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## Acknowledgement

The Nova Scotia Department of Energy acknowledges the Canadian Standards Association for the use of CAN/CSA Z341 Series-98 *Storage of Hydrocarbons in Underground Formations* in the preparation of this Code of Practice. A copy of CSA Z341 may be purchased by contacting the CSA directly at the following:

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5060 Spectrum Way, Suite 100
Mississauga, Ontario
L4W 5N6
CANADA

# Preface

This is the first edition of the Code of Practice Respecting the Underground Storage of Hydrocarbons. This Code of Practice has been developed to regulate industry in the planning, exploration, design, construction, operation and abandonment of underground formation hydrocarbons storage facilities. The Code provides both requirements and guidance in the management of storage facilities throughout project life, with a primary purpose of safe operation to protect both the public and the operator's employees.

In all provinces where there is underground formation storage of hydrocarbons the industry applies the national standard CAN/CSAZ341-98. The standard provides the essential requirements and minimum standards for the design, construction, operation, abandonment and safety of underground storage systems. This Code is based on the Z341 standard and similarly is not a design handbook. It does, however, provide direction on best practices that must be applied to allow for the safe storage of hydrocarbons in underground formations. Good judgment and competent engineering practice must be applied with its use.

In Nova Scotia at the time of first writing of the Code, there are no existing underground hydrocarbon storage facilities. Certain requirements are prescribed in this Code that differ from the requirements provided in Z341-98. These requirements are considered to be best management practices within the industry that warrant adoption when underground storage is first developed in the province.

Commentary that does not form part of the Code of Practice is inserted in the body of the document as notes.

# 1.0 Overview

## 1.1 Introduction and Approach

This Code of Practice is adopted pursuant to the *Underground Hydrocarbons Storage Act*, s. 24 (1), and the *Underground Hydrocarbons Storage Regulations*.

This Code of Practice provides requirements and guidance for public safety and the design, construction, operation and abandonment of facilities for the storage of hydrocarbons in underground formations. A central purpose in the application of the Code of Practice is the protection of public safety through the appropriate design, construction, operation and abandonment of storage facilities. The application of this Code of Practice is to incorporate CAN/CSA Z341-98, which is the current version of the CSA standard. This standard encompasses all parts of a storage facility including the storage reservoir, the subsurface well, the wellhead and surface facilities up to and including the first emergency shutdown or block valve. This Code of Practice is intended to be applied with reference to other relevant standards and practices referenced herein.

## 1.2 Applicability and Scope

The applicability and scope of the specifications within this Code of Practice correspond generally to that of the CAN/CSA Z341-98. However, direction and guidance are also provided in this Code of Practice outside of that standard, where it is relevant to good practice related to underground formation storage of hydrocarbons.

This Code of Practice applies to the storage of hydrocarbons in solution-mined caverns and naturally formed geological reservoirs. The scope includes storage in underground formations and associated surface facilities.

Hydrocarbons within the scope of this Code of Practice include natural gas, methane, ethane, propane, butane, and other hydrocarbons by themselves or in mixtures, with the exceptions listed below.

The Code of Practice also provides guidance to operators in matters related to storage facilities beyond that scope.

The Code of Practice does not apply to:

- Underground storage of hydrocarbons in aquifers;
- Underground storage of sour gas;
- Underground storage of other gases or fluids other than hydrocarbons, unless these fluids or gases are used specifically for the displacement of stored hydrocarbons or other functions for developing, testing or operating underground hydrocarbons storage;

- Underground storage facilities used for purposes other than storing hydrocarbons such as reaction chambers or waste disposal;
- Underground storage in overburden materials involving the use of tanks, such as tanks for storing gasoline or heating fuel;
- Heat exchangers, pumps, compressors and piping in processing plant facilities, manufacturing plants or industrial plants;
- Gathering lines, flow lines, metering, compressors and associated surface equipment beyond the first emergency shutdown or block valve; or
- Underground storage in mined excavations.

Where any requirements of this Code of Practice are at variance with the requirements of other standards or codes incorporated by reference into this Code of Practice, the requirements of this Code of Practice take precedence.

The requirements of this Code of Practice apply to existing caverns, mines, wells or reservoirs that may be converted to use as part of a storage facility.

Note: The Code of Practice does not apply to sour gas storage operations. No salt cavern storage facilities in Canada are used for sour gas storage

Note: The Code of Practice does not apply to aquifer underground formation storage. Although this is included in Z341-98,.no aquifer underground storage facilities exist in Canada.

Note: This Code of Practice does not apply to storage in mined caverns. Although this is included in Z341-98 no mined storage exists in Canada.

As this Code of Practice has a primary focus on the safety of storage facilities, the critical components for safety are provided as separate sections addressing safety and safety equipment specifically. However, all other components that prescribe or define good industry practice contribute to the safety of storage facilities.

The Code of Practice applies to underground storage leasing and approvals. A licence is required to evaluate the potential of an area for underground storage. A lease is required to provide an operator with the rights to develop and utilize a storage area. An operator must have a valid lease for all phases of a storage project from design to abandonment.

An operator must apply to the Board for approvals, first to construct and then to operate a storage facility. Also an operator must apply to the Board for approval to suspend or discontinue a storage facility operation or to abandon a storage facility.

This Code of Practice does not provide requirements for licensing to evaluate the potential of an area for underground storage. Requirements of this Code of Practice do apply to wells developed under a license, when such wells are used under a lease. Operators are referred to the *Onshore Petroleum Drilling Regulations* and the *Onshore Petroleum Geophysical Exploration Regulations*. All drilling and geophysical work related to a hydrocarbon storage-area licence must be completed under the authority of a drilling or geophysical permit issued under the *Petroleum Resources Act* and Regulations. A licence holder must conduct drilling, re-entry, suspension, completion and abandonment of wells in accordance with good petroleum drilling

practice. Good practice is defined as accepted industry practice, including the specifications of the American Petroleum Institute (API) and of the Alberta Recommended Practices (ARP) or of Industry Recommended Practices (IRP), as developed by the Canadian Petroleum Safety Council.

The Code of Practice identifies minimum standards for design, construction, operation and abandonment of storage. It also provides technical requirements for applications to the Board for approvals to develop, operate or abandon storage facilities. Direction and non-prescriptive guidance are provided direction for an operator in the safe development and operation of its facilities.

Notwithstanding requirements of this Code of Practice and CAN/CSA Z341, operators may apply to the Minister or the Board for a variance from the requirements listed under CAN/CSA Z341 if the application is supported by an assessment that demonstrates equal or greater safety. The application must include the rationale and reasoning for the variance prepared by a qualified person.

Note: CSA Z341 has some requirements that are different for reservoir storage than for cavern storage.

## 1.3 Organization of the Code of Practice

The organization of the Code of Practice is similar to that of CSA Z341-98. However, the structure has been partially modified to follow the sequence of a storage project through the phases of a project.

The Code of Practice in Section 3.0, begins with geology and other storage location issues. These are presented first to emphasize the importance of early planning and thorough evaluation to meet the Code of Practice requirements as well as those for environmental assessment. Early incorporation of all requirements in planning can assist in the approval and environmental assessment processes.

Subsequent sections address the design phase considerations of well completion and conversion, materials and corrosion control. These are followed by a section addressing construction.

Sections on surface facilities, and safety and safety equipment provide considerations that must be incorporated into design for the operating phase of the project.

Monitoring and measurement, and maintenance sections are also primarily operational phase components.

Closure and abandonment is provided as a separate section defining the last phase of a project.

Recording and reporting are presented as the last section that applies throughout all phases of a project and has some continued requirements following closure and abandonment of a storage facility.

## 1.4 Relationship of the Code of Practice to Other Nova Scotia Acts and Regulations

Other acts and related regulations also apply to the development, operation and abandonment of storage facilities. Some requirements or guidelines provided in this Code of Practice may also serve to meet requirements of other legislation. Legislation most relevant to underground formation storage is listed below under the Department with authority over the legislation.

**Nova Scotia Department of Environment and Labour**

***Environment Act, 1994-95, c.1, s.1.***
*Environmental Assessment Regulations*
*Activities Designation Regulations*
*Approvals Procedure Regulations*
*Emergency Spill Regulations*

This Act provides for environmental assessment of a storage facility as a Class I undertaking. Approvals are also required for various activities related to storage facilities, which may include water supply wells, solid waste management, on-site sewage disposal systems and watercourse crossings.

The *Emergency Spill Regulations* would apply to leaks or spills of hydrocarbons. The regulations provide reporting requirements, address training for emergency responders, and provide for emergency orders and powers in the event of a spill.

***Occupational Health and Safety Act*, 1996, c.7, s. 1.**
*Occupational Safety General Regulations*

Provides requirements for the health and safety of persons at the workplace. The Act is founded on the Internal Responsibility System for which all those associated with the workplace share responsibility for health and safety. This Act does not include requirements for public safety. For these issues the user is referred to Z341 and this Code of Practice.

**Nova Scotia Department of Natural Resources**

***Mineral Resources Act*, 1990, c. 18, s. 1.**
*Mineral Resources Regulations*

This Act regulates exploration, mining, and production of minerals. It provides the licensing and leasing of areas for exploration and mineral extraction. As a requirement of the *Underground Hydrocarbons Storage Act*, storage-area licenses or leases are not permitted on leases or special leases granted to a third party under the *Mineral Resources Act*. The initial exploration and definition of suitable areas for underground hydrocarbon storage in salt formations must be carried out under a Special License for exploration for salt issued under the *Mineral Resources Act*.

***Gas Storage Exploration Act,* 1989, R.S., c. 181, s. 1.**
*Gas Storage Exploration Regulations*

The Act and Regulations are to be repealed when the *Underground Hydrocarbons Storage Act* is proclaimed.

**Nova Scotia Department of Energy**

***Petroleum Resources Act*, 1989, R.S., c. 342, s. 1.**
*Onshore Petroleum Drilling Regulations*
*Petroleum Resources Regulations*

This Act regulates exploration for and extraction of hydrocarbons. The Act is relevant to the development of hydrocarbon reservoirs, that when depleted may be used for underground hydrocarbons storage. The *Onshore Petroleum Drilling Regulations* apply to the drilling associated with a storage licence or lease.

***Energy Resources Conservation Act*, 1989, R.S., c. 147, s. 1.**
*Onshore Petroleum Geophysical Exploration Regulations*

This Act regulates safe and efficient practices related to energy resources. In common with the *Petroleum Resources Act*, this Act regulates onshore geophysical exploration. The *Onshore Petroleum Geophysical Regulations* apply to geophysical work associated with a storage licence or lease.

***Pipeline Act,* 1989, R.S.,c. 345, s. 1.**
*Pipeline Regulations*

This Act regulates the transmission of oil and gas. It is relevant to the approvals for the design and operation of pipelines connecting to a storage facility outside the defined physical scope.

Note that this is not intended as a complete list of acts and regulations that may apply to various aspects of approval or operation of a storage facility or related components. For instance, federal requirements for environmental assessment may apply to the extraction of water for brining and for the disposal of brine. It is the responsibility of the operator to meet all regulatory requirements.

## 1.5 Definitions

Definitions provided in the *Underground Hydrocarbons Storage Act* and Regulations, as well as the definitions in CAN/CSA Z341 apply to this Code of Practice. Where there is a conflict in the definitions between the Act or Regulations and Z341, those of the Act or Regulations shall apply.

- "aquifer" means underground, porous and permeable, water-bearing geological strata.

- "authorized representative" means a person designated pursuant to Section 14 of the *Underground Hydrocarbons Storage Regulations*.

- "blanket material" means material used in solution mining to prevent erosion of the cavern roof or deterioration of salt around the casing seat. Blanket materials must be lighter than water and inert to salt. They are generally hydrocarbons such as diesel oil, condensate or liquified petroleum products.

- "block valve" means a valve placed on a pipeline system so as to isolate sections of pipeline during maintenance or in the event of leaks or failures.

- "Board" means the Nova Scotia Utility and Review Board and may also mean a person designated by the Board, including the Administrator, an appointed inspector or a certifying authority engaged by the Board.

- "brine" means saline water naturally occurring in porous sedimentary rock formations, and fluid resulting from the dissolution of salt formations with water for the purposes of salt solution mining.

- "casing shoe" means a reinforced collar of steel attached onto the bottom joint of a casing to prevent abrasion or distortion of the casing as it is installed in a borehole.

- "cathodic protection" means an electrochemical, anticorrosion technique for the protection of metal structures such as well casings, pipelines, tanks and buildings, whereby electric currents are induced to offset the current associated with metal corrosion.

- "christmas tree assembly" means an assembly of valves and fittings attached to the uppermost connection of the tubing head of a well.

- "deflagration" means a combustion mechanism caused by the reaction of a mixture of a reducing material such as a combustible gas and an oxidizer such as air or oxygen that transmits energy in the form of heat to the unreacted medium, this results in the expansion of reaction products and subsequent compression waves that propagate at speeds usually less than the speed of sound and up to 300 m/s in gaseous materials.

- "ESD" means emergency shutdown, which may be achieved by remote or manual operation of valves.

- "formation" means a geological bedrock unit of relatively uniform properties that distinguish it from adjacent formations.

- "fracture gradient" means the overburden gradient that is standardized as 22.6 kPa/metre (1.0 psig/foot) of depth.

- "hydrocarbon" means an organic compound containing carbon and hydrogen and includes oil and natural gas.

- "LPG" means liquified petroleum gas, which may be a mixture of various hydrocarbon components that are liquid at storage pressures and temperatures.

- "maximum allowable operating pressure (MAOP)" means the maximum pressure, at any time, authorized by the Administrator or the Board and measured at the wellhead. The MAOP shall not exceed 80% of the fracture gradient (FG) referenced at the last casing (seat) shoe or 0.8 x FG at depth to casing shoe.

- "maximum operating pressure" means the maximum pressure monitored during a 24 hour period, measured at the product side of the wellhead.

- "MIT" means mechanical integrity test, which is a procedure that verifies that a cavern or casing string is capable of containing fluids within design pressure limitations.

- "operator" means the holder of a licence, lease or approval for any phase of a hydrocarbon storage in underground formation facility.

- "qualified person" means a professional engineer registered and licenced to practice in Nova Scotia or a professional geoscientist registered and licenced to practice in Nova Scotia.

- "reservoir storage" means the storage of hydrocarbons in formations that have been depleted of commercial hydrocarbons and that have been developed to prevent the loss of stored product.

- "salt cavern storage" means the storage of hydrocarbons in man-made solution-mined cavities in underground salt formations.

- "solution mining" means the process of injecting fluid through a well to dissolve rock salt or other readily soluble rock or mineral and the production of the artificial brine so created.

- "sour gas" means natural gas containing hydrogen sulphide.

- "storage facility" means an underground storage reservoir or cavern, either natural or artificial, and associated wells and surface facilities for the storage of hydrocarbons in an underground formation, including all subsurface process equipment, the wellhead, and all safety equipment, including monitoring, control and emergency shutdown systems, related to the storage reservoir, wells and wellheads.

- "storage project" means all phases of the location, selection, design, construction, development, operation, maintenance, closure and abandonment of a storage facility.

- "storage reservoir" means space or spaces in geological formations, whether occurring naturally or otherwise, that may be used for storage of hydrocarbons, but does not include underground tanks for the storage of fuels.

- "storage zone" means the zone contained within the vertical interval of a cavern or reservoir and the lateral extent of formation directly affected by the storage operation.

- "underground hydrocarbons storage" means the storage of hydrocarbons, whether liquid or gaseous, in a storage reservoir in a geological formation, but does not include storage of fuels in underground tanks or storage or disposal of waste hydrocarbon products.

- "wellhead" means all permanent equipment between the uppermost portion of the surface casing and the tubing head adapter connection.

- "workover" means any activity, the intent of which is to examine and or repair the wellhead and downhole equipment for the purpose of ensuring the integrity and suitability of the facility for continued service.

- "Z341" means the Canadian Standards Association, Storage of Hydrocarbons in Underground Formations, A National Standard for Canada, CAN/CSA Z341.

# 2.0 Responsibility

## 2.1 Persons' Responsible Duty

The persons responsible for storage facilities shall comply with all requirements of this Code of Practice and apply due diligence in the application of guidance provided in this Code of Practice.

Persons responsible include operators, employers, employees and self-employed persons at a storage facility.

Persons responsible include third parties performing work, providing services or supplying materials for the development, operation or abandonment of a storage facility.

The responsibility for creating and maintaining a safe and secure storage project is that of each person responsible, to the extent of each party's authority and ability to do so.

# 3.0 Specifications, Requirements and Guidance

All storage facilities shall be designed, constructed, operated and abandoned in compliance with the requirements and guidance of CAN/CSA Z341-98, unless otherwise specified by portions of the following Code of Practice.

## 3.1 Geology

This section refers to the exploration, design and development phases of a storage project. Good planning practice integrates technical design and location consideration with early public safety and environmental planning.

### *3.1.1 General*

Operators shall assess the suitability of the site for storage development.

Prior to commencing design work for a storage facility, the operator shall determine the geology, geometry, and overburden strata of the formation under consideration for storing hydrocarbons. The operator shall also assess other existing and past surface and subsurface activities that may impact the development or operation of the storage facility.

Information about formation anomalies (including tectonic-induced stresses and strains, formation fracturing characteristics, faulting and rock properties) should be included in the overall design study if this information is available or undertaken by the operator. Some of this information may be obtained from core analysis lab tests and modelling studies.

The operator shall address the potential for subsidence in the design of salt caverns.

The operator shall prepare maps that show structural geology and all other wells, boreholes and water supply wells present in the defined area of study.

### *3.1.2 Geotechnical Studies (Cavern Storage)*

The area of study is to include the area within 3 km of the edge of the cavern, where practical.

The suitability of an area for storage of hydrocarbons should be assessed using site-specific data regarding the geology of the storage zone, surrounding formations and structures, and formations above and below the storage zone.

The operator should consider the use of any existing or site specific studies of mechanical and chemical properties of the salt and confining rock formations based on core analyses, logging data, or other evaluation techniques that can be used to develop and maintain computer model(s)

for predicting the behaviour of the storage cavern(s) under various development and operational scenarios.

### *3.1.3 Geotechnical Studies (Reservoir Storage)*

The area of study is to include at a minimum the plan area of the storage reservoir plus 3 km, where practical or a greater area as determined by the Minister or the Board.

Site-specific data regarding the geology of the storage zone, surrounding formations and structures, and formations above and below the storage zone, should be assessed for suitability for storage of hydrocarbons in reservoirs.

The operator shall develop and maintain computer model(s) that will predict the behaviour of the storage field; and shall include, but not be limited to:

a) the potential for gas migration from the field, laterally or vertically;
b) individual well and field performance curves - (injection & withdrawal); and
c) formation fluid production forecasts.

### *3.1.4 Depth and Thickness of Salt Formations (Cavern Storage)*

An assessment shall be made of the characteristics of the salt formation to demonstrate its suitability for storage cavern development and operation. The operator shall provide salt formation information with the cavern design in the application for approval to develop the salt cavern.

Knowledge of the physical location and dimensions of the salt bed formations and any non-salt layers that have potential to become part of the cavern is critical to design work.

In bedded salt, knowledge of the depth and thickness of overburden rocks is required.

### *3.1.5 Faulting and Structural Anomalies*

Faults in the surrounding formations that intersect the storage zone shall be documented and recognized as areas to avoid intersection with a wellbore.

Where possible, identify anomalies in the storage zone and consider them in the design. Insoluble layers of intrusions and any permeable layers must be considered in the design of salt caverns.

### *3.1.6 Structure of Overlying Strata*

In the development of bedded salt caverns, information on the thickness and strength of the overlying rock layers should be determined and reported as these layers are part of the structural support for the cavern.

Any water-bearing strata that intersect the wellbore must be identified and the development plan developed to ensure against introducing cross communication between water strata and the salt formation.

### *3.1.7 Location of Nearby Existing Caverns or Other Underground Facilities*

The development of storage caverns in salt introduces stresses in the salt formation. The design of the cavern must consider the stresses induced by all caverns, operating or abandoned, within 300 metres of the perimeter of the cavern.

The operator shall consider the interaction of all caverns in the formation when developing caverns in developed cavern fields.

An operator must not carry out exploration, development or operation within 3 kilometres of a mine as defined by the *Mineral Resources Act* or of a storage reservoir except with the approval of and in compliance with any conditions specified by the Department of Natural Resources or the Department of Energy.

### *3.1.8 Salt Properties*

Proper design of a salt cavern requires knowledge of the *in situ* stress state and the mechanical properties of the salt. Knowledge of insolubles and minerals other than halite and how they occur (bands, beds, disseminated etc.) is also required.

### *3.1.9 Reporting Requirements*

The operator shall submit to the Minister or the Board, as applicable, all reports, geotechnical studies, core analyses, etc., that are associated with any storage development proposal as part of the application. The Minister or the Board may also request, at any time, reports based upon the results of any computer models of the storage development.

## 3.2 Location

This section applies to the selection of storage facility locations and the design phase of a storage project. Both technical and environmental considerations should be integrated in the storage facility location selection process.

### *3.2.1 General*

Public interest and technical requirements should both be considered in siting salt cavern storage facilities. Public safety considerations include monitoring and emergency response requirements relative to any nearby residences and population centres. Technical considerations include geology, topography, proximity to and effects on other subsurface activities such as active and inactive underground mines, other salt cavern storage, reservoir storage, or other solution mining operations.

### *3.2.2 Site Selection Criteria*

Storage facilities shall be located to provide separation from other facilities and residential areas. Consideration should be given to but not limited to the following factors:

a) Proximity to residences, residential areas and other facilities;
b) Possible effect on or from nearby facilities;
c) Proximity to environmentally sensitive areas;
d) Present and planned use of adjacent properties;
e) Methods of disposal of brine from salt cavern development;
f) Monitoring and emergency response requirements;
g) Access for emergency response;
h) Any existing abandoned wells or test holes on or nearby the proposed facility site;
i) Topography of the site;
j) Surface watercourses;
k) For non-bedded salt, proximity to the edge of the salt structure;
l) Types of hydrocarbons to be stored, operating flow rates; and
m) Numbers and size of caverns.

### *3.2.3 Distance and Spacing Requirements (Cavern Storage)*

This section supercedes section 6.1.4 of Z341-98.

Storage facilities shall be located to provide a safe distance from other storage facilities. There must be adequate separation between caverns and any defined salt boundary to ensure cavern stability and containment of stored hydrocarbons, gas or liquid. Site-specific geomechanical studies (laboratory tests on cores, numerical modelling etc.) seismic and borehole information,

and experience with similar storage operations in any area should be used to establish spacing requirements; or in the absence of such information, the following shall apply:

a) The distance between any two adjacent solution-mined caverns shall be a minimum S/D of 3:1 where S equals the distance between the centres of the two caverns and D equals the averaged value of the maximum diameter for each of the two caverns, unless appropriate studies or experience show, to the satisfaction of the Board, that a lower S/D ratio is safe and satisfactory; and

b) The distance between any cavern centre and the boundary of an adjacent cavern field, which is owned by another operator, should satisfy 3.2.3 a); in no case shall a cavern wall be less than 60 metres from the boundary of an adjacent field.

### *3.2.4 Proximity to Rights of Way*

All pipelines, railways, roads and road allowances, transmission lines and other surface or subsurface utility corridors shall be identified and considered in the design and siting of any storage facility.

### *3.2.5 Proximity to Residences*

Any residences in the area of a proposed facility shall be identified and considered in the siting of any storage facility. A separation distance of 200 metres shall be maintained from the well center(s) of an underground storage facility and any residence. In the event that a residence is less than 200 metres from a well of a proposed facility, a written agreement between the operator of a storage facility and the owner of a residence is required. In no case shall the separation distance of a well from a residence be less than 75 metres.

If a residence is constructed within this separation distance after approval to develop or operate a storage facility has been provided, the requirements do not apply to the operator for that residence.

Note: An operator should encourage the municipality, where a storage facility is located, to zone a 200 metre or larger separation area around the well(s) of a storage facility for non-residential use.

Operators should expect to provide a demonstration in the environmental assessment for a storage facility that the separation distances from residential areas is sufficient. Facilities for the storage of LPG may require larger separation distances than those for natural gas.

Note: Public consultation is desirable or may be a requirement in a statutory environmental assessment. Early and ongoing communication with and involvement of nearby communities in a project usually benefits a proponent in public acceptance of a project.

### *3.2.6 Potable Water*

Storage cavern construction and operation shall be conducted in a manner to protect any identified underground source or potential source of potable water.

## 3.3 Well Completion and Conversion

This section applies to the development and construction phase of a storage project.

The operator shall follow all provincial requirements for well drilling and completion. Operators are referred to the *Onshore Petroleum Drilling Regulations* and the *Onshore Petroleum Geophysical Exploration Regulations*. All drilling and geophysical work related to a hydrocarbon storage-area lease must be completed under the authority of a drilling or geophysical permit issued under the *Petroleum Resources Act* and Regulations. A lease holder must conduct drilling, re-entry, suspension, completion and abandonment of wells in accordance with good petroleum drilling practice. Good practice is defined as accepted industry practice, including the specifications of the American Petroleum Institute (API) and of the Alberta Recommended Practices (ARP) or of Industry Recommended Practices (IRP), as developed by the Canadian Petroleum Safety Council.

Note: For cavern storage, well drilling and completion design and methods may be different than conventional oil and gas exploration drilling, such as the use of salt-saturated cement (and drilling muds) in salt zones (Z341-98, s. 5.4.1.3 (b)).

### *3.3.1 Cathodic Protection*

The main production casing and surface pipeline systems shall be cathodically protected as described in Section 3.5 Corrosion Control.

In addition, information obtained from casing potential profile logs shall be considered in optimizing anode current output.

### *3.3.2 Closure of Unacceptable Wells*

Wells that do not meet the requirements of this section shall not be converted for storage operations.

Any well drilled into or through the storage zone, whether for reservoir or cavern storage, that represents a risk to the integrity of the storage zone, that cannot be remedied, must be plugged in accordance with Z341.

Where practical, for plugging wells it is recommended that the entire wellbore be filled with cement.

### *3.3.3 Reservoir Storage*

Note: Z341 includes a section on well stimulation for reservoir storage related to formation fracturing. This does not apply to cavern storage.

## 3.4 Materials

This section applies to all phases of a storage project.

### *3.4.1 General*

The use of the proper materials and equipment in design and operation of an underground hydrocarbon storage facility is of critical importance. Materials used for pipe, tubing and casing, shall be of sufficient weight, grade, condition and properties to satisfy the design conditions and criteria specified during construction and operation. Pumps, valves, electrical and safety equipment, instrumentation, and other components of the storage facility shall be designed using the applicable codes and standards for the actual facility design parameters. Selection of materials shall take into account the depth of the storage zone, operating pressure, surface and subsurface temperatures, the various storage processes, intended service life of the project and local geology. The cited technical codes must be met for materials used, especially wellhead components, casing, tubing, piping and valves. The material specification shall be included on all drawings and included in the application for any storage facility. Material mill certificates shall be obtained from the manufacturer to ensure that the material complies with the requirements or standards. A tracking process shall be used to ensure the proper material is installed and a record management system implemented for the material records.

Wellhead equipment is to comply with API Specification 6A. Wellhead fittings, valves and flanges shall be rated for a pressure equal to or greater than the pressure rating for the wellhead assembly and Christmas tree assembly.

Casing used for a storage well shall comply with the requirements of API 5C and the Alberta Energy and Utilities Board (EUB) Guide 10.

### *3.4.2 Non Compliance with Materials Requirements*

If it appears to a representative of the Minister or the Board that any tools, equipment or materials used in the drilling, completion or operation of a storage well are inadequate, defective or hazardous, the representative may require the replacement or reconditioning of the equipment, casing or tubing and may order orally, confirmed by a signed notice, that operations be discontinued in whole or in part until the required action is taken.

# 3.5 Corrosion Control

This section refers to design, development and operation phases of a storage project.

## *3.5.1 General*

Metallic structures in contact with soil or submerged under water are subject to corrosion. Adequate procedures shall be adopted to ensure that corrosion is not affecting safe and economical operation of well casings and other components that may be subject to corrosion.

The operator shall have a system designed by a qualified person in place for the corrosion control and cathodic protection of the various metallic components of the storage system and for the control of external corrosion of steel well casings in contact with the ground. A program shall be established for the routine monitoring and maintenance of the corrosion control system and recording of relevant operation data and to ensure there is sufficient protective current to protect the well casings to meet the criteria for cathodic protection. This could be accomplished by a series of annual inspections/surveys, visual examinations, measurements, wire line logging, periodic tests and/or pressure testing.

Areas for protection shall include:

a) Downhole casing strings;
b) Surface wellhead components;
c) Surface piping systems; and
d) Below ground piping.

Surface piping systems shall be coated (painted) with an appropriate coating for the actual site-specific environment encountered (i.e. salt environment).

Only impressed current cathodic protection systems shall be used for the cathodic protection of storage well casings.

The location, number and type of cathodic protection measurements shall be selected using sound engineering practices to suit the monitoring requirements of each specific piping system and to ensure that corrosion control has been achieved throughout the entire piping system. Remedial programs are required where deficiencies are found.

The decisions governing the need for cathodic protection of well casings shall be based on data obtained from corrosion surveys, operating records, prior tests with similar systems in similar environments, and on a study of design specifications and engineering, operating and economical operation of well casings.

### *3.5.2 Routine Monitoring, Inspection and Surveys*

Routine monitoring and inspection of the cathodic protection system shall consist of:

a) Monitoring – monthly pipe to soil potential readings (time between readings not to exceed 6 weeks), to verify the operation and continuity of the cathodic protection system;
b) Inspections – annual rectifier and groundbed checks to verify functionality;
c) Surveys - annual cathodic protection survey to determine the level of cathodic protection to minimize in-service failure;
d) Aboveground Inspections – visual inspections or non-destructive testing (NDT) methods for wellhead and piping components;
e) Belowground Piping Surveys - to evaluate the performance of external coatings and coating defects; the survey methods may include AC and DC voltage;
f) Annual DC pipe –to-soil potential surveys; and
g) Gradient Surveys, coating conductance surveys (electromagnetic field loss evaluation surveys) as needed based on risk.

Appropriate test equipment shall be used to obtain each electrical value.

Instruments and related equipment shall be maintained in good operating condition, calibrated as required and checked annually.

### *3.5.3 Methods of Determining Design Current Requirements*

The following methods may be used to determine design current requirements:

a) Use of a profile tool to measure a voltage (IR) drop across a portion of well casing in service by electrically isolating two sets of contacts from each other to determine the magnitude and direction of the current flow in the casing (well casing potential profile);
b) Average current density ($A/cm^2$) may be used to calculate the quantity of current required to prevent external corrosion;
c) Mathematical modelling may also be used to determine design current requirements; and
d) Use of the E-log-I method.

### *3.5.4 Remedial Programs*

Any remedial measures determined necessary by a qualified person shall be carried out as soon as practical after the surveys, tests or inspections that indicate corrosion protection is not adequate. These measures may include the following:

a) Repair, replace or adjust components of cathodic protection systems;
b) Provide additional cathodic protection facilities; and
c) Repair or replace damaged or deteriorated coating.

### *3.5.5 Additional Methods to Protect Well Casings*

The following methods may also be applied, where appropriate, to protect well casings from corrosion:

a) Inhibitors and bactericides used in drilling fluid;
b) Corrosion-resistant materials;
c) Cement for zones known to be corrosive;
d) Electrical isolation to limit possible foreign current discharge from casings and to ensure that cathodic protection currents are applied to the well casing; and
e) Dielectric coating on the outer surface of casing.

### *3.5.6 Records*

Operators shall maintain cathodic protection records, inspections and tests plus maintenance records for the life of the storage facility.

### *3.5.7 Reference Standards*

The following standards are to be followed in corrosion control:

- NACE RP 0186.94 – Application of Cathodic Protection for Well Casings
- CGA RP OCC-1-1996 – For the Control of External Corrosion on Buried or Submerged Metallic Piping systems
- EUB Guide 51 – Injection and Disposal Wells, Well Classification, Completion, Logging and Testing Requirements.

## 3.6 Construction

This section applies to the design and construction phases of a storage project.

### *3.6.1 General*

This section supercedes Z341 s. 8.3.3.2 to allow the use of caverns that do not pass a mechanical integrity test, where leakage can be managed with the use of suitable means.

<u>Caverns</u>

a) The operator is required to control the shape of the cavern during development. Specific requirements for blanketing, shape control and sonar logs are specified in Z341. The operator is also required to provide cathodic protection. A nitrogen or gas brine interface mechanical integrity pressure test is required prior to commissioning. If mechanical integrity cannot be demonstrated, an assessment shall be prepared by a qualified person and provided to the Board demonstrating that the cavern can be safely used for storage, or

the well shall not be used for storage and shall be closed in accordance with Section 3.3.2.

b) Salt caverns should be developed by solution mining using blanket material. Proper use of blanket material is critical to the development of salt caverns to control overall shape (to ensure mechanical stability) and protection of the cavern roof and casing seat from uncontrolled dissolution of salt.

Reservoirs

a) The operator is required to confirm and maintain the integrity of both the well(s) and the storage reservoir(s). Specific requirements are given for the testing of well integrity in Z341. Requirements for well stimulation are also defined. The operator is also required to provide cathodic protection.

### *3.6.2 Cathodic Protection*

The production, surface and any intermediate casing strings shall have a cathodic protection system installed as per section 8 in CSA-Z341 and Section 3.5 of this Code of Practice.

### *3.6.3 Cavern Construction and Shape*

Cavern shape should be controlled during solution mining by hydrocarbon blanket material, water injection rate, water injection and brine removal locations, and salinity of injected water. Control may be facilitated by the use of computer simulations of cavern development. Evidence of cavern and roof shape control should be obtained during development by:

a) monitoring and/or periodic verification of the location of roof blanket material;
b) monitoring the total volume of salt removed from the cavern; and
c) sonar surveying of the completed cavern shape.

At least 2 sonar surveys shall be run during the construction of any storage cavern. One of these surveys shall be run during cavern washing and one after cavern washing has been completed.

For caverns developed for natural gas storage, suitable blanket control material shall be used.

Operating procedures that are protective of cavern integrity shall include the following:

1) storage caverns that are solutioned or washed shall use a blanket pad to prevent uncontrolled leaching of the storage cavern roof. The following shall apply:
    a) the blanket pad may be composed of any non corrosive material approved by the Administrator that is immiscible with water and is lighter than water.
    b) Acceptable blanket pad materials include propane, natural gas, diesel fuel and nitrogen.

### *3.6.4 Wellhead Design*

a) All major wellhead components shall be specified to withstand low temperature conditions to at least minus 40 degrees Celsius.

b) All wellheads shall have at least 2 valves on any flow line connections – 1 working valve on the downstream side and 1 master valve on the wellhead side. The wellhead shall be operated such that the master valve is never opened or closed unless the working valve is completely closed.

All wellhead equipment shall comply with API Specification 6A.

### *3.6.5 Cavern Integrity*

This section supercedes Z341 to allow the use of caverns that do not pass a mechanical integrity test, where leakage can be managed with the use of suitable means.

Cavern integrity shall be ensured by the following test requirements:

a) prior to commissioning a cavern, a mechanical integrity test (MIT) shall be conducted that demonstrates the integrity of the wellbore, the casing shoe, and the wellhead. The MIT should be a nitrogen (or gas) brine interface test (or equivalent).
b) For caverns in bedded salt where permeable non-salt interbeds potentially exist in the storage interval, a brine pressure test shall also be performed to verify cavern tightness.
c) Where mechanical integrity of the cavern system cannot be demonstrated, an assessment shall be provided to the Board by a qualified person demonstrating that the cavern can be safely used for storage, or the well shall not be used for storage and shall be closed in accordance with Section 3.3.2.
d) Mechanical integrity tests shall be conducted periodically after the cavern is commissioned to demonstrate that integrity has been maintained, as provided under Section 3.11 Maintenance.

### *3.6.6 Reservoir Integrity*

Reservoir integrity shall be ensured by the following:

a) wells penetrating the storage zone that do not have mechanical integrity as defined in Section 5 of CSA Z341 shall be re-completed or abandoned in accordance with the requirements specified in CSA Z341.
b) Where fracture stimulation is used in a storage zone, it shall be completely contained within the storage zone.
c) Wells shall be designed and tested as required under CSA Z341.

# 3.7 Surface Facilities

This section applies to the design, construction and operation phases of a storage project.

## *3.7.1 Scope*

Surface Facilities include all equipment, facilities and instrumentation between the wellhead casing bowl and the downstream side of the first emergency shutdown or block valve. This shall include any above or belowground piping plus wellhead enclosures.

## *3.7.2 Design*

All surface facilities shall be designed to meet or exceed the following: CSA Z341, CSA Z662, CSA Z276, ASME B31.3, API 6A, API 5C3.

All non-storage facilities (i.e. field piping not directly associated with the storage well) shall be designed such that the possibility of explosion or fire damage to equipment and/or services necessary for the satisfactory operation of the emergency shutdown systems is minimized.

## *3.7.3 Emergency Shutdown Valves (Cavern Storage)*

All storage facilities shall be equipped with emergency shutdown valves as described in Section 3.9, Safety Equipment.

## *3.7.4 Emergency Shutdown Valves (Reservoir Storage)*

Emergency shutdown valves are not required at the wellhead, however, there shall be an emergency shutdown valve installed at some location at the storage facilities for isolation of the storage zone from the transmission pipeline. Remote, local and manual control of the emergency shutdown valve shall be provided.

## *3.7.5 Gas Detection*

a) It is not mandatory to install gas detection equipment at natural gas cavern or reservoir wells, however, gas detection shall be provided for the detection of hydrocarbon vapours within an enclosure.
b) Gas detection is mandatory for LPG storage wells.

### *3.7.6 Instrumentation*

Instrumentation is required for flow rates, pressure and temperature. The facilities shall include a system of continuous real time monitoring of storage facility operations to provide a warning of and response to upset and emergency situations to ensure containment and isolation of hydrocarbons. Instrumentation shall be linked to a control room at the storage facility or at a remote location that is continuously monitored.

## 3.8 Safety

This section applies primarily to operations, however, safety must be a consideration in all phases of a storage project.

Public safety related to storage facilities is within the jurisdiction of the Department of Energy, under the *Underground Hydrocarbons Storage Act* and Regulations. Occupational Health and Safety requirements are prescribed under the *Occupational Health and Safety Act* and regulations, which are administered by the Department of Environment and Labour. Since safety is such a central issue in this Code of Practice, both public and occupational health and safety requirements and guidance are provided. However, where any requirements of this Code of Practice are at variance with the requirements of the *Occupational Health and Safety Act* and Regulations, the requirements of that Act or Regulations shall govern.

### *3.8.1 General*

Operators shall have safety procedures in place at all underground hydrocarbon storage facilities for the protection of the general public with regard to the safe handling and storage of all types of hydrocarbon product.

Design and construction of other surface facilities, which are not components of the storage facility, shall minimize the possibility of explosion or fire damage to equipment or services necessary for the satisfactory operation of emergency shutdown system.

All personnel working on or at the storage facility shall have appropriate safety training and be qualified to operate all equipment, devices and instrumentation for the safe storage of hydrocarbons in the storage reservoir and shall have the required personnel safety training.

Operators shall have documented procedures for the routine/normal operation of the facilities plus emergency response plans and actions.

The operator shall prevent unauthorized access to wells and storage facilities. Security measures should be appropriate with respect to the location, population density, terrain and environment of areas adjacent to the storage facility.

The following items should be considered in the development of a comprehensive security plan for a storage facility:

a) area patrol, security lighting, video surveillance and alarms;
b) controlled access;
c) boundary/perimeter control fencing;
d) security plans; and
e) locks.

### *3.8.2 Fire Prevention and Control*

Operators shall consider the following when designing underground hydrocarbon storage facilities:

a) spacing of permanent equipment;
b) control of combustible materials ;
c) buildings; and
d) flaring of any hydrocarbon product.

### *3.8.3 Staff Training and Certification*

Operators shall develop a written plan for training and testing of operating staff. The plan should include, as appropriate, apprenticeship and formal training programs.

Staff training and certification should be consistent with the practices outlined in API Standard RP 750, Management of Process Hazards.

All personnel on site shall be informed of the hazards and have knowledge of safety and emergency procedures.

Only qualified and competent people shall be involved with the supervision of personnel and/or the operation of equipment used for the following types of activities:

a) well drilling, well completions, well workovers, well servicing or well reconditioning;
b) storage operations; and
c) fire fighting/fire safety.

A hazardous operations review shall be performed annually with records retained and any resulting actions or equipment changes documented.

Any functional changes made to existing facilities shall have a hazardous operations review completed prior to facility modification.

### *3.8.4 Emergency Planning*

Operators shall:

a) establish an emergency response plan in accordance with all applicable provincial and federal regulations; the plan shall include procedures for the safe control or shutdown of the storage facility in the event of a failure or other emergency;

b) develop an emergency plan to deal with accidental hydrocarbon or brine releases, equipment failures, natural perils, and third-party emergencies; this plan shall be documented and include - roles and responsibilities; emergency response procedures; and training, testing and implementation requirements;

c) audit and test these plans annually.

Reference document: CAN/CSA Z731-95 (R2002), Emergency Planning for Industry.

### *3.8.5 Occupational Health and Safety*

Safe working conditions and a safe work environment shall be provided to employees in accordance with the *Occupational Health and Safety Act*, 1996, c.7, s.1.

**Employees**
Operators shall develop a written safety program for employees. Each employee should review and comprehend the contents of the safety manual according to the facility Health and Safety Plan. The program should emphasize the unique characteristics of storage wells and associated systems such as brine and fresh water. Employees shall be trained, as appropriate, to respond to emergency situations. A record of personnel trained and subject matter covered during the training period shall be maintained.

**Contractor Safety**
Operators should develop a written safety plan for application to contractors. Operators should ensure that the written contractor safety data be reviewed before a contract agreement is made, and again by the contract supervisor before work at the job site begins.

## 3.9 Safety Equipment Devices and Instrumentation

This section applies to exploration, design, development and construction, and operation phases of a storage project.

### *3.9.1 General*

Operators shall have documented records of all safety equipment used on a storage well for both surface and downhole equipment and for devices and instrumentation used to control the injection and withdrawal of hydrocarbons from the storage reservoir.

Operators shall have the required equipment, devices and instrumentation to prevent the uncontrolled/accidental release of hydrocarbons from the storage well and facility as well as for the detection of any uncontrolled/accidental escape/release (leaks) of hydrocarbons from the well or facility.

LPG storage operators shall function test each critical control system and emergency shutdown valve monthly. In addition to ESD valves, such systems include gas detection instruments and any monitoring instrumentation system that provides an alarm. Approval for less frequent testing may be provided by the Board, where the frequency to be used is considered to be sufficient by a qualified person.

Natural gas storage operators shall function test each critical control system and emergency shutdown valve semi-annually. Approval for less frequent testing may be provided by the Board, where the frequency to be used is considered to be sufficient by a qualified person.

### *3.9.2 Well Drilling, Workovers, Wireline and Logging Procedure Safety*

Operators shall use proper well control equipment, devices and personnel when drilling a well and for all workover procedures.

Operating staff shall have the required training for the safe operation and control of all equipment on site and have completed appropriate safety training.

### *3.9.3 Surface Facility Safety (Cavern Storage)*

Storage facilities shall have emergency shutdown valves complete with controls and instrumentation on all hydrocarbon, brine or water outlets on all storage wells located at the storage facility and the emergency shutdown wells shall be capable of both local and remote activation.

Note: Manual valves on water inlets and outlets are permitted where use of these valves is an attended operation such as back flushing a tubing or casing string with fresh water to remove a salt buildup on the inside of the pipe.

Each of the instruments shall be connected to an alarm system that is continuously monitored (except in the case of dry gas storage).

Wellhead pressure monitoring shall be included in the control system.

Operators shall consider protecting all piping and valves against thermal expansion of hydrocarbon or brine.

Routine maintenance shall include removal of collected snow and ice to ensure access to critical valves and monitoring units.

The following instrumentation shall be included as part of the control system to monitor storage operations for salt cavern storage facilities and these instruments shall be connected to an alarm:

a) volumetric flow meters for hydrocarbons and brine; and
b) pressure gauges for both hydrocarbons and brine located at the wellhead.

Equipment shall be included as part of the wellhead control equipment for surface facilities, as identified in Sections 3.7.3 and 3.7.4.

Note: Emergency shutdown valves are required on all cavern hydrocarbon and brine outlets. These valves are essential, as there is no pressure relief on an underground hydrocarbon storage system. The purpose of emergency shutdown is to shut in the whole storage system in case of emergency or unsafe conditions. The shutdown system is also required to be failsafe.

## 3.10 Monitoring and Measurement

This section applies to development and operation phases of a storage project.

### *3.10.1 Development (Cavern Storage)*

In addition to the monitoring requirements of cathodic protection and emergency shutdown valves, the following applies:

a) Operators shall monitor the shape of the cavern during development to ensure a stable shape and configuration is achieved; and

b) Operators planning to solution mine under stored gas should develop a cavern monitoring plan on a case-by-case basis; the resultant monitoring information shall be documented and retained on site for the life of the storage operation and provided to the Administrator on request.

c) Any solution mining of the storage cavern shall be monitored by the operator for the flow rate and saturation level of the inlet water and outlet brine on a daily basis.

### *3.10.2 Operation (Cavern Storage)*

Wireline interface/density logs may be used to locate the position of the product/brine interface.

For storage operations the operator shall have inventory monitoring procedures in place to provide supplementary means to indicate whether control and containment of hydrocarbon product within the storage reservoir and storage facilities is being maintained. Product measurement is recommended for custody transfer, for internal record keeping, or as an operational tool to provide early warning to prevent the unintentional emptying or overfilling of the storage reservoir.

The operator shall:

a) Meter the flows (product, water) into and out of the cavern system;
b) Investigate any loses or gains in the system;
c) Monitor cavern growth by sonar logs; and
d) Conduct subsidence monitoring.

Subsidence monitoring surveys should take place in the same season of the year to minimize the effects of ambient temperature.

### *3.10.3 Operation (Reservoir Storage)*

The operator shall have inventory monitoring procedures in place to provide supplementary means to indicate whether control and containment of hydrocarbon product within the storage reservoir and storage facilities is being maintained. Product measurement shall be conducted for custody transfer, for internal record keeping, or as an operational tool to provide early warning to prevent the unintentional emptying or overfilling of the storage reservoir.

The results of monitoring and measurement shall be retained and provided to the Adminstrator on request.

## 3.11 Maintenance

This section applies to the operation phase of a storage project.

### *3.11.1 General*

Cavern systems should be treated as pressure vessels whereby records are kept on the caverns, wells, wellheads and associated equipment including a record of downhole well activities. The latter will facilitate the identification of potential adverse trends or downhole problems. For example, operators should monitor corrosion rates, cavern growth or other anomalies that may affect the integrity or structural stability of the storage reservoir.

### *3.11.2 Operating and Maintenance Procedures*

Operators are required to have specific written and current procedures and to ensure that personnel are familiar with these procedures. Procedures are required to ensure that the storage facility can be operated and maintained in accordance with the facility design and to ensure that unusual or upset conditions can be managed safely and effectively. Written copies shall be available on site for instruction and training of personnel. Operators shall review their operating and maintenance procedures at least every 5 years to ensure that they are consistent with current industry and government standards.

### *3.11.3 Maintenance for Release Prevention*

As part of the release prevention, the following operating and maintenance activities are required:

a) Blowout preventers for well work-over;
b) Wireline and logging procedures;
c) Well isolation and depressuring;
d) Record of changes and revisions; and
e) Operating and maintenance procedure audits.

### *3.11.4 Inspections and Testing Requirements*

These requirements include scheduled and documented preventive inspection and maintenance programs. Inspections include mechanical equipment and control systems such as wellhead seals, valving, casing, piping and instrumentation control systems for emergency shutdowns, alarms and indicators. Inspections are to be completed by the operator.

#### 3.11.4.1 Casing and Tubing (Cavern Storage)

a) For tubingless completions, both a casing inspection log and a pressure test are required within 5 years of startup and subsequently inspections are to be repeated in a frequency not to exceed 8 years.
b) For wells that have downhole packers installed, an annulus pressure test shall be conducted annually.

#### 3.11.4.2 Casing and Tubing (Reservoir Storage)

a) Either a casing inspection log or a pressure test is required every 5 years.
b) CSA Z341 requires pressure tests depending on the amount of metal loss confirmed by an inspection log.

### 3.11.4.3 Cavern Workovers (Cavern Storage)

CSA Z341 has different inspection and MIT requirements for liquid filled caverns than for dry gas storage caverns.

## *3.11.5 Cavern System Integrity Verification*

This section supercedes Z341 with respect to the use of stored product in MIT's.

Operators are required to conduct an inspection within 5 years of start up to verify well mechanical integrity and all above ground components. The frequency of subsequent casing inspections shall not exceed 8 years.

Mechanical integrity testing is conducted to ensure the pressure containment of the cavern system (and verify that the cavern and cased well are capable of containing the stored product at design conditions), including the wellhead, product casings, casing seat and the cavern cavity. Test results shall be recorded and filed on site. Following the initial mechanical integrity test prior to commissioning, all subsequent MIT's shall be performed *in situ* (in place) using the same product that was or is to be stored in the cavern or by some other approved method.

Test methods for these demonstrations may include: nitrogen (or natural gas) brine interface tests; or shut-in gas pressure tests

Note: API RP 1114 (10.4) identifies that for liquid filled caverns a satisfactory pressure test is one in which the recorded wellhead pressures change no more than 14 kPa over a 24 hour interval.

**Source References:** Documents that deal in some depth with MIT's - nitrogen and brine testing plus liquid pressure tests - API RP 1114 (10.4) and API RP 1115.

## *3.11.6 Reservoir System Integrity Verification*

Operators are required to conduct an inspection or pressure test of the cemented production casing or liner every 5 years following startup to verify well mechanical integrity and all above ground components. Integrity testing is conducted to ensure the pressure containment of the reservoir system (and verify that the cased well is capable of containing the stored product at design conditions), including the wellhead product casings and casing seat. The results of all casing inspections and tests shall be recorded and copies retained on site. Pressure testing of the well shall be conducted following workovers and if significant metal loss has been confirmed. If wellbore integrity is jeopardized by corrosion or damage, the operator shall commence remedial action to either fix the problem or abandon the well.

# 3.12 Closure and Abandonment

This section applies to the last phase of a storage project.

## *3.12.1 General*

The objective is to isolate the storage reservoir from other subsurface formations, have records of the size and the extent of the cavern system for future developments at the site, to ensure the wellbore is permanently isolated and to return the surface site to near original condition.

CSA Z341 has different requirements for abandonment for cavern storage wells than for reservoir storage wells to address unique differences between the two types of storage. For reservoir wells a perforated or open hole section or a cased hole section must be considered. For cavern wells the hydrocarbon product must be removed from the salt cavity, and additionally surveys and MIT's are required.

## *3.12.2 Cavern Evacuation and Decommisioning*

The operator shall ensure that the following requirements are completed:

a) All practically recoverable hydrocarbons have been removed/evacuated from the storage reservoir (cavern and wellbore);
b) The well has been left dormant to allow full brine saturation; and
c) The operator shall complete a sonar survey, wellbore conditions permitting.

Also the operator shall complete the following:

a) A sonar survey has been conducted, cavern and wellbore conditions permitting; or
b) The mechanical integrity of the wellbore has been tested (Mechanical Integrity Test).

## *3.12.3 Well Abandonment Program*

The operator shall submit to the Board for approval a comprehensive program for the abandonment of any hydrocarbon storage cavern. Following approval, the operator shall:

a) Ensure that the storage zone is isolated from all porous zones and fresh water aquifers with cement plugs; or
b) Where practicable, fill the entire wellbore with neat cement.

## *3.12.4 Surface Abandonment*

The operator shall cut off the production and surface casing at least one meter below ground level and cap the surface casing with a welded steel plate.

### *3.12.5 Site Restoration*

The operator shall return the area of surface facilities to a condition acceptable to the Administrator or the Board.

### *3.12.6 Monitoring and Measurement (Cavern Storage)*

During the evacuation of all product from the storage facility, the operator shall measure the amounts of brine used to fill up the cavern during displacement and all subsequent flushes to remove the last remnants of product that can practicably be removed. The amount of product recovered shall also be measured.

### *3.12.7 Record Keeping*

The operator shall maintain all records of the abandonment of any cavern well or reservoir well for the life of the storage facility or until otherwise notified by the Board. A set of records must also be maintained at the provincial office of the operator or its representative.

### *3.12.8 Reporting Requirements*

The operator shall give the Board at least 5 working days notice before the commencement of approved abandonment activities and shall continue to give notice of the commencement of major phases of the abandonment program as may be required by the Board. The operator shall provide the Minister with copies of all sonar surveys, well logs, and abandonment reports within 30 days of receipt by the operator.

### *3.12.9 Public Safety*

A public safety plan shall be developed and implemented for the closure of a storage facility.

### *3.12.10 Environmental Concerns and Issues*

The closure and abandonment of the storage facility should include completion of any requirements under the environmental approvals for the facility.

## 3.13 Record Keeping and Reporting

This section applies to all phases of a storage project and continues beyond closure and abandonment.

Reporting requirements under a licence or lease are to be forwarded to the Minister through the Administrator.

Reporting requirements under an approval issued by the Board are to be forwarded to the Board.

### *3.13.1 Record Keeping*

This section outlines the basis for establishing and maintaining a records system for ongoing operation of underground storage reservoirs and associated surface facilities. Thorough, accurate, and detailed documentation of the entire project shall be of major importance to the operator.

An operator shall maintain records of all pertinent documents relating to the development, operation and history of a storage reservoir within the province of Nova Scotia. The categories of records to be kept shall consist of design and construction, regulatory compliance, maintenance and ongoing operations; and also include, the work program, lease information and development program as well as all relevant information pertaining to any studies, investigations, reports, surveys (both geophysical and geotechnical), analyses and investigations. Included in this shall be a record management system for the materials records.

### *3.13.2 Design and Construction Records*

Design data and "as-built" drawings and equipment documents shall form the basis for the facility equipment and asset files. Drilling and completion reports, area geology mapping, and associated logs should be an integral part of the files. Any sonar logs used to determine the shape and volume of the cavern should be part of these files. All facility modifications, revisions, and additions must be promptly added to the files, and all piping and instrument drawings must be kept current and reflect all changes. The following records shall also be retained, as a minimum:

a) Materials and equipment specifications used both on surface and subsurface;
b) Casing design and pressure test reports;
c) Salt core analysis;
d) Well logs (open and cased hole);
e) Cementing program design, results and reports;
f) Well conversion reports;
g) Development criteria;
h) Cavern commissioning and testing;
i) Subsidence monitoring; and
j) Manufacturer's mill certificates.

The above list is not intended to limit or restrict the records to be maintained. Records relating to other activities should be kept, as warranted.

### *3.13.3 Regulatory Compliance Records*

The operator shall retain all necessary permits, licenses and records as required by federal and provincial agencies and authorities. Such regulatory authorities may establish operating parameters and periodic reporting requirements and may establish statutory requirements for specifications and frequency of periodic inspection and maintenance. All required government forms must be maintained. All records and reports shall be made available for inspection by a representative of the Minister or the Board on request. Records must be kept on file at the facility location or an operator's nearby business establishment for the life of the project and only be destroyed by approval of the Administrator.

### *3.13.4 Maintenance Records*

The operator shall establish, and keep current, a formal records system for all significant maintenance activities. Particular emphasis shall be placed on those activities that assure a continued safe operation and protection of assets. Periodic inspection, testing, and repair frequencies should be set by the operator for selected equipment items. Provincial regulations and/or national standards may have established specifications and minimum time intervals.

The following records shall also be retained, as a minimum:

a) Pressure safety valves;
b) Emergency shutdown valves and associated instrumentation and control systems;
c) Cathodic protection systems and corrosion control programs;
d) External corrosion;
e) Well work over and conversion reports;
f) Well integrity testing results;
g) Instrument/instrumentation testing and calibration;
h) Level indication and overfill monitoring devices;
i) Firewater pumps and controls;
j) Condition of brine pond;
k) Operating and maintenance procedures;
l) Changes, revisions and repairs;
m) Inspections and testing (MIT's, equipment, instrumentation, emergency shutdown valve tests);
n) Subsidence monitoring; and
o) Inventory monitoring.

The above list is not intended to limit or restrict the records to be maintained. Records relating to other equipment, activities and facilities should be kept, as warranted.

### *3.13.5 Ongoing Operations Records*

It is important to record data that reflects the overall condition and performance of the facility.

Typical data collected for an in-service storage facility includes product pressure and temperature, cavity pressure, brine pressure and temperature, brine pond level, cavern interface level, pipeline conditions, and flow rate readings.

Appropriate log sheets shall be developed for the operators' use in recording operational data. This record is particularly needed where product volumes are metered in and out of numerous wells, accounting for simultaneous transfer and injection. A file shall be kept for each cavern that documents metered or estimated inventory in the cavern. From this it can be estimated when the cavern will be full or empty.

All underground storage well product and brine pressures shall be monitored and recorded on a monthly basis.

Surface facilities important to the operation shall be monitored and key parameters recorded.

Equipment condition-monitoring reports shall be maintained.

For LPG operations, management of the brine pond system may be a major operational function. Appropriate records systems shall be established to facilitate that function. An operations log shall be established to record all pertinent activities concerning the facility operation not recorded elsewhere. Any phenomenon concerning the performance that appears to be abnormal shall be documented in the operations log.

### *3.13.6 Safety Control, Emergency Plans and Training*

Appropriate records shall be maintained as required in Section 3.8, Safety.

A hazardous operations review shall be performed with results recorded and retained. Before functional changes are made to existing facilities a hazardous operations review shall be made.

A written safety program shall be developed. The program should emphasize the unique characteristics of storage wells and associated systems. Employees shall be trained, as appropriate, to respond to emergency situations. A record of personnel training shall be maintained.

### *3.13.7 Plugging, Abandonment and Site Restoration*

Records must be kept of any well plugging, abandonment and site restoration work. Following storage facility abandonment, records shall be retained by the operator in a location in Nova Scotia for a period of not less than 5 years.

### *3.13.8 Reporting Requirements*

Operators shall comply with the legislative requirements of all Acts and Regulations or other requirements relevant to the development, operation and abandonment of a storage facility.

### *3.13.9 Regulatory Compliance Reporting Underground Storage*

The operator shall immediately report any contraventions to the Code of Practice to the Administrator or the Board. Operators shall submit all required data and information using authorized forms or a format approved by the Administrator or the Board.

### *3.13.10 Submission of Information for the Drilling and Completion of Wells for Storage Operations - Well data*

In addition to the requirements of Section 25, Data/information, of the *Underground Hydrocarbons Storage Regulations,* the data collection and submission requirements under this section and those of Sections 3.13.11, 3.13.12, 3.13.13 and 3.13.14 must be met.

On request by the Minister or the Board, all information connected with or derived from the drilling, production or other work performed on a well must be made available, and when so required, must be submitted to the Minister or the Board.

All submissions must be sufficiently legible to permit reproduction by standard processes.

"Well reports and well data" means

a) information obtained from a well, for example, drilling reports, well history reports, unprocessed and processed log data, dipmeter surveys, directional surveys, drill stem test data and analysis, wire line data, pressure-volume-temperature and flow test data and analyses, subsurface pressure data and analyses, completion information, geological information, drilling depths, casing and cementing information, well status, gas, oil or water sample or analysis data, drill cuttings and any analysis and description of the drill cuttings and cores, and

b) proprietary geological information, engineering data and supporting calculations contained in pre-application submissions for well authorizations, but does not include

geological and geophysical reports in the possession of the Minister or the Board that have a confidential status.

### *3.13.11 Daily Reports*

A daily report, on a form approved by the Minister, must be kept at the site of a well drilled or otherwise being worked on. Legible copies of the daily reports for each calendar week must be submitted within the next week to the Minister, if requested, and copies must be retained by the operator as part of the permanent record.

The daily report must set out complete data on all operations performed during the day.

### *3.13.12 Deviation and Directional Surveys*

Within 14 days of obtaining the results of a directional survey, the report must be sent to the Minister, if requested.

### *3.13.13 Samples and Cores*

Drill cutting samples must be forwarded to the Minister as soon as possible after total depth is reached, but not later than 14 days after the date of rig release.

The Administrator must be advised of the interval over which a core was taken, and the result of all analyses made from it must be submitted to the Minister, in duplicate, within 30 days of the completion of the analysis.

If core data is obtained in digital form, both hard copies and digital copies of the data must be submitted, each clearly labelled with the well number and the well location of the core analyzed.

### *3.13.14 Tests, Analyses, Surveys and Logs*

Reports must be filed with the Minister of all relevant well data regarding the completion, suspension or abandonment of any storage well.

Three copies of all logs run, including any computer enhanced logs, shall be submitted to the Minister within 30 days of the date on which the log was taken, but a copy of the log must be made available to an authorized government employee upon request.

A clear and non-fading print of a pressure chart and a report containing complete details on fluid recoveries and other pertinent facts for each drill stem test or wire line test taken on a well must be submitted to the Minister within 30 days of the date on which the test was made.

If recoveries on drill stem tests or wire line tests from a well permit good sampling, the operator must submit to the Minister, within 30 days of analysis completion, 2 copies of all analyses made of any oil, gas or formation water recovered from each formation.

On obtaining the data and results of a bottom-hole sample analysis or other pressure-volume-temperature analysis, the data results must be submitted to the Minister within 30 days of analysis completion.

### *3.13.15 Well Summary*

Within 30 days after the date of rig release, a signed Well Summary, or on a form provided, must be submitted to the Minister and formation test services reports, together with the charts resulting from pressure testing, must be attached to it.

### *3.13.16 Well History Reports*

Within 60 days after the date of rig release of the drilling rig for an exploratory well, a well history report must be submitted to the Administrator.

The well history report must be compiled in accordance with instructions issued by the Administrator.

### *3.13.17 Completion and Workover Reports*

A completion or workover report, in chronological format, detailing all significant operations, treatments and resulting well behavior, and including a downhole schematic diagram, must be submitted to the Minister within 30 days of the end of completion or workover operations.

For each separate completion or workover operation on a well, a report must be submitted in accordance with the above.

### *3.13.18 Submission of Information for Design, Development and Construction*

Operators shall submit, on a form or format authorized by the Board, the following types of information as part of an application for approval to develop and construct a storage facility:

a) Assessment of neighbouring activities;
b) Geological studies;
c) Maps and mapping;
d) Subsidence monitoring program plan;
e) Operational maximum and minimum pressure limits planned;
f) Maximum injection and withdrawal rates planned;
g) Corrosion control programs and systems planned;

h) Safety equipment (devices and instrumentation) planned;
i) Well completion or recompletion details;
j) Well conversion details;
k) Casing design;
l) Cementing design;
m) Changes to casing string(s);
n) Surface facilities including wellhead design;
o) Public safety – emergency response plans; and
p) Environmental approvals obtained.

As terms and conditions of approval, operators may be required to submit, on a form or format authorized by the Board, the following types of information following the development and construction of a storage facility:

a) Casing pressure test data;
b) Casing inspections;
c) Changes to casing string(s);
d) As-built records for completed wells;
e) Any changes to the submissions provided in the application for an approval; and
f) Any other requirements of the terms and conditions of approval.

### *3.13.19 Submission of Information for Operation and Maintenance*

Operators shall submit on a form or format authorized by the Board the following types of information in an application for approval to operate:

a) Operating and maintenance procedures;
b) Emergency plan procedures;
c) Cavern sonar survey results;
d) Subsidence monitoring results;
e) Public Safety – emergency response plans; and
f) Environmental approvals obtained.

As terms and conditions of approval, operators may be required to submit, on a form or format authorized by the Board, the following types of information during the operation of a storage facility:

a) Well workover results;
b) Copies of all wireline logs;
c) Repairs, changes and revisions to wellhead or casing;
d) Casing inspections;
e) Mechanical Integrity Pressure Test results;
f) Annual results of cathodic protection inspections and tests;
g) Hydrocarbon product inventory verification losses or migrations (gains?);
h) Integrity issues or concerns of the storage system;
i) Cathodic protection survey and/or inspection reports; and

j) Any other requirements of the terms and conditions of approval.

### *3.13.20 Submission of Information for the Closure and Abandonment*

Approval of the abandonment program must be obtained from the Board. Sufficient information must be submitted to the Board to allow the effectiveness of the proposed abandonment program to be evaluated.

Operators shall submit on a form or format authorized by the Board the following information in an application for approval to abandon a storage facility:

a) Cavern abandonment/decommissioning program and design;
b) Site restoration program;
c) Public safety;
d) Confirmation from the Department of Environment and Labour of site rehabilitation completion; and
e) Consent of surface owner for site abandonment.

As terms and conditions of approval, operators may be required to submit, on a form or format authorized by the Board, the following types of information following the closure and abandonment of a storage facility:

a) Cavern sonar survey results;
b) Mechanical Integrity Test results;
c) Copies of all wireline logs run;
c) Abandonment plugs – cement;
d) Surface treatment of wells;
e) Surface restoration; and
f) Any other requirements of the terms and conditions of approval.

Confirmation of completion of restoration must be submitted to the Board after the restoration of the surface of any abandoned well or storage facility. Confirmation must include evidence of restoration in compliance with any terms and conditions provided in the approval to abandon the well or storage facility.

# 4.0 References

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