Feasibility Study of Comprehensive Collection and Recycling Programs for Single-use Propane Cylinders in Canada

Final Report

Prepared

for

Canada

Action Plan 2000 on Climate Change
Enhanced Recycling Program

by

The Nova Scotia Department of Environment and Labour

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1. PURPOSE OF THE STUDY

More and more Canadians are purchasing small, non-refillable propane cylinders every year for heating and cooking during outdoor activities and for torch fuel use. It is estimated that 2.2 million single-use cylinders are consumed annually in Canada. However, due to the lack of a recycling system for this product, both residual propane and the resources embedded in the steel cylinder are lost when spent cylinders are disposed along with regular household waste. These cylinders also pose a fire and explosion risk due to improper handling at the time of disposal and impose financial burdens on municipalities that must dispose of the cylinders as hazardous wastes.

The main purpose of this study is to examine the feasibility of a comprehensive collection and recycling program for single-use propane cylinders in Canada.

The first part of this report (Sections 2 - 6) provides an overview of propane and propane cylinders; management of risks associated with their use; standards and guidelines affecting use and end-of-life management options; status of recovery and recycling of these products across Canada and the U.S; and, a greenhouse gas reduction impact analysis of recovering steel and residual propane.

The objective of the second part of this report is to examine possible options for collecting propane cylinders for recycling. The suitability of individual options is dependent upon population density and geography, thus several different systems may be utilized within a province. Within the various options, ongoing consideration of worker and public safety must be observed. Specific points examined in Sections 7 - 10 of this report include:

- **Collection and storage**: Collection of single-use propane cylinders may include pick-up from independent drop-off facilities, curbside, scheduled collection events, or the incorporation of existing collection infrastructures. Storage of the cylinders, following collection, requires appropriate protective systems for staff and the public to minimize the potential for fire and explosion.
- **Transportation**: Transportation of single-use propane cylinders from the collection site must consider federal regulations regarding the transportation of dangerous goods, appropriate equipment, current transportation practices, the use of existing infrastructure, and cost.
- **Existing infrastructure**: There is an existing infrastructure for recycling single-use propane cylinders, however, current operations are fragmented and provide only parts of the required activities from collection to recovery of the residual propane and steel. An integrated system is lacking.
- **Extended producer responsibility**: Extended producer responsibility incorporates the concept of shifting responsibility for waste products upstream to the producer and providing incentives for producers to include environmental considerations in the design of a product.

2. PROPANE AND PROPANE CYLINDERS

2.1 Propane ($CH_3CH_2CH_3$)

Propane gas is a paraffinic hydrocarbon first discovered by an American scientist, Dr. Walter Snelling in 1912. It soon became popular for use as a clean and affordable fuel in residential heating.

Propane will liquefy under pressure. Propane exists as a gas at atmospheric temperature and pressure. It is stored at higher pressure in its 270 times more compact liquid phase. Propane is an odourless gas but for the safety of consumers, ethyl mercaptan (CH_3SH- 30 ppm) is added so that users can quickly detect propane leaking into the air. The smell of ethyl mercaptan has been compared to rotten eggs or boiling cabbage. Propane gas is flammable and may produce a visible vapour cloud near the surface because its molecular weight is greater than that of air. Some physical characteristics of propane gas are shown in Table 1.

Table 1: Physical characteristics of propane

Boiling Point °C	Flash Point °C	Auto Ignition Temperature °C	Molecular weight
- 42.1 °C (-43.8 °F)	-104 °C	450°C	44

2.2 Propane cylinders

Two types of propane cylinders and systems: "vapour withdrawal" and "liquid withdrawal", are used in both refillable and non-refillable cylinders. Single-use propane cylinders and most other household or utility type refillable cylinders are vapour withdrawal system. As such, they must be used, stored, mounted and transported in the vertical position. This type of system withdraws only the propane vapour from the top part of the cylinder, above the liquid. If this type of cylinder were on its side or upside down, liquid propane would be withdrawn and pose extreme danger.

Large cylinders, such as the lift truck cylinder, use the liquid withdrawal system. They are used, mounted, stored and transported on their side.

There are two types of single-use propane cylinders on the market: camp size 465 g (16.4 oz) capacity cylinders (Figure 1)**Error! Reference source not found.** that are used for camp stove cooking and 400 g (14.1 oz) tall skinny cylinders (Figure 2**Error! Reference source not found.**) that are used for torch fuel, soldering, heating and lighting.

Non-refillable single-use cylinders are recognized by Transport Canada (TC) under the guideline TC 39M NRC 16/20 M33. In the United States, the Department of Transportation recognizes non-refillable cylinders under the D.O.T. 39 NRC 228/286 M1003 guideline. In this study all mention of cylinders, hereafter, refer to single-use propane cylinders as defined by Transport Canada.

The net weight of the empty 465 (±3%) g capacity cylinder is 403 (±3%) g and the net weight of the full cylinder is 868 g (±3%). The net weight of 400 g capacity torch fuel propane cylinder is 430 g and the net weight of the full torch fuel cylinders is approximately 830 g (±3%).

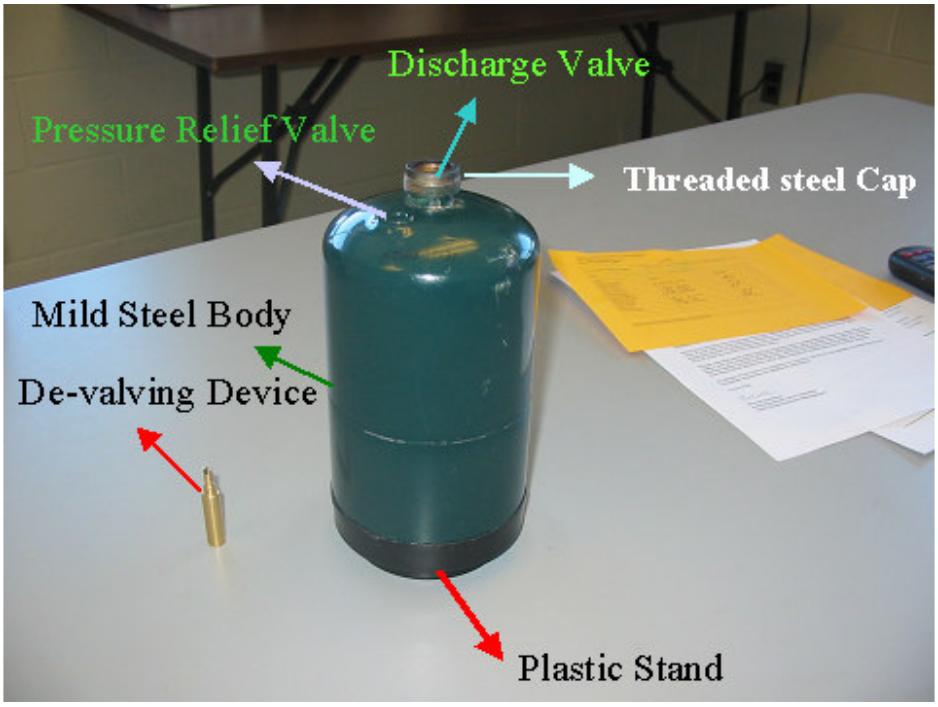

Figure 1: 465 g (16.4 oz) capacity single-use propane cylinder

Figure 2: 400 g (14.1 oz) capacity single-use torch fuel propane cylinder

The body of both non-refillable and refillable cylinders is made of mild steel, typically American Iron and Steel Institute (AISI), grades 1005-1025. The top threaded part is made of mild steel-1008, and may contain lead[1]. A pressure relief valve is mounted beside the discharge valve in order to release the propane from a container in the event of accidental overpressure or excess heating. The carbon content of mild steel of single-use propane cylinders may vary from trace levels up to 0.3% of the material's composition. Mild steel is weldable and has reasonable cold bending properties, as shown in Table 2.

Table 2: Physical characteristics of mild steel

Thermal Conductivity kJ ($h.m^2.K/m$)	Density g/cm^3	Melting Point ^oC	Thermal Expansion mm ^oC
188	7.86	1410	0.003675

There are two main differences between refillable cylinders and non-refillable cylinders. Refillable cylinders are uniformly heat-treated after all forming and welding operations. The steel is thicker and the cylinder is equipped with an overflow protection device. Heat treatment increases the elasticity of the cylinder allowing it to be refilled time after time. A single-use cylinder cannot be refilled because their structure is such that they will rupture when under the stress of refilling. Despite this danger, single-use cylinder "refill kits" can be found advertised on the Internet (Figure 3**Error! Reference source not found.**)[2].

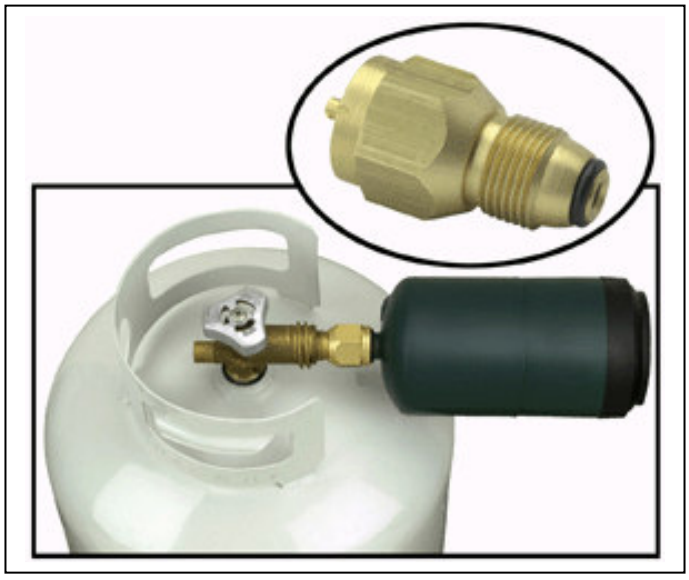

Figure 3: Illegal single-use propane cylinder refill kit

[1] Canadian Steel Producers Association, www.canadiansteel.ca

[2] Propane Bottle Refill Kit available from Harbour Freight Tools, www.harborfreight.com/cpi/ctaf/Displayitem.taf?itemnumber=45989

The pressure relief valve and discharge valve on a single-use cylinder are made of steel; the needles are plated with other materials. The valves, washer and o-ring can be removed after discharging any residual propane using a hard knife and an automobile tire valve remover.

The external paint on a single-use cylinder is made of crystalline silica quartz (SiO_2) with pigment applied as a powder coat. The thickness specification of the paint is 1.5 to 2 μm[3]. The maximum inside pressure of 465 g capacity cylinders ranges from 1.599 to 1.999 MPa at 54.44 ^oC (232-290 psig at 130 ^oF). The pressure of a single-use cylinder is a function of both the service pressure indicated upon filling and the external temperature of the environment in which the cylinder is located.

2.3 Feasibility of substitution of non-refillable cylinders to refillable

Non-refillable propane cylinders have a thin wall thickness and are not heat-treated. Refillable propane cylinders are heat-treated after all forming and welding operations are complete. Heat treatment softens the metal and restores its elasticity. Refilling non-refillable cylinders is dangerous because the inelasticity of the metal concentrates stresses and fatigues the steel.

Because non-refillable type cylinders are not heat treated, they are much thinner-walled than refillable cylinders. DOT standards for refillable cylinders are DOT 4BA. A DOT 4BA cylinder is a cylinder with a water capacity of 1,000 pounds or less and a service pressure that ranges between 225 to 500 psig. These kinds of cylinders are made from two seamless hemispheres and joined by the welding of one circumferential seam. Minimum wall thickness should be 1.9939 mm (0.0785 inches).

Technically, it is possible to make a 465 g capacity refillable cylinder. The thickness of the non-refillable propane cylinder is 0.7112 mm (0.028 inch). To change this cylinder to a refillable design would increase the weight of the cylinder to approximately 1.3 kg. Valve systems should meet refillable standards and an overflow protection device must be mounted in the cylinder. Manufacturing of a refillable 465 g capacity propane cylinder using thick aluminum sheet would reduce the weight of the cylinder by half of a comparable steel vessel. There is no authorized company in Canada to refill or transport used cylinders to the U.S.

In reference to phone conversations with single-use propane cylinder producers, it is technically possible to make single-use propane cylinders refillable and feasible to do so, but from marketing standpoint, producers are reluctant to take on this change.

[3] Coleman Company Inc. Phone interview with Rex Weigand, March 2005.

3. STANDARDS AND REGULATIONS

The Canadian Standards Association (CSA) develops standards for transportation, testing, inspection and safety matters related to non-refillable cylinders as stated in the National Standard of Canada under CAN/CSA B339-02. Canada's Transportation of Dangerous Goods (TDG) B339-96 covers requirements for the manufacturing, inspection, testing, marketing, re-qualification, reheat treatment, repair and re-building of propane cylinders, spheres and containers.

Non-refillable cylinders are regulated under Transport Canada's TC-39M regulation. TC-39M containers are defined as non-refillable, seamless or welded carbon steel, aluminium, or brazed carbon steel spheres or cylinders. Under these regulations, service pressure should not exceed 80% of the test pressure. The body of single-use propane cylinders should be carbon steel of uniform and, where applicable, weldable quality conforming to the chemical composition of 0.12% carbon, 0.04% phosphorous and 0.05% sulphur. Completely de-oxidized steels (Killed Steel) used for welded containers are not subjected to the heat treatment, such as single-use propane cylinders. According to the standard, steel for propane cylinders with integrity formed ends and made of hot drawn and finished seamless tubing should be carbon steel with a chemical composition not exceeding 0.55%, carbon, 0.045% phosphorous, and 0.05 % sulphur.

The standard for manufacturing the cylinders indicates that any attachment added to the cylinders should not affect the integrity of the containers. Welding or brazing of attachments to the containers should be completed prior to all pressure tests. The maximum service pressure for longitudinally or helically welded cylinders is 3.5 MPa.

The standard requires manufacturers to perform flattening and pressure tests of the manufactured cylinders. Pneumatic pressure tests and burst tests should be conducted for 30 seconds as well as leak tests performed by submerging the tanks in water.

Each propane container is required to be labelled using durable and waterproof material. The label must display the following:

- Transport Canada Mark "TC" followed by the specification designation (TC-39M);
- The letters "SF/RU" (single fill/remplissage unique) for non-refillable containers
- The service pressure in MPa correct to one decimal place
- The manufacturer's registration number
- The lot number
- The date of manufacture

Single-use propane cylinders manufactured in the U.S. display the following label:

TC-39M NRC 16-20 M1110 (Transport Canada Regulation- Law Code for Non Refillable Cylinders)
DOT-39 NRC 232/290 M1110 (U.S. Department of Transportation Regulation-law code)

Based on the Canadian and U.S. standards, refilling and transportation of refilled disposable propane containers is a federal offence. The U.S. Department of Transportation DOT-39 and Transport Canada's TC-39M regulations impose some very high fines and jail term penalties for

transporting a refilled container on U.S. and Canadian roads respectfully. Almost all the single-use propane cylinders manufactured in the U.S. display the following warning:

"FEDERAL LAW FORBIDS TRANSPORTATION IF REFILLED - PENALTY UP TO $500,000 AND 5 YEARS IMPRISONMENT (49 U.S.C. 5124)"

Torch fuel cylinders display the following label:

D.O.T. 39 NRC 228/286 M1003
T.C. 39M NRC 16/20 M33 (NRC stands for non-refillable cylinder and M33 is a law-code)
CAS No. 74-98-6 UN 1978
In National Standard of Canada CAN/CSA-B340-97, Propane classified as, Class 2.1, UN1978

3.1 Transportation and storage regulations

The transportation of single-use propane cylinders is subject to Transport Canada's Transportation of Dangerous Goods regulations. The regulation allows propane cylinders to be transported as scrap metal if all valves and safety marks have been removed. Otherwise cylinders must be labpacked in standard drums by certified environmental service providers prior to transportation to recovery and recycling facilities. Current regulations are intended to promote public safety in Canada. Provincial and municipal programs should provide service to Canadians for the safe collection, transportation and recycling of non-refillable cylinders.

Figure 4: Disposed propane cylinders in Nova Scotia provincial parks (Halifax East District)

In Nova Scotia, piles of used propane cylinders are stored in camping sites and parks (Figures 4 - 7). They cannot be shipped to HHW depots or recycling facilities before being properly labpacked or having their valve and safety marks removed. Campgrounds, park authorities and residents are looking for a way to send spent propane cylinders to HHW depots or other waste resource management systems without violating the TC-39M regulation. In the province of Nova

Scotia, parks and campgrounds do not have standard storage facility for used cylinders and trained technicians are not provided on site to safely remove valves and recover residual propane.

Figure 5: Disposed propane cylinders in Nova Scotia provincial parks (Halifax East District)

Figure 6: Disposed propane cylinders at the Valley Waste Resource Management facility (Kentville, NS)

Figure 7: Disposed 400 g torch fuel propane cylinders at the Valley Waste Resource Management facility (Kentville, NS)

3.2 Fire safety regulations

In the province of Nova Scotia, propane cylinders are regulated under Section 51 of the Fire Safety Act.

4. RISK ANALYSIS

4.1 Risks associated with propane gas

Propane is a highly flammable and explosive material that can be used safely if the necessary precautions are observed. Reduction of risk is the first priority in managing discarded single-use propane cylinders.

While fire and explosion are the most obvious hazards of propane, there are several others to take into consideration such as frostbite, asphyxiation, and carbon monoxide build-up.

Frostbite

For consumer use, propane is condensed into its more compact liquid phase. Propane gas normally turns to liquid at very low temperature therefore, when its compressed state is released at warmer temperature, it quickly evaporates and converts into a gas phase. To do this, it must absorb heat from it surrounding very rapidly. Frostbite will occur if bare skin is exposed to liquid propane because of the absorption of heat from the evaporating propane. Liquid propane can escape from opened valves on cylinders, especially if the tank is tripped or removed.

When emptying used propane cylinders, insulated neoprene gloves must be worn to avoid direct contact with liquid propane. Other body protection, such as neoprene aprons or arm protectors may also be necessary.

Asphyxiation

Propane is 1.5 times heavier than air and will settle or accumulate in low-lying areas and confined spaces. The gas will dilute and displace air in a space and result in an atmosphere with insufficient oxygen for breathing. This can cause light-headedness, dizziness, loss of consciousness and even death from asphyxiation. It is very important for any operation utilizing propane, whether indoors or outdoors, to properly ventilate the area and capture any escaping propane.

Carbon monoxide build-up

Carbon monoxide is produced through incomplete combustion of fuels including propane when the oxygen content in the air is insufficient for complete combustion. Propane fuelled equipment can produce the deadly gas when operated in a confined space, or if the carburetor or burner on the equipment is dirty. Any area where propane fuelled machines are operated should also be adequately ventilated.

Fire and explosion

Propane gas is highly flammable when mixed with air. If ignited in an enclosed space it can instantly combust and cause an explosion.

4.2 Risks associated with single-use propane cylinders

Propane cylinder collection

Single-use propane tanks can explode during collection from the curbside when the waste is compacted, resulting in injuries to the garbage collection labourers. Risk to human health, the environment and equipment are likely to happen at waste collection facilities if force is exerted upon spent cylinders.

Propane cylinder storage and transportation

Propane cylinders should always be stored outdoors, preferably in a well-ventilated area such as an open-sided shed with a lockable gate. Appropriate signage, such as “no smoking” or “source of ignition”, should always be displayed where propane cylinders are being stored. Propane cylinders should not be stored near oxygen cylinders.

Propane cylinders must be kept upright and properly secured to prevent them from tipping over or rolling around.

As long as the valves and safety marks have been removed, propane cylinders can be transported as a scrap metal.

Propane cylinder piercing

Piercing the body of the mild steel cylinder may produce sparks. Therefore the entire process must be performed in an ignition free and oxidant free environment such an environment vented using an inert gas or high vacuum.

4.3 Fire safety code of practice for the recycling and waste handling industry

In the U.S., propane facilities with more than 4,000 gallons of propane on site are required to prepare a fire safety analysis under a revised code for liquefied petroleum gas published in April 1998 by the National Fire Protection Association (NFPA). The code covers highway, marine, and pipeline transportation of propane, plus containers, piping, and associated equipment for end users.

The NFPA code requires that facility fire-safety planning should consider the safety of emergency personnel, workers, and the public. It requires that facilities with more than 4,000 gallons of propane on site evaluate their potential fire hazards and safety procedures and document them in a written fire-safety analysis. The code also recommends that facilities make their fire analysis report available to local emergency response personnel.

4.4 Propane accident response plans

The Propane Gas Association of Canada Inc. (PGAC) and the Liquefied Petroleum Gases Mutual Aid Program have announced an updated emergency response plan for propane incidents. The emergency response plan provides for office staff, field emergency response advisors, and emergency response teams strategically located throughout the country, that are ready to respond to an emergency call on the plan’s 24-hour bilingual national emergency response line. Industry members, companies, government agencies, fire and police officials have access to the plan.

4.5 Industrial safety programs

Risk management is mandatory for a propane cylinder recovery program. Qualitative risk assessment methods will quickly identify single-use propane cylinder decommissioning systems as necessary. Fully automated systems greatly reduce the health risks that workers face when dealing with propane cylinders.

Systems that prevent and protect against fire and explosion are the necessary components of a safe decommissioning system. Fire is an exothermic oxidation reaction in air (oxidants: O_2, CO, N_2O and NO) with possible flame and high temperature. Ignition of propane either in a liquid or vapour phase can result in fires. Fire ignition sources such as friction/mechanical sources, overheating, open flames, welding and cutting, static discharges and electrical sparks must be eliminated. Shockwaves from explosions can cause human, equipment, and environmental damage; this may occur due to vessel rupture or combustion reactions. Explosion prevention protects labourers and the facility from consequence of an explosion. Propane gas concentrations can be minimized through ventilation, the addition of inert material, and the use of barriers and seals, which will help to mitigate explosions.

Installation of a leakage control system, level detectors, continuous ambient air monitoring system for detection of propane, appropriate ventilation systems, and fire prevention and fire fighting systems can reduce the risks originated from the operation.

Personnel risks

An inherently safe propane cylinder decommissioning system and following safety precautions in handling of propane cylinders will minimize the risk to operators, their co-workers and the public. In addition, an accidental release prevention program for the main residual propane storage tank, which is based on current regulation and standards, also reduces human risk in the recycling facility. Comprehensive safety training for employees plays a crucial role in minimization of risk. Employees should respect the safety regulations to prevent exposing themselves or their co-workers to unnecessary risk. Advisories issued by the facility's occupational health and safety committee on preventive maintenance, surveillance and inspection, working methods, protective equipment, and health and safety training are vital for a safe operation.

Environmental risks

Identifying the critical environmental protection system in propane cylinder decommissioning can reduce environmental risk, which can be done using environmental risk assessment methods. A poorly designed decommissioning system may result in significant environmental releases. An analysis of environmental consequences from a propane release is necessary to manage environmental risks:

- Identification of environmental receptors in the vicinity of the cylinder decommissioning process.
- Determination of the environmental pathways to these receptors.
- Determination of likely pollutants concentrations to which these receptors might be exposed.
- Assessment of the impact of propane exposure.

It is recommended that the employees at the propane cylinder decommissioning facility be made fully aware of the environmental protection system and that they conduct an appropriate level of monitoring and maintenance of the system. Implementation of the environmental protection program will reduce accidental and unauthorized emissions into the environment.

5. CURRENT STATUS OF SPENT SINGLE-USE PROPANE CYLINDER MANAGEMENT

In Canada and the U.S., nationwide management programs do not exist for the approximately 40 million single-use propane cylinders added to municipal waste stream every year. Some municipalities in Canada and the U.S. collect single-use propane cylinders through their HHW programs.

Municipalities in North America are struggling with the financial and logistical challenges of managing discarded single-use propane cylinders within the municipal waste stream. The magnitude of the problem is increasing each year and poses environmental, financial and safety risks.

5.1 Inventory of propane cylinders in Canada

According to the Coleman Company Inc[4] approximately 2,000,000 single-use propane cylinders are purchased in Canada each year for camping use. There are an additional 200,000 cylinders of other brands and types purchased each year, meaning an estimated 2,200,000 cylinders are used every year in Canada. Of this total, approximately 142,000 are used annually in Nova Scotia.

5.2 Residual propane in disposed single-use propane cylinders

Single-use propane cylinders, when discarded in regular household trash, can contain enough residual propane to explode when compressed in a garbage truck, or when processed at waste resource recovery facilities. Residual propane was measured at several waste resource recovery centres and provincial parks in Nova Scotia using a 2.2 kg capacity *Pelouze* digital balance. Statistical analysis of the data indicated that residual propane in the both camp stove fuel cylinders and torch fuel cylinders ranged between 4.63% and 16.35% by weight with a mean value of 10% of total capacity (Tables 4 through 7 in the Appendix). It can be seen then, that improper disposal means not only missed opportunities to recover steel, but the loss of propane gas into the environment (a serious health and safety, economic and environmental issue).

5.3 Financial considerations

Propane cylinders are very expensive for municipal household hazardous waste (HHW) collection programs to manage. Halifax regional municipality (HRM), for instance, pays $2.62 per cylinder for recycling. If all of the single-use propane cylinders sold in Nova Scotia were collected through municipal HHW programs, the estimated disposal bill could reach $370,000 per year for recycling, without considering the additional costs for collection, transportation, separation and storage. When applied to the total number of cylinders used in Canada each year, the total processing bill alone could reach $6,600,000.

5.4 Existing processing facilities for cylinder recycling

In Canada, municipally run recycling facilities for propane cylinders and other HHW exist. For instance, the Valley Waste Resource Management Facility in Kentville, Nova Scotia has designed and constructed a prototype for recycling single-use propane cylinders. The system is at

[4] Coleman Company Inc. Phone interview with Rex Weigand, March 2005.

a research stage and may be commercialized in the future. The system shears the single-use cylinder in half and crushes the cylinder in one step in an enclosed chamber. Residual propane is vented to the atmosphere. Valley Waste is currently developing a flaring device that would allow the propane to be combusted and is researching methods for capturing the residual gas.

Private recycling and environmental service companies are already actively recycling pressure vessels, including propane cylinders, in North America. Most of the spent single-use propane cylinders collected in the Maritimes are transported to Ontario or Quebec for proper recycling. However, a shortfall exists, as a well-developed collection system is not available within the individual provinces.

5.5 Single-use propane cylinder decommissioning systems

A simplified design for a semi-automated decommissioning system for spent single-use propane cylinders is shown in (Figure 8). The basic design outlines how a system for pressurized gas cylinder decommissioning might be constructed thereby allowing the collecting of residual propane, scrap steel from the cylinders and minimizing the risk to personnel, assets and the environment.

Single-use propane cylinders are transferred to the off-loading tray in horizontal position. Cylinders move slowly toward the confined chamber where an inclined pneumatic belt conveyor equipped with speed control directs the propane cylinders toward the confined cutting, flattening and residual gas recovery chamber.

The confined chamber consist of a hydraulic press, an ark shaped titanium cutting blade, inert gas injection system and residual propane recovery system. An arc shaped blade, made from titanium, is mounted on a hydraulic press so that the cylinders will be cut in half before flattening. A hydraulic press system with a capacity of two tonnes is needed for flattening the spent propane cylinders.

A perforated sintered steel plate allows the circulation of the injected inert gas and suction of the residual propane from the confined chamber. When a significant volume of residual propane is contained in a cylinder, both liquid and gas phase propane may be released into the chamber, potentially damaging the gas injection and vacuum system. A rupture disk should be installed at the bottom of the confined chamber, so that in the case of explosion, the disk will open, directing the explosive forces away from the machinery and workers.

Inert gas injection is necessary to purge oxygen from the chamber thereby minimizing the risk of fire and explosion. An industrial grade nitrogen (N_2), argon (Ar) or helium (He) gas cylinder equipped with gas regulator and pressure gauge is needed for injection of inert gas to the system to complete residual recovery operation.

A residual propane recovery system is an essential part of the spent propane cylinder decommissioning system. A recovery system reduces the risk to human, assets and the environment and saves a large amount of unused clean fuel. Brass gas valves are used to control the flow rate into the propane cylinder decommissioning system. Check valves will prevent the back flow of gas from the storage tank into the confined chamber.

A two-stage, oil free industrial vacuum pump is needed to suck the residual propane from the confined chamber. The vacuum should have ultimate vacuum power of 1×10^{-4} Torr (0.009 psi) and a motor stronger than 5 horse power (HP). A stainless steel low-pressure vacuum gauge 0-5 psi is needed to monitor the performance of the vacuum pump.

A certified 500 US gallon (1892 l) capacity above-ground propane cylinder equipped with a relief valve is needed for storage of recovered residual propane from the spent single-use propane cylinders. The location of the tank must be at least 15 m (50 feet) from any potential ignition source. Warning signs such as "no smoking" and other warnings must be posted in the area.

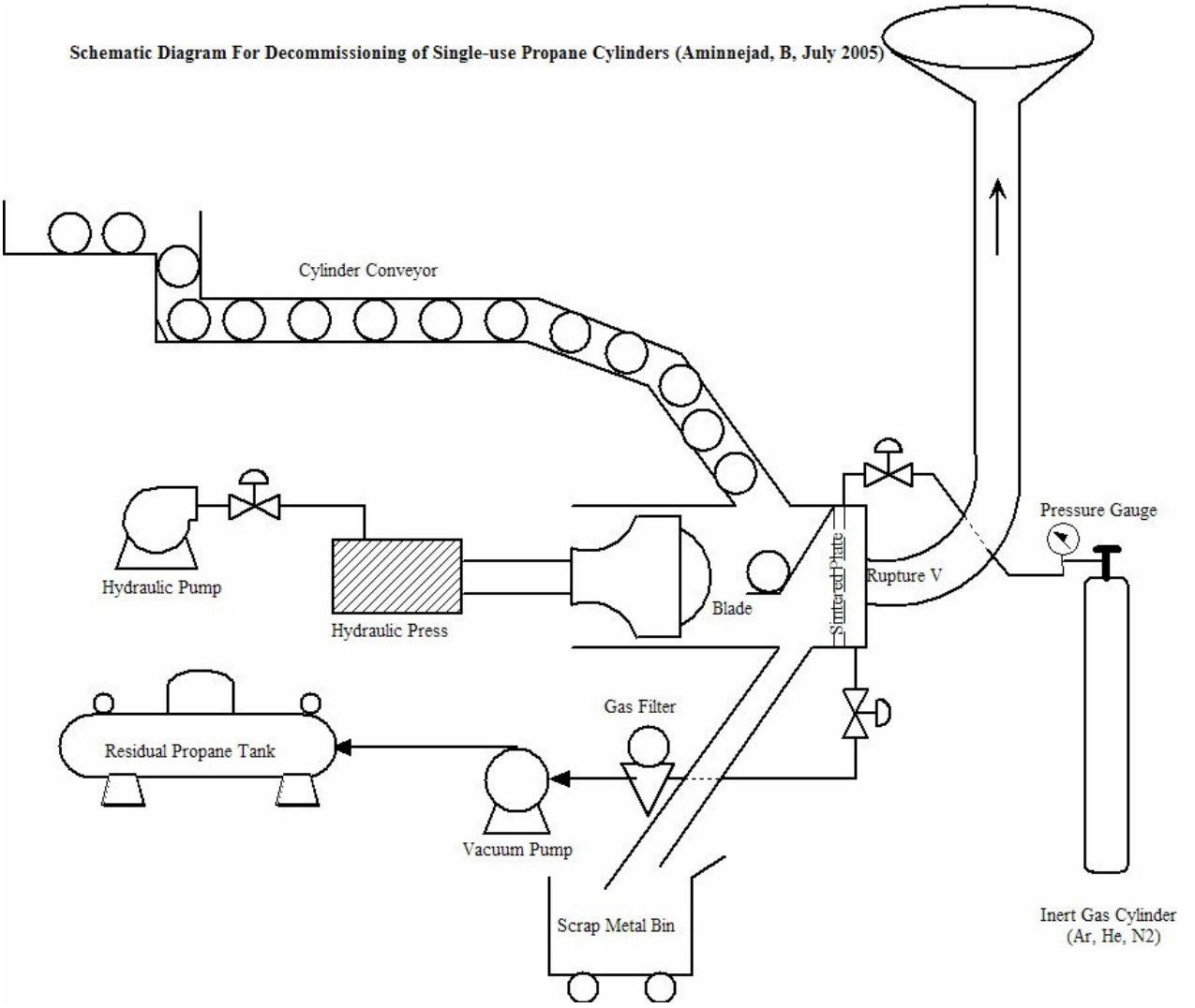

Figure 8: Schematic diagram of a system for decommissioning spent single-use propane cylinders

5.6 Current single-use propane cylinder management in Canada

Nova Scotia

In Nova Scotia, there are several facilities that provide propane cylinder collection and recycling within the private and public sectors. The result of preliminary research indicates that approximately 142,000 single-use propane cylinders are added to the municipal waste stream every year. The majority of these cylinders are disposed in regular refuse, though 22% were recovered for recycling in 2004. Collected cylinders from municipal household hazardous waste (HHW) depots and waste resource recovery facilities are labpacked by environmental service companies and shipped to Quebec or Ontario for residual propane recovery and cylinder recycling.

Irving Propane and Superior Propane, private sector propane providers within the province, collect propane cylinders from their customers and ship the cylinders out of province for disposal. Thrifty Propane, a division of Corroless Atlantic and Blue Ribbon Propane, has a system that shears single use cylinders into two pieces and vacuums the residual propane into a 2000 lb capacity tank. Thrifty Propane recycles propane cylinders of various capacities with the province. Discarded propane cylinders are collected from landfills and HHW depots for recycling.

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Valley Waste Resource Management (VWRM), located in the Kentville Industrial Park, in Kentville, Nova Scotia accepts single-use propane cylinders as a HHW item. A mobile propane cylinder cutting and crushing prototype was designed and constructed by VWRM in 2003 with financial assistance provided from the RRFB Nova Scotia. Spent cylinders have their valves removed using a pneumatic drill, and then are chopped and flattened in a confined press prior to shipment to scrap metal dealers. The residual propane is released to the atmosphere, however VWRM is examining options for flaring with the potential to recover the residual propane in the future.

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New Brunswick

New Brunswick has 12 solid waste management regions, each with a mandate to oversee waste management within its jurisdictions. The HHW depots operated by the municipalities collect propane cylinders that are labpacked and transported out of New Brunswick for disposal by Atlantic Environmental Services Co. The municipalities also have a one-day HHW collection day campaign in the summer whereby mobile units collect HHW items within the major cities. The Maritime Propane Cylinder Recycling Depot in Chatham, New Brunswick is the only recycling facility in the province that processes single-use propane cylinders. The facility

currently receives propane cylinders, which are then pierced and residual propane is vacuumed from the cylinder into a propane storage tank for reuse. Empty propane cylinders are chopped and flattened prior to shipment to scrap metal dealers. The facility charges $1 per cylinder.

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URL: www.maritimepropane.com

Prince Edward Island (PEI)

Prince Edward Island doesn't have a program for the management of single-use propane cylinders. Spent propane cylinders are accepted as a HHW item at depots across the island.Collected cylinders are labpacked and sent out of province for disposal by industrial environmental service companies. The municipalities pay $285 - $325 per drum ($3 per cylinder). Discarded propane cylinders are transported to Nova Scotia. Blue Ribbon Propane and Thrifty Propane assist in recycling spent propane cylinders.

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E-mail: hchowen@iwmc.pe.ca

Newfoundland and Labrador

The Newfoundland Department of Environment has indicated that recycling infrastructure is not available in Newfoundland or Labrador for recycling single-use propane cylinders.

The city of St. John's collects propane cylinders during three HHW days held each year. The province also facilitates a HHW campaign day to collect single-use propane cylinders from homes and recreational centres each year. Collected single-use propane cylinders are labpacked by local environmental companies and sent to Quebec or Ontario for decommissioning.

Contact: Derrick Maddocks
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Quebec

The Department of Environment stated that at the present time Quebec doesn't have a provincial program to collect and recycle single-use propane cylinders. The province, however, would consider propane cylinders a priority if they address dangerous waste issues within an EPR program. If this happens, Quebec could consider adding a schedule pertaining to propane cylinders to an eventual EPR regulation. Quebec intends to conduct research into sales information, domestic and non-domestic use cylinders, the current fate of these used materials, and the potential for a propane cylinder-recycling program.

Quebec is planning to search Canadian and foreign experience on the subject, and identify the means of reclamation and recycling as well as risk assessments for these operations. Currently Quebec doesn't have a record of the annual sale of single-use propane cylinders.

The government agency responsible for the management of parks and reserves in the province, le Société des établissements de plain air du Québec (SEPAQ), has previously tried to implement an on-site voluntary "collect and recycle" program for single-use propane cylinders. The Ministry of Environment in Quebec is in the process of studying that program and its results. It basically offers to campers, hunters, anglers and hikers an on-site deposit bin for single-use cylinders. Some educational tools are also provided in order to demonstrate to land-users the importance of not leaving this equipment in the forest.

The request to manage single-use propane cylinders was first launched by the car shredding industry. It was observed that some scrap yards would dispose of refillable domestic propane tanks in vehicles prior to their shipping to shredding facilities. Even after many education programs aimed towards the dismantlers, it seems that accidents still happen and explosions occur inside the shredders. The shredding industry has thus requested a study on the matter in order to prevent any further risk.

Municipalities often receive used propane cylinders through their HHW collecting depots. Four private sector environmental service firms provide single-use propane cylinder recycling in Quebec. These firms provide collection and transportation of the propane cylinders as well as recovery of the residual propane and recycling of the scrap steel.

CRI Environmental Inc. is a certified hazardous waste management company located in the Coteau-du-Lac Industrial Park. CRI operates a propane cylinder and aerosol can recycling infrastructure. Discarded cylinders and aerosol cans from the Atlantic Provinces are shipped to CRI Environment Inc for recycling.

Contact: Jean Bissonnette
Phone: 450-763-5541 / 1-800-571-5541
Phone (Montreal): 514-643-1414
Fax: 450-763-0282

Onyx Industries is a certified hazardous waste management company that operates several branches in Quebec and provides labpacking and recycling services.

Ressourcerie des 3-R is a certified environmental services company in Shawinigan, Quebec, which provides cylinder labpacking and recycling services.

Solva-rec Environmental Inc. is a certified environmental services company, located in Saint-Jean-Sur- Richelieu, Quebec that provides cylinder recycling services.

Ontario

Ontario doesn't have an official province-wide program for the management of single-use propane cylinders. The province holds about three HHW campaign days in cooperation with

stakeholders in order to collect single-use propane cylinders from homes and recreational centres every year.

Stockpiles of more than 30,000 single-use propane cylinders were removed from Ontario campgrounds in 2003. This clean-up was managed by Bumble Bee Recycling and funded by the Coleman Company Inc. as the result of a series of meetings between the Association of Municipal Recycling Coordinators, the City of Toronto, the Recycling Council of Ontario (RCO), Parks Ontario, the propane cylinder industry, and cylinder recycling facilities.

Stakeholders continue to meet in an effort to develop a permanent collection system. Parks Ontario is pushing a proposal to allow individual parks to transfer propane cylinders to a central collection point.

RCO is advocating that industry pay for proper disposal. A proposal to reclassify single-use propane cylinders as household waste is currently being discussed. The theory is that, as household waste, cylinders could be collected through blue box programs much as empty aerosol containers are now collected in some Ontario communities. Redesignation may provide the means to pull in sufficient numbers of cylinders to make their recycling economical. However, given the perceived risks, it is doubtful that municipalities would be interested in adding propane tanks to their recycling programs. Manufacturers have agreed to approach the Ministry of the Environment with a proposal to study the feasibility of curbside recycling for propane cylinders through two pilots. Guelph and Kitchener-Waterloo have been suggested as pilot sites. Manufacturers have also been working on an industry code of practice that will include handling and processing procedures for recyclers.

Ontario now requires that all personnel handling propane in the workplace receive training that is recognized and delivered by an accredited training company. The training must also be appropriate and specific to the task being performed, such as dispensing propane, or handling and exchanging cylinders on propane powered industrial and construction equipment.

Material Resource Recovery (MRR) is a certified waste recovery centre providing hazardous waste treatment and disposal solutions in Ontario. The MRR facility is located in Cornwall and provides recycling for cylinders that contain compressed gasses. MRR is able to dispose of a wide range of gases in a variety of cylinder sizes. Discarded cylinders are pierced and residual gas is removed and purged using an inert gas.

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Manitoba

Manitoba doesn't have provincial or municipal programs for the management of single-use propane cylinders. HHW depots accept propane cylinders for free and the collected cylinders are

labpacked by environmental service companies and shipped to Alberta for residual propane recovery and cylinder recycling. Disposal costs the government approximately $3 per cylinder.

In Manitoba, the Miller Environmental Group provides recycling services for recycling single-use propane cylinders and aerosol cans at their facility in Winnipeg. The Miller Group operates a patented piercing system for recovering residual propane, whereby the residual propane is adsorbed using an activated carbon filter. The discharged cylinders are chopped and flattened for collection by scrap metal dealers. Environmental service companies in Saskatchewan, Alberta and British Columbia ship labpacked propane cylinders to the Miller Group for recycling.

Contact:
Phone: 204-925-9600
Fax: 204-926-9601
URL: www.millergroup.ca/waste/index.html

Saskatchewan

Saskatchewan doesn't collect information on propane cylinder sales and there isn't a program in place to collect and recycle single-use propane cylinders. Provincial parks collect propane cylinders from campers. The municipalities of Regina and Saskatoon have one or two HHW collection days in late summer.

Saskatchewan does not have facilities that decommission propane cylinders. Superior Propane collects 10 and 20 lb refillable propane cylinders at their depot in Saskatoon collects and labpacks the spent propane cylinders, which are shipped to the Recycle Systems Co., in Nisku, Alberta for processing to recover residual propane.

Contact: Envirotech Waste Manufacturing Ltd.
Phone: 306-244-9500

Alberta

There isn't a provincial program for single-use propane cylinders in Alberta. Discarded cylinders are disposed in the regular garbage collection system. Municipalities are not required to segregate single-use propane cylinders. The municipalities are managing propane cylinders in accordance with the provincial waste control regulation, which stipulates that propane cylinders must be empty of residual propane before they can be landfilled.

Recycle Systems Co. is located in Nisku, Alberta. Recycle Systems Co. recycles cylinders and aerosol cans from across Canada as well as the U.S. Recycle Systems uses vacuum extraction equipment designed and maintained within the company, which punctures the propane cylinder. Recycle Systems is investigating a recovery process for the extraction of residual propane. Currently the residual gas is flared.

Contact: Tim Underwood
Phone: 780-955-2508
Fax: 780-955-2509
Toll-Free: 1-800-387-4459

E-mail: recycle@recyclesystems.com
URL: www.recyclesystems.com/index.htm

Custom Environmental Services, an environmental services firm in located in Edmonton, processes propane cylinders to extract the propane for use in a dual fuel internal combustion engine. This process is also licensed for all flammable gases such as acetylene and MAPP (a gas made by combining liquefied petroleum gas with methylacetylene-propadiene). Custom Environmental uses these fuels for cogeneration at their facility.

Contact: Brian Winters
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Fax: 780-440-2428
Toll Free: 1-800-661-5792
E-mail: info@proeco.com

British Columbia

British Columbia does have a product stewardship program for waste coatings, flammables, pesticides and petroleum products. However, the program does not cover spent single-use fuel cylinders. Empty cylinders may be placed in the waste stream.

Single-use propane cylinders are either landfilled, collected and crushed by local contactors in order to recover the steel, or shipped out of province in labpacks to Alberta for recycling. Municipal landfills/transfer stations and private contractors accept single-use propane cylinders for recycling. The following are firms that are currently accepting single use propane tanks for drop off:

Viper Fuels
Murry Hatter (provides pick up for transfer stations/landfills in the Lower Mainland (Vancouver area)
Phone: 250-246-1838

Tank 4 Tank
Phone: 604-524-8586

Dell's Propane
Phone: 250-561-7077
Phone: 250-392-2971 (Williams Lake location)

Caribou Propane
Phone: 250-992-7553

Autogas Propane Ltd
Phone: 604-276-9924

Delta Propane
Phone: 604-591-3804

The Northwest Territories

The Northwest Territories does not have a territorial or municipal programs for the management of single-use propane cylinders.

Yukon

The Yukon does not collect information on propane cylinder sales and there isn't a program in place to collect and recover single-use propane cylinders.

5.7 Current single-use propane cylinder management in the U.S.

There isn't a country-wide comprehensive system for collection and recovery of single-use propane cylinders in the United States. Some states, however, practice their own collection and recycling of propane cylinders, such as Florida.

The State of Florida recently worked with the Product Stewardship Institute (PSI) and Sarasota County HHW program to improve management solutions for these cylinders. PSI has convened a national dialogue to address problems associated with the end-of-life management of small non-refillable propane cylinders.

In Florida, it is recommended that residents recycle small non-refillable propane cylinders through their local HHW programs. Some HHW programs recycle spent cylinders through waste-to-energy facilities for residual propane recovery, some offer partially full cylinders to other residents through SWAP shops, while others contract a cylinder recycling company to do the collection and processing.

Based on information provided by NE Cylinder Disposal, based in New York, some disposal companies charge as much as $5.50 U.S to take small single-use propane cylinders from municipal HHW depots.

NE Cylinder Disposal has a fully automated prototype developed for piercing and cutting single-use propane cylinders. This company receives propane cylinders, including the single-use type, from across the U.S. Cylinders enter a compartment by conveyor, where the cylinders are pierced and residual propane is vacuumed into a 100-gallon propane tank. Then cylinders are chopped into two pieces and flattened for scrap processing. At this time, NE Cylinder Disposal charges $0.75 U.S for decommissioning each single-use propane cylinder.

6. GREENHOUSE GAS BENEFITS OF SINGLE-USE PROPANE CYLINDER RECOVERY

There are two potential reductions in the emission of greenhouse gases by the recycling of single-use propane cylinders: recycling of steel and the reuse of residual propane from discarded cylinders. Recycling the cylinder conserves landfill space and natural resources, generates lower CO_2 emissions than producing steel from raw materials, and forestalls the consumption of additional propane.

6.1 Steel recycling and reduction of CO_2 emissions

Steel production in Canada generates about 2 percent of Canada's annual greenhouse gas emissions[5]. If all propane cylinders were recycled in Canada, an estimated 877 tonnes of steel would be recovered annually. For the purposes of estimating the benefits of recycling propane tanks, a number of points need to be considered:

- The production of one tonne of virgin steel requires 1,250 kilograms of iron ore, 700 kg metallurgical coal and 60 kg of limestone[6].
- Producing one tonne of steel from 100 percent virgin inputs requires 25.45 Giga joules (GJ) of energy and creates 2.20 tonnes of carbon dioxide equivalent (eCO_2), which is the standard measure for greenhouse gas emissions[7].
- For every tonne of steel produced from 100 percent recycled materials, the amount of energy required is 9.67 GJ, which creates 0.7 tonnes eCO_2[8].
- However, it is estimated that steel contains 14 percent recycled content on average. As a result, the energy requirement for the "current mix" is 23.23 GJ per tonne and the eCO_2 generation rate per tonne of steel produced is estimated to be 1.99 tonnes.[9]
- Therefore, the benefit of recycling a tonne of steel (100 percent recycled content versus the current mix) is estimated to be 13.56 GJ per tonne (23.23 – 9.67 = 13.56) and 1.29 tonnes eCO_2 (1.99 - 0.70 = 1.29).

Since 887 tonnes of recoverable steel are sold in Canada each year, it can be calculated that if all this material were recycled, this activity would reduce the requirement for 1,096 tonnes of iron ore, 614 tonnes of coal and 53 tonnes of limestone. In addition, the net gain in terms of energy savings and GHG emission reductions would be 11,892 GJ of energy and 1,131 tonnes eCO_2, respectfully.

Additional savings include the sale of the scrap steel. Assuming the current value of steel is $120/tonne, upwards of $105,000 in revenue could be generated nationwide.

[5] See Canada's 2003 Greenhouse Gas Inventory at www.ec.gc.ca/pdb/ghg/inventory_report/2003summary/2003summary_e.cfm
[6] See www.canadiansteel.ca/current/recycling.htm (Jan-2006)
[7] ICF Consulting, 2005, *Determination of the Impact of Waste Management Activities on Greenhouse Gas Emissions 2005 Update*, Environment Canada, Natural Resources Canada
[8] Ibid.
[9] Ibid.

6.2 Residual propane recovery and reduction of CO_2 emissions

The contents of a full single-use propane cylinder are 465 g, however the average contents of spent cylinders weighed in this study was 35 g (see description in Section 5.2). The estimated residual propane is:

$\Sigma_{\text{Residual Propane}}$ = 2,200,000 x 0.000035 t = 77 tonnes

Based on the results of this study, upwards of 154,000 litres of propane, with a retail value of 0.8749 $/l (plus tax – Halifax, May 2005) can be recovered. The value of the residual propane is approximately $135,000.

Propane released to the atmosphere is subject to a chain of photochemical reactions (mainly photo-oxidation) that rapidly oxide the propane to form CO_2, based on the following reaction:

$C_3H_8 + 5O_2 \Rightarrow 3CO_2 + 4H_2O$

If all the residual propane released from single-use propane cylinders is converted to CO_2 in the atmosphere, then upwards of 231 tonnes of CO_2 could be formed.

The primary benefit in recovering the residual propane is in the prevention of additional consumption of propane that would be necessary to replace the quantity discarded in the spent single-use cylinders.

7. COLLECTION AND STORAGE OPTIONS FOR END-OF-LIFE SINGLE-USE PROPANE CYLINDERS

The collection method and frequency of collection that works best for a particular area should be selected based on household density, household geographic distribution, availability of storage and recycling infrastructures, the location of seasonal tourist facilities, point sources of waste generation (i.e. parks), and the management costs of the system.

Any collection point will normally require short-term storage prior to shipment in order to minimize costs - it is usually cheaper to ship full truckloads rather than partial loads. Short-term storage requires a controlled, well-ventilated area that is protected with a suitable fire suppression system, commonly Class B and C fire extinguishers, and a spark proof electrical system. There should be sufficient separation distances from other flammable materials, based upon existing provincial fire safety codes.

Municipalities are the service providers in most cases, as it is municipalities that are tasked with establishing waste collection infrastructure for their residents and for some businesses. Entire systems, however, could be provided by the private sector. In choosing this option, municipalities or other authorities will have to consider whether a private sector run infrastructure would provide the necessary incentives for consumers to bring the empty containers to that facility.

There are two basic collection options for spent propane cylinders:

- Collection depots
  - Permanent municipal depots
  - Temporary municipal depots
  - Private depots
  - Retail depots
- Curbside collection

As indicated, collection depots can take many different forms. Some or all of these options could operate in any province or territory. When choosing which option is appropriate for an area, the merits and drawbacks of each need to be considered. It should also be noted that regardless of the system, lab packing of the spent cylinders prior to transport will be required.

All collection systems share the same requirements. For example, trained personnel are necessary to accept the waste materials, segregate the materials, and package the waste for transport. Collection systems also require secure storage with fire suppression systems, preferably Class B and C fire extinguishers, and should be isolated from non-compatible materials.

Depending upon the particular collection system selected, the stakeholders involved in the recovery of single-use propane cylinders for recycling may change. A list of potential stakeholders from the public and private sectors are provided:

- **Federal Government**: Environment Canada, Transport Canada, and Parks Canada

- **Provincial Government**: Environment Department, Occupational Health, Fire Marshall, and Provincial Parks
- **Municipal Government**: Solid Waste Management Authorities
- **Private Sector**: Campgrounds, Retailers, Waste Depot Operators, and Environmental Services Companies
- **Other**: Product Stewardship Organization

The participating stakeholders within a province-wide single-use propane cylinder recycling program will be dependent upon the method(s) of collection and the willingness of the various stakeholders to participate.

7.1 Collection depots

Permanent municipal depots

For municipally operated depots, residential users of single-use propane cylinders are asked to bring their spent cylinders to municipally sponsored Household Hazardous Waste (HHW) depots. HHW depots currently segregate incoming waste streams for short-term storage and transportation for treatment. HHW depots are a suitable recipient of propane cylinders as the employees are trained to handle hazardous materials and the sites are designed to accept wastes that pose dangers to human health and assets. The cylinders are required to be stored in a secured, well-ventilated area prior to lab packing and transport to a recycling location.

HHW depots usually also accept flammable liquid solvents, used oil and paint. These materials are incompatible with the storage of single-use propane cylinders, thus the HHW depots may require upgrading to accept and store propane cylinders in a safe manner. This could be accomplished by adding an enclosed outdoor annex equipped with spark proof electrical systems.

Temporary collection depots

Where permanent depots are best suited to urban areas, offering year round disposal and storage, rural regions sometimes utilize temporary depots in order to provide service to outlying areas. These facilities effectively act as transfer stations to a central facility. Therefore, such depots could act as part of a larger network with permanent urban-based depots.

Parks and campgrounds could also serve as temporary depots. These recreational sites are the primary sources of spent single-use propane cylinders, most commonly in the summer months. Many of these locations are further away from other centers of generation but can yield considerable numbers of spent cylinders. As such, these sites could provide temporary perforated storage bins made of steel or another fire resistant material. Visitors could be encouraged via signage and informational materials to handle their propane cylinders properly and deposit them in the storage area when they leave the park.

A more specialized form of temporary depots is the HHW collection event. Usually sponsored by municipalities, local waste management authorities extend the geographic reach of their facilities and operate spent propane cylinder collection programs via HHW depots.

Private depots

A private sector system of depots could also be used to collect single-use propane cylinders. For instance, Enviro-Depots™ are a network administered by the RRFB[10] Nova Scotia that already accepts many recyclables from residents. Enviro-Depots™ or other similar depots can be upgraded to accept propane cylinders and other forms of HHW.

These facilities currently receive beverage containers as well as used paint. Most of the recyclables in the depots are not compatible with flammable materials such as propane, used oil or solvents, thus some structural upgrades may be necessary in order that the propane cylinders are separated and stored properly, as with municipal HHW depots.

Retail depots

Many retail stores already provide for the exchange of larger 20lb refillable propane cylinders. The Blue Rhino™ system[11], for instance, is used by many grocery stores, hardware stores, and service stations across the country. These stores typically have outdoor storage facilities with a fenced area, isolated from ignition sources and oxidizers, and equipped with fire extinguishers. It is possible that this system could be adapted to include single-use non refillable propane cylinders. However, there could be some retailer resistance, since some of these stores do not generally sell single-use propane cylinders.

7.2 Curbside collection

Another option for the collection of spent cylinders is curbside collection in residential areas. However, it should be recognized at the outset that curbside/roadside collection of propane cylinders alone would rarely be a feasible option for municipalities because of the small number of single-use propane cylinders used in the home.

Combining propane cylinder collection with curbside collection of other compatible hazardous wastes, such as other cylinders filled with compressed gases, may make this option more attractive and allow residents to conveniently dispose of all of their household hazardous wastes. However, the cost of providing separate collection vehicles would make this option extremely cost-prohibitive, as will be detailer further in the following section.

7.3 Analysis of collection options

With any collection method, there will be positive and negative aspects. Some systems can result in low collection rates, while others would be prohibitively expensive. Curbside collection could have a high recovery rate but would also have a high collection cost. For example, in the Halifax Regional Municipality (HRM) curbside collection and disposal of residential wastes costs each household $185-$240/annum, depending upon population density. Included in this number is the collection cost for the 4 waste stream system employed by HRM at approximately $80/annum. If

[10] RRFB Nova Scotia is a non-profit corporation intended to ensure that Nova Scotians benefit from solid-waste management, by developing sustainable industry stewardship programs that increase diversion, assisting in the establishment of new industries based on the processing of materials diverted from the waste stream, and providing incentives for residents to reduce, reuse, recycle and compost.

[11] Blue Rhino operates an exchange program that allows the consumer to return empty 20lb refillable cylinders for filled cylinders without waiting for their cylinder to be refilled.

a fifth waste steam (propane cylinders / pressurized cylinders), were added to the system, the collection cost could increase by upwards of 20%. On a provincial basis, the estimated curbside collection cost for single-use propane cylinders sold annually in Nova Scotia would be upwards of $ 5 million, based upon the following assumptions:

- Pressurized cylinders / HHW waste collected every 2 weeks
- Annual collection cost per household: 20% * 80 = $16
- Number of households in Nova Scotia: 360,020
- Number of cylinders sold in Nova Scotia: 142,000
- Cost of collection = $16 * 360,020 = $5.7 million
- Cost per cylinder - $5.7 million/142,000 = $40.60 / cylinder

Based upon this analysis, curbside collection is not a viable option. A table of the various collection options, with benefits, liabilities and results is provided as follows:

Table 3 Collection option analysis

	BENEFITS	LIABILITIES	RESULTS
Permanent Municipal Depot	Year round access for public. Facilities generally accept a wide range of materials. Education component can be consistent with other initiatives. No provincial regulatory structure required.	Requires return of cylinder to a site not commonly used by consumers. Does not provide easy service for rural residents living far away from disposal sites. Segregation of non-compatible wastes is required.	Capture rates can be consistent. Higher return rate anticipated than temporary facilities.
Temporary Municipal Depot	Eliminates cost of maintaining year round infrastructure. Can be set up close to center of generation. No provincial regulatory structure required.	Education component is variable, as collection staff that operates the depot may have high turnover. Segregation of non-compatible wastes is required.	Capture rates are variable. Return rate for temporary facility is typically very low.
Private Depot	Year round access for public. Facilities generally accept a wide range of materials. Education component can be consistent with other initiatives. More numerous facilities than municipal operated depot, providing easier access	Provincial regulatory structure may be required. Requires return of cylinder to a site that may not be commonly used by consumers. Segregation of non-compatible wastes is required. Funding from municipality may be required, otherwise fee may be charged to public.	Capture rates can be consistent. Higher return rate anticipated than temporary facilities.

	BENEFITS	LIABILITIES	RESULTS
Retail Depot	Year round access for public. More numerous facilities than municipal operated depot, providing easier access. Education component can be consistent with other initiatives. Can be built upon current return structure for large refillable cylinders.	Provincial regulatory structure may be required. Willingness of retail sector to undertake this activity may be limited.	Return rates will be highest if a linkage is formed by the public between consumption of a product and its disposal.
Curbside Collection	Easy access for residential users. High rate of recovery. No provincial regulatory structure required.	Would substantially increase the current cost of curbside collection Dedicated vehicles may be required due to incompatibility with other wastes.	Not likely viable due to collection costs.

Based upon economics, curbside collection will be prohibitively expensive to implement. Permanent collection sites, either municipally or privately operated would have higher anticipated collection rates than the temporary sites, however, there will be costs accrued to the municipality or the general public. The preferred approach that minimizes cost to the municipality and encourages a high rate of return for the cylinders would be a retail depot system. Some of the larger retailers of single-use propane cylinders, such as Wal-Mart, Home Hardware, and Canadian Tire, operate stores across the country where the consumer could return the spent cylinder and then purchase a replacement.

8. MANAGEMENT COSTS OF RECOVERING SPENT CYLINDERS

Spent single-use propane cylinder disposal management costs can be broken into two types of costs (Figure 9):

- Fixed Costs: program administration, depreciation on equipment / facilities owned by municipality, collection contracts with private collectors, wages for municipal employees, insurance, advertising.
- Variable Costs: transportation costs (fuel) and tipping fees (variable quantity of cylinders collected).

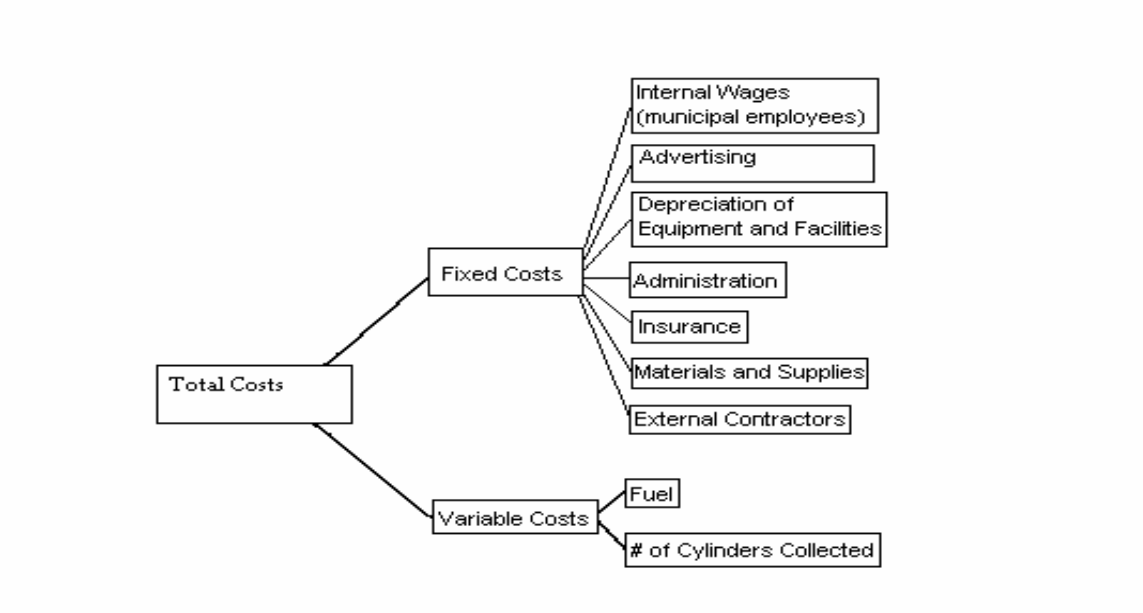

Figure 9: Total costs flow chart

Transportation can be a significant cost associated with the collection of single-use propane cylinders for many options.

Based upon discussions with Atlantic Industrial Services (AIS), a local environmental services company, the cost of labpacking propane cylinders is $265 - $285 CAN per 45 gallon drum, while transportation from remote collection sites (parks, satellite HHW depots) is estimated at $235 / 160 km (100miles). The cost of transportation for HHW wastes is commonly 2.5 times the transportation cost for non hazardous wastes.

8.1 Implications of propane cylinder consumption

Single-use propane cylinders pose a risk to refuse and recycling material handlers when left unidentified in the waste stream and result in a disposal problem for collection site operators (HHW depots, parks, etc) due to the regulations regarding transportation and storage. The potential for fire and explosion from improper handling of these vessels increases the disposal cost of a low value commodity.

Exacerbating the situation is the cost of lab packing prior to transportation for disposal when compared to the value of the recoverable material. For example, lab packing all the cylinders sold in Nova Scotia (~142,000) would cost approximately $325,000, prior to transportation. The recovered steel and propane from these cylinders is worth approximately $11,000, if the cylinders retain 7.5% propane. Transportation costs will only increase this disparity. The estimated cost of collection, packing, and transportation for Canada is in excess of $6,000,000. Collection and recycling of the cylinders therefore can only be justified as a workplace safety issue that also reduces the emissions of greenhouse gases.

9. TRANSPORTATION OF SPENT CYLINDERS FOR DISPOSAL

9.1 Transport to collection sites

The restrictions imposed upon the vehicle transporting the cylinders in bulk do not apply to the general public when transporting a cylinder for disposal. The public can transport their spent single-use propane cylinders to collection centres in their own vehicles (TC-39M Exemption). There are requirements regarding the transportation of small propane cylinders by pickup truck and car. Cylinders should be secured in an upright position for transportation and it is recommended that a plastic valve plug be installed in the outlet opening as an additional safety precaution. Carrier compartments must be ventilated and sealed from the vehicle's interior.

9.2 Transport from collection sites

Collected cylinders are transported from HHW depots and waste resource management facilities to recycling facilities across the country after being properly lab packed by certified environmental personnel, and transported in an approved vehicle. Appropriate signage on the vehicle identifying that propane cylinders are being transported is required under the authority of Transport Canada's Transportation of Dangerous Goods regulations. The operators of a vehicle transporting spent single-use propane cylinders should receive the necessary training regarding hazardous materials regulations and should be familiar with labelling of the lab packs, preparing a manifest for the cargo, and appropriate signage for the vehicle.

10. EXTENDED PRODUCER RESPONSIBILITY

The current concept of a non-refillable vessel that is inexpensive, but results in excessive disposal costs to municipalities is not sustainable. There is an opportunity for all levels of government (Municipal, Provincial, Federal) to leverage their regulatory powers to reduce these costs, shift them upstream towards producers and in the process, improve the environmental performance of propane cylinders. An "Extended Producer Responsibility" (EPR) program could accomplish these goals.

Thomas Lindhqvist defined EPR in 1990, as "a policy principle to promote total lifecycle environmental improvements of product systems by extending responsibilities of the manufacture of the product to various parts of the product's life cycle and especially to the take-back, recovery and final disposal of the product". EPR necessitates that responsibility for end-of-life management be shifted from municipal governments (and tax payers), upstream to producers. The ultimate goal of EPR is least environmental impact.

There are three possible economic models for an EPR program for propane cylinders:

- Deposit-refund system
- Visible fee at retail, and
- Cost internalization (an 'invisible' fee).

All three models could operate within the collection systems discussed in Section 3. Product fees would cover the costs of operating and administering the program. Fees would have to be carefully calculated to ensure that all program expenses were covered. Mechanisms would need to be worked out to manage program deficits, as well as funding surpluses. An external product stewardship organization, such as RRFB Nova Scotia, could be effective in administering such a program.

10.1 Deposit-refund option

A "half-back" deposit-refund system would provide a funding mechanism for the end-of-life management of propane cylinders while also providing consumers with a financial incentive to return their spent cylinders. Such a system could be modeled after Nova Scotia's beverage container system, where recovery rates are as high as 80%. However, there are disadvantages to this system. First of all, it could entail significant complexity and an administrative burden in remitting deposits and refunds. Secondly, such a system does not entail producer responsibility. Where consumers bear much of the cost burden, a deposit-refund system may not provide an incentive for producers of propane cylinders to lower program costs through re-design.

Collection system (deposit-refund option)

A deposit-refund system could operate through either a private depot system, or return-to retail. Neither municipal HHW depots, nor Parks have the administrative experience and capacity to participate in such a program; furthermore, the remote location of Parks would cause problems for urban consumers wishing to return spent cylinders (used elsewhere) for refunds.

In some provinces, such as Nova Scotia, private depots are already structured to operate deposit-refund systems for beverage containers, and consumers are in the habit of returning waste goods to these locations.

A return to retail system could also be convenient for consumers wishing to replace their spent cylinders. Such a system is already familiar for consumers purchasing refillable propane tanks from gas stations and some retailers. However, retailers could be resistant to this option, due to the administrative complexity it would entail.

Stakeholder roles and responsibilities (deposit-refund option)

For both collection options, an administrative body (ie. product stewardship organization) would be required to oversee the management of the system. This body would shoulder much of the responsibility for the program in terms of administration, reporting requirements and financial management. Physical responsibility for collection would be placed on the collection agency (either the depot operator or retailer) and on the consumer. A contract between the administrative body and the collector would have to be worked out to cover administrative costs.

A deposit-refund system would also require provincial regulation, under the authority of Provincial Environment Departments to implement the system. Other stakeholders would include depot operators, truckers and transport authorities.

10.2 Visible fee option

The second structure for a stewardship program could be modeled after Nova Scotia's used tire management program, where consumers pay a one-time, non-refundable fee upon purchase of new tires. The fee would be based upon cost recovery (an estimated $2 - $3 per cylinder). Again, consumers rather than producers would cover the costs of the program. However, the relatively high fee could be expected to depress sales of cylinders, which could encourage redesign for the environment, in an effort from producers to lower program costs.

This model would also face challenges. In the case of Nova Scotia's tire program, recovery rates are high, since most consumers have their tires changed on site at retailers, where used tires are collected. With propane cylinders, however, cylinders are used off site, and it would be less convenient for consumers to return their cylinders to either depots or retailers.

It should be noted that neither option involves true producer responsibility, as required in the strict definition of EPR. However, both would result in the shifting of financial responsibility away from municipalities, towards consumers and distributors/retailers. This could at least serve as a start in solving the end-of-life management problems associated with spent propane cylinders.

Collection system (visible fee option)

Collection systems are less restrictive for a visible fee system than for a deposit-refund system, since no financial mechanism would be required to provide refunds to consumers. In this respect, in addition to private depots and retailers, municipal depots and parks could also serve as collection agents. Without the incentive of a refund, convenience to consumers would take on more priority.

Stakeholder roles and responsibilities (visible fee option)

Stakeholder roles and responsibilities would be similar to a deposit-refund option. Both government legislation and an administrative agency would be required. However, a visible fee option would be less complex to administer (for both the administrative agency, and the collection agency). Private collectors in particular, would likely be more receptive to this system, over a system that required them to remit refunds to consumers. On the other hand, a non-refundable fee would be less palatable to the public, and could be misinterpreted by consumers as a government tax.

10.3 Cost internalization option

A cost internalization model is often viewed as 'true' EPR, since it requires producers to incorporate costs of the end-of-life management of their products into their operations.

When producers are required to pay the costs of end-of-life management, now being borne by municipalities, they have an incentive to redesign products for reuse and recycling. Propane cylinders are complex, multi-material products. Their unique design features impede easy re-use and recycling. A cylinder designed to be refillable would be preferable to the current design, as it would encourage consumers to use the same bottle many times instead of discarding it, while also facilitating the recovery of residual propane.

Producer responsibility is a challenge when product supply chains are highly dispersed geographically and producers are external to the regulatory agent, which is the case for propane cylinders in Canada, where manufacturers are foreign-based firms. At the same time, it is still possible to shift management costs onto distant producers, or "brand owners", as Nova Scotia's EPR experience with paint stewardship has demonstrated. In Nova Scotia's Consumer Paint Product Stewardship Program, consumers return leftover paint to Enviro-Depots in the province, and the program is administered by an arms-length organization (RRFB Nova Scotia). However, program costs are paid by producers (brand owners), who have contracts with the RRFB. This structure requires brand owners to play a financial role in the end-of-life management of their products, without being required to take physical responsibility for the operation of the program (in terms of product take-back and administration.)

Such a model could be applied to a propane cylinder stewardship program, particularly where brand owners are few and easily identified. Much like paint, consumers would return their spent cylinders to depots or other collection sites. Propane cylinder brand owners would be responsible for the costs of the program, giving them an incentive to re-design cylinders for less costly management.

This model would result in the same challenge as the 'visible fee' model, in terms of its lack of incentive in encouraging consumers to return their spent cylinders. This issue could be addressed by ensuring that the chosen collection system is convenient to consumers. In addition, this model has advantages over the other two models in that cost internalization could drive innovation and environmental design.

Collection system (cost internalization option)

An internalized fee option would be compatible with all collection systems, including municipal and private depots, retailers, and parks.

Stakeholder roles and responsibilities (cost internalization option)

Stakeholder roles and responsibilities would differ only slightly from a visible fee option, in that financial responsibility for the program would shift from consumers towards producers, or brand owners. Brand owners may choose to pass this cost downstream to consumers. However, the responsibility for this fee would rest with producers.

11. CONCLUSIONS

In order to meet the requirements of safe collection, transportation and disposal of spent single-use propane cylinders, the provinces will need to adopt regulations that will govern the mandatory collection, transportation and disposal program with the co-operation of municipal and federal governments.

There is significant cost incurred in collecting, storing, lab packing, and transporting spent propane cylinders for recycling that is not offset by the value of the recovered steel and propane. As waste collection activities are initiated at the municipal level, it is the municipalities that currently incur the burden of disposing for this product. The concept of EPR should be extended to single-use propane cylinders to reduce the burden upon the municipalities and to encourage recycling.

The retailers of single-use propane cylinders should be integrated into the process of collecting and recycling of the cylinders. The use of retail depots to collect spent propane cylinders has several benefits to the public:

- Collection rates will be increased as the linkage between consumption and disposal is formed by the public,
- Recovered steel and propane will reduce the emission of greenhouse gases and conserve resources, and
- Additional costs that would be imbedded in the cost of a propane cylinder will either depress consumption of the single-use cylinders or encourage the retailers to use their purchasing power on the manufacturers of the cylinders to develop refillable cylinders that are cheaper to recycle.

Additional collection depots at parks and campgrounds may be required to achieve the high recovery rates. These collection depots will assist in reducing the quantity of propane cylinders that enter the residential waste stream and should be funded through the EPR program.

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APPENDIX

The following are the data sets for residual propane measured in used cylinders at the Valley Waste Resource Management Facility and the Otter Lake Waste Management Facility (both in Halifax).

Table 2: Measured residual propane in 465 g capacity single-use propane cylinders, Valley Waste-Resource Management Facility, Halifax

Sample count = 156
Average amount of residual propane = 34.74 g, 7.47% of capacity
Standard deviation (g propane) = 48.69

Total Weight (g)	Empty Weight (g)	Residual Gas (g)	% Residual
459	403	56	12.04
420	403	17	3.66
419	403	16	3.44
467	403	64	13.76
418	403	15	3.23
451	403	48	10.32
520	403	117	25.16
477	403	74	15.91
418	403	15	3.23
433	403	30	6.45
444	403	41	8.82
417	403	14	3.01
420	403	17	3.66
566	403	163	35.05
709	403	306	65.81
411	403	8	1.72
413	403	10	2.15
418	403	15	3.23
437	403	34	7.31
417	403	14	3.01
440	403	37	7.96
411	403	8	1.72
413	403	10	2.15
419	403	16	3.44
414	403	11	2.37
420	403	17	3.66
425	403	22	4.73
427	403	24	5.16
413	403	10	2.15
422	403	19	4.09
446	403	43	9.25
417	403	14	3.01
421	403	18	3.87
412	403	9	1.94
419	403	16	3.44
413	403	10	2.15
423	403	20	4.30

Total Weight (g)	Empty Weight (g)	Residual Gas (g)	% Residual
415	403	12	2.58
416	403	13	2.80
538	403	135	29.03
417	403	14	3.01
442	403	39	8.39
418	403	15	3.23
412	403	9	1.94
412	403	9	1.94
419	403	16	3.44
418	403	15	3.23
437	403	34	7.31
414	403	11	2.37
416	403	13	2.80
413	403	10	2.15
477	403	74	15.91
414	403	11	2.37
455	403	52	11.18
464	403	61	13.12
418	403	15	3.23
423	403	20	4.30
417	403	14	3.01
498	403	95	20.43
418	403	15	3.23
425	403	22	4.73
488	403	85	18.28
446	403	43	9.25
489	403	86	18.49
410	403	7	1.51
429	403	26	5.59
411	403	8	1.72
413	403	10	2.15
414	403	11	2.37
433	403	30	6.45
414	403	11	2.37
418	403	15	3.23
442	403	39	8.39
415	403	12	2.58
413	403	10	2.15
412	403	9	1.94
432	403	29	6.24
418	403	15	3.23
506	403	103	22.15
420	403	17	3.66
410	403	7	1.51
461	403	58	12.47
437	403	34	7.31
410	403	7	1.51
412	403	9	1.94
508	403	105	22.58
459	403	56	12.04
419	403	16	3.44
411	403	8	1.72

Total Weight (g)	Empty Weight (g)	Residual Gas (g)	% Residual
420	403	17	3.66
449	403	46	9.89
771	403	368	79.14
415	403	12	2.58
410	403	7	1.51
414	403	11	2.37
478	403	75	16.13
459	403	56	12.04
413	403	10	2.15
418	403	15	3.23
428	403	25	5.38
418	403	15	3.23
412	403	9	1.94
412	403	9	1.94
418	403	15	3.23
425	403	22	4.73
507	403	104	22.37
613	403	210	45.16
410	403	7	1.51
459	403	56	12.04
412	403	9	1.94
431	403	28	6.02
412	403	9	1.94
579	403	176	37.85
420	403	17	3.66
433	403	30	6.45
413	403	10	2.15
420	403	17	3.66
417	403	14	3.01
437	403	34	7.31
415	403	12	2.58
432	403	29	6.24
416	403	13	2.80
487	403	84	18.06
494	403	91	19.57
464	403	61	13.12
416	403	13	2.80
413	403	10	2.15
413	403	10	2.15
421	403	18	3.87
414	403	11	2.37
423	403	20	4.30
466	403	63	13.55
430	403	27	5.81
420	403	17	3.66
422	403	19	4.09
419	403	16	3.44
418	403	15	3.23
425	403	22	4.73
503	403	100	21.51
415	403	12	2.58
410	403	7	1.51

Total Weight (g)	Empty Weight (g)	Residual Gas (g)	% Residual
419	403	16	3.44
410	403	7	1.51
420	403	17	3.66
417	403	14	3.01
412	403	9	1.94
465	403	62	13.33
489	403	86	18.49
415	403	12	2.58
469	403	66	14.19
411	403	8	1.72
412	403	9	1.94
416	403	13	2.80
412	403	9	1.94
413	403	10	2.15
413	403	10	2.15

Table 3: Residual propane in 465 g capacity single-use propane cylinders, Halifax East District

Sample count = 107
Average amount of residual propane = 21.52 g, 4.63% of capacity
Standard deviation (g propane) = 27.98

Total Weight (g)	Empty Weight (g)	Residual Gas (g)	% Residual
422	403	19	4.09
415	403	12	2.58
470	403	67	14.41
410	403	7	1.51
423	403	20	4.30
418	403	15	3.23
455	403	52	11.18
417	403	14	3.01
411	403	8	1.72
413	403	10	2.15
412	403	9	1.94
410	403	7	1.51
420	403	17	3.66
414	403	11	2.37
415	403	12	2.58
413	403	10	2.15
417	403	14	3.01
413	403	10	2.15
429	403	26	5.59
420	403	17	3.66
469	403	66	14.19
427	403	24	5.16
455	403	52	11.18
413	403	10	2.15
418	403	15	3.23
434	403	31	6.67
418	403	15	3.23

Total Weight (g)	Empty Weight (g)	Residual Gas (g)	% Residual
415	403	12	2.58
415	403	12	2.58
417	403	14	3.01
411	403	8	1.72
415	403	12	2.58
420	403	17	3.66
411	403	8	1.72
421	403	18	3.87
489	403	86	18.49
418	403	15	3.23
411	403	8	1.72
437	403	34	7.31
414	403	11	2.37
413	403	10	2.15
414	403	11	2.37
412	403	9	1.94
433	403	30	6.45
412	403	9	1.94
411	403	8	1.72
412	403	9	1.94
413	403	10	2.15
462	403	59	12.69
417	403	14	3.01
413	403	10	2.15
416	403	13	2.80
414	403	11	2.37
415	403	12	2.58
416	403	13	2.80
411	403	8	1.72
420	403	17	3.66
418	403	15	3.23
465	403	62	13.33
413	403	10	2.15
414	403	11	2.37
457	403	54	11.61
413	403	10	2.15
420	403	17	3.66
411	403	8	1.72
413	403	10	2.15
418	403	15	3.23
410	403	7	1.51
411	403	8	1.72
412	403	9	1.94
421	403	18	3.87
417	403	14	3.01
413	403	10	2.15
411	403	8	1.72
413	403	10	2.15
412	403	9	1.94
419	403	16	3.44
413	403	10	2.15
412	403	9	1.94

Total Weight (g)	Empty Weight (g)	Residual Gas (g)	% Residual
418	403	15	3.23
410	403	7	1.51
411	403	8	1.72
515	403	112	24.09
418	403	15	3.23
413	403	10	2.15
417	403	14	3.01
411	403	8	1.72
425	403	22	4.73
438	403	35	7.53
411	403	8	1.72
418	403	15	3.23
412	403	9	1.94
417	403	14	3.01
490	403	87	18.71
424	403	21	4.52
530	403	127	27.31
422	403	19	4.09
421	403	18	3.87
413	403	10	2.15
411	403	8	1.72
433	403	30	6.45
412	403	9	1.94
417	403	14	3.01
613	403	210	45.16
415	403	12	2.58
414	403	11	2.37
420	403	17	3.66

Table 4: Residual propane in 465 g capacity single-use propane cylinders, Otter Lake Waste Management Facility

Sample count = 52
Average amount of residual propane = 73.88 g, 15.87% of capacity
Stabdard deviation (g propane) = 132.93

Total Weight (g)	Empty Weight (g)	Residual Gas (g)	% Residual
866	403	463	99.57
420	403	17	3.66
414	403	11	2.37
452	403	49	10.54
410	403	7	1.51
418	403	15	3.23
523	403	120	25.81
429	403	26	5.59
413	403	10	2.15
415	403	12	2.58
417	403	14	3.01
418	403	15	3.23
419	403	16	3.44

Total Weight (g)	Empty Weight (g)	Residual Gas (g)	% Residual
414	403	11	2.37
416	403	13	2.80
415	403	12	1.51
411	403	8	1.72
413	403	10	2.15
414	403	11	2.37
426	403	23	4.95
414	403	11	2.37
480	403	77	16.56
418	403	15	3.23
418	403	15	3.23
424	403	21	4.52
483	403	80	17.20
860	403	457	98.28
418	403	15	3.23
414	403	11	2.37
813	403	410	88.17
437	403	34	7.31
422	403	19	4.09
423	403	20	4.30
418	403	15	3.23
410	403	7	1.51
410	403	7	1.51
413	403	10	2.15
464	403	61	13.12
850	403	447	96.13
416	403	13	2.80
860	403	457	98.28
619	403	216	46.45
455	403	52	11.18
432	403	29	6.24
423	403	20	4.30
412	403	9	1.94
690	403	287	61.72
413	403	10	2.15
432	403	29	6.24
416	403	13	2.80
412	403	9	1.94
506	403	103	22.15

Table 5: Residual propane in 400 g capacity single-use torch fuel Mastercraft cylinders, Otter Lake Waste Management Facility

Sample count = 15
Average amount of residual propane = 66.53 g, 16.63% of capacity
Standard deviation (g propane) = 85.55

Total Weight (g)	Empty Weight (g)	Residual Gas (g)	% Residual
492	431	61	15.25
453	431	22	5.50

Total Weight (g)	Empty Weight (g)	Residual Gas (g)	% Residual
448	431	17	4.25
732	431	301	75.25
478	431	47	11.75
452	431	21	5.25
479	431	48	12.00
523	431	92	23.00
472	431	41	10.25
458	431	27	6.75
664	431	233	58.25
441	431	10	2.50
433	431	2	0.50
487	431	56	14.00
451	431	20	5.00

GLOSSARY

Accident -- An undesirable event that result in harm to people, damage to environment, damage to property or loss to process-or a combination of these.

Assessment -- A process that evaluates activities, facilities or systems against requirements of expectations.

BTC -- Board of Transportation Commissioners for Canada.

CRC -- Canadian Railway Commission

CTC -- Canadian Transport Commission.

Cylinder -- a container of cylindrical shape with a water capacity not greater than 454 L designed to withstand an internal pressure greater than 275 kPa.

DOT -- U. S. Department of Transportation

First Aid Injury -- Injury attended to through the use of standard first aid treatment, which no time lost on the job.

Hazard --The potential of machine, equipment, process, material or physical factor in the working environment to cause harm to people, environment, asset or production. For Example, a chemical has the potential to cause adverse effects at various level of exposure.

Housekeeping -- A way of controlling hazards along the path between the source and the worker. Good housekeeping means having no necessary items in the workplace and keeping all necessary items in their proper places. It includes proper cleaning, disposal of wastes, clean up of spills and maintaining clear aisles, exits and work areas.

Human Error -- Human error, which accounts for the majority of incidents, includes not only errors by worker but also error such as engineering deficiencies and lack of adequate organizational control, and poor management systems.

Incident -- An undesired event that results (or could result) in injury to people, damage to the environment or loss of assets and/or production. Definition of incident includes both an actual loss and a near-miss. An incident leading to a loss is most often the result of contact with substance or source of energy (mechanical, electrical, thermal, etc.) above the threshold limit of the body or structure involved or the environment.

Incident Investigation -- Systematically gathering and analyzing information about an incident in order to identify the basic causes and recommend ways to preventing the incident from happening again.

Incident Recall -- A system to encourage employees to report all incidents, including near-miss incidents, in a no fault/no blame atmosphere.

Loss Control or Loss Prevention -- Measure taken to prevent and reduce loss through injury and illness, property damage, poor work quality, etc.

Medical Aid Injury -- An injury that is attended to by a medical doctor but is minor enough to allow the injured person to return to the job on the day of injury.

Near Miss -- An incident that could have resulted in a loss, but did not.

Non-refillable Container --A container that can be filled only once for the transportation of dangerous good.

Personal Protective Equipment -- Any device worn by a worker to protect against hazards; for example, dust masks, gloves, earplugs, hard hats and safety goggles.

Pressure Relief Device -- A device intended to rupture of a container in the event of accidental overpressure or expose to fire.

Procedures -- Step-by-step description of safe and efficient approaches to tasks, jobs or activities.

Process -- Any activity involving the production, manufacture, use, storage or movement of potentially hazardous materials.

Propane -- Bottled gas, dimethylmetthane, EEC No. 601-003-00-5; Liquefied Petroleum Gas; n-Propane; Propyl Hydrate; Propyl Hydride; RTECS. No. TX 2275000

Risk -- A function of the probability of an unwanted incident and the potential severity of its consequences.

Risk Analysis -- The use of available information to estimate the risk of a hazard- to individuals or populations, property or the environment. Risk analyses generally contain the following steps: scope definition, hazard identification, probability analysis, consequence analysis and risk estimation.

Risk Assessment -- The complete process of understanding risk, assessing risk and making decisions about implementing effective risk controls.

Risk Assessment -- The process of risk analysis and risk evaluation.

Risk Control -- The process of making decisions about managing risk, and implementing, enforcing and re-evaluating the effectiveness of those decisions from time to time.

Risk Evaluation -- The stage at which values and judgements enter the decision-making process, explicitly or implicitly. A range of alternatives for managing risk is identified by considering the importance of the estimated risks and the social, environmental and economic consequences.

TC -- Transport Canada.

TC-39M Containers – TC-39 M cylinders are non-refillable, seamless or welded carbon steel or aluminium, or brazed carbon steel spheres or cylinders. For service pressure up to 3.5 MPa (507 Psig) the maximum capacity shall be 25 L of water. For service pressure greater than 3.5 MPa the maximum capacity shall be 4.54 L of Water. The service pressure shall not exceed 80% of the rest pressure.

Wall Thickness – the actual minimum wall thickness of a container shall not be less than the design wall thickness and shall not include galvanized or any other protective coating. The minimum design wall thickness shall be calculated as follows using **Equation 1** and **Equation 2**.

(a) For cylinders and tubes:

$t = \frac{D}{2}\left(1 - \sqrt{\frac{S - 1.3P}{S + 0.4P}}\right)$	Equation 1

(b) For Spheres

$t = \frac{PD}{4SE}$	Equation 2

Where

t = Maximum design wall thickness (mm).
S = Maximum Design wall stress in accordance with each specification, MPa.
D = Outside diameter
P = Specified test pressure MPa.
E = Joint confidence factor of longitudinal seam.