

**Testing Protocol for the Direct Measurement of  
Uncollected Volatile Organic Compound (VOC) Loading Losses  
During Marine Vessel Loading**

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## 1.0 Introduction

This testing protocol applies to the determination of Volatile Organic Compounds (VOCs) fugitive emission rates during the controlled loading of inerted tanker ships or ocean-going barges with organic liquids. The principle of the procedure is as follows. Components on board a ship that may emit VOCs in the course of a loading activity are identified. These components are screened for leaks of VOCs using EPA Reference Method 21. When possible, components are also screened using a remote gas imaging device. For components determined from screening to have leaks, a component-specific emission rate is determined using a portable device capable of measuring total hydrocarbon mass emission rate. Screening values and measured emission rates are calculated to estimate uncollected VOC emissions for the entire loading event.

When referenced in a New Source Review (NSR) permit, this protocol specifies necessary procedures for satisfying applicable compliance demonstration, recordkeeping and reporting requirements of the permit.

The remainder of this protocol is organized as follows. Section 2 of this protocol details the loading process, summarizes the types of components on a tanker ship that may emit VOCs, and identifies applicable VOC control requirements for tanker ship loading events. Section 3 identifies requirements for proper sampling, including work practice and recordkeeping requirements for sampling data. Section 4 identifies approved instrumentation that may be used in conducting testing in accordance with this protocol. Section 5 identifies reporting and recordkeeping requirements for non-instrumental data collected during the test. Section 6 identifies quality assurance and quality control requirements for instruments. Section 7 identifies reporting requirements. Section 8 includes references.

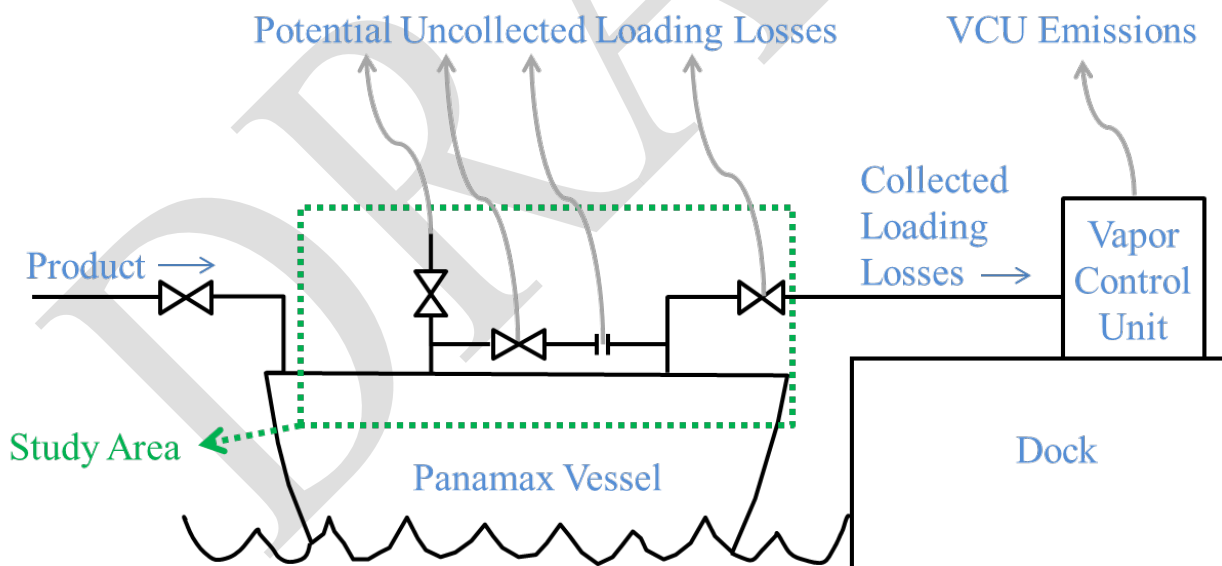
## 2.0 Loading Process Description

Testing shall be restricted to inerted tanker ships or ocean-going barges while they are loaded with volatile liquid cargo. Inerted tanker ships are those where an inert atmosphere (typically stack gas from an on-board diesel-fired combustion source) has been delivered to each cargo tank on the vessel prior to loading.

Before loading takes place, Company personnel will board the tanker to review paperwork and ensure that all of the necessary testing and operational equipment is in place and in working order consistent with the requirements of the ship's Captain and governance of the owners of the ship.

Once all pre-transfer preparations are completed, product loading can begin. Loading the tanker primarily consists of pumping product into the vessel's cargo tanks. As product enters the cargo tanks, the vapors inside the tanks will be routed to the permitted vapor control unit on the dock. Loading typically begins slowly at a low pressure to ensure that equipment is working correctly and that connections are tight. Steady pressure is eventually achieved and held until the "topping-off" phase when the tanks are nearly full. As the tanker approaches capacity, personnel will direct the flow of product and maintain close contact with the pumping facility to decrease and ultimately stop the flow of product.<sup>1</sup>

A loading process diagram is provided in Figure 2-1.



**Figure 2-1. Process Diagram and Study Area Boundary**

## 2.1 Loading Loss Determination

Data collected during testing shall be used to estimate uncollected loading emissions and collection efficiency for the loading event. Methods for calculation of collection efficiency are detailed in this section.

Loading losses occur as organic vapors inside the empty vessel are displaced by the petroleum liquids being loaded into the vessel. Loading losses may be calculated according to the formula provided in EPA document AP-42, Section 5.2 – Transportation and Marketing of Petroleum Liquids<sup>2</sup>. All collected loading loss emissions are subject to permit control requirements.

$$L_L = \frac{12.46(S)(P)(M)}{T}$$

Where  $L_L$  = Loading loss (lb/10<sup>3</sup> gallons of liquid loaded)  
S = Saturation factor from AP-42 (dimensionless)  
P = Vapor pressure of liquid loaded (psia)  
M = Molecular weight of vapors (lb/lb-mol)  
T = Temperature of bulk liquid loaded (°R)

Values for the vapor pressure and molecular weight of the materials loaded should be the same values that would be used for calculating controlled emissions from the vapor combustion or vapor recovery system. Uncollected loading emissions are also referred to as “loading fugitives.” Uncollected loading emissions ( $L_{LF}$ ) are related to total loading losses by the following equation:

$$L_{LF} = (L_L) (100\% - CE)$$

Where CE = collection efficiency (%)

Uncollected loading emissions ( $L_{LF}$ ) will be directly measured in this study. Collection efficiency (CE) is calculated using the following equation:

$$CE = 100\% - \frac{L_{LF}}{L_L} = 100\% - \frac{(L_{LF})(T)}{12.46(S)(P)(M)}$$

Uncollected loading emissions ( $L_{LF}$ ) will also be used to determine an emission factor expressed as pounds of uncollected fugitive emission generated per 1,000 barrels of cargo loaded.

## 2.2 VOC Emissions Regulations

This protocol is designed to quantify uncollected loading emissions from the controlled loading of inerted, vapor-tight tanker ships. Marine loading operations are subject to the requirements of Title 40 of the Code of Federal Regulations, (40 CFR) Part 63, Subpart Y - *National Emission Standards for Marine Tank Vessel*

*Loading Operations*<sup>3</sup>. Testing shall be restricted to those tanker ships for which annual vapor-tightness testing in accordance with 40 CFR §63.565(c) is documented.

Coast Guard regulations for facilities transferring oil or hazardous materials in bulk require that a facility vapor collection system must maintain the pressure in a vessel's cargo tanks between 0.2 psig and 80% of the lowest setting of any of the vessel's pressure relief valves for an inerted tank vessel 30 CFR 154.2103(b). Testing shall be restricted to those tanker ships which employ vapor collection systems in accordance with Coast Guard regulations and applicable permit conditions.

### **3.0 Measurements Approach**

Instrumental measurements taken during testing, and calculations performed following testing shall be performed as detailed in this section.

The following measurement/calculation methods are covered by this section:

- Identify any leaking components during loading (Section 3.1),
- Measure emission rates of leaking components (Section 3.2), and
- Estimate total VOC emissions from all leaking components to determine the cumulative uncollected loading emissions ( $L_{LF}$ ) of VOCs from the vessel during loading (Section 3.3).

Hydrocarbon concentrations in the headspace of the cargo tanks reach their highest levels at the end of the loading process, representing a worst-case scenario with regard to the generation of fugitive emissions. In order to calculate a conservative estimate of emissions from any leaking components, field measurements shall be conducted over a period of approximately six hours as close to the end of the loading process as practical. Out of concern for worker safety, testing can be scheduled so that it does not take place during non-daylight hours or during periods of adverse weather.

Testing shall be conducted by a team consisting of no fewer than four qualified persons, with roles and responsibilities as detailed in Table 3-1.

A "Start-Up" phase shall be conducted as follows. Before leak detection efforts begin, the Project Field Lead shall consult with ship crew in order to identify all components on the ship that may emit uncollected loading losses. The Project Lead will develop a Component Master List that includes each component identified during the Start-Up Phase. Each component on the list is assigned a unique identifier. Testing and calibration of data collection equipment following Section 6.0 shall also be conducted during the Start-Up phase.

Following completion of the Start-Up phase, the rest of the test is divided into two partially overlapping periods: one of leak detection (Section 3.1) and another of leak measurement (Section 3.2). During the leak detection phase the primary emphasis of the testing team is on determining which components are leaking. During the leak measurement phase the emphasis of the testing team is on quantifying various leak rates as accurately as possible. Each of the phases of testing, and the general responsibilities of each team member during each phase, is summarized in Table 3-1.

This protocol concerns the measurement of authorized VOC emissions due to release of uncollected loading losses. The direct measurement of unauthorized emissions occurring during an emissions event (30 TAC §101.1(28)) is not required under the protocol. Any process upsets that occur during testing, and that result in unauthorized emissions, shall be identified in the submitted test report. Any leaks detected during testing must be included in the calculation, even if they are repaired before the end of the loading activity. However, if leaks are identified prior to the start of loading, and repaired before loading commences, emissions from the leaks would not need to be included in the calculation of collection efficiency.

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**Table 3-1. General Responsibilities of Field Personnel during Various Phases of Testing**

| Testing Phase                 | Phase Description  | Project Field Lead<br>(1 person)  | Leak Detection Staff<br>(2 people)   | Leak Measurement Staff<br>(1 person)  |
|-------------------------------|--|---|--|---|
| <b>Start-Up Phase</b>         | Pre-sampling preparations  | <ul style="list-style-type: none"> <li>Work with ship personnel to identify all potential leak points and fill out the "Component Count Master List "</li> <li>Provide completed "Component Count Master List" to other field personnel</li> </ul>                                    | Conduct instrument calibration checks to confirm proper instrument performance and document results. See Section 6.0 for more information.   | Conduct Bacharach Hi Flow Sampler calibration check to confirm proper instrument performance and document results.  |
| <b>Leak Detection Phase</b>   | <ul style="list-style-type: none"> <li>Primary focus is on leak detection efforts</li> <li>Phase lasts until each component has been screened for leaks at least twice.</li> </ul>   | <ul style="list-style-type: none"> <li>Assist leak detection and leak measurement personnel and provide guidance as needed.</li> <li>Ensure all team members are aware of significant findings noted by other testing personnel.</li> </ul>   | <ul style="list-style-type: none"> <li>Look for leaks as required in Section 3.1.</li> <li>Screen tank tops, P/V valves and manifold vapor connection spools first</li> <li>Notify Project Field Lead and Leak Measurement Staff when any non-marginal leaks are detected.</li> <li>Ensure each component is screened for leaks at least twice.</li> <li>Film video of any leaks detected with an IR gas imaging device</li> </ul> | <ul style="list-style-type: none"> <li>Assist Project Field Lead and Leak Detection Staff when not measuring leak rates.</li> <li>Ensure that an emission rate measurement is collected on any component found to be "leaking" as soon as possible after leak detection.</li> </ul> |
| <b>Leak Measurement Phase</b> | <ul style="list-style-type: none"> <li>Phase may begin once significant leaks are identified by screening.</li> <li>Once all components have been screened twice during the leak detection phase, the focus shifts from leak detection efforts to leak measurement efforts.</li> </ul> | <ul style="list-style-type: none"> <li>Assist leak measurement personnel with bagging any larger "leaking" components (e.g., tank tops).</li> <li>Ensure, to the extent practicable, that leak detection and measurement takes place on cargo tanks actually being loaded.</li> </ul> | <ul style="list-style-type: none"> <li>Continue with follow-up, handheld screening measurements on components found to be "leaking" or "marginally leaking".</li> <li>The IR gas imaging device operator should work with Leak Measurement Staff as needed to help demonstrate that total capture is achieved on any significant leaks during Hi Flow Sampler Measurements.</li> </ul>   | <ul style="list-style-type: none"> <li>Conduct two or more emission rate measurements on any components identified as "leaking" by screening.</li> </ul>  |



### **3.1 Leak Detection Approach**

The first method (“Method 21”) is the use of handheld hydrocarbon monitoring devices to monitor for leaks in accordance with EPA Reference Method 21. Method 21 shall be employed during each test as the means for determining whether a component is non-leaking, marginally leaking, or leaking. Method 21 handheld monitors are certified as intrinsically safe and their use on the deck of a marine vessel during loading generally presents no issues. The second method (“infrared (IR) device for optical gas imaging”) is the use of a device such as the FLIR GF320<sup>1</sup> gas imaging VOC detector. Devices such as the FLIR GF320 may not be certified as intrinsically safe and are only permitted on the deck of the vessel during loading at the discretion of the ship’s captain or the captain’s designee.

Handheld monitoring via EPA Method 21 is generally capable of detecting smaller leaks that the IR gas imaging device may not detect, but it is a more time consuming method. An IR gas imaging device can detect VOC leak rates as low as six grams per hour at a distance of twenty feet under ideal weather conditions. It is able to survey a large number of components in a relatively short time period and is particularly well suited for quickly identifying large leaks. During the leak detection phase, leak detection using Method 21 and the IR gas imaging device method (if permitted) shall be performed by at least two members of the field team. When the IR gas imaging device method is not permitted, both testing staff will perform Method 21 screening.

Since the IR gas imaging device survey method can investigate and identify potential leak points faster than EPA Method 21, it is anticipated that the Method 21 and IR gas imaging device leak detection teams can work independent of one another during the leak detection phase. If a leak is identified by the IR gas imaging device method, personnel conducting Method 21 screening shall be promptly notified in order to conduct an independent examination of the leak point.

The potential fugitive emission points on the master component list are located on the deck of the vessel and are suitable for testing using either of these leak detection methods. All components shall be assigned a unique ID. Testing personnel shall use a component’s unique ID when documenting leak detection and measurement results. Each potential emission source will be inspected for leaks at least two times during testing.

#### **3.1.1 EPA Method 21 Screening (primary leak detection method)**

EPA Method 21 – Determination of Volatile Organic Compound Leaks – is the standard procedure for the determination of VOC leaks from process equipment<sup>4</sup>. This method applies, but is not limited to, valves,

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<sup>1</sup> Over time, equipment brands, technology and models may change i.e., the FLIR GF320 is not the only acceptable gas imaging device to be used for this protocol. The Operating Company shall use the same, equivalent or improved equipment technology.

flanges and other connections, pumps and compressors, pressure relief devices, process drains, open-ended valves, pump and compressor seal system degassing vents, and access door seals.

Application of Method 21 is also referred to as screening. Each potential leak point identified in the "Component Count Master List" shall be screened at least twice during testing. Prior to screening a component, any obstructions that might interfere with monitoring at the interface (e.g., grease on the component interface) should be eliminated<sup>5</sup>. The instrument measurement may exceed the scale of the instrument. This is referred to as a pegged readout and the measurement result will be noted as "pegged." Care must be taken to avoid fouling the probe with grease, dust, or liquids. A short piece of Teflon® tubing will be used as a probe tip extender. This extender will be snipped off as the tip fouls. Instrumentation that may be used as a part of this approach is discussed in Section 4.

Research on fugitive emissions in refineries has revealed that the vast majority of the fugitive emissions typically derive from a few large leaks<sup>6</sup>. Therefore, this testing protocol seeks to direct monitoring resources toward the detection and measurement of large leaks as opposed to smaller, insignificant leaks. This testing protocol establishes a three-way distinction between "non-leaking" components, "marginally leaking" components, and "leaking" components. For the purposes of this study, any component with a screening concentration less than 500 ppm-c (i.e., ppm as methane) will be considered to be "non-leaking" at the time of that measurement. Based on results from previous studies, components with a screening concentration less than 2,500 ppm-c generally had no detectable emissions using the leak quantitation method described in Section 3.2 (i.e., the leak emission rate was zero). Therefore, any components with a handheld screening value between 500 and 2,500 ppm-c will be classified as "marginally leaking," but no direct measurement of leak rate will be required for these components. Components with a screening concentration above 2,500 ppm-c will be classified as leaking and will require an emission rate measurement.

For each potential leak point with a screening concentration below 500 ppm-c, the following data shall be recorded:

- Component ID
- Measurement Time
- Sampler Initials

For each potential leak point with a screening concentration above 500 ppm-c, the following data shall be recorded:

- Component ID
- Measurement Time
- Sampler Initials
- Ambient concentration (ppm-c)
- Screening concentration (ppm-c)
- Any other pertinent details

As an alternative to recording ambient concentration, an ambient concentration of 0 ppm-c VOC can be assumed.

Once all components on the Component Count Master List have been screened, the screening process for all components will be repeated. The classification of components according to the three-way leak definition outlined in this section, with associated sampling and recordkeeping requirements, is summarized in Table 3-2.

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**Table 3-2. Summary of General Handheld Leak Detection Screening Procedure**

| <b>Handheld Screening Concentration</b> | <b>Leak Classification</b> | <b>Record Keeping Requirements</b>  | <b>Follow-up requirements</b>  |
|---|----------------------------|---|--|
| Less than 500 ppm-c                     | Not Leaking                | Write down the component ID, time, sampler initials   | <ul style="list-style-type: none"> <li>• Make sure the component is screened for leaks at least twice during testing.</li> <li>• No follow-up leak rate measurement is required.</li> </ul>  |
| 500 - 2,500 ppm-c                       | Marginally Leaking         | <ul style="list-style-type: none"> <li>• Write down the component ID, time, sampler initials, screening concentration and any other pertinent details on the field data sheet, "Handheld Hydrocarbon Measurements."</li> <li>• Place a green tag on the component noting the component ID, the screening concentration and the time.</li> </ul>   | <ul style="list-style-type: none"> <li>• No follow-up leak rate measurement is required.</li> <li>• Continue to screen the component periodically throughout testing (at least twice, ideally more).</li> </ul>  |
| Greater than 2,500 ppm-c                | Leaking                    | <ul style="list-style-type: none"> <li>• Write down the component ID, time, sampler initials, ambient concentration, screening concentration and any other pertinent details on the "Field Data Sheet – Handheld Hydrocarbon Measurements."</li> <li>• Place a red tag on the component noting the component ID, the screening concentration and the time. If a green tag is already present, locate the red tag directly next to the green tag.</li> </ul> | <ul style="list-style-type: none"> <li>• Leak rate measurement is required – notify leak measurement personnel and/or field lead as soon possible so that follow-up Hi Flow Sampler measurement can be conducted.</li> <li>• Continue to screen component periodically throughout testing (at least twice, ideally more).</li> </ul> |

### **3.1.2 IR Gas Imaging Device Survey**

When the IR gas imaging device method is permitted, personnel will perform remote screening using the IR gas imaging VOC detector to identify potential VOC emission points and qualitatively assess each point's relative emissions potential. Once the IR gas imaging device is in the optimal position relative to the potential leak point and all operating parameters are optimized, at least 20 seconds will be spent inspecting each potential leak point. If any leaks are detected then video of the leak will be recorded, the leaking component will be tagged with a yellow tag, and a record of the leak will be documented on the IR gas imaging device field data sheet, noting:

- the filename/number
- the component ID
- the time, and
- any other pertinent details.

Any videos of leaking components will be provided with the final report. Once all of the components of interest have been surveyed by the IR gas imaging device, the survey process for all components will start again. When conducting subsequent rounds of surveying, components with previously detected leaks may be evaluated more frequently than non-leaking components. At least one video will be recorded featuring each component type, regardless of whether that component type was found to be leaking. For instance, regardless of whether any tank access plates were found to be leaking, at least one video of a tank access plate will be recorded.

### **3.2 Leak Emission Measurement Approach**

During the leak measurement phase, leak emission rates shall be measured using a Bacharach Hi Flow Sampler. A detailed description of the Bacharach Hi Flow Sampler is provided in Section 4.3. Quality assurance and quality control procedures are addressed in Section 6.3. This section provides a description of how this sampler is expected to be utilized in this study.

Leak rate measurements will be collected on those components classified as “leaking” following the criteria presented in Section 3.1.1. In cases where multiple “leaking” components are simultaneously active, leaks shall be measured as soon as practicable, with priority given to measuring whichever leak is believed to be more significant. Any component with a detected leak rate (i.e., a non-zero leak rate) should have its leak rate quantified as many times as practicable throughout the loading process, though not less than twice. In the event that leak measurements are performed only once on a “leaking” component, the report shall contain an explanation why a second measurement was not made. In the event that no leak measurements are performed on a “leaking” component, the report shall contain an explanation why no measurements were made, and a proposed conservative estimate of the emission rate for the leaking component shall be reported.

Before measuring emissions from a particular leak point using the Hi Flow Sampler, the appropriate capture device for the leak/emission source must be selected. Choices include a set of conventional capture tools (crevice tool, a bag, flange tool, etc.) and a set of “non-conventional” capture tools.

After sampling has started, the emission measurement reading should be monitored until a stable leak measurement is obtained. At this time, the following information should be recorded on the field data sheet:

- component ID,
- time,
- sampler initials,
- sampler flow rate (LPM),
- sampler concentration (% as methane),
- sampler emission rate (LPM as methane), and
- any other pertinent information.

An entire Hi Flow Sampler test run typically lasts between one and five minutes. If IR gas imaging device is allowed on the deck of the vessel during testing, the leak monitoring process outlined above should be filmed at least once in the field to help demonstrate that all VOC emissions from the leak in question are being captured by the Hi Flow Sampler. The purpose of filming the Hi Flow measurement is to demonstrate technique and the ability of the sampler to capture the entire leak. Performing this observational check once or twice during the entire test event shall be considered sufficient for this demonstration.

### 3.3 Calculation of VOC Emission Rates and Total Uncollected Emissions

The Hi Flow Sampler displays emission rate readings in liters of hydrocarbon (as methane) per minute (LPM) with a measurement resolution (sensitivity) of 0.1 LPM. These emission rate values will be converted to grams of hydrocarbon per hour using the following equation<sup>2</sup>:

$$(3.3-1) \text{ THC emission rate } \left( \frac{\text{g}}{\text{hour}} \right) = \frac{\text{liters of methane}}{1 \text{ minute}} \times \frac{1 \text{ mole(STP)}}{22.4 \text{ liters}} \times \frac{16 \text{ grams}}{1 \text{ mole}} \times \frac{60 \text{ minutes}}{\text{hour}}$$

Using this equation, an emission rate reading of 0.1 LPM corresponds to 4.3 grams of hydrocarbon per hour. For purposes of this testing, VOCs are assumed to account for 100% of the total hydrocarbon concentration. Any reading of zero may be interpreted to mean that the emission rate was less than the sensitivity of the sampler (i.e., < 4.3 g/hour). The leak emission rate is equal to the measured concentration multiplied by volumetric flow rate. Components with low screening values may yield a leak rate reading of zero due to the low volumetric flow rate of the leak.

If no Hi Flow Sampler measurements are collected on a component because all screening concentrations are below 2,500 ppm-c then the average leak rate for that component is dependent on the maximum screening

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<sup>2</sup> Formula assumes standard temperature and pressure (STP) – 22.4 L/mole

concentration associated with that component. If the maximum screening concentration for a given component is less than 500 ppm-c then the average leak rate for that component is assumed to be 0.0 g/hour. If the maximum concentration for a given component is between 500 ppm-c and 2,500 ppm-c then the average leak rate for that component is assumed to be equal to one-half of the measurement sensitivity of the Hi Flow Sampler (2.2 g/hour).

All components with a maximum screening concentration greater than 2,500 ppm-c should have at least two Hi Flow Sampler measurements. For these components, the average leak rate will be determined by taking the arithmetic average of all the Hi Flow Sampler measurements collected on that component. In any instance where a leak rate measurement of 0.0 g/hour is measured, a leak rate measurement equal to one-half of the measurement sensitivity of the Hi Flow Sampler (2.2 g/hour) will be assumed. This process is summarized in Table 3-3.

The average leak rate for each component shall be summed to provide the cumulative average leak rate for the vessel, which is an estimate of the uncollected loading fugitive emissions. This leak rate, expressed in grams per hour, shall be multiplied by the total loading duration, expressed in hours, to calculate total uncollected emissions over the course of loading. The cumulative average leak rate for the vessel shall be reported to the nearest 0.01 lb using units of lb.

**Table 3-3. Screening Concentrations and Corresponding Emission Leak Rate Values**

| <b>Maximum Handheld Screening Concentration for the Component</b> | <b>Leak Classification</b> | <b>How Average VOC Leak Rate for Component is Determined</b>  |
|---|----------------------------|---|
| Less than 500 ppm-c   | Not Leaking                | The component is assumed to have an emission leak rate average of 0.0 g/hour. No Hi Flow Sampler measurement is required.   |
| 500 - 2,500 ppm-c   | Marginally Leaking         | The component is assumed to have an emission leak rate average of 2.2 g/hour. No Hi Flow Sampler measurement is required.   |
| Greater than 2,500 ppm-c  | Leaking                    | <ul style="list-style-type: none"> <li>• If Hi Flow Sampler measurement data are available then the average emission leak rate is equal to the arithmetic average of all the Hi Flow Sampler measurement values (where 2.2 g/hour is substituted for any zero readings).</li> <li>• If no Hi Flow Sampler measurement data are available then provide a conservative estimated emission rate and document the reason for failure to perform a leak rate measurement.</li> </ul> |

## **4.0 Sampling and Measurement Equipment**

All equipment described in this section is certified as intrinsically safe with the exception of the FLIR GF320 gas imaging device. Non-intrinsically safe equipment may be permitted on board by discretion of the ship captain or the captain's designee.

The following subsections summarize the function of the primary sampling and measurement equipment to be used in this study. Over time, equipment brands, technology and models may change. The equipment discussed in Sections 4.1-4.3 is the equipment expected to be used at the time this protocol was developed. The Operating Company shall use the same, equivalent or improved technology when executing this ship testing protocol. Quality assurance and quality control procedures for this equipment are addressed in Section 6.0.

### **4.1 IR Gas Imaging Device**

Infrared gas imaging is conducted using a FLIR GF320. The FLIR GF320 has a spectral range of 1– 5.4  $\mu\text{m}$ . The detector is operated at near liquid nitrogen temperatures using an integral Stirling cooler which provides the system with an NEDT less than 25 milliKelvins, providing excellent sensitivity.

The spectral range is further limited with the use of a notch filter specifically designed for the detection of hydrocarbon infrared absorptions in the 3 micron region. The narrow band pass range of the filter is less than the infrared spectral absorption of gas phase hexane. The filter notch is positioned such that alkane gases have a significant response within the band pass range.

The use of a narrow band pass filter provides spectral discrimination that allows the detection of compounds that have a vibration mode in the infrared region of the filter. Not all hydrocarbons have infrared absorptions within the filter range. Using propane as the reference spectrum with a relative response of 100, methane's response is approximately 10% of the same concentration of propane and hexane is 1.5 times the response of propane at the same concentration. The filter is set to the infrared region of the spectrum that corresponds to the infrared absorption of alkanes, primarily.

### **4.2 phx21™ Hydrocarbon Analyzer**

Handheld screening for VOCs shall be conducted using a phx21 or a similar handheld VOC monitor (e.g., Thermo TVA-1000, etc.) that meets Method 21 requirements. The pxh21™ FID analyzer is a portable, battery-powered, intrinsically safe hydrocarbon analyzer that utilizes a flame ionization detector (FID).



### **4.3 Bacharach Hi Flow Sampler**

The Hi Flow Sampler is a portable, intrinsically safe, battery-powered instrument designed to determine leak rates around various components. This is accomplished by sampling at a large flow rate (between 140 and 300 LPM) to completely capture all vapors leaking from a component. By measuring the flow rate of the sampling stream and the hydrocarbon concentration within that stream, the total hydrocarbon leak rate can be calculated. This protocol requires the use of the Bacharach Hi Flow Sampler or equivalent technology.

### **5.0 Other Measurement Data**

In addition to field data sheets compiled as required by Section 3, the facility operator, or its designee, shall collect and report the following data to the extent practicable:

- the true vapor pressure of the cargo loaded (psia),
- the vapor molecular weight of the cargo loaded (lb/lb-mol),
- the average temperature of cargo loaded (°R),
- ship particulars (e.g., ship age, dimensions, etc.),
- the inspector's report (e.g., information on prior load, potential for a heel, etc.),
- a copy of the last vapor-tightness certification,
- loading rates and individual cargo tank loading rates over time,
- vapor collection system operating pressures and individual cargo tank pressures over time, and
- cargo tank fill levels and ullage over time.

Wherever possible, high time-resolution (e.g., 1-minute average) electronic data should be requested and collected. Any data directly collected by the facility operator through their computer data historian such as Supervisory Control and Data Acquisition (SCADA) system during routine loading operations (e.g., dockside loading rates) shall be provided in electronic format. Any electronic data files collected during this study shall be provided with the final report. In some instances, high time-resolution electronic data may not be available or ship personnel may refuse to provide such data. For example, although loading rates and pressures for individual cargo tanks are monitored by ship personnel, a request for an electronic record of these data may not be granted by ship personnel. In instances where a request for electronic data is denied, the facility operator or its designee shall request for ship personnel to provide hardcopy documentation of these data (e.g., a table summarizing hourly average data). In instances where a request for hardcopy documentation is denied, the facility operator or its designee shall periodically (e.g., every 60 minutes) document relevant data (e.g., cargo tank loading rates, cargo tank pressures, cargo tank fill levels and ullage) to the extent that such collection is practicable and does not significantly interfere with leak detection and measurement data collection, by manually checking diagnostic monitoring equipment on the ship and writing down the results. This data format preference order is summarized in Table 5-1.

**Table 5-1. Data Collection Needs and Data Format Preference Order**

| Data Type   | When to obtain data?                        | Who should provide data? | Data format preference order   |
|---|---|--------------------------|--|
| True vapor pressure of cargo loaded (psia)  | Prior to testing                            | [facility operator]      | PDF report   |
| Vapor molecular weight of cargo loaded (lb/lb-mol)  |   |                          |  |
| Ship particulars (Q88)  |   |                          |  |
| Copy of last vapor-tightness certification  |   |                          |  |
| Loading rates and individual cargo tank loading rates over time                           | During testing or immediately after testing | Marine Vessel            | <ol style="list-style-type: none"> <li>1. High-time resolution electronic data (SCADA)</li> <li>2. Hardcopy data summary</li> <li>3. Periodic manual documentation of data by testing personnel</li> </ol> |
| Vapor collection system operating pressures and individual cargo tank pressures over time |   |                          |  |
| Cargo tank fill levels and ullage over time.  |   |                          |  |
| Inspector's report  | After testing                               | [facility operator]      | PDF report   |
| Loading rates over time   |   |                          | <ol style="list-style-type: none"> <li>1. High-time resolution electronic data (SCADA)</li> <li>2. Hardcopy documentation</li> </ol>   |
| Vapor collection system operating pressures over time                                     |   |                          |  |

## 6.0 Quality Assurance and Quality Control (QA/QC) Procedures

All instruments and equipment to be used in the field will be tested following manufacturer's specifications and/or EPA Method 21 (as applicable) prior to deployment to verify proper working condition. During this testing, all analyzers will be calibrated to verify proper instrument response. Backup parts and/or devices shall be kept on hand against foreseeable instrument or equipment failures/malfunctions in the field. Any analyzer or piece of equipment suspected of having performance issues will be promptly removed from service and repaired or replaced with an equivalent backup unit as soon as possible.

For all written field documentation, indelible ink will be used, and any hand corrections will be made by a single line through the incorrect entry with the author's initials immediately following the correction. All work performed during the data collection, review, and validation process must be traceable to the author, and all data products must be able to be reversed to their original result at all times.

Sections 6.1–6.3 summarize QA/QC procedures which apply to particular device types. Over time, equipment brands, technology and models may change. The equipment discussed in Sections 6.1-6.3 summarize the equipment used at the time this protocol was developed. The Operating Company shall use the same, equivalent or improved technology when executing this ship testing protocol.

## **6.1 FLIR GF320**

Before testing begins, the FLIR GF320's operation will be verified on site by releasing a known emission rate of hydrocarbon vapors (e.g., methane) and measuring the distance from which the release can be reliably detected. This check will be performed at two emission rates: a low emission rate (e.g., approximately 6 grams/hour) and a higher emission rate (e.g., approximately 60 grams/hour). The distance from which each emission rate can be detected will be recorded and relevant weather conditions will be noted. These checks will be imaged and recorded on a hard drive for inclusion in the final report.

The performance of the GF320 can be affected by changes in the weather. Below are listed some weather conditions known to adversely affect the GF320's performance.

- Overcast/Early Morning Hours – The GF320 requires infrared radiation contrast in order for the technician to distinguish emissions from the background. If infrared contrast is lower during these conditions, the performance of the GF320 can be adversely impacted.
- Strong winds – Strong winds can impede the operator's ability to see a small leak from a distance as these winds dissipate emissions quicker. However, it is anticipated that most components will be surveyed within 10 feet of the technician.
- Rainy conditions/high humidity/fog – The GF320 is waterproof so its internal electronics are unaffected by moisture. However, rain and high humidity have the potential to affect the thermal properties of the components being surveyed in this study.

Should adverse weather be encountered during testing, the operator will make a professional judgment on whether conditions are significantly affecting the instrument's ability to detect leaks.

## **6.2 phx21™ Hydrocarbon Analyzer**

The phx21™ will be calibrated in accordance with EPA Method 21. The phx21™ will be calibrated in the field before testing takes place. Drift checks will be performed to assess analyzer accuracy. These checks will be performed by analyzing one of the methane calibration gases (e.g., 500 ppm-c) used to calibrate the portable monitoring instrument. If the drift check measurement is within 10% of the actual methane concentration the instrument is considered to have passed the drift check and no adjustment need be made to the instrument. If the drift check reading is off by more than 10% the instrument shall be recalibrated. If the analyzer fails to respond to a drift check (i.e., a false negative reading), then the instrument shall be recalibrated and measurements since the last calibration or passed drift test shall be repeated. All drift check data will be documented.

Periodic ambient air monitoring checks will be performed. If ambient concentrations readings suggest that analyzer baseline readings are unstable or drifting the analyzer should be re-zeroed and a drift check should be conducted.

### **6.3 Bacharach Hi Flow Sampler**

The Hi Flow Sampler shall be calibrated and checked before testing following the methodology in the operation manual. Instrument response should be within 10% of the expected value using 2.5% methane calibration gas. This is applicable to both the leak (gas) channel and the background channel. If calibration is necessary, the analyzer will be recalibrated per the Hi Flow Sampler manual and the results will be documented. The calibration will be checked at six-hour intervals during the test event. If the instrument has drifted less than 10%, the instrument calibration is acceptable, and testing will continue. If the instrument has drifted more than 10%, previous data will be flagged, and the instrument will be recalibrated. In this case, the next calibration check will be performed at a three-hour interval.

For all measurements, the flow rate of the sampler should be lowered and an additional reading should be collected at this lower flow. This is a test of capture efficiency, in that the flow rate drops and the concentration should rise, with the product remaining constant. These lower flow rate readings should agree with the original readings within 10% or 0.1 LPM, whichever is greater. In any instances where the two emission rate measurements are different the higher emission rate will be used in emissions calculations.

### **7.0 Data Reduction and Reporting**

Data review, validation, and verification procedures are presented in this section. Data shall be declared invalid whenever documented evidence exists demonstrating that an instrument was malfunctioning. The testing report shall identify and report any data having been declared invalid, with an explanation for why data were invalidated. Any data that were not collected under representative conditions shall be flagged. For instance, were an emission upset to occur during non-routine loading operations (non-representative conditions) any affected data collected around the time of the emission upset shall be flagged. The impacts of including or excluding flagged data from the emissions calculations discussed in Section 3.3 will be evaluated and discussed in the final report.

The activities involved in validation of the data in general include the following:

- reviewing the field documentation, calibration data; and
- examining the analyzer data for measurement values that seem incongruous with normal measurement ranges.

All field measurement data shall be documented on field data sheets. Copies of field data sheets shall be provided with the final report. Additionally, field data sheets shall be compiled by the facility operator or its designee in a computer readable format (e.g., xlsx, csv) and an electronic copy of these compiled data shall be submitted with the final report. The specific data fields included in this electronic data deliverable are discussed in Section 3 and are summarized in Table 7-1. The final report shall contain a sample calculation showing estimation of the uncollected loading fugitive emissions.

A report summarizing all results shall be produced and submitted within 45 days of completion of each test. The report shall specifically identify any deviations from this protocol and provide explanation for the deviation. If it is determined that significant deviations from this protocol have occurred, or the data reported is not sufficiently complete or representative, EFSEC, shall either require revisions to the testing report, declare the test results invalid, and/or require testing to be repeated.

**Table 7-1. Data Fields in Field Measurements Electronic Data Deliverable**

| EPA Method 21 Data Fields   | FLIR GF320 Data Fields  | Bacharach Hi Flow Sampler Data Fields   |
|---|---|---|
| <ul style="list-style-type: none"> <li>• Component ID</li> <li>• Measurement Time</li> <li>• Sampler initials ambient concentration (ppm-c)</li> <li>• Screening concentration (ppm-c)</li> </ul> | <ul style="list-style-type: none"> <li>• Component ID</li> <li>• Video time</li> <li>• Operator Initials</li> </ul> | <ul style="list-style-type: none"> <li>• Component ID</li> <li>• Measurement Time</li> <li>• Sampler Initials</li> <li>• Sampler flow rate (LPM),</li> <li>• Sampler concentration (% as methane),</li> <li>• Sampler emission rate (LPM as methane)</li> </ul> |

## 8.0 References

- <sup>1</sup> Hayler, William B.; Keever, John M. (2003). American Merchant Seaman's Manual.
- <sup>2</sup> US EPA Compilation of Air Pollutant Emission Factors – AP-42 (<http://www.epa.gov/ttnchie1/ap42/ch05/final/c05s02.pdf>)
- <sup>3</sup> CFR Title 40: Part 63 – Subpart Y - National Emission Standards for Marine Tank Vessel Loading Operations (<http://www.epa.gov/ttn/atw/marine/marinepg.html>)
- <sup>4</sup> EPA Method 21 – Determination of Volatile Organic Compound Leaks (<http://www.epa.gov/ttnemc01/promgate/m-21.pdf>)
- <sup>5</sup> United States. Environmental Protection Agency., & United States. Environmental Protection Agency. Enforcement and Compliance Assurance. Leak detection and repair: A best practices guide. [Washington, D.C.]: U.S. Environmental Protection Agency, Office of Enforcement and Compliance Assurance, [2010].
- <sup>6</sup> Test/QA Plan for Verification of Leak Detection and Repair Technologies. U.S. EPA Environmental Technology Verification Program, Battelle, Columbus, Ohio, November 2005 (<http://nepis.epa.gov/Adobe/PDF/P100EL3T.pdf>).