CCME

Canadian Council of Ministers of the Environment
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ENVIRONMENTAL CODE OF PRACTICE FOR THE MEASUREMENT AND CONTROL OF FUGITIVE VOC EMISSIONS FROM EQUIPMENT LEAKS

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The Canadian Council of Ministers of the Environment (CCME) is the major intergovernmental forum in Canada for discussion and joint action on environmental issues of national, international and global concern. The thirteen member governments work as partners in developing nationally consistent environmental standards, practices and legislation.

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Environmental Code of Practice for Measurement and Control of Fugitive VOC Emissions from Equipment Leaks

Abstract

The CCME Environmental Code of Practice for the Measurement and Control of Fugitive VOC Emissions from Equipment Leaks has been prepared as an initiative of the CCME Management Plan for NO_x/VOC. The Code has been developed for petroleum refineries and organic chemical plants. It can have application in other industries producing or using volatile organic compound (VOC) streams. In this document, environmental considerations have been developed for the measurement and control of VOC emissions from equipment leaks in operating plants. Practices are included for the application, performance, testing for compliance, record keeping and measurement of emissions. These practices are intended to reduce the contribution of fugitive VOC emissions from equipment leaks. The Code has been prepared by a multi-stakeholder task force, consisting of federal, provincial and regional governments as well as industry and environmental groups.

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Glossary of Terms

The words and phrases used in this Environmental Code of Practice shall have meanings as follows unless otherwise indicated by the context.

Bagging - enclosing an equipment component with a bag to measure its leak rate.

Component - a specific piece of process equipment, i.e. pump seal, connector, valve, flange, compressor seal, vent, etc.

Connector - flanged, screwed or other joined fittings used to connect two pipes or a pipe and a piece of process equipment.

Control Device - an enclosed combustion device or vapour recovery system or any other device used to control emissions to the environment.

Emission Factor - the mass emission rate per component, applicable to populations of sources (valves, flanges, etc.), which has been determined by averaging field measurements of a number of similar components. It is used to characterize the emissions from a given individual component.

Fugitive Emissions - VOC emissions or leaks coming from equipment.

Inaccessible Source - equipment that for monitoring is more than 2 metres above a permanently available support surface. Equipment that is unsafe to monitor, which could expose monitoring personnel to imminent hazard from temperature, pressure or explosive process conditions. A source may also be inaccessible because it is cover protected or insulated.

In gas/vapour service - equipment in use which contains process fluid that is in the gaseous state at operating conditions.

In heavy liquid service - equipment in use which is handling hydrocarbons with a vapour pressure less than 1.013 kPa (0.147 psia) at 20 degrees centigrade.

In light liquid service - equipment in use which contains a light hydrocarbon liquid with a vapour pressure greater than 1.013 kPa (0.147 psia) at 20 degrees centigrade.

In vacuum service - equipment in use which is operating at an internal pressure which is at least 5 kPa below ambient pressure.

Leak - the VOC concentration as determined by a monitoring instrument at which action will be initiated to rectify the problem; that is, the point where a component is identified as a "leaker".

Leak Frequency - the percentage of leaking components over the total population of similar components.

Leaking Emission Factor - the per component mass emission rate associated with the population of sources (e.g. valves) with screening concentrations at or above the leak definition.

Leaking Source - a source whose screening concentration is greater than or equal to the leak definition.

Mass Emission Rate - the quantity of VOC released to the atmosphere through the leak point, in terms of total mass per unit time.

Monitoring Instrument - a portable hydrocarbon analyzer meeting the performance specifications given in U.S. EPA Method 21.

Non-emitting Source - a source whose screening value is 8 ppmv or less.

Non-leaking Emission Factor - the per component mass emission rate used to characterize the leaking sources with screening concentrations less than the leak definition.

Non-leaking Emitting Source - a source whose screening concentration is greater than 8 ppmv above background levels, but less than the leak definition.

Open-ended Valve or Line - a valve, except safety relief valves, having one side of the valve seat in contact with process fluid and one side open to the atmosphere, either directly or through open piping.

Organic Chemical Plant - a plant engaged in manufacturing activities as described in Statistics Canada Standard Industrial Classification No. 3712 and No. 3731; see Appendix B.

Petroleum Refinery - an establishment engaged in manufacturing activities as described in Statistics Canada Standard Industrial Classification No. 3611 and No. 3612; see Appendix B.

Process - includes all equipment and components used to treat, process, purify, transfer or route VOC streams to storage.

Repaired - equipment that has been adjusted or otherwise altered in order to eliminate a leak.

Response Factor -

$$RF = \frac{\text{actual concentration of a compound}}{\text{observed concentration for the detector}}$$

Response Time - the time delay after a step change in VOC concentration, at the input of a sampling system, to the time at which 90% of the corresponding final value is reached as displayed on the analyzer readout meter.

Screening - the process of using a monitoring instrument to measure the hydrocarbon concentration being emitted from a component.

Screening Concentration - the instrument reading, assuming appropriate calibration, of a VOC generally expressed in parts per million by volume (ppmv).

Speciation - the identification of each of the chemical species in a VOC emission.

Volatile Organic Compounds (VOC) - any organic compound that participates in atmospheric photochemical reactions, that is, any organic compounds other than the following which have been excluded because of their negligible photochemical reactivity: methane, ethane, 1,1,1-trichlorethane, methylene chloride, chlorofluorocarbons (CFCs), fluorocarbons (FCs), hydrochlorofluorocarbons (HCFCs).

Abbreviations

BACTEA	Best Available Control Technology Economically Achievable
CAA	Clean Air Act
CCD	Catalytic Combustion or Hot Wire Detectors
CCME	Canadian Council of Ministers of the Environment
CCPA	Canadian Chemical Producers Association
CMA	Chemical Manufacturers Association (U.S.)
CPPI	Canadian Petroleum Products Institute (was PACE)
ENGO	Environmental Non-Government Organization
EPA	Environmental Protection Agency (U.S.)
FID	Flame Ionization Detectors
FVE	Fugitive VOC Emissions
GVRD	Greater Vancouver Regional District
HAP	Hazardous Air Pollutants
IPAC	Independent Petroleum Association of Canada
LDAR	Leak Detection and Repair
LFV	Lower Fraser Valley, British Columbia
MACT	Maximum Achievable Control Technology
MTBF	Mean Time Between Failure
MUC	Montreal Urban Community
NO_x	Nitrogen Oxides
NAAQS	National Ambient Air Quality Standards
NDIR	Non-Dispersive Infrared Detectors
NESHAP	National Emission Standards for Hazardous Air Pollutants
NSPS	New Source Performance Standards
OVA	Organic Vapour Analyzer
PID	Photo Ionization Detectors
P&ID	Process and Instrumentation Diagrams
PSV, PRV	Pressure Safety or Relief Valve
QIP	Quality Improvement Program
SAR	Southern Atlantic Region
SIC	Standard Industrial Classification
SOCMI	Synthetic Organic Chemical Manufacturing Industry
TACB	Texas Air Control Board
TQM	Total Quality Management
TRI	Toxic Release Inventory
VHAP	Volatile Hazardous Air Pollutant
VOC	Volatile Organic Compound
WQC	Windsor-Quebec Corridor

Units of Measurement

°C	centigrade, temperature scale
kg/h	kilogram per hour
kPa	kilopascal, a unit of pressure
ppb	parts per billion
ppmv	parts per million by volume
psia	pound per square inch, a unit of pressure
psig	pound per square inch gauge

Preface

In October 1988, the Canadian Council of Ministers of the Environment (CCME) launched the development of a management plan for the control of emissions to the atmosphere of nitrogen oxides (NO_X) and volatile organic compounds (VOC). Phase 1 of a three-phase plan to resolve ground-level ozone problems by reduction of the ozone formation precursors, NO_X and VOC, was issued in May 1991. Three initiatives in the NO_X/VOC Management Plan (referred to herein as the "CCME Plan"), Initiatives V304, V607 and V609 call for the implementation of fugitive VOC emissions (FVE) inventory and leak reduction programs at organic chemical plants and petroleum refineries by 1993. V304 is directed at new organic chemical plants, while V607 and V609 address existing organic chemical plants and existing refineries, respectively. New refineries were not addressed because it was believed that there would be no new refineries built in the foreseeable future.

Ground-level ozone concentrations often exceed the Canadian maximum acceptable objective of 82 ppb in the summer months in a number of locations in Canada. Ground-level ozone is caused by the atmospheric photochemical reactions between NO_X and VOC under the effect of sunlight. Three regions are designated ozone non-attainment areas for the purpose of establishing interim emission targets for the Phase I Plan; these are the Lower Fraser Valley of B.C., the Windsor-Quebec Corridor in Ontario and Quebec and the Saint John area of Southern Atlantic Region.

A reduction in the formation of ground-level ozone can be achieved by control of emissions of NO_X and VOC.

This Code addresses only the reduction of FVE. As other issues arise, such as the control of Hazardous Air Pollutants (HAP), Air Toxics or Odour Control, modifications of the Code may result.

The Code of Practice applies to petroleum refineries and organic chemical plants. It may also be applied by the authority having jurisdiction to industrial plants that produce or use process streams that could result in FVE from equipment leaks.

Fugitive emissions are those that are not released through a stack, duct or other confined enclosure and are not treated or controlled by specific equipment. Such equipment leakage is defined as the uncontrolled loss of process fluid through the sealing mechanism separating the process fluid from the atmosphere. Leakage from such equipment may be characteristic of the equipment itself or may result from faulty equipment or inadequately maintained equipment.
This Code is performance-based and it will serve as a guideline for minimizing the emissions of VOC from fugitive sources through measurement, performance guidelines, record keeping and work practices.

The Code of Practice, published by the CCME, was developed by a multistakeholder Task Force chaired by Environment Canada (see the list of Task Force Members in Appendix A).

During the development of the Code, the Task Force benefited from contributions from the United States Environmental Protection Agency (EPA) and the Texas Air Control Board (TACB) who kindly provided time and expertise in the interpretation of the U.S. experience in FVE control.

Since 1988, the CCPA and the CPPI have undertaken a number of studies and assembled databases to support codes of practice. It is intended that this Code will promote a convergence to one guideline generally acceptable to all industries across the country. Subsections will be included to cover the particular needs of special industrial sectors as these needs are defined.

It is intended that this Code be offered to the authority having jurisdiction over environmental protection as a guideline to developing and implementing a program to assist plant owners/operators in reducing FVE.

The contributions of all participants and stakeholders who helped develop this Code are gratefully acknowledged.

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Introduction

This Code of Practice is intended as a reference document to help plant operating personnel, regulators and the public to implement consistent and uniform methods for the measurement, control and reduction of fugitive VOC emissions (FVE) from leaking equipment.

The Code specifically addresses Initiatives V304, V607 and V609 of the NO_X/VOC Management Plan approved by the Canadian Council of Ministers of the Environment (CCME) in November 1990 (hereafter called the "CCME Plan"). Initiative V304 refers to fugitive emission inventory and leak reduction programs at new organic chemical plants, while Initiatives V607 and V609 refer to fugitive emission inventory and leak reduction programs, respectively, at existing petroleum refineries and existing organic chemical plants in the LFV, WQC and SAR. The Code may also be used as guidance for any other industrial sector that handles VOC and requires reduction of emissions through control of equipment leaks.

The Code is written in eight parts and is intended as a map to facilitate implementation by the user.

Part 1 Describes the various sources and types of fugitive emissions and specifies the scope of the Code.

Part 2 Deals with the application criteria for the measurement and control of FVE.

Part 3 Summarizes the performance guidelines associated with equipment leak sources.

Part 4 Highlights the methodology applicable to ensuring that the field monitoring and the data gathered meet the requirements of the authority having jurisdiction.

Part 5 Provides the user with the requirements to ensure that the emission monitoring program meets the performance guidelines.

Part 6 Provides requirements for record keeping which will make the data useful to the owner and the jurisdictions.

Part 7 Contains recommendations for reporting the results of a monitoring program to the authority having jurisdiction.

Part 8 Makes recommendations on the good operating practices that will help the owner and authority having jurisdiction to implement FVE control in a simple and effective way.

Appendices

The Appendices include additional background data, explanations of various items and issues, reference tables, sample forms and detailed procedures to assist in the interpretation and implementation of the Code.

Part 1
Description of Fugitive VOC Emissions Control

Section 1.1 Fugitive VOC Emission Sources

1.1.1 Process equipment components that are sources of fugitive emissions through leaks include:

- block valves
- control valves
- pump seals
- compressor seals
- pressure relief valves
- equipment and piping flanges and connectors
- open-ended lines
- sampling connections.

Agitator seals are to be treated as pump seals using similar emission factors.

Connections to equipment or piping other than flanges would be threaded fittings and compression couplings.

Open-ended lines should be closed by a terminal valve or a blind flange or otherwise plugged.

Sampling connection systems should have closed purge or closed vent systems.

Section 1.2 Sources Not Included

1.2.1 Emissions that are released through a stack, duct or other confined controlled enclosure or sources controlled by specific equipment are not covered by the Code. Area sources are not included. These sources are specifically not included:

- stacks
- vents
- combustion systems
- storage tanks
- open storage piles
- ponds
- sludge drying beds
- cooling tower sumps
- wastewater separators.

Consideration of these other sources is addressed in other CCME Plan initiatives. These potential sources should be recognized and monitored when appropriate at the time of monitoring for fugitive VOC.

Section 1.3 Principles of Fugitive Emissions Control

The suggested approach to fugitive emissions control by order of priority is as follows:

- prevention by the selection of non-leaking or leak-tight equipment
- monitoring for detection of leaks
- reparation as promptly as possible, (LDAR)
- continuous upgrading or leak prevention achievements.

Installation of leak-tight equipment is the preferred option. Other alternatives such as capturing emissions and sending them to a control device may be considered by the authority having jurisdiction.

Part 2
Application Criteria
Section 2.1 General

2.1.1 The control of fugitive VOC emissions from leaking equipment will be implemented according to the requirements of this Code with due consideration given to the application criteria developed in this part.

2.1.2 Specific industry applications according to the CCME Plan are:

- under Initiative V304, all new organic chemical plants in Canada;
- under Initiative V607, all existing petroleum refineries and rerefineries in the provinces of British Columbia, Ontario, Quebec and New Brunswick; and
- under Initiative V609, all existing organic chemical plants in the provinces of British Columbia, Ontario and Quebec.

2.1.3 The Code is intended principally for organic chemical plants and refineries in areas of Canada where ground-level ozone concentrations exceed the Canadian maximum acceptable levels in summer months. The actual boundaries of the high ozone areas will be defined by the authority having jurisdiction.

2.1.4 Equipment carrying VOC streams should be monitored. VOC streams are process streams containing at least 10% VOC by volume.

2.1.5 Leak detection and repair (LDAR) will be applied to pipe sizes greater than or equal to 1.875 cm nominal diameter (3/4 inch).

Section 2.2 Exemptions

2.2.1 Components in continuous vacuum service.

2.2.2 Components in heavy liquid service.

2.2.3 Components that are inaccessible.

2.2.4 Valves less than 3/4" or 1.875 cm nominal size.

2.2.5 Valves that are not externally regulated (i.e. check valves).

2.2.6 Components that are of leakless design (i.e. sealless pumps, bellow seal valves, pumps with double mechanical seals and a barrier fluid at higher pressure than operating pump pressure).

2.2.7 Open-ended lines equipped with a cap, blind, flange, plug or second valve.

Part 3
Performance Guidelines

Section 3.1 General

3.1.1 Performance guidelines for the application of FVE measurement and controls will follow the articles of this section. Performance requirements are further discussed in Appendix C.

3.1.2 The owner/operator of a plant site will develop a plan for FVE reduction for approval six months after notification by the authority having jurisdiction, following approval by the CCME.

3.1.3 The owner/operator of a plant site may divide the plant site into manageable, distinct entities for the purpose of LDAR program implementation, management and reporting.

Section 3.2 Leak Definition

3.2.1 A leak in this Code is defined as the detection of a VOC concentration of 10,000 ppmv or more at the emissions source using a hydrocarbon analyzer according to the measurement protocol of Appendix F.

Section 3.3 Leak Detection and Repair

3.3.1 LDAR is required:

- quarterly for compressor seals and annually for all the other components;
- immediately after repair for any component that was found to be leaking;
- within 24 hours for a pressure relief valve that has been vented to the atmosphere.

3.3.2 The leak frequency should not be more than 2% for any group of components monitored, excluding the category pumps/compressors.

3.3.3 The leak frequency of pumps/compressors should be less than 10% of the total number of pumps/compressors or three (3) pumps/compressors, whichever is greater.

3.3.4 If the leak frequency for a component (e.g. flanges) is less than 2% in two or more successive required LDARs monitoring, a statistical sampling method for that component (see Appendix L), as approved by the authority having jurisdiction, may be used to demonstrate that the component is in compliance with the 2% leak frequency.

Section 3.4 Repair and Maintenance

3.4.1 The repair of leaks found during monitoring will be started within 5 working days and completed within 15 working days unless a plant shutdown is required or the number of components requiring repair is beyond the current capability of the maintenance resources (a record of these exceptions and when they were corrected should be maintained).

3.4.2 Components which cannot be repaired without a unit shutdown will be identified and the repair will be planned for the next shutdown.

Part 4
Methodology

Section 4.1 General

4.1.1 These guidelines provide a choice of estimation, measurement and leak reduction protocols that can be used by both plant operators and regulators. The guidelines should be referred to when establishing the level of compliance of a plant or site in meeting FVE reduction.

4.1.2 The preparation of an FVE inventory involves the identification of the VOC streams and the source of leaks, and the application of emission factors to those leaks. The stratified measurement method and use of the corresponding emission factors shall be the minimum for inventory preparation. Stratified emission factors for organic chemical plants and petroleum refineries are given in Appendix D, Table D-2.

4.1.3 Leaks for all components monitored shall be categorized using an instrument capable of meeting the requirements of a measurement protocol, which has been approved by the authority having jurisdiction. See Appendix F, Method 21, for a recommended measurement protocol.

4.1.3.1 Components should be monitored with consideration to the variables associated with leak detection. See Appendix E.

4.1.3.2 Significant factors to recognize in the field measurement of emissions to identify most likely leak sources are:

- service type: gas is more liable to leak
- process cycling: temperature and pressure
- VOC stream type: light molecules leak more
- type of equipment component: control valves, PRVs, open-ended lines.

4.1.4 Monitoring results obtained using an approved instrument should be recorded in a database of the operator's choice.

4.1.4.1 The results of the monitoring should be summarized in a report for the authority having jurisdiction in accordance with the requirements of Part 7 of this Code. A sample reporting package is included in Appendix K.

Section 4.2 Equipment Inventory

4.2.1 The owner/operator shall prepare an inventory for the plant of the total number of pieces of equipment or equipment components that are potential leak sources as defined in Section 1.1. Exempted leakless components should be included in this inventory.

4.2.2 The sources shall be categorized according to type, i.e. valves, pumps, etc.

4.2.2.1 Each component of a category should be further defined by size and service.

4.2.2.2 The equipment components could be further classified by service conditions such as temperature, pressure and volatility of process streams at the owner's/operator's discretion.

4.2.3 Take-offs from current accurate plant drawings and/or inventory should be included. Actual field surveys of the unit or plant components may be used for preparing an inventory.

Section 4.3 Emission Factors

4.3.1 Each category of components will be assigned an emission factor using stratified emission factors or better.

4.3.2 The owner/operator may use his choice of emission factors as long as the requirements of the level of compliance (see Part 5), as agreed by the authority having jurisdiction, are met.

4.3.3 The field measurement of component emissions will be done according to the protocol included in Appendix F, EPA Method 21.

4.3.4 The equipment used to measure the emissions from equipment leaks will meet the requirements of the protocol. A list of commonly used instruments and their specific characteristics are included in Appendix E.

4.3.4.1 The owner/operator may use an alternate instrument or method of measurement with the approval of the authority having jurisdiction.

4.3.4.2 The particular aspects of emission measurement along with associated difficulties are reviewed in Appendix E.

Section 4.4 Development of Emissions Inventory

4.4.1 Using the database generated in Section 4.1 and applying the appropriate factors determined in Section 4.3, the inventory of FVE will be calculated and recorded as an entry to the reporting form in Part 7.

4.4.2 The FVE inventory will be developed using the most current emission factors.

4.4.2.1 Organic chemical plants and refineries will apply the emission factors listed in Appendix D, Table D-2.

Part 5
Compliance

Section 5.1 General

5.1.1 A facility should meet the requirements of this Code within 3 to 5 years from the date of CCME approval of its publication.

5.1.2 The owner/operator of a plant site will be in compliance when the requirements of the Code as defined in Part 3 are met.

Section 5.2 Compliance Inclusions

5.2.1 A review of the site as a joint cooperative effort between the owner/operator and the authority having jurisdiction using the application criteria in Part 2 of the Code, and assessed on the FVE reduction requirements of the site location.

5.2.2 An inventory of sources and total emissions will be maintained by the owner/operator based upon the methodology in Part 4 of this Code (as required).

5.2.3 The results of the owner's/operator's monitoring and evaluation will be reported to the authority having jurisdiction in a pre-approved format. See Part 7, Reporting.

5.2.4 The owner/operator will maintain records for review by the authority having jurisdiction.

5.2.5 The owner/operator may propose and use an alternative method for meeting the required FVE reductions after approval from the authority having jurisdiction.

Section 5.3 Non-Compliance

5.3.1 When the conditions of Section 3.3 are not met then the owner/operator will repeat a full monitoring survey of all component sources at the next leak detection cycle.

5.3.2 In the case where two consecutive full monitoring cycles (after the agreed upon compliance deadline) fail to show a leak frequency of 2% or less for components excluding the category of pumps/compressors, the authority having jurisdiction may require the implementation of a Quality Improvement Program (QIP) for those categories of components not in compliance. See Appendix H for details on QIPs.

5.3.3 For the category pumps/compressors, if the leak frequency is greater than 10% of the total number of pumps/compressors or three (3) pumps/compressors, whichever is greater, the authority having jurisdiction may require the implementation of a Quality Improvement Program (QIP).

Section 5.4 Other Compliance Considerations

5.4.1 Processes enclosed in buildings under negative pressure and vented to atmosphere with 95% or better control of air movement and having a monitored control device are exempt from LDAR monitoring, subject to approval by the authority having jurisdiction.

5.4.2 The owner/operator is referred to Appendix G for a review of Equipment Standards which may be used to enhance the level of compliance through better technology.

Part 6
Record Keeping

Section 6.1 General

6.1.1 Records are to be kept in a form easily accessible by the authority having jurisdiction.

6.1.2 Records should be kept for at least three years or as required by the authority having jurisdiction.

6.1.3 The user is referred to Appendix K2 to K8 for a sample survey format which may be used to record the field data for various components.

Section 6.2 Objectives of Record Keeping

6.2.1 To develop an initial screening base for a plant site.

6.2.2 To provide a basis for the inventory of emissions.

6.2.3 To identify components screened.

6.2.4 To provide a basis for performance evaluation.

6.2.5 To keep track of leakers and repairs.

6.2.6 To identify inaccessible or unsafe-to-access components.

Section 6.3 Data Management

6.3.1 The method of data preparation and tools for storing field information from equipment monitoring will be the sole responsibility of the owner/operator.

Part 7
Reporting

Section 7.1 General

7.1.1 Reporting for compliance with performance guidelines will be done according to the requirements of the authority having jurisdiction with a uniform reporting format.

7.1.2 The data entries of a summary report will be set out as in Appendix K, Table K-1.

7.1.2.1 The K-1 report and attachments submitted to the authority having jurisdiction will be available to the public.

7.1.3 Annual reports will be submitted to the authority having jurisdiction by March 31 of the year following the year being reported or as required by the authority having jurisdiction.

Part 8
Recommendations

Section 8.1 General

8.1.1 Implementation of this Code must not compromise plant safety or the health of workers or the community.

8.1.2 The primary objective of the Code is the reduction of fugitive VOC emissions. It is appropriate that priorities be given to the most cost-effective alternatives available for meeting the objective.

8.1.3 Leak prevention strategies are preferred over control and reparation strategies.

8.1.4 Plant operating areas may be screened periodically using a gas tester or other instruments, set at the low range for detection (most sensitive) to sense elevated hydrocarbon levels. Follow-up leak monitoring should then be done with a prescribed analyzer to identify leaking components.

Section 8.2 Quality in Maintenance

8.2.1 Consideration should be given to a total quality management program which includes:

- identification of poor performing equipment and prompt repair and replacement of these units;
- an ongoing review and analysis of available technology;
- in-plant performance trials;
- frequent inspection of control valves, pumps and compressor seals; and
- rescreening of equipment that has been taken out of service as it is returned to service.

8.2.2 Records should be kept that identify all components sampled and provide measurement details for those found to be leaking. Records should document repair and replacement activities for leakers.

Section 8.3 Long-Term Planning

8.3.1 The owner/operator should endeavour to develop a long term plan for FVE reduction at his plant site.

8.3.2 It is recommended that leak reduction programs be carried out early in the calendar year in order to ease the ozone problem which peaks in the hot summer months.

8.3.3 In order to demonstrate compliance with the objective of the FVE control and reduction program, a record of effort and accomplishment over a period of time is suggested.

Section 8.4 Operating Practices

8.4.1 The owner/operator should consider the use of best available technology when replacing components in high leak frequency service. See Appendix I for additional comments on Equipment Standards.

8.4.2. The emphasis on FVE reduction should be on high leakers as a priority with a concerted effort to reduce those to an acceptable level.

8.4.3 Equipment should be monitored by trained personnel.

8.4.4 FVE should be measured recognizing the difficulties associated with weather conditions. See Appendix E for details of Leak Detection Variables.

8.4.5 Equipment monitoring should be carried out with an understanding of the variables associated with leak detection. See Appendix E for additional information.

Appendices

Appendix A

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Note: Some corresponding members joined the group during the development of the Code.

Appendix B
Canadian Industrial Codes for Petroleum Refineries and Organic Chemical Plants

Statistics Canada Standard Industrial Classification (1980)	EPA Standard Industrial Classification (International)
Major Group 36 - Refined Petroleum and Coal Products Industries	29
361 - Refined Petroleum Industries	
3611 Refined Petroleum Products Industry (except Lubricating Oil and Grease) Establishments primarily engaged in manufacturing a family of petroleum products except lubricating oils and greases. Establishments primarily engaged in manufacturing lubricating oils and greases are classified in 3612 - Lubricating Oil and Grease Industry. Alkylate, petroleum Butane gas, refinery Diesel fuel Feedstocks, petrochemical Fuel oils Gasoline (incl. aviation) Kerosene Liquified petroleum gases (LPG), refinery Naphtha Petroleum alkylating Petroleum bases for lubricating oils and greases Petroleum cracking and reforming Petroleum distilling Petroleum polymerizing and isomerizing Petroleum refining Propane gas, refining Refinery still gas Turbo fuel, aviation	2911
3612 Lubricating Oil and Grease Industry Establishments primarily engaged in manufacturing and blending lubricating oils and greases. Establishments primarily engaged in reprocessing waste oil are classified in this industry. Axle grease Cutting oils Differential oils Grease hydrogenating Grinding oils Lubricating oil and grease blending Lubricating oil purifying and rerefining Lubricating oils and greases Motor oils Penetrating oils Transformer oils Transmission oils Waste oil reprocessing	
Major Group 37 - Chemical and Chemical Products Industries	
371 - Industrial Chemicals Industries	
3712 Industrial Organic Chemical Industries Establishments primarily engaged in manufacturing organic industrial chemicals such as aliphatic acids, alcohol (except ethyl alcohol), glycol, unsaturated monomers, amine function compounds and betone and quinine compounds. Secondary products of establishments in this industry include plastic materials not shaped and additives for petroleum products. Establishments primarily engaged in manufacturing plastic materials not shaped are classified in 3731 - Plastic and Synthetic Resin Industry; those primarily engaged in manufacturing additives for petroleum products are classified in 3799 - Other Chemical Products Industries and those primarily engaged in manufacturing ethyl alcohol are classified in 1121 - Distillery Products Industry.	2824, 2869

Statistics Canada Standard Industrial Classification (1980)	EPA Standard Industrial Classification (International)
3712 Industrial Organic Chemical Industries (cont'd)	

Acetic acid and derivatives
Acetone (2-propanone)
Acetylsalicylic acid
Acids, organic (their anhydrides, halides, peroxide, peracids and derivatives)
Acrylic acid and derivatives
Acyclic hydrocarbons
Alcohols and their derivatives (halogenated,sulphonated, nitrated, nitrosated)
Aldehydes
Aldrin technical
Amino acids
Amino function compounds
Benzene (benzol)
Benzene hexachloride
Benzoic acids and derivatives
Beta-naphthol
Bisphenol A
Butyl alcohols
Camphor, natural and synthetic
Carbolic acid
Carbon tetrachloride
Chlorinated phenols
Chloroform
Citric acid
Cresols
Cresylic acid
Cyclohexane
Decyl alcohol
Dichlorbenzene, ortho-, para-
DDT, technical (dichlorodiphenyltrichloroethane)
Esters
Ethyl chloride
Ethylene dibromide (ethylene bromide)
Ethylene dichloride
Ethylene glycol, mono-
Fatty acids and derivatives
Flourinated halogen hydrocarbons
Formic acids and derivatives
Glycerol (glycerine), crude or refined
Halogenated hydrocabon derivatives (aromatic, acrylic, saturated or not)
Hexamethylenediamine
Hexylene glycol
Hydrocarbons
Isophorone
Ketone-function compounds
Lactic acid
Lindane
Methyl alcohol (methanol, wood alcohol)
Methyl amyl alcohol
Methyl chloride
Methyl chlorophenoxyacetic acid (MCP or MCPA)
Methyl ethyl ketone
Methyl isobutyl ketone
Methylene chloride
Monoacids and their derivatives
Monohydric alcohols, saturated and their derivatives
Naphthalene
Nitrogen-function compounds
Octyl alcohol (2 ethylhexanol)
Organo-inorganic compounds
Organo-sulphur compounds
Oxygen-function acids and derivatives
Pentachlorophenol and its salts
Pentaerythritol
Perchloroethylene
Phenols and phenol-alcohols and their derivatives
Picric acid (trinitrophenol)
Polyacids and derivatives
Polyhydric alcohols and their derivatives
Propyl alcohols
Propylene glycol, mono-
Quinone-function compounds
Resorcinol (metadihydroxybenzene)
Salicylic acid
Salts of oxygen-function acids
Silicone fluids (exc. resins)
Sorbitol
Styrene monomer
Synthetic rubber, butadiene or butyl type
Tartaric acid (aromatic, acrylic, saturated or not)
Tetraethyl lead
Toluene (toluol)
Trichloroethylene
Trimethylol ethane
Urea (exc. fertilizer)
Vinyl chloride monomer (monochloroethylene)
Xylene (xylol)

Statistics Canada Standard Industrial Classification (1980)	EPA Standard Industrial Classification (International)
373 - Plastics and Synthetic Resin Industry	
3731 Plastic and Synthetic Resin Industry	2821, 2822, 2823
Establishments primarily engaged in manufacturing synthetic resins in such forms as powders, granules, flakes or liquids, or in compounding synthetic resins into moulding. Establishments primarily engaged in producing chemicals for use in making synthetic resins are classified in 3712 - Industrial Organic Chemical Industry. Acrylic resins Amino-aldehyde resins Cellulose acetate (incl. acetate butyrate) Cellulose nitrate (nitrocotton) Cellulose xanthrate (viscose) Cellulosic resins Coumarone-indene resins Epoxy resins Hardened protein resins Hydroxyethylcellulose Ion exchange resins Methylcellulose Phenol-formaldehyde resins Plastics and synthetic resins, condensing Plastic and synthetic resins, polymerizing (solution, emulsion, radiation) Plastics and synthetic resins, compounding and blending Plastics and synthetic resins, regenerating, precipitating and coagulating Polyamide resins (incl. nylon) Polyester resins Polyethylene resins Polypropylene resins Polyurethane resins Resins, condensation Resins, polymerization Silicone resins Sodium carboxymethylcellulose Styrene resins Synthetic resins Vinyl resins	

Appendix C
Performance Requirements

Performance guidelines are set out in Part 3 of the Code. In order to meet Canada's obligation internationally to reduce VOC emissions, it is necessary to establish the baseline levels for current emissions in real terms such as kilotonnes VOC per year. Future measurements must relate to this baseline quantity in order to properly quantify actual emission reductions achieved.

Estimates of total plant emissions without screening surveys are not sufficient for quantifying emission reductions. These estimates are useful in identifying possible magnitudes of emissions and the components and the types of service which yield high emissions. Reductions should be based on the results of field measurements to reflect the state of the equipment. Older equipment may tend to have more leaks due to wear.

Minimum Performance Requirements

In order to demonstrate compliance with the objective for measurement and prevention of fugitive VOC, a record of effort and accomplishment over a period of time is suggested. The minimum requirements suggested are:

a) Preparation of an inventory of all plant equipment components in VOC service.

b) LDAR program with a leak definition as set out in Part 3 for all plant components in VOC service. Alternatively, consideration may be given to accepting a program with sufficient field sampling of known non-leakers to allow statistically valid correlations to cover all plant equipment.

Records should be kept that identify all components sampled, leaking or non-leaking, provide measurement details and document repair and replacement activities for leakers.

This requirement will serve as a baseline for the total plant fugitive VOC emissions estimate.

c) Follow up screening programs to identify continuing progress in leak prevention and reduction.

d) Leak definition is currently set at 10,000 ppmv. It can become more stringent over time and may vary for different equipment components.

e) Demonstrated progress in meeting emission prevention targets.

Recommended Approach

Experience reported by U.S.A industry points to the necessity of updating drawings as a first priority to ensure:

- Δ reliable and consistent source of knowledge for the process units
- Δ accurate identification of equipment to be monitored
- Δ accurate database
- Δ no unnecessary work handling components which do not require monitoring.

It must also be remembered that a stepwise approach will ensure reductions sooner than if all VOC streams were to be addressed at once. Again, the U.S.A experience points out the value of doing one unit at a time completely (drawing update, tagging, database generation, monitoring), then moving on to the next. Doing otherwise has resulted in additional work to rectify errors and omissions due to pressure of line assembly approach.

The stepwise approach should also be applied to the types of VOC streams to be monitored. Light materials and gaseous process streams will carry more VOC and will likely be more prone to leaks. Heavier streams carry less VOC and on the whole would be a much lower percentage of the emission inventory.

A stepwise approach will allow implementation in a way that does not overburden the available resources while still providing meaningful VOC emissions reduction.

Appendix D
Emission Factors – Origin and Application

Methods of Estimating Fugitive Emissions

The methods for estimating mass emissions from process equipment leaks range from the use of emission factors with equipment counts to comprehensive field measurement techniques. These methods have evolved from a number of studies of the organic chemical and petroleum refining industries by the U.S. EPA.

The methods commonly used to estimate fugitive emissions, in order of increasing accuracy and increasing resource-intensiveness are:

- Δ Petroleum Refinery and "Average" SOCMI (Synthetic Organic Chemical Manufacturing Industry) Emission Factors
- Δ Leaking and Non-Leaking Emission Factors
- Δ Stratified Emission Factors
- Δ EPA Leak Rate/Screening Value Correlation Equations
- Δ Plant-Derived Process-Specific Leak Rate/Screening Value Correlation Equations.

Note: *It should be remembered that the above EPA methods are based on plant data that came from the SOCMI group and, as such, are biased on the high side due to the inclusion of **polyethylene** plants which operate at 15,000 to 40,000 psig. Also, the development of all these various methods to establish emission inventories in the U.S. EPA approach is based on the same set of SOCMI data; only a different method of analysis has been applied.*

1. Fugitive VOC Databases

A number of studies of fugitive emissions were carried out in the United States from the late 1950s through to the late 1970s. A need for better controls was recognized and between 1987 and 1989 the American chemical industry, with the help of the EPA, state authorities and interested environmentalists undertook an extensive data gathering program for evaluating fugitive emissions from equipment leaks. Twenty-five chemical companies participated, members of the Chemical Manufacturers Associates (CMA). They gathered data from 40 processing units in the following industries: acrolein, 1-3 butadiene, ethylene oxide and phosgene. All valves, pumps, compressors, safety valves and a statistical sampling of flanges and other connectors, altogether over 92,000 equipment components, were screened for leaks using the definition of a leaker as 10,000 ppmv. From the data gathered, the SOCMI emission factors were developed for estimating the total mass emission rate for fugitive emissions from a given count of equipment components. The information gathered allowed correlation equations to be developed that indicated the probable frequency of leakers as well as the probable leakage rates for various components.

The results of the SOCMI studies also indicated significant differences in leakage rates for different industries. Subsequent industry screening surveys revealed leak frequencies substantially lower than the EPA findings as shown in Table D-1.

TABLE D-1 COMPARISON OF LEAK FREQUENCIES FOR CRITICAL COMPONENTS RELATIVE TO THE ORIGINAL EPA STUDY

(values as average leak frequency %)

	Valves		Pumps	Flanges
	Gas Service	Liquid Service		
EPA	11.4	6.5	8.8	2.1
Butadiene (13 plants)	1.7	2.4	7.7	0.1
Ethylene Oxide (12 plants)	1.2	0.1	4.2	0.6
Acrolein (2 plants)	0.0	0.08	3.7	0.0
Phosgene (13 plants)	0.0	0.0	0.0	0.0

Source: Berglund, R.L., 1991

In the phosgene industry, 99.8% of the components screened at background air reading. The findings shown in Table D-1 illustrate the significant difference in leakage levels between industries and support the argument for continuing development of industry-specific leak-rate screening value correlation curves.

The difference in performance between industries has been attributed to:

- Δ quality of leak monitoring programs
- Δ effectiveness of maintenance programs
- Δ leak prevention measures.

Emission Quantification

Methods commonly used to estimate or measure the total quantity of fugitive VOC emissions from a plant have been developed from data collected in the United States under EPA programs. These methods are subject to revision and/or refinement as technology advances. These methods, in order of increasing precision, are as follows:

Petroleum Refinery and Average SOCMI Emission Factors

This is an estimate for total plant emissions made by multiplying an average emission factor for each type of equipment by the equipment count to obtain the emission rate. A complete count of each component type for a given service (e.g. gas, light liquid, heavy liquid) and a knowledge of stream composition is required. The plant equipment inventory and standard emission factors shown in Table D-2 are used.

Leak/No-Leak Emission Factors

This is the first level of leak survey sometimes referred to as component screening. Mass emission rates are not measured but equipment components are tested for leaks.

TABLE D-2 FUGITIVE EMISSION SOURCES AND EMISSION FACTORS FOR ORGANIC CHEMICAL PLANTS AND PETROLEUM REFINERIES

Equipment	Service	Stratified Screening Values, ppmv		
		0 - 1,000	1,001 - 10,000	> 10,000
		kg/source/h		
Valves	Gas/vapour Light liquid Heavy liquid	0.00014 0.00028 0.00023	0.00165 0.00963 0.00023	0.0451 0.0852 0.00023
Pump Seals	Light liquid Heavy liquid	0.00198 0.00380	0.0335 0.0926	0.437 0.3885
Compressor Seals	Gas/vapour	0.01132	0.264	1.608
Pressure Relief Valves	Gas/vapour	0.0114	0.279	1.691
Flanges	All	0.00002	0.00875	0.0375
Open-Ended Lines	All	0.00013	0.00876	0.01195
Threaded Connections	All	0.00002	0.00875	0.0375
Sampling Connections	All	Same as equipment components		

This table was developed by the U.S. EPA during its industry study. It is based on the average of the values obtained when screening the components. Components were defined as leakers when the screening value was more than 10,000 ppmv. The values measured were recorded and were subquently used to determine the typical emission rate such a component would have. This allows an estimate of emissions for similar components in the industry when inventories are required.

Caution: The factors are based on specific operating units. Direct application of the factors does not recognize the age or potential differences in operating conditions which could lead to very different emission rates. Field measurements have demonstrated that the factors over-estimate the true emissions in most cases. Sample field measurement to characterize a plant are recommended. Leakers are defined as > 10,000 ppmv concentration.

The number of leaking and non-leaking components of each type is multiplied by the appropriate emission factor to estimate the total emission rate.

In most instances it is expected that repairs can be made in the field immediately to stop leaks as they are identified.

Leaks are determined using hand-held portable explosion-proof instruments (see Appendix E) and the EPA Method 21 measurement protocol (Appendix F). A leak is defined in Method 21 as an emission resulting in a local concentration that yields an instrument reading equal to or greater than the reading of a reference standard, for example, methane at 10,000 parts per million by volume (ppmv).

Method 21 includes a description of an alternative leak screening test based upon the soap bubble test which may be used for locating leaks. Once located a leak would have to be measured against the reference standard using an instrument in order to determine whether to apply a leak or a no-leak emission factor for the particular component.

Stratified Emission Factors (minimum recommended for the Code)

The stratified emission factor method is a refinement of the leak/no-leak method and involves identifying several levels of leakage and assigning different emission factors for each level. The three screening ranges used by the EPA are: 0 - 1,000, 1001 -10,000 and > 10,000 ppmv. Plant inspectors may find that with very little extra effort several instrument response levels can be recorded. Use of the stratified method can yield estimates of total plant emission substantially lower than estimates using the leak/no-leak method.

EPA Leak Rate Screening Value Correlation Equations

For this method of estimating leak rates industry experience gained for certain specific component service conditions may permit the use of direct correlation equations to calculate an emission rate from the instrument reading obtained from a component. For example, the leakage rate using an OVA instrument for a SOCMI process valve in gas service may be calculated **(in ppmv)** using the following equation:

$$LR=4.4 \times 10^6 \text{ (instument reading, corrected) } 0.79$$

Using correlation equations, the total leakage from a number of components can be calculated.

Plant Specific Leak Rate Screening Value Correlation Equations

This method of estimating most closely approaches actual total emissions measurement for a plant. It requires comprehensive in-plant leak screening and measurement to the extent that instrument readings for component types in different services can be plotted against actual measured leakage rates and that sufficient data can be gathered to give statistical validity to derived correlation equations.
In order to measure actual component leakage rates a procedure known as component bagging is followed. This procedure involves totally enclosing an equipment component and measuring the flow rate of leakage.

Two methods of bagging currently in use are:

Vacuum or Dilution method - the leaking component is tightly enclosed, and a slipstream matching the leakage is collected under a vacuum maintained by measuring pressure. The flow is metered and the composition of the leaking stream is analyzed.

Blow-through method - the component is bagged and nitrogen is purged through. A sample is taken of the mixture in the bag.

The user is encouraged to contact experienced people in the business of equipment bagging to obtain the necessary knowledge or contract such work.

Area Leak Rate Measurement

There may be some instances where a whole process area may be monitored for leakage and when no leakage is observed, all of the contained equipment and components therein can be rated as non-leaking. It is also feasible to rigorously control some process area ventilation systems and to organize specific exhaust streams to monitor the flow and composition of those streams to allow calculation of total mass emission rates. Continuous emission monitoring of a process area or a building is preferred over attempting bagging or once-only isolation and measurement.

Appendix E
Leak Detection Variables

The efficiency and accuracy of the detection of leaks in a plant site depend on a number of factors. Each and every one of the factors listed has an impact on the results to a lesser or greater degree. The user of the leak detection equipment is cautioned to review the following before any measurement, in order that the data gathered can be assessed and classified as reliable:

- Δ Response factor of the chemical species being measured or the chemical mixture being measured;
- Δ Temperature at which measurements are being taken;
- Δ Physical variables associated with the leak measurement, such as pressure behind the leak, size of hole or porosity of the leaking component;
- Δ Wind effects during sampling;
- Δ Incorrect positioning of the sampling probe;
- Δ Interference from other nearby leakers affecting background levels;
- Δ Accessibility to components for sampling;
- Δ Interference from insulation coverings;
- Δ Instrument calibration errors;
- Δ Instrument malfunctions;
- Δ Slow instrument response time;
- Δ Precision of the instrument scale; and
- Δ Leaking probes, handles; plugged probes; oil droplets in probe.

Monitoring Instruments

Instrument Performance Criteria

Criteria for satisfactory monitoring instruments have been specified in Appendix F.

For many chemical plant applications the OVA is the preferred instrument. For petroleum refineries a TLV catalytic combustion detector may be preferred.

- Δ The instrument should be capable of measuring the leak definition concentration, i.e. 10,000 ppmv. For further discussion of measurement limits see Appendix J.
- Δ The instrument must have a calibration precision of equal to or less than 10 percent of the calibration gas value.
- Δ The instrument should have a reasonably quick response time, i.e. less than 30 seconds.
- Δ The instrument should be intrinsically safe.

Instrument Descriptions

Currently available screening instruments include:

- Δ Flame Ionization Detectors (FIDs)
- Δ Photo Ionization Detectors (PIDs)
- Δ Non-Dispersive Infrared Detectors (NDIRs)
- Δ Catalytic Combustion or Hot Wire Detectors (CCDs).

A comparison of instrument characteristics is shown in Table E-1.

Flame Ionization Detectors (FIDs)

With this instrument the sample is introduced into a hydrogen flame where organic vapours are ionized. A positively charged collector surrounds the flame and the ion current between the flame and the collector is measured electronically. FID analyzers are usually calibrated using methane at standard concentrations.

Photo Ionization Detectors (PIDs)

These instruments use ultraviolet light to ionize organic vapours. The ionization potential for most organic compounds is less than the ionization energy of the lamp or energy source. The detector response varies with the functional groups in the organic compound being detected.

Non-Dispersive Infrared Detectors (NDIRs)

These instruments are based upon the principle of the light absorption characteristics of certain gases at specific wavelengths. The concentration of the chemical constituent being measured is related directly to the amount of light absorbed.

Catalytic Combustion or Hot Wire Detectors (CCDs)

The heat of combustion of a gas is used for the quantitative measurement of the gas concentration. This is not a chemical-specific response but it may be used to measure combustible gas concentrations when the leaking species is known.

Measurement Protocol

A method for the determination of volatile organic compound leaks by the use of portable, explosion-proof instruments is described in detail in EPA Method 21, which can be found in Appendix F of this Code. The method sets out specifications and performance criteria for suitable analyzers. It also provides a leak definition as an emission resulting in a local concentration that yields an instrument reading equal to or greater than the reading of a reference compound, for example, methane of 10,000 parts per million by volume (ppmv). The method is intended for the location and classification of leaks, but not for the measurement of mass emission rates from individual sources.

Method 21 describes precisely how to sample for leaks, where to place the probe and how long to sample at the location of maximum response. Methods for calculating the instrument readability, response time and calibration precision are included. A definition for no detectable emission is given.

Method 21 includes a description of the use of an alternative leak screening procedure based upon bubble formation following the application of soap solution at potential leak sources.

TABLE E-1 MONITORING INSTRUMENTS CHARACTERISTICS

	Flame Ionization	Photo Ionization	Non-Dispersive Infrared	Catalytic Combustion
Measures	Total carbon content	Substances ionized by UV light	Light absorption at specific wavelengths	Thermal conductivity or heat of combustion
Good for	Aliphatics and aromatics, simple halogenated aliphatics	Chlorinated hydrocarbons, aromatics, aldehydes, formaldehyde	Gasoline, naphtha	
Not good for	Highly halogenated aliphatics, i.e. chloroform, carbon tetrachloride, formaldehyde			Formaldehyde, carbon tetrachloride
Ranges, ppmv	1 - 10,000	1 - 20 0 - 200 0 - 2000		1 - 100 1 - 1000 0 - 10,000
Calibration gases	Methane	Benzene Vinyl Chloride Isobutylene		Hexane
Interference	O_2 at less than 4%		H_2O CO_2	
Notes	Refinery and general chemical plant monitoring	Consider for applications where FIDs or CCDs cannot be used		Consider for petroleum refineries

Appendix F
Measurement Protocol

U.S. Federal Register, "Method 21 - Determination of Volatile Organic Compound Leaks", Vol. 40, Appendixes to Code of Federal Regulation Part 60, p. 1020-1023, July 1, 1990.

Appendix G
Guidance for Equipment Standards

As new emission regulations come into effect in the United States, there is a very obvious positive response from equipment suppliers (Chemical Engineering, 1991; Adams, W.V., 1991; Brestel, R. et al, 1991). New lines of equipment are coming out specifically to address performance criteria for very low leak rates or no-leak service. It is, therefore, most appropriate that operators keep records on the performance of specific equipment types in order to identify superior performing equipment. This is expected to promote a rapid development of industry standards for setting out purchasing specifications and maintenance protocols.

The plant owners are encouraged to request equipment suppliers to participate in a systematic identification of "bad actors" and a concerted effort to produce improved equipment technology which will ensure reduced leaks in new facilities.

It is important to identify critical process variables such as pressure, temperature, pH, corrosivity, and to determine sources of equipment erosion and mechanical failures since this will assist industry and suppliers in addressing performance requirements.

In the development of new technology the following priorities should be kept in mind:

- equipment functionality
- plant safety and fire precautions
- operational reliability of equipment
- fail-safe requirements
- ready access to equipment for maintenance.

Valves

Valves have been identified in the past as a significant source of equipment leaks. This is due in part to the very large number of valves that may be installed in a process under a very large range of different service conditions, with some being quite severe. Process control valves may have high operating cycle frequencies.

Past industry surveys have identified an unacceptably high frequency of valve leakers; some valve pretesting programs have reported failure rates as high as 25% under severe service conditions. These initial experiences are now being reversed. In a recent review (Chemical Engineering, December 1991), major improvements in process valve designs are noted for rotary, sliding stem, swing gate, butterfly, ball, diaphragm and hinged check valves. New designs are being offered for packings, stuffing boxes, seal bellows and engineered plastic parts to withstand more rugged service and higher temperature applications. Mechanical process design improvements include softer closing solenoid valves, fail-safe leakproof closures, in-line maintenance access, dual packings with leak detection ports and some new complex flow control and process sensing valve assemblies.

Valve packing for sliding stem and rotary action valves has received much attention. Major design improvements include:

- prevention of packing extrusion out of the packing area by installing less pliable anti-extrusion rings on either side of the packing;
- keeping the valve stem aligned with stem bushings installed near the packing;
- minimizing the adverse effects of thermal cycling by using only the minimal amount of packing required to affect a seal; and
- applying a constant and proper packing stress with live load springs for the type of valve and packing system used. Some suppliers insist on the use of a torque wrench to apply a specified torque when bolting up packing assemblies.

A variety of packing materials and composite assemblies are available. Suppliers should be contacted regarding recommendations for any particular application.

Valve repairs are being managed more carefully either by trained in-house maintenance personnel or by specialized outside valve repair contractors. A valve may be repaired five or six times in its lifetime. Quality parts should be used for replacements. Contractors should be asked for repair quality assurances and their facilities may be inspected to ensure that they have the proper valve testing equipment for testing before shipment.

- Δ Valve stems should be protected from physical damage and corrosion to maintain a good seal.

Pumps and Seals

Pumps are relatively high frequency leakers. They require frequent monitoring and considerable maintenance attention to keep emission levels down.

There is a wide range of pump designs available to meet a wide range of service applications. Pump selection is a highly specialized design activity best left to plant engineers and pump suppliers.

The suitability of single mechanical seals for pumps in process services has been a subject of considerable discussion. Adams (1991) reported on the work of the Seals Technical Committee of the Society of Tribologists and Lubrication Engineers Emission Working Group, which published a set of guidelines for pump seal selection.

It is generally agreed that single mechanical seals are very satisfactory in some services and are preferred over packed seals. Some services may require the use of double mechanical seals and a barrier fluid between the double seals. The barrier fluid must be compatible with the process fluid because some may leak into the process. Any barrier system should be connected by a closed vent to a VOC control system or be purged to a process stream to ensure that VOC emissions from the barrier fluid are minimal.

Adams reports the results of a 1990 survey of 107 pump seals in light hydrocarbon service at three refineries located in the Los Angeles basin. Follow-up investigations after this survey, which revealed 9% leakers (> 10,000 ppmv), led to the following conclusions:

- Δ few seals leak abnormally and these can be readily identified and corrected;
- Δ excessive seal leakage is a direct symptom of the misapplication of a seal and/or improper operation of the seal or its associated rotating equipment; and
- Δ a strong correlation exists between the level of seal leakage and the mean time between failure (MTBF) of its associated equipment.

Recent studies have shown that a contributory factor in pump seal failure is vibration/deflection of the shaft. There are now pumps available with larger shafts and which are stated to have low emissions even when using single seals. These types of pumps are worthy of consideration as original and replacement units.

Compressors

The requirements for seals on rotary, centrifugal and horizontal reciprocating compressors are the same as for pump seals. Rotary or centrifugal compressors are much easier to seal than reciprocating units.

Since compressors handle gas, the choice of barrier fluid in dual mechanical seals is critical to avoid contamination of the gas stream. With enclosed rod extension housings on reciprocating compressors it is necessary to provide for purging to dispose of gas blow-by. This purging should be a controlled system.

Pressure Relief Devices

Where allowable, pressure relief devices should discharge through a closed-vent system to a flare stack or to a VOC control device. In cases where controlled discharge is not permitted, two alternate methods for control of fugitive emissions can be used:

- Δ Install a rupture disk upstream of the pressure safety valve (PSV) set at a higher pressure than the PSV. This system controls fugitive emissions but once the disk ruptures the system has to be rebuilt at the first opportunity; or

- Δ Install PSVs in parallel with a valving system which ensures that under all conditions when the leaking PSV is shut off, the second unit is operative. This system allows on-line repairs to a PSV. Installation of a shut-off valve in front of a PSV is prohibited under safety regulations unless a foolproof chain locking control system is approved as required in the parallel dual-valve system.

Open discharge PSVs should be equipped with flexible, easily expandable coverings over the tailpiece outlet to prevent water (rain) entry and subsequent freezing or corrosion. The flexible covering can also serve as an indicator of a leaking PSV.

Flanges

Wherever possible, piping and fittings can be joined by welding. Chemical plant operations do however, require frequent removal of some equipment for cleaning and maintenance, and flanges are required.

Flange connections should be installed with flange faces parallel and flush so that no undue force is required in bolting up to achieve a tight seal. Concentric grooved raised face sealing surfaces should be selected over smooth faced design. Flange connections should be bolted up using a torque wrench to achieve uniform loading on the gasket/flange faces. Flanges used in hot service should be retorqued when they are up to operating temperature.

Gasketing materials should be carefully selected to match service requirements. A new gasket should be used each time a flange is reconnected.

Bolting procedures should include care to ensure proper alignment of bolts. Bolts damaged through strain should be identified and discarded.

Sampling Connections

Closed-loop purging and sampling is recommended. Dedicated sampling bombs are also recommended so that unused samples can be returned to the source at the time of subsequent sampling. A method of retractable plug sampling is recommended to avoid line flushing when tank sampling.

Open-Ended Lines

Open-ended lines typically include tank and piping drains, purge lines for level sight glasses and float chambers, and sample collection lines. Each open-ended line should be plugged using a cap, bull plug or blind flange at the open end when not in use. The Texas Air Control Board regulations state that, except for safety pressure relief valves, no valves shall be installed or operated at the end of a pipe or line containing VOC unless the pipe or line is sealed with a second valve, blind flange, plug or cap. The sealing device can only be removed when a sample is being taken or during maintenance operations.

Appendix H
Quality Improvement Programs

Total Quality Management

Total quality management (TQM) is defined as a collection of continuous process improvement activities that involve everyone in an organization. Managers and workers work in a totally integrated effort toward improving performance at every level. The continuous quality improvement approach is recommended for programs designed to reduce fugitive VOC emissions.

Implementation of TQM in FVE Reduction

There are six main reasons quoted for implementing a quality improvement program (QIP) in the approach to reducing equipment leaks in petroleum refineries, organic chemical plants or any industry handling VOC. They are:

- Δ plant safety to reduce the incidence of explosions and fires;
- Δ worker and community health care;
- Δ process reliability;
- Δ regulatory compliance;
- Δ community image and corporate proactivity; and
- Δ reduction of process losses resulting in improved economics.

Definition of a Quality Improvement Program

QIP requires data collection and analysis of valve variables, performance trials, quality assurance and improvement demonstrations. Specific information on valve design, materials of construction, packing, type of service and screening performance test results are required. One objective is to identify valve designs and conditions that assure operating in compliance. This is defined as "superior performing valve technologies". This effort results in the identification and replacement of components that are continually repeat leakers.

An advantage of choosing QIP over LDAR is that QIP offers the possibility of continued plant operations even if the leaking frequency for certain components does not come into compliance. It is recognized that, in the long run, replacement of defective components will produce a permanent solution to leaking equipment.

As an example, for valves there are two QIP options: demonstrate progress in reducing the percentage of leaking valves; or carry out a valve technology review and implementation program for the ultimate satisfactory repair of valve leaks or the replacement of valves with better performing units.

Ultimately a QIP should result in minimum design standards for each type of component in plant service, procedures for bench testing specific components, quality control procedures for purchasing department and for maintenance activities.

Voluntary QIP

The quality approach to FVE prevention may be applied at any time.

Plant sites may choose to implement a QIP as a means of ensuring that the site FVE prevention performance requirements are met. In this case, the scope and method of application will depend on the objective set by the management and there will be no need to submit the details of the program to the authority having jurisdiction.

Directed QIP

A directed QIP is a quality approach to FVE reduction which is mandated by the authority having jurisdiction.

A directed QIP may be put in place when the plant has had two consecutive cycles of non-compliance with the requirements of Part 3 of this Code.

The scope of the application would be agreed to with the regulator and progress would be audited regularly. It may happen that the QIP is applied only to the unit where the target maximum leakers has not been achieved for the last two full-scale monitoring cycles.

Appendix I

United States Experience

Technology for the measurement and control of fugitive emissions (equipment leaks) is documented in the United States back to 1939. By 1978 a significant body of federal regulations had been developed. A big increase in regulations occurred in the 1980s with the development of the EPA Clean Air Act (CAA).

National Ambient Air Quality Standards (NAAQS) have been published and New Source Performance Standards (NSPS) have been legislated.

In 1988 a Toxic Release Inventory (TRI) was completed. About 50% of the air emissions were estimated to be from fugitive sources.

Areas in the United States were found to be not in compliance with NAAQS and steps towards remedial action included requirements for State Implementation Plans (SIPs) by November 1992. Other legislation which addressed non-compliance included Section 3B of Title III of the Superfund Amendments and Reauthorization Act (SARA, 1986).

This Act requires affected facilities to quantify, on a chemical-specific basis, toxic chemical releases to the environment, fugitive emissions included.

The practice in the United States is that the federal agency, EPA, prepares legislation for enactment by Congress. State and local authorities may pass additional laws and these agencies carry out the implementation of regulations through their permitting authority.

To improve the regulatory development process and to develop more universally acceptable regulations, a Regulatory Negotiation process (REGNEG) was introduced by the EPA. The objective was to replace strict work practice and equipment standards with a more flexible Maximum Achievable Control Technology (MACT). The negotiating committee included private industry, environmental groups, governments, regulators and specialists along with general public observers. Following negotiations, which took over two years, the Clean Air Act Amendments (CAAA, 1990) were prepared. National Emission Standards for Hazardous Air Pollutants (NESHAPs) were included. The Act was passed into law and published in March 1991 for implementation in early 1992.

There are some conflicts in the regulations of different jurisdictions. These are resolved by always applying the more stringent regulation.

The American federal, state and local regulations are very detailed in spite of the negotiated objective of MACT. Compliance is very carefully prescribed and detailed schedules for compliance are usually enacted.

It should be noted that the United States regulations most often include mention of chemical specificity and references are made to hazardous emissions rather than to the more general VOC reference used in this Code.

An example of the regulations that would apply to fugitive VOC emissions in Texas is shown in Table I-1. The Texas regulations are important as they are the most advanced in covering petroleum refinery emissions. Texas Air Control Board (TACB) jurisdiction includes 254 counties, about 20 of which are in ozone non-attainment areas.

TABLE I-1 TEXAS REGULATIONS APPLIED TO VOC EMISSIONS

Industry	Federal	State	County
Organic Chemical Manufacturing Industry	NSPS VV NESHAPS F NESHAPS J MACT	TACB Permit	Harris
Petroleum Refineries	NSPS GGG NESHAPS J MACT	TACB Permit	11
Offshore Natural Gas Processing Plants	NSPS KKK	TACB Permit	Harris

The State of Texas works through implementation of new improved technology (MACT). Fugitive volatile emissions prevention is achieved by control equipment and/or by frequent inspection and maintenance. Reductions may only be claimed on components monitored. Ambient monitoring is not accepted as a substitute. Permitting is focused on the prevention of emissions.

United States Regulations

National Emission Standards for Hazardous Air Pollutants (EPA)

The proposed equipment leak regulations for hazardous air pollutants were published in an information notice in the Federal Register dated March 6, 1991, page 9315. They are expected to come into effect in November 1991 as the Hazardous Organic National Emission Standards for Hazardous Air Pollutants (NESHAP) or HON (Hazardous Organic NESHAP). These regulations include the following:

- Δ a phase-in period for valves and pumps;
- Δ a linkage of monitoring frequency with performance with some incentives for using low emission equipment and for reducing FVE; and
- Δ a quality improvement program (QIP) to ensure the replacement of poorly performing equipment and/or to ensure that all elements of MACT are used.

The regulations apply to SOCMI facilities, both new and existing processing units, that may involve chemicals that are listed in Appendix B of this Code of Practice.

The regulations apply to equipment handling process streams with a 5% or greater VHAP content. Equipment operating less than 300 hours per year is exempt. Plants with less than 250 valves are subject to a quarterly maximum monitoring frequency.

Processes enclosed or in buildings under negative pressure and vented to atmosphere with a 95% efficient control device are exempt from LDAR monitoring.

For batch processes the monitoring frequency may be prorated to the time in use and when it is in VHAP service or in use with a surrogate VOC or other detectable compound.

Appendix J
Explanation of Measurement Limits

Reference to Table E-1 in Appendix E of the Code indicates the range for flame ionization, photo ionization and catalytic combustion detectors as from 1 to 10,000 ppmv of the reference gas. The photo ionization detector limit is shown as 2,000 ppmv; however, with the use of a dilution probe this can be expanded to 10,000 ppmv.

It is unlikely that any of the instrument scales will have satisfactory precision below 10 ppmv. This is the background level usually assigned for air with no contaminant present. In addition, instrument response factors may be poor at readings below 100 ppmv. Accordingly, 0 - 100 ppmv is normally taken as the lowest screening value range.

Appendix K
Records and Reporting

It is recommended that reporting be brief and only sufficient to clearly demonstrate compliance with the objectives of this Code.

The estimate of emissions using SOCMI factors without screening surveys is not considered valid as evidence of actual fugitive VOC reductions achieved. A baseline screening survey – using the stratified leak classification method – with subsequent screening surveys at reasonable time intervals can be used as the basis for emission reduction estimates.

Proposed Summary Report Form

It is recommended that the forms in this appendix be used for reporting. This will provide a uniform approach to reporting.

Part 1 FVE Prevention Program, Summary Report – Table K-1.

Part 2 FVE Prevention Program, Component Monitoring Summary Sheet – Table K-2.

Part 3 FVE Prevention Program, Emissions Estimate Sheets – Tables K-3 to K-9.

Backup records to substantiate summary reports should be retained by the plant site personnel to provide detailed information to the authority having jurisdiction when the request is made.

Data should be kept for at least three years.

TABLE K-1 FUGITIVE VOC EMISSIONS – SUMMARY REPORT

Company ABC CHEMICAL

Date FEBRUARY 3, 1992

Property/Process SYN-EX

Permit No. 10762

Contact Person BILL GOOD

Code Classification ______

Phone ______

FAX ______

Process Design Operating Capacity 16 250 TONNES/YEAR

Performance Record

Year	1991				
Total Components	7064				
Leak Rate, Percentage	0.25				
Mass Emission, ktonnes/yr	30,590				

Monitoring Conducted: In house __ By Contract __ Phone ______

Consultant: Name ______ Address ______

Monitoring Period: JULY - AUGUST

Comments: AN ONGOING PROGRAM OF VALVE REPLACEMENT CONTINUES.

Attachments:

Signed

Title Environmental Manager

Date February 3, 1992

TABLE K-2 FUGITIVE VOC EMISSIONS – COMPONENT MONITORING SUMMARY SHEET

COMPANY ABC CHEMICAL CO. PROPERTY/PROCESS UNIT SYN-EX

Dates Monitored	Component Type	Number of Components								Total Emission Estimate (kg/year)	Comment
		Inventory	Not Inspected	Inspected	Non-Leakers	Leakers	Repaired	Replaced	Tagged for Repair or Replacement		
July - Aug 1991	Valves	1403	0	1403	1396	7	4	2	1	7,058	
July - Aug 1991	Pump Seals	63	0	63	61	2	2	0	0	10,090	
July - Aug 1991	Compressor Seals	5	0	5	4	1	0	1	0	2,450	
July - Aug 1991	Pressure Relief Valves	6	0	6	6	0	0	0	0	542	
	Flanges	5587	0	5587	5579	8	5	2	1	10,450	
	Open-Ended Lines	0	0	0	0	0	0	0	0	0	
	Sampling Connections	0	0	0	0	0	0	0	0	0	LEAK RATE ON TESTED COMPONENTS 18/7064 = 0.25
1991	**Totals**	7,064	0	7,064	7,046	18	11	5	2	30,590	

TABLE K-3 FUGITIVE VOC EMISSIONS – SAMPLE SURVEY SHEET – VALVES

Equipment Type: Valves

				Count	Emission Factor (kg/h/source)	Time in Service (hours/yr)	Emission Estimate (kg/yr)
Method # 1	Stratified	Gas/Vapour	Strata 1	690	0.00014	7,920	765
			Strata 2	53	0.00165	7,920	693
			Strata 3	5	0.0451	7,920	1,786
		Light Liquid	Strata 1	586	0.00028	7,920	1,300
			Strata 2	14	0.00963	7,920	1,068
			Strata 3	2	0.0852	7,920	1,350
		Heavy Liquid	Strata 1	49	0.00023	7,920	89
			Strata 2	4	0.00023	7,920	7
			Strata 3	0	0.00023	7,920	0
Method # 2	Correlation	Gas/Vapour Light Liquid					
Method # 3	Unit-Specific Correlation						
Other	(specify)						
Total				**1,403**			**7,058**

TABLE K-4 FUGITIVE VOC EMISSIONS – SAMPLE SURVEY SHEET – PUMP SEALS

Equipment Type: Pump Seals

				Count	Emission Factor (kg/h/source)	Time in Service (hours/yr)	Emission Estimate (kg/yr)
Method # 1	Stratified	Light Liquid	Strata 1	38	0.00198	7,920	596
			Strata 2	5	0.0335	7,920	1,327
			Strata 3	2	0.437	7,920	6,922
		Heavy Liquid	Strata 1	17	0.00380	7,920	512
			Strata 2	1	0.0926	7,920	733
			Strata 3	0	0.3885	7,920	0
Method # 2	Correlation Light Liquid						
Method # 3	Unit-Specific Correlation						
Other	(specify)						
Total				**63**			**10,090**

TABLE K-5 FUGITIVE VOC EMISSIONS – SAMPLE SURVEY SHEET – COMPRESSOR SEALS

Equipment Type: Compressor Seals						
			Count	Emission Factor (kg/h/source)	Time in Service (hours/yr)	Emission Estimate (kg/yr)
Method # 1	Stratified	Strata 1	4	0.01132	7,920	359
		Strata 3	1	0.264	7,920	2,091
		Strata 3	0	1.608		
Method # 2	Correlation					
Method # 3	Unit-Specific Correlation					
Other	(specify)					
Total			**5**			**2,450**

TABLE K-6 FUGITIVE VOC EMISSIONS – SAMPLE SURVEY SHEET – PRESSURE RELIEF VALVES

Equipment Type: Pressure Relief Valves

			Count	Emission Factor (kg/h/source)	Time in Service (hours/yr)	Emission Estimate (kg/yr)
Method # 1	Stratified	Strata 1	6	0.0114	7,920	542
		Strata 2	0	0.279		
		Strata 3	0	1.691		
Method # 2	Correlation					
Method # 3	Unit-Specific Correlation					
Other	(specify)					
Total			**6**			**542**

TABLE K-7 FUGITIVE VOC EMISSIONS – SAMPLE SURVEY SHEET – FLANGES

Equipment Type: Flanges

			Count	Emission Factor (kg/h/source)	Time in Service (hours/yr)	Emission Estimate (kg/yr)
Method # 1	Stratified	Strata 1	5,475	0.00002	7,920	867
		Strata 2	104	0.00875	7,920	7,207
		Strata 3	8	0.0375	7,920	2,376
Method # 2	Correlation					
Method # 3	Unit-Specific Correlation					
Other	(specify)					
Total			**5,587**			**10,450**

TABLE K-8 FUGITIVE VOC EMISSIONS – SAMPLE SURVEY SHEET – OPEN-ENDED LINES

Equipment Type: Open-Ended Lines

			Count	Emission Factor (kg/h/source)	Time in Service (hours/yr)	Emission Estimate (kg/yr)
Method # 1	Stratified	Strata 1	0	0.00013		
		Strata 2	0	0.00876		
		Strata 3	0	0.01195		
Method # 2	Correlation					
Method # 3	Unit-Specific Correlation					
Other	(specify)					
Total			**0**			**0**

Appendix L
Examples of Statistical Evaluation

This is a sample table of values for defining the number of components which need to be monitored when a statistically reliable number of source components are checked. It has been built with the two ends of the range for 10,000 components. It can be expanded at will.

The following table was prepared by Duncan McLeod of Environment Canada for a target 2% maximum leakers for a pass. Therefore, there would be, as an example, a 95% certainty that there are no more than 2% leakers in:

a) 10,000 components if 12 leakers or less were found in a sample of 1,000 randomly picked components.

b) 1,000 components if two (2) or less leakers were found in a sample of 300 randomly picked components.

MAXIMUM ALLOWABLE LEAKING COMPONENTS IN SAMPLE FOR DETECTION OF A 2% RATE OF DEFECTIVE ITEMS

Sample Size	1,000 Components Group			10,000 Components Group		
	Confidence Level*			Confidence Level*		
	90%	95%	99%	90%	95%	99%
100	—	—	—	—	—	—
200	1	0	—	1	0	—
300	3	2	1	2	1	0
400	4	4	2	4	3	1
500	6	5	3	5	4	3
1,000				14	12	9

*Confidence Level: The level of certainty that the results reflected in the sample components will be the same for the total family of components in the operating unit (e.g. there is a 95% confidence that the same ratio of leakers would be found if all leak sources were screened).

Appendix M
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