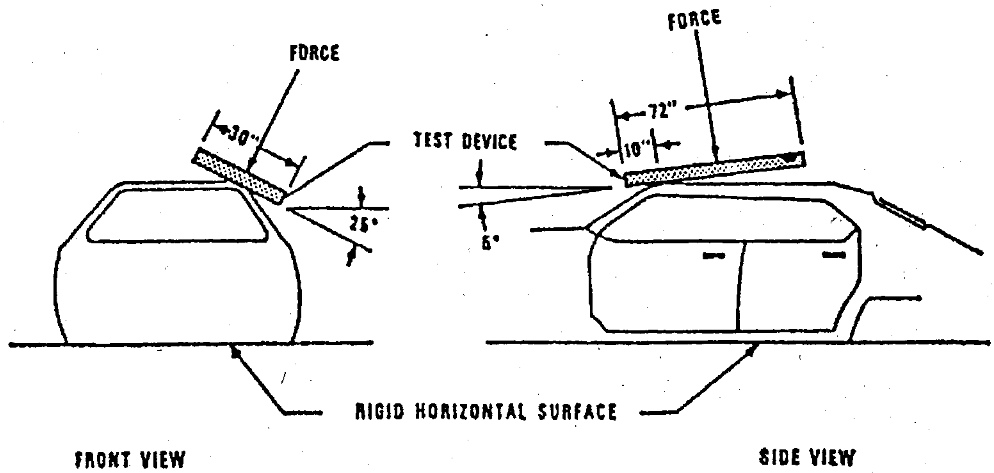
Report Number 97-11



Rollover Protection and Wheelchair Securement for Special Transportation Services

Research

Technical Report Documentation Page

1. Report No.	2.	3. Recipient's Accession No.
MN/RC - 97/11		

4. Title and Subtitle	5. Report Date
ROLLOVER PROTECTION AND WHEELCHAIR SECUREMENT FOR SPECIAL TRANSPORTATION SERVICES	March 1997
	6.
7. Author(s) Patrick J. Starr	8. Performing Organization Report No.
9. Performing Organization Name and Address University of Minnesota Department of Mechanical Engineering 125 Mechanical Engineering Building 111 Church St. S.E. Minneapolis, Minnesota 55455	10. Project/Task/Work Unit No. 11. Contract (C) or Grant (G) No. (C) 74708 TOC #11
12. Sponsoring Organization Name and Address Minnesota Department of Transportation 395 John Ireland Boulevard Mail Stop 330 St. Paul, Minnesota 55155	13. Type of Report and Period Covered Final Report 1996-1997 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract (Limit: 200 words)

This report examines the Minnesota Rules that pertain to rollover protection and wheelchair securement in vehicles that provide Special Transportation Services (STS) for elderly and disabled populations. Large vans converted for STS needs have a raised roof that affords little rollover protection. Minnesota adopted the roof crush provision of FMVSS 220, and van converters responded by producing rollbar systems, passing costs on to transit providers. This assessment included a literature review, visits to van converters, and analytical estimates of center of gravity changes and aerodynamic efforts.

The report recommends that vans with raised roofs should comply with FMVSS 220 while those without raised roofs should comply with FMVSS 216 or 220. For wheelchair securement, a Minnesota Rule provides some detailed requirements for attaching securement devices to the vehicle. In some cases, the requirements differ from the manufacturer's instructions, which may compromise the strength. After review and discussion with installers, the report recommends following manufacturer's instructions and encouraging manufacturers to upgrade the quality of instructions.

17. Document Analysis/Descriptors	18. Availability Statement
Rollover Protection Standards Wheelchair Securement Standards	No restrictions. Document available from: National Technical Information Services, Springfield, Virginia 22161

19. Security Class (this report)	20. Security Class (this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	24	

Rollover Protection and Wheelchair Securement for Special Transportation Services

Final Report

Prepared by:

Patrick J. Starr

Department of Mechanical Engineering

University of Minnesota

111 Church Street SE
Minneapolis, MN 55455

March 1997

Published by

Minnesota Department of Transportation
Office of Research Administration
200 Ford Building Mail Stop 330
117 University Avenue
St. Paul Minnesota 55155

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EXECUTIVE SUMMARY

The project objective was to assess two Minnesota Rules pertaining to the transportation of the disabled. Minnesota Rule 8840.5940 subpart 1 requires that any vehicle first used to transport the disabled after January 1, 1993 must comply with the rollover protection stated in Federal Motor Vehicle Safety Standard (FMVSS) 220. This standard applies to school buses and was adopted in Minnesota since there were no federal standards that applied to vans which were converted to accommodate handicapped transit. The conversion consists of installing a fiberglass pop-up top and increasing the door height to accommodate American with Disabilities Act (ADA) standards. Since the pop-up top affords little rollover protection, van converters designed and installed roll bar structures to comply with FMVSS 220, and passed the costs along to transit providers. Complaints of these providers to the Minnesota Department of Transportation (Mn/DOT) provided one motivation for this assessment. A second motivation was the amending of FMVSS 216 in April 1993 which extended passenger car rollover protection standards to multipurpose passenger vehicles. It was thought that this standard may be more appropriate, and thus remove the need for the Minnesota Rule.

The second rule was Minnesota Rule 7450.0400 dealing with securement devices for wheelchairs during transit. Specifically, Part E provides detailed requirements for attaching securement devices to the vehicle. The problem is that these instructions are different than those provided by some manufacturers of the devices. The issue is whether the Minnesota rule should be amended to allow compliance with manufacturer's instructions.

Assessment of rollover protection involved gathering information, visiting local conversion shops, estimating center of gravity changes due to the roll bars, estimating the aerodynamic effects of a raised roof, and examining minivans with floors lowered rather than raised

roofs. Federal standards 216 and 220 were compared in terms of motivation, GVWR categories and load placement. The outcome is the following recommendation. Vehicles with a raised roof should comply with the crush test of FMVSS 220. Those without raised roofs should comply with FMVSS 216 or 220. This could be accommodated by rephrasing Minnesota Rule 8840.5940 to allow compliance with either the crush test of FMVSS 216 or 220.

Assessment of wheelchair securement involved gathering manufacturer's installation instructions and discussing the issues with local installers. The Minnesota Rule requires that devices must meet the strength requirements of FMVSS 209 and compliance of the device with this standard can be compromised if the manufacturer's instructions are not followed. A problem is that these instructions vary in clarity, completeness and level of detail. The recommendation consists of two parts: (1) manufacturer's instructions should be followed for the installation of the securement devices, and (2) manufacturer's installation instructions need to be upgraded. This will require contacting the manufacturers and requesting revisions in their instructions to follow a uniform format.

CHAPTER 1
INTRODUCTION

The project objective is to investigate the current standards for rollover protection in small vans carrying handicapped persons and determine the "fit" between the needs and the standards. In addition, as there is some confusion regarding the interpretation of current standards for wheelchair securement, installation instructions and procedures will be investigated. These objectives were expressed as two main tasks which were to be performed simultaneously:

Task 1 - Assess Rollover Protection

Task 2 - Assess Wheelchair Securement

In the proposal, various activities were outlined for the accomplishment of each task, but those activities could be condensed into the following two main activities:

- Identify, locate, and acquire written information regarding the origin of standards, rollover protection, and securement installation.
- Visit local installers of rollover protection devices and securement systems and discuss the two tasks stated above.

Specifics of these main activities that have been undertaken are listed below.

- Gathered information from the Federal Register regarding the origins of Federal Motor Vehicle Safety Standards (FMVSS) 216 and 220, and the amending of FMVSS 216 to multipurpose vehicles.
- Gathered information from Society of Automobile Engineers (SAE) documents regarding test procedures for rollover and roof crush as well as recommended practice for seat belt attachment and roof modifications.
- Gathered sections of the final rule implementing the transportation provisions of the Americans with Disability Act (ADA).

- Obtained copies of letters to Minnesota Department of Transportation (Mn/DOT) from General Motors and Chrysler regarding the roof crush testing of various vans.
- Spoke with a Viking Formed Products representative regarding reinforced pop-up tops and obtained their test report of compliance with FMVSS 220 roof crush.
- Identified the persons at the National Highway Traffic Safety Administration (NHTSA) who are affiliated with FMVSS 216 and 220 and spoke with them regarding the origins and engineering basis of each standard.
- Spoke with a Kinedyne representative regarding securement hardware.

Visited the following companies:

- Complete Mobility System, Roseville, MN, and spoke with Bill Snyder, and the shop foreman.
- HDS Specialty Systems, Burnsville, MN, and spoke with Dan Peterson.
- Associated Handicapped Vans, Burnsville and spoke with Dan Delie.

At each visit, the objectives of the study were discussed, with a focus upon their response to FMVSS 220, the ADA door height requirements and wheelchair attachment. Vans undergoing modification were examined in their shops including a look at the reinforced Viking pop-up tops and a production line of minivans having the floors lowered and other modifications at Associated Handicapped Vans. Trends in van construction and industry responses were also discussed.

CHAPTER 2
ROLLOVER PROTECTION ASSESSMENT

The State of Minnesota adopted rules that prescribe standards for vehicle construction to protect passengers in vehicles that transport elderly and handicapped persons. Protection in rollover incidents is afforded in Minnesota Rule #8840.59940 subpart 1 which requires compliance with the roof crush test of FMVSS 220. Affected vehicles were intended to be full sized vans that were modified by raising the roof so as to maintain at least the ADA door height within the passenger area.

VAN ROOF MODIFICATIONS

Van roofs are modified for two reasons:

1. Meet door height requirement of 56 inches as specified in ADA section 38.25 part C for vehicles of 22 feet in length or less. The door height requirement requires cutting into the roof, adding a higher door frame to the body-roof structure, and adding material to the tops of the doors.
2. Provide the door height clearance within the passenger compartment. This requires a raised roof, and it usually consists of a fiberglass pop-up top. I was told that some vans have been seen with only the door height raised to meet the letter of the law, but the roof remains at its original height in the passenger area!

VENDOR RESPONSES TO FMVSS 220

The three companies visited had each designed their own roll bar system. The rollover protection is provided by adding a series of side to side roll bars under the roof and mounted on the tubular headers that extend from front to rear where the van body side walls meet the roof. The Society of Automobile Engineers (SAE) has published recommendations for "Raised Roofs and Structured Reinforcement" [1] which shows diagrams and suggested sizes of the roll bars and mounting methods. Each company had its system tested for roof crush compliance with FMVSS 220 on a full sized van. Viking Formed Products, (Middlebury, IN) designed a reinforced pop-up top and had it tested on a full size van [2]. These roll bar structures and the reinforced pop-up top all passed the roof crush requirements of FMVSS 220. Each of these operations have costs. I was told by the installers that the roll bar structure and pop-up top adds about $1500-1800 to the cost of the van, and that it is cut in half if the reinforced pop-up top is used. Providing the increased door height adds additional costs.

CHANGES IN VEHICLE CENTER OF GRAVITY

Adding a pop-up top with internal reinforcement or with a roll bar system will add weight to a vehicle, above its original roof line and may increase the risk of rollover. Vehicle rollover is a complicated topic and is studied both from a vehicle dynamics viewpoint and from an accident analysis viewpoint. The simplest indicator of rollover propensity is the "rollover threshold" defined as the track width divided by twice the height of the center of gravity.

Table 2.1 shows some values for various vehicles [3]. It indicates a Center of Gravity (CG) height range of 0.76 - 1.02 meters (30 - 40 inches) for a passenger van and a Rollover Threshold range of 0.8-1.1. The threshold is the fraction of vehicle weight that must be exerted sideways at the CG in order to initiate tipping. A threshold value of 1.0 means that a side force equal to the weight of the vehicle must be exerted.

One form of side load is the centrifugal force generated while turning. This force is resisted by the friction at the tires. If the tires cannot develop sufficient friction, the vehicle will slide sideways. Vans are only capable of providing a maximum tire friction force in the range of 0.7-0.8 times the vehicle weight. Since this is exceeded by the rollover threshold, a van will slide sideways on dry pavement rather than tip. However, rollover can be initiated in many ways, such as collision, or sliding sideways into a curb, or having a wheel dig into a soft shoulder in an offroad excursion or evasive action. Obviously the lower the CG, the higher the threshold, and the higher the CG, the less is the threshold. The medium and heavy trucks have the lowest threshold values.

Vehicle Type	CG Height (m)	Tread (m)	Rollover Threshold(g)
Sports car	0.45-0.51	1.27-1.52	1.2-1.7
Compact car	0.51-0.58	1.27-1.52	1.1-1.5
Luxury car	0.51-0.61	1.52-1.65	1.2-1.6
Pickup truck	0.76-0.89	1.65-1.78	0.9-1.1
Passenger van	0.76-1.02	1.65-1.78	0.8-1.1
Medium truck	1.14-1.40	1.65-1.91	0.6-0.8
Heavy truck	1.52-2.16	1.78-1.83	0.4-0.6

Table 2.1

Typical CG Heights and Rollover Thresholds

More specific data on the center of gravity heights of vans and recommended changes in the heights was obtained. When a vendor performs the final stages of vehicle manufacturing, such as a van conversion, the original vehicle manufacturers must supply an "incomplete vehicle document" to aid in determining conformity to various federal safety standards. The section from such a document that pertains to allowable center of gravity locations in General Motors (GM) vans was obtained, [4]. This document also states nominal center of gravity heights for unmodified vans. An SAE paper that lists center of gravity heights for various vehicles, including minivans, was located to corroborate the GM data [5]. The nominal CG height for full sized GM vans was 0.81m (32 inches), and the maximum recommended height was 1.22m (48 inches). The nominal CG for GM minivans was 0.71m (28 inches) and the maximum recommended height was 0.91m (36 inches). Reference [5] shows a range of measured CG heights for GM, Ford and Chrysler minivans in the 0.58-0.69m (23 to 27 inch) range, all of which are less than the nominal GM value. Thus the nominal values will be used in the following example.

The change in the CG height will be estimated when a reinforced top is added. Data needed and the estimated values are as follows.

- Vehicle weight, full size van: 2727 kg. (6000 lbs)
- Added weight of rollbar structure 72 kg. (160 lbs)
- CG height of vehicle with stock roof: ----0.81 m. (32 inches)
- CG height of roll bar structure: ----1.98 m. (78 inches)

The estimated weight of the rollbar structure was computed using the material and size of the rollbar hoops as recommended by SAE [1], which yields about 9.1 kg (20 lb) per hoop. The number of hoops was selected at eight. One of the local vendors whose rollbar passed the FMVSS 220 uses 5 hoops, so 8 is a conservative value.

The vehicle CG height changed from 0.81 m (32 inches) to 0.84 m (33.2 inches). This is well within the maximum of 1.22 m (48 inches) recommended by GM. Incomplete vehicle documents were not obtained from other manufacturers, but I believe it is a safe assumption that a change of 0.03 m (1.2 inches) in CG height will not exceed any manufacturer's maximum allowable values. Thus the added weight of the roll bar structure will raise the CG height less than 0.05 m (2 inches), and the result is well below the maximum recommended height. It also maintains the CG height within the range of the rollover threshold for vans as shown in Table 2.1.

AERODYNAMIC CONCERNS OF RAISED ROOFS

The aerodynamic force upon the vehicle is dependent upon the area that is presented to the wind. When there is no crosswind, the main aerodynamic force upon a van is the drag force which acts primarily upon the front of the van. When a crosswind is encountered, there is additional force upon the side of the van. Crosswinds are classified as "steady" or "gusts" [6], and vehicle response to them is a topic of ongoing research. There is no doubt that vans and trucks which present a large area to a crosswind can respond in such a way that requires driver correction.

One interaction between vehicle response and aerodynamic forces deals with the front to rear location of the center of gravity, and the location of the center of pressure. The center of pressure is a point on the vehicle where the sum of the aerodynamic forces appear to be placed. That is, aerodynamic forces act upon the entire outer surface of the vehicle, but their effect can be represented as a single force acting at the center of pressure. For vehicle stability at high speeds, it is important that the center of pressure be behind the center of gravity. A simple example is an arrow, which has a heavy point at the front, and feathers at the rear. The feathers primarily interact with the air, so most aerodynamic force, and the center of pressure, is at the rear which maintains stable flight. For vans, the large rear body section causes the center of pressure to be more rearward, than say a pickup truck. The raised roof should not affect the front to rear placement of the center of pressure, so it should not affect vehicle stability.

However, the raised roof will "catch more wind" by presenting a larger area, and so the side forces upon the van will increase. The response of the vehicle is a complicated matter, but a simple analysis can estimate the force due to a crosswind. This force will do one of two things:

a. Cause the vehicle to veer slightly off course, but if the CG is ahead of the center of pressure, a simple steering correction from the driver will bring it back on course. All van drivers have experienced this and it is nothing new. As the raised roof does not change the for-aft location of the center of pressure, there should be no problem.

b. Cause the van to roll over. If the vehicle is in a turn, centrifugal force is acting sideways at the CG. If it now catches a sidewind, an aerodynamic force will also act sideways at the center of pressure. Is the combined effect enough to cause a rollover?

The answer is no. An analysis was done for the vehicle with the raised roof described previously as it negotiates a curve at a speed which causes a side force of 70% of the weight of the vehicle to act upon the CG. (a "0.7G" turn). Then a 80 kph (50 mph) side wind was applied and the aerodynamic side load was estimated using the van side area with the projected roof and acting at a center of pressure that was estimated at half way up the side of the van. These are extreme conditions. Most driving is done at cornering levels of 0.1 to 0.3 "G" turns, but here we choose 0.7. Under the action of these two forces the rollover threshold was not reached for this vehicle under these conditions.

The conclusion is that the additional aerodynamic forces on the roof may require a bit more of the steering correction that the driver is already engaged in, but the vehicle response is stable. It will come back on the desired path and it will not rollover.

TECHNOLOGY CHANGES: MINIVANS

Another means of accommodating the door height is lowering the floor. This generally cannot be done on the full-size vans, because of the high truck-type chassis, but it can be done on minivans. In fact, such vans are being produced on a large scale. Associated Handicapped Vans is one of four Chrysler Certified converters and produces about 10 vans per week. The floor is lowered, fuel tank moved, exhaust and various lines are rerouted, etc. With the lowered floor, the vans can meet the ADA door height standard and a ramp of reasonable length can be used for entry and exit, so the expense of a lift can be avoided. These vans are crash tested to comply with applicable federal laws, including FMVSS 216, but they are not tested for FMVSS 220. Other vehicle manufacturers also offer such lowered-floor conversions such as the Ford Windstar models modified by Vantage Minivans of Phoenix, AZ.

COMPARISON OF FMVSS 216 AND 220

The following describes aspects of each standard and concludes that FMVSS 216 is a more severe test than 220, but that 220 is more appropriate for vans with raised roofs.

Origins of Federal Standards

When the proposal was written, I thought it would be possible to easily trace the engineering foundation for crush tests. I presumed that studies had been done of rollover accidents, which would indicate that vehicles of a certain size and service landed on the roof in some predominant manner in rollover. Then the crush standards would be created to insure that vehicles had sufficient strength in the predominant rollover. My task was to find the right person at NHTSA and the door to the information would be opened. Upon speaking to Mr. Charles Hott at NHTSA, I was told that the Federal Register information is all there is. The history of the development of a standard, in terms of the details of the initial discussions and hearings are summarized in the Federal Register in the paragraphs that precede the various versions of the standard, from "proposed" to its later revisions. Any further detail, I was told, resides in the memories of the various participants. Standard 216 originated in 1971 and 220 in 1976, years before the current staff came on board, so there is no available memory.

Gross Vehicle Weight Rating (GVWR) Categories

FMVSS 216, as amended in April 1993 applies to multipurpose passenger vehicles, trucks and buses with GVWR up to 2727 kg (6000 lbs). This includes minivans but not fullsize vans.

FMVSS 220 applies to vehicles sold as schoolbuses and classifies vehicles into two categories based upon GVWR. The details of the loading for the roof crush test differ among categories and will be discussed shortly. The GVWR categories are vehicles below 4545 kg (10,000 lbs), which would include large vans sold as schoolbuses, and vehicles above 4545 kg (10,000 lbs), which includes fullsize schoolbuses.

Load Placement

The roof crush test of FMVSS 220 applies a horizontal flat plate upon the roof of the vehicle. For vehicles below 4545 kg (10,000) GVWR, the plate is wider and longer than the vehicle roof, which insures that all <u>four</u> corners of the passenger compartment are resisting the load. For vehicles over 4545 kg (10,000) GVWR, the plate is 0.91 m (36 in) wide (which is less than the width of the passenger compartment) and 0.30 m (12 in) <u>shorter</u> than the roof. Thus the load is not directly supported by the corners of the passenger compartment in the larger vehicles designed as schoolbuses.

The importance of supporting the load by all four corners was emphasized in the discussion preceding the original establishment of School Bus Rollover Protection Standard 220 of the Federal Register. The <u>proposed</u> standard specified a rigid rectangular force application plate 0.91m (36 in) wide and 0.51 m (20 in) <u>shorter</u> than the vehicle roof, "preventing reliance on roof end structures for rollover protection.... Commenters pointed out that the end structures of the roof are almost certain to bear the weight of a rollover and should be included in a test..." Later, it is reported that, "Ford Motor Company stated it had performed the test as proposed and asserted that the roof of its van-type vehicle as presently designed could not meet the requirement without an increase in the size of force application plate to distribute the load over the entire vehicle roof" [7, p.3871].

These remarks suggest two points:

- The entire roof structure is expected to be loaded in a van rollover.
- The corners or "end structures" are major sources of strength in resisting roof crush in vans.

FMVSS 216 applies a tilted flat plate to either the left or right front corner of the passenger compartment. The plate is 1.83 m (72 in) long and 0.76 m (30 in) wide and is placed at angles as shown in figure 2.1. The maximum allowable crush distance is 0.13 m (5 in). Figure 2.2 shows a side and front view of the plate if it had moved the full 0.13 m (5 in) on a typical roof. Note the plate still only loads one corner directly. Other corners resist by internal forces transmitted though the chassis and roof structure. Even when the plate is moved the full 0.13 m (5 in), it does not directly load the other corners.

FMVSS 216 is More Severe Than 220

Since only one corner of the passenger compartment directly resists the load in FMVSS 216, I believe it is a more severe test than the under 4545 kg (10,000 lb) GVWR vehicle category test of FMVSS 220, which supports the load with four corners. It should be noted that both tests require a load of one and one half times the vehicle weight.

This conclusion is also suggested in the memos to Mn/DOT from General Motors and Chrysler [8]. Those manufacturers tested representative full size and minivans for compliance with the FMVSS 220 roof crush test. The minivans are required to comply with FMVSS 216, as their GVWR is below 2727 kg (6000 lb), and they did pass the FMVSS 220 test. The full sized vans also passed. In addition, the memo from GM stated that all tested vehicles comply with FMVSS 216, though it is not required that they do. These tests suggest that original equipment vans that comply with FMVSS 216 should also comply with FMVSS 220.

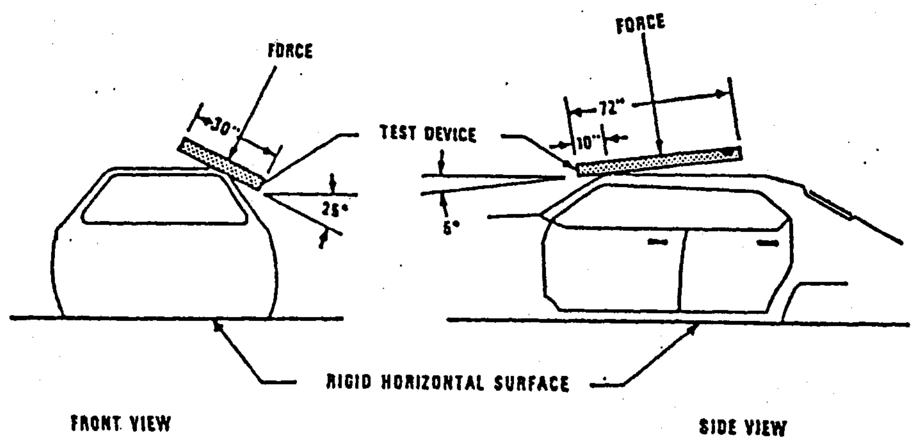

Figure 2.1 FMVSS 216 Load Placement

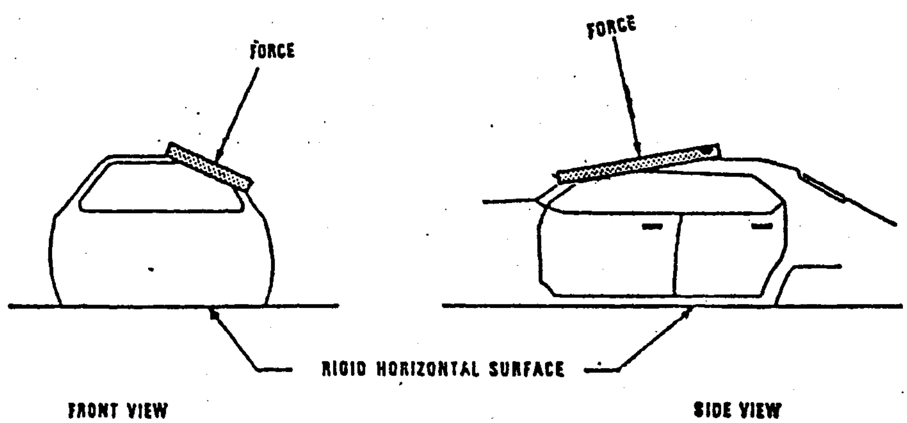

Figure 2.2 FMVSS 216 Load Displaced 0.13 m (5 inches)

Raised Roofs and FMVSS 216 and 220

In November 1989, the NHTSA proposed to extend the requirements of FMVSS 216 to "light trucks" (including trucks, buses, vans and other multipurpose passenger vehicles) having a GVWR of 4545 kg (10,000 lbs) or less, but when the Final Rule was presented in April 1991, it only applied to vehicles below 2727 kg (6000 lbs) GVWR. It is instructive to examine the comments in the Federal Register regarding this change in GVWR.

FMVSS 216 had been in effect since 1971 as applied to passenger cars[9]. NHTSA cited the convergence between light trucks and passenger cars both in their structure and use for personal transportation, along with a significantly greater incidence of rollover crashes per registered vehicle for light trucks than for passenger cars. NHTSA believed that amending the standard to include light trucks would prevent collapse of the passenger compartment. That is, as the driver and passenger in many light trucks are in the front seat, the FMVSS 216 crush test, which applies load to the left or right front corner of the roof, seemed appropriate.

Various parties responded to the proposed changes and their comments are summarized in the "Supplemental Information" published with the Final Rule [10]. Some quotes from this reference show the motivation for the change in GVWR requirements.

> "The Recreation Vehicle Industry Association (RVIA) urged NHTSA to exclude motor homes, vans, and van conversions from the standard. If those types of vehicles are not generally excluded, RVIA urged NHTSA to exclude those that have a GVWR of more than 6,000 pounds. A number of individual companies made similar comments and one, Kentron, Inc., suggested a cut-off of 5,500 pounds GVWR." [10, p.15512]

"In the proposal, NHTSA addressed the issue of light trucks that are manufactured in more than one stage or altered after they are certified by the original manufacturer. There are a number of final-stage manufacturers, many of which are small businesses, involved in installing truck bodies and/or work-related equipment on chassis. There are also a number of alterers involved in modifying the structure of new vehicles. Based on information from commenters, the majority of such vehicles have a GVWR greater than 6,000 pounds." [10, p. 15515]

"NTEA (National Truck Equipment Association) further stated that there currently are no vehicles with a GVWR of 6,000 pounds or less that are assembled from incomplete chassis." [10, p. 15515]

"NHTSA believes that limiting the coverage of the standard to light trucks with a GVWR of 6,000 pounds or less will greatly lessen the problems cited by NTEA and RVIA." [10, p. 15515]

The issue of raised roofs on large vans was thus largely avoided by limiting the applicability of the extended standard to vehicles under 2727 kg (6000 lbs) GVWR.

In the Summary of the Amended Final Rule for FMVSS 216, NHTSA indicated that the proposed standard raised issues concerning the feasibility of extending the standard to light trucks in the 2727 to 4545 kg (6000 to 10,000 lbs) GVWR range. It states that, "NHTSA will investigate those issues further and may possibly conduct future rulemaking concerning such light trucks." In my most recent conversation with Mr. Charles Hott at NHTSA, December 4, 1996, I asked if any roof crush rules are being considered for multipurpose vehicles over 2727 kg (6000 lbs) GVWR. He said that no rules were in the pipeline, and emphasized that there are no roof crush standards for full sized vans over 2727 kg (6000 lbs) GVWR except those sold as schoolbuses

As part of the argument to reduce the GVWR, some commentors suggested that the roof crush test of FMVSS 220 should be adopted as it would "...take into account the special characteristics and features of motor homes, vans and conversions".[10, p.15511] The raised roof is one of the "special characteristics" that is a central issue in the following quote.

> "Grumman Olsen (Grumman) suggested that the test procedure in Standard No. 220, *School Bus Rollover Protection*, would be more appropriate for walk-in vans and cargo vans. Mark III Industries (Mark III) suggested that the test procedures of Standard No. 220 would be more appropriate for van conversions. Mark III asserted that the standard No. 216 procedure tests the integrity of the original equipment manufacturer's chassis, rather than the structural integrity of the raised roof installed by the van converter. Mark III further asserted that the Standard No. 220 procedure tests the integrity of the raised roof as well as the structural integrity of the chassis." [10, p. 15514]

These remarks underscore the change in structural integrity that can occur with the raised roof and the appropriateness of FMVSS 220 as a means of testing the raised roof and chassis together.

RECOMMENDATION

For the population of vehicles for handicapped transit, a key distinction is between vehicles with and without a raised roof. Those with a raised roof should comply with the crush test of FMVSS 220. Those without raised roofs should comply with FMVSS 216 or 220. This could be accommodated by rephrasing Minnesota Rule 8840.5940 to allow compliance with either the crush test of FMVSS 216 or 220. Expected reaction would be:

- Minivan conversions with lowered floors following the recommended practices of the original manufacturer would already comply with FMVSS 216.

- Minivans with raised roofs would have a choice but most likely would opt for FMVSS 220 using a vendor roll bar structure or reinforced pop-up top. These devices would have to be tested on the minivan chassis.

- Full size vans, over 2727 kg (6000 lbs) GVWR, currently do not have to comply with FMVSS 216. The memos from GM and Chrysler [8] indicate that they do meet FMVSS 220. However, these vans have a chassis and do not easily lend themselves to lowered floors, so they would most likely require pop-up tops to accommodate transit of the handicapped.

- Full size vans over 2727 kg (6000 lbs) GVWR with raised roofs have a choice but would most likely opt for FMVSS 220, as currently available roll bar systems and reinforced tops already comply.

CHAPTER 3
WHEELCHAIR SECUREMENT ASSESSMENT

The second task of the project was to investigate means of installing wheelchair securement devices and advise as to whether the Department of Public Safety should amend its rule that approved devices be installed as required by the manufacturer. The rule in question is Minnesota Rule 7450.0400 Minimum Standards for Frame Attached Devices. The standard requires that the devices must meet or exceed the requirements of FMVSS 209 or be certified for to meet or exceed certain strength levels. The Minnesota Department of Public Safety has published a list of approved devices, dated December 21, 1994, by Duane Bartels of the Minnesota State Patrol.

The standard also requires that each frame attached securement device, "must be anchored to the frame at not less than two separate points with bolts, nuts and lockwashers or self-locking nuts." This is stated in Part E of the standard which continues as follows:

(1) Bolts used must be not less than 3/8 inch in diameter and National Fine Thread SAE grade 5 designation or equivalent.

(2) Where anchorage bolts do not pierce the vehicle frame, subframe, body post, or equivalent metal structure, a metal reinforcement plate or washer 1/16-inch thick and not less than four square inches or 2-1/4 inches in diameter respectively, is required.

(3) Interior paneling may not be used to constitute anchorage for a point of securement.

(4) A metal track, rail, or similar device permitting attachment of the securement device at optional points on it may be used to anchor the securement device, only if:

(a) the track, rail or other device is secured to the vehicle in compliance with anchorage requirements of this part; and

(b) the attachment of the securement device to the anchor point is by means of a positive attachment metal fitting.

These are very detailed instructions and in some cases are at odds with manufacturers instructions. Thus if the manufacturers instructions are not followed, the compliance of the device with FMVSS 209 or equivalent may be compromised.

On the surface this looks easy: the manufacturers certify compliance with the strength standards, so a device should be installed according to their instructions. Some problems with this are listed below.

- Installation information varies in quality and the level of detail. Some diagrams are generic and do not explicitly show the location of bolts.
- Some manufacturers do not include all necessary hardware, but emphasize the importance of using the correct hardware.
- Some manufacturers include hardware and emphasize the importance of not substituting other hardware.
- The recommended bolt diameter for some installations is 1/4" which is less than the Minnesota Rule specification.
- Some instructions refer to graded "bolts or screws", but they do not mean the hardware store variety wood screws. This was clarified with a phone call to Kinedyne where I was told that "screws" refer to an SAE graded fastener that resembles a king sized sheet metal screw and is driven with a wrench or an internal driver (allen head or similar).
- Some vehicles have lowered floors which are welded in according to rigid specifications, and the tracks for web straps are also welded in. These vehicles are certified to meet the various federal standards, but for those sold in Minnesota, two

additional holes must be drilled in each track and bolts installed in order to comply with the standard.

- Vehicle technology is continually changing which challenges the installation of certain systems. Electrical cables, fluid lines, various sensors, exhaust systems and shields, and other components below the floor pose problems that make it difficult to follow the manufacturer's instructions for all installations.

The current Minnesota Rule is simple. An inspector can look for bolts of a certain size, and if in place, O.K. How does one insure that a device has been installed according to manufacturer's instructions? Must inspectors become familiar with all the instructions, and their variations? Especially those which are vague or incomplete and open to diverse interpretation? I believe the answer is yes, if we do not want to interfere with the manufacturer's certification of the restraining device.

RECOMMENDATION

There are two elements to my recommendation.

- The manufacturers instructions should be followed for the installation of the securement devices and that Part E of Minnesota Rule 7450.0400 should state so explicitly. (The instructions would be included in the information packet that travels with the van.) The current part E may be appropriate if there are no instructions.

- Manufacturer's installation instructions need to be upgraded and presented in a graphical manner which shows suggested layouts in vans, dimensions, bolts sizes and spacing, identification and placement of special hardware such as backing plates, and acceptable variations to "standard" installations. In addition, if all necessary hardware is not included, then the proper items must be clearly identified for purchasing or fabrication. This will require contacting the various manufacturers and requesting revisions in their instructions to follow a uniform format. It is within their interest to do so, since it will increase the confidence that their restraint systems are installed properly.

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