**Discussion Paper for Potential Measures to Control Lightering**
**Prepared for the Ozone Transport Commission (OTC)**
**September 13, 2010**

**Name of potential measure**: Controlled Lightering Operations

**Description of lightering:**
In general, "lightering" refers to the bulk transfer of goods from one marine vessel to another. However, in the context of this paper, lightering refers specifically to the bulk transfer of crude oil or refined petroleum products from one marine vessel (the "ship to be lightered," or STBL) to another vessel (the "lightering service vessel").

Over the past few decades, strong economic incentives have led to the use of very large marine tankers (120,000-165,000 deadweight tons (DWT), with a capacity of around 1 million barrels) for the long haul of crude oil from the Persian Gulf and Africa to the United States and other distant destinations. Because these ships are too deep and too wide to approach or enter most U.S. ports safely, some or all of the crude oil is transferred to smaller vessels that deliver it to refineries (NRC, 1998[1]). Currently approximately 25 percent of all imported crude oil is lightered before delivery to U.S. ports. For the United States, offshore lightering (conducted outside the territorial waters, generally three miles from the coastline) accounts for about 80 percent of total lightering volume and inshore lightering (within territorial waters) accounts for about 20 percent of total lightering volume. Most of the U.S. offshore lightering takes place in the Gulf of Mexico. Roughly 15 percent of all U.S. inshore crude oil lightering activity occurs in Delaware Bay (NRC, 1998). Inshore lightering must be conducted in U.S. Coast Guard-approved "lightering zones," often called anchorages.

Small tankers (30,000 to 50,000 DWT, with a capacity of approximately 400,000 barrels) from the Caribbean, the Gulf of Mexico, Canada, Europe, or from within the U.S. transport refined petroleum products to East Coast ports. According to the United States Coast Guard, quantities of refined petroleum products are lightered in New York Harbor, Long Island Sound, Narragansett Bay, and Chesapeake Bay. Lightering of these refined products is performed either because the vessel's draft is too deep to enter the destination port directly or because the product is destined for two or more end points, and it is more economical to transfer the cargo to lightering service vessels for multiple port calls (NRC, 1998). The lightering service vessels may be tankers themselves or barges powered by tugboats.

Table 1. Lightering Emission Factors. *Units are tons of VOCs per million barrels lightered.*

| Product | Emission Factor |
|---|---|
| #2 Diesel | 0.20 |
| Crude | 19.80 |
| Naphtha | 25.90 |
| Gasoline | 70.70 |

EFs derived from AP-42.

In Delaware, the primary product lightered is crude oil. In other East Coast lightering areas, crude oil is not the dominant product being lightered. In New York Harbor, Long Island Sound, Narragansett Bay, and Chesapeake Bay, a variety of refined petroleum products are lightered in addition to small amounts of crude oil. These refined products include gasoline, jet fuel components, diesel fuel, and others. Emission factors from lightering vary with the volatility of the liquid being lightered. Table 1 shows the emission factors of the most commonly lightered products used to estimate emissions from East Coast lightering.

Through the lightering process, VOC vapors form in the service vessel's cargo tank and are compressed as the tank is filled with liquid. To avoid the dangerous buildup of compressed vapors inside the service vessel, a vapor outlet

[1] For more information on lightering, this book can be read online at http://www.nap.edu/catalog.php?record_id=6312.

is necessary. "Uncontrolled" lightering refers to lightering events in which VOCs are vented freely into the atmosphere.

In a "controlled" lightering operation, the transfer of liquid occurs in a closed system and VOC vapors that form within the service vessel are piped back into the STBL. The use of vapor balancing during lightering can greatly reduce the emission of VOC-laden vapors. However, there are times when operating conditions cause an interruption in vapor balancing during a controlled lightering operation. A significant pressure change (caused by a sudden temperature change, for example) may require the system to be vented in order to stabilize the pressure. When this occurs during a controlled lightering operation, VOC vapors escape into the atmosphere. The constant possibility of a sudden increase in pressure requiring venting in the middle of a controlled lightering operation implies that zero VOC emissions from lightering cannot be reasonably expected. However, the possibility that venting will be necessary during a controlled lightering operation is low enough that Delaware's regulation requires any new lightering service company to utilize vapor-balancing technology during lightering operations for at least 95 percent of its annual volumetric total.

**Previous programs, model programs or historical significance:**
Lightering regulations have already been adopted by the State of Delaware, which hosts the majority of lightering activity in the northeast U.S. in its Delaware Bay (SR1124 §46, May 11, 2007[2]). There is a significant amount of lightering in New York Harbor as well, and there are smaller lightering operations that take place in Long Island Sound, in the Narragansett Bay, and in the Chesapeake Bay. Accordingly, the adoption of Delaware's lightering requirements throughout the entire Ozone Transport Region (OTR) is under consideration.

Delaware's regulation requires:

1) Marine service companies that become licensed to lighter in Delaware after the regulation's effective date ("new lightering services") are limited to a maximum allowable uncontrolled crude oil lightering volume that is equal to 5 percent of the company's total volume of crude oil lightered. Basically, new lightering services must be fully equipped with vapor balancing systems and must use these systems whenever technically possible.
2) All existing services were required to meet a maximum allowable uncontrolled lightering volume equal to 80 percent of the baseline levels[3] beginning May 1, 2008, with further reductions equal to 61 percent of baseline levels beginning May 1, 2010, and to 43 percent by 2012. Lightering service companies existing prior to the regulation's effective date are not regulated as stringently as new lightering services because upgrading existing lightering service vessels to be capable of vapor-balanced lightering requires significant capital investment, making a 5 percent limit impractical for the legacy fleet in the short term.
3) By 2014 and every 5 years thereafter, the Delaware Department of Natural Resources and Environmental Control (DNREC) and owners of existing lightering operations will report on the feasibility of achieving a 5 percent maximum allowable uncontrolled lightering volume for all lightering services.

The requirements of the Delaware regulation apply to the owner or operator of a lightering service that carries out crude oil lightering operations in the waters of the State.

Other provisions in the regulation pertain to equipment maintenance, reporting of uncontrolled venting during lightering, compliance plans, emergency conditions when operators are exempt from the requirements, and – importantly – provisions that ban uncontrolled lightering operations on ozone action days as established by the DNREC.

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[2] Available at: http://regulations.delaware.gov/AdminCode/title7/1000/1100/Split1124/1124-45.shtml.

[3] The baseline lightering volume is the average annual volume lightered in calendar years 2004 and 2005.

Note that the Delaware regulations apply to the lightering of crude oil, only. This is because in Delaware the majority of lightering-related VOC emissions result from the lightering of crude oil. Outside of Delaware, most lightering is not of crude oil, but of finished petroleum products such as No. 2 fuel oil (heating oil), gasoline, and jet fuel. Lightering of gasoline and jet fuel results in significantly more VOC emissions than lightering of crude oil. If a version of Delaware's regulation is to be adopted throughout the OTC region, it may be appropriate to address those additional refined petroleum products with the potential to emit VOC-laden vapors that are lightered in the region in the OTC version.

**Major Issues:**
In Delaware, lightering operations are subject to Title V operating permit requirements as stationary sources even though STBLs move in and out of anchorages. Delaware defines a "stationary source" as "any fixed building, structure, facility, installation, equipment or any motor vehicle, waterborne craft, aircraft or diesel locomotive deposited, parked, moored, or otherwise remaining temporarily in place, which emits or may emit any air contaminant" (DE Administrative Code, Title 7, Section 1101[4]).

However, other states may have different definitions of a "stationary source," meaning in other states lightering may be regulated as a different source category. States in the OTR are currently investigating how lightering would be regulated within their respective Administrative Codes.

Other issues that need to be considered in the development of lightering regulations include:

- Enforcement cost; since the potential reductions vary considerably from state to state, the cost of enforcement and administration relative to the emission reduction may be prohibitive in some states.
- Cost to lightering service vessel owners; the cost to industry is outlined below.
- Coordination with other agencies that regulate maritime activities (port authorities, Coast Guard, etc.).
- Enforcement of lightering operations; it is unclear whether states' departments of the environment have the authority to board marine vessels in order to ensure compliance.
- The complexity that may arise from regulating lightering operations of multiple types of petroleum products with the potential to emit VOCs. Regulating multiple types of petroleum products could lead to more regulated entities, and could bring opposition from entities such as the fuel oil industry, whose products are less volatile and emit fewer VOCs than crude oil.

**Lightering volume estimates:**
This white paper relies on data on "inshore" lightering (lightering occurring inside the boundary of the U.S.' contiguous zone—within 12 miles of shore) from a variety of sources. Annual lightering activity in Delaware comes from the Delaware DNREC. The data presented here was collected in 2004 and 2005. For New York Harbor, records are maintained by the Coast Guard Vessel Traffic Service. The annual figures presented are extrapolated from data collected over a three-month period in 2009. Data for Long Island Sound is taken from the National Research Council report entitled Oil Spill Risks from Tank Vessel Lightering (NRC, 1998). Though the NRC reports that only crude oil is lightered in the Long Island Sound, discussions with the fuel transport industry suggest that currently only finished petroleum products are lightered there. Lightering data for the Chesapeake Bay is maintained by Coast Guard Sector Baltimore, was reported to NESCAUM for the months January to October, 2009 and was normalized to provide an estimate of total lightering in 2009.

Data concerning "off-shore" lightering (that is, lightering that occurs beyond 12 miles of the coastline) also comes from the 1998 NRC report, Oil Spill Risks from Tank Vessel Lightering. The locations where offshore lightering

[4] Available at http://regulations.delaware.gov/AdminCode/title7/1000/1100/1101.shtml.

is conducted off the East Coast are Montauk Point, New York; Cape Henlopen, Delaware; Cape Henry, Virginia; and Great Issacs, Bahamas (NRC, 1998).

**Lightering emissions estimates:**
AP-42 provides emissions factors associated with the lightering of crude oil, gasoline, #2 distillate, jet naphtha, and jet kerosene. However, emissions from lightering these products can vary based on the recipient vessel's size, its previous cargo (which affects the amount of residual vapors), and the ambient temperature. According to AP-42, the emission factors listed are estimates with a probable error of ±30 percent.

For some petroleum products, lightering emission factors are unavailable. For these liquids, we apply an emission range from liquids with a similar volatility. And when the product being lightered is not specified, we apply the emission factor for gasoline lightering, which has the highest lightering emission factor.

Uncertainty within our estimates comes from three stages in the analysis: 1) information on the chemical properties of the products lightered is not exact; 2) information on the lightering conditions during each operation (i.e. type of vessel and residual vapors in the vessel) is unavailable; and 3) the equation from AP-42 used to estimate emissions carries an error bar of +-30%.

The figures in Tables 1 and 2 represent our mid-range estimate for VOC emissions and potential reductions. Based on the uncertainty described above, the following are estimates of low-high ranges of VOC emissions for each region: Long Island Sound, 41-147 tons per year (tpy); New York Harbor, 374-1333 tpy; Chesapeake Bay, 5-16 tpy; and Narragansett Bay, 2-6 tpy.

**Emission reduction benefit estimates:**
As mentioned above, VOC emissions could theoretically be reduced by up to 99 percent with the use of vapor balancing systems. Practically however, lightering events that commence using vapor balancing may be forced to disconnect the system prematurely due to sudden pressure changes or other circumstances. Delaware is therefore aiming for 95 percent reductions in its future requirements (5 percent maximum allowable uncontrolled lightering; see Delaware's requirement 3 above.)

**"Inshore" Lightering (**million barrels per year)

Table 2: Potential VOC Emission Reductions with Adoption of the Delaware Lightering Requirements throughout the Entire OTR

| | | | | **Potential Reductions (tons)** | |
|---|---|---|---|---|---|
| **Area** | **Product** | **Volume (million BBLs)** | **VOC Emissions (tons)** | **57%** | **95%** |
| Long Island Sound | Finished Products | 1.4 | 99 | 56 | 94 |
| New York Harbor | Gasoline, Fuel Oil, Other | 48.3 | 889 | 506 | 844 |
| Delaware Bay | Crude | 98.8 | 1956 | 1115 | 1858 |
| Chesapeake Bay | Gasoline | 0.3 | 11 | 6 | 10 |
| Narragansett Bay | Gasoline, Kerosene | 0.2 | 4 | 2 | 4 |
| | | **TOTAL**[5] | 2959 | 570 | 1695 |

[5] Beginning May 1, 2012, Delaware's lightering regulation will reduce annual VOC emissions by 1,115 tons. This quantity is *excluded* from TOTAL potential reductions since these emissions reductions are anticipated to result from existing Delaware regulation.

**"Offshore" Lightering** (million barrels per year)

Table 3: Potential VOC Emission Reductions with Control of "Offshore" Lightering in the OTR

| | | | | Potential Reductions (tons) | |
|---|---|---|---|---|---|
| **Area** | **Product** | **Volume (million BBLs)** | **VOC Emissions (tons)** | **57%** | **95%** |
| Off-shore | Crude Oil | 15.5 | 306 | 174 | 291 |

Delaware has opted to place a steadily decreasing cap on uncontrolled lightering. In 2008 and 2009, this cap requires that approximately 20 percent of lightering is controlled, reducing emissions by approximately 391 tons per year. The stringency of the regulation ramps up in two stages so that 39 percent of lightering will be vapor-balanced beginning May, 2010 and 57 percent will be vapor-balanced beginning May, 2012, reducing emissions by 762 tons and 1,115 tons, respectively. If 95 percent reductions are achieved in Delaware, VOC emissions will be reduced by 1,858 tons per year from the baseline.

In the rest of the OTC region, if VOCs resulting from uncontrolled lightering were reduced by 57 percent, emissions would be reduced by 569 tons per year. If emission reductions reach the technical limit of 95 percent in the OTR, including the additional reductions from Delaware that are not yet written into regulation, a total of 1,691 tons could be reduced.

In addition, we note that "offshore" lightering takes place in U.S. (but not state) waters. Nearly 291 tons of VOC emissions per year could be reduced through federal measures but it is not clear to what extent these emissions affect air quality in northeast states or which agency has jurisdiction to regulate them.

**Control Cost Estimate:**
For any tanker transporting volatile chemicals, vapor recovery capability is a function of several factors relating to the vessel's capacity to handle the increased pressure from volatile compounds in its tanks during transfer: the vessels' vapor tightness, the pressure relief threshold of the ships' manifolds, and an inert gas generation system.

During any controlled or uncontrolled lightering operation, the head spaces in the cargo tanks of both the STBL and the lightering service vessel experience increased pressure. In an uncontrolled lightering operation, the gases are vented into the atmosphere to alleviate the pressure. Vapor balancing is utilized to control the release of these gases by closing the system to the atmosphere. In turn, this causes a significant increase in the pressure in each cargo tank. Thus, the feasibility of vapor-balancing during a lightering operation is contingent upon both vessels' cargo tanks withstanding the increased pressure.

Most new tankers are built with the capability to withstand the increased pressure that occurs during vapor-balanced lightering, [1] but older vessels need to be upgraded. The cost to upgrade a lightering service vessel that holds 25,000 barrels would be about $250,000-300,000. The cost to upgrade a vessel capable of holding 100,000 barrels or more would cost approximately $1 million.

Significantly, the Oil Pollution Act of 1990 (OPA 90) requires that all tankers operating in U.S. waters be double-hulled by 2015. Since many new tankers are built with vapor-balancing capability, the fleet upgrade required by

[1] Personal email from Bernie Kelly of Global Partners LP

OPA 90 will have the co-benefit of making some service vessels and STBLs capable of complying with lightering regulations. Other single-hulled vessels are being retrofitted with a double hull without the upgrades that would enable vapor balanced lightering, meaning that these vessels would require further investment to enable compliance with a lightering regulation. The capital cost relevant to the lightering regulation is the additional expense to build new lightering service vessels earlier than they would have otherwise been built (to meet the requirements of OPA 90) and the cost required to upgrade enough older service vessels and STBLs to achieve the required percentage of vapor-controlled lightering.

In Delaware, three lightering service vessels, owned by OSG America, L.P., are responsible for all of Delaware's lightering activity. To date, one of these service vessels is capable of vapor-balanced lightering operations, which enables OSG to comply with Delaware's regulation. As the maximum allowable uncontrolled lightering volume is reduced in 2010 and 2012, additional service vessels capable of vapor balancing will be brought online.

**National program possibilities:**
Given that the vast majority of lightering in the eastern U.S. takes place in the Gulf of Mexico, Delaware Bay, and New York State waters, it seems that a state/regional approach to the control of these emissions is the most appropriate means of addressing the problem. However, a significant fraction of lightering occurs in "offshore" waters that are not part of state jurisdiction.

**Other Comments:**
Two key stakeholders on these issues could be the U.S. Coast Guard, Sector New York (01-37040), 212 Coast Guard Drive, Staten Island, NY 10305, and U.S. Coast Guard, Sector Long Island Sound (01-37030), 120 Woodward Avenue, New Haven, CT 06512-3698 (ph. 203-468-4401).

Lightering in New York is conducted by six companies, four of which are in-state companies: Bouchard Transportation Company, Reinhauer, Moran, K-Sea Transportation, and two of which are out-of-state companies: Vane Brothers and Seaboats. In the Chesapeake Bay, nearly all of the lightering is done by Vane Brothers.

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