SECTION 8. METHODS OF MEASURING EMISSIONS ACURATELY

MONITORING TO DETERMINE LEAKING LOSSES

Leaking losses are often hard to determine since there are many potential sources and they are very dependent on how well the installation is operated, maintained and inspected.

Some important causes of leaking losses are:

- ill-fitting sealing elements
- installation
- construction faults
- wear and tear
- corrosion
- ageing
- equipment failure
- contamination of the sealing element
- excursions out of normal process conditions
- poor maintenance procedures

Leaking losses are generally higher from dynamic equipment (compared with static equipment) and from older equipment.

Leaking losses are also very dependent on process conditions:
- pressure
- temperature
- speed of pumps and compressors
- choice of sealing solution
    - Single Mechanical Seals leak more than double seals (where barrier fluid is the leakage to atmosphere)
    - Gaskets and Packings need careful selection to have correct style selected for the particular service.
    - All seals need careful and correct fitting.

A structural reduction of leaking losses is only possible when insight on the leaking losses is gained. There are various methods to determine the leaking losses.

There are several accepted methods for measuring leakage. The most commonly followed technique used on Chemical plants, Refineries and oil and Gas upstream production facilities is the **US Environment Protection Agency (EPA) Method 21.**

There are several other methods available. These include:
- **CWP 453/R/95** where EPA method 21 is called up
- **IR OGI Alternative Work Practice (AWG)**, using an Infra-Red camera
- **API 220**
- **EPA 6560-50-P 2008** where two measures Parts per Million PPM) and KG/Hr. can be considered the same.
- **Netherlands Technical Agreement (NTA) NTA 8399**, which focusses on VOC emissions and takes into account Air Temperature; Wind Speed; Humidity and Cloud cover.
- **DIAL LIDAR** technique.

Monitoring frequency is a key issue to be agreed, as are acceptable leakage rates.

The simplest way to estimate the leaking losses is by multiplying the number of each type of equipment by an *emission factor* for that type of equipment. This method can be applied to obtain a general estimation of the emissions *without measurements*. Please note that emission factors are not intended as an accurate measure of a single piece of equipment, and do not reflect the site-specific conditions of process units.

Many companies determine their leaking losses by calculations or estimations based on measurements, but it is hard to measure all possible sources in a large plant (possibly tens of thousands) and not all sources are accessible. In most cases, a representative sampling of sources will suffice to estimate or calculate the leaking losses of the plant. The number of samples depends on the kind of process fluids in the plant and the kind of equipment (the sources). However, to provide the best estimate of emissions, every potential "source" on a site must be monitored (usually using a "sniffing" process such as EPA Method 21).

Leaking losses from equipment and fittings can be significantly reduced by the use of monitoring and maintenance programmes such as **LDAR (Leak Detection and Repair**). Leaks are detected by monitoring equipment and repairs must be carried out if the leakage rate exceeds certain levels. A leak detection and repair programme consists of using a portable VOC detecting instrument to detect leaks by "sniffing" (usually, according to EPA Method 21) during regularly scheduled inspections of valves, flanges, and pump seals. Leaks are then repaired immediately or are scheduled for repair as quickly as possible. An LDAR programme could reduce fugitive emissions by 40% to 60%, depending on the frequency of inspections, the process conditions and the fluid emitted.

LDAR can be structured to meet local requirements using appropriate techniques, frequencies and priorities, but in all cases the largest losses should be tackled first. Such programmes have shown that gland leaks on valves and pumps are often responsible for the majority of leaking releases.

Monitoring has been identified as a common activity across industrial processes and is the subject of a horizontal **BREF note, entitled, "Monitoring of Emissions"**. The document provides generic information on sampling and analysis, and should be read in conjunction with other industry-specific BREF notes.

Monitoring is often expensive and time consuming, so the objectives should be clear when a programme is established. Process operators and regulators may use monitoring to provide information on a wide range of topics.

For this Fugitive Emissions Reduction guidance note on sealing technologies, the key objectives of monitoring are:

- Process control and optimisation; monitoring is the way used to control a process by means of following-up significant physical and chemical parameters. By control of the process, it is meant the application of conditions in which the process operates safely and economically.
- Emission monitoring; emissions to air and water are characterised and quantified to provide a check on compliance with permit requirements (or other performance measures). This also provides a check of whether all significant emissions are covered by the permit and can indicate the effectiveness of abatement techniques and sealing technologies employed. For the latter, emission monitoring can give an assessment of leaking losses and will indicate equipment where attention is required.

Wherever possible, data should be collected on flow rates to enable the calculation of mass discharges.

- Occupational health and safety; tests to identify the short and long term risks to personnel from work place exposure.
- Troubleshooting; intensive, short duration programmes may be used to study specific topics.
- A monitoring programme to address any of these topics will need to stipulate the frequency, location and method of both sampling and analysis. Monitoring usually involves precise quantitative analysis, but simple operator observations (either visually or by smell) can also play an important role in the detection of abnormal releases. The results of monitoring programmes should be actively utilised; records of results should be kept for trend analysis and diagnostic use.

Some estimates have been made of the costs of monitoring schemes. For example, a simple LDAR scheme, involving the annual inspection of gas and volatile liquid service components, is estimated to have a net annualised cost of over €25K per year (for a typical plant handling 20000 tpa of gaseous hydrocarbon streams and 30000 tpa of volatile liquids).

DIAL LIDAR technique. A strategy to reduce VOC emissions may include a complete inventory and quantification by a DIAL LIDAR technique (differential absorption light detection and ranging). In some cases, emissions estimates using "sniffing" methods give lower emissions than estimates based on the DIAL monitoring. In some cases, the discrepancies are very large. For example, by using the method for estimating fugitive emissions proposed by EPA "Workbook for estimating fugitive emissions from petroleum production operations 1992", the emissions from the process area at an average European refinery have been estimated to be 125 tonnes per year. Extrapolations of the DIAL measurements to a yearly emission give emissions of 500- 600 tonnes per year.

Note that most reported fugitive emissions are calculated rather than monitored (measured), but unfortunately, correlations are often dubious! Equally, not all calculation formats are comparable. For example, monitoring at well-maintained plants in the Netherlands shows that the average emissions factors are generally higher than measured (monitored) values.

Leaks are then repaired immediately or are scheduled for repair as quickly as possible. An LDAR programme could reduce fugitive emissions by 40 to 60%, depending on the frequency of inspections, the process conditions and the fluid emitted.

Measuring leakage

The current onsite method of measuring PPMv values using an Organic Vapour Analyser, commonly known as a **SNIFFER** is used due to the EPA's method 21 (see link to EPA document) and frankly the lack of a better way.
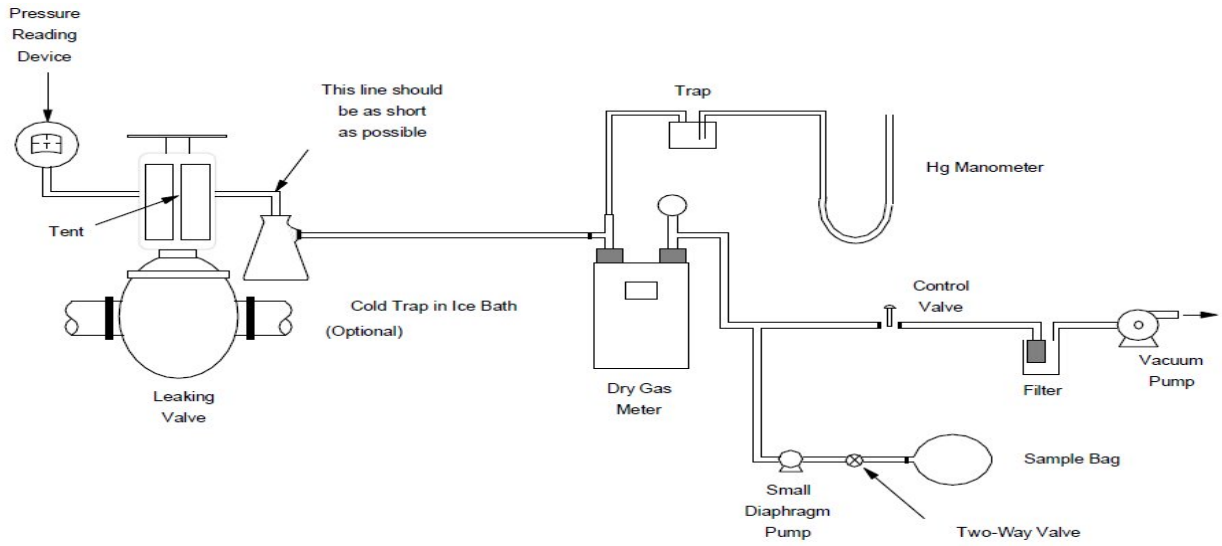
Method 21 Survey Specifics

- 8.3.1 Type I -- Leak Definition Based on Concentration. Place the probe inlet at the surface of the component interface where leakage could occur. Move the probe along the interface periphery while observing the instrument readout. If an increased meter reading is observed, slowly sample the interface where leakage is indicated until the maximum meter reading is obtained. Leave the probe inlet at this maximum reading location for approximately two times the instrument response time. If the maximum observed meter reading is greater than the leak definition in the applicable

regulation, record and report the results as specified in the regulation reporting requirements. Examples of the application of this general technique to specific equipment types are:

- 8.3.1.1 Valves. The most common source of leaks from valves is the seal between the stem and housing. Place the probe at the interface where the stem exits the packing gland and sample the stem circumference. Also, place the probe at the interface of the packing gland take-up flange seat and sample the periphery. In addition, survey valve housings of multipart assembly at the surface of all interfaces where a leak could occur.
- Other sub paragraphs discuss flange, screwed connections, etc

- **Bagging method**
    - the leaking component is enclosed in a "bag" or tent
    - An inert carrier gas (e.g., nitrogen) is conveyed through the bag at a known flow rate.
    - When the carrier gas attains equilibrium, a gas sample is collected from the bag, and the TOC (total organic compounds) concentration of the sample is measured.

Bagging Vacuum Method

Pressure Reading Device

This line should be as short as possible

Trap

Hg Manometer

Tent

Cold Trap in Ice Bath (Optional)

Control Valve

Vacuum Pump

Filter

Leaking Valve

Dry Gas Meter

Sample Bag

Small Diaphragm Pump

Two-Way Valve

Bagging Blow-Through Method

1/4" Insulated Teflon® Tubing

Valve Stem

Carrier Gas Source

Pressure Regulator

Tape or Adjustable Metal Band

Dessicant (if needed)

Rotameter

Sample Port for Collecting Data on
- Temperature
- Hydrocarbon Concentration
- Oxygen Concentration

Activated Charcoal (if needed)

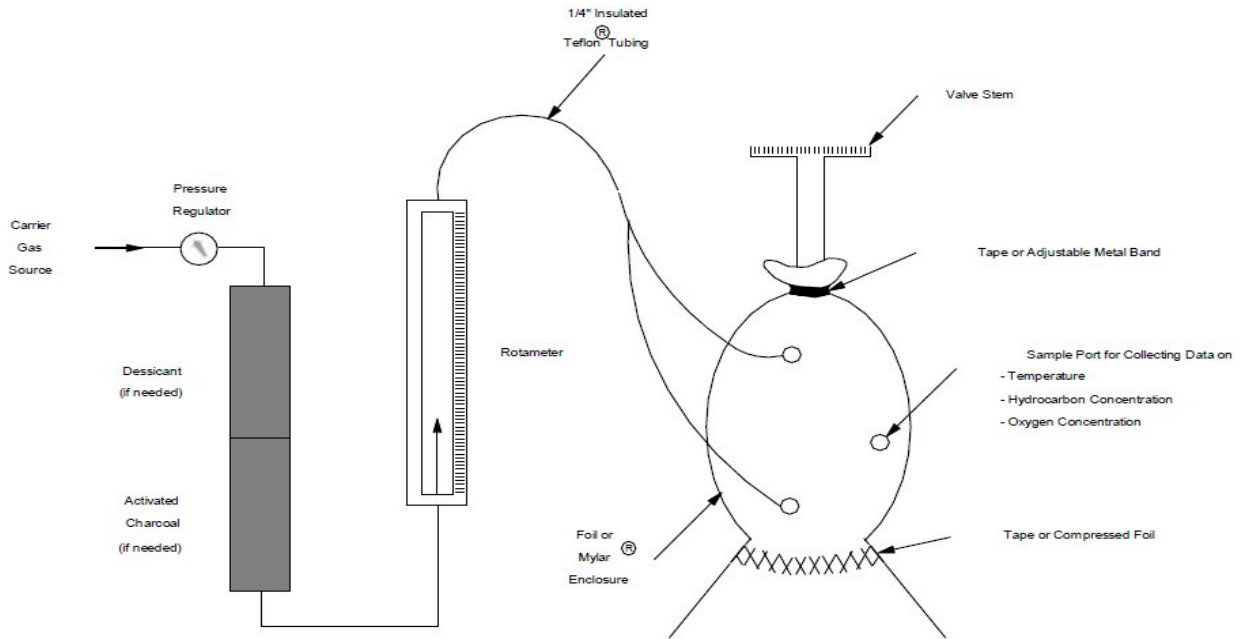Foil or Mylar® Enclosure

Tape or Compressed Foil

Table 2-2. Equipment Leak Rate for Petroleum and SOCMI Equipment

Equipment Type (All Services)	Default Zero Emission Rate (kg/hr/source)	Pegged Emission Rates (kg/hr/source)		Correlation Equation[b] (kg/hr/source)
		10,000 ppmv	100,000 ppmv	
Leak Rates for Petroleum Industry (Refinery, Marketing Terminals, and Oil and Gas Production)				
Valve	7.8E-06	0.064	0.14	$2.29\text{E-}06 \times SV^{0.746}$
Pump	2.4E-05	0.074	0.16	$5.03\text{E-}05 \times SV^{0.610}$
Other[c]	4.0E-06	0.073	0.11	$1.36\text{E-}05 \times SV^{0.589}$
Connector	7.5E-06	0.028	0.030	$1.53\text{E-}06 \times SV^{0.735}$
Flange	3.1E-07	0.085	0.084	$4.61\text{E-}06 \times SV^{0.703}$
Open-ended line	2.0E-06	0.030	0.079	$2.20\text{E-}06 \times SV^{0.704}$
Leak Rates for Synthetic Organic Chemical Manufacturing Industry (SOCMI)				
Gas valve	6.6E-07	0.024	0.11	$1.87\text{E-}06 \times SV^{0.873}$
Light liquid valve	4.9E-07	0.036	0.15	$6.41\text{E-}06 \times SV^{0.797}$
Light liquid pump[d]	7.5E-06	0.14	0.62	$1.90\text{E-}05 \times SV^{0.824}$
Connector	6.1E-07	0.044	0.22	$3.05\text{E-}06 \times SV^{0.885}$

Note: kg/hr./source = kilograms TOC per hour per source
a Data reported in U.S. EPA, 1995b.
b SV is the screening value (SV, ppmv) measured by the monitoring device.
c The "other" equipment type was developed from instruments, loading arms, pressure relief devices, stuffing boxes, vents, compressors, dump lever arms, diaphragms, drains, hatches, meters, and polished rods. This "other" equipment type should be applied to any equipment other than connectors, flanges, open-ended lines, pumps, or valves.
d The light liquid pump factors can also be applied to compressors, pressure relief valves, agitators, and heavy liquid pumps.

- When a screening value is zero use the default zero in Table 2-2 to estimate TOC emissions.
- When the meter is pegged (goes to the maximum) use the pegged values in Table 2-2 are used to estimate emissions.
  - Note - one value for instruments with a maximum of 10,000 and another for 100,000
- The uncertainty of the correlations for any single measurement may be as much as a factor of 3 higher or a factor of 10 lower than the actual but when summed over thousands of components, the uncertainty in the cumulative total emissions is expected to be much less.
  - Example – Monte Carlo simulations of 100 leaking components using an uncertainty of plus or minus a factor of 10, the uncertainty in the cumulative emissions is approximately plus or minus a factor of 1.4

Hi-Flow Monitor

- **High volume sample allows for direct measurement of mass**
  - **Method 21 with an OVA is a point measurement**

Table 2-3. Screening Ranges Emission Factors [a]

Equipment type	Service	Refinery Factors[b]		SOCMI Factors[c]	
		≥10,000 ppmv emission factor (kg/hr/source)[b]	<10,000 ppmv emission factor (kg/hr/source)[b]	≥10,000 ppmv emission factor (kg/hr/source)[c]	<10,000 ppmv emission factor (kg/hr/source)[c]
Valves	Gas	0.2626	0.0006	0.0782	0.000131
	Light liquid	0.0852	0.0017	0.0892	0.000165
	Heavy liquid	0.00023	0.00023	0.00023	0.00023
Pump and agitator seals	Light liquid	0.437	0.0120	0.243	0.00187
	Heavy liquid	0.3885	0.0135	0.216	0.0210
Compressor seals	All	1.608	0.0894	1.608	0.0894
Pressure relief valves	All	1.691	0.0447	1.691	0.0447
Connectors	All	0.0375	0.00006	0.113	0.000081
Open-ended lines	All	0.01195	0.00150	0.01195	0.00150

a. Data reported in U.S. EPA, 1995.
b. These factors are for non-methane organic compound emissions.
c. These factors are for total organic compound emissions.

The EPA takes the recorded methane PPMv screening value (SV) and converts it to a mass emission rate (ER) in kg/hr using a correlation chart measured in real world plants.

See link in excel file for document **https://www3.epa.gov/ttnchie1/efdocs/equiplks.pdf**

The SV can be changed depending on the content of the leak media using a correction factor i.e. for different hydrocarbons and /or hydrocarbon mixes, but they then still use the same conversion method to get to a final kg/hr ER.

So when measuring in PPMv, the idea was always to end up finally with a mass flow rate. i.e. measuring PPMv was only to get to an indication of the mass flow rate.

The idea was that because there are measurements at lots of points when measuring a whole plant it is not necessary to be accurate, because it sorts itself out with the average over many measurements.

Now in labs it is possible to measure the mass flow rate directly and accurately, using either displacement of helium or methane. So there is no need to make many measurements. At these leakage levels mass spectrometers are not even required.

Therefore we should measure in mass flow rates and convert back to expected PPMv rates. Not measure in PPMv directly as that is, by the EPA's own admission, inaccurate unless done many times.

Also we all know the EPA also have a kg/hr level for a 0 PPM reading. It is about 5 x 10-7 kg/hr (~1.50e-4 mg/s) for "connections" this is all in the EPA document linked in the excel file.

For final limits for the test in Germany they like 0.01 mg/s Helium as a leakage allowance,

using this EPA method that's a PPMv reading of around 20 PPM, our old limit of 0.1 mg/s would have been around 500 PPM.

While we want to follow EPA criteria that is used in the field (since that is mostly what end-users care about), we don't think laboratory tests need to be concerned with "screening values" and mass emission rates. While we are "sniffing" leaks, the method that we are proposing should be capturing most, if not all the gas coming out, which is not the case for field screenings.

For methane testing. Most sensors being used report in PPMv. If they are calibrated according to API 622/624/641, then the sampling rate is standardized as 1000 cc/min. So the PPMv reading can be easily and accurately converted to a leak rate by dividing by 1000 for a cc/min leak. So 100 PPMv equals 0.1 cc/min leak rate. If mass flow is wanted, then multiply by the density of the gas. (.66mg/cc for methane)

For helium mass spectrometers, it is common to use flow standards to calibrate. The PPMv output given by machine is calculated from an average sampling rate. Pfeiffer samples at about 40 cc/min for sniffing. So a 100 PPMv concentration at a 40 cc/min sampling rate would equal 0.004 cc/min. Conversely, a 0.1 cc/min helium leak rate equals 2500 PPMv.

So there is the dilemma using 2 different gases. Do we set the allowable as a PPMv or a flow rate?

Density when added to the equations will complicate things even further.

Optical Gas Imaging (OGI)

Advances in Optical Gas Imaging (OGI) Technology allows improved Leak Detection and Repair (LDAR) surveys by more efficiently identifying fugitive sources. Unfortunately they are not too good at quantifying emission rates. Other methods can be used when leak identified.

- An owner of an affected source who chooses to use the alternative work practice must comply with the requirements of paragraphs (e)(1) through (e)(5).
    - (1) *Instrument specifications:* The optical gas imaging instrument must comply with the requirements specified in paragraphs…
    - (2) *Daily instrument check:* On a daily basis, and prior to beginning any leak monitoring work, test the optical gas imaging instrument at the mass flow rate determined in paragraph…
    - (3) *Leak survey procedure:* Operate the optical gas imaging instrument to image every regulated piece of equipment selected for this work practice in accordance with the instrument manufacturer's operating parameters. All emissions imaged by the optical gas imaging instrument are considered to be leaks and are subject to repair.
    - (4) *Recordkeeping:* Keep the records described in paragraphs…
    - (5) *Reporting:* Submit the reports required in the applicable subpart.

Toxic Vapour Analyser

A common alternative is to use Toxic Vapour Analyser (TVA), which use photo ionisation detectors (PID). There is a further option using detectors that use the principle of Flame Ionisation (FID).