Emission control at marine terminals

Results of recent CONCAWE studies

BACKGROUND

The European 'Stage 1' Directive 94/63/EC on the control of volatile organic compound (VOC) emissions mandates the installation of vapour emission controls for automotive gasoline storage and loading of road and rail tankers and inland waterway barges. Ship loading emission controls were not included as the EU Commission was awaiting the revision of the International Maritime Organization (IMO) MARPOL Convention to include a new Annex VI on the prevention of air pollution from ships.

Although IMO approved the new Annex in September 1997, it will not come into force until 12 months after ratification by 15 Port States with a combined merchant fleet of not less than 50 per cent of the worldwide gross tonnage.

As there is likely to be a lengthy period before ratification of the new Annex and, due to the non-prescriptive nature of the IMO regulation on VOCs, it is likely that the EU will proceed to develop new legislation on emission controls for ship loading of volatile cargoes. A study sponsored by the Commission is already assessing the economic and technical feasibility of possible measures to reduce emissions of VOCs during the loading and unloading of sea-going ships in Community ports.

CONCAWE Report 92/52 reviewed the costs and cost-effectiveness of installing vapour emission controls for the loading of gasoline onto ships and barges. Due to the small number of project studies at that time, CONCAWE has subsequently undertaken an update of this study. Initial findings were reported in the CONCAWE *Review* in October 1998.

Since then two further studies have been undertaken: gasoline loading in sea-going ships and emissions from ship ballasting at gasoline off-loading terminals. Both studies are discussed on the following pages of this article.

Safety concerns highlighted in CONCAWE Report 92/52 have been addressed in the new MARPOL Annex VI which references IMO publication MSC circular 585 'Standards for vapour emission control systems'.

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Gasoline loading

Cost-effectiveness of emission controls for ship loading

INVESTMENT COSTS

The initial CONCAWE study published in 1998[1] used the cost data from 20 vapour emission control systems, which had either been installed for gasoline loading in the USA or for benzene loading in Europe, or from project studies. It established that:

- The costs of installing a vapour emissions control system for loading gasoline onto sea-going vessels vary significantly at sites with similar loading rates because of site-specific issues—reported costs for sites with loading rates typical of a large refinery ranged from 4 to 20 million Euros.
- Vapour collection piping will have to be installed on board about 600 sea-going vessels of less than 40 000 dead weight tonnes (DWT) to permit trading at terminals fitted with shore-side vapour emission control systems—the total retrofit costs for these vessels are estimated at 151 million Euros.

The second phase of the CONCAWE study obtained data on 64 terminals in the EU-15 identified as loading gasoline into sea-going ships. These terminals loaded a total of 47.2 million tonnes of gasoline in 1998, representing 32 per cent of the EU-15 gasoline production. The terminals include both refineries and depots where gasoline is imported, stored and onward distributed by ship.

The size of these terminals, the estimated investment cost for installing vapour emission controls and the cost effectiveness of the VOC emissions reduction are shown in Table 1.

Table 1

Gasoline loading terminals: size and cost profiles

Throughput gasoline (kt/a)	*Number of gasoline terminals (cumulative)*	*% of total gasoline loaded (cumulative)*	*Cumulative cost, million EUR (shoreside facilities only)*	*Cost-effectiveness kEUR/t abated* (shore and ship)*
>3000	1	10.2	8	3.3
>2000	6	37.9	38	3.7
>1000	13	56.5	75	5.0
>750	23	75.1	123	5.9
>500	33	87.7	168	7.0
>250	44	96.6	217	9.2
>100	52	99.3	251	14.5
>0	64	100.0	300	32.2

* The cost-effectiveness relates to the throughput range only, e.g. 32.2 kEUR/t relates to the range 0–100 kt/a. All other columns are cumulative.

The total cost of vapour collection and emissions control during ship loading of gasoline at the 64 terminals identified would be 451 million Euros, being the sum of the on-board ship costs of 151 million Euros and the shore-side costs of 300 million Euros.

[1] *CONCAWE Review October 1998*

UNCONTROLLED EMISSIONS

The uncontrolled emissions during gasoline loading can be calculated using an emission factor published by the US EPA of 0.034 per cent by volume loaded and a density of 0.6 kg/l for condensed gasoline vapour. Thus for a total of 47.2 million tonnes per year of gasoline loaded, the annual uncontrolled emissions are equal to 13 190 tonnes. This can be compared to the total annual man-made VOC emissions in the EU-15 of 9.7 million tonnes in 2000[2].

The emissions from ship loading with gasoline are approximately 0.14 per cent of the total annual man-made VOC emissions in the EU-15 in 2000.

COST-EFFECTIVENESS

The cost-effectiveness of both on-board and shore-side investments can be calculated from the achievable emission reduction, the annualized cost of the capital investment and the operating and maintenance costs. Using an annual capital charge of 15 per cent, and operating and maintenance costs for on-shore systems of 5 per cent and 2 per cent of capital respectively:

the overall cost-effectiveness of vapour emission controls on ship loading of gasoline would range from 3300 to more than 32 000 EUR/t, with effectiveness reducing as terminal throughput decreases.

These costs need to be seen in the perspective of other available control measures. Using the example of France, Figure 1 was developed using the IIASA-VOC[3] cost curve from their RAINS[4] model. Here, some eighty control measures are ranked from lowest to highest cost per tonne of VOC abated. Each individual measure is shown as an open blue bar. The width of each bar corresponds to the emission reduction achieved by that measure. Although France is shown here, the IIASA cost curves for other EU countries are similar.

To provide for ready comparison, the costs of marine vapour recovery for gasoline loading are shown in Figure 1 in three ranges for terminals with a throughput greater than 1 Mt/a, between 0.25 and 1 Mt/a and less than 0.25 Mt/a respectively.

The emission ceiling target proposed for France in the National Emission Ceilings Directive (NEC) is shown along with France's commitment under the UN-ECE Gothenburg Protocol signed in 1999 (The original EU base case or 'Reference' scenario is also indicated in the graph).

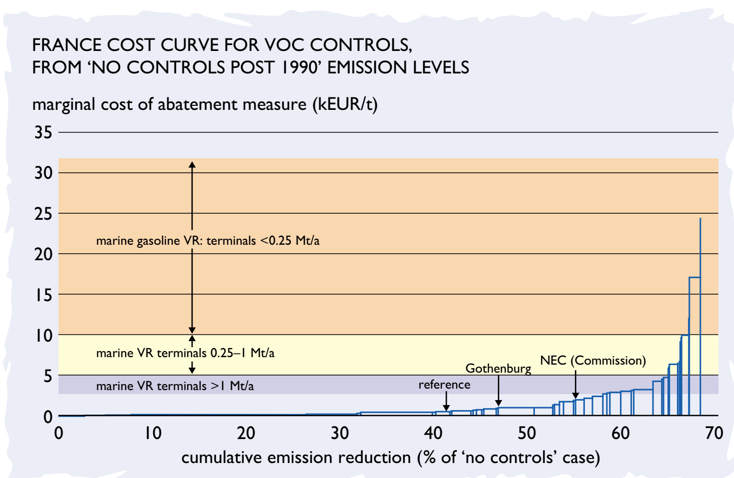

Figure 1
France cost curve for VOC controls from 'No Controls Post 1990' emission levels (Source: IIASA)

It is clear from Figure 1 that, at the Gothenburg Protocol target level, marine vapour recovery would not be justified, at least on cost-effectiveness grounds. At the original NEC target level proposed by the European Commission, justification would be marginal even for the largest terminals. Control at smaller terminals is clearly much less cost-effective than many other VOC control measures still to be implemented. CONCAWE's analysis also included IIASA data for Italy, Spain and the UK. Conclusions were similar to those for France given above.

[2] *Senco 1999; Commission's Second Auto/Oil Programme* [3] *International Institute for Applied Systems Analysis*
[4] *Regional Air Pollution Information and Simulation model*

Ballasting

Emission controls for loading ballast water at gasoline off-loading terminals

As mentioned on page 5, the Commission is sponsoring a study that aims to assess measures to reduce emissions both during the loading and the unloading of sea-going ships. The emissions that arise from shore-side gasoline tankage during a ship unloading operation are already covered in the Stage 1 Directive.

Another source is from loading ballast water into the cargo tanks of ships after they have been off-loaded. When a sea-going tanker discharges gasoline at a product off-loading terminal it must take on ballast water to achieve a seaworthy condition for the subsequent voyage. The amount of ballast water taken on board for this purpose varies between 15 per cent and 30 per cent of the total vessel capacity.

Ballast water can be taken into:

a) segregated ballast tanks (SBTs)—these are tanks dedicated to carry ballast within the cargo spaces of the ship or the double hull spaces (double bottom and wing tanks); or
b) cargo tanks which have previously held cargo.

Tanks of type 'a' are used solely for carrying ballast, so there are no hydrocarbon emissions when these are being filled. When ballast water is put into a cargo tank of type 'b', however, it will displace any hydrocarbon vapours remaining from a previously held volatile cargo.

IMO regulations state that sea-going vessels of more than 30 000 DWT ordered after 1976 and all others greater than 600 DWT ordered after 1993 shall have dedicated tanks or hull spaces which can carry ballast water. Loading data from seven terminals indicate that less than 20 per cent of volatile products were loaded into non-SBT tankers in 1999. Additionally a study by a major EU refinery showed a gradual downward trend in the use of non-SBT tankers from 45 per cent in 1993 to 13 per cent in 1999.

In any event, emissions due to ballasting will be eliminated in time as older ships that ballast into cargo tanks are either removed from volatile cargo service or decommissioned and replaced with more modern tankers with dedicated ballast water tanks conforming with IMO regulations.

UNCONTROLLED EMISSIONS

For a total of 47.2 Mt/a of gasoline loaded into ships in the EU-15, the emissions due to ballasting can be calculated using the following assumptions:

a) The percentage of total gasoline carried in non-SBT tankers is 20 per cent.
b) The amount of ballast water loaded averages 25 per cent of ship capacity. Taking the worst

case (i.e. that ballast is always pumped into tanks that previously held gasoline and never into tanks that held non-volatile products such as automotive diesel fuel) this is equal to 3.2 million m^3/a of ballast water being loaded into cargo tanks that have previously held gasoline.

The US EPA quote a factor for crude oil ballasting of 0.111 kg of emissions per m^3 of ballast water when the ship had been previously fully loaded. However, there is no published emission factor for the ballasting of product carriers, although measurements undertaken by a major oil company gave a factor of 0.1 kg/m^3 ballast. Using this factor and data above:

The total annual emissions due to ballasting are estimated to be 320 tonnes, this is equivalent to 0.003 per cent of the total man-made VOC emissions in the EU-15 in 2000.

SHORE-SIDE INVESTMENT

The rate at which ballast water is pumped into cargo tanks depends on the size of the ship and can range from 500 to 1000 m^3/h. Distribution terminals are served by ships of varying sizes, and thus in the worse case would have to handle vapours emitted at 1000 m^3/h during ballasting operations, although this occurrence might be rare. For the purposes of this study it has been assumed that all ballasting emission control systems, irrespective of the volume of gasoline off-loaded per year, are designed for a ballasting rate of 750 m^3/h.

The average cost of installing an emission control system for a vapour flow rate of 750 m^3/h is about 3 million Euros.

For Marine operations there is currently no requirement to provide vapour recovery facilities at off-loading terminals, as there is no on-board release of hydrocarbon emissions during cargo discharge operations.

COST-EFFECTIVENESS

Using the same assumptions as for ship loading of gasoline, cost-effectiveness for vapour recovery during ballasting operations would range from 190 000 to 1 900 000 EUR/t of VOC recovered. Compared with the IIASA cost curve given in Figure 1, this indicates that such a requirement would be some five to fifty times more expensive per tonne of VOC controlled than the highest cost measure in the IIASA cost curve, and is therefore not justifiable on economic grounds.