demand amongst a range of tanker owners," concludes Lothe.

### **VOCON and laden voyages**

It has always been known that considerable volumes of cargo vapours are also generated during the course of a laden tanker voyage, especially if the cargo is a high vapour pressure crude oil and ambient temperatures are high. However, it is only recently, with the close and systematic monitoring of the behaviour of a number of crude oil cargoes, that the industry has been able to gauge the volumes of cargo vapour lost with any degree of accuracy.

Research work carried out during the 1996-1999 CRUCOGSA programme - the Physical Behaviour of Crude Oil Influencing its Carriage by Sea - showed that under certain conditions a VLCC could lose up to 800 tonnes of cargo per voyage through VOC emissions out of the ship's pressure/vacuum valves or mast riser. This not only poses an environmental hazard but also represents lost revenue. An extrapolation of this VLCC cargo vapour loss across the tanker fleet would equate to lost revenues of approximately \$700 million worldwide each year. It is estimated that annual tanker emission losses work out at about 6.5 million tonnes (mt) of crude oil, comprising 3.3 mt of loading losses and 3.2 mt of in-transit losses.

A CRUCOGSA spinoff project called Vapour Emission Control (VOCON) is focusing on providing tanker masters with a better idea of when to shut tank vents to prevent the unnecessary escape of vapours. The vents are opened at the start of a laden voyage when the buildup of vapour pressure in the tanks is greatest but these vents tend to be left open longer than they need to be.

The VOCON procedure relies on an understanding of the different physical properties of the two components of the gas mix in a cargo tank - unsaturated gas from the inert gas supply and saturated hydrocarbon vapours from the crude oil cargo. Cargo officers are advised to shut the vent valve when the rate of pressure drop during the gas release becomes constant, a step which will lead to a considerable reduction in lost cargo vapours.

### **Venturie stops emissions**

The Norwegian engineering company Venturie AS has been working on an oil-gas absorption methodology over the past two years that leads to a 100 per cent reduction of methane and non-methane VOC emissions during laden tanker voyages. During the pilot phase Venturie has worked with the tanker operator Frontline and a prototype Venturie Cargo System (VCS) was installed on the Suezmax tanker Front Granite.

This experimental work has led to further refinement of the original technology and the design of a so-called Twin System VCS which is now available on the market. The approach uses the pressure differential between the top and bottom of the cargo tank to achieve the desired effect. More specifically, the treated crude oil stream, which contains the inert gas/VOC mix, is directed to the bottom of the cargo tank, where the pressure is greatest, to assist with the gas absorption process. The choice of pump, motor, start function and controlling units is critical to optimising the potential of the system and its successful operation.

"Our system utilises primary and secondary absorption units to mix the crude oil and inert gas/VOC streams and to process them in such a way that the absorption of the VOC gas back into the crude oil is total," states Jorn Heimstad of Venturie AS. "The simple deck-mounted absorption tower, incorporating both units, stands just over 2 metres high and the cost of the full installation is \$375,000 per ship. The VCS system also absorbs a considerable amount of any hydrogen sulphides present back into the oil stream."

### **Tank pressure and loading**

Although the Venturie AS work has been primarily focused on the control of vapour emissions during laden tanker voyages, the company's monitoring of cargo operations during the two-year trial period has provided information that should help minimise the volumes of VOCs generated during tanker loading operations.

The stability of the VOC components in the crude oil is directly related to a number of parameters, most notably pressure, temperature and inert atmosphere. Just as the VOCON study concluded, Venturie also found that pressure is the most critical factor and that, by exercising a degree of control over this parameter, some reductions in VOC losses during loading can be achieved.

At the start of loading the atmosphere in the tank above the liquid level is comprised of about 20 per cent VOC vapours and 80 per cent inert gas. The inert gas share decreases to about 20 per cent as the cargo fill level is reached.

### **Setting the valves**

Venturie discovered that by increasing the pressure in the cargo tank during the loading process, significant reductions in VOC emissions could be achieved. With one particular crude oil loaded at a North Sea production platform, for example, a modest increase in the tank pressure to 1,000 mm water column, using the mast riser as the central control point, achieved a 45 per cent reduction in VOC emissions.

If instead the ship's automatic p/v valves were used as the control point, with the set-to-open pressure at 1,450 mm WC, then VOC emissions could be reduced by 60 per cent.

"Another option," says Heimstad, "is to have an automatic p/v valve in the mast riser set to open at 1,000 mm WC and to load the tanks at a reduced rate for the first 30 minutes or so. We found that with this combination reductions in VOC emissions of some 50 per cent were possible with the North Sea oil in question.

"If this lesson was applied at a typical VLCC loading terminal, tank pressure control could result in an additional 300 tonnes remaining onboard, rather than being vented to the atmosphere. Assuming an oil price of \$25 per barrel, this represents a saving of \$125,000."