CANADIAN ASSOCIATION
OF PETROLEUM PRODUCERS

BEST MANAGEMENT PRACTICES

Control of Benzene Emissions from Glycol Dehydrators

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The Canadian Association of Petroleum Producers (CAPP) represents 150 companies that explore for, develop and produce natural gas, natural gas liquids, crude oil, oil sands, and elemental sulphur throughout Canada. CAPP member companies produce more than 95 per cent of Canada's natural gas and crude oil. CAPP also has 130 associate members that provide a wide range of services that support the upstream crude oil and natural gas industry.

Review by August 2008

Disclaimer

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Executive Summary

The Canadian upstream oil & gas industry is committed to minimizing health risks related to benzene emissions from glycol dehydrator operations through a continued reduction program. A target to reduce emissions by 90% from the 1995 national emissions baseline (estimated 9000 tonnes/year) was expected to be reached by January 1, 2005. This target may still be achievable over a longer timeframe. As of December 31, 2004, benzene emissions by glycol dehydrators have been reduced by 76%.

Although industry is approaching the limit for benzene emission reductions from dehydrators using the current technology, further reductions may be achieved through:

- improvements to the design of new or relocated glycol dehydrators;
- further optimization of gas gathering systems; and
- more efficient operations of glycol dehydrators according to manufacturer's specifications and operating conditions.

To further encourage emissions reductions, the EUB and Alberta Environment have jointly issued Directive 039, entitled Revised Program to Reduce Benzene Emissions from Glycol Dehydrators dated July 10, 2006. This "Dehydrator" Directive, comes into effect July 10, 2006. Licensees must comply with the following new requirements by January 1, 2007:

1) When evaluating dehydration requirements in order to achieve the lowest possible benzene emission levels, licensees must use the Decision Tree Process in Appendix A of this Canadian Association of Petroleum Producers (CAPP) Best Management Practices for Control of Benzene Emissions from Glycol Dehydrators, June 2006 ("Dehydrator" BMP) and retain appropriate documentation for review by regulatory agencies. Licensees must follow the public consultation process as outlined in Chapter 11.
2) Licensees must ensure that all their dehydrators meet the following benzene emission limits:

Date Dehydrator Installed or Existing Dehydrator Relocated	Benzene Emission Limits
Prior to January 1, 1999	
Greater than 750 m to permanent resident or public facility	5 tonnes/yr
Less than 750 m to permanent resident or public facility	3 tonnes/yr
From January 1, 1999, to January 1, 2007	3 tonnes/yr
After January 1, 2007	1 tonne/yr

Specific Benzene Emission Limits

i) If more than one dehydrator is located at a facility or lease site, the cumulative benzene emissions must not exceed the limit of the oldest dehydrator on site. Modifications may be required to existing unit(s) to meet the site limit.

ii) Any new or relocated dehydrators added to an existing site with dehydrator(s) must operate at a maximum benzene emission limit of 1 tonne/yr or less. The cumulative benzene emissions must not exceed the limit of the oldest dehydrator on site.

iii) For dehydrators that are only in operation for a portion of the year, the daily benzene emission rate must never be above a rate determined by the above Benzene Emissions Limits divided by 365. (See Section 2.3 of the Benzene Reduction BMP for details on calculating and reporting of emissions from dehydrators that only operate a portion of the year).

For reporting, the calculation of the annual emissions volume must be as follows:

- Determine and report the typical or average daily benzene emissions rate in kilograms/day (or per hour) for a dehydrator.
- Determine and report the number of operating days (or hours) in a year for that dehydrator.
- Determine the annual emissions volume by multiplying these two values and convert from kilograms to tonnes.

For example, for a dehydrator with an annual benzene emission limit of 3 tonnes, that only operates for six months of the year, the maximum annual emission limit would be 1.5 tonnes or a maximum daily emission rate of 8.2 kg/day.

3) Licensees are required to complete a Dehydrator Engineering and Operations Sheet (DEOS) (see Appendix B) to determine the benzene emissions from each dehydrator. This sheet summarizes optimum operating conditions to minimize benzene emissions and must be posted at the dehydrator for use by the operations staff and inspection by the EUB. The DEOS must be revised annually (each calendar year), upon relocation, or upon a change in status of the dehydrator (resume operation, shut-in, bypassed).

4) Licensees must complete and submit an annual Dehydrator Benzene Inventory List which lists all the licensees' dehydrators, as set out in Appendix C, by July 1 each year. Copies of the annual Dehydrator Benzene Inventory List are available at www.capp.ca. This information must be submitted to the EUB through the multi-stakeholder Benzene Technical Advisory Team (Benzene TAT) by email to benzene.tat@capp.ca, attention: Manager of Alberta Operations, CAPP.

This updated BMP complements the Directive by providing guidance on:

- Health effects associated with exposure to benzene; Selecting glycol dehydrators or alternative methods of dehydration - the decision tree analysis process, (The latest status report shows that only 26% of new dehydrator installations have used the Decision Tree Process outlined in the 2002 BMP);
- The decision process for the design of new or relocated glycol dehydrators;
- Methodology for calculating benzene emissions, with impact of exposures;
- Available control technologies to assist glycol dehydrator designers to minimize benzene emissions;
- Preventing and minimizing emission from a glycol dehydrator through efficient operations;
- Facility optimization and supplementary controls;
- Solid waste, waste glycol, and produced water disposal alternatives;
- Appropriate strategies for managing multiple dehydrators on site to minimize cumulative benzene emissions;
- The completion of the Dehydrator Engineering and Operations Sheet (DEOS) to minimize benzene emissions;
- Public consultation to inform neighbours, and
- Reporting to the industry's dehydrator benzene inventory to track industry progress.

With the issuance of this Directive, the EUB and Alberta Environment have established specific limits and reporting requirements to ensure continued reductions of benzene emissions to minimize public health risks.

These limits and requirements are now mandatory.

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1. Introduction

This document was originally prepared by the Working Group on Benzene Emissions from Glycol Dehydrators, and has been updated by the Benzene Technical Advisory Team, with the following objectives:

- to promote effective management of benzene emissions from glycol dehydrators in Canada;
- to promote awareness of human health risks and risk controls associated with exposures to benzene, in both workplace and domestic environments; and
- to promote adoption of emission limits and reporting by the natural gas industry in Canada.

1.1 Background

The upstream oil and gas industry uses glycol dehydrators to remove water from natural gas. The main reason for this application is to enhance the properties of the raw natural gas as a saleable commodity. The dehydration process also helps to prevent corrosion and hydrate formation in pipelines.

A 2004 industry survey identified about 3863 glycol dehydrators in service in Canada. The majority of the units are installed in rural environments. The units are typically unmanned/unattended.

This document is intended for use by management, engineering, and field operations personnel in the upstream oil and gas industry. It provides guidance on how to consider potential benzene emissions during:

- decision-making (whether glycol dehydration is the most appropriate dehydration technique);
- project planning;
- engineering and safety design;
- operating conditions; and
- maintenance procedures.

Operators in the Canadian oil and gas industry have assessed benzene emissions from their glycol dehydrators and installed emission controls such as condensers, flare stacks, and incinerators for still column vent vapours. Member companies from CAPP have also reported the use of other approaches, such as piping the still column vent emissions to tankage (for condensation) and the installation of flash tanks in order to collect non-condensable vapours to use as fuel, or to send to a flare or incinerator.

In general, emissions from glycol dehydrators can be reduced by:

- optimizing operations;
- modifying or replacing equipment; and/or,
- adding emission control equipment.

Emission reduction opportunities are site-specific. Operational and equipment options may be applied singularly or in combination. Site factors to consider include: weather, location (i.e. remoteness), operation (i.e. automation), hydrate control (for efficiency / market value), throughput, gathering systems, and economics.

1.2 Working Group on Benzene Emissions from Glycol Dehydrators

Benzene is classified as a toxic substance under the Canadian Environmental Protection Act. It is also classified as a Group 1 carcinogen by the International Agency for Research on Cancer (IARC).[1] As a non-threshold carcinogen there is considered to be some health risk at any level of exposure. It is to be managed by reducing human exposure to the extent possible and practicable.

Environment Canada formed the Working Group on Benzene Emissions from Glycol Dehydrators in early 1995. The Working Group was composed of representatives from government, industry, and environmental organizations (see Appendix G for membership listing).

On July 24, 1995, the Minister of the Environment announced that federal action on regulations limiting benzene releases would be accelerated. Part of this announcement was a directive to produce regulations that would control emissions of benzene from natural gas dehydrators.

Initially, the Working Group sought to compile information on the number, distribution, and emissions associated with glycol dehydrators in Canada. Accordingly, the Working Group developed a strategy for controlling benzene emissions and reducing associated health risks to neighbouring residents through a voluntary non-regulatory program. In essence, the program would be maintained by industry and monitored by government. To carry this voluntary dehydrator benzene emissions reduction program forward, the Working Group was renamed the Benzene Technical Advisory Team or BTAT.

While the BTAT is encouraged with the benzene emission reductions achieved from glycol dehydrators, it has determined that new requirements are needed to maintain the benzene reductions achieved to date, improve the reporting of emissions, strive for continuous improvement in controlling emissions, and operate dehydrators more efficiently. The changes described herein have now become regulated requirements as

1. **Government of Canada, Environment Canada, Health and Welfare Canada**, 1993. Canadian Environmental Protection Act, Priority Substances List Assessment Report – Benzene. Minister of Supply and Services, Ottawa.

described in the EUB Directive 039, “Revised Program to Reduce Benzene Emissions from Glycol Dehydrators” (The Dehydrator Directive), effective July 1, 2006. This new regulatory initiative should result in further reductions in benzene emissions and potential health effects.

Further benzene emission reductions could be achieved by reducing the allowed benzene limits for existing dehydrators, however the BTAT decided to improve the information available to an operator through a tool called the Dehydrator Engineering and Operations Sheet (DEOS). This annually reviewed document posted near the dehydrator provides the operator with operating information for that dehydrator specific for the gas handled, and a graph showing the relationship between gas water content, glycol circulation rate, and benzene emission volumes. By reducing glycol circulation rates, the minimum benzene emissions can be achieved while still meeting water content limits.

Finally, this BMP expands on:

- the Decision Tree Analysis (DTA) process for determining if glycol dehydration is the best dehydration choice;
- the design and optimum operation of single dehydrators;
- the design limits for multiple dehydrators on one site;
- the public consultation process, and
- the annual reporting requirements.

Note that Section 8.0 Venting, of EUB Directive 60: *Upstream Petroleum Industry Flaring, Incineration, and Venting* requires that all sources of benzene emissions on a site must, in aggregate, have emissions volumes that are below the dehydrator limits noted in the table in Section 2.3, subparagraph 2.

What's Next?

The results of this next phase of benzene emissions control, as required by Directive 039 and described by this CAPP BMP, will be reviewed by the BTAT commencing in August 2008.

During this time the BTAT will consider the following requests for improvements to the next revision of the Dehydrator Directive:

- reductions in allowable benzene emissions per dehydrator regardless of commissioning date,
- limits on aggregated benzene emissions from groups of dehydrators near residences regardless of ownership,
- the structure for measurement and reporting of other possible benzene sources on a site, e.g. storage tanks, to make this Directive a benzene management directive rather than a dehydrator benzene directive,
- evaluate the need for additional ambient air benzene monitoring as a basis for accurate benzene dispersion modeling, and
- establish acceptable models to estimate benzene dispersion from multiple sources.

2 Regulated Benzene Emission Limits

2.1 Goal

The upstream oil & gas industry is committed to minimizing health risks related to benzene emissions from glycol dehydrator operations through continued reduction of benzene emissions.

2.2 Principles

In recognition of the potential health risks associated with benzene emissions, operators of glycol dehydrator facilities will:

- determine and report benzene emissions from all glycol dehydrators;
- protect employee health by educating employees about the risks associated with benzene exposure, and about good practices that will reduce exposures and risks by posting of a Benzene Health and Safety Sheet (see Appendix E);
- modify the dehydrators to meet the Emission Limits noted below;
- communicate and maintain good relations with potentially impacted neighbours;
- use operational practices that reduce benzene exposure potentials; and,
- share innovations and successful benzene emission control methods with industry.

2.3 Regulated Emission Limits

The following paragraphs are adapted from the Dehydrator Directive. Note that these limits only deal with dehydrator emissions which are a portion of all benzene emissions that could occur at a site. EUB Directive 60, Section 8.3 requires that all sources at a site be evaluated and limited.

Licensees must comply with the following new requirements effective January 1, 2007:

1) When evaluating dehydration requirements in order to achieve the lowest possible benzene emission levels, licensees must first use the Decision Tree Process in Appendix A to determine if glycol dehydration is the most appropriate method, and retain appropriate analysis documentation for review by regulatory agencies. Licensees must follow the public consultation process outlined in this BMP.

2) Licensees must ensure that all their dehydrators meet the following annual benzene emission limits.

Date Dehydrator Installed or Existing Dehydrator Relocated	Benzene Emission Limits
Prior to January 1, 1999	
Greater than 750 m to permanent resident or public facility	5 tonnes/yr
Less than 750 m to permanent resident or public facility	3 tonnes/yr
From January 1, 1999, to January 1, 2007	3 tonnes/yr
After January 1, 2007	1 tonne/yr

Specific Regulated Benzene Emission Limits

i) If more than one dehydrator is located at a facility or lease site, the cumulative benzene emissions must not exceed the limit of the oldest dehydrator on site. Modifications may be required to existing unit(s) to meet the site limit.

ii) Any new or relocated dehydrators added to an existing site with dehydrator(s) must operate at a maximum benzene emission limit of 1 tonne/yr or less. The cumulative benzene emissions must not exceed the limit of the oldest dehydrator on site.

iii) For dehydrators that are only in operation for a portion of the year, the daily benzene emission rate must never be above a rate determined by the above Benzene Emissions Limits divided by 365. For reporting, the calculation of an annual volume must be as follows: Determine and report the typical or average daily benzene emissions rate in kilograms/day (or per hour) for a dehydrator. Determine and report the number of operating days (or hours) in a year for that dehydrator. Multiply these two values and convert from kilograms to tonnes.

The Benzene Emission Limits stated in the Directive are annual volumes that assume a dehydrator is operating 365 days in a year. The annual limit divided by 365 sets the daily maximum benzene emission rate allowed. This daily rate determines the concentration of benzene in air and has been set to limit the exposure of people to benzene. The designer and operator of a dehydrator must limit the benzene emissions to this daily maximum. In the case of multiple dehydrators on a site, the maximum daily benzene emission rate allowed is the annual Benzene Emission Limit for the oldest dehydrator on site, divided by 365, for all the dehydrators added together.

For example, if a dehydrator is currently installed within 750 meters of a resident, the Benzene Emission Limit is 3 tonnes/year.

- The daily limit is 3 tonnes/year x 1,000 kilograms/tonne divided by 365 days per year, or 8.22 kilograms/day (or 0.3425 kg/hour).

- If the dehydrator is designed for 8 kg/day, and it operates at that rate for only 180 days in the calendar year, then the reported annual emission is 8 x 180 / 1000 = 1.44 tonnes
- If this unit were to operate for 365 days, the units emissions would be 2.92 tonnes/year, safely within the Benzene Emission Limit.

3) Licensees are required to complete a Dehydrator Engineering and Operations Sheet (DEOS) (see Appendix B) to determine the benzene emissions from each dehydrator. This sheet summarizes optimum operating conditions to minimize benzene emissions and must be posted near the dehydrator for use by the operations staff and inspection by the EUB. The DEOS must be revised annually (each calendar year), upon relocation, or upon a change in status of the dehydrator (resume operation, shut-in, bypassed). Operators must use the operating information provided to reduce emissions to as low a level as possible.

4) Licensees must complete and submit an annual Dehydrator Benzene Inventory List listing all the licensees' dehydrators, as set out in Appendix C, by July 1 each year. Copies of the annual Dehydrator Benzene Inventory List are available at www.capp.ca. This information must be submitted to the EUB through the multi-stakeholder Benzene Technical Advisory Team (Benzene TAT) by email to benzene.tat@capp.ca, attention: Manager of Alberta Operations, CAPP.

2.4 EUB Compliance and Enforcement

These requirements will be subject to compliance review by the EUB. Regulatory requirements are those rules that industry has an obligation to meet and against which the EUB may take enforcement action in cases of noncompliance. For the purpose of *Directive* 039, noncompliance events are listed in Table 1 below. Refer to the EUB Web site at www.eub.ca and *Directive 019: EUB Compliance Assurance - Enforcement* for details regarding EUB compliance and enforcement.

Alberta Environment (AENV) may also review for compliance, and failure to comply may result in the issuance of Environmental Protection Orders (EPO), as outlined in the Alberta *Environmental Protection and Enhancement Act*

Table 1 – EUB Noncompliance Enforcement Ratings

Enforcement Rating	Noncompliance Event
High	Dehydrator or site benzene emissions over the limits
Low	Failure to complete Decision Tree analysis
Low	Dehydrator Engineering and Operations Sheet (DEOS) not done, incomplete/inaccurate, and/or not posted
Low	Failure to submit annual Dehydrator Benzene Inventory List to Benzene TAT

If all noncompliance items are not addressed, escalating consequences will be applied in accordance with *Directive 019: EUB Compliance Assurance—Enforcement* (*Directive 019*). Operators should also be aware that if they are identified as "persistently noncompliant," enforcement will be applied as outlined in *Directive 019*.

The EUB encourages companies to voluntarily self-disclose any noncompliances as described in Section 6 of *Directive 019.*

3 Health Effects of Exposures to Benzene Emissions

3.1 Chemical – Physical Properties

Benzene (CAS # 71-43-2) is a simple aromatic or "ring-shaped" hydrocarbon. A short list of physical and chemical properties[2] for benzene is provided below in Table 2.

Table 2 - Physical-Chemical Properties of Benzene

Property	Value	Notes
Freezing Point	5°C	Higher than water.
Boiling Point	80°C	Lower than water.
Density	0.8 g/mL @ 20°C	Liquid benzene will float on water.
Vapour Pressure	10 kPa @ 25°C	Strong tendency to evaporate to air.
Half-life Degradation (air)	0.1 to 20 days	Degraded by sun and other chemicals.
Flammability	Extreme	Use caution with all ignition sources.

3.2 Long–Term (Chronic) Exposure

Fatalities from human exposure to high concentrations of benzene have been documented since the early 1900s. Since then, there has been an increasing focus on the impacts of benzene at ever lower levels of exposure. Human (epidemiological) studies have shown correlations between workplace exposure to benzene and the onset of certain forms of leukaemia, and at the same time there has been an increased understanding of the mechanisms by which benzene exerts its toxic effects.

Workers may become exposed by inhalation or by direct contact with the skin. This may occur when changing filters and pumps, and when handling rich glycol at dehydrators.

The main route of exposure to a person is through inhalation. Once inhaled, benzene is either exhaled or absorbed into the blood. The benzene that is absorbed into the blood is distributed throughout the body and processed into a form that is more easily

2.**Agency for Toxic Substance and Disease Registry**, 1995. Toxicological Profile for Benzene: Draft for Public Comment. Prepared for the US Department of Health and Human Services by Research Triangle Institute, Research Triangle Park, North Carolina.

excreted. Some of the by-products of this can be toxic to bone marrow and produce blood disorders such as anaemia and leukaemia.[3]

Benzene is not easily absorbed through skin contact. The absorption of benzene vapor through the skin is unlikely to be significant at concentrations below 25 ppm.

Acute Non-Lymphocytic Leukaemia (ANLL) is the only form of cancer associated with benzene exposure in the workplace. The risk of developing a benzene-related illness increases with the intensity, frequency, and duration of exposure. A study by Rinsky et al.[4] compared cumulative worker exposure to calculated indicators of leukaemia mortality. The results suggest that exposures to 120,000 $\mu g/m^3$ (40,000 ppb) per year over a 40 year period strongly correlate to the incidence of leukaemia.

Short term benzene concentrations may approach or exceed Occupational Health and Safety (OH&S) regulation limits in close proximity (on the facility site) to the glycol dehydrators, depending on wind conditions and dispersion conditions at the facility.[5]

3.3 Short – Term (Acute) Exposure

In Alberta, the Occupational Exposure Limit (OEL) for benzene is 1 ppm. High concentration short-term exposures (greater than 3200 $\mu g/m^3$ (1000 ppb) over an 8-hour period) are very unlikely to occur during routine glycol dehydrator operations and worker activities. Exposure could conceivably involve inhalation, ingestion, and/or skin contact.

3.**Amdur, M.O, Doull, J., Klaassen, C.D.**, 1991. Casarett and Doull's Toxicology: The Basic Science of Poisons. 4th Ed., Pergamen Press, Toronto, pp. 685-690.

4.**Rinsky, R., Smith, A., Horning, R., Filloon, T., Young, R., Okun, A., Landrigan, P.**, 1987. Benzene and Leukemia: An Epidemiological Risk Assessment. N. Eng. J. Med., Vol. 316, pp. 1044-1050.

5.**Ortech Corporation**, 1997. Dispersion Modeling of Benzene from Point Source (Natural Gas Dehydrators). Prepared for Toxics Substances Section, Health Canada.

4 Selecting Glycol Dehydrators or Alternative Methods of Hydrate Inhibition or Dehydration

4.1 Why Control Water in Natural Gas

An evaluation of the gas production, gathering, and processing system is required when considering the need for dehydration. Three factors that determine the need for dehydration are:

- Process requirements for water content in the gas stream. Gas sold from a compressor station or gas plant into a transmission or distribution pipeline system must meet the water content and dew point specifications of the pipeline system. Gas produced from a gas well or production facility and taken by a gathering system flow-line to a central production facility prior to sales into a pipeline system, may not need to meet pipeline system specifications. In these cases, installing dehydration at a central production facility may be the best decision.
- Potential for hydrate formation. Gas hydrates may form under certain combinations of temperature, pressure, and water content. The need for hydrate protection must be determined on a case by case basis. Hydrate control may be achieved using dehydration, or simply by injecting hydrate inhibitors into the gas stream.
- Corrosion protection. Protection of piping, vessels and other equipment must also be evaluated on a case by case basis.

The choice of dehydration, hydrate control and corrosion protection should be evaluated from economic and environmental perspectives. If the need for a glycol dehydrator is established, the design of the unit will depend on factors such as the operating temperature, pressure, water content, gas flow rate (inlet and outlet), and required outlet gas dew point. These variables are all incorporated in equations from GPSA[6], section 20 (*Dehydration*) that can be used to determine the water content and the appropriate type of glycol and flow rate.

One of the main considerations along the natural gas transport system is the removal of free water and the prevention of hydrate formation. Hydrates can result in ice-like obstructions (plugs) in pipelines that affect the capacity of the lines, cause pressure fluctuations and result in a build-up of differential pressures across the hydrate plugs. Excessive differential pressures can move hydrate plugs with enough force to cause mechanical damage and can cause pipeline failures. Therefore, the formation of hydrates in pipelines may pose a significant risk to people, environment, production, and company assets.[7]

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6. **Gas Processors Suppliers Association**, 1994. GPSA Engineering Data Book. Volume II, Section 20.

7. **Canadian Association of Petroleum Producers**, 1994. Guideline for Prevention and Safe Handling of Hydrates.

A typical pipeline gas specification related to the removal of water and prevention of hydrate formation[8] is that the maximum water content shall be less than 4 lb/MMSCF of gas at standard temperature and pressure.

4.2 The Decision Tree Analysis Process

Effective August 14, 2001, in IL 2001-07, the EUB requested that companies evaluate natural gas water content control by using a Decision Process Flowchart that included an evaluation of the alternatives for natural gas water content reduction, including glycol dehydration. In this chapter CAPP recommends that Industry use a procedure similar to the Decision Tree Analysis (DTA) for alternatives to solution gas flaring as described in Directive 060.

This DTA procedure, as adapted to evaluate different types of natural gas water content reduction projects, is described in the Flowchart "Decision Tree Analysis for Alternative Methods of Controlling Water in Natural Gas" found in Appendix A. The economic factors and the location of pricing information to allow consistent, across-Industry evaluations, are provided in Section 4.4.

Generally stated, the DTA, is conducted to determine if glycol dehydration is the appropriate alternative for reducing water in the gas stream. As described in more detail later (see Section 4.3), some alternatives to glycol dehydration are:

- methanol injection
- gas line heating
- regenerative adsorption materials
- membrane separation.

Overall, the DTA process proceeds as follows:

Determine the need for control of water in the natural gas feed:

1) For all gas streams from wells and batteries, considering the sales gas water content specification, investigate the gathering system, compressor station, and gas plant layout to determine the requirements for avoiding hydrate formation, and excess liquid formation as pipelined gas temperatures and pressures change in winter and summer.
2) Often a representative C7+ hydrocarbon analysis of the inlet gas to the proposed dehydrator is available. If the C6+ portion of the analysis is 0.0, then no benzene will be emitted from a dehydrator and alternatives to glycol dehydration do not have to be considered under this regulation. Even so, a company may now want

8.**Nova Gas Transmission**, 1997. Personal communication.

to continue with this evaluation to determine the lowest cost, lowest energy-usage alternative for removing or controlling water.

3) If you do not have an analysis, or the C7+ analysis shows a greater than 0.0 C6+ composition, then obtain another sample and get an extended analysis to C10+ to clearly identify the benzene component.

4) Identify the proposed operating conditions, and then use process simulation such as GRI-GLYCalc™, or HYSYS™, or other simulator, to estimate benzene and other hydrocarbons emissions volumes, and outlet gas water content.

5) Optimize the design to minimize benzene emissions at lowest levels possible while maintaining dewpoint suppression. The maximum allowed benzene emissions are set by the EUB Directive 039 for new or re-located dehydrators. For the entire site, the aggregate of all benzene emissions sources must be less than the maximum volumes allowed by the EUB Directive 060. See Chapters 5 to 10.

6) Determine maximum allowable annual benzene emissions from the oldest dehydrator on site and divide by 365 to get the maximum allowed daily benzene emissions. The daily benzene emissions from the new or relocated dehydrator, plus those emissions from the other dehydrators on site and other benzene sources, must not be greater than the daily benzene emissions of the oldest dehydrator on site.

7) If benzene emissions are greater, and the new or relocated unit has been optimized, re-design the older dehydrators to meet regulations and include the cost in the evaluation of alternatives. Evaluate mitigation strategies including design, equipment changes, improved monitoring and control systems, benzene capture, recovery and/or incineration, and other emission controls.

8) Build AFE-quality capital and operating cost estimates, and net present values.

9) Do the same design and cost evaluation for any potential alternatives.

10) The alternative project value is the same in all cases – prevention of shut-in production, equipment damage, environmental emissions, and safety issues due to hydrate formation. The capital and operating costs vary among the alternatives.

11) If an alternative to glycol has a higher NPV than the glycol dehydration case, based on the economic factors listed under Section 4.7, then it is recommended that the alternative be installed. This would eliminate benzene emissions for this project.

12) A document called the Natural Gas Water Content Reduction Projects Record of Decision must be created with calculation and evidence documentation appended. The report must incorporate the preceding information and provide sufficient detail to allow the results to be verified. If glycol dehydration is the most economic method, this Record of Decision must be available for audit at the nearest operator's field office to the dehydrator.

13) If glycol dehydration is chosen, include location and emissions volumes in your company's annual dehydrator inventory list.

14) Note also that if glycol dehydration is chosen, and if these dehydrators are in close proximity to residents (within 750 meters), you must meet with the residents, describe the work, and advise them of the expected benzene emissions. See Chapter 11 regarding Public Consultation. Record, and file with the Record of Decision, a summary of your meetings, including who you met with, comments and concerns, and how they were addressed.

4.3 Alternatives to Glycol Dehydration

Alternatives are available for hydrate control and dehydration. Selection of alternative processes should be based on an evaluation of capital and operating costs, and emission reductions. Hydrate control, without dehydration, can be achieved through the use of physical separators, chemical inhibitors, or line heaters.

- Methanol or Glycol Injection. These chemical inhibitors mix with the water vapour and condensed water and effectively suppress the hydrate temperature of the gas. The selection of the specific chemical depends mainly on the operating (chemical) cost, because both are equally effective as inhibitors for wellhead dehydration applications. However, glycols injected at a well site could be easily recovered if the gas is further processed in a glycol dehydrator at a downstream central location. There is the potential for chemical inhibitors to create excess liquid hold-up in the gathering system which may require routine pipeline pigging.
- Separator Package. A separator provides physical separation and removal of free liquids (including water) in the inlet gas stream. This substantially reduces the volume of chemical hydrate inhibitor injection required in the pipeline gathering system.
- Line Heater. The use of a line heater elevates the gas temperatures above the temperature at which hydrates form. This option can be used when chemical injection or separator packages are not viable options. Line heaters may require the use of insulated pipelines to minimize heat input requirements.

Dehydration can also be achieved using various "processes".

- Solid Desiccant / Molecular Sieve Plants. Solid desiccants are selectively chosen for treating high pressure gases when it is economical to carry out both the water and hydrocarbon (HC) dew point controls in a single step process, or when lower water dew points must be achieved. The pressure loss is considerably lower compared to the conventional two step processes involving separate dehydration and HC dew point control units.

  Molecular sieve plants are usually restricted to low-temperature processes requiring very low water content gas as feeds to turbo expander or other types of cryogenic/refrigeration plants. In such applications the desiccant systems are

commonly positioned as polishing (secondary) units downstream of primary liquids recovery plants.

A variety of solid desiccants are available in the market for specific applications. Some are good only for dehydrating the gas while others are capable of performing both dehydration and removal of heavy hydrocarbon components. However, in both cases, the desiccant beds must be routinely regenerated with heat to liberate contaminants. The physically adsorbed material is released as a gas and typically disposed of by flaring, incineration, or recovered as liquids if economically feasible. Desiccant systems have substantial capital and operating costs.

- Membrane Technology. This technology is used for the selective removal of contaminants, such as water from a natural gas stream. Use of the technology can eliminate certain emissions, relative to glycol dehydration. Membrane technology is not currently in use for production-scale gas dehydration.[9]
- Other Commercial Processes. There are many commercially available packages for customized dehydration packages. These types of products are often designed to enhance conventional equipment performance. The suitability of these processes should be evaluated on a case-specific basis.

4.4 Natural Gas Water Content Reduction Economic Decision Parameters

For consistent decision tree analyses that will be applied to all natural gas water content reduction decisions, the following paragraphs define the parameters that must be used in an economic evaluation.

- The evaluation will be a before-tax analysis.
- The commodity price forecasts used in evaluations of fuel savings will be the most recently published values by Chenery Dobson Resource Management Ltd., in their survey called *Survey of Hydrocarbon Price Forecasts Utilized by Canadian Petroleum Consultants and Canadian Banks*. This survey is updated semi-annually and available at a nominal cost per publication. The publication is also available in the EUB Library.
- In this survey, the natural gas prices to be used are listed under the average column for Large Firms in the table called Aggregator 'Blended' @ Plant gate ($Cdn/MMBtu).
- The power price forecast for electrical power usage will be the time weighted average of the previous twelve months paid by the Alberta Power Pool for

9. **Newbold**, 1995. Solvent-Resistant High-Pressure Membrane Modules for Natural Gas Dehydration. Presented at 1995 Gas Research Institute Glycol Dehydrator/Gas Processing Air Toxics Conference. Denver, Colorado, November 5-8, 1995.

power generated or the cost of the power displaced at a site. The power price will be escalated at the annual rate of inflation.

- The operator will give a detailed breakdown of capital costs, showing equipment, material, installation, and engineering costs. Capital costs will be AFE (approved for expenditure) quality numbers. Capital costs incurred prior to the initiation of the natural gas water content reduction project (sunk costs) will not be included in the analysis. Only future capital costs related to natural gas water content reduction projects will be included.
- Incremental annual operating costs for the project will be estimated. If no information is available, use operating costs equal to 10 per cent of the capital cost to initially install the facilities.
- The long-term inflation rate will be based on the Consumer Price Index forecast, which is available from the same table in the Chenery Dobson Survey used for natural gas prices.
- The discount rate will be equal to the prime lending rate of the Alberta Treasury Branch on loans payable in Canadian dollars plus 3 per cent based on the month proceeding the month that the evaluation is conducted. The discount rate will be reviewed periodically by ADRD/EUB and will be revised if the cost of capital for the oil and gas industry changes significantly.
- As noted in Section 4.2, the alternative project value is the same in all cases – prevention of shut-in production, equipment damage, environmental emissions, and safety issues due to hydrate formation.

Calculate the Net Present Value (NPV) of the alternatives. If an alternative to glycol dehydration has a higher NPV than the glycol dehydration case, then that alternative is recommended.

As noted in Section 4.2, a document called the Natural Gas Water Content Reduction Projects Record of Decision must be created with calculation and evidence documentation appended. The report must incorporate the preceding information and provide sufficient detail to allow the results to be verified.

If glycol dehydration is the most economic method, this Record of Decision must be available for audit at the nearest operator's field office to the dehydrator.

4.5 Glycol Choice

Companies can employ one of three glycols to minimize benzene emissions for dehydration at a location, specifically:

- triethylene glycol (TEG);
- diethylene glycol (DEG); and/or

- ethylene glycol (EG).

TEG is the most common type of glycol used. It has the advantage over DEG of a higher boiling point that reduces glycol losses during regeneration. Its low vapour pressure also helps to reduce glycol losses from vapourization into the gas stream. However, the higher molecular weight of TEG increases its solubility with hydrocarbons, including lighter hydrocarbons such as methane, and hence it has a higher affinity for benzene, toluene, ethylbenzene, xylene, and other heavy hydrocarbons. The use of TEG is preferable in processes where the absorber contact temperature is relatively high and the required dew point is relatively low.

All types of glycols are regenerated and used as part of a continuous dehydration cycle. TEG units are used throughout the industry at gas wells, gathering stations, and processing facilities. EG is used in low temperature natural gas liquids recovery plants and is conventionally referred to as a hydrate inhibitor. It picks up considerably smaller volumes of hydrocarbons compared to TEG, however, these plants typically handle higher gas volumes than field dehydrators, resulting in significant benzene emissions from glycol regeneration.

4.6 Benzene Sources and Emissions Characteristics from Glycol Dehydrators

Benzene occurs naturally in some gas streams. Within the glycol dehydrator system, benzene and other hydrocarbons are absorbed by the glycol in the absorber. The rate of absorption is proportional to the glycol circulation rate. The still column vent is typically the focus of most emission concerns. During heating of the rich glycol in the still column and reboiler, water and hydrocarbons (including benzene) are emitted as vapours from the still column vent. The still column vent can also be the source of methane, ethane and propane emissions from stripping gas and the processed gas.

Operators in the upstream oil & gas industry often purchase standard sized and equipped glycol dehydrator packages for their operations. In the field, companies typically operate the dehydrators at conditions that attempt to remove more water to minimize system operating problems. Such practices can increase benzene emissions from glycol dehydrators, due to over-circulation of the glycol and unnecessary use of stripping gas. This is especially common for glycol dehydrators at gas wells where gas production rates decline over time.

Although gas driven glycol pumps may emit a significant amount of fuel gas, they are typically not a significant source of benzene emissions. The flash separator may also vent gas, but is not a significant source of benzene emissions. Flash separator vapours are typically connected to the fuel gas system or a flare system, and do not emit directly to atmosphere.

The key parameters[10] affecting benzene emissions are:

- Benzene content in inlet gas. Benzene is present in some but not all natural gas produced in Canada. Where benzene is not present in the inlet gas processed by a glycol dehydrator, there will be no benzene emissions from the still column vent. Where there is benzene present in the inlet gas, the amount of benzene absorbed by glycol is proportional to the concentration of benzene in the gas.
- Glycol circulation rate. The amount of benzene absorbed by the glycol is proportional to the volume of glycol circulated.
- Absorber temperature. The temperature in the absorber vessel is determined primarily by the temperature of the inlet gas, and to a lesser amount by the temperature of the lean glycol. Higher gas temperatures are associated with higher water content, increased volatility of benzene, and less benzene absorption into the glycol.
- Absorber pressure. The absorber pressure is determined by the pressure of the inlet gas. At higher absorber pressures, the amount of benzene absorbed by glycol increases.
- Gas flow rate. The amount of benzene absorbed by glycol is affected by the gas flow rate, but the effect is not as great as the other parameters described above.

4.7 Evaluations of Downwind Benzene Exposures

Benzene emitted from a glycol dehydrator mixes with the surrounding air. The benzene is carried by the wind and dispersed, effectively decreasing in concentration. Benzene also degrades in the atmosphere through various mechanisms including photo-oxidation.

Benzene emissions should be investigated if elevated concentrations of benzene could conceivably reach workers on-site, or reach the off-site public. The assessment of exposures may involve consultations with public health, engineering, and risk assessment specialists. The basic approach to assessing human exposures from a point source emission would include:

- Characterization of dehydrator emissions. The first step is to characterize the emissions from the glycol dehydrator. This can be done using the GRI-GLYCalc™ program using a process gas analysis, and operating temperatures and pressures around the dehydrator. In general, emissions from glycol dehydrator still column vents are water saturated, exit at relatively low temperatures (less than 100 °C), flow-rates and velocities, and are near ground level. A general understanding

10.**Radian Corporation**, 1996. Technical Reference Manual for GRI-GLYCalcTM: A Program for Estimating Emissions from Glycol Dehydration of Natural Gas. Version 3. Prepared for the Gas Research Institute, GRI Contract NO. 5088-254-2796.

should be established for frequency, duration, and intensity of emissions, and how emissions relate to operating conditions.

- **Exposure Assessment**. Based on GRI-GLYCalc™ results, plume dispersion models can be used to determine how benzene is dispersed around glycol dehydrators[11, 12]. In general, the highest ambient concentrations of benzene from glycol dehydrator still column vents occur in close proximity to the dehydrator. The first phase of a site-specific assessment of downwind exposure would often be based on such predictive dispersion models.[13] Models that could be used are the SCREEN and ISC3 models. If modeling confirms that there is a potential problem, a more accurate assessment of exposure should be completed. A second phase assessment would supplement the dispersion model with actual field measures and/or monitoring of actual individual exposure. It should be realized that estimates of human exposure are based on assumptions regarding a number of factors such as the pattern of daily human activities, meteorological conditions, and emission rates from the dehydrator. Each assumption carries an inherent level of uncertainty.
- **Assessment of the potential risks associated with exposure to dehydrator emissions**. General guidelines for assessing human health risks associated with exposures to toxic substances may be obtained from Health Canada.[14] The Priority Substances Reports, under CEPA, provide more specific information for compounds like benzene, toluene[15], ethyl benzene, and xylenes [16]. Estimates of risk should not be interpreted as fine lines between acceptable and unacceptable, but can serve as indications of relative risk from one exposure scenario to another.
- **Comparison with Standards and Guidelines**. No Canadian exposure standards or guidelines for ambient air levels of benzene currently exist, although the Canadian Council of Ministers of the Environment (CCME) has issued a Canada Wide Standard (CWS) for benzene (Phase 1 and 2) that requires industry-level reductions in benzene emissions, the use of Best Management Practices, and the monitoring and reporting of benzene emissions (see

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11. **Ortech Corporation**, 1997. Dispersion Modeling of Benzene from Point Source (Natural Gas Dehydrators). Prepared for Toxics Substances Section, Health Canada.

12. **TRJ Environmental Incorporated**, 1997. A Methodology for Estimating Incremental Benzene Exposures and Risks Associated with Glycol Dehydrators. Document prepared for the American Petroleum Institute, Publication #4644.

13. **United States Environmental Protection Agency**, 1995. User's Guide for the Industrial Source Complex (ISC3) Dispersion Models. Office of Air Quality Planning and Standards Emissions, Monitoring, and Analysis Division, Research Triangle Park, North Carolina, EPA-454 / B-95-003a.

14. **Government of Canada, Environment Canada, Health and Welfare Canada**, 1994. Human Health Risk Assessment for Priority Substances. Minister of Supply and Services, Ottawa.

15. **Government of Canada, Environment Canada, Health and Welfare Canada**, 1992. Canadian Environmental Protection Act, Priority Substances List Assessment Report – Toluene. Minister of Supply and Services, Ottawa.

16. **Government of Canada, Environment Canada, Health and Welfare Canada,** 1993. Canadian Environmental Protection Act, Priority Substances List Assessment Report – Xylenes. Minister of Supply and Services, Ottawa.

http://www.ec.gc.ca/CEPARegistry/agreements/cws.cfm). British Columbia and Saskatchewan have set goals for benzene reduction that reference the Canada Wide Standard and the upstream Oil & Gas Industry's commitment to reduce benzene emissions by 90% by 2005. The government expectation is that the Oil & Gas Industry will comply with the methods and reporting stated in this CAPP Best Management practice across all of the provinces.

- Alberta Environment has published Ambient Air Quality Objectives (AAAQO) that include a one-hour average benzene limit of 30 micrograms/m^3 limit on benzene concentrations in air (see http://www3.gov.ab.ca/env/protenf/approvals/factsheets/ABAmbientAirQuality.pdf). Health Canada has published documentation that provides guideline values for understanding the health risk associated with exposure to toxic substances.[17]

  The Benzene Emission Limits stated in Section 2.3, on a daily basis, and with sufficient distance to a resident, will not expose the resident to a higher concentration of benzene in the outside air than that person will normally be exposed to in a city, or within their own homes. The same Benzene Emission Limits, taken on a daily basis, will not expose a worker to higher benzene air concentrations, under normal working conditions, than the one-hour average benzene limit of 30 micrograms/m^3 stated in the AAAQO. As Industry technology and operations change, these emissions will continue to decrease.

- Making a final decision. Before making a final risk management decision as to whether or not to use glycol dehydration, consideration should be given to a broad range of relevant factors. These include but are not limited to:what is the normal exposure to benzene during the course of everyday life;
- what are the uncertainties in the assessment of exposure (and risk);
- is the risk of exposure increased by the proximity of other dehydrators;
- are residents subject to increased exposure by their proximity to dehydrators;
- does the contour of the land increase the risk of exposure and the concentration of benzene to workers and nearby residents;
- do weather and wind patterns increase the risk of exposure and concentration of benzene; and
- is the exposure for a short duration or an extended time period; etcetera?

17. **Government of Canada, Environment Canada, Health and Welfare Canada**, 1996. Health-Based Tolerable Daily Intakes / Concentrations and Tumorigenic Doses / Concentrations for Priority Substances. Minister of Supply and Services, Ottawa, Canada.

5 Benzene Emissions Determinations

There are a number of methods available to estimate or measure glycol dehydrator emissions. These types of programs are useful for assessing existing conditions and evaluating (or predicting) emission reductions associated with various changes to dehydrator operations and/or emission control equipment.

5.1 Estimation Methods

Four methods of determining benzene emissions from glycol dehydrators are used in Western Canada. These are:

- reviewing gas analysis for benzene presence;
- analysis of rich and lean glycols to determine the amount of benzene removed from the glycol;
- simulation using software such as GRI-GLYCalc™ or HYSYSTM (Aspen Technologies); and
- total air emissions capture and analysis.

Gas Analysis Review

Gas analyses that show no benzene in the wet gas predict no benzene emissions from still column vents.

Rich-Lean Glycol Calculation

The rich/lean glycol analysis determines benzene emissions by the difference between benzene concentrations in the rich glycol upstream of the reboiler and the lean glycol downstream of the reboiler. While this method provides actual measurements rather than computer simulation, it requires very careful sample handling, special containers, and careful laboratory analysis. See the GRI Topical Report (GRI 95/0368) "Atmospheric Rich/Lean (ARL) Method for Determining Glycol Dehydrator Emissions" for details. This is available for a fee from http://www.gastechnology.org.

GRI-GLYCalc™ Version 4.0

GRI-GLYCalc™ Version 4.0[18] is a Windows-based computer software package that helps predict benzene and other hydrocarbon emissions from triethylene glycol (TEG), diethylene glycol (DEG), and ethylene glycol (EG) dehydration units. Process data inputs required for the program are listed in Table 3 below.

18. **Radian Corporation**, 1996. Technical Reference Manual for GRI-GLYCalcTM: A Program for Estimating Emissions from Glycol Dehydration of Natural Gas. Version 3. Prepared for the Gas Research Institute, GRI Contract NO. 5088-254-2796.

The GRI-GLYCalc™ simulation model, developed by the Gas Research Institute in the U.S, (now called the Gas Technology Institute) has received scrutiny throughout the United States by regulatory, environmental and industry stakeholders. Version 4 includes SI values. Accurate (C10+) gas analyses or rich/lean glycol analyses are required to run the model. Note however, that some caution must be considered. GRI-GLYCalc allows the use of default values that can sometimes lead to misleading results. Note that GTI is no longer supporting the program and will not address the "computational instabilities" that can lead to misleadingly high emissions from EG units processing lean gas.

Table 3: GRI-GLYCalc™ Calculation Parameters

Input Parameter	Source of Data
Wet gas composition	Sample and analysis - commercial laboratory
Wet gas temp. / press.	Gauge readings
Wet gas water content	Measure or assume saturation
Cold Separator (EG only)	Temperature & pressure measurement device
Dry gas flow rate	Meter readings
Dry gas water content (TEG only)	Measure or calculate based on assumptions
Lean glycol circulation rate	Count pump strokes and use to calculate flow from the pump chart
Lean glycol water content	Sample and analysis - commercial laboratory
Glycol pump type	Program provides defaults for pump type
Flash tank temp. / press.	Gauge readings / assumptions
Stripping gas rate / composition	Gauge readings / assumptions
Condenser temp. / press.	Gauge readings / assumptions
Flare / Incinerator efficiencies	Assume 90% for flares and 95% for incinerators
SI values	

The GRI-GLYCalc™ program requires the user to obtain a number of input parameters. A detailed description of sampling and analytical procedures for benzene from the site equipment is provided with the program. Like all predictive computer programs, the answer provided is only as reliable as the input used in the calculations.

A “Rich – Lean” calculation option is also available on GRI-GLYCalc™ Version 4.0. To run these calculations, benzene concentrations must be measured from actual samples taken from the rich and lean glycol, using special techniques to prevent hydrocarbon loss. See the GRI Topical Report “Atmospheric Rich/Lean (ARL) Method for Determining Glycol Dehydrator Emissions” for details. This is available for a fee from http://www.gastechnology.org

The GRI-GLYCalc™ program is available online through the Gas Technology Institute (http://www.gastechnology.org/). The software comes with a user manual that outlines the steps involved with collecting input data, running the model, and interpreting results.

Total Air Emissions Capture (End-of-Pipe Testing)

One total air emissions capture method is routinely used. This is the BERT (Benzene Emission Reduction Trailer) operated by Norwest Labs. The BERT unit condenses all of the still column vapours over a two hour period. The captured gases and liquids are analyzed in the laboratory by gas chromatography and benzene mass emission rates are calculated. B.E.R.T. was designed to facilitate measurement and collection of the three phases which occur when an emission stream cools. Each phase is measured and analyzed separately to develop an accurate benzene emission value.[19]

19 **Norwest Labs Glycol Dehydration Estimation Procedure,** 2000 The B.E.R.T. (Benzene emission Reduction Trailer) Story.

6 Preventing and Minimizing Emissions from Glycol Dehydrators

6.1 Design Considerations

The most effective, and often the most cost-effective, method of controlling emissions from an engineered system is to incorporate proactive thinking in the design stages of the project. The key areas for controlling contaminant emissions from glycol dehydrators include:

- glycol circulation rate, concentration and purity;
- absorber and regenerator temperatures;
- the number of trays or contact stages in the absorber;
- any mitigating equipment (e.g., inlet scrubbers, flash drums, properly sized still columns, vent gas cooling/condensing systems with liquid collection tanks); and
- supplemental emission controls.

Most well-site glycol dehydrators use gas-operated equipment due to the lack of electricity. They are usually “skid” mounted, pre-fabricated packages with gas treating capacities in the range of 14,000 to 140,000 m3/d (.5 to 5 MMSCFD) or higher.

Operating companies typically purchase these short-delivery, off-the-shelf packages and install them in the field as quickly as possible. These units may be over-designed and over-sized for the application for which they were intended. Inlet gas flow can decrease over time and create a further exaggerated condition with respect to over-design. Some of the optional equipment (e.g. flash separators) may not be available. Field personnel can reduce benzene emissions by regularly optimizing the operation of the dehydrator.

Qualified technical personnel must complete a Dehydrator Engineering and Operations Sheet (DEOS) as per the instruction manual (see Appendix B). Field personnel must ensure that the sheet is posted and maintained in accordance with the Alberta Energy and Utility Board’s Directive 039. The Dehydrator Engineering and Operations Sheet posted near the dehydrator will ensure that operators are aware of optimal operating conditions to minimize benzene emissions for their dehydrators while meeting water removal requirements.

The following are guidelines to achieve a high level of performance.

6.2 Performance Evaluation

Field operating data can be fed into any of the technical evaluation programs being used to assess the performance of a dehydrator. These programs include the

previously discussed GRI-GLYCalcTM and Rich-Lean methods, or other programs such as Prosim, HYSYS[20], or "in-house"/ commercial simulators. Results of these evaluations can be used in a sensitivity analysis whereby specific components of the system can be identified as the most appropriate place for implementing emission control strategies.

6.2.1 Glycol Circulation Rate

The amount of benzene absorbed by glycol is proportional to the circulation rate. Of all operating variables affecting benzene emissions, the circulation rate has the greatest impact. This is especially important when considering that operators may have to maintain higher than necessary circulation rates for dehydrating the gas, to overcome some of the inherent physical limitations of the equipment (e.g., the glycol flow distribution across the trays, pump minimum flow requirements etc.). Operators can double-check the needed circulation rates, on a case by case basis, by referring to standard charts available or provided for the dehydrator by the supplier. Alternatively, operators may use simplified computer programs (e.g., GRI-GLYCalcTM) intended for this purpose, to generate their own operating charts. Refer to the Dehydrator Engineering and Operations Sheet (see Appendix B) or consult with your company's engineering personnel.

6.2.2 Absorber Operating Conditions

Generally speaking, benzene absorption by glycol increases with higher absorber pressure and lower absorber temperature.[21] Additional points are listed below.

- Adjusting absorber pressure for curtailing benzene emissions is generally not an option. However, absorber pressures may decline over time, at gas well and some facility installations.
- Absorber temperatures can be controlled in some cases by optimizing the lean glycol temperature (e.g. with heat exchangers) or by adjusting the inlet gas temperature (e.g. adjusting compressor discharge temperatures or installing a line heater upstream of the absorber). Increased temperature may also mean that more water stays in the gas, so the impact of the change must be carefully monitored.
- TEG absorption of benzene increases with the number of trays or packing height of the absorber for a fixed circulation rate. Therefore, absorbers with an excessive number of trays can add to benzene emissions. Stock dehydrator absorbers are especially prone to over-staging. If the absorbers are built with multiple entry

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20. **Hyprotech Limited**, 1994. Hysim™ User's Guide, Version C2.50. 300 Hyprotech Centre, Calgary, Alberta.

21. **TRJ Environmental Incorporated**, 1997. A Methodology for Estimating Incremental Benzene Exposures and Risks Associated with Glycol Dehydrators. Document prepared for the American Petroleum Institute, Publication #4644.

nozzles for the lean glycol, it would provide an opportunity for the operator to determine if some of the top trays could be bypassed during normal operation.

6.2.3 Reboiler Temperature

The reboiler reconcentrates the glycol to regain its absorption quality. Optimized reboiler temperatures are essential to reconcentrate glycol for achieving specification dryness in the product gas. Relevant charts are published in standard references such as GPSA7 and vendor supplied information for the operator to set the reboiler operating temperature.

Reboiler temperature deviations, either above or below the optimum temperature range, can make the dehydrator operation inefficient. Higher than optimum temperatures may still result in adequate dehydration of the gas stream, but can lead to glycol losses and excess consumption of fuel gas. Lower than optimum temperatures may result in reduced water removal efficiency. In this case, the glycol circulation rate may be set higher than if reboiler temperatures were within the optimum range.

6.2.4 Stripping Gas

Stripping gas is typically dry fuel gas introduced in the stripping section of the reboiler specifically to regenerate high concentration glycol for improved dehydration. The use and rates of stripping gas should be adequately evaluated because that is what finally escapes into the atmosphere and will therefore affect greenhouse gas emissions. Specialty charts are available in standard references such as the GPSA7 data book and other vendor publications, and should be consulted for estimating the stripping gas requirements for specified sets of conditions. Reductions in stripping gas consumption can translate directly into savings both in operating cost as well as increased production volumes.

One way of avoiding the use of stripping gas is by choosing suitable alternative technologies. For example, in the Cold Finger Process, cool rich glycol is used for heat exchange purposes, causing water vapour in the accumulator vessel to condense. High glycol purity may thus be achieved without the direct use of stripping gas. The circulation rate and heat requirements for the regeneration of glycol are also reduced which potentially decreases benzene absorption by the glycol from the gas stream.[22]

6.2.5 Flash Tank

The main purpose of a flash tank is to remove dissolved gas from the rich glycol stream and improve the glycol reconcentration process. In addition, the liberated gas

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22. **Gas Conditions International Company**. Coldfinger - An Exhauster of Removing Trace Quantities of Water from Glycol Solutions used for Gas Dehydration. Gas Conditioners International Co., Houston, Texas.

can be used as fuel gas (i.e. reboiler burner), flared, vented, or conserved. An operational concern is that the flash gases are wet and can cause operating and freezing problems. The use of a flash tank increases the effectiveness of condenser systems in controlling benzene emissions.

6.2.6 Other Optimization Opportunities

The addition of structured packing to existing contactor trays may increase gas handling capacity and improve dew point suppression. Contaminants such as produced water, lubricants, well-treating chemicals, and scale, reduce the ability of glycol to absorb water. The heavier hydrocarbons increase benzene absorption by the glycol. Performance can therefore be optimized by providing some type of filtering device such as a Filter-Separator unit upstream of the dehydration facility.

The glycol dehydrator absorber operating pressure is an important factor because the solubility of benzene in glycol increases with increased pressure. This potential drawback is often offset by the limited capacity for high pressure gas to carry water which allows glycol circulation to be reduced. The gas temperature, which primarily controls the operating temperature of the absorber, also has an effect on benzene absorption because lower absorber temperatures favour dissolution of benzene in glycol. This is an especially important parameter to be considered during the design stage.

Modifications to the glycol pump system can also provide emission reduction benefits. Many well site dehydrators use gas-driven pumps that exhaust gas to the atmosphere. Optimization opportunities include routing the exhaust gas back into the fuel gas header for firing the reboiler or changing the drive mechanism to an electric motor.[23] As well, new pumps have been developed which do not discharge the gas to atmosphere, and can therefore reduce or eliminate the exhaust gas stream. These opportunities are site-specific, but do provide potential benefits such as reduced fuel gas consumption and reduced methane emissions.

6.3 Maintenance Procedures

Filter change-out is a frequent maintenance activity undertaken at dehydrators in the field. Company protocol(s) should be in place for everyday access, and there should be ongoing training programs to ensure that benzene exposures are minimized while handling filter elements. Consultation with a qualified occupational hygiene professional may be required if policies are outdated or non-existent. Worker exposure is typically controlled through the use of appropriate personal protective equipment and adequate ventilation in the work area.

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23. **Myles, J., Johnston, B.**, 1995. Managing Emissions of BTEX and Methane from Multiple Sources *on TEG Dehydrators*. Presented at 1995 Gas Research Institute Glycol Dehydrator/Gas Processing Air Toxics Conference. Denver, Colorado. November 5-8, 1995.

Special care should be taken to ensure that the operating/maintenance personnel do not open the filter housing before the trapped hydrocarbon liquids are drained through a properly installed drain pipe into a dedicated collection tank for safe disposal. This is the time of critical care, as it is the situation where the highest level of benzene exposure is expected.

Glycol sludge deposits are often found at the bottom of various vessels and heat exchangers when they are opened for inspections and annual turnarounds. These deposits should be flushed out with water and drained to dedicated containers for proper disposal. The affected equipment should all be purged with air for a sufficient amount of time before cleaning scale as a safety precaution to drive off the remaining hydrocarbon vapours.

7 Supplementary Emission Controls / Facility Optimization

Supplementary or “add-on” emission controls are used to remove or destroy pollutants in the still column vent emissions. The most common practices involve the use of condenser and thermal systems, either separately or in series. These emission control options could be considered as an optimization of facility design and are best handled on a site-specific basis.

7.1 Condenser Systems

Condensers reduce the temperature of the still column vent vapours to condense water and hydrocarbons (including benzene). The condensed liquids are then collected for further treatment or disposal. Generic types of condensers are air-cooled, gas-cooled, water-cooled, glycol-cooled, and ground-cooled. Air-cooled condensers typically rely on the ambient air for removing the heat from the condenser; the condenser may use fins or a fan to improve heat exchange. Gas-cooled and glycol-cooled condensers utlilize cool medium (dry gas or rich glycol) from the glycol dehydrator operation as the heat exchange mechanism. Water-cooled condensers follow similar principles, but have not been used in Canada due to freezing concerns. Ground-cooled condensers consist of piping and storage vessels installed below surface grade, where the surrounding soils act as a heat sink.

An approach currently used by some operators is to route the still column vent (off gas) line to either an aboveground or underground storage tank for cooling. This approach can be effective in cold climate locations where ambient temperatures act as a convenient heat sink. It also lends itself to further emissions control through rerouting flows from the tanks to a flare or incinerator system.

There are several patented designs available in the market, developed by various companies based on the cooling concepts discussed above. They include the Texaco-Coastal BTEX System, R-BTEX Process, CONOCO’s Aromatic Recovery Unit, and others. Most of these patented designs are used on large gas processing facilities and not at well sites and small dehy applications. None of these systems are known to be in operation in Canada.

Condensing systems benefit from (and may require) a flash tank in the glycol process upstream of the exchange mechanisms to liberate non-condensables (e.g. methane, ethane, etc.). The use of stripping gas (being a non-condensable) reduces the cooling efficiency of condenser units. Condensing system designs can range from a simple vessel and piping-modification to commercial type heat exchangers.

In cold climates, above ground condensing units are susceptible to frequent operating problems due to freezing of the condensates (e.g., as water, benzene). Proper heating and insulation are required to prevent or minimize problems from freeze-ups, however, the cost of such measures can be prohibitive. Ground-cooled installations

are made relatively resistant to such freeze-ups by carefully laying the pipes and tanks sufficiently below grade.

7.2 Thermal Systems

Thermal treatment systems include flare systems and incineration systems. Both can provide effective control of benzene emissions from glycol dehydrators. Both types of systems have been installed at glycol dehydrator locations in Canada. To date, these systems have typically been installed for control of hydrogen sulphide emissions (i.e. where gas containing hydrogen sulphide is being processed) or for odour control (e.g. where gas contains mercaptans).

7.2.1 Flare Systems

A flare system design involves the collection of off-gas vapours (i.e. instrument vents, flash tank, pump exhaust, still column vent) to an underground tank where condensables are collected, and venting the tank to a low pressure flare. A fuel gas purge is recommended to sweep the system (and/or use of a flame arrestor) to prevent flare flashback. This system may be used in conjunction with underground piping and a collection tank ground-cooled condensor. Flaring will help BTEX destruction through combustion and improve emission dispersion by elevating the point source emission which subsequently reduces ground level concentrations. It is possible to attain higher combustion efficiencies by choosing properly designed atomizer and burner systems that promote complete combustion of the BTEX compounds. However, the fuel gas consumption needed to maintain sweeping gas and burner firing increases operating costs as well as emission of carbon dioxide.

7.2.2 Incineration Systems

Off gas can be directly incinerated or an incineration system can be installed after a condenser system. Incineration at temperatures of 730 °C (1500 °F) can provide almost complete (>99%) destruction of BTEX and eliminate hydrocarbon odours. Incinerator stack height and location should be based on safety and ground level concentration requirements. There are also freezing protection and fuel gas related costs associated with the decision to install incineration systems.

8 Waste Management Alternatives

There are a number of waste streams generated from the operation of glycol dehydrators in the natural gas industry. The following are recommended management practices for each one of these waste streams:

Waste Glycol Filters. There are two basic types of glycol filters: activated carbon and sock-type filters. Unless specific analyses have been performed on the filters, all glycol filters should be considered Dangerous Oilfield Wastes, Special Wastes or Waste Dangerous Goods, and should be handled, stored, transported, and disposed at an approved hazardous waste treatment facility. The hazardous nature of these filters is primarily related to flammability and combustibility.

Waste Glycol. Glycol can become contaminated (usually by chlorides) and is then not effective in removing water from the gas stream. Waste glycol is generally not considered a Dangerous Oilfield Waste or Special Waste (except if the flashpoint is less than 61°C). Glycol is considered a Waste Dangerous Good in Saskatchewan. Waste glycol is not suitable for disposal into the environment. Whenever possible, waste glycol should be recycled at an approved recycling facility.

Produced Water and Hydrocarbon Condensate. There are two sources of produced water, inlet separators (predominantly water and hydrocarbon) and glycol dehydrators, that generate a glycol - water - hydrocarbon mixture from condensed regenerator still vapours. These streams could be sent directly to an approved disposal well or depending on the volume and quality of the hydrocarbon condensate could be run through a facility to separate the aqueous phase from the hydrocarbon condensate.

9 Managing Multiple Dehydrators at One Site to Minimize Cumulative Benzene Emissions

Directive 60 has had limits on the aggregate volumes of benzene emissions from all sources on a site since 1999.

Accordingly, regulators established that the addition of one or more dehydrators to a site should not increase the aggregate dehydrator emissions more than the maximum Benzene Emissions Limit set for the oldest dehydrator on that site. This limit is set by Directive 60 on the aggregate benzene emissions of all sources on that site.

For example, if two existing dehydrators were installed on a site in 2002 and the site is more than 750 meters from any resident, the annual total Benzene Emission Limit is 3 tonnes/year per the EUB Directive, as restated in Section 2.3 of the BMP. Again, this annual volume assumes that the dehydrators, plus other sources, are operating 365 days a year. This annual limit divided by 365 sets the daily maximum benzene emission rate allowed on this site, regardless of the number of dehydrators present, or, 3 tonnes/year x 1,000 kilograms/tonne divided by 365 days per year, or 8.22 kilograms/day (or 0.3425 kg/hour).

Again, check if there are other benzene sources on site and add the volumes to the sum of the emissions from the dehydrators. If, for example, the two dehydrators emit a total of 1.9 tonnes/year, and there is a compressor engine on site emitting 0.2 t/y of benzene, then the total of 2.1 t/y allows the new dehydrator to emit a maximum of 0.9 t/y of benzene. Obviously, this is below the 1 t/y limit for new dehydrators. An operator can re-examine the older dehydrators or the engine source to see if it is easier or more economic to reduce those emissions, or the new dehydrator will have to be re-designed to this maximum of less than 0.9 tonnes of benzene.

Let’s say that the old dehydrators have high glycol circulation rates as determined by the DEOS on each unit, and that they operated all of the days up to the end of March. If reducing these rates achieve a 0.5 t/y reduction on each unit, leaving total site emissions at 0.9 +0.2 = 1.1 t/y, this allows the new unit to be added without restrictions (this assumes that all units are operating 365 days of the year). If the addition was done in early April, then the annual emissions reported would be the daily rates of each of the old units up to the end of March times the days on stream, plus the daily rates of all three units times the number of days on stream for the rest of the year. See Appendix A for a simplified flowchart of this process.

10 Completion of the Dehydrator Engineering and Operations Sheet (DEOS)

As described in Section 2.4 the DEOS is a listing of the design and operating details of each dehydrator, and a graph showing the relationship between outlet gas water content and benzene emissions from the vent stack versus glycol circulation rate. For new dehydrators most of this data can be assembled and entered by the engineering contractor.

The DEOS is a very useful tool for understanding the capability and potential misuse of a dehydrator. Some of the information it provides includes:

- the design flowrate, distance to the nearest residence, inlet gas benzene content, typical number of operating days per year, the number of dehydrators on site;
- glycol pump information such as make, model number, normal operating speed, and plunger information to verify glycol circulation rate;
- the method used to calculate the benzene emission volumes (typically the GRI-GLYCalc™ application);
- the types of benzene controls installed;
- the benzene emissions volumes calculated before and after controls;
- the allowed benzene emission limits for this dehydrator, and the aggregated benzene emission limit if there are other dehydrators on the site; and
- the dehydrator operations graph;
- The contact information for the person who set up the DEOS, and who likely will be the contact for updates;
- Site details such as name, LSD, type, dates, etc.

The Operations Graph

The operation graph is assembled by the Technical Contact, who will use the procedure for calculating the data as described in the Appendix B document "Preparation of Dehydrator Operations Graph". The graph provides a visual estimate of the benzene emission volume for a set glycol circulation rate. At the same rate an operator can see the water content of the gas after the glycol contactor. Typically the water content is calculated for two different gas flowrates that straddle the normal gas flowrate at which the dehydrator typically operates. This is not necessarily the design capacity of the dehydrator.

Feedback from Industry has indicated that many dehydrators are operated at a much higher circulation rate than is necessary for adequate removal of water from the inlet gas. As shown in the example DEOS form, the water content rapidly flattens out below the acceptable water content as the glycol circulation increases. Note that the

benzene volumes emitted rise rapidly with the circulation rate. Depending on ambient temperatures, and the potential for decreasing underground soil temperatures that promote hydrate formation in pipes, the operator sets a glycol circulation rate.

With this operating graph, an operator can pick a glycol circulation rate that is near the beginning of the flattened part of the curve with the confidence that the exit gas will be dry enough to prevent hydrates from forming. This circulation rate is given to the Technical Contact who will update the DEOS with the new benzene emissions volume and send out a laminated DEOS copy for posting near the dehydrator.

Benzene Limits

Note that the emissions rates on the graph are given in tonnes/year but this depends on the number of days of operation and the emission rate per day. Referring back to Section 2.3, the annual benzene emissions limit assumes that the dehydrator operates 365 days of the year. If the dehydrator operates for a shorter time, the operator cannot raise the daily emissions times fewer operating days, with the net effect of maintaining the average annual limit, without raising the daily ambient air concentration of benzene. To do this would be a detriment to the health of workers and nearby residents. Stay within the daily limits established by taking the annual limit and dividing by 365 regardless of the number of actual operating days. Or, reduce the benzene emissions by other control methods to allow increasing gas processing.

Other DEOS Benefits

The DEOS provides immediate feedback to supervisors and government inspectors of the actual operating condition of the dehydrator. An inspector will likely do a speed check on the glycol pump and check against their tables of typical flowrates for available pump manufacturers. If the circulation rates do not match their tables, they will be asking for explanations, and encouraging a circulation rate reduction.

In addition, the energy usage for regenerating the glycol, and circulating the glycol, rises rapidly with rising circulation rates. Industry experience has shown that reductions in glycol circulation rates, while still obtaining adequate gas dryness, can achieve reductions in fuel usage often valued at tens of thousands of dollars per dehydrator, assuming a value of $6.00/gigaJoule (GJ).

Finally, the DEOS information can be maintained in a corporate database and updated easily. This database can be linked to the annual inventory reporting spreadsheet shown in Appendix C, and described in the Section 12 on Reporting, for rapid and accurate compilation of the total benzene emissions for a company.

11 Public Consultation

11.1 Purpose

Public consultations are required to ensure that residents living in close proximity (<750 m) to a dehydrator are informed that the new or existing units comply with Alberta Energy and Utilities Board (EUB) and Alberta Environment regulations limiting benzene emissions. If existing facilities do not comply after optimizing the units operating conditions then you must self-declare to the EUB and provide a plan for modifications to achieve compliance. If the implementation of the plan is not acceptable to the EUB, enforcement action may include shutting in the unit.

11.2 Communication Guidelines

If the facility is in the planning stages, meet with the residents to advise them that the facility will meet Alberta regulations limiting benzene emissions to less than 1 tonne per year. Also advise residents that licensed facilities, as a standard term of their approval, can not exceed the Alberta Ambient Air Quality Objective of 30 micrograms /m3 in a 1-hour period. The AAAQO is set to protect the environment and human health.

Personal contact is preferred wherever possible. Do not indiscriminately pass out information that creates a perception of uncontrolled risk, because it could unnecessarily alarm residents.

Emphasize the efforts to control benzene and the need to control benzene. State specifically that control of benzene is a priority in Canada.

Keep the message simple and direct. Consider using the CAPP Brochure, entitled "Benzene Emission Reductions by the Upstream Petroleum Industry", available at http://www.capp.ca/raw.asp?x=1&dt=NTV&e=PDF&dn=60315 and leave a copy for the resident.

It is important to ensure that people in the close proximity area are informed, but remember that any information circulated to residents could have unintended effects. Personal contact and an informal approach are most important.

If a resident requests information on the human health effects of benzene, he/she should contact the local Medical Officer of Health (MOH). A list of MOHs is provided in Appendix H.

11.3 Suggested Messages

The following is suggested text for communication with your landowners. Please alter as fits your specific site:

“Benzene is a naturally occurring compound that has been identified as a potential cancer causing agent. The oil and gas industry is one potential source of this substance and has made, and is continuing to make equipment and operating changes to ensure that benzene emissions from natural gas facilities are minimized.

On January 1, 1998, Canada’s oil and gas industry, in co-operation with provincial and federal environmental agencies, initiated a program to reduce benzene emissions, and by 2006 had achieved a 76% reduction compared to 1995 emission volumes. In 2006 the voluntary program became a regulated requirement.

The best way to address possible health concerns is to reduce benzene emissions at the source. The facility located near you either (a) already complies with the latest regulations, or (b) will have emissions reduced to the required levels by [DATE INSERTED BY OPERATOR].

The benzene emitted from a natural gas facility is diluted quickly by the air, with benzene exposure dropping rapidly within 100 to 200 meters from any oil or gas facility. At this site benzene control reduces emissions even more, and regulations require that this operating condition be checked and improved regularly.

If you have any concerns about benzene releases, or wish to see the industry’s BMP on benzene emissions, please contact [CONTACT PERSON INFORMATION TO BE INSERTED BY OPERATOR].”

12 Reporting

All parties are committed to ensuring that there is an excellent record of industry experience and results achieved through the application of the Best Management Practices document and the EUB Directive. This means that the need for these reports will be reinforced with industry operators, and that government representatives will remind industry of the requirement to complete reporting in accordance with the EUB's Dehydrator Directive.

Operators must submit an annual comprehensive benzene emissions report for all glycol dehydrator facilities.

The Dehydrator Benzene Inventory List template is shown in Appendix C and is available electronically at www.capp.ca . It must be completed and emailed to CAPP, attention the Benzene Technical Advisory Team, Manager of Alberta Operations at benzene.tat@capp.ca by July 1 of each year.

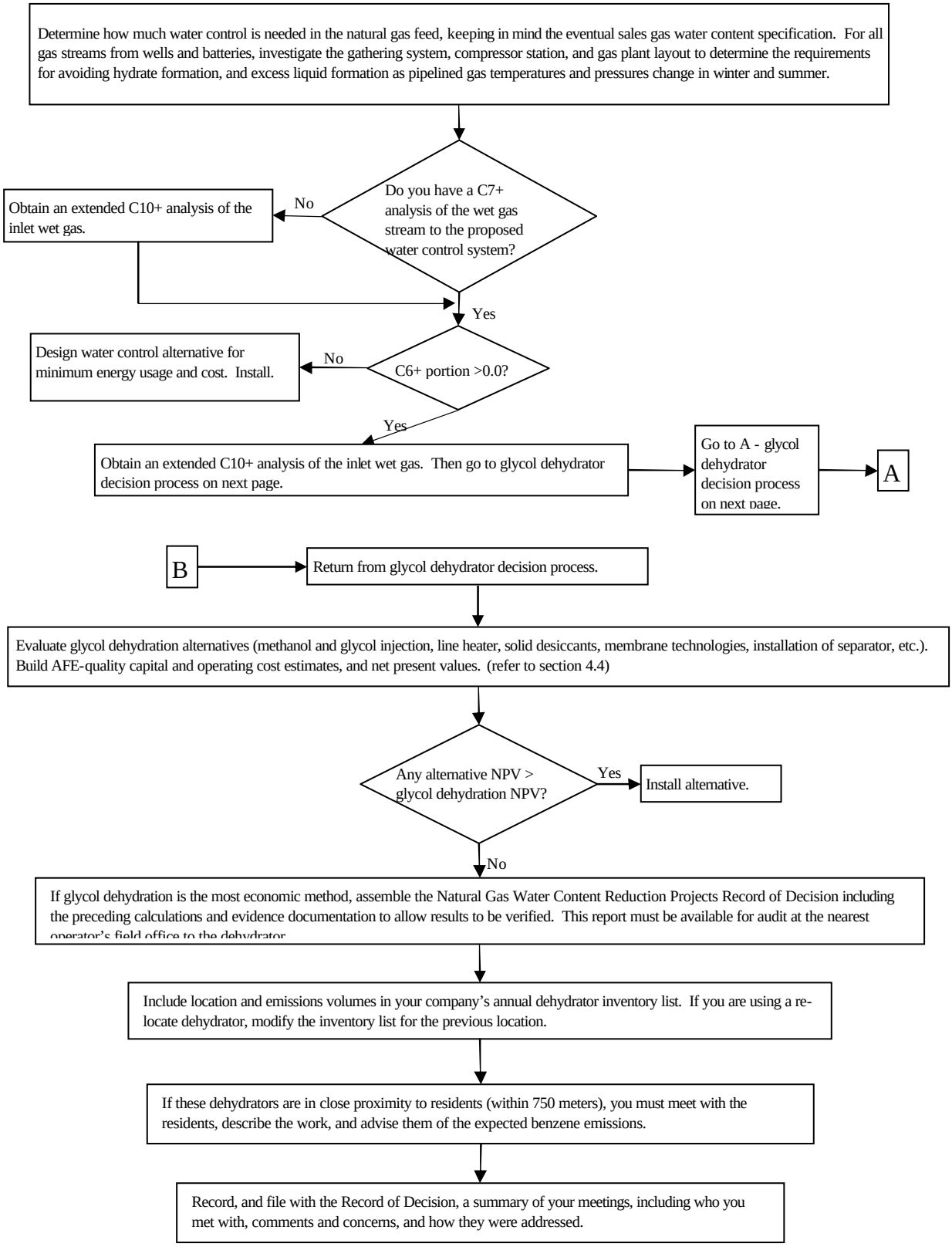
The report will include the following information, for each calendar year:

- A list of all glycol dehydrators by site if it is connected to process piping and ready to operate, acting as a separator, or is operating as a dehydrator.
- Show the status of each glycol dehydrators taken out of service, or shut in to use other dehydration methods. Do not remove a dehydrator from a list until it is relocated, sold, or dismantled.
- Provide the initial date of production for new or relocated glycol dehydrators (if new or relocated after January 1, 1999);
- Provide the allowed emissions per dehydrator, unless there is more than one dehydrator on site. If so, then show the allocated maximum benzene emissions to meet the cumulative maximum limit of the oldest dehydrator on site.
- If a glycol dehydrator is in close proximity (less than 750 m) to residences and public facilities, provide the distance to the closest residence;
- Provide the number of days in a year that the dehydrator is on stream.
- Provide the average benzene emissions rate in units of kilograms/day for each glycol dehydrator during the time on-stream.
- Multiply the number of operating days by the benzene emissions rate and convert to tonnes per year and submit this value, and
- Provide a company name, contact name, telephone number, and email address.

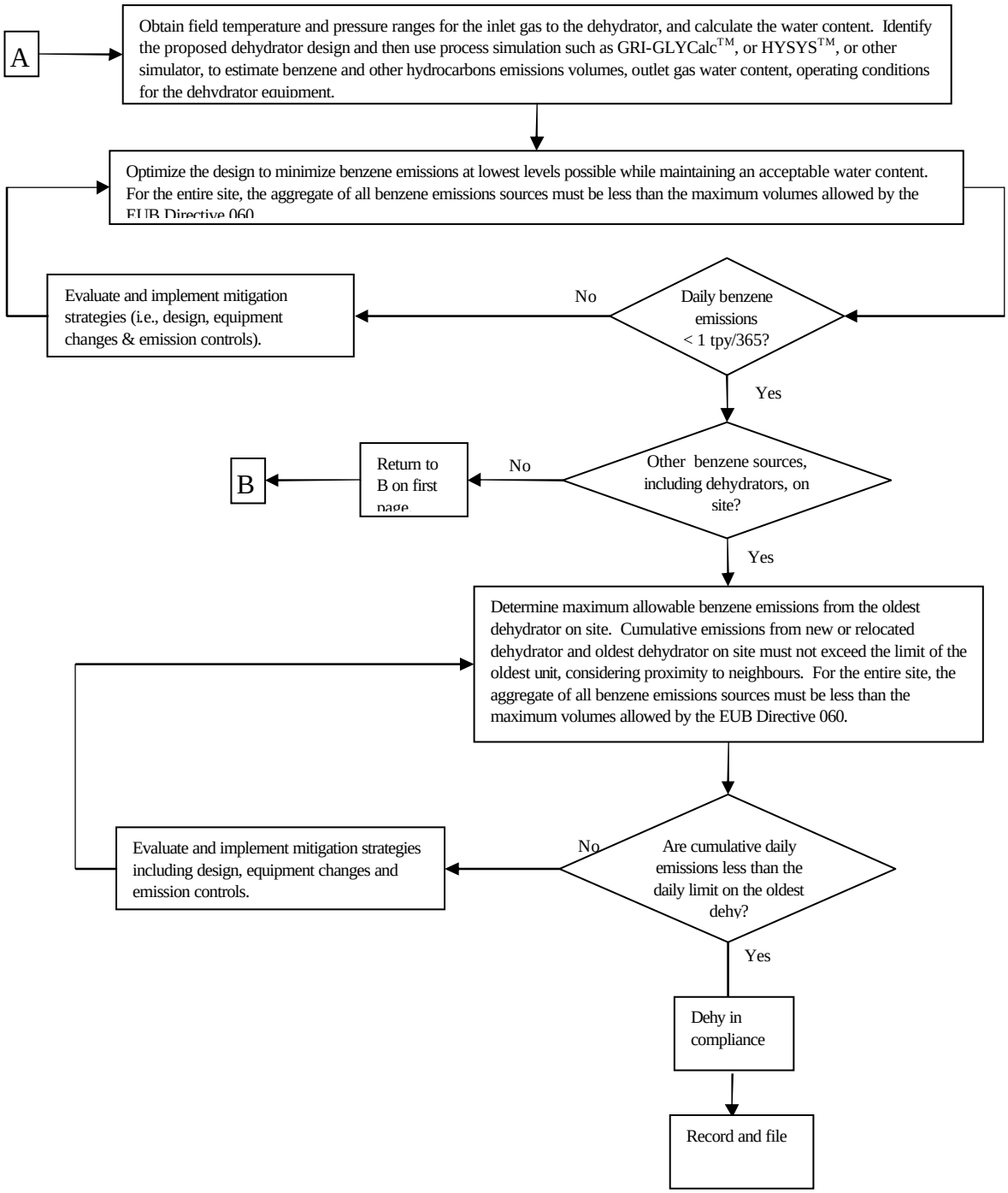
As noted in previous sections, the calculation of benzene emissions for the above report will require operators to create an administrative record, including data such as gas composition and production data, actual glycol circulation rates, temperatures, pressures, and equipment configurations to prove that any annual average is correct. This is best done using the DEOS.

Appendix A Decision Process For New or Relocated Glycol Dehydrators

Decision Tree Analysis for Alternative Methods of Controlling Water Content in Natural Gas (refer to section 4.2)



Decision Process for New or Relocated Glycol Dehydrators



Decision Process for New or Re-located Glycol Dehydrators: Record of Decision

Evaluate Alternate Hydrate Prevention Technologies (record of decision)	**Supporting Documentation in File**
Dehydrator Location:	
Field / Area:	
Legal Description:	
Number of Dehydrators on site:	
☐ Allowed Maximum Benzene Emissions from Oldest Dehydrator on Site:	_____
☐ Line Heater	Calculations, Costs, NPV calculation
☐ Methanol or Glycol Injection	Calculations, Costs, NPV calculations
☐ Other Technology (List)	Calculations, Costs, NPV calculations

Evaluate Alternate Dehydration Methods (record of decision)	**Supporting documentation in file**
☐ Ethylene Glycol	Calculations, Costs, NPV calculation
☐ Diethylene Glycol	Calculations, Costs, NPV calculation
☐ Triethylene Glycol	Calculations, Costs, NPV calculation
☐ Membrane technology	Calculations, Costs, NPV calculation
☐ Solid Desiccants	Calculations, Costs, NPV calculation
☐ Other Technology (Describe)	Calculations, Costs, NPV calculation

Chosen Water Control Alternative

Identify Potential Benzene Emissions (record of decision)			**Supporting Documentation in File**
☐ Representative Extended Hydrocarbon Gas Analysis			Attach Copy of Gas Analysis
☐ Expected Operating Conditions			Attach Copy of Expected Op Conditions
Gas Flow Rate	_____	$10^3 m^3$ / day	
Contactor / Wet Gas Temperature	_____	deg C	
Contactor / Wet Gas Pressure	_____	kPag	
Low Temperature Separator - Pressure	_____	kPag	
Low Temperature Separator - Temperature	_____	deg C	
Wet Gas Water Content	_____	%	
Annual Days of Operation	_____	hrs	
Dry Gas Water Content	_____	%	
Lean Glycol Circulation Rate	_____	Litres/hour	
Lean Glycol Water Content	_____	%	
Pump Type / Make / Model	_____		
Glycol Flash Separator Temperature	_____	deg C	
Glycol Flash Separator Pressure	_____	kPag	
Glycol Regenerator Stripping Gas Rate	_____	m^3 / day	
Glycol Regenerator Stripping Gas Source	_____		
Still Column Vent Emissions Control Temperature	_____	deg C	
Still Column Vent Emissions Control Pressure	_____	kPag	
Number of Residences/Public Facilities within 750m	_____		
☐ Method of Emissions Estimation	_____		Attach Copy of Emissions Estimates
☐ Estimated Initial Benzene Emissions	_____	tonnes per year	(daily benzene emissions rate x annual days of operation)

Optimization Options Implemented (record of decision)*	**Supporting Documentation in File**
☐ Minimize Glycol Circulation Rate	Decision Rationale
☐ Increase Reboiler Temperature	Decision Rationale
☐ Install Flash Separator	Decision Rationale
☐ Install electric glycol circulation pump	Decision Rationale
☐ Other (describe)	Decision Rationale

☐ Estimated Optimized Benzene Emissions _____ tonnes per year

☐ Benzene Emissions Reduction Through Optimization _____ % reduction

* Optimization of dehydrator operation should attempt to achieve the lowest emissions level achievable.

If Necessary Evaluate Control Options (record of decision)	**Supporting documentation in file**
☐ Condenser (field fabricated)	decision rationale
☐ Condenser (commercial / engineered)	decision rationale
☐ Flare System	decision rationale
☐ Incinerator	decision rationale

☐ Other (describe) decision rationale

Control Options Implemented (record of decision) **Supporting documentation in file**

☐ Describe details of emissions control

☐ Estimated controlled benzene emissions _____ tonnes per year **

☐ Benzene emissions reduction via emissions control _____ % reduction

** Benzene emissions cannot exceed 1 tonnes per year for a single new or relocated dehy or the cumulative emissions from all dehydrators on site plus other benzene sources cannot exceed the maximum benzene emissions allowed for the oldest dehy on site.

Document and file records *** **Supporting documentation in file**

Or

(For dehydrators to be located within 750 metres of a residence or public facility) Document and file records *** **Supporting documentation in file**

_____ _____

_____ _____

_____ _____

Date: Position:

_____ _____

Name (Print): Name (sign):

_____ _____

***** Operators are reminded to record information pertaining to emissions from new or relocated dehydrators and glycol dehydrators taken out of service (including shut-in units and units used as separators).**

As a part of industry's efforts to manage benzene emissions from glycol dehydrators, the CAPP Multistakeholder Technical Advisory Team on Benzene Emissions from Glycol Dehydrators will request information related to dehydrators taken out of service.

Appendix B Dehydrator (Dehy) Engineering and Operations Sheet (DEOS) and Instruction Manual

Attachment 1 Dehydrator (Dehy) Engineering and Operations Sheet (DEOS) Version Date: June 2006

(This sheet must be revised annually, or upon dehydrator relocation or change in status, and posted at the dehy.)

Technical Contact: Print Name/Phone #/email:_____

Revision Date (dd-mm-yyyy): _____ **Facility or Site Name:** _____

Licensee Name: _____ **Operator Name:** _____

Gov't Licence No: _____ **Location, DLS:** __-____-_____-__W_(**or NTS:**_____)

Installation Type: • Well • Compressor • Battery • Plant • Cavern • Other **DEHY Type:** • TEG • DEG • EG

Date Dehy installed/relocated? (dd-mm-yyyy): _____**Current Dehy Status:** • Producing • Shut-In • Bypassed • Other: _____**Date Dehy Status Changed? (dd-mm-yyyy):**_____

Typical number of operating days per year: _____ **Number of dehys on site:**_____

Distance to Closest Resident (if < 750 metres**):** _____**Normal Gas Flow Rate to Dehy:** (e^3 m^3/d):_____

Benzene Content in Gas to Dehy (mole %):_____(If zero, Dehy operations sheet must still be posted)

Feed gas benzene determination method: • Analysis Date of analysis (dd-mm-yyyy):_____ • Other (describe):_____

Glycol Pump Make/Model# _____**Normal Pump Speed:** _____RPM or SPM

Plunger diameter/stroke length: _____ inches, or _____ mm

Normal Glycol Circulation: _____USgpm **Normal Absorber Temp:** _____•C **Normal Absorber Press:** _____kPag

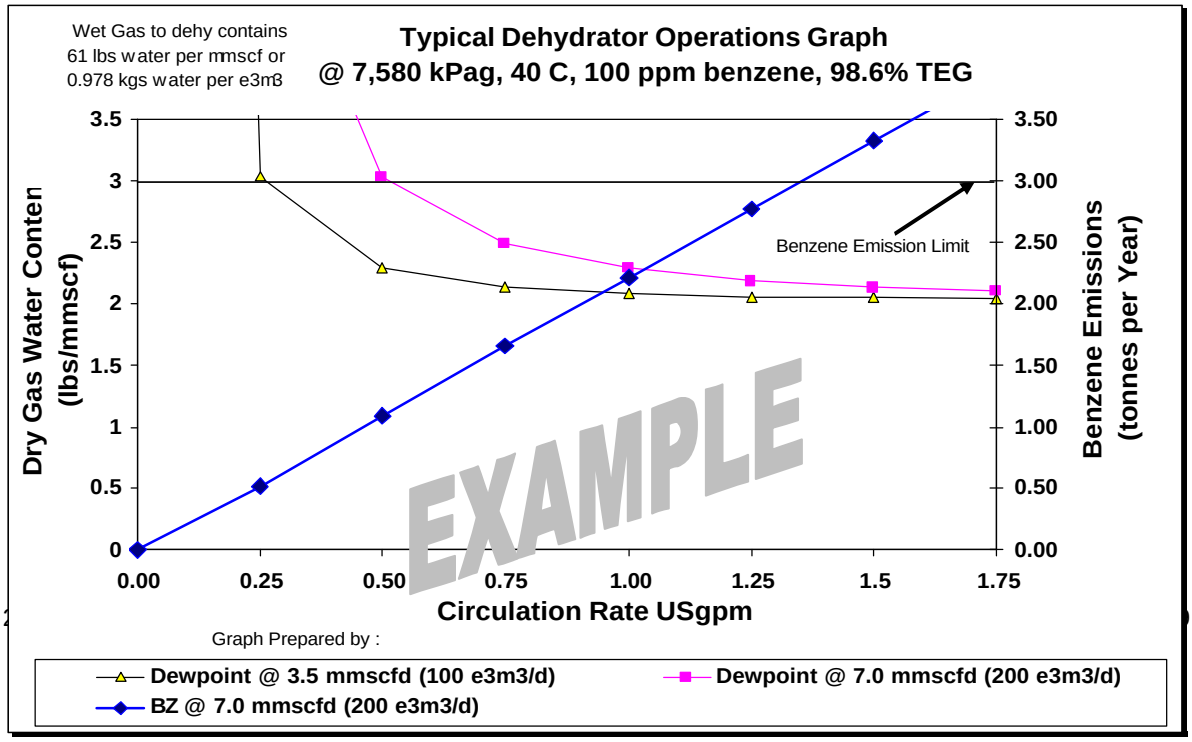
Emission Calculation Method: • GRI GLYCalc™ Version #:__ • HYSYS™ • ProSim™ • Total Capture • Rich/Lean Glycol • Other—Describe: _____

Benzene Emission Controls: • No • Yes Describe (condenser, tank, incinerator, flare, other): _____

Dehy decision tree analysis (DTA) completed?: • No • Yes (**mandatory for all new or relocated dehys**)

When operating, average benzene emissions (in tonnes/yr)* Before Controls: _____After Controls: _____

***Note: In accordance with EUB Directive 039, this dehydrator must be operated below _____ tonnes/yr benzene emissions. If multiple dehys exist on this site, the aggregate benzene emissions must be less than _____ tonnes/yr, which is the maximum per year allowed for the oldest dehy on site**



B.1 Dehydrator Operations Graph Preparation Instructions

Preface

Benzene is a non-threshold carcinogen and is defined in the Canadian Environmental Protection Act (CEPA) as a toxic substance. This enables Environment Canada to take steps, including the development of regulations, to control benzene emissions. A multi-stakeholder taskforce agreed to a voluntary approach whereby the oil and gas industry committed to reduce and report benzene emissions. This process is outlined in the Canadian Association of Petroleum Producers (CAPP) document "Best Management Practices for the Control of Benzene Emissions from Glycol Dehydrators" (BMP).

The voluntary approach has resulted in benzene emission reductions of 76% from 1995 levels. This compares with an identified target of 90% reduction. The Benzene Technical Advisory Team has requested that an example Dehydrator Operations Graph be developed to assist operators in achieving further reductions on a case by case basis. This document describes how to prepare a Dehydrator Operations Graph which is a requirement of the DEOS.

Introduction

Dehydrators are used to remove water from a wet gas stream, lowering the water dewpoint and thus reducing the chance of hydrate formation and corrosion in the downstream pipeline. Some dehydrators are also emitters of benzene and other volatile organic compounds.

The use of the graph in the DEOS is intended to help operators produce adequately dry sales gas while emitting as little benzene as possible through the adjustment of glycol circulation rates. This will also result in reduced operating costs by reducing excess fuel gas consumption and by reducing the emissions of methane, a potent greenhouse gas.

The calculated dry gas water content is illustrated on the left Y axis while the calculated annual benzene emission rate is illustrated on the right Y axis. The circulation rate is illustrated on the X axis.

The "Decision Process for New Glycol Dehydrators" requires operators to assess glycol circulation rate as a component of the analysis. Optimizing this rate while maintaining adequate dry gas water content reduces benzene emissions to the lowest practical level for each unit.

Disclaimer: The procedures described herein are suitable for calculating benzene emissions for regulatory compliance purposes. However, the dew point calculations are to be considered as directional only because actual dehydrator effectiveness is dependant upon factors beyond the scope of this project such as maintenance, glycol chemistry, lean glycol cooling effectiveness and others.

Calculating Benzene Emissions

- Four methods of calculating benzene emissions from glycol dehydrators are used in Western Canada. These are:
- reviewing gas characteristics,
- analysis of rich and lean glycols,
- total air emissions capture and analysis, and
- simulation using software such as GRI-GLYCalc™ .

Gas analyses that show no benzene in wet gas predict no benzene emissions from still column vents. This is a valid tool and is mentioned in the BMP.

The rich/lean glycol analysis determines benzene emissions by the difference between benzene concentrations in the rich glycol upstream of the reboiler and the lean glycol downstream of the reboiler.

One total air emissions capture method is routinely used. This is the BERT (Benzene Emission Reduction Trailer) operated by Norwest Labs. The BERT unit condenses all of the still column vapours over a two hour period. The captured gases and liquids are analyzed in the laboratory by gas chromatography and benzene mass emission rates are calculated. This method is also described in the BMP.

The GRI-GLYCalcTM simulation model has received scrutiny throughout the United States by regulatory, environmental and industry stakeholders. Version 4 includes SI values. Gas analyses or rich/lean glycol analyses are required to run the model.

Predicting Water Content at Dewpoint Conditions

The GPSA Engineering Data Book contains graphs that, when used sequentially, can be used to predict the water content at dewpoint that can be achieved with a given set of gas temperatures, pressures, lean glycol water concentrations and glycol circulation rates. This method uses a number of graphs and adjustments for gas composition and can be difficult to use to prepare the operations graph. In practice, it is far better to use these parameters in conjunction with a process simulation model such as GRI-GLYCalcTM.

Data Collection and Calculation Methods

Data that need to be gathered to prepare a dehydrator operations graph using the GPSA Data book or GRI-GLYCalcTM include:

Gas Composition

A recent, representative, extended (C10+) gas analysis of the wet gas is required to calculate benzene emissions. In some circumstances a conventional gas analysis can be used as described below.

Benzene Concentration in Wet Gas

For the purpose of building the DEOS operating graph, calculating benzene emissions requires knowledge of the benzene concentration in the wet gas or the difference between the benzene concentration between the rich glycol and the lean glycol. In either case an extended (C10+) dehydrator inlet, wet gas analysis must be performed.

At the operating conditions, and for the operating pump speed, if the extended analysis simulation shows benzene emissions close to the regulatory threshold you may wish to measure the actual benzene emissions for more accurate results (i.e., the Benzene Emission Reduction Trailer from Norwest Labs). This initial simulation should be one point in the upper range of the various pump speeds.

Glycol Circulation Rate

It is critical that an accurate glycol circulation rate be obtained. Data books provided by pump manufacturers and vendors often contain circulation rate information. Tables are typically provided to convert pump strokes per minute to a circulation rate.

With a piston pump (in the absence of such a table), get the pump strokes per minute, the stroke length, the cylinder diameter and the number of cylinders, and do the following calculation:

Glycol circulation in US gpm = strokes/minute x stroke length (inches) x 3.1416 x cylinder diameter (inches) x cylinder diameter (inches) / 4 x 1 cubic ft / 1,728 cubic inches x 7.48 US gallons per cubic foot.

Inlet and Outlet Gas Temperature, Pressure, and Daily Production

These data are required to calculate the water load on the system and as input for process simulation models.

Lean Glycol Water Content

The percentage of water in the lean glycol is used in predicting dewpoint in both GPSA charts and GRI-GLYCalcTM. Often chemical suppliers provide this information as a component of routine glycol sampling and analysis.

Reboiler Temperature

The reboiler temperature can also be used to predict the purity of the lean glycol. For example, with TEG a regenerator operating at 200°C produces 1.5% water content in the lean glycol.

Stripping Gas Usage

The rate of stripping gas injection (if any) should be measured or estimated. GTI suggests that a typical design rate is 1 scf per gallon of glycol circulated (0.0075 m3/L) and that the amount of stripping gas should not typically exceed 3 scf/gal (0.022 m3/L).

Production Rate

The average annual daily production should be used to calculate the annual benzene emission rate. As production rates vary, the typical high and low production rate are needed to prepare a dehydrator operations chart.

Flash Tank Operating Conditions

The temperature and pressure of any flash tank are needed for any process simulation software.

Contactor Tray Count

The number of trays in the contactor affects water removal rates.

Emission Control Devices

Often still gas vapours are routed to a storage tank before being vented to atmosphere. Operating companies should assume that all gas vents from the storage tank, resulting in effectively 0% control efficiency, unless site-specific details are documented outlining the rationale for an alternate control efficiency.

Regarding combustion of the dehydrator emissions, for the purposes of estimating benzene emissions from glycol dehydrators in compliance with the BMP only, operating companies should assume a 90% control efficiency for flares and a 95% control efficiency for incinerators unless site-specific or equipment-specific documentation is available outlining the rationale for increased control efficiencies. (The flaring value is based on research done under the supervision of Dr. L. Kostiuk at the University of Alberta in 2004.)

Graph Preparation

The calculated dry gas water content is illustrated on the left Y axis while the calculated annual benzene emission rate is illustrated on the right Y axis. The circulation rate is illustrated on the X axis.

Most spreadsheet programs have an “auto-scaling” function for these axes but it is recommended that the left Y axis for water content be scaled the same as the right axis to allow the annual benzene emission limit to be shown as a horizontal straight line.

The production rates modeled should represent the highest and lowest anticipated production rates.

The X axis should start at 0 (zero) and the saturated wet gas water content could be plotted at this point, however the value is typically so large that the plotted point is off the chart. Calculations of benzene emissions and dewpoint water content should be simulated at increasing circulation rates up to a limit of either the highest pump speed for the pump or the highest anticipated actual pump rate.

For ease of use, the graph can be in SI or Imperial units but the benzene emissions should be represented in tonnes per year.

Discussion

The major factors affecting benzene emissions are:

- The concentration of benzene in the raw gas;
- The glycol circulation rate;
- The glycol type; and,
- Still column vent emissions controls devices.

The most significant factors are the benzene concentration in the wet gas and the glycol circulation rate. Benzene emissions are directly proportional to both factors; doubling either will double benzene emissions. Other factors such as gas temperature and pressure affect emissions to a lesser degree. Of these, the glycol circulation rate is most easily and cost effectively adjusted.

The operating graph illustrates the change in the water content of the outlet gas and the amount of benzene emitted by the dehydrator depending on the glycol circulation. Generally accepted industry practice is to circulate 25 litres of TEG per kilogram (3 gallons/pound) of water to be removed. The two dewpoint curves, shown for two different inlet gas flowrates, flatten out after this point illustrating that only minimal increased water removal is achieved despite the increase in glycol circulation rate.

Note that the benzene emissions rapidly increase with the glycol circulation increase despite the fact that water removal does not increase.

Over circulating glycol also affects the entire dehydrator in other ways, resulting in:

- Increased heat duty in all coolers and reboiler;
- Increased pump energy usage, either from a drive gas, or from electricity;
- Increased glycol losses;
- Increased fuel gas consumption for the regenerator and stripping gas;
- Increased emissions of hydrocarbons; and,
- Increased risk of foaming.

If better dehydration is required it is generally better to produce a leaner glycol than to increase the circulation rate. No amount of over-circulation will produce adequately dry gas. A reboiler operating at 204 ^{o}C will produce lean TEG with 98.6% purity. Plants that run with a reboiler temperature lower than recommended will have more than 1.4% water in the lean glycol. It is better, from an energy and practicality standpoint, to increase reboiler temperature and reduce the circulation rate.

In cases where water removal efficiency needs to be higher than what a 98.6% TEG can provide, stripping gas can be use to increase TEG purity. Stripping gas is dry fuel gas that is injected either into the bottom of the reboiler or into a small packed column that transports the glycol from the reboiler down to the accumulator.

Stripping gas helps by lowering the partial pressure of water in the vapor space, thus making it easier for water to travel from the liquid phase to vapor phase. The result is less water in the TEG even at the same temperature. Stripping gas rates typically range from 30-55 m3/kg of TEG (3-7 scf/gal of TEG). At 200•C in the reboiler, adding 30 m3 of stripping gas per kg of TEG circulated will result in a TEG strength of at least 99.4%. At 55 m3/kg TEG can be as strong as 99.99%.

It should be noted that stripping gas is vented to atmosphere. Without a combustion device on the still column vapour stream the vented methane becomes a potent greenhouse gas. It is not uncommon for uncombusted stripping gas to be the single largest contributor of C02 Equivalent (CO2E) from a dehydrator. In addition, the presence of this non-condensable gas in the still column vapours markedly decreases the effectiveness of any condenser placed on this stream, reducing the amount of benzene and other aromatics that can be liquefied and recovered.

Production rates can rise and fall with little or no notice to the operator. If the volume of gas to the absorber increases, so then does the volume of water. Note the vertical lines for 3 US gallons of glycol circulation per pound of water removed for the two different raw gas flowrates. Find your current gas flowrate, estimate a new vertical line position and adjust your glycol circulation rate down to stay around or at this new

vertical line. This will minimize benzene emissions while keeping water content below the amounts that will cause hydrates.

Note that the above dewpoint and benzene emission curves are estimates based on simulation software. To get a much better curve, use a water dewpoint analyzer at various glycol circulation rates to get the real outlet gas water content.

Appendix C Dehydrator Benzene Inventory Reporting Form

Note: To obtain the Reporting Form in an electronic format please contact CAPP at benzene.tat@capp.ca or access the Benzene Technical Advisory Team section of MemberNet for the most current version.

Attachment 2 **Canadian Oil and Gas Industry - Annual Dehydrator Benzene Inventory List For:** **2006 (yyyy)** Company Net Gas Production: 10^3 m^3 /day

Instructions: This form must be completed and submitted annually by July 1st for the previous year of operations. Upon completion, submit this form to the Benzene Technical Advisory Team by email to benzene.tat@capp.ca Attention: Manager of Alberta Operations, CAPP

Company Data Revision Date: July 1, 2007 **Date Submitted to CAPP:** July 1, 2007

DEOS Completed	Multiple Dehys on Site?	Licensee	Unique Identifier								Dehydrator Use (Installation Type)			Production Status	Benzene Concentration (Gas to Dehy)	Number of Operating Days per year	Benzene Emissions Rate While Operating	Annual Benzene Emissions for dehydrator	
		Operating Company Name	Field Name	BC Centizone	Complete LSD 01-01-020-25W4	LSD	Sect	Twn	Rge	Mer	Installation Type	Glycol Type	Operating Status	Normal gas flowrate to dehy				Emissions Prior to Control	Emissions After Control
Yes No / Specify: - Shut In - Separator Ops - Sold	Yes / No		Field Name	BC Centizone	Complete LSD	LSD	Sect	Twn	Rge	Mer	Compressor Battery Wellsite Gas Plant Storage Cavern Other	TEG DEG EG Other	Operating Shut-in De-commissioned By-passed Operating as a separator Other	10^3 m^3 /day or shut-in or by-passed, or operating as separator or other	Mole % for each dehy	days	kilograms/day	tonnes Number of Operating Days x Emissions Rate	
Example Data:																			
Yes	Yes	ABC Resources Inc.	Sample Location Field		01-01-020-25W4	1	1	20	25	4	Compressor	TEG	Operating	200	0.015%	300	2.00	3.50	0.60
Yes	Yes	ABC Resources Inc.	Sample Location Field		01-01-020-25W4	1	1	20	25	4	Compressor	TEG	Operating	200	0.018%	200	9.50	6.00	1.90

Sample

*Note: Copies of the Annual Dehydrator Benzene Inventory List Forms are available from CAPP at www.capp.ca

Annual Dehydrator Benzene Inventory List (continued)

	Cumulative Annual Benzene Emissions		Emissions Calculation Method	Emission Control Method	Installation Details											Comments
Above Dehy Limit?	For all dehydrators on site	Above Site Limit?			Installed / Modified after Jan. 1, 2001?	Date of Installation/ Relocation, if known	Decision Tree Analysis Completed? (EUB Directive 039)	Number of dehys on site	For This Dehy Allowed Annual Benzene Emissions	For This Dehy Allowed Daily Benzene Emissions	Oldest Dehy Allowed Annual Benzene Emissions	Oldest Dehy Allowed Daily Benzene Emissions	Distance to Closest Residence	Were residents contacted?	Date Site Record Changed	Additional Comments
Yes / No	tonnes Add up the emissions from all previous rows per site. **Leave single dehys blank.**	Yes / No	GRI-GLYCalc™ HYSYS™ Prosim™ Total Capture Rich/Lean Glycol Other (describe)	No Control / Emit to Atmosphere Aboveground/ Underground Tank Flare / Incinerator Process Optimization Commercial Condenser Other (describe)	Yes / No	yyyy-mm-dd	Required for all New/ Relocated Dehydrators		tonnes/yr Show dehydrator limit only	kilograms/day Show dehydrator limit only	tonnes/yr Show dehy limit of oldest dehy on site if more than one dehy	kilograms/day Show dehy limit of oldest dehy on site if more than one dehy	m Flag red if <750 m a	Yes / No c	yyyy-mm-dd	
No			GRI-GLYCalc™	No Control	Yes	2/1/2001	Yes	2	3.0	8.22	5.0	13.70	1,120	**No**	10/12/2005	New unit
No	2.50	No	GRI-GLYCalc™	No Control	No	2/1/1998	Yes	2	5.0	13.70	5.0	13.70	1,120	**No**	10/12/2005	Old unit

Sample

*Note: Copies of the Annual Dehydrator Benzene Inventory List Forms are available from CAPP at www.capp.ca

Appendix D Frequently Asked Questions

Frequently Asked Questions (FAQ's)

Reduction of Benzene Emissions from Glycol Dehydrators

The questions detailed below have been most frequently raised since the publication of "Best Management Practices for the Control of Benzene Emissions from Glycol Dehydrators (CAPP – 1997, 2000). The answers are intended to clarify industry's intentions and obligations in the pursuit of a 90% reduction in benzene emissions from 1995 levels.

Q - What is the definition of "Close Proximity" dehydrator?

A - Close Proximity dehydrators are those units that are located within 750 metres of a residence or public facility. The distance is measured from the dehydrator, not from the boundary of the lease or facility.

Q - What is the definition of a public facility?

A - For the purposes of managing benzene emissions from Close Proximity glycol dehydrators, a Public Facility is defined as a permanent facility within which people other than operating company employees are potentially exposed on an ongoing basis. Examples include schools restaurants and businesses. .

Q - What is the public consultation requirement?

A - Operating companies are expected to consult with and provide relevant information (see Section 12 of the BMP for details) to residents adjacent to all operating Close Proximity dehydrators.

Q - Are diethylene glycol (DEG) and ethylene glycol (EG) processes considered glycol dehydrators?

A - Yes. Although DEG and EG processes may differ from triethylene glycol (TEG) dehydrator processes they are still considered glycol dehydrators. Any system that uses glycol as the primary (TEG, DEG) or secondary purpose (EG) of water removal has the potential for benzene emissions during glycol regeneration stages. Therefore, all glycol dehydration processes should be evaluated for benzene emissions.

Q - Should operating companies include shut-in dehydrators, decommissioned units, or units used as separators in their inventory of glycol dehydrators?

A - Yes. The shutting-in or decommissioning of an active dehydrator, and / or the use of a glycol dehydrator as a separator or as building heat should be included in all dehydrator equipment and emissions inventories. These

practices can be effective management options for reducing benzene emissions and should be captured in emission inventories to ensure that industry and company-specific reductions from 1996 levels can be documented.

Q - How are two or more units located on a single lease reported?

A - When two or more units are located on a single lease the emissions from all units must be summed to arrive at the total emission from the lease. Total benzene emissions levels must meet the criteria identified in the BMP and Directive 039. i.e., The cumulative benene emissions from all dehydrators must not exceed the limit of the oldest dehydrator on the lease.

Q - If there are two or more units on a lease do you need more than 1 Dehydrator Engineering and Operations Sheet (DEOS)?

A - Yes you need a DEOS for each unit.

Q - Should all dehydrators be sampled?

A - Companies may not need to obtain an extended hydrocarbon analysis for each dehydrator surveyed. However, benzene emissions levels are dependant upon both the benzene content in the raw gas and key dehydrator operating parameters. Therefore, operators should determine as a minimum: Anticipated benzene concentration in the wet gas based upon conventional gas samples and site-specific dehydrator operating conditions.

Q - What method should be used to estimate emissions?

A - Companies may elect to use the glycol dehydrator process simulation model: GRI-GLYCalc Version 4.0. The model is simple to use, designed specifically for this purpose, and endorsed by Environment Canada, U.S. EPA, and various provincial agencies and industry associations. However, any method that employs sound engineering principles is acceptable. Refer to section 5 of this BMP.

Q - Who is responsible for estimating and reporting emissions?

A - The licensed operator of the glycol dehydrator is responsible for estimating and reporting benzene emissions.

Q - What emissions control efficiency should be assumed for still column vent storage tanks acting as condensers?

A - Conventional underground and aboveground storage tanks can achieve a wide range of emissions control efficiencies (0-90%) depending on design details,

ambient temperature, frequency of liquid removal, and flow rates. Operating companies should assume 0% control efficiency for a storage tank unless site-specific details are documented outlining the rationale for alternate control efficiency.

Q - What emissions control should be assumed for still column vent combustion devices?

A - For the purposes of estimating benzene emissions from glycol dehydrators in compliance with the BMP only, operating companies should assume a conservative 90% control efficiency for flares and a 95% control efficiency for incinerators unless site-specific or equipment-specific documentation is available outlining the rationale for increased control efficiencies.

Appendix E Benzene Workplace Health and Safety Sheet

Benzene

Workplace Health and Safety

- What is Benzene?

Benzene is classified as a toxic substance under the Canadian Environmental Protection Act. As a non-threshold carcinogen there is considered to be some health risk at any level of exposure. It is to be managed by reducing human exposure to the extent possible and practicable. It is also classified as a Group 1 carcinogen by the International Agency for Research on Cancer (IARC). It is a colourless, flammable liquid with a sweet odour.

- Where is Benzene found in the workplace?

Crude oil and natural gas condensate contain benzene. The concentration varies depending on the geology and location of the well site. Benzene and other hydrocarbons may be released from stacks, flares, glycol dehydrators, hydrocarbon storage facilities, and other operations that involve crude oil or condensate. Occupational exposure to benzene in the upstream oil and gas industry occurs mainly through the use of glycol dehydrators, as benzene is removed from the gas stream during dehydration.

- How can workers become exposed to Benzene?

Workers may become exposed by inhalation or by direct contact with the skin. This may occur when changing filters and pumps, and when handling rich glycol at dehydrators. Although readily absorbed after inhalation, benzene is not easily absorbed through skin contact. The absorption of Benzene vapour through the skin is unlikely to be significant at concentrations below 25 ppm.

15) What are the health risks of Benzene exposure? Short-Term Acute Exposure

Acute exposures (greater than 3200 µg/m3 or 1000 ppb over an 8-hour period) are unlikely during routine operations and worker activities. Limited studies suggest that acute exposure to benzene may depress the central nervous system. Common symptoms at 50 to 150 ppm are drowsiness, dizziness, headache, nausea, vomiting, sleepiness, fatigue, nose and throat irritation, slurred speech, loss of balance, and disorientation. Exposure above 20,000 ppm for 5 to10 minutes can cause death.

- Long-Term Chronic Exposure

Chronic exposure may result in a range of health effects, depending on the dose and frequency of exposure. Health effects of prolonged exposure relate mainly to the skin and blood. Prolonged and repeated contact with benzene can cause redness, drying and cracking of the skin. Above workplace limits, prolonged

exposure may suppress the production of red blood cells, white blood cells, and clotting cells by damaging bone marrow. Benzene may also increase the incidence of a specific type of leukemia (acute myelogenous leukemia) and other forms of leukemia and lymphomas.

Exposure to Benzene along with other substances may enhance health effects. Exposure to benzene and ethanol can increase the effects to the blood system. Exposure to toluene and benzene can reduce the body's ability to remove benzene as toluene slows the rate of clearance of benzene by competing for metabolic pathways.

- **How can you avoid exposure to Benzene?**

Engineering Controls:

- Optimize glycol circulation.
- Implement alternatives for hydrate control and dehydration, such as flash tank separator, a line heater or solid desiccant or molecular sieve plants.
- Ensure that equipment and barriers for preventing exposure are working and maintained according to specifications.

Administrative controls

- Verify that safe work practices are formalized, reviewed and updated.
- Ensure employees are properly trained in safe work practices.
- Monitor air to ensure it does not exceed Occupational Exposure Limit.

Personal protective equipment

- Use close fitting goggles or a NIOSH (National Institute for Occupational Safety and Health) approved SAR (Search and Rescue) with a full face mask that includes an end of use indicator.
- Wear, wash and maintain chemical resistant clothing (gloves, coveralls, boots) appropriate for conditions of use.

Appendix F List of Abbreviations

Abbreviations

The abbreviations used in this Code of Practice, for units of measure, names of associations, government agencies and other words shall have the meanings assigned to them in this section.

ANLL	Acute non-Lymphocytic Leukemia
BMP	Best Management Practices
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes
CAPP	Canadian Association of Petroleum Producers
CEPA	Canadian Environment Protection Act
CGA	Canadian Gas Association
CO2	Carbon Dioxide
CSA	Canadian Standards Association
DEG	Diethylene Glycol
EG	Ethylene Glycol
GPSA	Gas Processors Suppliers Association
GRI	Gas Research Institute
HC	Hydrocarbons
MMSCF	Million Standard Cubic Feet
PSL	Priority Substances List
SEPAC	Small Explorers and Producers Association of Canada
TEG	Triethylene Glycol
DEOS	Dehydrator Engineering and Operations Sheet

Appendix G Working Group on Benzene

Working Group Membership (Disbanded)

The Working Group on Benzene Emissions from Glycol Dehydrators was Chaired by Environment Canada included the following stakeholders:

- Alberta Energy and Utilities Board
- Alberta Environment
- British Columbia Ministry of Environment, Lands, and Parks
- Canadian Association of Petroleum Producers
- Canadian Gas Association
- Environment Canada
- Health Canada
- Pembina Institute for Appropriate Development
- Saskatchewan Environment and Resource Management
- Small Explorers and Producers Association of Canada

Multi-stakeholder Benzene Technical Advisory Team Membership (Sucessor)

The Technical Advisory Team, chaired by CAPP, includes the following stakeholders:

- Alberta Energy and Utilities Board
- Alberta Environment
- British Columbia Ministry of Environment, Lands, and Parks
- Canadian Association of Petroleum Producers
- Environment Canada
- Health Canada
- Saskatchewan Environment and Resource Management

Appendix H Medical Officers of Health

Medical Officers of Health

British Columbia Health District Service Areas:

British Columbia Ministry of Health
Northern Interior Health Unit #181444
Edmonton Street
Prince George, B.C. V2M 6W5
Phone: (250) 565-7334
Fax: (250) 565-1386

Saskatchewan Health District Service Areas:

Swift Current Health District
350 Cheadle Street West
Swift Current, Saskatchewan S9H 4G3
Phone: (306) 778-5280
Fax: (306) 778-5408

Moose-Jaw Thunder Creak Health District
107 – 110 Ominica Street West
Moose Jaw, Saskatchewan S6H 6V2
Phone: (306) 691-6400
Fax: (306) 691-6444

South Central Health District
Box 2003
Weyburn, Saskatchewan S4H 2Z9
Phone: (306) 842-8618
Fax: (306) 842-8637

Regina Health District
Community Health Division
2110 Hamilton Street
Regina, Saskatchewan S4P 2E3
Phone: (306) 766-7777
Fax: (306) 766-7607

East Central Health District
72 Smith Street East
Yorkton, Saskatchewan S3N 2Y4
Phone: (306) 786-0600
Fax: (306) 786-0620

Saskatoon Health District
101, 310 Idylwyd Drive North
Saskatoon, Saskatchewan S7L OZ2
Phone: (306) 655-4605
Fax: (306) 655-4414

Midwest Health District
Box 1300
Rosetown, Saskatchewan SOL 2VO
Phone: (306) 882-6413
Fax: (306) 882-6474

Battlefords Health District
Rm. 204 Prov. Bldg. 1146 – 102nd Street
North Battleford, Saskatchewan S9A 1E9
Phone: (306) 446-6400
Fax: (306) 446-6432

Prince Albert Health District
C/o PA Co-operative Health Centre,
110-8th Street East, Prince Albert,
Saskatchewan S6V 0V7
Phone: (306) 763-6464
Fax: (306) 763-2101

Alberta Health Authority:

Chinook Regional Health Authority
960 - 19 Street S
Lethbridge AB T1J 1W5
Phone: (403) 388-6009
Fax: (403) 388-6011

Calgary Regional Health Authority
10101 – Southport Road SW
Calgary AB T2W 3N2
Phone: (403) 943-1104
Fax: (403) 943-1108

East Central Regional Health
4703 - 53 Street
Camrose AB T4V 1Y8
Phone: (780) 608-8800
Fax: (780) 672-5023

Aspen Regional Health Authority
10003 - 100 Street
Westlock AB T7P 2E8
Phone: (780) 349-8705
Fax: (780) 349-4879

Northern Lights Health Region
7 Hospital Street
Fort McMurray AB T9H 1P2
Phone: (780) 791-6024
Fax: (780) 791-6029

Palliser Health Authority
666 - 5 Street SW
Medicine Hat AB T1A 4H6
Phone: (403) 529-5633
Fax: (403) 529-8998

David Thompson Health Region
602, 4920 - 51 Street
Red Deer AB T4N 6A1
Phone: (403) 341-8622
Fax: (403) 341-8632

Capital Health Authority
1J2 WMC, 8440 - 112 Street NW
Edmonton AB T6G 2B7
Phone: (780) 407-8008
Fax: (780) 407-7481
Capital Health Link: (780) 408-5465

Peace Country Health
10015 - 98 Street
2101 – 10320, 99 Street
Grande Prairie AB T8V 6J4
Phone: (780) 538-5387
Fax: (780) 538-5455