VRTC-DCD 9142
EA08-015

Investigation of Liftgate Strut Failure

On 2005 Honda Odyssey

VEHICLE RESEARCH AND TEST CENTER
EAST LIBERTY, OHIO 43319

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16. Abstract

The objective of the program was to evaluate and compare the performance of the power liftgate system with functional struts to a system equipped with struts at various levels of degradation. Testing during this program yielded the following results:

- The force required to fully open the liftgate could not be generated by the electric drive motor alone. Once the liftgate reached a position approximately 5 degrees down from fully open, the electric drive motor disengaged and the struts alone provided the force required to fully open the liftgate and hold it open.
- The minimum combined strut force that would support the liftgate in the fully open position was approximately 320lb.
- The minimum combined strut force that would prevent the liftgate from dropping quickly and engaging the electric drive motor was between approximately 275 and 285 lb.
- One of the in-service struts from a vehicle provided only 102 to 120 lbs of force (variation based on temperature).
- When the liftgate closed slowly without the electric drive motor engaging, the contact force imparted by the liftgate ranged between 6 and 117 lb.
- When the electric drive motor engaged during closing, the liftgate imposed a contact force between approximately 8 and 47 lbs, and a subsequent greater force on the obstruction between approximately 28 and 92 lbs as the electric drive motor attempted to overcome the obstruction and fully power-close the liftgate.
- The contact force during the initial drop, before the motor engaged varied between approximately 39 and 149 lb.
- The force supplied by the liftgate struts varied with temperature. Testing showed an average of 15% reduction in available force between 110° F and 35° F.
- Activation of the perimeter contact switches that are meant to reverse the closing of the liftgate upon contact with foreign objects required approximately 3.5 lb.

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1.0 Introduction

This program was performed at the Vehicle Research and Test Center (VRTC) at the request of the Office of Defects Investigation (ODI) of the National Highway Traffic Safety Administration. ODI opened an Engineering Analysis (EA08-015) on the 2005 Honda Odyssey Touring model (subject vehicle), which is equipped with a power liftgate. Owners of subject vehicles claim that the rear liftgate can power-close unexpectedly, or drop and close without power actuation after power-opening. The objective of the program was to evaluate and compare the performance of the power liftgate system equipped with functional struts to a system equipped with struts at various levels of degradation.

2.0 Description of Operation

Subject vehicles are equipped with an electric drive motor that opens and closes the rear liftgate and a pair of gas struts, one on each side of the liftgate, that, when fully functional, help open the liftgate and hold it in the fully-open position. Powered opening and closing of the liftgate can be activated by pressing a button on the keyless remote or on the instrument panel near the driver's left knee. Additionally, powered closing can also be activated by pressing a button located on the bottom of the liftgate. A single-tone warning horn activates for approximately ½ second when the liftgate is power-opened and power-closed. Additionally, the hazard flashers flash three times when the motor is activated to open the liftgate.

The liftgate can be opened manually by squeezing a paddle-shaped lever to release the liftgate latch. The lever is located under the small overhang that houses the license plate light. Once the latch is released, the liftgate can be pulled toward the open position.

Subject vehicles are equipped with two mechanisms that, when activated, reverse the direction of a power-operated liftgate that encounters something blocking its path. 1) Perimeter contact strip switches are attached to each side of the liftgate that, when depressed, will cause the electric drive motor to reverse and open the liftgate. 2) A sensing device detects if something interferes with a power-opening or power-closing liftgate. When this feature activates, the electric drive motor reverses and re-opens a power-closing liftgate or re-closes a power-opening liftgate (i.e.,

the liftgate "auto-reverses"). A dual-tone warning horn sounds three times when either of these systems activates.[1]

3.0 Project Tasks

The following tasks were performed during the course of this program.

3.1 Consumer Experience

A list of owners of subject vehicles registered in Ohio was obtained from the Ohio Bureau of Motor Vehicles. VRTC personnel generated and mailed a questionnaire to approximately 1,050 owners requesting information regarding their experience with the liftgate struts on their vehicle. A copy of the questionnaire is shown in Appendix I. Out of 504 responses, (48% response rate), 50 (10%) responded that they had already replaced the liftgate struts.[2] Three owners (0.6%) responded that their struts would currently not support the liftgate in the open position. These last three owners were contacted and arrangements were made for them to have an authorized Honda dealership replace their struts. The owners then forwarded their old struts to VRTC. Additionally, one new strut was purchased for comparative purposes. The seven struts were labeled A – G as follows:

Strut A: New strut purchased from an authorized Honda dealer.
Struts B & C: Original equipment struts from VIN: 5FNRL38855B024510
Struts D & E: Original equipment struts from VIN: 5FNRL38815B100725
Struts F & G: Original equipment struts from VIN: 5FNRL388X5B128538

3.2 Determination of Force Exerted by Struts

The seven struts were tested to determine how much force each exerted through its range of travel. Each strut was installed in a United Tensile Test machine and stroked (compressed and

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[1] Honda refers to these liftgate control functions as "pinch protection." Honda's pinch protection utilizes both direct and indirect sensing methods. The perimeter contact switch represents a direct sensing method. However the auto-reversing feature, by contrast, utilizes (two) indirect sensing methods. One reversing method calculates the motor speed by counting the pulses of the ring magnet mounted to the drive shaft with pulse sensors and then calculates the drive shaft speed by dividing the number of pulses by the time period. The other indirect method relies on monitoring the electrical current draw from the power liftgate drive motor and using the load trend to calculate motor force and the presence of an obstruction. When the indirect sensing methods determine or detect contact with an obstruction the auto-reverse function is enabled. A finite amount of time is required for indirect sensing during which the force exerted on the obstruction increases as the drive motor continues to operate. See Honda's Information Response letter dated 12/5/2008, response to request # 13.

[2] A listing of how consumers became aware of the need to replace the liftgate struts, the mileage at which the struts were replaced, and the replacement cost to the consumer is provided in Appendix II

allowed to extend) through the available travel of the strut. The exerted force and the displacement of the strut were measured during compression and extension. In order to determine the effect of ambient temperature on the operation of the struts, each strut was tested after a three-hour temperature soak at 110° F, 72° F, and 35° F. Three tests were performed at each temperature. A separate soak cycle was performed prior to each test.

The test results showed that the force exerted by each strut was greatest after a 110° soak and least after a 35° soak. This was found to be true throughout the entire range of travel for each of the struts. The average reduction in force between 110° and 35° was approximately 15%. Generally, the force that each strut exerted was greatest when the strut began to be compressed. The force then decreased as the strut was compressed and usually increased somewhat as the strut reached full compression (see Appendix III).

Table 1 lists the average value of the maximum force exerted by each strut during the three tests at each temperature.

	Average Force (lb)		
Strut ID	110° F	70° F	35° F
A	236	206	192
B	120	105	102
C	249	231	216
D	241	223	206
E	237	218	205
F	242	219	203
G	245	226	212

Table 1
Average Maximum Strut Forces
at 110°, 70°, and 35° F

3.3 Test Instrumentation and Vehicle Preparation

A rotary potentiometer was calibrated and installed in line with the liftgate hinges on the test vehicle (as shown in Figures 1 and 2) to measure and record the angular position of the liftgate. A 500-lb capacity load cell was calibrated and used to measure force exerted by the liftgate as it closed during all phases of testing. A list of instrumentation is provided in Appendix IV.

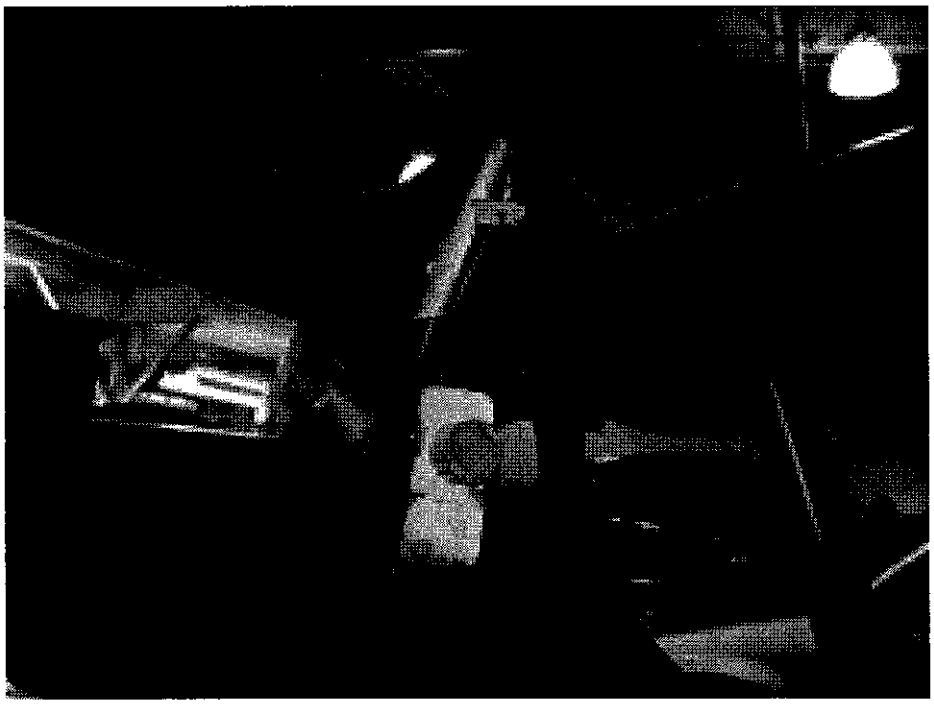


Figure 1
Rotary Potentiometer with Liftgate Open

Figure 2
Rotary Potentiometer with Liftgate Closed

3.4 Vehicle Testing

A 2005 Honda Odyssey Touring (VIN: 5FNRL38865B005707) (test vehicle) was procured for testing. The liftgate was removed, weighed, and reinstalled. The liftgate weighed 86 lb.

3.4.1 Determination of Force Required to Support the Liftgate

The force required to support the liftgate at various positions was determined by fabricating a series of solid struts that, when installed on the test vehicle in place of the liftgate struts, could support the liftgate in the fully open position and at 15, 30, and 45 degrees down from fully open. Each of the solid struts was equipped with a load cell that measured the compressive force in the strut. Additionally, the distance from the liftgate striker plate to the floor was measured and recorded at each test position described above. The results of this test are listed in Table 2.

Position (deg. down. from open)	Force on strut (lb)	Striker Distance from Floor (in)
Open	307	71.2
15	309	58.5
30	326	47.5
45	336	37.5

Table 2
Forces Required to Support Liftgate

3.4.2 Simulated Usage Testing

In order to determine whether strut performance degraded with use, a device was fabricated that allowed four of the consumer-supplied struts to be cycled repeatedly through their operating range. The remaining three struts were left untested so that they could be used as a control group.

With four struts installed, the device was adjusted to cycle at approximately six cycles per minute to minimize overheating due to repeated compression of the internal gas. The test was terminated after 1225 cycles since the struts were showing signs of warming and this was thought to simulate between two and twelve years of use, depending on how often the liftgate was operated. The force exerted by each of the four struts was approximately the same at the start of the test as it was at the end of the test. Figure 3 shows the test device with four struts installed.

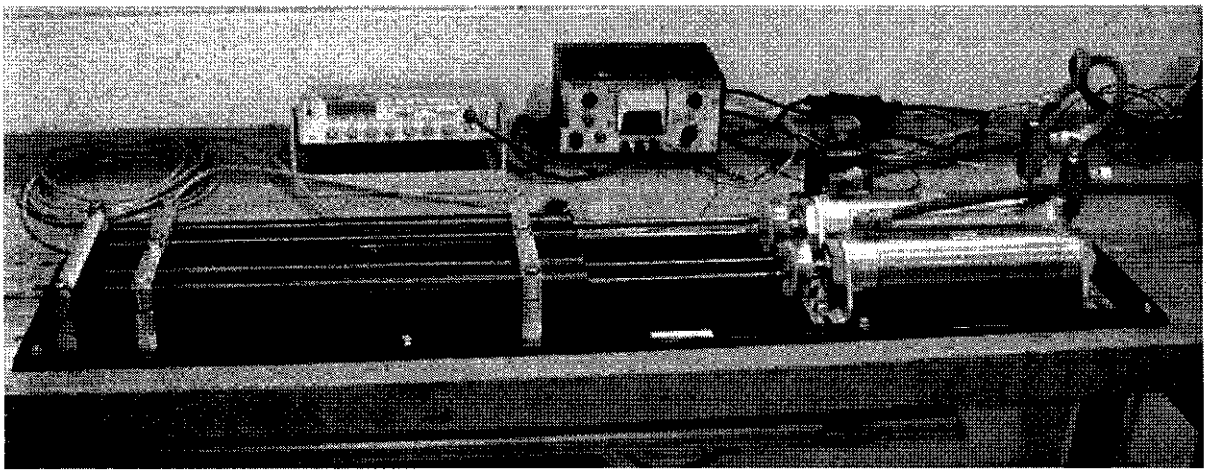


Figure 3
Strut Cycling Device

3.4.3 Test Struts

A pair of new struts was purchased and fitted with plumbing and valves that allowed the internal gas pressure to be adjusted to any desired level. A device was then fabricated that would hold a test strut, allow it to be compressed slightly, and measure the force exerted by the strut. With the strut installed in the device and compressed to a position just short of fully extended, the valve was then used to slowly bleed off the internal strut pressure until the strut exerted the desired force. Two adjusted struts then were installed on the test vehicle for on-vehicle testing.

Tests were performed starting with a combined strut force of 320 lb. Subsequent tests were performed at decreased levels of combined force. Between each test, the modified struts were removed from the test vehicle and the internal strut pressure was adjusted to the level desired for the next test. Figure 4 shows the modified struts. Figure 5 shows a standard strut installed in the measurement device.

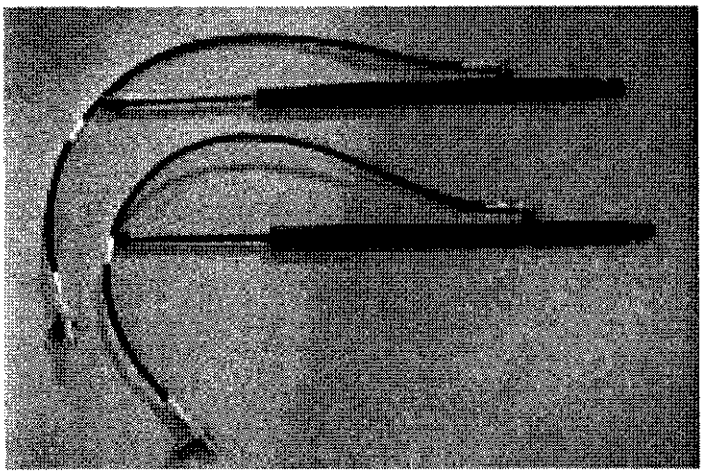


Figure 4

Struts Modified to Allow Variable Pressure

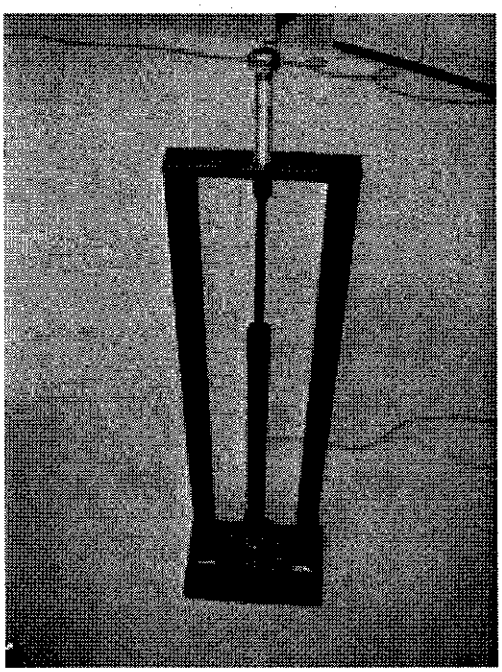


Figure 5

Strut-Force Adjustment Fixture

3.4.4 Failure Mode Descriptions

Without any liftgate struts installed, the electric drive motor was capable of raising the liftgate to approximately five degrees down from the fully open position. Additional force above what the electric drive motor could provide, which is normally provided by functional struts, was required to open the liftgate fully and to support the liftgate in the fully-open position. With struts that provided a combined force of 320 lb or greater, the liftgate opened fully and remained fully open. With struts that provided a combined force between 285 and 310 lb, the electric drive motor opened the liftgate to a position that was between approximately 3 and 5 degrees down from fully open. When the electric drive motor disengaged, the liftgate remained open at the lower position. As the combined force of the struts was reduced below 285 lb, the struts progressed through the following two failure conditions.

3.4.4.1 Failure Condition 1

With struts that provided a combined force between 275 and 285 pounds, the electric drive motor opened the liftgate to a position that was approximately 5.7 degrees down from fully open and then disengaged. Upon disengagement of the electric drive motor, one of two actions took place: (1) The liftgate would sometimes drop a few degrees, the motor would engage to reopen the liftgate and then disengage, and the liftgate would then begin to close without the motor engaging; or (2) The liftgate gradually started to close without an initial drop or motor engagement. In either case, the rate of downward movement was low at first, and then increased as the liftgate neared the fully closed position. There were no visible or audible warnings under this failure scenario because the motor drive did not engage to power-close the liftgate.

3.4.4.2 Failure Condition 2

With struts that provided a combined force of approximately 275 lb or less, the electric drive motor power-opened the liftgate to a position that was approximately 6.2 or more degrees down from fully open and then disengaged. Upon disengagement, the liftgate immediately dropped several degrees (initial drop position)[3]. After this initial drop, the electric drive motor engaged, power-opened the liftgate, and then disengaged. The liftgate dropped a second time, and the electric drive motor engaged, reopened the liftgate a second time, and then power-closed the liftgate. A dual-tone warning horn sounded when the motor engaged the second time and sounded continuously until the liftgate reached the fully closed position.

Multiple tests were performed to determine the failure conditions described above and to document the forces exerted by the liftgate as it closed. Data that were collected or calculated during this series of tests included the following parameters:

- maximum opening position of the liftgate
- initial drop position
- initial drop rate
- average final drop rate (as liftgate approached the closed position)

The following trends were noted during testing:

[3] When the motor disengages the tailgate drops in a "free-fall' like manner that is uncontrolled by the liftgate motor.

- The maximum opening position and the initial drop position both decreased as the available strut force decreased.
- The initial drop rate increased as the available strut force decreased.
- When the motor engaged to close the liftgate, the final drop rate was approximately nine degrees per second, regardless of the available combined strut force.

Data from this test series are presented in Table 3.

Combined Strut Force (lb)	Max Opening (deg down from fully open)	Rest Position (deg down from fully open)	Initial Drop Position (deg down from fully open)	Initial Drop Rate (deg/sec)	Avg. Final Drop Rate (deg/sec)	Description
320	-0.5	-0.5	N/A	N/A	N/A	A
310	-3.3	-3.3	N/A	N/A	N/A	A
300	-6.9	-7.4	N/A	N/A	N/A	A
290	-6.7	-8.6	N/A	N/A	N/A	A
285	-5.6	-5.7	N/A	N/A	N/A	A
280	-5.7	N/A	-10.1	7.0	14.0	B
275	-6.2	N/A	-9.4	6.4	9.2	C
270	-7.7	N/A	-10.9	6.2	9.0	C
250	-8.4	N/A	-12.0	11.4	8.9	C
230	-9.0	N/A	-12.5	15.0	9.2	C
180	-9.2	N/A	-12.8	17.5	8.9	C
160	-10.2	N/A	-13.4	16.0	9.2	C
140	-10.7	N/A	-14.3	14.7	8.7	C
0	-12.3	N/A	-17.6	24.5	9.5	C

A = Liftgate remains open
B = Liftgate drifts closed without motor or warning
C = Motor controls closing with warning horn

Table 3
Performance of Liftgate at Various Combined Strut Forces

3.4.5 Determination of Force Applied by Downward Motion of Unsupported Liftgate

The force that the liftgate exerted on an obstruction (blockage) as it closed was measured at various degrees of liftgate closure, measured downward from the fully open position, and with varying combined strut forces. A load cell (the obstruction or blockage) was positioned for each test position (or catch position) so that the latch cover on the liftgate contacted the load cell. A piece of dummy "skin" was placed on the load cell in order to more closely simulate the human

body if it was caught in the closing liftgate, and to help attenuate shock loading that the liftgate applied to the load cell. The load cell was mounted to a device that allowed the load cell to be elevated, rotated, and rolled into position so that it was perpendicular to the movement of the liftgate at the point of contact. To begin a test, the motor drive was activated with the liftgate in the closed position. As the liftgate opened, the load cell was inserted into the desired test position before the liftgate began to close.

3.4.5.1 Contact Forces for Failure Condition 1

In Failure Condition 1 the liftgate drifted closed slowly without engaging the drive motor, and the closing rate increased as the liftgate approached the closed position. In this condition, no audible or visual warnings were provided as the liftgate was closing. With a combined strut force of 280 pounds, the contact force measurements were taken as the liftgate contacted the load cell at 15, 30, 45, and 66 degrees down from fully open. The latter position, 66 degrees down from fully open, was the lowest point that could be measured as the liftgate approached the fully-closed position. This measurement was taken by positioning the load cell on the rear bumper as close as possible to the closed position of the liftgate. A final resting force measurement was taken after the liftgate came fully to rest on the load cell. Results of these tests are shown in Table 4.

Combined Strut Force (lb)	Catch Position (deg down from fully open)	Contact Force (lb)	Final Resting Force (lb)
280	15	6	4
280	30	23	4
280	45	29	5
280	66	117	9

Table 4
Test Data for Failure Condition 1

3.4.5.2 Contact Forces for Failure Condition 2

In Failure Condition 2, where the combined strut force was less than 275 lbs, the force that the liftgate exerted on the load cell was measured at 10, 15, 30, and 45 degrees down from fully open. The tests were conducted at seven (7) levels of decreasing combined struts force.

In tests where the electric drive motor engaged before the liftgate contacted the load cell, primarily the 15, 30 and 45 degree tests, the following sequence of events occurred. When the power-closing liftgate encountered the load cell, the electric drive motor reversed direction and power-opened the liftgate. After reversing and opening, the electric drive motor initiated power-closing of the liftgate a second time. If the power-closing liftgate encountered the load cell during this second power-closing, the electric drive motor disengaged. At that point, the liftgate came to rest on the load cell.

Five forces were measured and recorded during this testing. The first and third values ("First Contact Force (lb)" and "Second Contact Force (lb)", respectively) were generated when the liftgate contacted the load cell. The second and fourth values ("First Reverse Force (lb)" and "Second Reverse Force (lb)", respectively) were generated when the electric drive motor continued to attempt to close the liftgate after the liftgate contacted the load cell but before the motor drive reversed direction or disengaged. The fifth force was the at-rest weight of the liftgate on the load cell after the electric drive motor disengaged. Results of these tests are shown in Table 5. Selected data plots are shown in Appendix V.

Combined Strut Force (lb)	Catch Position (deg down from fully open)	First Contact Force (lb)	First Reverse Force (lb)	Second Contact Force (lb)	Second Reverse Force (lb)	Final Resting Force (lb)	Avg. Final Drop Rate (deg/sec)
270	15	18.0	29.5	14.2	30.1	5.8	7.6
270	30	23.2	33.2	18.7	35.1	5.7	9.8
270	45	18.8	31.5	25.3	32.8	8.3	9.7
250	15	14.5	33.1	13.5	33.0	9.5	7.0
250	30	20.0	35.7	24.8	35.7	9.8	9.4
250	45	17.5	33.7	18.6	32.3	11.3	10.0
230	10	21.3	43.0	19.3	42.3	13.6	4.6
230	30	18.5	39.5	19.0	38.1	N/D	8.9
230	45	19.1	36.1	18.1	35.9	15.6	9.7
180	15	28.1	48.7	34.9	64.9	21.0	7.0
180	30	27.5	47.2	30.9	68.9	20.6	8.9
180	45	8.3	28.3	13.6	31.5	14.3	9.9
160	15	23.1	50.3	21.7	65.0	23.2	4.8
160	30	29.0	48.0	30.5	71.7	N/D	9.2
160	45	26.0	45.5	24.8	59.3	23.8	10.1
140	30	32.8	52.3	34.8	77.5	26.7	8.7
0	30	43.7	66.5	46.8	91.5	47.2	7.7

Table 5
Forces Applied by Liftgate at Various Drop Angles - Failure Condition 2

In all but one of the Failure Condition 2 tests where the load cell was placed at 10 degrees from the fully open position, the liftgate contacted the load cell before the lift motor was able to engage or control the liftgate motion. In these tests, the nature of the initial contact on the load cell was more of an impact type loading due to the fact the liftgate was effectively 'free-falling' as opposed to being controlled by the motor. Although the liftgate did reopen and subsequently contact the load cell after this initial contact, the initial strike resulted in a significantly higher force than any subsequent contact, therefore only the initial contact force is reported for these tests. Results of the 10-degree drop tests where the motor did not engage are shown in Table 6.

Combined Strut Force (lb)	Catch Position (deg down from fully open)	Contact Force (lb)
270	10	39.4
250	10	54.3
230	10	74.2
180	10	97.6
160	10	111.4
140	10	134.4
0	10	149.0

Table 6
Test Data for 10 Degree Drop from Fully Open Without Motor Engagement
Failure Condition 2

3.4.6 Determination of Force Required to Activate the Perimeter Contact Strip Switch

One of the perimeter contact strip switches was removed from the vehicle and bench-tested to determine the force that was required to activate it. After connecting a continuity meter to the switch contacts, force was gradually applied using a calibrated force gage. The force required to activate the switch varied slightly from test to test, but was determined to be 3.5 ± 0.5 lb.

4.0 Conclusions

The following conclusions were formed during this testing.

- The force required to fully open the liftgate could not be generated by the electric drive motor alone. Once the liftgate reached a position approximately 5 degrees down from fully open, the electric drive motor disengaged and the struts alone provided the force required to fully open the liftgate and hold it open.
- The minimum combined strut force that would support the liftgate in the fully open position was approximately 320 lb.
- The minimum combined strut force that would prevent the liftgate from dropping quickly and engaging the electric drive motor (Failure Condition 2) was between approximately 275 and 285 lb.
- One of the in-service struts from a vehicle provided only 102 to 120 lbs of force (variation based on temperature).
- When the liftgate closed slowly without the electric drive motor engaging (Failure Condition 1), the contact force imparted by the liftgate ranged between 6 and 117 lb (Table 4).
- When the electric drive motor engaged during closing (Failure Condition 2, 15 degree drop or greater), the liftgate imposed a contact force (see Table 5 columns labeled, "First" and "Second Contact Force") between approximately 8 and 47 lbs[4], and a subsequent greater force on the obstruction (see Table 5, columns labeled "First" and "Second Reverse Force") between approximately 28 and 92 lbs as the electric drive motor attempted to overcome the obstruction and fully power-close the liftgate.
- The contact force during the initial drop before the electric drive motor engaged (Failure Condition 2, 10 degree drop) varied between approximately 39 and 149 lb (Table 6).
- The force supplied by the liftgate struts varied with temperature. Testing showed an average of 15% reduction in available force between 110° F and 35° F.
- Activation of the perimeter contact switches that are meant to reverse the closing of the liftgate upon contact with foreign objects required approximately 3.5 lb.

[4] This force varies depending on the position of the obstruction relative to the liftgate full open position and the combined lifting forces of the struts installed on the test vehicle. For example, as shown in Table 5, an obstruction positioned approximately 15 degrees below the liftgate full open position with struts having a combined force of 270 lbs received a lower contact force (18.0 lbs) than an obstruction positioned approximately 30 degrees below the liftgate full open position with the same struts installed.

Appendix I

Consumer Questionnaire

Dear Sir or Madam:

The Vehicle Research and Test Center (VRTC) and the Office of Defects Investigation (ODI), both offices of the National Highway Traffic Safety Administration (NHTSA), an agency within the United States Department of Transportation (DOT), are investigating the performance of the electric powered liftgate in certain Honda Odyssey vehicles.

As a registered owner, you can help with this investigation. Please answer the questions found on the reverse side of this page, then detach the postage-paid lower half and simply drop it in the mail. Your completing this questionnaire will be greatly appreciated and will help us to understand any problems that these vehicles may be experiencing. If you have any questions, please call me directly at 800-262-8309 Extension 265.

Thank you for your assistance.

Bob Esser
Test Engineer
Vehicle Research and Test Center
National Highway Traffic Safety Administration
United States Department of Transportation
Bob.Esser@dot.gov

Refer to the back of this page for more information. Then please respond to the following questions regarding your Honda Odyssey with Identification Number <<VIN>> (<<Batch>>):

1. If you no longer own this vehicle, please check here and return this form. _____
2. Have you replaced the support struts on the power rear liftgate? ..... _____YES _____ NO

   If yes, how did you become aware of the need to replace the struts? _____

   If yes, please provide the approximate date, mileage, and cost:

   Date: _____ Mileage: _____ Cost: _____
3. Does the power liftgate currently open fully when activated? ..... _____YES _____ NO
4. Does the power liftgate remain open when activated? ..... _____YES _____ NO
5. Has the power liftgate ever closed on its own? ..... _____YES _____ NO
6. Has the power liftgate ever caused an injury? ..... _____YES _____ NO

   If yes, please describe: _____
7. What is the current vehicle mileage? ..... _____ Miles

If we may contact you regarding your responses, please provide contact information:

Contact name:_____ Daytime Phone _____

Comments_____

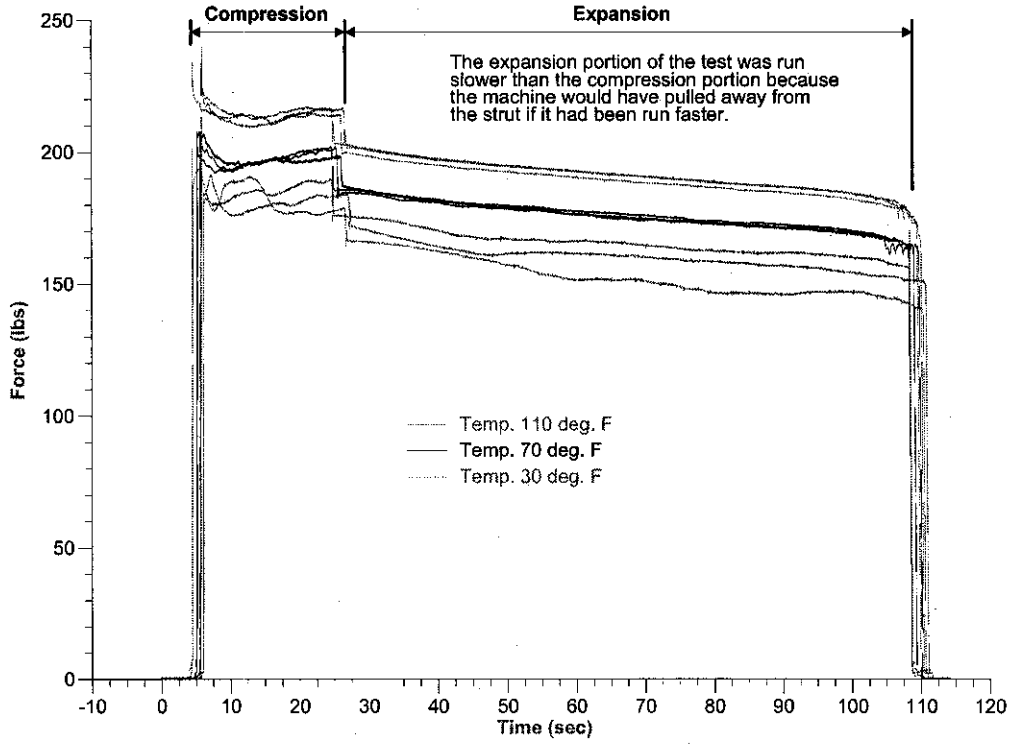
Appendix II

Listing of How Consumers Became Aware of the Need to Replace Struts, Mileage at Time of Replacement, and Cost

Comment	mileage	Cost
Lift gate would'nt stay up	57,721	147.10
Lift gt was slamming shut on its own very forcefully	25,000	?
Squeaking noise was heard when liftgate was used	36,000	warranty
Made a funny noise& tailgate wouldn't stay up	35,000	117.00
The door abruptly closed on myself & my 6 yr old daughter	90,000	500.00
I got pinned in the back,then it will start to close on its own.	76,000	250.00
Liftgate wouldn't work w/ liftgate button. If opened manually (with great difficulty. Liftgate wouldn't stay open	66,943	227.69
We couldn't open the liftgate too heavy.	72,791	133.54
Trunk lift would not stay open	60,000	warranty
liftfate failed to open or close	18,482	warranty
tailgate did not open due to weight & no strut support	70,000	$100-120
The hatch closed rapidly hitting me in the head	51,068	160.23
Rear hatch would not open fully, or remain up when lifted	37,000	NC
The lift gate would not open completely and would close on its own	55,405	139.36
it wouldn't open too heavy & would just fall on you	?	?
The door wouldn't stay open- it kept slamming shut.	49,833	260.00
Gate would not stay up. Replaced right rear strut as it appeared that liquid/fluid leaked from it.	49,000	50.00
Liftgate would not stay opened	26,000	Warranty
The rear liftgate would not stay open on its own	24,531	none
The tailgate would not stay up.	60,476	14.32
Door (liftgate) started falling down after opening.	53,000	120.00
gradually quit working.	DNA	DNA
The rear liftgate kept falling down.	45,000	250.00
Rear tailgate went up wiggles and re-closes itself right away replaced both tailgate struts.	24,018	164.00
tailgate did not stay up	35,920	Warranty
rear liftfate won't stay up. I had to manul/ malfunction 2 t oppend with power button, but wont stay up itself.	82,798	warranty
Lift gate would not stay up	?	0.00
liftgate wouldn't open all the way up.	15,000	warranty
The liftgate stopped staying up & would suddenly drop down.	35,000	Warranty
The rear liftgate would not stay open	78,847	246.61
The door would not open	25,000	Warranty
Door fell on my wife.	56,000	warranty
Liftgate would not stay up	10,000	0.00
the gate became heavy to lift and would not stay up. It would fall closed hard if you let it go	55,000	warranty
Door would not operate	54,937	warranty
the door(liftgate)fell down on my head several times	70,000	275.00
Tailgate would go to the top and come back down, without stopping.	70,740	169.30
Liftgate did not open all the way. Only partial opening, fell immediately when manually opened.	90,000	200.00

oil leakage	35,000	Warranty
Liftgate would not open automatically and would not remain up when opend manually.	27,446	Warranty
struts would not hold liftgate. It started lifting up to 80% & immediatley start to fall fast	36,000	Warranty
strut broke and rear hatch closed unexpectedly	37,907	120.30
the liftgate would not stay open or automatically open	under 12,000	Warranty
Tailgate would not "lift" automatically. Would not stay open if opened manually	71,114	161.58
the liftgate would bounce up & down then fall, after the button was pushed.	60,000	300.00
I was knocked on the head by the lift gate!	45,000	140.00
Worked fine when using hatchback oneteime,the next time the hatchback came down onto my back,	22,165	Warranty
The rear liftgate would not stay up on its own- goes up,teeters then comes back down & shuts . When opened manually,would not stay up.	61,594	167.41
The tailgate would no longer open automatically. We had to have someone hold it open while using it.	100,000	500.00
My tailgate would open activated, make a cracking sound when fully opend, then it would immediately close on it's own.	?	?

Appendix III
Data from Compression Tests

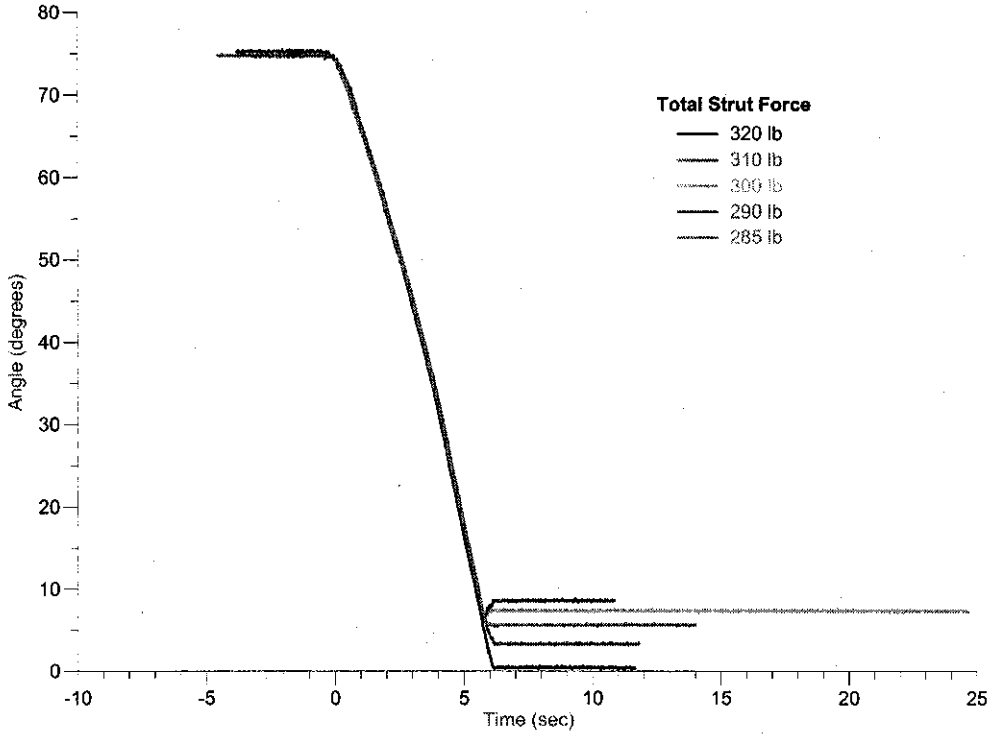


Typical Force/Time Plot
For Compression Testing
At Three Temperatures
(Strut A shown)

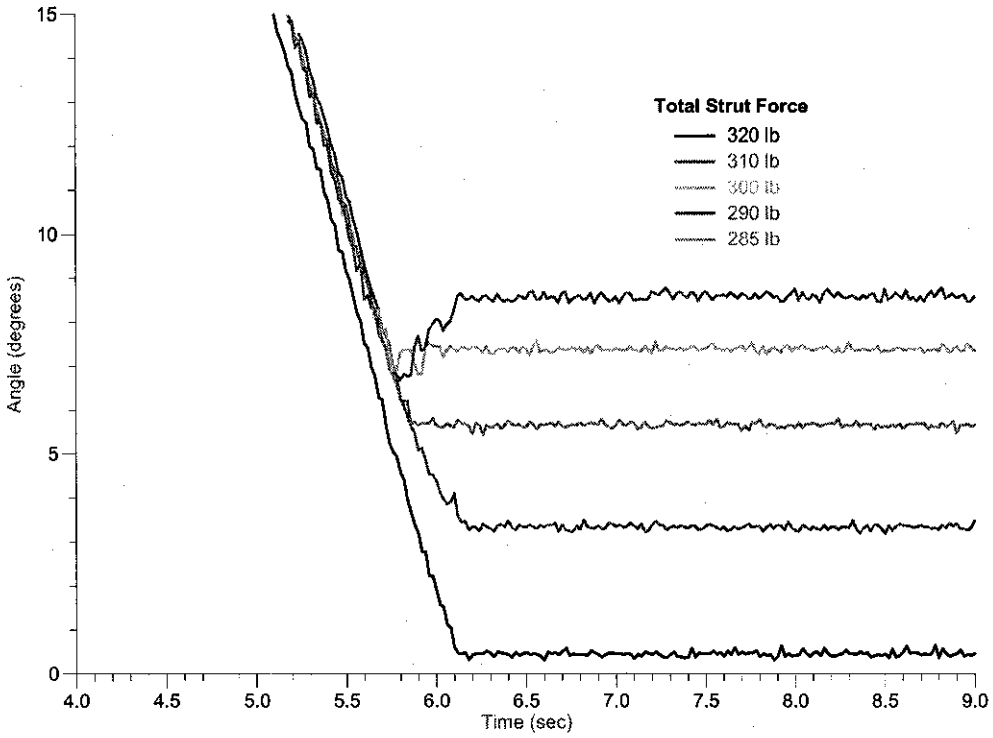
Appendix IV
List of Instrumentation

Item	Mfgr	Model	S/N	Purpose
Computer	Cyber Research	ATA-66		Data Gathering
Signal Conditioner	Analog Devices	3B18	(Multiple)	Signal Conditioning
Rotary Potentiometer	Bournes	3540S-001-103		Liftgate Angle Measurement
Load Cell	Sentran	ZB1-500-0000	941890	Force Measurement
Computer	Aris	3	253171	Calibration of Strut Force
Load Cell	Interface	1210 AF	24081	Calibration of Strut Force
Force Gage	Chatillon	DFE-10	T09988	Determine Strip Switch Force

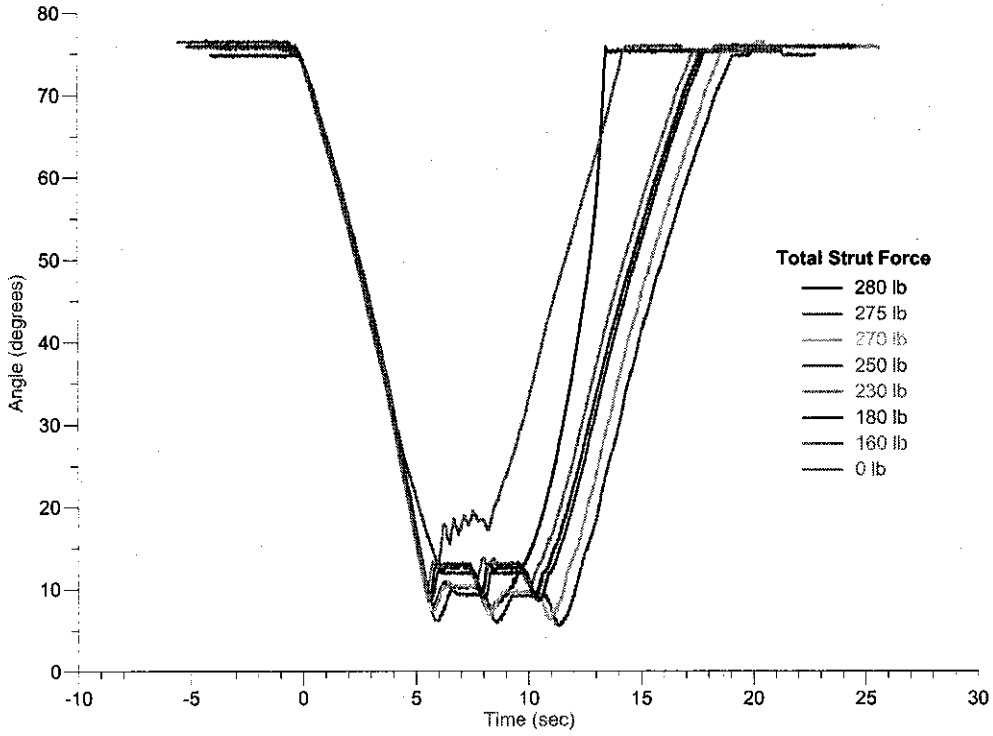
Appendix V
Selected Data Plots



Differences in "Open" Position of Liftgate with Combined Strut Forces Between 285 and 320 Lb. (0 Deg = Open Position) (Data from Table 3)



Differences in "Open" Position of Liftgate with Combined Strut Forces Between 285 and 320 Lb. (0 Deg = Open Position) Detailed View (Data from Table 3)



Time Liftgate Remains Open and Closing Rate with Combined Strut Forces Between 0 and 280 Lb. (0 Deg = Open Position) (Data from Table 3)