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Revision Memo

- 12/01**
1. Editorial revisions.
 2. References updated.
 3. Revised tank emission reduction tables based on new emission estimating procedures.
 4. Fugitive section revised pump guidance and pressure relief valves guidance.
 5. Tanks section new guidance on slotted guidepoles.



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SCOPE

This section of Design Practices discusses the selection of equipment and procedures for controlling air emissions of hydrocarbons, air toxics and other materials from fugitive sources, atmospheric storage tanks, wastewater collection and treating systems, and loading operations. It also includes guidance on how to respond to odor complaints.

Detailed design procedures and specifications are, in general, not contained in this DP section. For each of the technology areas described, the reader is referred to the appropriate DP and GP sections where the additional information is provided. The reader should also consult with a technology specialist for help in the selection and design of specific control equipment.

REFERENCES

DESIGN PRACTICES

DP II	Design Temperature, Design Pressure and Flange Rating
DP X-G	Pumps, Shaft Sealing
DP XI	Compressors
DP XV-C	Safety in Plant Design-Pressure Relief Devices
DP XV-J	Safety in Plant Design-Docks, Loading Racks and LPG Storage Facilities
DP XVIII-B	Industrial Hygiene
DP XIX-A1	API Separators
DP XIX-A2	Flotation Units
DP XXII	Atmospheric Storage
DP XXIII	Basic Loading Systems

GLOBAL PRACTICES

GP 3-2-1	Industrial Sewer Systems
GP 3-2-4	Pressure Relief Systems
GP 3-2-7	Manual Sampling Systems
GP 3-6-4	Vents, Drains, Flushing and Cleaning Connections
GP 3-12-1	Valve Selection Criteria
GP 3-12-8	Block Valve Packing Systems
GP 3-15-1	Pressure Relief Valves
GP 3-16-1	Flanges, Gaskets, Bolting and Fittings
GP 9-4-1	Atmospheric Storage Tanks
GP 9-7-1	Accessories for Atmospheric Storage Tanks
GP 9-7-3	Vents for Atmospheric Storage Tanks
GP 9-7-4	Internal Floating Covers for Atmospheric Storage Tanks
GP 10	Pumps, Compressors
GP 15-9-1	Control Valves
GP 15-8-1	Process Stream Analyzers

COMPANY MANUALS, APPLICATION GUIDES AND REPORTS

TMEE-23	EMRE Manual <i>Pump Sealing Technology Manual</i>
TMEE-46	EMRE Manual <i>Emissions Estimating Guide</i>
TMEE-61	EMRE Manual <i>Leak Detection and Repair (LDAR) Manual</i>
EE.72E.94	ER&E Report <i>Odor Control</i>
EE.58E.94	ER&E Report <i>Valve Packing Fire Tests Reinforce Recommendation Not to Use All-Braided Packings</i>

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EE.19E.94	ER&E Report <i>Biofilters for Air Pollution Control</i>
EE.84E.93	ER&E Report <i>New Low Emission Control Valve Packings Successfully Demonstrated in Plant Performance Tests</i>
EE.35E.93	ER&E Report <i>Selection Guide for Storage Tank Emission Controls</i>
EE.34E.93	ER&E Report <i>Low Emission Block Valve Packing Guidelines Updated</i>
EE.15E.93	ER&E Report <i>Improved Valve Stem Packing Design Criteria and Materials Selection for Block Valves</i>
EE.101E.92	ER&E Report <i>Plant Performance Evaluation of Traditional Versus New Low Emission Control Valve Packings</i>
EE.38E.92	ER&E Report <i>Testing Low Emission Valve Packings - Results of PERF Project 90-05</i>
EE.32E.92	ER&E Report <i>Five Ring Graphite Packing Systems Effective in Reducing Emissions from Rising Stem Block Valves</i>
EE.19E.92	ER&E Report <i>Identification and Abatement of Machinery Fugitive Emissions</i>
EEOP	ExxonMobil Chemical Company Environmental Engineering & Operating Practices

AMERICAN PETROLEUM INSTITUTE PUBLICATIONS

Manual of Petroleum Measurement Standards, Chapter 19 - Evaporative Loss Measurement.

API 342	Fugitive Emissions from Equipment Leaks I: Monitoring Manual, May 1998.
API 343	Fugitive Emissions from Equipment Leaks II: Calculation Procedures for Petroleum Industry Facilities, May 1998.

CONCAWE REPORTS

85/54	Hydrocarbon Emissions from Gasoline Storage and Distribution Systems
87/52	Cost Effectiveness of Hydrocarbon Emission Controls in Refineries from Crude Oil Receipt to Product Dispatch
90/52	VOC Emissions from Gasoline Distribution and Service Station in Western Europe Control Technology and Cost Effectiveness
92/52	VOC Emissions from the Loading of Gasoline into Ships and Barges in EC-12: Control Technology and Cost Effectiveness

SOCIETY OF TRIBOLOGISTS AND LUBRICATION ENGINEERS PUBLICATIONS

SP-30	Guidelines for Meeting Emission Regulations for Rotating Machinery with Mechanical Seals
SP-32	Guidelines for Meeting Emission regulations for Compressors with Advanced Sealing Systems
SP-33	Guidelines for Controlling Fugitive Emissions with Valve Stem Sealing Systems

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY DOCUMENTS

AP-42	Compilation of Air Pollutant Emission Factors, Fifth Edition, 1995
EPA-454/R-93-032	National Air Pollutant Emission Trends, 1900 - 1992
EPA-625/6-91-014	Control Techniques for Hazardous Air Pollutants
EPA-453/R-95-017	Protocol for Equipment Leak Emission Estimates
EPA-625/R-93-005	Control Techniques for Fugitive Emissions from Chemical Process Facilities
EPA-453/D-93-056	Control of Volatile Organic Compound Emissions from Industrial Wastewater
EPA-453/D-93-057	Control of Volatile Organic Compound Emissions from Volatile Organic Liquid Storage in Floating and Fixed Roof Tanks
EPA-600/R-92-047	Reference Guide to Odor Thresholds for Hazardous Air Pollutants Listed in the Clean Air Act Amendments of 1990

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DEFINITIONS

Air Pollutant - Any substance in ambient air which is present above its normally occurring standard concentration. This pollutant may or may not be harmful and can include naturally occurring substances such as volcanic dust. Air Pollutants generally include the emissions from industrial and agricultural activities; from transportation sources such as cars, buses, trains and ships; and also from the treatment of human and animal wastes. Almost any human or animal activity, or any natural occurrence, can generate an air pollutant. Many regulatory agencies have developed lists of specific air pollutants which they have the authority to control.

Air Toxic - A pollutant that has the potential to cause adverse effects in the general population or the environment above a specified concentration.

Ambient Air Quality - A measure of the relative concentration of species in air compared to a concentration limit which may have an adverse effect on humans, animals, vegetation, materials, structures, visibility, or the quality of life. Many regulatory agencies have developed concentration limits for specific air pollutants. These limits are often different for indoor and outdoor air as well as for worker and community exposure. There may also be more than one limit based on the adverse effect being considered.

Anthropogenic Emissions - These are emissions from "man-made" sources or activities. They include industry, manufacturing, transportation, agriculture, waste treatment, households, and all other sources which are not naturally occurring.

Ozone (Tropospheric or Ground Level) - A compound, O₃, that is a principal component of smog and that can be formed in the atmosphere from the reaction of volatile organic compounds and nitrogen oxides in the presence of sunlight.

Primary Air Pollutant - An air pollutant that is in the same chemical form as when it was released, although the concentration of the pollutant may be changed.

Secondary Air Pollutant - An air pollutant that is present in a form other than as originally released. Secondary Air Pollutants are formed in the atmosphere by the reaction of one or more Primary Air Pollutants.

Smog - A complex mixture of substances that form in the atmosphere as a result of chemical reactions involving volatile hydrocarbons, nitrogen oxides and sunlight. Ozone is a predominant species in smog.

Volatile Organic Compound (VOC) - Compounds containing carbon that react with nitrogen oxides in the presence of sunlight to form ozone.

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BACKGROUND

Since refineries and chemical plants handle large quantities of volatile organic compounds (VOCs), some emissions of these compounds occur during normal operations. The largest source of VOCs is typically fugitive emissions (e.g., valves, flanges / connectors, pumps, compressors and other "piping" components). VOC emissions also come from storage tanks, loading operations, and wastewater treating. **Table 1** shows the major sources of VOC emissions to the air from process plants. The relative percents vary depending on the specific processes employed and the type of emissions controls installed. In almost all cases, fugitive emissions are the largest source of VOCs and air toxics. In those locations with large uncontrolled marine, rail, or truck loading facilities, loading emissions may also be high. In locations that have implemented a fugitives control program, and have large but uncontrolled loading emissions, the contribution from loading may exceed that from fugitives. Air emissions from tanks and wastewater treating are usually smaller than those from fugitives and loading.

TABLE 1
MAJOR SOURCES OF VOCs RELEASED TO THE AIR FROM PROCESS PLANTS

SOURCE	TYPICAL PERCENTAGES*
Fugitive Equipment Leaks	40 - 60
Loading	20 - 30
Wastewater Treating	5 - 15
Storage Tanks	5 - 15
Process Vents	5 - 15

* Actual values vary based on plant configuration and existing controls.

Emissions of VOCs often must be controlled due to regulations which limit the emissions based on their potential to react with nitrogen oxides to form ozone and also since some VOCs are considered toxic. Additional background on the contributions of VOC to ground level ozone is contained in the 1991 National Research Council report. Air toxics issues are reviewed in the 1994 text by Lipfert. Some VOCs also have the potential to cause annoying odors in the communities surrounding process plants.

The most applicable and economic control system will depend on the specific emission source, the level of controls already in place, and the target emission level. Controls range from increased monitoring and maintenance frequency for valve leaks, to replacing rim seals on floating roof tanks, to installing a complete vapor control system at a loading facility. The costs can vary widely. **Table 2** lists options for controlling emissions of hydrocarbons and air toxics. These are discussed in more detail in the remainder of this DP section.

Health effects from exposure to air pollutants above certain concentrations include irritation of the eyes, nose, and throat, and respiratory and cardiovascular distress. Different effects may result from either short or long term exposures. The effects of exposure to air pollutants is discussed in [Section XVIII-B1](#). More detailed information may be obtained from your local industrial hygienist or from ExxonMobil Biomedical Sciences, Clinton, N.J.

Regulations to control air pollution may require the application of specific control equipment or practices, place limitations on the emission rates of specific chemicals, or require the assessment of risk. It is important to determine which specific regulations may apply in each situation before selecting any air pollution controls. Contact the plant environmental coordinator for the most recent applicable regulations.

When equipment or practices are specified, it is often possible to substitute alternatives which result in an equivalent effect on the quality of the ambient air. In most cases, these alternatives include the choice of equipment on a specific emissions source or a nearby source of the same pollutant. More recently, emissions trading between different companies and even different pollutants has been utilized. Check with the local regulatory agency to determine if these alternatives are an option.

The following subsections provide details on control equipment and procedures for the sources listed in **Table 1**. Care should be taken in applying these approaches that all the requirements of the appropriate GPs and DPs are considered. Check the reference list for GPs and DPs related to this DP section. In addition, a technical specialist in each area should be consulted for help in selecting and designing specific control equipment.

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BACKGROUND (Cont)

TABLE 2
CONTROLS FOR HYDROCARBON AND AIR TOXICS EMISSIONS

FUGITIVE EMISSIONS

Initiate a leak detection and repair program.
 Install new packing sets in block and control valves.
 Upgrade pump and compressor seals.
 Consider "on-line" valve repair for large leakers.
 Route pressure relief valves to flare system or install rupture disks upstream.
 Use of leakless technology such as bellows valves and canned pumps.

TANK EMISSIONS

Fixed Roof Tanks

- Install vapor balance system.
- Install vapor recovery / destruction.
- Install internal floating roof.

External Floating Roof Tanks

- Check condition of existing seals.
- Replace vapor-mounted primary with liquid-mounted primary seal.
- Control losses from roof fittings.
- Install sleeve on slotted giodpole.
- Install secondary rim seal.
- Convert tank to internal floating roof design.
- Install vapor recovery / destruction after conversion to internal floating roof design.

Internal Floating Roof

- Check condition of existing seals.
- Replace vapor-mounted primary seal with liquid-mounted seal.
- Control losses from roof fittings.
- Install secondary rim seal.
- Install vapor recovery / destruction.

WASTEWATER TREATING EMISSIONS

Decrease wastewater volume and organic concentrations by improved housekeeping and source reduction.
 Optimize stripper operation.
 Install sewer system emission suppression (e.g., P-traps on drains).
 Reduce air / water contact area (covering, nitrogen blanketing, etc.).
 Replace API separator with covered corrugated plate separator.
 Replace DAF with covered IAF.

LOADING EMISSIONS

Use "submerged" loading in place of "splash" loading.
 Use vapor balancing during loading.
 Install vapor recovery / destruction system.

VENTS

Route to flare.
 Install vapor recovery / destruction system.

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CONTROLLING FUGITIVE EMISSIONS

Fugitive emissions, also known as "equipment leaks", are emissions from valves, connectors / flanges, pump and compressor seals, pressure relief valves, and other "piping components" located throughout any process plant. Although these emissions are sometimes visually detected, they are most often located with sensitive gas detection instruments placed adjacent to the leak point. When environmental engineers refer to levels of fugitive emissions, they typically use parts-per-million (ppm) values measured with these instruments.

Although fugitive emissions from a single piping component are in most cases extremely small, there are such a very large number of components throughout a process plant that fugitive emissions are usually the largest source of hydrocarbons and air toxics. Approximately half of the total fugitive emissions are from valves. The next largest contributors to fugitive emissions are generally connectors and flanges. As locations continue to reduce valve and pump emissions through monitoring and better equipment, connectors and flanges may become a much larger percentage of the total fugitive emissions.

Fugitive emissions can be controlled in several ways. In order of increasing cost these are: monitoring and maintenance; use of lower leak equipment; collecting emissions; and use of "leakless" technology. The choice will depend on the current and anticipated need for emissions control; equipment configuration; and the current plant performance.

Control techniques for fugitive emissions can be work practice and/or equipment related. The most cost effective control measure to reduce fugitive emissions is to initiate an inspection and maintenance (I&M) program (also known as Leak Detection and Repair - LDAR or monitoring and maintenance - M&M). For those locations without any current controls, instituting an annual I&M program may, in some cases, reduce losses an amount exceeding the cost of the program. Actual emission reductions depend on the current condition of the components, with reductions of at least 50 to 75 percent being typically achieved compared to average factor emission estimates. These programs can be optimized by more frequent inspection of those components found to be leaking more frequently.

An I&M program consists of using a sensitive gas detection instrument and sampling each piping component individually to determine the concentration of hydrocarbon adjacent to a potential leak point (e.g., the packing gland on valves or the seal on pumps). If the instrument detects hydrocarbon above a predetermined "leak" level, the equipment is repaired. The definition of "leak" level depends on local regulations, although 10,000 ppm is a generally accepted leak level. In some US locations, new regulations set the "leak" definition as low as 100 ppm for valves and connectors / flanges and 500 ppm for pumps and compressors. Two European Plastics Plants have used trained dogs as a pre-screening technique to reduce the number of components that need to be monitored using instruments.

Initial repairs for valves include tightening the packing gland to further compress the packing and seal the leak path (The packing gland should not be so over tightened that it prevents movement of the valve stem). If this is not successful then, when the valve is next out of service, the packing may need to be replaced with a new improved "low emission" packing design. In cases where the valve stem is corroded or there are other mechanical problems, the valve may need to be replaced during the next turnaround. Pump emissions may be reduced by using a multiseal design with a fluid barrier or essentially eliminated by the use of "canned" or magnetic drive designs. Additional equipment controls include rupture discs and soft seats for pressure relief valves, plugs, caps, and blinds for open ended lines and closed loop sampling systems.

INSPECTION AND MAINTENANCE PROGRAMS

The emissions reduction potential for an I&M program depends on several factors including the frequency of monitoring, the leak definition level, and the current performance. Programs that have higher monitoring frequencies and lower leak definitions will generally result in a greater reduction of fugitive emissions. The following subsection provides guidance in establishing an I&M program. For additional details see the *Leak Detection and Repair Manual*, **TMEE-061**.

Although fugitive emissions for plants with an I&M program have been found to be at least 50 to 75% lower than emissions estimated using "average" factors, the actual reductions attributable to the I&M program are smaller. This is due to the application of newer technologies and practices as compared to when the original data that was used to develop the average emission factors were collected in the late 1970s. **Table 3** provides estimates of the range of I&M program control effectiveness (i.e., the reduction that can be achieved when implementing a program where none previously existed) based on studies in both refineries and chemical plants.

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CONTROLLING FUGITIVE EMISSIONS (Cont)

TABLE 3
CONTROL EFFECTIVENESS OF INSPECTION AND MAINTENANCE (I&M)
PROGRAMS (FROM EPA-625/R-93-005 & EPA-625/6-91-014)

COMPONENTS	PERCENT EMISSIONS REDUCTION		
	ANNUAL MONITORING	QUARTERLY MONITORING	MONTHLY MONITORING
Valves - Gas	24	59 - 64	70 - 73
Valves - Light Liquid	NA	44 - 63	59 - 73
Pumps - Light Liquid	NA	33 - 71	61 - 83
Pressure Relief Valves	NA	44	53
Compressors	NA	33	NA

NA: Not available

Procedures

The purpose of a monitoring program may be to reduce emissions, collect data, or both. In locations without reporting requirements, it is to identify leaking components and conduct repairs so that emissions are reduced. The first step in starting a program is to determine which components will be included. Initially some programs may only include valves and pumps, or just valves in light liquid service. Components in heavy liquid services and connectors and flanges are usually not monitored.

Components may be identified based on a piping and instrumentation flow diagrams and unit inspections. Process streams should be followed in a logical order to identify all potential fugitive leak sources which may be included in the monitoring program. Tags or other markings on the components to be monitored greatly facilitate the effort if there is a need to collect and report the monitoring data on an individual component basis.

One method of monitoring is described in **US EPA Method 21** and associated manuals (see **EPA-453/R-95-017** and the API Monitoring Manual, Publication 342). Using this method, monitoring readings for non-moving components (e.g., valves, flanges, connectors) are obtained by placing the instrument probe at the surface of the leak interface where leakage could occur and within 1 cm of the leak interface for moving components (e.g., pumps, compressors). The probe must be perpendicular, not tangential, to the leak interface. The probe should be moved along the entire leak interface to find the maximum reading.

Fouling of the probe with grease, dust, or liquids should be avoided. A short piece of flexible plastic tubing can be used as a probe tip extender and snipped off as the tip is fouled. The probe may also be packed with untreated fiberglass to act as a particulate filter, but the instrument should then be calibrated with the "filter" in place.

For valves, the most common leak source is at the seal between the valve stem and the housing. To screen this source, the operator should place the probe where the stem exits the packing gland, and move it around the stem circumference. The screening value is the maximum recorded instrument reading. The probe should also be placed at the packing gland take-up flange seat, and moved along the periphery. Valve housings of multipart assemblies (bonnet flanges) should also be screened at the surface of all points where leaks could occur.

For flanges, the probe should be placed at the outer edge of the flange-gasket interface, and moved along the circumference of the flange. Bolts should also be checked. For screwed fittings, the threaded connector interface should also be monitored along its entire interface.

Pumps and compressors are monitored with a circumferential traverse at the outer surface of the pump or compressor shaft and seal interface where the shaft exits the housing. If the source is a rotating shaft, the probe inlet is positioned within 1 cm of the shaft seal interface. If the housing configuration prevents a complete traverse of the shaft periphery, all accessible portions should be sampled, as well as all other joints on the pump or compressor housing where leakage could occur.

The configuration of most pressure relief devices prevents monitoring at the sealing seat. Because of their design and function, pressure relief devices should not be monitored during likely upset conditions or at other times when they are likely to activate. Instrument readings are taken with the probe tip placed at approximately the center of the exhaust area. The plant safety engineer should be involved in establishing proper procedures for monitoring fugitive emissions from pressure relief devices.

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CONTROLLING FUGITIVE EMISSIONS (Cont)

Monitoring Instruments

There are many different types of analyzers which can be used to measure fugitive emissions leaks. These analyzers operate on a variety of principles, but the three most common types are flame or photo ionization, infrared absorption, and combustion. The choice of device should be based on the types of compounds to be measured, convenience, and any local regulatory requirements. A list of some of the available instruments consistent with using **EPA Method 21** is contained in **TME-061**.

Ionization detectors are the most popular fugitive emission detector type. They operate by ionizing the gas sample and then measuring the charge (number of ions) produced. Flame ionization and photo ionization are the two methods of ionization currently used. Photo ionization detectors use ultraviolet light (instead of a flame) to ionize the organic vapors. Certain organic compounds containing nitrogen or oxygen are difficult to measure with a flame ionization device and an alternate method must be used. For example, since flame ionization detectors are not sensitive to formaldehyde, photo ionization detectors may be used for this application.

Nondispersive infrared instruments measure light absorption characteristics of gases. These instruments, however, are subject to interference from other gases such as water vapor and CO₂ which may absorb light at the same wavelength as the compound of interest. These detectors are generally used for streams of specific components at high concentration. The wavelength at which a certain compound absorbs infrared radiation is predetermined and the device is preset for that specific wavelength using optical filters.

Combustion analyzers are designed to measure either the thermal conductivity of a gas or the heat produced by combusting the gas. A limitation is that combustion analyzers exhibit reduced response to gases that are not combusted readily.

In the US, fugitive emission monitoring instruments need to meet the requirements of EPA Reference Method 21 (see Appendix 1 of **TME-061**). Most manufacturers sell devices which are designed to meet this requirement, and it is advisable that only instruments that meet Method 21 be purchased so that emissions estimates can be properly interpreted. EPA Reference Method 21 requires that the analyzer meet the following specifications:

- The VOC detector shall respond to those organic compounds being processed.
- The analyzer shall be capable of measuring at the "leak" definition.
- The scale of the analyzer shall be readable to +/- 5 percent of the "leak" definition.
- The analyzer shall take a continuous sample at a flow rate between 0.5 and 3.0 liters/minute.
- The analyzer shall be intrinsically safe for operation in explosive atmospheres.
- The instrument response factor must be less than 10 unless a correction curve is used.
- The instrument response time must be less than or equal to 30 seconds.
- The calibration precision must be less than or equal to 10 percent of the calibration gas value.

When an analyzer is calibrated with a reference gas, an equivalent instrument reading will not be obtained when measuring emissions of other gases because the analyzer responds differently to different compounds. A "response factor" is required to provide an accurate relationship when using an analyzer calibrated for one gas to measure leaks of other compounds. For example, if an instrument is calibrated with methane, different values will be obtained for the same concentration of any other gases.

A response factor of 1.0 means that the instrument readout is identical to the actual concentration of the chemical in the gas sample. A response factor greater than 1.0 results in an instrument readout that is proportionally lower than the actual concentration. A high response factor means that the instrument does not detect a compound very well. Many manufacturers provide response factors for their instruments when calibrated with either methane, hexane or butane.

Response factors are for pure gases at specified concentrations using a particular instrument. A listing of response factors for several different instruments is contained in Appendix 4 of **TME-061**. Although a pseudo response factor for a mixture may be obtained by adding the fractional contributions of the components, the behavior of response factors for mixtures is still not well understood.

Data Handling

Fugitive emissions monitoring often results in the collection of a very large quantity of data. The quantity depends on the number of components included in the program, the frequency of monitoring, and the type of information recorded. A basic system usually includes data on the type, number, service and location of components, screening values, equipment and conditions, and emissions estimates. The quantity of data collected will depend on the purpose of the monitoring program and local regulatory requirements. The data will usually be used by the monitoring personnel as well as the maintenance and environmental / regulatory areas. **Table 4** contains a list of suggested data that should be collected and maintained.

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Additional data on the components may be advantageous for planning further emissions reductions if warranted. These include manufacturer, model and other specific component information that may be used to identify better performing components.

TABLE 4
DATA COLLECTION SUGGESTIONS FOR I&M PROGRAMS

MODE	RECOMMENDED DATA
Monitoring Data	• Monitored value • Test date • Instrument used • Calibration gas used • Instrument response factor • When instrument calibrated • Background reading • Instrument maximum reading • Date of repair, if required • Instrument maximum reading after repair • Date of repeat reading
Component Data	• Component type • Component unique identification number • Monitoring frequency • Process • Stream • Type of service (H₂, gas, light liquid, heavy liquid) • Location • Accessible / Inaccessible

VALVES

Valves are used to control the flow of fluid through process piping. Most valve designs involve the lowering or rotating of a part of the valve internals so as to block the flow of the process fluid. A valve stem connects these internal parts that are lowered or rotated to outside the valve where they can be manually or automatically operated. The valve stem connection provides a potential leak path for fugitive emissions of the process fluid. Valves and packing should be selected in accordance with the requirements of **GP 3-12-1** and **GP 3-12-8**.

The valve stem requires a seal surrounding the stem to isolate process fluid inside the valve from the atmosphere. This seal is provided by a packing arrangement which, for rising stem gate valves, should be designed in accordance with **GP 3-12-8**.

The major factors affecting fugitive emissions from valves are the design and condition of the packing, and the design and condition of the valve. Low emission block valve packings consisting of 5 rings, with the three die-formed center rings of lower density flexible graphite and the bottom and top end rings being either graphite composite or interlaced braided graphite, are recommended. The preferred 5-ring graphite design provides for 3 sealing rings with the two end rings preventing the extrusion of the sealing rings. The lower density graphite sealing rings (70 lb/ft³, 1120 kg/m³) have performed better in leak testing than have the higher density (90 lb/ft³, 1440 kg/m³) ones. End rings should have a minimum density of 100 lb/ft³ (1600 kg/m³). Packing sets that consist of "all-braided" rings (either provided as sets or from spools) should not be used in VOC services due to their relatively high emissions. In addition, some all-braided packing designs do not meet the requirements of the Exxon valve packing fire safety test (see **EE.58E.94**). Braided design is acceptable for the top and bottom end rings, however. In addition, asbestos type valve packings are not recommended due to the potential personnel health concerns and because they do not control emissions as well as the newer graphite packing sets. Emission control performance of several different packings are reviewed in **EE.104E.98**, **EE.34E.93** and **EE.38E.92**. Valve packing for rising stem gate valves should be selected in accordance with **GP 3-12-8**.

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The use of more than 5 packing rings is not generally recommended under normal circumstances. Additional rings will usually not improve sealing and may actually lead to poorer performance since gland sealing forces are not effectively transmitted throughout the packing set when a large number of rings are utilized. In addition, the extra rings add to the packing consolidation, potentially requiring more frequent tightening of the packing gland. Spacing rings to shorten the effective depth of the stuffing box should be used on existing valves with large valve stuffing boxes that would normally accommodate more rings. New valves should be specified with stuffing boxes sized to accommodate a standard 5-ring packing set. See **EE.32E.92** for additional information.

Many plants have had reservations about using the 5-ring packing sets for field replacements on existing valves due to the perceived difficult installation or limited stocking. There are several newer types of graphite spool packings, however, that will pass the ExxonMobil fire test and may also provide for good control of fugitive emissions. Contact EMRE's Air Quality Control Group for the latest on recommended valve packings.

Maintaining packing gland bolt and nut tightness is a major part of reducing fugitive emissions. It should be used as a first attempt to decrease leak rates. In addition, valve packing glands should be checked and if necessary retightened after any shutdown or severe thermal cycling. A torque wrench should be used to tighten the gland bolts to ensure that the proper force is placed on the packings. In most cases, the packing manufacturer will recommend the bolt torque or packing compression. ER&E experience indicates that these recommendations do not always result in the maximum level of emissions control. The most effective method to set packing compression is to use a monitoring instrument to detect the quantity of emissions as the final bolt torque or packing compression is set.

Mechanical design features of the valve such as stem and stuffing box clearances and finishes may play a very important part in controlling emissions. Stem corrosion and pitting is known to be a major cause of poor valve emission control performance since the packing can be damaged each time the valve is cycled and the stem moves up and down. This is especially a problem in valves that are cycled frequently. See **EE.15E.93** for additional details.

Control valve designs are available that provide for high levels of emissions control. These low emission control valves are often cost effective based on decreased maintenance alone and are recommended for all new and retrofit installations even where there are no fugitive emission regulations. Results of emissions field testing are presented in **EE.84E.93** and **EE.101E.92**. When replacing the existing packing in control valves, care should be taken to determine if stem dragging (hysteresis) will increase resulting in the need for a different actuator. An instrument specialist should be consulted when selecting control valve types or packing. See also **GP 15-9-1**.

Control valve packing is sometimes designed as two sets of 4 to 5 rings each separated by a lantern ring. The lantern ring allows monitoring of the area between the two packing sets for early signs of leakage. It may also serve as a means to collect leakage into a vapor control system. Control valves should be selected in accordance with **GP 15-9-1**.

Maintenance for valves with stuffing box / packing arrangements involves periodic monitoring and retightening of the packing gland to compensate for wear and relaxation of the packing. In many cases, the manufacturers' recommendations for packing compression have been found to be far from the optimum. Therefore, it may sometimes be necessary to determine the correct packing compression by leak testing at the valve stem while the gland bolts are tightened. Care should be taken so as not to over tighten the gland bolts such that the valve becomes inoperable. When tightening of the packing gland no longer maintains leakage at desired levels, the packing should be replaced.

Valve packing is available in many different designs and materials and almost all manufacturers now seem to advertise that their products can meet the most stringent fugitive emissions regulations. The more expensive packings do not necessarily provide improved emissions control performance. Testing by ER&E has indicated that some packings perform better than others (see **EE.38E.92**). Contact EMRE's Air Quality Control Group when considering alternative packings for either new or replacement installations.

A new "on-line" valve stem and flange leak repair procedure has been used successfully at some Exxon locations. Sealing is achieved by injecting a pliable mixture of granulated graphitic material and silicone carrier through the fitting into the valve stuffing box, or into a flange that has been mechanically enclosed. The injection fitting is permanent and multiple future injections, if necessary, are possible. Because of the technology's relatively recent application, long term performance is not known. Additional information on the application of "on-line" injection is available from the Environmental Engineering Group, ExxonMobil Chemical Company, Baytown, TX.

"Live loading" is a means of applying a predetermined constant load on the packing gland to potentially reduce the frequency of packing gland adjustment and maintain low emissions performance. The technique provides for automatic gland adjustment to keep the packing under constant pressure, reducing the need for repeated bolt tightening. Disk or coil springs installed on the gland stud bolts, on the gland itself, or in the stuffing box are used to maintain a continual load. The springs maintain the predetermined load on the packing as it consolidates due to internal compression, shrinkage, wear, and thermal cycling. In many cases, live-loading can be retrofit onto existing valves provided the bolts are of sufficient length. The benefits of live loading have not yet been conclusively demonstrated for block valves. The technique has been incorporated, however, in many of the new "low emission" control valve designs.