TP 13246E

EVALUATION of SIX-WAY TRANSFER SEAT BASES

Prepared for
Transportation Development Centre
Safety and Security
Transport Canada

September 1998

Prepared by
Murray Sturk, P.Eng.
TES Limited

This report reflects the views of the author and not necessarily those of the Transportation Development Centre.

The Transportation Development Centre does not endorse products or manufacturers. Trade or manufacturers' names appear in this report only because they are essential to its objectives.

Un sommaire français se trouve avant la table des matières.

Transport Canada | Transports Canada

PUBLICATION DATA FORM

1. Transport Canada Publication No.: TP 13246E

2. Project No.: 9299 (8597)

3. Recipient's Catalogue No.:

4. Title and Subtitle: Evaluation of Six-Way Transfer Seat Bases

5. Publication Date: September 1998

6. Performing Organization Document No.:

7. Author(s): Murray Sturk

8. Transport Canada File No.: ZCD1450-103-121

9. Performing Organization Name and Address:
TES Limited
308 Legget Drive
Ottawa, Ontario
K2K 1Y6

10. PWGSC File No.: XSD94-00062-(671)

11. PWGSC or Transport Canada Contract No.: T8200-4-4508

12. Sponsoring Agency Name and Address:
Transportation Development Centre (TDC)
800 René Lévesque Blvd. West
6th Floor
Montreal, Quebec
H3B 1X9

13. Type of Publication and Period Covered: Final

14. Project Officer: Barbara A. Smith

15. Supplementary Notes (Funding programs, titles of related publications, etc.)

16. Abstract

TES Limited was contracted by the Transportation Development Centre to acquire three commonly prescribed six-way power transfer seat bases and to conduct an engineering analysis of their ability to withstand crash impact forces.

The work conducted in the course of this project involved several aspects:

- Reviewing relevant standards and recommended practices regarding seat and seat belt testing;
- Obtaining and examining three representative six-way transfer seat bases;
- Performing computer simulations on a representative six-way transfer seat base model; and
- Performing static pull tests on three representative six-way transfer seat bases.

The major results of the study were that all three representative six-way transfer seat bases withstood seat inertial forces commensurate with 20 g's of acceleration in the longitudinal direction, but that when combined with seat belt loads (as prescribed by CMVSS 207 and CMVSS 210) all three representative six-way transfer seat bases permanently deformed and failed to retain their original position.

It was evident from the results of the physical tests that while the six-way transfer seat bases examined were capable of supporting the vehicle seat under a simulated crash impact, they were not capable of additionally supporting part of the seat belt loads under simulated crash impacts.

Further research into how the six-way transfer seat base can be modified to support both seat inertial and seat belt loading is recommended.

17. Key Words: Six-way transfer seat bases, power seat bases, mobility aids, CMVSS 207, CMVSS 210

18. Distribution Statement: Limited number of copies available from the Transportation Development Centre

19. Security Classification (of this publication): Unclassified

20. Security Classification (of this page): Unclassified

21. Declassification (date): —

22. No. of Pages: xii, 20, apps

23. Price: —

Transports Canada / Transport Canada

FORMULE DE DONNÉES POUR PUBLICATION

1. N° de la publication de Transports Canada TP 13246E	2. N° de l'étude 9299 (8597)	3. N° de catalogue du destinataire
4. Titre et sous-titre Evaluation of Six-Way Transfer Seat Bases		5. Date de la publication Septembre 1998 6. N° de document de l'organisme exécutant
7. Auteur(s) Murray Sturk		8. N° de dossier - Transports Canada ZCD1450-103-121
9. Nom et adresse de l'organisme exécutant TES Limited 308 Legget Drive Ottawa, Ontario K2K 1Y6		10. N° de dossier - TPSGC XSD94-00062-(671) 11. N° de contrat - TPSGC ou Transports Canada T8200-4-4508
12. Nom et adresse de l'organisme parrain Centre de développement des transports (CDT) 800, boul. René-Lévesque Ouest 6e étage Montréal (Québec) H3B 1X9		13. Genre de publication et période visée Final 14. Agent de projet Barbara A. Smith

15. Remarques additionnelles (programmes de financement, titres de publications connexes, etc.)

16. Résumé

Le Centre de développement des transports a confié à TES Limited un marché qui consiste à soumettre à des essais techniques trois des bases de siège électriques à six positions les plus couramment prescrites, en vue d'évaluer leur résistance aux charges résultant d'un choc dû à une collision.

Les travaux réalisés dans le cadre de ce marché comportaient plusieurs étapes :

- étudier les normes et pratiques recommandées pertinentes touchant l'essai de sièges et de ceintures de sécurité;
- obtenir et étudier trois bases de siège électriques à six positions représentatives;
- réaliser des simulations numériques sur un modèle représentatif des bases de siège électriques à six positions;
- réaliser des essais statiques de traction sur trois bases de siège électriques à six positions représentatives.

L'étude a permis d'établir la capacité des trois bases de siège électriques à six positions retenues de résister à l'application d'une force d'inertie égale à une accélération longitudinale de 20 g. Mais l'application simultanée des charges prescrites pour la ceinture de sécurité (selon les NSVAC 207 et 210) a entraîné la déformation permanente et le déplacement des trois bases.

Les résultats des essais mécaniques ont clairement démontré la capacité des bases de siège électriques étudiées de résister à la force engendrée par une collision simulée, mais non à la force totale appliquée, lorsque les charges associées à la ceinture de sécurité sont également prises en compte.

Il est recommandé d'effectuer des recherches sur les modifications à apporter à la base de siège pour qu'elle puisse résister à la fois à la force d'inertie du siège et aux charges maximales prescrites pour la ceinture de sécurité.

17. Mots clés Sièges électriques à six positions, base de siège électrique, aides à la mobilité, NSVAC 207, NSVAC 210	18. Diffusion Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

19. Classification de sécurité (de cette publication)	20. Classification de sécurité (de cette page)	21. Déclassification (date)	22. Nombre de pages	23. Prix
Non classifiée	Non classifiée	—	xii, 20, ann.	—

SUMMARY

Over the last several years, a number of automotive adaptive products have been introduced into the commercial marketplace to enable persons with physical disabilities to operate passenger vehicles. One of these adaptive products, the six-way power transfer seat base, is used to facilitate the transfer of the user from a wheelchair to the driver's seat of a suitably-equipped passenger vehicle. The six-way transfer seat base is typically capable of a wide range of motion including vertical and longitudinal translation, and rotation (swivel) about the vertical axis. In most, if not all cases, it is designed to interface with the original equipment manufacturer (OEM) driver's seat.

A concern has been raised regarding the safety of this adaptive product in the event of a crash impact, whereby the forces imposed on it can be quite severe. This project was initiated to provide information on the ability of the six-way transfer seat base to sustain crash impact forces and maintain relative position within the vehicle.

The work conducted in the course of this project involved several aspects:

- Reviewing relevant standards and recommended practices with respect to seat and seat belt testing;
- Obtaining and examining three representative six-way transfer seat bases;
- Performing computer simulations on a representative six-way transfer seat base model; and
- Performing static pull tests on three representative six-way transfer seat bases.

An extensive review of existing publications and standards describing seat and seat belt testing methods was conducted. Numerous Society of Automotive Engineers (SAE) and Canadian Motor Vehicle Safety Standards (CMVSS) and recommended practices pertaining to seat and seat belt testing were reviewed. Computer models were developed to simulate the loads imparted to the six-way transfer seat bases during crash impacts. Finally, static pull tests were performed on three representative six-way transfer seat bases to compare with the computer simulations.

The major results of the study are:

- All three of the transfer seat bases tested withstood a static load equivalent to 20 times the combined weight of the entire seat assembly, applied horizontally (in both the forward and rearward direction) through the combined centre of gravity location. The seat assembly comprised a representative OEM seat weighing 15.5 kg (34 lb), and the six-way transfer seat base;
- None of the three six-way transfer seat bases tested was able to sustain the simultaneous application of the 20 times combined seat assembly weight and the 26,688 N (6,000 lb) seat belt assembly load comprising 13,344 N (3,000 lb) applied to both the pelvic and torso body blocks.

In conclusion, there is a significant probability that current state-of-the-art six-way transfer seat bases, when installed in conjunction with OEM seats, which retain the original inboard seat belt buckle assembly, will experience structural failure when subjected to loads commensurate with a 48 km/h (30 mph) frontal crash impact.

SOMMAIRE

Au cours des dernières années, sont apparues sur le marché diverses aides à la conduite conçues pour permettre aux personnes handicapées physiques de prendre le volant d'un véhicule de tourisme. Parmi ces aides, figure le siège électrique à six positions, qui facilite le transfert d'un fauteuil roulant au siège du conducteur d'un véhicule correctement adapté. Ce siège peut prendre une large gamme de positions : réglable en hauteur et d'avant en arrière, il peut aussi pivoter autour d'un axe vertical. Dans la plupart des cas, sinon tous, le siège électrique est constitué d'une base à laquelle est fixé le siège d'origine du véhicule.

Des inquiétudes ont été exprimées quant à la sûreté de ces sièges en cas d'accident, c'est-à-dire lorsqu'ils sont soumis à des forces qui peuvent être très grandes. Ce projet avait pour but de fournir des données sur la capacité des bases de siège électriques à six positions de résister aux forces en jeu lors d'une collision et de demeurer en place à l'intérieur du véhicule.

Les travaux réalisés dans le cadre de ce projet comportaient plusieurs étapes :

- étudier les normes et pratiques recommandées pertinentes touchant l'essai de sièges et de ceintures de sécurité;
- obtenir et étudier trois bases de siège électriques à six positions représentatives;
- réaliser des simulations numériques sur un modèle représentatif des bases de sièges électriques à six positions;
- réaliser des essais statiques de traction sur trois bases de siège électriques à six positions représentatives.

L'étude a d'abord pris la forme d'un vaste inventaire des publications et normes existantes concernant les méthodes d'essai des sièges et des ceintures de sécurité. Plusieurs pratiques recommandées de la Society of Automotive Engineers (SAE) et Normes de sécurité des véhicules automobiles du Canada (NSVAC) se rapportant à l'essai des sièges et des ceintures de sécurité ont été examinées. Des modèles numériques ont été développés pour simuler les charges exercées sur les bases de siège électriques à six positions lors du choc dû à une collision. Enfin, des essais statiques de traction ont été menés sur trois bases de siège représentatives, dont les résultats ont été comparés avec ceux des simulations par ordinateur.

Voici les principaux résultats sur lesquels l'étude a débouché :

- Les trois bases de siège électriques à six positions soumises aux essais ont supporté l'application d'une charge statique égale à 20 fois le poids du siège (base et siège comme tel) dans le sens longitudinal (tant vers l'avant que vers l'arrière), au centre de gravité de l'ensemble. Le siège était constitué d'un siège de série représentatif, d'un poids de 15,5 kg (34 lb), et de la base.
- Aucune des trois bases de siège électriques à six positions mises à l'essai n'a résisté à l'application simultanée de la force égale à 20 fois le poids du siège et de la charge de 26 688 N (6 000 lb) associée à la ceinture de sécurité, dans

laquelle est comprise une force de 13 344 N (3 000 lb) appliquée aux ancrages de la ceinture sous-abdominale et de la ceinture-baudrier.

En conclusion, il existe un degré significatif de probabilité que les bases de siège électriques à six positions répondant à l'état de la technique, et recevant le siège du conducteur équipant le véhicule standard et muni de la ceinture de sécurité d'origine, subissent des dommages structurels lorsque soumises aux charges résultant du choc d'une collision frontale à une vitesse de 48 km/h (30 mi/h).

TABLE OF CONTENTS

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.

Anchorage - The final point of attachment for transferring seat belt assembly loads to the vehicle structure (from SAEJ383).

Automotive Adaptive Product - A piece of equipment designed to enable a person to operate an automotive vehicle (from SAE J2094).

CoG (Centre of Gravity) - The centre of mass of in an assembly of separate mass particles.

CMVSS - Canadian Motor Vehicle Safety Standard.

H Point - See definition for SRP.

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.

SAE - Society of Automotive Engineers.

Seat Adjuster - A device anchored to the structure which supports the seat frame assembly and provides for seat adjustments in the longitudinal and/or vertical direction. This includes any track, link, or power actuating assemblies necessary to adjust the position of the seat (from SAE J879b).

Seat Frame - The structural portion of a seat assembly. The frame may be constructed with springs attached directly to the structural frame or with the springs attached as a separate assembly (from SAE J879b).

Six-Way Transfer Seat Base (Transfer Seat Base) - See Transfer Seat Base.

Six-way Under Test (SUT) - A term used in this report to refer to a representative six-way transfer seat base subjected to physical testing.

SRP (Seat Reference Point) - The Design H-Point with the seat in the rearmost, lowest normal design position. The “Design H-Point” has co-ordinates relative to the design vehicle structure. It is located at the H-Point of the two-dimensional drafting template placed in any designated seating position (from SAE J383).

Transfer Seat Base - A powered seat base that provides additional seat travel to facilitate movement of the handicapped user to and from the seat. This includes the following (from SAE J2094):

- Two-way transfer seat base
- Four-way transfer seat base
- Six-way transfer seat base
- Eight-way transfer seat base.

1. INTRODUCTION

1.1 Scope

This project was initiated in response to a concern for the safety of persons who have had installed, or are intending to install, in their personal vehicles six-way transfer seat bases (transfer seat bases). These transfer seat bases are normally installed between the vehicle floor pan and the OEM seat assembly. The primary objective of this project was to study the ability of three representative transfer seat bases to sustain the forces commensurate with a 48 km/h (30 mph) crash impact.

The evaluation performed during the course of study involved two phases:

1. An engineering evaluation was performed using a simplified computer model to simulate a representative transfer seat base subjected to calculated seat and occupant inertia loads; and
2. Static pull tests were conducted on three representative transfer seat bases.

This report details the results of the engineering analysis and the physical tests and provides recommendations for a follow-up investigation.

1.2 Report Structure

The main body of the report is organized into the following sections:

1. **Introduction.** This section provides a general overview of the purpose and objectives of the evaluation study;
2. **Standards and References.** This section lists the CMVSS and SAE Standards and References that are relevant to seat and seat belt testing;
3. **Engineering Analysis.** This section describes the visual inspection and stress analysis performed on the Transfer Seat Bases;
4. **Testing.** This section describes the test approach and test procedures;
5. **Results.** This section describes the results from the evaluation study;
6. **Conclusions.** This section lists the main findings of the report; and
7. **Recommendations.** This section provides recommendations for a follow-up investigation of important issues related to Transfer Seat Bases.

2. STANDARDS and REFERENCES

The standards, recommended practices, and references reviewed in the preparation of this report are listed in sections 2.1 and 2.2.

2.1 Canadian Motor Vehicle Safety Standards (Consolidated):

1. MVSR 207 Anchorage of Seats;
2. MVSR 208 Seat Belt Installations; and
3. MVSR 210 Seat Belt Assembly Anchorages.

2.2 Society of Automotive Engineers Standards (1993 SAE Handbook):

1. SAE J117 Dynamic Test Procedure - Type 1 and Type 2 Seat Belt Assemblies;
2. SAE J383 Motor Vehicle Seat Belt Anchorages - Design Recommendations;
3. SAE J384 Motor Vehicle Seat Belt Anchorages - Test Procedure;
4. SAE J385 Motor Vehicle Seat Belt Anchorages - Performance Requirements;
5. SAE J782b Motor Vehicle Seating Manual;
6. SAE J826 Devices For Use In Defining and Measuring Vehicle Seating Accomodation;
7. SAE J879b Motor Vehicle Seating Systems; and
8. SAE J2094 Vehicle and Control Modifications For Drivers With Physical Disabilities - Terminology.

3. ENGINEERING ANALYSIS

3.1 Initial Evaluation of Representative Transfer Seat Bases

During this project's initiation phase, TES consulted with a number of persons with experience in the field of mobility aids to select three models of six-way transfer seat bases (transfer seat bases) that could be considered representative of industry products or current "state-of-the-art". Persons consulted included Occupational Therapists and other professionals who prescribe mobility aids, mobility aid manufacturers, and Transport Canada officials. The aim was to select a sufficient number and variety of six-way transfer seat bases to encompass a large field of presently available products. Based on these consultations, three representative six-way transfer seat bases were selected and are listed below (in alphabetical order):

1. B&D Model 908D;
2. Braun Model 13085A; and
3. Ricon Model R-1208.

All three transfer seat bases that were obtained for the investigation can be considered state-of-the-art and are representative of transfer seat bases currently being sold for installation in medium- to full-size vans.

As part of the initial evaluation, all three transfer seat bases were visually examined with respect to physical geometry and construction details. Engineering sketches were produced and are presented in Appendix H of this report. All three transfer seat bases were found to share many similar design features, including:

- a rectangular base or frame, supporting the transfer seat base assembly, intended for bolting to the vehicle floor pan;
- a seat base, with multiple bolt hole arrangements, to which the OEM seat assembly is fastened;
- a hinged "scissors" or parallelogram structure powered by a direct current (DC) linear drive motor; used to raise or lower the seat base;
- a pinion and spur gear arrangement powered by a DC right angle drive motor used to provide "swivel" or rotational movement of the seat base about the vertical axis;
- a pinion and rack gear arrangement powered by another DC right angle drive motor used to provide longitudinal translation of the entire Transfer Seat Base (excluding frame) assembly; and
- a control box with three rocker switches for controlling movement in the vertical, fore/aft, and "swivel" directions.

There were, however, several notable differences among the three transfer seat bases. For example, the B&D 908D model came equipped with a limit stop used to set the final forward longitudinal movement of the Transfer Seat Base after final installation. It was not manually adjustable and would require the user to be in attendance during (some part of) the installation. The B&D 908D also came equipped with a right angle bracket/lug assembly. The installation instructions accompanying the B&D 908D did not explain the purpose of this bracket. However, it is shown in a promotional photograph as being installed on the rear right hand side of the upper base platform (the platform at the top of the transfer seat base) in close proximity to the OEM driver's inboard seat buckle assembly. It is evident that this bracket is intended as a seat belt anchor.

The RICON R-1208 was sold to TES without assembly instructions. There were no ancillary brackets accompanying the R-1208 that could be used to mount a seatbelt anchor.

The BRAUN 13085A did not have a scissors type lift arrangement, but rather used a parallelogram type of lift mechanism. The installation instructions accompanying the BRAUN 13085A did not specifically mention how the OEM seat belt anchors were to be dealt with; however, the instructions did include the following note: "Remove any safety belt securement devices and mounting hardware attached to the seat/base assembly. Keep this equipment for reinstallation." There was no further instruction given on how to re-install the previously removed seat anchors. The BRAUN 13085A was the only one of the three Transfer Seat Bases that came equipped with a circuit breaker.

3.2 Controls and Operation

The project's scope did not entail extensive testing for human factors. For example, rate of travel under load measurements does not appear to be required under CMVSS, although the recommendations of SAE J782b, 2.5.1.2 for powered seat adjusters appear to be a reasonable design goal. However, all three transfer seat bases were activated and checked for general smoothness of operation in all three modes of travel (fore/aft, up/down, swivel).

3.3 Computer Analysis

In order to determine the loads imposed on the Transfer Seat Bases, and hence the stresses in the critical components, a number of computer analyses were performed. The input forces and torques used in the computer analysis were derived after careful consideration of the applicable Standards (listed in Section 2) as discussed in the following sections.

3.3.1 Loading Configurations

The loads imparted to seat assemblies during vehicle crash impacts can not only be quite severe but can assume an infinite variety of form (magnitude vs duration) and direction. It was not within the scope of this project to determine probable crash impact forces on seat assemblies but rather to evaluate how previously determined seat and seat belt loads would affect the transfer seat bases. Therefore, the loading configurations considered in this evaluation were based upon CMVSS 207, 208, and 210. In interpreting the actual requirements of these standards, the corresponding SAE Standards (listed in Section 2) were also reviewed.

Based on the review of the associated standards, the loads imposed upon seat assemblies (and Transfer Seat Bases) as prescribed by CMVSS 207 essentially fall into three categories:

1. Seat Inertia Loading;
2. Rear Impact Loading; and
3. Combined Seat Inertia/Seat Belt Loading.

These three loading configurations are summarized in Table 1.

Table 1. Summary of Loading Configurations

CMVSS 207	APPLICATION	CONFIGURATION	LOADS
(1) (a)(i)	Seats w/ or w/o Integrated seat belts.	Any position in which seat can be adjusted.	20 x seat weight applied through seat CoG.
(1)(a)(ii)	Seats w/ integrated seat belts.	Seat in rearmost position	Loads applied simultaneously with (1)(a)(i). 13344N applied to pelvic block. 13344N applied to torso block.
(1)(b)	Seats w/ or w/o integrated seat belts.	Seat in rearmost position.	Force equal to that producing a moment of 365 Nm about Srp.

Following the determination of the loading configurations (Table 1), a computer simulation analysis was conducted on a representative transfer seat base. In order to apply the loading configurations with their associated loads to the computer model it was necessary to estimate a number of parameters, including:

1. the seat assembly (comprised of OEM seat and Transfer Seat Base) weight;
2. the seat assembly CoG location;
3. the seat belt anchorage positions with respect to the Transfer Seat Base;
4. the Seat reference point (Srp) with respect to the seat CoG; and
5. the seat back height with respect to the seat CoG.

Once the parameters were established, a computer model of a representative Transfer Seat Base was modelled using dynamic analysis computer software. A description of the model is given in Appendix A. The parameter values used in the analysis are listed in Appendix A with the resultant reaction forces. The seat belt loads were estimated from a separate computer analysis based upon the requirements of CMVSS 210 and relative seat belt anchorage points described in SAE J117 and in general agreement with CMVSS 208. The seat belt loads modelled in the separate analysis were then used in the static analysis for the transfer seat base.

Reaction forces in the critical components, namely the joints and drive elements, of the generic transfer seat base model were tabulated (as presented in Appendix A) and then used to analyse stresses in the critical components.

3.4 Stress Analysis

A representative transfer seat base was modelled using Finite Element Analysis (FEA) to determine reaction loads and stresses in constituent components. As expected, the reaction loads on the transfer seat base model were found to be highest when subjected to the combined seat inertia and occupant inertia loading. The reaction loads on certain components during the combined loading (details are given in Appendix A) were found to be as high as 70,723 N (15,900 lb) in the scissors pivot pins and 58, 714 N (13,200 lb) in the rear axles.

The reaction loads from the combined seat inertia and occupant inertia loading case, once determined, were used to estimate stresses in constituent components. Material properties (e.g. Young’s modulus) and sectional properties (e.g. Sectional modulus) for pins, axles and bolts were taken from the B&D 908D transfer seat base. Component stresses were then calculated based upon the reaction loads, moments, and material and sectional properties. The results of the stress analysis are presented in Table A6, Appendix A.

4. TESTING

4.1 Test Approach

As shown in Table 1, Section 3.3.1, there are three possible loading configurations to which a seat assembly could be subjected in accordance with CMVSS 207, 210. An important question related to the application of these test standards is whether transfer seat bases should be certified only with respect to the particular vehicle (model and year) and OEM seat combination that were used in the actual testing of the transfer seat bases. An obvious disadvantage of such an approach is that a representative vehicle and seat assembly is required which can be prohibitively expensive. The alternative to using a representative vehicle ("body in white") is to use a surrogate vehicle or test platform. A surrogate vehicle used to restrain the transfer seat base during the CMVSS 207, 210 tests would enable the test results to be applied more generally; the disadvantage being that the test results may be non-representative of "reality" due to the artificiality of the test configuration (specifically, the test platform).

For the purpose of this project, a surrogate vehicle was required due to the limited scope of testing involved. For example, there was only one test sample available for each of the three representative transfer seat bases. The use of a surrogate vehicle and surrogate seat raised another issue as to what was the most appropriate test configuration to use for the testing of the transfer seat bases. Based upon examination of the transfer seat bases, OEM seat assemblies, and from discussions with the various industry representatives, TES concluded there were four types of seat belt configurations related to transfer seat bases which are listed below for reference.

Configuration 1 - all seat belt anchorages are attached to the vehicle and are independent of the transfer seat base.
Configuration 2 - the female buckle portion of a seat belt assembly normally attached to an OEM seat, is relocated to a designated anchorage point on the transfer seat base.
Configuration 3 - the female buckle, normally attached to an OEM seat, is relocated to the vehicle floor via an extension adapter.
Configuration 4 - the female buckle, normally attached to an OEM seat, is not modified after installation of the transfer seat base.

From a testing perspective, the test loads associated with the four different configurations are as follows:
Configuration 1 - the transfer seat base would be tested only to the **seat inertial loading** in accordance with CMVSS 207 para.(1) (a) (i);

Configuration 2 - the transfer seat base would have to be tested to both **seat inertial loading** and **seat belt loads** in accordance with CMVSS 207 para.(1)(a)(i) and (1)(a)(ii);
Configuration 3 - the transfer seat base would be tested only to the **seat inertial loading** in accordance with CMVSS 207 para.(1) (a) (i); and
Configuration 4 - the transfer seat base would have to be tested to both **seat inertial loading** and **seat belt loads** in accordance with CMVSS 207 para.(1)(a)(i) and (1)(a)(ii).

How the transfer seat bases should be tested is a potentially contentious issue with possible arguments forthcoming from the manufacturers. For example, the RICON transfer seat base may or may not be intended to provide a seat belt anchorage; however, it is possible (perhaps even likely) an unskilled or uninformed installer could neglect to relocate the female buckle to the floor in the case of an OEM seat having an integrated female buckle.

The question, therefore, was determining how to test the three seats in a fair and equitable manner, but in a manner that also represented probable installation practice. With this in mind, TES proposed the following test strategy:

Step 1 - obtain an OEM driver's seat which has as standard feature the female buckle attached to the seat frame or seat track (e.g. 1997 FORD ECONOLINE VAN);
Step 2 - attach the aforementioned OEM seat to each of the transfer seat bases under test, in turn, for testing to the following:

i. Apply a force equivalent to 20 times the total seat assembly weight, in the forward direction, to the seat assembly center-of-gravity;
ii. Apply a force equivalent to 20 times the seat assembly weight, in the rearward direction, to the seat assembly center-of-gravity; and
iii. Apply a force equivalent to 20 times the seat assembly weight, in the forward direction, to the centre-of-gravity, while simultaneously applying a 26,688 N (6000 lb) force in the forward direction to the seat belt assembly (the female buckle assembly should be attached to the OEM seat for the purpose of this test).

There were other possible ways to organize the testing. However, the advantages of the proposed test strategy were that all three transfer seat bases were tested in identical (or as close to possible) manner, all three transfer seat bases were tested in "worst-case" conditions, and all three transfer seat bases were tested in a manner which was independent (or as close to possible) of the vehicle platform interface.

As described in the results of the engineering evaluation, It was determined that there was little benefit to be gained from testing the transfer seat bases to the 365 Nm (3300 lb.in) moment about the seat reference point. This decision was based on engineering analysis, which indicated this test would be of significantly lower value (i.e. severity) than the other tests.

TES received verbal authorisation from the Transportation Development Centre to proceed with the test procedures and test configurations based upon the proposed test strategy. To provide detailed clarification of the test approach and test procedures to be used, TES produced two test procedures, TES207 (Rev B) and TES210 (Rev B) corresponding to CMVSS 207 and 210, respectively. TES207 and TES210 are presented in Appendices B, and C, respectively. The test results from the TES207 and TES21O tests, which were performed on the three transfer seat bases, are presented in Appendices D, and E, respectively.

4.2 Test procedures

The test procedures used for the three transfer seat bases are embodied in TES207 and TES210, presented in Appendices B, and C, respectively.

4.3 Test Apparatus

4.3.1 Surrogate Vehicle

The test platform used for testing the transfer seat bases was a 1996 Dodge Caravan (minivan) that had a structurally reinforced floor and structurally reinforced seat belt anchorages. The rear door, rear seats, front windshield, and certain trim items had been previously removed to permit access to the hydraulic actuators, chains and linkages used by the NMEDA Test Rig. A steel rod was attached across the two “A” pillars to provide a datum point within the vehicle. The vehicle was restrained by chains, which were attached to the Test Rig support structure.

4.3.2 Seat Assembly

The surrogate seat used for testing the transfer seat bases was originally an OEM seat from a 1996 Dodge Caravan (minivan). The seat weighed 15.5 kg (34 lb) which was considered marginally acceptable for test purpose. The procedures specified 15.9 kg (35 lb) as a seat weight minimum based upon information that had been drawn from an OEM vehicle body builder’s handbook that had specified seat weights between 15.9 kg (35 lb) and 29.5 kg (65 lb). In the absence of available reference material, the test seat was considered as having the minimum acceptable mass for test purpose. The seat tracks and seat back were welded to make them inoperable. The female seat belt buckle assembly was replaced with a welded-on metal loop which was used to attach to the surrogate seat belt. The surrogate seat belts were wire cable enclosed in rubber sheaths.

The three transfer seat bases were installed on the surrogate seat prior to testing to determine the combined seat assembly (hereafter defined as the OEM seat in combination with a transfer seat base) weight and vertical Centre of Gravity (CoG) location. After the CoG location was determined, steel brackets were welded to the transfer seat base at the CoG location in the horizontal plane to accept the linkages for the rear push/pull hydraulic actuator.

Prior to test, the Six-way Under Test (SUT) was attached to the OEM seat according to the manufacturers' instructions and using the manufacturers' installed hardware and brackets.

4.4 Test Equipment

The equipment used to apply the forces to the transfer seat bases was the test rig presently owned by NMEDA Canada (sponsored and funded by Transport Canada), designed, constructed, and currently operated by SRD Bolduc of Blainville, Quebec. It is comprised of a number of hydraulic, double-acting cylinders (only three cylinders were used during the testing) mechanically attached to a structural steel support frame. The support frame also provides restraint for the test vehicle.

The hydraulic cylinder used to provide the seat inertia force, in both the forward and rearward directions, was located at the rear of the test vehicle. It was supported by adjustable brackets, which enabled the cylinder to be located in the same horizontal CoG plane as the Six-way Under Test (SUT). The angle of force application was checked with a spirit level prior to test and was within $\pm$ one degree. The cylinder was connected to a pressure gauge located near the operator's control panel. The pressure gauge was used to measure the force (either tensile or compressive) applied to the SUT. A correlation chart relating the pressure measured by the gauge with the actual force in the cylinder is presented in Appendix G. The pressure gauges were calibrated with a strain gage meter within one week of testing.

The hydraulic cylinders used to provide the occupant inertia forces (applied to the torso and pelvic body blocks) were located at the front of the vehicle. These cylinders were similarly instrumented with pressure gauges, which had been correlated with a force transducer just prior to testing. The torso and pelvic body block arrangement can be clearly seen in the figures presented in Appendix F.

Equipment data, including the pressure/force correlation chart, calibration certificates, and equipment serial numbers, are presented in Appendix G.

5. RESULTS

5.1 Engineering Evaluation

The engineering evaluation of the transfer seat bases comprised three principal tasks, namely:

- A visual examination of the transfer seat bases, documented with engineering sketches (presented in Appendix H);
- A computer simulation of a generic transfer seat base subjected to simulated seat inertia and occupant inertia loads to determine reaction loads on the transfer seat base; and
- A stress analysis performed on a generic transfer seat base to determine order-of-magnitude stresses in critical components.

The visual examination showed that all three transfer seat bases had several potential failure points or critical components. In the case of all three transfer seat bases, longitudinal restraint of the transfer seat base (and hence the intended occupant) is contingent upon the following:

- The rack teeth, rack fixing bolt, and rack body remaining intact;
- The mating pinion gear remaining intact and in mesh with the rack teeth;
- The worm gear right angle drive remaining intact (no slipping); and
- The rear guide rollers/axles remaining intact and within the guide tracks.

It should be noted the B&D 908D transfer seat base incorporated a limit stop which, in the event of failure of one of the components listed in the previous list, would prevent or retard longitudinal forward movement. However, the limit stop must be set into the maximum forward position desired by the user and is not manually adjustable; it therefore reduces to some extent the functionality of the transfer seat base and it is foreseeable it could be omitted from the installation.

The computer simulation of the generic transfer seat base under the three loading conditions clearly showed the highest reaction loads on the transfer seat base resulted from combined seat assembly and occupant inertia loading. The reaction loads from the 365 Nm (3300 lb.in.) seat back moment load configuration were substantially less than the other two load cases. Therefore, it was decided to not perform a seat back moment test on the actual three transfer seat bases.

A stress analysis performed on the generic transfer seat base components showed that many of the critical components could be subjected to stresses above the estimated safe working strength the material. The highest reaction loads and stresses were found in the rear axles and scissors pivot pins with estimated reaction loads exceeding 70,000 N (15,000 lb) and corresponding stresses in excess of 413 Mpa (60 ksi). It should be noted that although the rear axles did not actually fail, in two of the three transfer seat bases the rear axles did pull out of their track guides; consequently, the test loads were not achieved. In addition to the rear axles, significantly high stresses were estimated for the rack fixing bolts and rack teeth.

5.2 Test Results

The test results for the TES207 and TES210 Test procedures are presented in Appendices D and E, respectively.

5.2.1 Test Procedure TES207

The first physical test performed on the three transfer seat bases was a static force applied through the horizontal CoG plane in a forward direction equivalent to 20 times the weight of the seat assembly. All three transfer seat bases passed the test although one of the transfer seat bases sustained permanent deformation to the rear plate holding the rear axles.

The second physical test performed on the three transfer seat bases was a static force applied through the horizontal CoG plane in a rearward direction equivalent to 20 times the weight of the seat assembly. All three transfer seat bases passed the test although one sustained permanent deformation to the rear plate holding the rear axles; in fact, the rearward force application tended to reverse or undo some of the deformation that had occurred during the previous forward directed test.

All three transfer seat bases were checked for functionality after the test and were found to operate satisfactorily.

5.2.2 Test Procedure TES210

The third (and final) test performed on the three transfer seat bases was a combined force application of 20 times the seat assembly weight in the forward direction, applied simultaneously with the seat belt loads of 13,344 N (3000 lb) each applied to a torso and body block. The torso and body blocks were restrained by seat belt replicas (steel cables) and attached to two vehicle mounted anchorages (upper and lower “B” pillar) and one transfer seat base mounted anchorage. The complete test configuration can be seen in the figures presented in Appendix F.

The first transfer seat base tested to this procedure was the B&D 908D. The 908D failed to sustain the prescribed loads and therefore failed the TES210 test procedure. The approximate maximum loads sustained by the transfer seat base during the test were as follows:

- CoG location 5,930 N (1333 lb) vs required load of 11,300 N (2540 lb);
- Torso block 4,893 N (1100 lb) vs required load of 13,344 N (3000 lb); and
- Pelvic block 4,893 N (1100 lb) vs required load of 13,344 N (3000 lb).

Test failure was attributed to the rear guide rollers disengaging from the axles due to severe deformation of the plate holding the axles and deformation of the track guides constraining the guide rollers. This deformation, which allowed the entire SUT to displace upwards and forwards, is clearly evident in Figure F10 (Appendix F).

The second transfer seat base tested to this procedure was the Ricon R-1208. The R-1208 failed to sustain the prescribed loads and therefore failed the TES210 test procedure. The approximate maximum loads sustained by the transfer seat base during the test were as follows:

- Torso block 8,896 N (2000 lb) vs required load of 13,344 N (3000 lb);
- CoG location 7,940 N (1785 lb) vs required load of 11,209 N (2520 lb); and
- Pelvic block 8,896 N (2000 lb) vs required load of 13,344 N (3000 lb).

Test failure was attributed to deformation of the track guides/rear axles, which allowed the entire unit to displace upwards and forwards (Figure F11). Deformation was also clearly evident in the scissors legs and the rack assembly (bent rack, displaced pinion gear).

The third and final transfer seat base tested to this procedure was the Braun 13085A. The 13085A failed to sustain the prescribed loads and therefore failed the TES210 test procedure. The approximate maximum loads sustained by the transfer seat base during the test were as follows:

- CoG location 2,224 N (500 lb) vs required load of 10,853 N (2440 lb);
- Torso block 9,118 N (2050 lb) vs required load of 13,344 N (3000 lb); and
- Pelvic block: 6,227 N (1400 lb) vs required load of 13,344 N (3000 lb).

Test failure was attributed to slippage of the gears associated with the fore/aft drive mechanism (there was no visible evidence of damage or deformation to the support assembly). As an interesting note, the unit was still at least partially operable after the test.

6. CONCLUSIONS

The conclusions of the study can be summarized as follows:

- Current state-of-the-art transfer seat bases can be expected to be able to sustain simulated seat inertia loads equivalent to 20 times the seat assembly weight, allowing for a nominal OEM seat weight of 15.5 kg (34 lb);

- Current state-of-the-art transfer seat bases cannot be expected to be able to sustain simultaneous application of simulated seat inertia loads (equivalent to 20 times the seat assembly weight) and simulated seat belt loads where the inboard seat belt anchor is attached to the OEM seat.

- The situation regarding current installation practice with respect to the use of existing OEM seat-mounted seat belt anchors in conjunction with the transfer seat bases, is unclear and requires investigation.

7. RECOMMENDATIONS

As concluded from the study, current state-of-the-art transfer seat bases cannot be expected to sustain the forces commensurate with a 48 km/h (30 mph) impact when the transfer seat base is used to support an OEM seat where the inboard seat belt anchor is attached to the OEM seat. Since it is foreseeable that such a configuration may occur, and may possibly be the norm, further research will be conducted in the following topics:

- investigate current model year candidate vehicles for transfer seat bases (e.g. minivans) to determine the distribution of OEM seats with inboard seat belt anchors integrated with the OEM seats as opposed to inboard seat belt anchors affixed to the vehicle floor;

- investigate current transfer seat base installation practices to determine how the situation regarding integrated OEM seats/seat belt anchors is presently being dealt with;

- investigate whether it is feasible for current state-of-the-art transfer seat bases to be upgraded whereby they could pass a TES210 (or similar) test procedure; and

- prepare a draft test procedure for the testing of transfer seat bases using surrogate vehicles and surrogate seats.

APPENDIX A
STATIC STRESS ANALYSIS of a REPRESENTATIVE SIX-WAY TRANSFER SEAT BASE

A1. MODEL DESCRIPTION

The structure examined was a six-way transfer seat base (hereafter referred simply as a transfer seat base). A representative transfer seat base (B&D Model 908D) was procured from the manufacturer and examined. Based on the physical geometry of the actual Transfer Seat Base, a computer model of a generic transfer seat base, employing a scissors type lift mechanism, was constructed using Algor's Dynapak Analysis software. The model, shown in Figure A1, was constructed using the following elements:

1. Seven (7) rigid bodies or links (including ground);
2. Three translational joints;
3. Five (5) revolute joints; and
4. Two linear springs.

The links and interconnected joints represent the mechanical structure while the springs were used to represent two force actuators. The first spring represented the rack and pinion drive assembly used for fore/aft movement of the transfer seat base; the second spring represented the linear drive assembly used for up/down movement of the "scissors jack" assembly.

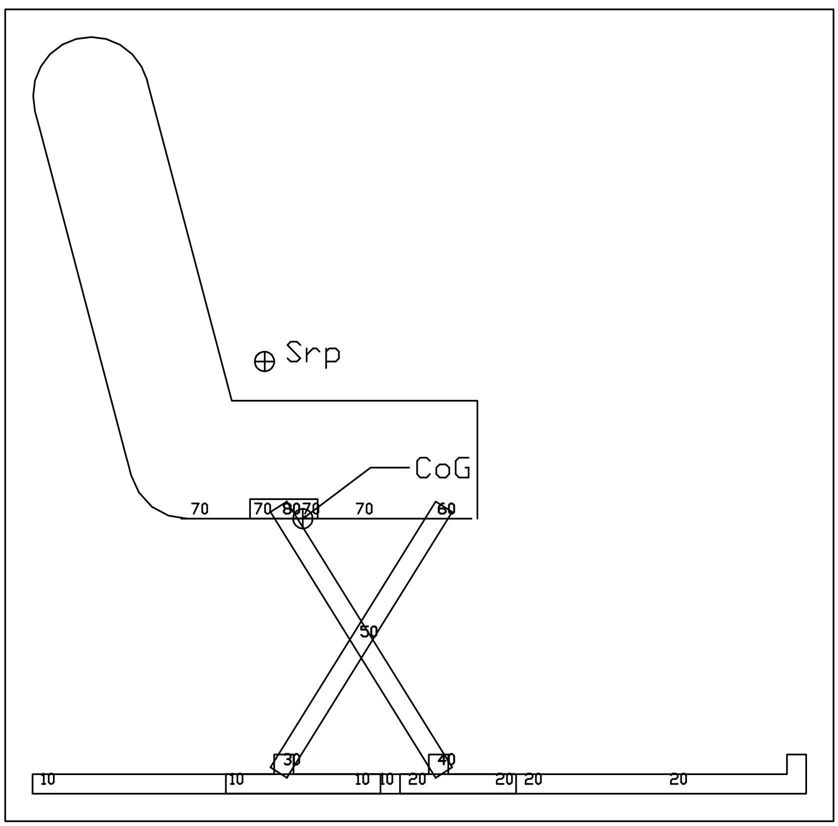

Figure A1. Transfer Seat Base Model

A2. LOADING CONFIGURATION

The analysis software allows for a variety of inputs, both motion and force. In the present study only static forces and equilibrium reactions were examined. With respect to the CMVSS regulations, three loading configurations were examined:

Seat Inertia Loading:
In consideration of CMVSS 207, a force equal to 20 times the “seat” weight was applied in a horizontal direction to the Centre of Gravity (CoG) of the “seat”. Note that the “seat” in this study was comprised of both the transfer seat base and the Trimmed Seat. The weight of the transfer seat base was taken as 43.6 kg (96 lb) and the weight of the Trimmed Seat was taken as 30.9 kg (68 lb), hence the combined weight was taken as 74.5 kg (164 lb).

Seat Inertial Loading Combined with Simultaneous Seat Belt Loading:
In considering that at least one (1) seat belt anchorage may be incorporated into the transfer seat base, a loading configuration was devised which incorporated both Seat Inertia Loading and Seat Belt Loading. The Seat Inertia Loading has been previously described. The Seat Belt Loading was devised in consideration of CMVSS 207 and 210. The Seat Belt Loads were derived from a separate modelling study used to determine the loads imposed upon the transfer seat base from by the Seat Belt Loads. This separate modelling study analysed Seat Belt Loads based upon a configuration of seat belt anchorages described in SAE J117 - Dynamic Test Procedure - Type 1 and Type 2 Seat Belt Assemblies. The loads that resulted from the modelling simulation are shown in Table A1. The loads at the inboard anchorage point were then transferred to the transfer seat base model to determine the reaction loads.

Table A1. Seat Belt Anchorage Loads

LOAD DIRECTION	UPPER POINT	OUTBOARD PT.	INBOARD PT.
Fx (transverse)	4463 N (1004 lb)	1307 N (294 lb)	5770 N (-1298 lb)
Fy (longitudinal)	12.82 kN (2884 lb)	4970 N (1118 lb)	8486 N (1909 lb)
Fz (vertical)	11.16 kN (2510 lb)	4414 N (993 lb)	11.38 kN (2559 lb)

Seat Back Loading:
In consideration of CMVSS 207 (b), a force was applied to the transfer seat base model that resulted in a moment about the Seat Reference Point of 373 Nm (3,300 lb.in)., to simulate the effect of a rearward impact. The input forces and resultant moment about the Seat Reference Point are shown in Table A2.

Table A2. Force and Moment Loads on Seat Back

	X (Longitudinal)	Y (Vertical)
Seat Ref. Point (Srp) W.R.T. Seat CoG	-50 mm (-2 in)	203 mm (8 in)
Location of Force W.R.T. Seat CoG	-50 mm (-2 in)	406 mm (16 in)
Magnitude of Force	-1834 N (-412.5 lb)	0
Moment W.R.T. Srp	373 Nm (3300 lb.in) ccw	
Moment W.R.T. Seat CoG	746 N m (6600 lb.in.) ccw	

A3. Reaction Loads

The model, diagrammatically shown in Figure A1 was comprised of seven (7) links (including ground), eight joints (J10 through J80) and two springs (S1 and S2). The reaction forces on the joints and springs resulting from the Seat Inertia loading case are tabulated in Table A3. The reaction forces on the joints and springs resulting from the Rear Impact load case are tabulated in Table A4. The reaction forces on the joints and springs resulting from the Seat Inertia and Seat Belt Loading case are tabulated in Table A5.

Table A3. Seat Inertia Loading Reaction Loads In Newtons and (lb)

PT.	J10	J20	J30	J40	J50	J60	J70	J80	S1	S2
Fx	0	0	-307 (-69)	-14268 (-3210)	14268 (3210)	-14580 (-3280)	0	0	-14580 (-3280)	307 (69)
Fy	-24270 (-5460)	23825 (5360)	24225 (5450)	-23914 (-5380)	24670 (5550)	-467 (-105)	-698 (-157)	751 (169)	0	0

Table A4. Rearward Impact Loading Reaction Loads In Newtons and (lb)

PT.	J10	J20	J30	J40	J50	J60	J70	J80	S1	S2
Fx	0	0	-165 (-37.2)	1996 449	-1996 (-449)	1831 (412)	0	0	1831 (412)	165 (37.2)
Fy	-991 (-223)	565 (127)	938 (211)	-618 (-139)	4712 (1060)	-3805 (-856)	-4036 (-908)	4089 (920)	0	0

Table A5. Seat Inertia and Seat Belt Loading Reaction Loads In Newtons and (lb)

PT.	J10	J20	J30	J40	J50	J60	J70	J80	S1	S2
Fx	0	0	-6756 (-1520)	-16002 (-3600)	-16002 (3600)	-22758 (-5120)	0	0	-22758 (-5120)	6756 (1520)
Fy	58674 (13200)	48451 (-10900)	58674 (-13200)	48451 (10900)	70676 (-15900)	12046 (2710)	22403 (5040)	22358 (-5030)	0	0

Table A6. Resultant Stresses From Table A5. Reaction Loads In Mpa and (ksi)

PT.	J10	J20	J30	J40	J50	J60	J70	J80	S1	S2
τ	234 (34)	193 (28)	414 (60)	356 (52)	290 42)	179 (26)	90 (13)	90 (13)	462 (67)	54 (7.8)
σ	- n/a -	- n/a -	- n/a -	- n/a -	- n/a -	- n/a -	- n/a -	241 (35)	- n/a -	-n/a-

Legend: τ = shear stress, σ = bending stress, n/a = not applicable or not available

APPENDIX B
TES207 (REV B) TEST PROCEDURE

(***Not available in electronic format/***
Non disponible en format électronique)

APPENDIX C
TES210 (REV B) TEST PROCEDURE

(***Not available in electronic format/***
Non disponible en format électronique)

APPENDIX D
TES207 TEST RESULTS

(***Not available in electronic format/***
Non disponible en format électronique)

APPENDIX E
TES210 TEST RESULTS

(***Not available in electronic format/***
Non disponible en format électronique)

APPENDIX F
TEST FIGURES

(***Not available in electronic format/***
Non disponible en format électronique)

APPENDIX G
TEST EQUIPMENT DATA SHEETS

(***Not available in electronic format/***
Non disponible en format électronique)

APPENDIX H
ENGINEERING SKETCHES

(***Not available in electronic format/***
Non disponible en format électronique)