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POWERED ADAPTIVE DRIVING CONTROLS

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Prepared By
Shawn Watson
T E S Limited

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Un sommaire en français de ce rapport est inclus avant la table des matières.

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16. Abstract

TES Limited was contracted by the Transportation Development Centre to review the need for a recognized standard or guideline in Canada to ensure that powered adaptive driving controls are designed, manufactured and installed in a safe manner and function according to or exceeding original equipment manufacturer (OEM) specifications.

Two types of powered controls were examined: servo-type controls and reduced effort controls. The powered adaptive controls in common use were determined through a survey of rehabilitation centres and mobility equipment dealer/installers across Canada. The powered adaptive controls commonly prescribed and installed were further reviewed to determine the features and utility provided to a driver with a disability and the vehicle modifications required to install the adaptive controls. An evaluation of the safety of the vehicle modifications was also conducted.

In addition to reviewing several existing standards and guidelines, the report incorporates a review of the extensive work conducted by the Society of Automotive Engineers (SAE), Adaptive Devices Committee. The Adaptive Devices Committee has developed six directly related Recommended Practice and Recommended Test Procedure documents currently in draft form. The draft SAE documents were reviewed for applicable content and the level of development of the available draft documents to determine whether they could be adopted directly as a standard or form a basis for initiating a Canadian standard.

The report concludes with a discussion of the need for a powered adaptive controls standard and the options available for implementing a standard nationwide. The advantages and disadvantages associated with each option are also presented.

The appendices of the report contain a description of the powered adaptive control products reviewed during the research study.

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16. Résumé

Le Centre de développement des transports a confié à TES Limited un marché qui consiste à examiner la nécessité, au Canada, de disposer d'une norme ou d'une ligne directrice reconnue pour veiller à ce que la conception, la fabrication et l'installation des commandes de véhicules adaptés respectent les règles de sécurité et que celles-ci fonctionnent conformément aux spécifications du constructeur du véhicule.

Deux types de commandes ont été examinées : les servocommandes et les commandes à effort faible. Un sondage effectué auprès des centres de réadaptation et des équipementiers canadiens a permis de dresser la liste des commandes les plus couramment utilisées pour l'adaptation des véhicules. Un examen approfondi des aides à la conduite ainsi recensées a permis de déterminer les caractéristiques de celles-ci et leur degré d'utilité pour un conducteur ayant une incapacité, ainsi que les modifications nécessaires pour doter de ces aides un véhicule de série. Les chercheurs ont également évalué la sûreté des modifications apportées au véhicule.

Outre l'examen des normes et lignes directrices en vigueur, le rapport fait le survol d'importants travaux réalisés par le Comité des aides techniques de la Society of Automotive Engineers (SAE), qui ont mené à des ébauches de pratiques et procédures d'essai recommandées. Le but des chercheurs était d'établir la pertinence de ces documents, de même que l'opportunité, compte tenu de leur degré d'achèvement, de les adopter tels quels en tant que norme ou de s'en servir comme base pour la rédaction d'une norme canadienne.

Le rapport expose finalement les motifs qui rendent nécessaire une norme sur les commandes de véhicules adaptés et les diverses options qui s'offrent pour la mise en oeuvre d'une norme pancanadienne. Les avantages et les inconvénients associés à chaque option sont présentés.

On trouvera, en annexe au rapport, une description des commandes de véhicules adaptés étudiées.

17. Mots clés	18. Diffusion
Commandes de véhicules adaptés, commandes à effort faible, servocommandes, normes, lignes directrices, modifications de véhicule	Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

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Summary

In recent years, technological advances have introduced automotive adaptive devices which either reduce the physical effort required to control and/or operate a vehicle or alter the way in which driver control initiatives are applied to the vehicle control systems. These adaptive devices provide the possibility of driving a vehicle for many drivers with disabilities.

This report is a review of the need for a recognized standard or guideline in Canada to ensure powered adaptive controls installed in automobiles are designed, manufactured and installed in a safe manner and function according to or exceed original equipment manufacturer (OEM) specifications. Although great strides have been made by mobility equipment dealers and manufacturers of these types of products, the performance and safety of these assistive devices are not currently regulated by a Canadian standard or guideline.

The report describes a study of two types of automotive adaptive controls, those that provide an external source of power to actuate existing vehicle controls and those that modify OEM components to alter the operation of vehicle control systems. Generally, these are referred to as servo-type motion control systems and reduced effort or zero effort control systems, respectively.

Research was conducted to identify the powered adaptive control products commonly prescribed by rehabilitation centres and installed by mobility equipment dealer/installers. Further analysis of the products provided a description of the features and utility these products provide to a driver with disabilities and the modifications required to install the products in a vehicle. The reduced effort controls were found to require significant modifications to OEM braking and steering components, whereas the installation of servo-type controls required little modification to the vehicle other than the attachment of actuating mechanisms.

In addition to reviewing several existing standards and guidelines, the report incorporates a review of the extensive work conducted by the Society of Automotive Engineers, Adaptive Devices Committee. The Adaptive Devices Committee has developed the following directly related Recommended Practice and Recommended Test Procedure documents currently in draft form:

- Recommended Practice and Recommended Test Procedure for Powered Gas/Brake Control Systems;

- Recommended Practice and Recommended Test Procedure for Reduced Effort Power Steering and Power Steering Backup Systems; and

- Recommended Practice and Recommended Test Procedure for Reduced Effort Power Brakes and Vacuum Powered Brake Backup Systems.

In addition to reviewing the draft SAE documents for applicable content, the method of initiating a Canadian standard was also reviewed considering both the applicable content of the SAE documents and the level of development of the available draft documents. The documents were found to sufficiently cover the specifications and associated test procedures necessary for regulating the design, manufacture, performance and installed utility of commonly prescribed powered adaptive controls.

The report concludes with a discussion of the options available for implementing a national standard and the advantages and disadvantages associated with each option. The recommended approach, considering the cost and time to develop a nationwide standard, involves having an industry organization like the National Mobility Equipment Dealers Association (NMEDA) adopt the released SAE Recommended Practices as a standard to be followed by their members. In this case, membership in NMEDA would need to be encouraged especially for third party funding arrangements.

Sommaire

À la faveur des progrès techniques accomplis ces dernières années, sont apparus sur le marché des dispositifs qui facilitent la conduite d'une voiture, soit en réduisant l'effort physique à fournir pour commander et/ou conduire le véhicule, soit en modifiant la façon dont le conducteur doit s'y prendre pour actionner les systèmes de commande du véhicule. Ces aides permettent à de nombreux conducteurs handicapés de prendre le volant.

Ce rapport examine la nécessité, au Canada, de disposer d'une norme ou d'une ligne directrice reconnue pour veiller à ce que la conception, la fabrication et l'installation des commandes de véhicules adaptés respectent les règles de sécurité, et que celles-ci fonctionnent conformément aux spécifications du constructeur du véhicule. Malgré les percées remarquables faites par les équipementiers et les fabricants de ces types de produits, on note encore l'absence, au Canada, d'une norme ou d'une ligne directrice pour réglementer ces produits sur les plans de la sécurité et des performances.

Deux types de commandes ont été examinées : les servocommandes, qui font intervenir une source d'énergie auxiliaire entre le conducteur et le véhicule, et les commandes à effort faible ou nul, qui nécessitent une modification des composants d'origine et supposent des manoeuvres de conduite différentes de la part du conducteur.

Un sondage a été effectué pour connaître les commandes de véhicules adaptés les plus couramment prescrites par les centres de réadaptation et installées par les équipementiers. L'analyse des produits ainsi recensés a permis de dresser un tableau des caractéristiques de ces produits, de leur degré d'utilité pour les conducteurs handicapés et des modifications à apporter au véhicule pour permettre leur installation. Les commandes à effort faible exigent des modifications majeures des freins et de la direction, tandis que les servocommandes nécessitent peu d'adaptation, si ce n'est la mise en place des mécanismes de commande (leviers, boutons, etc.).

Outre l'examen de plusieurs des normes et lignes directrices en vigueur, le rapport fait le survol d'importants travaux réalisés par le Comité des aides techniques de la Society of Automotive Engineers (SAE), qui ont mené à des pratiques recommandées et leurs procédures d'essai connexes. Ces pratiques et procédures d'essais portent sur :

- les servocommandes d'accélération et de freinage;
- les systèmes de direction servo-assistée à effort faible et les systèmes de direction servo-assistée de secours;
- les freins servo-assistés à effort faible et les systèmes de freins à dépression de secours.

Les chercheurs ont pris connaissance de ces documents de la SAE en vue d'établir la pertinence de ceux-ci, ainsi que l'opportunité, compte tenu de leur degré d'achèvement, de les adopter tels quels en tant que norme ou de s'en servir comme base pour la rédaction d'une norme canadienne. Ces documents, ont-ils estimé, énoncent toutes les spécifications et les procédures d'essai connexes nécessaires pour réglementer la conception, la fabrication, les performances et l'utilité des commandes de véhicules adaptés couramment prescrites.

Le rapport examine finalement les diverses options qui s'offrent pour la mise en oeuvre d'une norme nationale, ainsi que les avantages et les inconvénients associés à chacune. La démarche recommandée, compte tenu des coûts et du temps nécessaires pour élaborer une norme nationale, consiste à amener une association industrielle, comme la National Mobility Equipment Dealers Association (NMEDA) à adopter les pratiques recommandées de la SAE en tant que norme et à engager ses membres à y adhérer. Il y aurait lieu, dans un tel cas, de prévoir des mesures incitatives à l'intention des membres de l'association, notamment sous la forme d'ententes de financement par des tiers.

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Glossary

The following is an alphabetical list of the acronyms, abbreviations and definitions of terms used throughout this report. For brevity, acronyms and abbreviations will not normally be defined in the text.

Closed Loop Control — a control system which incorporates a feedback control system.

Controls, Primary — controls whose use is frequently or continuously required to maintain operational control of the vehicle or its functions.

Controls, Primary, Group A — the driver-operated controls which directly affect the direction and speed of the moving vehicle. These include the steering, brake and accelerator controls.

Controls, Primary, Group B — the driver-operated controls which are essential to the coordinated and safe operation of the vehicle in traffic situations. These include the ignition/starter switch, gear selector, parking brake, turn indicator lever, hazard flasher, horn, wiper/washer, defroster control, mirror, master lighting switch and headlight dimmer.

Dealer/Installer — any company or individual that represents a product manufacturer and is authorized to sell and/or install the manufacturer's products, also known as a Mobility Equipment Dealer.

Driving Control — any device, including hand controls, fitted to or intended to be fitted to a vehicle to enable the vehicle to be driven by persons with a disability.

Inertial Movement — a change of position of the vehicle operator that results from an acceleration or deceleration of the vehicle.

Nondisabled Driver — the driver for whom the OEM vehicle was originally designed.

Physical Disability — the absence or reduction of a neuromuscular or orthopaedic function of the human body.

Power(ed) — systems and devices that operate by means of an energy source other than manual effort.

Power Assisted — those systems which are operated by means of an energy source in addition to muscle power and which remain operable by muscle power when assist is lost.

Mobility Equipment Dealer — an individual or company that converts or modifies vehicles for use by persons with disabilities.

OEM (Original Equipment Manufacturer) — a term used to refer to the vehicle manufacturer, or to the vehicle and vehicle components as they are designed and produced by the vehicle manufacturer.

Servo — a power device which amplifies control forces and automatically corrects the output in proportion to an input.

Many of the above definitions have been adopted from the CSA standard Z323.1.2-94, *Automotive Adaptive Driving Controls (AADC) for Persons with Physical Disabilities* and several SAE standards and recommended practices.

1 INTRODUCTION

In recent years, technological advances have introduced automotive adaptive devices which either reduce the physical effort required to control and/or operate a vehicle or alter the way in which driver control initiatives are applied to the vehicle control systems. These adaptive devices provide the possibility of driving a vehicle for many drivers with disabilities.

This study examines two types of adaptive controls: those that provide an external source of power to actuate existing vehicle controls and those that modify original equipment manufacturer (OEM) components to alter the operation of vehicle control systems. Although great strides have been made by mobility equipment dealers and manufacturers of these types of products, the performance and safety of these assistive devices are not currently regulated by a Canadian standard or guideline.

In 1994, the Canadian Standards Association (CSA) released standard Z323.1.2-94, *Automotive Adaptive Driving Controls (AADC) for Persons with Physical Disabilities* which established a uniform procedure for ensuring the manufactured quality, installed utility and service performance of primarily hand control type of automotive adaptive devices. The standard focussed exclusively on products intended to be added to, or substituted for, vehicle controls such as pedals, wheels, levers, knobs and switches. The standard excluded adaptive products which require the removal or alteration of OEM vehicle control components typically mounted outside the occupant space, assistive devices that are powered and those devices that do not permit the conventional use of the OEM automotive controls.

Since powered adaptive controls can potentially affect the performance of critical automotive systems such as accelerator, steering and brake controls, a recognized standard or guideline is required to ensure that these driver control devices are designed, manufactured and installed in a safe manner and function according to or exceed OEM specifications. The primary automotive controls which control vehicle steering, braking and acceleration are the focus of the efforts of this study since failures in these automotive control systems represent the greatest safety concerns.

1.1 Project Objectives

The research described in this report was carried out by TES Limited for the Transportation Development Centre (TDC), Transport Canada. The initial objective of the research project was to develop test protocols to provide a method of evaluating powered adaptive controls and their installation in vehicles. The test protocols could form the basis for the development of detailed test procedures to be incorporated in a future Canadian standard.

After an initial search of related standards and guidelines, it was decided that it would be much more beneficial to incorporate a review of the extensive work conducted by the Society of Automotive Engineers (SAE), Adaptive Devices Committee.The Adaptive Devices Committee has developed the following directly related Recommended Practice and Recommended Test Procedure documents currently in draft form:

- Recommended Practice and Recommended Test Procedure for Powered Gas/Brake Control Systems;

- Recommended Practice and Recommended Test Procedure for Reduced Effort Power Steering and Power Steering Backup Systems; and

- Recommended Practice and Recommended Test Procedure for Reduced Effort Power Brakes and Vacuum Powered Brake Backup Systems.

The development of these recommended practices and test procedures was considered the fundamental work to be reviewed as the available resources for the development of a Canadian standard. In addition to reviewing the draft SAE documents for applicable content, the method of initiating a Canadian standard was also reviewed considering both the applicable content of the SAE documents and the level of development of the available draft documents.

2 POWERED ADAPTIVE DRIVING CONTROLS

In the context of this study, automotive driving controls are Group A, primary driver controls as defined by the Society of Automotive Engineers. The SAE defines these as driver-operated controls that directly affect the direction and rate of travel of the moving vehicle, including the steering, brake and accelerator controls. Generally, the assistive devices under consideration modify the OEM operation or the OEM components of one of these three critical automotive controls.

Powered adaptive controls are primarily used by individuals with strength or range of motion limitations of the upper and lower extremities or by individuals who cannot exert sufficient force to operate non-powered adaptive controls utilizing the highest amount of mechanical advantage practical. Powered adaptive controls employ a sensitive force-amplifying system to allow the driver to control the vehicle with minimal force input. In addition, various types of input devices can be used to reduce the range of motion required of the driver.

There are two types of powered adaptive driving controls that are used extensively. These include servo-type motion controls and reduced effort controls. Servo-type controls initiate the application of an energy source other than manual effort as input to automotive control systems that directly affect the direction and rate of travel of the moving vehicle. In contrast, reduced effort systems modify OEM power assist components while typically maintaining the existing vehicle controls. Reduced effort systems also operate by means of an energy source in addition to manual effort, yet unlike servo-type controls, remain operable when the assist is lost as intended by the OEM.

2.1 Reduced Effort and Zero Effort Controls

Generally, reduced effort motion control systems include modifications that are made to the hydraulic control mechanism of OEM power steering systems and to the vacuum actuated power booster of OEM power brake systems. By modifying the OEM power assist components, the effort required to initiate driver inputs can be significantly reduced. OEM accelerator controls are designed to minimize driver fatigue by maintaining low input forces and are therefore rarely modified to reduce the input control effort.

These types of systems are designated reduced effort or zero effort controls depending on the amount of effort required to initiate the driver input. OEM power steering normally requires a steering wheel break-away force of 10 to 13 N (36 to 48 oz) applied at the steering wheel rim which can be reduced to below 9 N (32 oz) for reduced effort steering systems. A steering system requiring less than 2.2 N (8.0 oz) is considered a zero effort system. OEM power brake systems typically require 89 N (20 lbs) of applied pedal force which can be reduced to 50 N (11 lbs) or less for reduced effort braking systems and below 31 N (7 lbs) for zero effort braking systems.

There are a number of methods of modifying OEM steering and brake systems to produce reduced effort controls. Manufacturers and dealer/installers consider the actual modifications to the OEM power assist components to be proprietary information. The actual modifications required do vary according to vehicle type and the desired input effort and are often tailored to suit specific applications.

2.2 Servo-type Motion Control Systems

Servo-type motion control systems employ remote-operated mechanisms which manipulate existing OEM pedals or mechanical linkages. This type of control transforms driver input signals into electrical, mechanical, fluid or thermal energy to produce a position change of an actuating mechanism acting on the OEM controls. The actuating mechanisms are often referred to as servo-mechanisms or servos and are actuated based on signals from an input device such as a joystick or a lever type control. Other adaptations can be incorporated if the driver's hand cannot exert sufficient grip to hold the control device.

By definition, a servo-type adaptive control incorporates feedback which compares the position, velocity or acceleration of a system to the desired input signal. Any powered control which does not incorporate a feedback provision, but instead depends on the driver, friction, inertia, vehicle dynamics or any other indirect means to limit or modify the control system output to achieve the desired position by the driver, is not considered a servo-type adaptive control device.

The transferability and expense are primary disadvantages of these types of adaptive devices. The complicated nature of servo-type controls requires them to be permanently installed and interconnected with other vehicle control systems. The technology employed in these types of controls is expensive and requires considerable design effort which increases the cost to the consumer.

2.3 Other Powered Adaptive Driving Controls

There are several other adaptive control products available which provide various methods of operation for Primary Group B and accessory controls. These range from transmission shift controls and parking brake controls to the actuation of accessory controls. These controls were not evaluated in the scope of this study. Future consideration of modifications to these controls may also be necessary to ensure that the related OEM systems and components are modified in a safe and functional manner.

3 COMMONLY PRESCRIBED POWERED ADAPTIVE CONTROLS

3.1 Rehabilitation Centre Survey

Several rehabilitation centres across Canada were surveyed for the powered adaptive driving control products they most frequently prescribe to drivers with a disability. Through the survey it was discovered that many centres were more familiar with the product dealers and installers they dealt with on a regular basis than with the specific products or product manufacturers. This is also a function of the limited number of powered adaptive controls being prescribed and the focus of these types of controls in larger cities with demonstration vehicles and greater experience in prescribing these controls.

Reduced effort control systems were found to be more commonly prescribed than servo-type control systems. This is based on the greater volume of clients requiring assistance with OEM automotive controls based on some mobility limitations or reduced muscular control. The servo-type controls are typically prescribed for clients with greater range of motion difficulties such as clients with quadriplegia. In addition, the servo-type controls are significantly more costly and require more intensive driver rehabilitation training.

Among the rehabilitation centres contacted, the Bloorview MacMillan Rehabilitation Centre in Toronto, Ontario, prescribed the largest number of the servo-type powered adaptive controls in Canada due to the centre's large client pool. The centre prescribes on the order of 10 to 15 servo-type control systems per year. This volume indicates the quantity of servo-type control installations performed is a small percentage of the overall assistive automotive products installed for drivers with disabilities.

3.2 Dealer/Installer Survey

In contacting the dealer/installers of powered control products, it was immediately evident that products from only a few manufacturers were being used on a consistent basis. The vast majority of servo-type controls are supplied by EMC Incorporated who exported an estimated 35 adaptive control systems to Canada last year. This far outweighs other manufacturers.

Reduced effort braking and steering systems and backup systems are most often supplied by Drive-Master Incorporated. As well, some dealer/installers perform their own modifications to produce reduced effort systems. Ricon Canada Inc. modifies a significant number of vehicles to reduce the effort required to operate OEM steering and/or brake systems. These modifications are done at Ricon according to their own modification procedures.

There were two other manufacturers contacted that either had not supplied or supplied very limited quantities of products to Canadian customers in the past including Ahnafield Corporation, Crescent Industries in Auburn, Maine and Assistive Technology International (ATI) in Raynham, Massachusetts. Due to the limited quantity of products sold in Canada, these manufacturers were excluded from the study. ATI did indicate that future sales in Canada are anticipated to increase considerably over the upcoming year. Information on the manufacturers and dealer/installers contacted during the study along with product information for each is presented in Appendix A.

3.3 Powered Adaptive Controls Selected for Further Study

The following manufacturers and dealer/installers were selected for further study based on the quantity and type of products provided to the driver with a disability in Canada:

- Electronic Mobility Controls Incorporated
- Drive-Master Incorporated
- Wells-Engberg Company Incorporated
- Ricon Canada Incorporated
- KVB Manufacturing

The following paragraphs provide a summary of the powered adaptive control products supplied by these manufacturers and dealer/installers. For more information on these manufacturers and dealer/installers and for further product information refer to Appendix A. Sample products were requested, however, due to the high cost of these products most dealer/installers did not maintain stock of the products and manufacturers were unwilling to supply a sample product. The technical information obtained on the products was extracted from product sales literature, installation manuals and owner/operator manuals.

3.3.1 EMC Incorporated

EMC Incorporated is one of the largest manufacturers of powered adaptive control devices. The majority of rehabilitation specialists and dealers contacted had previously used and are currently prescribing or installing EMC products. The two most common EMC products prescribed were the DS-2000 Digital Steering System and EGB-IIF Gas/Brake Control. Less frequently prescribed is the Digidrive II Digital Joystick Driving System.

All EMC products are digital controls operating via microprocessor control. The electrical signals from an input device are fed to a microprocessor which actuates either an accelerator/brake servo motor or a steering servo motor. The steering servo motor is not visible to the driver as it is integrated with the OEM steering column and the accelerator/brake servo motor is mounted to the vehicle floor. The accelerator/brake servo incorporates an accelerator cable and a brake drive arm to apply the OEM controls. Both

servos also incorporate an encoder for transmitting feedback information to the controller. The EGB-IIF system incorporates a sliding joystick lever integrated with the controller whereas the DS-2000 and Digidrive systems require a separate input device and controller.

EMC also manufactures an electric parking brake which is an integral part of the backup system. The electric parking brake can be automatically coupled to the accelerator/brake input joystick to apply the parking brake whenever the joystick is moved to the full brake position.

The installation of EMC products does not affect the vehicle's original air bag supplemental restraint and anti-lock brakes, if equipped. The original accelerator and brake pedals are not altered and the vehicle remains completely operable by nondisabled drivers after installation.

3.3.2 Drive-Master Incorporated

Drive-Master Incorporated is the largest supplier of reduced-effort braking and steering systems and backup driving systems to Canadian dealer/installers. Drive-Master supplies modified OEM power brake boosters, power steering boxes and rack and pinion steering systems as well as modifying OEM power assist components sent to the factory. Drive-Master also manufactures complete backup systems which provide emergency power assisted steering and braking in the event the modified OEM system fails.

Other products from Drive-Master include horizontal and extended steering columns, manual hand controls, foot steering controls, left foot accelerator pedals, wheelchair lifts, pedal extensions and complete van conversions.

3.3.3 Wells-Engberg Company Incorporated

The Wells-Engberg gas/brake hand control is a pneumatically actuated control for accelerator and brake application. The system consists of a compressor unit, an accumulator, electrical controls and two actuating cylinders. The compressor unit incorporates an accumulator tank as well as a filter with integral air drier and automatic water drain.

The system has a unique feature of allowing the accelerator to be depressed prior to starting the vehicle engine so that the choke on some vehicles can be trip activated. The electrical control box of the system incorporates a green light indicating that the system is fully functional and a red light indicating low vacuum pressure which includes an audible warning.

Installation of the gas/brake control requires the installation of the compressor unit in the occupant space as well as the installation of the pneumatic cylinders on the OEM brake and accelerator pedals. Installation of other components requires simple attachment of components to the vehicle floor pan and/or structural members.

3.3.4 Ricon Canada Incorporated

Ricon is an international company manufacturing and installing a wide range of products for persons with disabilities. Some of the products from Ricon include a variety of wheelchair lifts, six-way power seat bases, and fully converted vehicles for various applications. Ricon also installs adaptive control products from other manufacturers and performs modifications to OEM power assist components to produce reduced effort brake and steering systems.

Ricon modifies OEM power assist components according to their own modification techniques. Ricon maintains an engineer on staff and the actual modifications are performed by an experienced certified mechanic. Ricon also installs backup steering and brake systems and parking brake applicators from other manufacturers with modifications as necessary depending on the vehicle application. Ricon performs full inspections on each completed vehicle prior to delivery to the customer.

3.3.5 KVB Manufacturing

KVB Manufacturing primarily modifies vehicles, other than vans or minivans, for incorporation of the Elaine Anne Lift System. The lift system is designed for the driver position of various General Motors vehicles including Tahoe/Yukon, Extended Cab Pickup Trucks and Suburbans. The company also installs a unique powered swivel seat for passenger and driver positions.

KVB Manufacturing claim they have worked with General Motors (GM) to develop reduced effort steering and braking components which carry a GM part number and are directly installed in their modified GM vehicles replacing supplied OEM components. GM could not confirm that these reduced effort components exist as GM manufactured parts. KVB does not install backup systems for their reduced effort steering and braking systems. Since KVB is installing GM reduced effort parts by simple exchange with the OEM supplied components, they expressed concern over the safety of backup systems which are incorporated as add-on systems to the existing vehicle systems.

3.4 Powered Adaptive Controls Features and Utility

The following elements were considered in the review of the features and utility the selected adaptive control products provide to the driver with a disability:

- conveniences provided for driver;
- ease of use;
- amount of training required for use;
- operational safety concerns;
- required maintenance;
- appearance; and
- comparison to similar products.

The assessment of the selected adaptive control products according to the above categories is based on the general types of controls commercially available.

3.4.1 Servo-type Powered Adaptive Controls

The available servo-type powered adaptive controls have many advantages over other adaptive driving controls and are designed primarily for persons with severe mobility limitations in the upper and lower extremities. The servo-type systems provide the user with an input device, typically a joystick type control, which requires very little effort and range of motion to input driver initiatives. The input device can also be located in any comfortable location that allows application of the full range of the joystick control. Most joystick controls also offer interchangeable adapters to facilitate various preferred methods for activating the controls. Generally, the systems evaluated had very attractive appearances using well designed ergonomics.

These systems are very easy to use due to the simplicity of the joystick control, but require a significant amount of training to be able to safely control a vehicle in a variety of conditions and situations. One of the operational safety concerns of the servo-type adaptive controls is the operation of the joystick under heavy braking or acceleration. The concern is that the joystick may be pushed to extreme positions by the inertial movement of the driver's body. A partial solution for this is to decouple the control input from the vehicle dynamics by requiring the driver to pull rearward to apply the brakes and to push forward to apply the accelerator which is opposite to the inertial movement of the driver's body.

The servo-type systems are complicated systems incorporating, in addition to the input device, a control module, servo actuators, associated wiring harnesses and some form of backup power. Actual maintenance requirements will be minimal; however, frequent checks of the vehicle and the servo control system will be required to ensure safe operation. The EMC products incorporate a thorough system check each time the system is powered up prior to use. Wear and degradation of vehicle components may not be as directly detectable during driving with a servo system and this will necessitate having the vehicle mechanically inspected on a more frequent basis.

Servo-type adaptive controls typically utilize electricity or pressurized fluids as the source of actuating and backup power. In general, servo systems which incorporate pressurized fluids such as air or hydraulic oils may require more frequent maintenance. For example, systems using pressurized air or pneumatics incorporate a moisture removing device which may need to be checked regularly since the moisture present in pressurized air may freeze at cold temperatures. In these types of systems, a lack of regular maintenance could become more consequential.

3.4.2 Reduced Effort Powered Adaptive Controls

Reduced effort systems incorporate vehicle modifications to provide a greater amount of power assistance for steering and brake controls thereby reducing the effort required to activate these controls. Reduced effort steering is designed for drivers with minor strength limitations in the upper extremities and reduced effort brake systems are designed for drivers with minor strength limitations in the lower extremities. The drivers must, however, have full range of motion of their extremities as the vehicle steering wheel and brake pedal will retain their designed travel and location as supplied by the vehicle manufacturer. Reduced effort controls may also be used in conjunction with other types of adaptive controls.

An emergency backup system may be required to provide emergency power steering or braking in the event the vehicle power assist components fail. Failure may occur as a result of engine stall, a broken drive belt, pressure or vacuum loss, power assist component failure or fluid leaks. If power assistance is lost the vehicle controls will continue to be operable, but will require a significant increase in the amount of effort required to actuate the controls. The driver will not have sufficient strength to operate the controls in the absence of power assistance.

These modifications are typically marketed as relatively minor modifications to OEM vehicle systems which can be performed inexpensively. The modifications can also be performed on existing user owned vehicles and may only require the installation of emergency backup components typically located under the vehicle or in the vehicle interior. The vehicle is required to have OEM power brakes and/or power steering. Modifications to the vehicle body, frame, engine and drivetrain components are not necessary to install reduced effort adaptive controls.

3.5 Evaluation of Required Vehicle Modifications

3.5.1 Servo-type Powered Adaptive Controls

Servo-type adaptive controls require vehicle modifications to install the servo actuators, a control module, an input device and associated wiring harnesses. There are also requirements for backup power sources such as batteries or hydraulic and pneumatic accumulators. Due to limited information from other manufacturers, the evaluation of the modifications necessary to install servo-type control products is based on information provided by EMC Incorporated. This corresponds well with the products sold and installed in vehicles for use in Canada which are predominantly supplied by EMC Incorporated.

EMC requires dealer/installers to be trained in the installation procedures of their adaptive controls prior to performing installations. An installation manual is provided with EMC products; however, it is designed as reference material for EMC trained technicians. There are some areas where the dealer/installer is allowed some latitude in the installation of EMC products and these primarily pertain to the component mounting brackets and the exact location of components. If the vehicle application is a vehicle other than one of the several for which EMC manufactures vehicle specific mounting kits, the responsibility for the installation will reside entirely with the dealer/installer.

The EGB-IIF Electronic Gas & Brake System manufactured by EMC requires the installation of two components: a controller and a gas/brake servo. The controller can be installed in any convenient position except the vehicle door due to additional shock loads imposed by the opening and closing of the door as well as exposure to environmental elements. The gas/brake servo incorporates an accelerator cable and a brake drive arm. The servo unit is attached to the vehicle floor beside the brake pedal using suitable mounting brackets located with the drive arm positioned over the brake pedal or brake pedal lever arm. The accelerator cable is routed to the accelerator pedal and is attached to the vehicle using brackets.

The EMC DS-2000 Digital Steering System and the Digidrive II Digital Joystick Driving System both involve substantial modifications to the OEM vehicle steering column. For this reason, the steering columns are removed from the vehicle and shipped to EMC Inc. for modification. The steering columns are modified and then return shipped to the dealer/installer for re-installation. The removal and installation procedures follow OEM recommended procedures. In addition to installing the EMC modified steering column, the EMC DS-2000 and Digidrive II systems require installation of the servo motor from the EGB-IIF System and installation of a computer module and a separate input device (joystick or remote steering wheel).

The actual installation of these types of systems does not require major vehicle modifications. The modifications are essentially limited to attaching the system components to the vehicle using brackets. Often connection to the vehicle engine wiring is also required. This allows the system to sense vehicle speed and engine failure for automatic backup activation. An additional battery may be installed for backup system power. With these limited vehicle modifications being performed, the installation of these type of systems is not expected to adversely affect the operation of the OEM vehicle components.

3.5.2 Reduced Effort Powered Adaptive Controls

Reduced effort steering systems

On most passenger cars, the OEM power steering assistance is provided by hydraulic pressure produced by an engine driven pump acting on a piston in the steering linkage. The amount of assistance is controlled by a valve actuated by the steering wheel which controls the pressure on the piston. The valve is held in its neutral position by a centering device and any steering effort greater than the preload of the centering device allows the valve to develop a steering assistance proportional to the steering effort. The assistance added to the manual steering effort will normally vary between zero during straight line driving to a maximum of 100 percent. With appropriate modifications either to the OEM power steering valving and/or the centering device, a reduced effort steering system will provide a much greater amount of assistance proportional to the manual effort input and reduce the break-away force required to turn the steering wheel.

The modifications necessary to install a reduced effort system are significant since they directly affect a critical vehicle control component yet, are usually isolated to the power steering unit and/or power steering pump with integrated fluid reservoir. Other vehicle modifications are associated with installing a power steering backup system. Installation of the backup system requires the mounting of a secondary source of power for the steering system other than the vehicle engine. This typically consists of an electrically powered pump, a reservoir, hoses and electrical wiring. The backup system should also incorporate automatic activation which requires some sensing devices and connection to existing vehicle systems.

Reduced effort brake systems

OEM power assisted brake systems typically use a vacuum booster which amplifies the manual effort input at the brake pedal. The vacuum source is provided by the engine intake manifold. When vacuum assistance is not available, sufficient effort on the brake pedal can still apply the brakes, though less effectively. The pedal effort will increase and the ultimate

pressure produced in the brake lines will be significantly lower than when power assistance is available. An inherent feature of the vacuum type power assisted brakes is the existence of vacuum, without an additional reservoir, for at least one brake application after the engine is stopped or stalled.

Reduced effort brake system modifications are also significant in that they affect a vehicle control component; however, the modifications are typically isolated to the brake, vacuum power booster. The modifications associated with installing a powered brake backup system primarily consist of attaching additional components to the vehicle. A backup system will include some form of vacuum generator such as a pre-pressurized storage tank or vacuum pump, with interconnection hoses, actuating valves and visual and auditory indicating devices like a pressure gauge. The system should also be automatically activated requiring sensing devices and connection to existing vehicle systems.

3.6 Safety of Vehicle Modifications

Reduced effort systems

The level of assistance provided by OEM power steering systems has been designed to reduce, but not eliminate, the road reactions and shocks felt by the driver. These road reactions allow the driver to sense the motion of the steering system which may indicate loss of control due to slippery road conditions, road surface variations, cross winds as well as conditions such as flat tires and steering system problems. These road reactions are commonly referred to as “road feel”.

The neutral position of the OEM steering system is often lost or significantly reduced after modification to reduce the effort required to activate the vehicle steering system. OEM power steering systems have a centering action in addition to the caster designed in the front steering wheels to aid in straightening the path of the vehicle when it is coming out of a turn. The OEM system also provides zero assistance during straight highway driving to allow the steering system to be freely reversible providing direct road feel input to the driver. The amount of road feel provided during straight line driving will be affected by reducing the break-away force provided by the preload of the OEM steering system. The resulting reduced effort system will require greater attention by the driver to keep the vehicle driving along a straight line. The driver will need to constantly correct for minor variances in vehicle direction and be aware of vehicle behaviour cues which will be far reduced from the OEM vehicle.

In modifying the OEM brake system to reduce pedal effort, the anti-lock brake system is sometimes disabled due to electronic error signals that may be present after modifying the vacuum booster. This may or may not be a safety concern depending on the abilities of the driver and their past driving experience. Anti-lock brakes primarily provide increased stability of the vehicle during heavy braking in slippery road conditions. Increased driver

training may be required to ensure that the driver is aware of the vehicle behaviour during braking in these conditions.

Servo-type systems

Although the modifications to install a servo-type system are not considered to be significant, the driver is no longer in direct contact with the vehicle controls which will greatly affect overall driving performance as well as other factors.

The degradation in driving performance is a result of actuating the vehicle controls by a mechanized device. This can be compensated for by training individuals to be aware of the differences between the OEM system and the servo controls like the increase in sensitivity and the effects of inertia on the body as the vehicle decelerates and accelerates. Once drivers are made aware of these important differences, they will be much more prepared to expect particular vehicle behaviours as a result of driver initiatives.

The OEM controls also perform another role in transmitting information to the driver to indicate problems such as component wear and loss of control. Because the driver is no longer in direct contact with the vehicle controls the majority of this information will not reach the driver. This may necessitate more frequent mechanical inspections to discover wearing components prior to a possible failure. The feeling of loss of control can be accommodated by additional training and through driver experience. Being acutely aware of a vehicle's behaviour can, in many circumstances compensate for the lack of direct contact with the vehicle controls. This will be highly vehicle-specific and transferring to another vehicle, especially different types of vehicles, will require becoming aware of the new vehicle's reactions and behaviour.

All EMC Inc. control systems incorporate redundant joystick, computer and power circuits to produce a fault tolerant design. Since the EGB-IIF controller is capable of operating the OEM braking system without the aid of any power assist from the vehicle, a backup to the OEM brake booster is not required. In the event of a servo motor failure, the EGB-IIF will access the electric parking brake (if installed) when full brake is applied. Otherwise the standard OEM emergency brake can be accessed to stop the vehicle. An emergency backup button is incorporated on the Digidrive II and DS-2000 products to manually engage the backup systems. The Digidrive II system incorporates a status module which informs the driver of the system operating mode and displays the function of the sensor systems.

Driver training

As can be seen from the previous discussion, the introduction of powered controls may not adversely affect the safe operation of a vehicle if proper driver training is provided. This not only includes instructing the driver on the differences to be expected from the OEM vehicle, but also providing knowledgeable assistance in the use of orthotic devices and seat supports for correct body posture and resistance to vehicle motion. This includes assistance in positioning of controls with respect to vehicle movement. It is also imperative the input controls of the servo-type systems be carefully placed so that the driver can comfortably execute the full range of the control during the many vehicle movements that may occur like turning corners and hard acceleration and braking.

4 REVIEW OF EXISTING STANDARDS AND GUIDELINES

4.1 Related Standards and Guidelines

A search was conducted for existing standards and/or guidelines related to adaptive controls. The search revealed the following directly related documents:

- Australian Standards Association, AS 3954.1-1991, *Adaptive Systems for People with Disabilities, General Requirements*;
- Australian Standards Association, AS 3954.2-1991, *Adaptive Systems for People with Disabilities, Hand Controls- Product Requirements*;
- Institution of Mechanical Engineers, London, England, *Guidelines on the Adaptation of Car Controls for Disabled People*;
- Society of Automotive Engineers, Recommended Guideline J1903, *Automotive Adaptive Driver Controls, Manual*;
- Canadian Standards Association, Z323.1.2-94, *Automotive Adaptive Driving Controls for Persons with Physical Disabilities*; and
- *Design Guidelines,* National Mobility Equipment Dealers Association (NMEDA).

In addition, organizations such as the Association of Driver Educators for the Disabled (ADED) and Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) were surveyed for information relating to powered adaptive controls. Both organizations provide certification to qualified individuals working in their respective fields, but do not provide specific design or installation guidelines related to powered adaptive controls. ADED supports the Certified Driver Rehabilitation Specialist program and RESNA supports the Assistive Technology Practitioner Certificate and Assistive Technology Supplier Certificate programs.

4.2 Canadian Motor Vehicle Safety Act

The Canadian Motor Vehicle Safety Act (MVSA) incorporates the Canadian Motor Vehicle Safety Standards (CMVSS), that are directly applicable to modifications performed on OEM vehicle control systems. The standards not only apply to new vehicles, but also to vehicles which were purchased with the intent of modifying them for use by a driver with disabilities. The standards do not, however, apply to pre-owned vehicles converted for a driver with a disability. The following discussion summarizes the requirements specified in the CMVSS standards applicable to the installation of powered adaptive controls.

4.2.1 Applicable Standards

CMVSS 101 — Location and Identification of Controls and Displays

The following controls and components, where fitted on a vehicle, shall be fitted in such a manner that they are operable by the driver while the driver is seated in the driver's designated seating position with the driver's seat belt assembly correctly fastened:

- accelerator;
- automatic vehicle speed system;
- choke (if manually operated);
- clutch pedal;
- driver's sun visor;
- engine start control;
- engine stop control;
- hand throttle;
- hazard warning switch and indicator;
- headlamp upper or lower beam switch and indicator;
- horn;
- ignition switch;
- illumination intensity control;
- master lighting switch;
- parking brake pedal or lever;
- rear window defog and defrost control;
- service brake pedal or control;
- steering wheel;
- transmission shift control (except the transfer case if one is exists);
- turn signal control and indicator;
- windshield defog and defrost system control;
- windshield washing system control;
- windshield wiping system control;
- clearance lamps switch;
- identification lamps and switch;
- side marker lamps;
- antilock system failure;
- battery charging;
- brake failure;
- engine coolant temperature;
- engine oil pressure;
- fuel;
- gear position;
- odometer;
- seat belt;
- speedometer;
- extreme position for heating and air conditioning; and
- fan for heating and ventilation system.

As well, the displays for functions and malfunctions shall be mounted in such a manner that they are identifiable by the driver while the driver is seated in the driver's designated seating position with the driver's seat belt correctly fastened.

Generally, the extra effort in following the above specifications should not be extensive as the accessibility of controls is one of the aims of modifying a vehicle for a person with a disability. A potential major difficulty in meeting these requirements is the altering of the OEM driver position which may directly affect viewing of the displays.

CMVSS 105 — Hydraulic Brake Systems

The vehicle is to be equipped with a service brake system acting on all wheels with indicators and displays as set out in the standard. In addition, the vehicle is to be equipped with a friction type parking brake. The vehicle brake system must be capable of passing the tests prescribed in the standard including stopping within the distances established with and without power assistance.

Inspection of a modified vehicle does not normally involve testing; however, a large portion of this standard pertains to testing according to the specified requirements. A substantial modification of the hydraulic system as in reducing the effort required to apply the brakes may require performing this testing. The installation of servo motors actuating the functional hydraulic components of the OEM brake system may not require testing since the OEM system is not actually modified. However, the partial system failure performance requirements of the standard dictate that the system provide the requisite force input applied by operation of the service brake control to stop the vehicle as specified.

CMVSS 107 — Reflective Surfaces

The specular gloss of wiper arms and blades, inside windshield molding, horn ring and inside mirror must meet the CMVSS 107 requirements.

Components introduced in the driver’s field of view may need to be evaluated to ensure that the specular gloss of the components meet the requirements of this standard.

CMVSS 124 — Accelerator Control Systems

The vehicle throttle control system shall return to the idle position from any accelerator position, if disconnected or severed and have two sources of energy for returning the throttle to the idle position. In addition, the throttle shall return to idle within the times specified in the standard.

This is essentially a performance-based requirement specifying two energy sources for returning the vehicle throttle to the null or idle position and the time required to return from full throttle. The actuation of the accelerator by servo-type controls will also need to meet the requirements of this standard.

CMVSS 201 — Occupant Protection

A vehicle must have adequate energy absorbing material in the defined head impact area. The instrument panel of a vehicle shall be constructed so that the deceleration of a spherical head form will be limited to the specifications of the standard. The area of a seat back that is within a head impact area shall comply with the specifications of the standard. The sun visor and arm rest shall also meet the requirements of the standard.

Significant modifications to head impact areas in the vehicle may require testing according to the requirements of this standard and/or SAE J921b - Motor Vehicle Instrument Panel Laboratory Impact Test Procedure — Head Area and SAE J211 - Instrumentation For Impact Tests. Introduction of components in the defined head impact area may need to be evaluated or tested to ensure the location of the components or the components themselves comply with the impact test criteria.

CMVSS 203 — Driver Impact Protection

The steering control system of a vehicle shall be constructed in such a manner that, during normal driving manoeuvres, no component or attachment, including any horn actuating mechanism and trim hardware, is capable of catching the clothing, watch, rings, bracelets, other than bracelets with loosely attached or dangling members, or other jewelry of the driver. The steering system must also limit the impact force developed on the chest of a body block and transmitted to the steering control system to the specifications of the standard when tested in accordance with SAE Recommended Practice J944, Steering Control System-Passenger Car-Laboratory Test Procedure.

Significant modifications to the physical configuration of the OEM steering column and steering wheel may require testing according to SAE J944, Steering Control System-Passenger Car-Laboratory Test Procedure. The installation of additional steering controls as a part of a powered adaptive control system may affect the specifications of this standard. Proper component design and location may avoid the necessity for testing. The installation of a reduced effort system should not affect compliance with this standard since the modifications should be isolated to the power assist components.

CMVSS 204 — Steering Column Rearward Displacement

The vehicle steering column must meet the rearward displacement requirements specified in this standard.

Modifications to the OEM steering column may require barrier impact testing to verify compliance with this standard. The installation of a reduced effort steering system should not affect compliance with the requirements of the standard. Compliance is more questionable in the installation of steering servo motors which may affect the collapsing feature of the steering column. Compliance should be achievable with careful design of the modifications necessary to the OEM steering column.

CMVSS 208 — Seat Belt Installations

A vehicle shall be equipped at each front outboard designated seating position with a Type 2 seat belt assembly that has a non-detachable upper torso restraint or an automatic occupant protection system meeting the requirements of the standard. A vehicle shall also be equipped at each forward facing rear outboard designated seating position with a Type 2 seat belt assembly that has a non-detachable upper torso restraint. A vehicle equipped with a front outboard designated seating position with a gas-inflated occupant protection system shall also be equipped at that position with a Type 2 seat belt assembly. The system must also incorporate the appropriate warning indicators and the seat belt assemblies must fit the required occupant sizes and meet the adjustment requirements.

Compliance with this standard primarily pertains to maintaining the integrity of the OEM air bag supplemental restraint systems. Vehicle air bags will be a requirement for compliance with MVSA after January 1, 1998. This is because of the introduction of the new CMVSS 208 which does not specify the installation of an air bag but rather specifies requirements that will necessitate an air bag. Therefore, disconnection of the vehicle air bag will no longer be permitted as a modification. This may have serious implications where the installation of adaptive controls necessitates modifications to the vehicle which potentially create an unsafe situation in the event the air bag supplemental restraint system is deployed.

CMVSS 302 — Flammability

The following material covered components shall not burn in excess of or transmit a flame front across its surface, at a rate of more than 102 mm (4 inches) per minute or have stopped burning in 60 seconds and has not burnt more than 51 mm (2 inches):

- seat cushions;
- seat backs;
- seat belts;
- headlining;
- arm rest;

- trim panels;
- head restraints;
- floor covering;
- sun visors;
- wheel housing cover;
- engine compendiment covers; and
- any other materials that are designed to absorb energy or contact by occupants in the event of a crash, including padding and crash-deployed elements.

Testing to verify compliance with this standard is not normally required if OEM components are replaced by materials and/or components which meet the CMVSS requirements.

4.2.2 Enforcement of CMVSS Compliance

The Enforcement Branch of Road Safety, Transport Canada, currently does not normally require performance testing of a vehicle due to the installation of powered adaptive controls. The current approach is to examine the installed systems and modifications performed on the vehicle to ascertain whether the OEM vehicle certification has been affected. The installation of some controls may not affect the OEM certification. The dealer/installers are encouraged to contact the OEM for information on the required modifications. As well, dealer/installers typically employ personnel responsible for compliance with CMVSS who must evaluate the modifications and provide proof of compliance. In addition, installed adaptive control systems which are assessed as being quickly removable and which retain the OEM systems after removal are not currently inspected with the aim of enforcing compliance with CMVSS standards. This is based on a clause in the standards which excludes “removable” components not permanently installed.

Aside from enforcing compliance, there are areas of the MVSA which lack standards specifically oriented to ensuring vehicles modified by the installation of powered adaptive controls meet specific performance and safety requirements. For example, a CMVSS standard specifically referencing steering performance criteria is not included in the MVSA. Therefore, performance of a modified steering system cannot be measured and evaluated against a set of standard requirements.

4.3 Canadian Standards Association

The CSA does not currently have a standard that is applicable to powered adaptive controls; however, a representative standard is the standard Z323.1.2-94, *Automotive Adaptive Driving Controls (AADC) for Persons with Physical Disabilities*. This standard specifies performance requirements for manual adaptive controls that allow vehicles to be

driven by persons with physical disabilities. The main objective of the standard is to minimize as far as possible the hazards associated with these devices arising from their design, the quality of manufacture, installation and use. The standard is based on the SAE's Recommended Guideline, J1903 and the Australian Standards documents AS 3954.1-1991 and AS 3954.2-1991.

The development of standards through the CSA process is a voluntary, self-regulating and consensus process through a structured standards development process. The structure allows for the managed input of business, government, labour, consumers, driver rehabilitation centres, funding agencies and other associations with a common interest of developing a national standard. Consensus as defined by the CSA means an attempt to resolve all objections and implies much more than the concept of a simple majority. In addition, all national standards developed through the CSA are prepared in accordance with Standards Council of Canada Publication CAN-P-2, *Criteria and Procedures for the Preparation and Approval of National Standards of Canada*.

Development of a standard through the consensus principle is essential to developing a standard which is founded by a substantial agreement reached by concerned interests. Concerned interests include government agencies, manufacturers, dealer/installers and the user community often represented by interest groups. In the preparation of a standard, the CSA regulations governing standardization also require a technical committee to take into account all available directly relevant national and international documents. This requirement would certainly direct the CSA technical committee to review the SAE Recommended Practices reviewed in this report.

4.4 Voluntary Standards and Self-Regulation

The voluntary Quality Assurance Program (QAP) initiated by the National Mobility Equipment Dealers Association (NMEDA), U.S.A., represents an example of the motor vehicle conversion industry attempting to regulate itself through the use of standards, guidelines, recommended practices and certification.

The requirements to be certified under NMEDA's QAP include the following and are quoted from the Transport Canada/TDC report entitled "*Persons with Disabilities and Converted Vehicles*", by Goss Gilroy Incorporated. Individual installers/dealers must:

- follow specific guidelines when performing modifications;
- have a certified welder on staff;
- have a individual (on staff) who is trained and certified in dealing with assistive components for vehicles;
- have an individual responsible for quality control;
- agree to a review of payroll information to verify the individuals identified as being certified are in fact involved in vehicle modifications;

- have a minimum of one million dollars product liability insurance; and
- agree to two mandatory site inspections each year (either announced or unannounced) where the company's facilities and products are inspected by an independent engineering firm.

Due to the voluntary nature of the program and the absence of a requirement to comply with FMVSS and CMVSS requirements, the QAP has been viewed as an industry quality control program as opposed to compliance to regulations. However, NMEDA, in general, is advancing towards a pro-active approach to incorporating applicable standards and guidelines as they become available. This will aid in changing the current perception of self regulation.

The Design Guidelines produced by NMEDA were also reviewed. The guidelines contain the following sections applicable to powered adaptive controls:

- Reduced Effort and Zero Effort Steering;
- Emergency Backup Steering;
- Reduced Effort Braking (incorporating specifications for Emergency Backup Braking);
- Joystick Driving Systems;
- Parking Brake; and
- General Electrical Specification.

The guidelines address the general issues associated with installing powered adaptive controls; however, the guidelines lack the detail observed in the SAE documents and therefore do not cover some important aspects particularly in the design of adaptive controls. It is anticipated that NMEDA could reference any future released documents, such as SAE Recommended Practices, to supplement or replace their existing specifications.

5 REVIEW OF SAE DRAFT DOCUMENTS

The following review is presented to provide a summary of the contents of the SAE draft documents under consideration. For more detailed information, the SAE Adaptive Devices Committee should be contacted.

5.1 General Document Structure

The SAE Recommended Practice documents are designed to establish a uniform procedure for assuring the manufactured quality, installed utility and performance of automotive adaptive driving controls other than those provided by the vehicle manufacturer (OEM). Each Recommended Practice document has an accompanying Recommended Test Procedure document which establishes a method of qualification testing to ensure compliance with the applicable recommended practices. The documents are generally structured in a similar fashion and address similar areas of concern. The Recommended Practice documents address the following subject areas:

- Scope, Classification, Limitations and Definitions;
- Applicable Documents;
- Design Requirements;
- Materials and Components;
- Operation;
- Method of Installation; and
- Quality Control and Maintenance.

The Recommended Test Procedure documents address the following subject areas:

- Document Scope;
- Receiving Inspection Tests;
- Visual Inspections;
- Operation of the Installed System;
- Specification Tests;
- System Endurance Tests; and
- Conditions of Compliance.

It must be stressed that the SAE Recommended Practices and Test Procedure documents were reviewed in draft form and have not been released for publication. The documents are likely to change over the course of the Adaptive Devices Committee review process. Once thoroughly reviewed and ready for publication, the Recommended Practices will be released for use.

5.2 Recommended Practice for Powered Gas/Brake Control Systems

The scope of the Powered Gas/Brake Control Systems document includes recommended practices for powered accelerator and brake control systems which are operated by a driver with a physical disability. The purpose of the document is to provide criteria to evaluate powered accelerator/brake control system design, manufacture, installation, operation, maintenance and performance.

The document considers powered control systems designed to not only transfer foot-operated functions to the hands or from one side of the body to the other, but those that supplement by power, other than by the driver's own muscular efforts, the force output of the driver. Therefore the document is specifically concerned with mechanical and electrical products intended by the manufacturer to meet the following criteria:

- substituted for the use of OEM vehicle accelerator and brake pedals, yet retains the OEM pedals for use by non-disabled drivers; and
- output of the powered control is applied to the OEM brake and accelerator assembly in order to change the force or range of motion required of the driver with disabilities.

The document specifically excludes manual driver controls which simultaneously modify the force and range of motion required to operate the OEM controls. The document also excludes adaptive products which modify the OEM accelerator and/or brake systems other than modifications to the OEM pedals to facilitate attachment. The document also does not consider modifications to Group B controls or accessory controls. The revision of the document reviewed does not include servo-type steering controls; however, SAE is hoping to incorporate guidelines for this type of control in future revisions.

In addition to specifying design and performance criteria for powered throttle/brake systems, the document also specifies requirements for fasteners, electrical wiring and other materials and components. The document specifies a mandatory requirement for an automatically actuated redundant backup of the powered throttle/brake system. Included in this requirement is the necessity to have a brake backup system in the event that both the primary and redundant power sources fail. This provides the driver with a means of stopping the vehicle with a powered throttle/brake control emergency backup system without any other control motions other than applying the brake.

5.3 Recommended Practice for Reduced Effort Power Steering and Power Steering Backup Systems

This document specifies recommended practices for modifications to an OEM power steering control system to reduce the physical effort required by the driver to actuate the steering system. In the context of this document, a steering modification is limited to modifying the hydraulic control mechanism of the OEM power steering system specifically to reduce the feedback torque of the power steering system.

The design requirements section describes many aspects of the design of a reduced effort steering system including the requirement for a mandatory backup power steering system with automatic activation. In addition, certain design parameters are stated including the torque required for steering, the number of turns lock to lock, and the conservation of OEM design standards. This is in relation to minimizing the introduction of additional failures other than those designed into the OEM system. In particular, one OEM design standard specified is that modifications shall not introduce new single-point failures.

Other sections specify the component quality which is to be equal or better than OEM components. Wiring, electrical components, hydraulic components, fasteners and peripheral components are all required to meet specified applicable standards. The document also specifies all installation hardware necessary to install all of the associated components is to be provided with delivery of the system. There are also general system requirements including hydraulic fluid cooling specifications.

The actual operation specifications of the reduced effort steering system require a power steering backup system designed to meet several manual operation and automatic activation requirements including a manual activation switch, a manual shut-off switch, specific wiring requirements and warning indicators. Due to the amount of space that the backup system can claim, there are requirements that ensure that the installed equipment is accessible for maintenance of the system or the primary vehicle components.

Other requirements specified include labels, a user's manual, an installation manual for both the reduced effort steering system and the backup system and other information including flow diagrams, electrical diagrams, parts lists and instructions for label locations. As well, warranty and identification requirements are specified.

5.4 Recommended Practice for Reduced Effort Power Brakes and Vacuum Powered Brake Backup Systems

This document refers to OEM power brake control system modifications which reduce the physical effort required by the driver to actuate the OEM brakes. The document is limited to modifications which retain an OEM pedal and linkages, the OEM master cylinder and all brake line plumbing including brake wheel cylinders and/or actuators.

The design section of the document specifies several important design requirements that significantly increase the safety of the modified system. The section references the preservation of OEM specifications in several instances specifically in reference to single-point failure modes, conventional use of the motor vehicle, deceleration and stopping distances and pedal reserve. These design requirements are to be based on OEM

specifications prior to any modification of the brake system. The Recommended Practice also references SAE J299 *Inservice Brake Performance Test Procedure Passenger Car and Light Truck* which is used to establish a test method for the force needed to apply the brakes. This test method does not substitute for the requirements stated in federal specifications for hydraulic brake systems.

The document specifies that a power brake backup system is required to provide the driver with a disability the same protection from failure available to nondisabled drivers. The performance requirements of a backup system are also prescribed. The document specifies material requirements for components, electrical and wiring requirements and labeling requirements. The document also specifies the need for a vacuum gauge, low vacuum warning devices and indicators for automatic backup activation.

Regarding operation, the document specifies the requirement for a user's manual for both the reduced effort system and the backup system. The document specifies the requirement of an installation manual with parts lists, schematics and installation for maintainability requirements. The installation instructions should specifically state any differences in the installation of modified OEM components. The document states the manufacturer is to provide documentation which verifies that modifications and installations of reduced effort braking system components are performed by trained personnel. Warranty requirements, identification markings and accessibility requirements are also specified specifically defining all components requiring maintenance shall be readily accessible without major disassembly or use of special tools and maintenance accessibility of OEM components shall not be degraded.

5.5 Recommended Test Procedures

The Recommended Test Procedure documents specify test procedures for qualification testing of powered adaptive control systems to ensure compliance with the recommended practices established in the Recommended Practice documents. The purpose of the Recommended Test Procedures is to provide methods to measure the criteria specified in the Recommended Practice documents. An adaptive control system which passes all of the tests contained in a Recommended Test Procedure document shall be considered to be in compliance with the applicable recommended practices.

The documents first establish a test protocol which specifies the items to be submitted for testing which include a complete installed adaptive control system, an uninstalled system, a documentation package and a failure analysis. Since most installations are performed by an dealer/installer and not the manufacturer, an installation manual will need to be provided in the documentation package and evaluated during the qualification test procedures.

The first test specified is a receiving inspection of all test items including all supplied components and documentation. This test involves evaluating the documentation for specific requirements such as flow diagrams, electrical schematics and warranty information as well as other information requirements. The test also involves comparing the supplied unassembled system with the parts lists and drawings to ensure all parts required are furnished and the documentation is correct.

Further tests include a visual inspection of the installed system and various performance tests. The visual inspection includes observing the location of components and method of installation to ensure that the system meets the many requirements specified. The performance tests include operating the applicable system in its various operating modes including emergency backup modes. The performance tests monitor actual performance as well as the activation of audible and visual warnings.

The one difference that appears in the documents is the presentation of specification tests as a separate section in the Reduced Effort Steering document. The other documents include specification tests under the Operation Tests section. Specification tests are actual measurements of the system parameters such as the number of steering turns lock-to-lock.

6 DISCUSSION

6.1 The Need for a Powered Adaptive Controls Standard

In reviewing the SAE draft documents it was obvious that although manufacturers and dealer/installers are generally manufacturing and installing quality products, a standard is needed to provide a minimum level of safety and quality to be met by every installed product. Not withstanding the safety of ensuring powered controls are manufactured and installed safely, a standard provides a great deal of advantages including establishing a minimum set of requirements for third party funding. A standard, however, should not deter the development of innovative products or product adaptations that may be required for a particular individual. The final standard must benefit all parties involved including the actual product users, the industry and government regulatory agencies.

Design and manufacture

Design and manufacture is the initial point where safety and utility are built into the product. A standard will provide minimum design requirements for manufacturers and dealer/installers to follow to ensure products are designed and manufactured to provide an acceptable level of utility and safety to the driver and other drivers on the road.

An example of a lack of specification is in steering control performance. Since MVSA does not specify steering control performance some other means is required to ensure OEM steering controls are modified in a safe and appropriate manner. By specifying the number of turns from lock-to-lock of the reduced effort steering system, the SAE documents effectively specify a performance requirement for the steering system. Greater than eight turns will take an excessive amount of time to change the direction of the vehicle and less than one turn will change the direction of the vehicle far too quickly which may cause an unsafe situation.

Installation

The installation of powered adaptive controls must be capable of being examined and verified as this is the point at which the product becomes integrated with the vehicle. It should be a necessity for manufacturers to provide documented installation information even if installations are performed at the factory. The SAE documents specify that an installation manual is not required if the system is installed by the factory; however, the fluid flow diagrams, electrical diagrams, parts list and installation drawings are required in any case.

An approach taken by EMC Incorporated includes requiring their trained dealer/installers to fill in an installation questionnaire to first ensure installers have considered all of the necessary installation requirements, and then to maintain a record of the installation for future reference.

Payment by third parties

A more basic need for a standard stems from the payment for the cost of converted vehicles by third parties. The costs for converting vehicles are often paid by a third party such as an insurance company or funding agency. These costs can be based on a competitive bid process where the lowest cost wins the conversion contract. When a converted vehicle involves the installation of powered adaptive controls, having the manufacturer and dealer/installer follow a recognized standard ensures that the final product will meet a minimum set of safety and quality requirements.

Standardization

In addition to benefitting people engaged in designing, manufacturing and installing powered adaptive controls, a Canadian standard would benefit road safety administration authorities, advisers to people seeking information on powered adaptive control needs, driving rehabilitation specialists, driving instructors, occupational therapists and other health professionals engaged in the rehabilitation of people with physical disabilities.

Having installed powered adaptive controls meeting minimum requirements will also benefit the industry by allowing easier servicing and maintenance of vehicles. Once powered adaptive control components meet a certain recognized specification, replacement of components and general maintenance can be performed by trained personnel in other than the original installation location. In addition, maintenance and repair documentation will meet specific criteria and thereby reduce the chance of a failed system due to improper maintenance procedures. These benefits along with others have the potential to ease liability and insurance risks assumed by the dealer/installer.

6.2 Development of a Canadian Standard

Development of a Canadian standard specifying performance requirements for powered adaptive driving controls can be accomplished in various ways: the standard can be mandated as a regulatory standard that is entirely the product of Transport Canada; the standard can be a consensus developed standard through an organization such as the Canadian Standards Association (CSA); or an established SAE Recommended Practice can be referenced and administered by an industry association such as NMEDA.

It must be stressed that any form of a powered adaptive controls standard that is developed will not substitute for existing standards or guidelines and the requirements of the MVSA. A future Canadian standard should be developed with the intent of including any existing applicable standards/recommended practices.

6.2.1 Implementation Options

Several advantages and disadvantages associated with the above described avenues of approach for implementing a standard for use in Canada are:

1) The SAE Recommended Practices could be directly adopted by Transport Canada for incorporation into the MVSA. The Recommended Practices would need to be released by the SAE. Incorporation in the MVSA is a lengthy process which can take several years to fully review and legislate the recommended practices. This method may also preclude the involvement of the industry and other interest groups. The advantage to this approach is that the implemented standard would be a federal standard and enforced as such. Depending on the applicability stated in the standard, all installations performed by dealer/installers could be regulated and inspected to ensure conformance.

2) The SAE released documents could be used as a seed document by the CSA incorporating a census-type evolution towards creating a CSA standard. Although a more timely approach, this will involve the highest cost and will still involve a lengthy review of the Recommended Practices prior to publishing a CSA standard. The advantage of this approach is the involvement of industry and interest groups in the evolution of the standard and the incorporation of related Canadian specifications and standards by reference. The final CSA standard could be adopted by Transport Canada and referenced in the MVSA or the standard could be incorporated into regulations at the provincial level. The disadvantage is that provinces will have the flexibility to adapt portions of the standard possibly not incorporating the standard in its entirety. This inhibits the advantages of nationwide standardization.

3) The SAE released Recommended Practices could be adopted by an industry association such as NMEDA. This appears to be the most timesaving and cost efficient method of establishing an industry standard. This would also allow the industry to phase in the standard with direct industry involvement and education. The disadvantage to this approach is that the standard would not be legislated and its use would only be enforced by the industry association. Non-members would not be required to follow the standard. This approach is also inconsistent with the intended use of the SAE standards. The standards were originally developed to form the basis for product certification to quality and safety requirements by the manufacturer primarily to guard against low bid sales when third party funding is involved. There is some conflict in potentially having only a portion of the manufacturers working to the standard (NMEDA members) which allows other manufacturers to obtain sales based on lower costs by possibly providing an inferior product.

There are of course other methods of implementing a standard, but the above options appear to be the most likely. The recommended practices would need to be further developed and released by the SAE prior to initiating the above approaches. Therefore, some form of assistance to the SAE Adaptive Devices Committee would directly benefit the further development and release of the documents.

6.3 Adoption of SAE Recommended Practices in Canada

Adopting SAE Standards and Recommended Practices is not uncommon in the development of Canadian Standards. The federal vehicle safety standards (CMVSS) included in the MVSA were primarily developed from established SAE Standards and Recommended Practices. In addition, precedents, like the SAE J1903 Automotive Hand Control Standard have been set where CSA Standards were developed from existing SAE recommended practices/standards.

The review of the SAE draft documents indicates the documents are approximately ninety percent complete. The SAE Adaptive Devices Committee has indicated that funding for validation of the test procedures is the element impeding further development of the Recommended Practices. Although a specific completion date is not available, with this degree of completion, the SAE documents could be released for use in the near future.

It is obvious there has been a great deal of effort expended in developing the documents to their current state. The documents cover many aspects of establishing the manufactured quality, installed utility and performance of automotive powered adaptive controls. The six SAE documents reviewed include the powered adaptive controls determined through this study to be currently in general use in Canada (excluding Quebec), with the exception of servo steering controls. The primary obstacle to directly adopting the SAE final version of the documents as federal standards is the difference in referenced documents. Providing the appropriate references will also distinguish philosophical inconsistencies such as the recent divergence in the mandatory use of supplemental restraints.

6.3.1 Terminology Conflicts

Generally, the terminology of the MVSA is comparable to that used in the SAE documents. The MVSA was originally developed from SAE defined terminology; however, some terminology specific to Canadian references has been incorporated in the MVSA.

6.3.2 Referenced Standards and Specifications

In their current state, the SAE documents exclusively reference other SAE Standards and Recommended Practices and U.S. Federal vehicle safety standards (FMVSS) developed and maintained by the National Highway Traffic Safety Administration, U.S. Department of Transportation. The FMVSS safety standards are very similar to the CMVSS standards; however, there are subtle philosophical differences that have been incorporated over recent years.

In addition, the MVSA is structured differently with respect to specific Canadian legal and legislative techniques. A prime example of this is the requirement for all converted vehicles to be compliant with CMVSS specifications which is enforced by the Road Safety Branch of Transport Canada. This method for regulating vehicle modifications is unique to Canada. Therefore, references for a Canadian powered controls standard may need to be slightly modified to reference existing Canadian standards including CMVSS standards and CSA standards as well as others.

6.3.3 Absence of Servo Steering Guidelines

The revision of the SAE Powered Gas/Brake Control document reviewed did not include guidelines specifically for servo steering controls. The document did not exclude these controls and it is anticipated that the Powered Gas/Brake Control document will be expanded to include servo steering controls. This is supported on the basis of the servo steering control products reviewed which were very similar to the gas/brake servo systems. These systems differ only in the extent of the modifications necessary to install the servo steering system which often requires factory modification of the OEM steering column. The systems function in an identical fashion and allow disconnection of the steering servo motor via a clutch mechanism rendering the steering system operational as designed by the OEM.

6.4 Other Areas for Consideration

The SAE draft documents reviewed have been designed to be applied to a product for certification according to the requirements of the applicable Recommended Practice. Therefore, they do not establish requirements for areas that extend beyond the product itself. This philosophy allows the product to be self-certifiable in that in order for the product to be considered for purchase it must meet the requirements set out in the SAE documents. The following areas, although not covered by the SAE documents should be reviewed in the development of a Canadian standard.

6.4.1 Dealer/Installer Training

The necessity for specifying dealer/installer training in a future standard is dependent on the level of documentation provided by the manufacturer. The SAE documents specify the manufacturer is to supply sufficient information to allow installation of their products including detailing special considerations, electrical and flow diagrams and other installation requirements. However, it may be necessary to specify dealer/installer training as a requirement due to the complicated nature of powered adaptive control systems and the criticality of the OEM systems being modified. This is the approach currently adopted by EMC Incorporated.

6.4.2 Additional Driver Training

Although the specification and regulation of driver training does fall under provincial jurisdiction, the developed standard should include some reference to the necessity for thorough driver training after assessment and prescription by driver rehabilitation specialists. Driver training not only includes training an individual in the safe control of the vehicle in various hazardous situations, but also includes instructing the driver on proper operation of the adaptive controls and backup systems as well as necessary maintenance requirements.

6.4.3 Inclusion of Supplementary Information

The CSA typically includes supplementary information in their standards to provide information not only on the manufacture and design of products, but also on the application of the product and the safe use of the product. The advisory section of CSA standards typically presents valuable information which is not a mandatory part of the standard. Areas for consideration may include:

- abilities of the user;
- licensing requirements;
- vehicle selection;
- a test report format;

- factory vehicle options;
- ergonomic considerations; and
- advisory notes.

This type of information may be provided as appendices to a standard or possibly in the form of advisory circulars issued by the governing agency. This may also be an optimal location for driver training information.

7 CONCLUSIONS AND RECOMMENDATIONS

From the results of this study the following conclusions can be drawn:

- The following SAE Draft Recommended Practices were reviewed:
  - Recommended Practice and Recommended Test Procedure for Powered Gas/Brake Control Systems;
  - Recommended Practice and Recommended Test Procedure for Reduced Effort Power Steering and Power Steering Backup Systems; and
  - Recommended Practice and Recommended Test Procedure for Reduced Effort Power Brakes and Vacuum Powered Brake Backup Systems.

  These documents were found to cover the specifications and associated test procedures necessary for regulating the design, manufacture, performance and installed utility, of powered automotive adaptive controls. In addition, the Recommended Practices provide specifications on documentation, warranty, markings and labeling, and recall requirements.

- The major items missing from the SAE documents are: the absence of driver training and instruction guidelines and specifications for servo steering controls. The servo steering controls are anticipated to be incorporated in future revisions of the Recommended Practices. It is recommended to review existing driver training/instruction regulations and provide this as supplementary information preferably in the form of an appendix to a standard or as advisory circulars.

- The most efficient method of implementing a standard in Canada is the direct adoption of the released SAE documents by a recognized industry association such as NMEDA. This method reduces both development time and financial expense, and increases the probability of acceptance. This method also ensures the standard will be implemented nationwide and not restricted to the decisions of provincial governments.

- The disadvantage to an industry standard is that it would only be used on a voluntary basis by manufacturers and dealer/installers outside the NMEDA membership. Encouraging NMEDA membership would aid in establishing the standard as providing a set of minimum quality and safety requirements especially for third party funding arrangements where the lowest price often wins the sale.

- Assistance provided to the SAE Adaptive Devices Committee would expedite the release of the recommended practices and test procedures and therefore expedite any of the options chosen for adopting the recommended practices as a Canadian standard.

- As with any other road safety based initiative, registration of accidents involving converted or modified vehicles for use by persons with disabilities is necessary to identify potential problems not foreseen in the initial development of a standard. Therefore, it is recommended that the Road Safety Branch of Transport Canada initiate registration of accidents involving converted vehicles.

- Finally, it is recommended that future work focus on developing standards for the design, manufacture and installation of Group B Primary Controls and accessory controls.

APPENDIX A

POWERED ADAPTIVE CONTROLS
PRODUCT INFORMATION

Product Description #1

Manufacturer

Ahnafield Corporation Incorporated
3219 West Washington Street
Indianapolis, Indiana
46222, U.S.A.
Tel: (317) 636-8061
Fax: (317) 636-8098

Product Description

In addition to many other products, Ahnafield Corporation produces three powered adaptive control products: the Joy-Stick Driving Control, the Power Assist Hand Control (PAC) Unit and the XL Steering System. The PAC Unit is a servo mechanism that operates automotive brake and accelerator controls. The brake and accelerator controls utilize a joystick type control to activate an electronic microprocessor which controls hydraulic cylinder actuators.

Similarly, Ahnafield's XL Steering System and Joy-Stick Driving Control both use a mechanically controlled hydraulic servo steering system. The steering control is a closed loop proportional position control system. The systems are installed parallel to the OEM steering system to allow operation of the vehicle by the OEM steering wheel or the steering system input device depending on the position of a single switch.

Other products from Ahnafield include the Acc-u-trol Secondary Control Centre which is a computer controlled device capable of operating forty-eight accessory functions. All of these products are available as options on Ahnafield's full conversion vans which can also include wheelchair lifts.

Vehicle Application

Ahnafield's adaptive control products can be installed in Chevrolet, Dodge or Ford mini and full size vans.

Installation Requirements

Installation details were not supplied by the manufacturer as this was considered proprietary information.

Vendor Experience/Market Presence

Ahnafield Corporation was selected since they are considered the second largest manufacturer of powered adaptive controls. Ahnafield currently does not export products to Canada.

Information Source

Product and manufacturer information was obtained from the following sources:

- manufacturer's brochure/sales data; and
- contact with manufacturer’s office.

Product Description #2

Manufacturer

Assistive Technology International Incorporated
65 Ryan Drive, Unit F-5
Raynham, Massachusetts
02767, U.S.A.
Tel: (508) 884-8970
Fax: (508) 884-8961

Product Description

Assistive Technology International (ATI) Inc. manufactures remote control servo operated systems for steering, braking and accelerator controls. The XLS 300 Steering Control utilizes a mechanical, hydraulic closed loop servo system for actuating the OEM steering control. The ABC 300 Accelerator/Brake Control utilizes an electric servo system to operate the OEM brake and accelerator pedals. Both systems incorporate built in automatic backup systems. The OEM air bags are retained and the steering control can be changed from the OEM system to the XLS system by flipping a switch.

Vehicle Application

ATI's adaptive control products can be installed in Chevrolet, Dodge or Ford mini and full size vans.

Installation Requirements

The interface requirements of ATI's powered adaptive controls, were not disclosed due to their current development. ATI is currently documenting procedures which they have been using in training courses offered both at the factory and at the dealer/installer location.

Vendor Experience/Market Presence

Bob Alba, Designer for ATI has been involved in designing and developing powered adaptive controls for many years. ATI is now in the process of progressing towards producing larger quantities of their products.

Information Source

Product and manufacturer information was obtained from the following sources:

- manufacturer's brochure/sales data; and
- contact with manufacturer's office.

Product Description #3

Manufacturer

Drive-Master Incorporated
9 Spielman Road,
Fairfield, New Jersey
07004-3403, U.S.A.
Tel: (201) 808-9709
Fax: (201) 808-9713

Product Description

Drive-Master Incorporated markets a number of products for drivers with disabilities. Pertinent to this study are the steering and braking modifications Drive-Master performs for customers to OEM vehicle components. In addition, Drive-Master manufacturers backup systems for modified brake and steering systems. The OEM systems are either modified from a vehicle delivered to Drive-Master or the OEM components are sent to Drive-Master for modification.

No Effort and Reduced Effort Steering

Th reduced effort modification to the O.E.M. steering system will reduce the effort required to steer the vehicle by approximately 45% (from 40 ounces to 20-24 ounces of effort). The zero effort system modification will reduce the required steering effort by approximately 83% (from 40 ounces to 6-8 ounces of effort).

Backup Steering System

The Backup Steering System is designed to automatically activate upon failure of the OEM power steering system. The backup system incorporates a separate fluid reservoir and a hydraulic pump which produces the necessary fluid pressure for power assistance. The system also incorporates a test circuit and visual/auditory alarms to alert the driver of an OEM system failure.

No-Effort and Reduced Effort Braking

Drive-Master's low-effort modification reduces the force required to apply OEM power brakes by 45% (from 20 to 11 ft.lbs of moment). The no-effort modification reduces the actuating force by 65% (from 20 to 7 ft.lbs of moment).

Backup Braking System

Backup braking system provides emergency power assisted braking if the OEM power brake system fails due to engine failure or low vacuum. The system automatically activates when engine vacuum drops below a satisfactory operating level. The system utilizes a vacuum storage tank which provides the vacuum power assistance.

Vehicle Application

Both steering and braking modifications are available for all American vans and most American and Foreign cars with factory power brakes and power steering. Full-size General Motors and Chrysler (Dodge/Plymouth) cars, the 1/2 Ton Chevy (G10) and the Dodge/Plymouth (B100) vans must have heavy duty (tandem) power brakes for no-effort brake system modifications.

Installation Requirements

Vehicle modifications are required to the OEM steering box or rack and pinion steering assembly of the vehicle for reduced effort steering and the OEM vacuum booster for reduced effort braking systems. The modifications are performed at the Drive-Master factory and installed by a dealer/installer in the vehicle according to OEM installation procedures.

Vehicle modifications are also required to install the backup systems, but systems require installing components in various locations on the vehicle. The backup systems are also connected to the modified OEM power assist components which requires the installation of hoses, valves and electrical connections as well as indicators for alerting the driver.

Vendor Experience/Market Presence

Drive-Master has been in the business of providing mobility products to persons with disabilities since 1952. They currently supply a large profile of driving aids including manual controls, powered controls, steering devices, wheelchair lifts and complete van conversions.

Information Source

Product and manufacturer information was obtained from the following sources:

- manufacturer's brochure/sales data; and
- contact with manufacturer’s office.

Product Description #4

Manufacturer

Electronic Mobility Controls, Incorporated
2001 Wooddale Boulevard
Baton Rouge, Louisiana
70806, U.S.A.
Tel: (504) 927-5558
Fax: (504) 924-5556

Product Description

Electronic Mobility Controls Inc. (EMC) produces a large range of powered adaptive control products which allow operation of a vehicle by persons with disabilities. EMC produces the DS-2000 Digital Steering System, the EGB-IIF Throttle/Brake Control and the Digidrive II Digital Joystick Driving System. The DS-2000 system uses an electric steering servo motor, the EGB-IIF uses an electric throttle/brake servo motor and the Digidrive system utilizes both the throttle/brake and steering servo motors.

All EMC products are digital operating via microprocessor control. The electrical signals from an input device are fed to a microprocessor which actuates either an accelerator/brake servo motor or a steering servo motor. The steering servo motor is not visible to the driver as it is integrated with the OEM steering column and the accelerator/brake servo motor is mounted to the vehicle floor. The accelerator/brake servo incorporates an accelerator cable and a brake drive arm to apply the OEM controls. Both servos also incorporate an encoder for transmitting feedback information to a controller. The EGB-IIF system incorporates a sliding joystick lever integrated with the controller whereas the DS-2000 and Digidrive systems require a separate input device and controller.

EMC also manufacturers an electric parking brake which is an integral part of the backup system. The electric parking brake can also be automatically coupled to the accelerator/brake input joystick to apply the parking brake whenever the joystick is moved to the full brake position.

EMC Inc. specifies stringent requirements to maintain reliability of the installed systems. For example the touchpad controls exhibit electrical and mechanical life of 480,000 cycles computed on 8 switches at 60,000 cycles each. The modular electrical connectors are tested to 750 mating cycles. The functional relays are tested at 10 g shock input levels at 10-55 Hz frequency with a double amplitude of 2 mm and destructive tested at 100 g shock level. The relays have a contact life of 100,000 cycles at a nominal load.

Vehicle Application

The EGB-IIF Digital Gas/Brake Driving System is designed to operate the accelerator and brake of virtually any vehicle equipped with an automatic transmission and power brakes. The DS-2000 Digital Steering System is adaptable to virtually any vehicle equipped with power steering as installation of the system does not require modification to the OEM steering column nor the OEM steering gear or pump.

Vehicle Installation Requirements

The installation of the EGB-IIF system requires the mounting of an input device and the gas/brake servo motor. The installation of the DS-2000 steering system requires sending the OEM steering column to the factory for installation of the servo motor. The remainder of the components for the steering system and the Digidrive system requires the mounting of the controller and joystick input device. The systems also require electrical connection to the engine management system to indicate when engine failure has occurred.

The installation of EMC products does not affect the vehicle's original air bag supplemental restraint and anti-lock brakes, if equipped. The original accelerator and brake pedals are not altered and the vehicle remains completely operable by nondisabled drivers after installation.

Vendor Experience/Market Presence

EMC Inc. is the largest manufacturer of powered adaptive controls. EMC has over 100 factory trained dealers in North America including large vehicle modification companies such as Braun Mobility and Ricon. EMC Inc. has distributors in U.S.A., Canada, Scandinavia, the United Kingdom, France, Switzerland, Germany, Israel, Saudi Arabia, and Puerto Rico.

Information Source

Product and manufacturer information was obtained from the following sources:

- manufacturer's brochure/sales data;
- product installation manuals;
- product owners manuals;
- contact with product installers/dealers; and
- contact with manufacturer's office.

Product Description #5

Manufacturer

KVB Manufacturing
62 Maple Avenue N.
Smiths Falls, Ontario
Canada, K7A 2A7
Tel: (800) 565-9845
Fax: (613) 283-9882

Product Description

KVB Manufacturing primarily modifies vehicles, other than vans or minivans, for incorporation of the Elaine Anne Lift System. The lift system is designed for the driver position of in various General Motors vehicles. The company also installs a unique powered swivel seat for passenger and driver positions.

KVB Manufacturing installs reduced effort steering and braking components which carry a GM part number and are directly installed in their modified GM vehicles replacing supplied OEM components. KVB does not install backup systems for their reduced effort steering and braking systems.

Vehicle Application

KVB Manufacturing performs modifications to General Motors vehicles including Tahoe/Yukon, Extended Cab Pickup Trucks and Suburbans.

Installation Requirements

The installation requirements for KVB's reduced effort systems are minimal since GM specific components are installed according to OEM specified procedures.

Vendor Experience/Market Presence

KVB has been converting vehicles for a number of years and has continuously refined the development of their products for persons with disabilities.

Information Source

Product and manufacturer information was obtained from the following sources:

- manufacturer's brochure/sales data; and
- contact with manufacturer's office.

Product Description #6

Manufacturer

Ricon Canada Incorporated
4870 Courval Street
Ville St-Laurent, Quebec
Canada, H4T 1L1
Tel: (514) 342-5000
Fax: (514) 342-2600

Product Description

Ricon is an international company manufacturing and installing a wide range of products for persons with disabilities. Some of the products from Ricon include a variety of wheelchair lifts, 6-way power seat bases, and fully converted vehicles for various applications. Ricon also installs adaptive control products from other manufacturers and performs modifications to OEM power assist components to produce reduced effort brake and steering systems. Ricon also installs backup steering and brake systems from other manufacturers with modifications as necessary depending on the vehicle application.

Vehicle Application

Ricon primarily modifies mini and full size vans, however, modifications to produce reduce effort systems could be accomplished on virtually any vehicle with factory power brakes and power steering.

Installation Requirements

Installation requirements are identical to those described in Drive-Master Inc. product description. In certain instances, the ABS brakes of a vehicle may need to be disconnected due to error signals introduced by modifying the OEM power brake system.

Vendor Experience/Market Presence

The Ricon Group is a collection of companies providing a variety of products for persons with disabilities. The group has a long history in the vehicle conversion industry and currently supplies products to other installers, as well as performing full vehicle conversions.

Information Source

Product and manufacturer information was obtained from the following sources:

- manufacturer's brochure/sales data;
- visit to manufacturing facility; and
- contact with manufacturer’s office.

Product Description #7

Manufacturer

Wells-Engberg Company Incorporated
P.O. Box 6388
Rockford, Illinois
61125, U.S.A.
Ph: (815) 227-9765
Fax: (815) 227-9737

Product Description

Wells-Engberg Inc. produces various types of adaptive driving controls primarily manually non-powered controls. The company also manufactures a pneumatic accelerator and brake powered adaptive control system. The system uses pneumatic cylinders to actuate the OEM brake and accelerator pedals. The system incorporates an accumulator tank, compressor, filter with integral air drier and automatic drain, and electrical controls. The backup to the system is provided by the accumulator storage tank.

The system has a unique feature of allowing the accelerator to be depressed prior to starting the vehicle engine so that the choke on some vehicles can be trip activated. The electrical control box of the system incorporates a green light indicating the system is fully functional and a red light indicating low vacuum pressure which includes an audible warning as well.

Vehicle Application

The controls are described as being supplied with a complete and concise installation manual and can be installed on most cars, vans and light trucks in a few hours by a qualified mechanic.

Installation Requirements

Vehicle installation requirements include mounting of a pneumatic power pack, an electrical control box, cylinders for the brake and accelerator pedals, and an operator control box. These products are mounted in the vehicle interior and connected by means of pneumatic hoses and electrical wiring. Other than attaching to the OEM brake and accelerator pedals, there are no other vehicle modifications required. Installation of components will require simple attachment of components to the vehicle floor pan and/or structural members.

Vendor Experience/Market Presence

Mobility products for persons with disabilities are the only products provided by Wells-Engberg and are therefore, the focus of their work. The controls are made of high quality materials and are provided with a one year warranty.

Information Source

Product and manufacturer information was obtained from the following sources:

- manufacturer's brochure/sales data; and
- contact with manufacturer’s office.

APPENDIX B

BIBLIOGRAPHY

SAE Draft Document
Recommended Practice for Reduced Effort Power Steering and Power Steering Backup Systems
November 15, 1996

SAE Draft Document
Recommended Test Procedure for Reduced Effort Power Steering and Power Steering Backup Systems
November 15, 1996

SAE Draft Document
Recommended Practice for Powered Gas/Brake Control Systems
September 19, 1997

SAE Draft Document
Recommended Test Procedure for Powered Gas/Brake Control Systems
September 19, 1997

SAE Draft Document
Recommended Practice for Reduced Effort Power Brakes and Vacuum Powered Brake Backup Systems
November 15, 1996

SAE Draft Document
Recommended Test Procedure for Reduced Effort Power Brakes and Vacuum Powered Brake Backup Systems
November 15, 1996

Institution of Mechanical Engineers (1990)
Guidelines on the Adaptation of Car Controls for Disabled People
Automotive Division, Institution of Mechanical Engineers,
London, England

AS 3954.1— 1991
Motor Vehicle Controls — Adaptive Systems for People with Disabilities
Part 1: General Requirements
Standards Association of Australia
Australia

Design Guidelines
National Mobility Equipment Dealers Association
909 E. Skagway Avenue
Tampa, Florida
33604, U.S.A.

Standards for Automotive Adaptive Equipment and Vehicle Modification
Texas Rehabilitation Commission
4900 North Lamar Blvd.
Austin, Texas
78751-2316, U.S.A.

Driving Controls for People with Disabilities
New Zealand Standard NZS 5832:Part 1:1988
Standards Association of New Zealand
Wellington Trade Centre
181-187 Victoria Street
Wellington 1, New Zealand

Hand Controls and Assistive Devices for the Physically Disabled Driver
Research and Training Institute
National Centre on the Employment of the Handicapped
Human Resources Centre
Albertson, New York
11507, U.S.A.

Automotive Adaptive Driving Controls for Persons with Physical Disabilities
Document No. Z323.1.2-94
Canadian Standards Association
178 Rexdale Boulevard
Etobicoke (Toronto)
Ontario, Canada
M9W 1R3

Persons with Disabilities and Converted Vehicles
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