TP 14013E

DEVELOPMENT OF SAFETY STANDARDS FOR COMPRESSED GAS VEHICLE FUEL SYSTEMS

Prepared for:

Transportation Development Centre
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Prepared by:

Powertech Labs Inc.
12388 88th Avenue
Surrey, B.C.
V3W 7R7

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Craig Webster
Powertech Labs Inc.
12388 88th Avenue
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16. Abstract

Professional staff from Powertech Labs Inc. and Charonic Canada Inc. participated in Canadian Standards Association (CSA) and International Organization for Standardization (ISO) standards committees to support the development of standards covering compressed gas vehicle fuel systems and the supporting fuelling infrastructure. The purpose of the involvement was to ensure safety in a relatively new vehicle industry, and to allow for the introduction of new compressed gas fuel system technologies developed by Canadian industries.

Revisions were performed on the following CSA standards:

- CSA B51 for natural gas vehicle and station cylinder requirements
- CSA B108 for natural gas vehicle filling station installations
- CSA B339 & B340 codes for high pressure cylinders used in transportation of dangerous goods applications

Assistance was also provided in the development of the following draft ISO standards:

- ISO TC 22/SC 25 for CNG vehicle fuel system components
- ISO TC 58/SC 4/WG 2 for the acoustic emission testing of steel cylinders
- ISO TC 58/SC 4/WG 3 for the in-service inspection of CNG fuel tanks
- ISO CD 15869 for hydrogen vehicle storage tanks
- ISO TC 58/WG 7 for materials compatibility with high pressure hydrogen
- ISO/DIS 11119 for high pressure composite-wrapped cylinders used in transportation applications

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16. Résumé

Le personnel technique de Powertech Labs Inc. et de Charonic Canada Inc. a participé à des comités de l'Association canadienne de normalisation (CSA) et de l'Organisation internationale de normalisation en appui au développement de normes visant les systèmes d'alimentation des véhicules fonctionnant au gaz naturel et l'infrastructure de ravitaillement. Cette collaboration avait pour but d'assurer l'adoption de règles de sécurité adéquates dans une industrie relativement jeune et de permettre l'utilisation de nouvelles technologies développées par des industries canadiennes et destinées aux systèmes d'alimentation en gaz comprimé.

Des révisions ont été apportées aux normes CSA suivantes :

- CSA B51, sur les bouteilles à bord des véhicules fonctionnant au gaz naturel et dans les postes de ravitaillement.
- CSA B108, sur les installations des postes de ravitaillement des véhicules au gaz naturel.
- CSA B339 et B340, sur les codes régissant les bouteilles à haute pression utilisées pour le transport des matières dangereuses.

Les deux entreprises ont également prêté leur aide à la rédaction des projets de normes ISO suivantes :

- ISO TC 22/SC 25, sur les composants pour véhicules routiers fonctionnant au gaz naturel comprimé.
- ISO TC 58/SC 4/WG 2, sur la vérification des bouteilles en acier, au moyen d'émissions acoustiques.
- ISO TC 58/SC 4/WG 3, sur les méthodes d'inspection en service des réservoirs de gaz naturel.
- ISO CD 15869, sur les réservoirs d'hydrogène pour véhicules terrestres.
- ISO TC 58/WG 7, sur la compatibilité entre les matériaux et l'hydrogène haute pression.
- ISO/DIS 11119, sur les bouteilles de gaz en matériau composite, bobinées, pour le transport de gaz haute pression.

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SUMMARY

Canada is a world leader in the development of advanced products for compressed natural gas and hydrogen-fuelled vehicles. Standards covering compressed gas fuel systems and the fuelling infrastructure are under development at both the Canadian Standards Association (CSA) and International Organization for Standardization (ISO) levels. These standards can affect the safety and economic viability of alternatively fuelled vehicles. They can also affect the ability of Canadian industries to compete by preventing the introduction of new technologies. Powertech Labs Inc. and Charonic Canada Inc. participated in relevant standards meetings to protect Canadian interests while ensuring adequate safety was maintained. The standards that were involved, and their status at the time of this report, are as follows:

- ISO TC 58/SC 3/WG 11 (ISO/DIS 11119): Composite Cylinders for Transportation Uses
  - Approved as an ISO standard.
- CSA B339/B340 - Technical Committee on Cylinders for Transportation of Dangerous Goods
  - Changes to existing standard approved with comments (to be resolved).
- ISO TC 58/SC 4/WG 2: Acoustic Emission Requalification of Steel Tube Trailer Units
  - Approved as an ISO standard.
- ISO TC 58/SC 4/WG 3: Inspection and Requalification of Natural Gas Vehicle Cylinders
  - Submitted for committee vote as a Draft International Standard.
- ISO TC 197/WG 6 (ISO/CD 15869): Compressed Hydrogen Vehicle Tanks
  - Submitted for committee vote as a Draft International Standard.
- ISO TC 22/SC 25: Road Vehicles Using Natural Gas
  - Submitted for international vote as an International Standard.
- CSA B51 - Cylinders and Pressure Vessels Used for Natural Gas Vehicles and Stations
  - Revisions to existing standard to be published in 2002.
- CSA B108 - CNG Vehicle Fuelling Station Installation Code
  - Changes to existing standard approved and to be published in 2003.
- ISO TC 58/WG 7 (ISO/DIS 11114-4): Selecting Metallic Materials Resistant to Hydrogen Embrittlement
  - Submitted for committee vote as a Draft International Standard.

SOMMAIRE

Le Canada est un leader mondial dans le développement de produits très élaborés destinés aux véhicules fonctionnant au gaz naturel ou à l'hydrogène comprimés. Des normes visant les systèmes d'alimentation en gaz comprimé ainsi que l'infrastructure de ravitaillement sont en voie d'élaboration à l'Association canadienne de normalisation (CSA) et à l'Organisation internationale de normalisation (ISO). Ces normes peuvent avoir des incidences sur la sécurité et sur la viabilité économique des véhicules à carburant de substitution. De plus, si ces normes empêchent l'introduction de nouvelles technologies, elles peuvent également influer sur la compétitivité des industries canadiennes. Les entreprises Powertech Labs Inc. et Charonic Canada Inc. ont participé à des réunions concernant les normes pertinentes afin de protéger les intérêts canadiens tout en s'assurant qu'un niveau adéquat de sécurité pourra être maintenu. Voici une liste des normes à l'étude et leur statut au moment de publier le présent rapport :

- ISO TC 58/SC 3/WG 11 (ISO/DIS 11119) : Bouteilles de gaz en matériau composite pour le transport.
  - Norme ISO approuvée.
- CSA B339/B340 – Comité technique des bouteilles pour le transport des matières dangereuses.
  - Changements à la norme existante approuvés, avec commentaires (points à régler).
- ISO TC 58/SC 4/WG 2 : Requalification par émissions acoustiques des remorques-citernes tubulaires en acier.
  - Norme ISO approuvée.
- ISO TC 58/SC 4/WG 3 : Inspection et de requalification des réservoirs à combustible des véhicules fonctionnant au gaz naturel.
  - Soumise au comité en tant que projet de Norme internationale.
- ISO TC 197/WG 6 (ISO/CD 15869) : Réservoirs d'hydrogène pour véhicules terrestres.
  - Soumise au comité en tant que projet de Norme internationale.
- ISO TC 22/SC 25 : Véhicules routiers fonctionnant au gaz naturel.
  - Soumise au comité international en tant que Norme internationale.
- CSA B51 – Norme portant sur les bouteilles à bord des véhicules et dans les postes de ravitaillement.
  - Les révisions à la norme existante devaient être publiées en 2002.
- CSA B108 - Centres de ravitaillement des véhicules au gaz naturel : Code d'installation.
  - Les modifications à la norme existante ont été approuvées et seront publiées en 2003.
- ISO TC 58/WG 7 (ISO/DIS 11114-4) : Sélection de matériaux métalliques résistant à l'action de l'hydrogène.
  - Soumise au comité en tant que projet de Norme internationale.

TABLE OF CONTENTS

LIST OF TABLES

1.0 INTRODUCTION

Canada is a world leader in the development of advanced products for compressed natural gas (CNG) and hydrogen-fuelled vehicles. Examples of Canadian technologies include the Dynetek lightweight storage cylinders, Ballard fuel cells, and the Fuelmaker vehicle refuelling appliances. Compressed gas is becoming recognized as a large-scale vehicle fuel of the future. For example, there are an increasing number of automobile manufacturers producing dedicated compressed natural gas vehicles. Similarly, compressed hydrogen is becoming the fuel of choice for hydrogen-powered vehicles. For example, the Michelin Bibendum car rally in October 2001 featured 16 hydrogen-powered vehicles, of which 13 operated on compressed hydrogen fuel systems.

The properties of CNG and compressed hydrogen are very similar, thus product and standards developments in one market tends to benefit both industries. Active participation in the development of standards for compressed natural gas and compressed hydrogen vehicles is necessary to protect Canadian industrial interests, and to improve the world market by allowing the introduction of new technologies that encourage the adoption of alternative fuels. While standards are necessary to permit the uniform and safe development of an industry, excessive limitations or unnecessary requirements can severely affect the economics of an industry by preventing the use of new technologies.

Standards covering various aspects of compressed hydrogen and CNG fuel systems used to fuel automotive vehicles are currently under development in Canada and internationally. These standards apply to high pressure vehicle fuel systems, high pressure filling stations, transportation systems, and inspection methods. Canada has a financial and environmental interest in the safe and successful application of compressed gas fuel systems for alternative fuel vehicles.

The Canadian Standards Association (CSA) has proven to be a useful vehicle for introducing advances in compressed gas fuel system technologies to the world. As a world leader in CNG and compressed hydrogen fuel system technologies, Canada often initiates the development of new technologies for improving the safety or economics of compressed gas fuels. These advances in high pressure technologies can often first be incorporated into CSA standards. These changes to the CSA standards can then be used as a proven basis for introducing changes at the International Organization for Standardization (ISO) level. Similarly, Canada generally has a policy of adopting ISO standards or United Nations regulations (that typically reference ISO standards) where possible.

Both Powertech Labs and Charonic Canada participated in CSA committees and ISO working groups that were involved in the revision or development of standards involving compressed gas fuel systems for alternative fuel vehicles. This report describes the status of each standard at the start of this reporting period, and the results achieved during the reporting period. Copies of the CSA standards described in this report can be obtained from the Canadian Standards Association. Copies of the ISO standards can be obtained from the International Organization for Standardization. Copies of draft ISO standards can be obtained from the conveners of the relevant ISO working groups.

2.0 STANDARDS ACTIVITIES

2.1 ISO TC 58/SC 3/WG 11 (ISO/DIS 11119): Composite Cylinders For Transportation Uses

2.1.1 Background

The ISO draft international standard (ISO/DIS) 11119 standard covers the design of transportable fibre-reinforced plastic (FRP) composite-wrapped compressed gas cylinders for industrial and medical uses. In Canada, the transportation of compressed gases, including natural gas and hydrogen, using lightweight composite pressure vessels is regulated by Transport Canada using the CSA B339 and 340 standards. The CSA B340 standard covers the selection and use of pressure vessels for transporting dangerous goods, while the CSA B339 standard details the design, construction and testing of these pressure vessel types. The CSA B339 and B340 standards are therefore vital in determining the economics of transporting compressed gas fuel to vehicle filling stations.

The Transport Dangerous Goods Directorate of Transport Canada has indicated that this future ISO 11119 standard will be used as the basis for updating portions of the CSA B339 standard. The test methods and design requirements developed in the ISO 11119 standard for composite cylinders will therefore have a direct effect on the economics and safety of transporting compressed gas fuel in Canada.

Pending the approval and adoption of the ISO 11119 standard, the CSA B339 and B340 standards required some immediate changes to allow the compressed gas fuel industry to progress. For example, the CSA B340 standard did not allow CNG or hydrogen to be transported in specification TC-3FCM cylinder designs, and the CSA B339 standard does not cover the use of carbon fibre-reinforced cylinders. Cylinders that comply with this TC-3FCM design specification, such as those manufactured by Dynetek in Canada, have been safely used for over 10 years to carry compressed natural gas as an engine fuel on-board vehicles, and to safely transport compressed hydrogen as a vehicle fuel since 1995.

2.1.2 Status of the Standards

The development of the ISO/DIS 11119 standard was delayed due to technical disagreements primarily involving the fibre stress ratios and cylinder burst pressures to be used for different designs.

The CSA B339 and B340 standards are in the process of undergoing the mandatory 5-year review.

2.1.3 Progress Achieved

Powertech attended a special meeting of ISO TC 58 SC 3 on gas cylinders held in London, England, in June 2000 to resolve differences of opinion regarding the technical requirements in the proposed ISO 11119 standard for composite-wrapped compressed gas cylinders. It was found necessary to hold a second meeting in Clearwater, Florida, in November 2000. Following both meetings, most differences in opinion regarding the fibre stress ratios and the performance test requirements for composite cylinder designs were resolved. As a result, the ISO/DIS 11119 document was submitted in 3 parts for international voting to become an ISO standard.

A meeting of the Technical Committee on Cylinders for Transportation of Dangerous Goods (CSA B339/B340) was held in Toronto, Ontario, on March 19/20, 2001, for the purpose of considering revisions to the standards. At the meeting Charonic presented data to support changing the B340 standard to include a definition of the composition of CNG, thereby allowing it to be transported. This change has been accepted and incorporated into the revised draft.

At the same meeting, Powertech raised the issue of including the use of carbon fibre as a reinforcement material. As a result, a working group (WG) has been formed, with Powertech as the chair, to recommend an approach for introducing carbon fibre into the CSA B339 standard. Powertech has also introduced the need to include the transportation of compressed hydrogen in Type TC-3FCM designs. Both issues will be addressed at the next meeting of CSA B339/B340 in Ottawa, Ontario, in October 2002.

2.2 ISO TC 58/SC 4/WG 2: Acoustic Emission Requalification Of Steel Tube Trailer Units

2.2.1 Background

This ISO working group is concerned with standardizing a non-destructive test method for the periodic reinspection of the steel tubes used on trailers for transporting compressed gases, including natural gas and hydrogen. Currently tube trailers must be disassembled every five years for hydrostatic proof testing. This method would allow the tubes to be inspected in-situ every five years, a significant cost savings. In addition, a non-destructive test method would be preferable to hydrostatic testing, since the latter method has limited ability to detect the presence of growing cracks.

Transport Canada has already issued several permits for equivalent safety to users of acoustic emission (AE) methods to reinspect tubes at hydrostatic test pressure. However, there is currently no standard in Canada or the U.S. covering this inspection method. An ISO standard for the AE inspection of gas cylinders would likely be adopted in Canada as a CSA standard.

Powertech has considerable experience in performing the acoustic emission testing of vehicle fuel cylinders of steel and of composite construction.

2.2.2 Status of the Standard

The ISO working group was in the process of defining the inspection requirements for using acoustic emission on compressed gas cylinders and tubes.

2.2.3 Progress Achieved:

Powertech Labs attended a meeting of the acoustic emission working group in Clearwater, Florida, in November 2000. Originally, the working group was investigating the standardization of an acoustic emission test method for both steel and composite-wrapped pressure vessels. However, this work was limited to steel pressure vessels when it was determined that insufficient data was available to validate an AE method for composites.

The procedures for performing acoustic emission tests on steel tube trailers were finalized at the meeting, and the ISO document was submitted for international voting as an ISO standard.

2.3 ISO TC 58/SC 4/WG 3: Inspection And Requalification Of NGV Cylinders

2.3.1 Background

It has been determined that CNG fuel cylinder failures can largely be prevented by performing a periodic visual inspection of the external surfaces for damage. Currently, the natural gas vehicle (NGV) industry relies on the use of U.S. standards written primarily for the reinspection of specific industrial cylinder designs. These U.S. standards include the Compressed Gas Association (CGA) pamphlets C-6.1 and C-6.2 for metal cylinders, and CGA C-6.4 for composite cylinders.

This ISO working group was established to define the visual reinspection requirements specifically for NGV fuel cylinders. The inspection requirements are largely based on visual inspection of the exterior condition of cylinders. All failures of CNG cylinders manufactured to NGV standards have originated in the exterior surface, either due to mechanically induced damage or corrosion mechanisms. The rejection criteria were therefore based on the length and depth of defects in the cylinder surface. Inspections will preferentially be performed with the cylinders remaining installed on-board the vehicles – experience has shown that removal of the cylinders for inspection is far more likely to cause damage and create future gas leaks by tampering with connections.

An ISO standard would be adopted in Canada as a Canadian Gas Association code to replace the use of the CGA pamphlets.

2.3.2 Status of the Standard

The standard was generally based on the CGA C-6.4 pamphlet, along with input from various working group members worldwide. A draft outline was available, but critical questions remained regarding the extent of the inspections.

2.3.3 Progress Achieved

Powertech Labs attended a meeting of the working group in Clearwater, Florida, in November 2000. At that meeting the inspection requirements for CNG cylinders were largely finalized. Powertech provided the working group with a rationale document justifying the fact that internal CNG cylinder inspections were not required. The document provided a summary of corrosion studies performed using CNG on cylinders, and the results of internal CNG cylinder inspections performed worldwide. In addition, Powertech provided the working group with a report to justify the absence of any need to inspect under mounting brackets for damage. The report detailed the results of tests that demonstrated how any damage hidden under mounting brackets of up to 50 mm width would have to become visible outside of the brackets to affect the life of the cylinders.

The working group document has now been circulated for committee voting to advance the committee draft (CD) to the status of draft international standard (DIS).

2.4 ISO TC 197/WG 6 (ISO/CD 15869): Compressed Hydrogen Vehicle Tanks

2.4.1 Background

Powertech Labs is the convener of this ISO working group. The objective is to develop a fuel tank standard for fuel cell vehicles that require compressed hydrogen storage. There is no standard in Canada or anywhere in the world that covers this application of hydrogen storage as a vehicle fuel. The development of the ISO standard for compressed hydrogen fuel cylinders would be adopted in Canada as a part of the CSA B51 standard that currently defines the requirements for compressed natural gas fuel cylinders. The hydrogen tank standard was being developed based on the ISO 11439 standard for compressed natural gas vehicle fuel cylinders.

2.4.2 Status of the Standard:

A CD had been prepared and circulated for review by the working group members. However, work was delayed pending the resolution of a jurisdictional issue regarding whether the working group should be under TC 197 for hydrogen technologies, or under TC 58 for pressure vessels. The problem was subsequently resolved by the ISO Central Secretariat through the creation of a joint working group between the 2 Technical Committees.

2.4.3 Progress Achieved

The first meeting of the joint Working Group was held in Munich, Germany, in September 2000. Comments from working group members on the Committee Draft were reviewed. As a result of the meeting in September, ISO CD 15869 was submitted for international voting to advance to the DIS status.

2.5 ISO TC 22/SC 25/WG 3 (ISO/DIS 15500): Road Vehicles – Compressed Natural Gas Fuel System Components

2.5.1 Background:

Current Canadian standards for NGV components (i.e. valves, refueling connectors, pressure relief devices, regulators, etc.) and CNG on-board installations are outdated. In-service experience with CNG vehicles has identified the need for numerous changes to component requirements to improve safety and to allow for the development of new technologies. ISO is in the process of developing new standards for CNG road vehicles, thus providing an opportunity to eliminate the need to duplicate this effort in Canada. The following CSA and CGA standards used in Canada would be replaced by the corresponding ISO standards:

CGA NGV1	=	SC 25/WG 1 - CNG Refueling Connectors
CSA B149.4	=	SC 25/WG 2 - CNG Fuelling System Safety Requirements
CGA 12.3	=	SC 25/WG 3 - CNG Fuel System Components

2.5.2 Status of the Standards

All three standards were at the DIS stage, with a review of comments on the DIS versions still to be performed before the draft international standards were circulated for final balloting.

2.5.3 Progress Achieved

Powertech Labs attended its first meeting of ISO TC 22/SC 25 in Sidney, Australia, in March 2000. This timing was fortunate, because this meeting turned out to be the final meeting of these three working groups. At the meeting Powertech was able to influence the performance test requirements to address issues that were experienced in Canada. All major remaining issues were resolved at the meeting and the draft standards were submitted for international voting to become ISO standards.

2.6 CSA B51: Compressed Natural Gas (CNG) Vehicle & Ground Storage Cylinders

2.6.1 Background

Part 2 of the CSA B51 standard covers CNG cylinder design for vehicles, and Part 3 of the CSA B51 standard covers ground storage for CNG filling stations. The standard periodically requires updating to keep it consistant with the U.S. ANSI/CSA NGV2 and ISO 11439 standards for CNG vehicle fuel cylinders.

The CSA B51 standard also provides a convenient platform to address the use of vehicle tanks in compressed hydrogen service. The regulatory authority in British Columbia is already involved in providing temporary registration to hydrogen tank designs for use in Canada. This authority has indicated that it requires as soon as possible the inclusion of hydrogen tank requirements in a standard to provide it with the basis to continue to provide design registrations. The requirements for hydrogen tanks will be dependent to a large extent on the requirements finalized in the draft ISO 15869 standard for hydrogen tanks (see section 2.4).

As a result of a new code requirement for the indoor refuelling of CNG vehicles, and the recent reformatting of the B109 code for natural gas vehicle installations, it was recognized by Charonic that the CSA B108 Natural Gas Fuelling Stations Installation Code similarly required revision to simplify the format and address the need for specifying maintenance requirements.

2.6.2 Status of the Standards

The CSA B51 standard was last published in 1997. It is due for formal review in 2002.

The CSA B108 code was last published in 1999. Revisions could be published in a 2002 edition.

2.6.3 Progress Achieved

There was no formal activity on the CSA B51 standard during the contract period. However, changes are in progress for the 2002 review, including the addition of materials and performance requirements for compressed hydrogen vehicle tanks. This addition would make Canada the first country in the world to have a standard covering the use of hydrogen as a vehicle fuel.

The CSA B108 Natural Gas Fuelling Stations Installation Code was revised and reformatted in its entirety by Charonic Canada. The revised draft was submitted to the B108 committee. The committee accepted the draft reformat and the inclusion of a section on general maintenance requirements.

2.7 ISO TC 58/WG 7 (ISO/CD 11114-4): Selecting Metallic Materials Resistant To Hydrogen Embrittlement

2.7.1 Background

This working group is investigating test methods that can be used to evaluate a materials resistance to hydrogen embrittlement. These test methods would become part of the ISO 11114 standard (Part 4) "Compatibility of cylinders and valves materials with gas contents, Transportable gas cylinders". This information would be used to determine materials that would be resistant to embrittlement when used in compressed hydrogen fuel systems for vehicles. This standard would become an important component of ISO/CD 15869 on hydrogen vehicle storage tanks (see section 2.4).

2.7.2 Status of the Standard

The working group has only been active for about one year. A CD has been prepared, covering several test methods. One test involves a comparative approach, exposing metallic disks of the material under consideration to constant pressurization to failure using hydrogen and an inert gas. The other test is based on fracture mechanics principles, where compact tension specimens machined from the material of interest are placed under stress and exposed to hydrogen.

2.7.3 Progress Achieved

Literature from previous working group meetings was reviewed by Powertech and input provided. The results of round robin hydrogen embrittlement tests using a proposed fracture mechanics test method and conducted at Powertech were also provided. No meetings were attended during the reporting period due to scheduling conflicts. The working group has a CD approved and is now proceeding to international balloting as a DIS.

3.0 STATUS OF STANDARDS ACTIVITIES IN CANADA

In Canada, standards committees are typically composed of representatives from multiple disciplines, including industry, regulatory agencies, and research agencies. As a result, there is a balance of opinions that tends to moderate against domination of the standard by any particular industry member. However, many CNG and hydrogen vehicle standards in Canada are based on standards that have been developed previously in the U.S. and by ISO. Unfortunately, unlike Canada, these other standards groups do not require a balance in membership. As a result, industry members will often dominate committees and, in some cases, attempt to benefit from the lack of balanced representation by introducing requirements into standards that favour their own products. Since Canada is a world leader in the use of innovative materials and designs for compressed gas fuel systems, it is important that Canadian interests are represented on these international committees to ensure that provisions are made in standards to allow for the introduction of new technologies.

Over the past 20 years, CNG standards in Canada have become well established. However, the CNG operating experience gathered over the past 20 years has identified areas where changes could be made to standards to improve the economics of the industry. Examples of improvements include the following:

- Using vehicle storage cylinders for ground storage at filling stations.
- Eliminating the five year hydrostatic retesting of steel cylinders in ground storage service by allowing the use of ultrasonic scanning for 15 year recertification.
- Reducing the pressure cycle requirements of vehicle cylinders.
- Allowing the use of alternative inspection techniques for the periodic inspection of cylinders used in the large-scale transportation of compressed gas fuel.
- Allowing the use of higher strength materials for cylinder construction.

For hydrogen vehicles, hydrogen filling stations, and hydrogen transportation systems, there are currently no standards in existence anywhere in the world. The largest impediment to the development of a hydrogen vehicle industry would be if regulatory agencies began to adopt existing industrial hydrogen standards for vehicle applications. This approach initially occurred in the CNG industry, with sometimes disastrous results. It is therefore necessary for the hydrogen vehicle industry to be based on the experiences and standards associated with the CNG industry.

Standards relevant to the hydrogen vehicle industry are being developed primarily on an international level. However, the international standards process is necessarily slow, since a wide variety of diverse opinions and service conditions must be considered. Ultimately, these international standards will be adopted into standards and regulations in Canada. The problem with this approach is that there will be a considerable time delay before hydrogen vehicles can be introduced in Canada.

To maintain Canada's lead in the development of a hydrogen vehicle industry, it is necessary to introduce standards in Canada and not wait for international developments. This will allow

Canadian hydrogen technologies to develop in advance of competitors. In the future, the Canadian standards can be harmonized with the international standards as they become available. Extensive testing on hydrogen fuel systems has demonstrated a remarkable similarity in performance with CNG fuel systems. As a result, it should be a relatively simple process to adapt Canadian CNG standards to include hydrogen fuel applications.

4.0 REGISTERED CSA B51 VEHICLE CYLINDER DESIGNS

Table 1 summarizes the cylinder designs that have been registered by various provincial governments in Canada in accordance with the CSA B51 (Part 2) standard**.** The list only includes cylinder models that are still available from manufacturers.

Table 1: Registered CSA B51 Cylinder Designs

Manufacturer	Design Type	Pressure (bar)	Diameter (mm)	Length (mm)
Faber Industrie (Model 156L)	Type 1 steel	250	406	1524
Faber Industrie (Model 121L)	Type 1 steel	250	406	1220
Faber Industrie (Model 109L)	Type 1 steel	250	305	1829
Faber Industrie (Model 58L)	Type 1 steel	250	363	762
Faber Industrie (Model 63L)	Type 1 steel	250	363	813
Faber Industrie (Model 76L)	Type 2 glass hoop-wrapped steel	250	330	1219
Faber Industrie (Model 99L)	Type 2 glass hoop-wrapped steel	250	330	1524
Faber Industrie (Model 62L)	Type 1 steel	250	370	800
Faber Industrie (Model 152L)	Type 1 steel	250	406	1486
Pressed Steel Tank (Model CE1661C)	Type 2 carbon hoop-wrapped steel	250	414	1543
Pressed Steel Tank (Model CE1150C)	Type 2 glass hoop-wrapped steel	250	286	1270
Pressed Steel Tank (Model CE1235C)	Type 2 glass hoop-wrapped steel	250	298	883
Pressed Steel Tank (Model CE1053C)	Type 2 glass hoop-wrapped steel	250	262	1346
Pressed Steel Tank (Model 8FR38)	Type 2 glass hoop-wrapped steel	200	222	962
Pressed Steel Tank (Model 10FR37.5)	Type 2 glass hoop-wrapped steel	200	261	949
SCI	Type 2 glass hoop-wrapped steel	250	305	889 - 2133
SCI (Model ALT788)	Type 3 glass fully-wrapped aluminum	200	387	2547
SCI (Model ALT701)	Type 3 glass fully-wrapped aluminum	200	390	1947
SCI (Model ALT703)	Type 3 glass fully-wrapped aluminum	200	403	2548
SCI (Model ALT576)	Type 3 glass fully-wrapped aluminum	200	272	991

Manufacturer	Design Type	Pressure (bar)	Diameter (mm)	Length (mm)
Dynetek Industries (Model L033)	Type 3 carbon fully-wrapped aluminum	250	274	795
Dynetek Industries (Model Q120)	Type 3 carbon fully-wrapped aluminum	250	328	1840
Dynetek Industries (Model W224)	Type 3 carbon fully-wrapped aluminum	200	402	2184
Dynetek Industries (Model Q54)	Type 3 carbon fully-wrapped aluminum	200	327	905
Dynetek Industries (Model W320)	Type 3 carbon fully-wrapped aluminum	250	404	3048
Dynetek Industries (Model V174)	Type 3 carbon fully-wrapped aluminum	200	384	1944
Dynetek Industries (Model W205)	Type 3 carbon fully-wrapped aluminum	250	408	2110
Dynetek Industries (Model W076)	Type 3 carbon fully-wrapped aluminum	200	402	864
Dynetek Industries (Model W150)	Type 3 carbon fully-wrapped aluminum	350	413	1534
Dynetek Industries (Model ZM180)	Type 3 carbon fully-wrapped aluminum	350	602	972
Dynetek Industries (Model V260)	Type 3 carbon fully-wrapped aluminum	200	387	2800
Dynetek Industries (Model Z137)	Type 3 carbon fully-wrapped aluminum	250	520	946
Dynetek Industries (Model L035)	Type 3 carbon fully-wrapped aluminum	350	280	906
Dynetek Industries (Model V074)	Type 3 carbon fully-wrapped aluminum	350	399	900
Dynetek Industries (Model W205)	Type 3 carbon fully-wrapped aluminum	350	416	2110
Dynetek Industries (Model G021)	Type 3 carbon fully-wrapped aluminum	250	225	860
Lincoln Composites (Model RB36A18)	Type 4 hybrid fully-wrapped plastic	250	467	3048
Lincoln Composites (Model RB36A16)	Type 4 hybrid fully-wrapped plastic	250	404	3048

5.0 RECOMMENDATIONS

Canada should continue to actively participate in the development of national and international standards for CNG and hydrogen-fuelled vehicles. In addition to the primary benefit of ensuring road safety, participation in standards development should be for the purpose of introducing technological advances that would improve the economics of purchasing and operating CNG and hydrogen-fuelled vehicles.