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SCI-NASS COMBINATION INFLATABLE CURTAIN WITH EJECTION INVESTIGATION

CASE NUMBER - 2009-11-016A
LOCATION - Michigan
VEHICLE - 2007 MERCURY MARINER
CRASH DATE - January 2009

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The crash investigation process is an inexact science which requires that physical evidence such as skid marks, vehicular damage measurements, and occupant contact points be coupled with the investigator's expert knowledge and experience of vehicle dynamics and occupant kinematics in order to determine the pre-crash, crash, and post-crash movements of involved vehicles and occupants.

Because each crash is a unique sequence of events, generalized conclusions cannot be made concerning the crashworthiness performance of the involved vehicle(s) or their safety systems.

Technical Report Documentation Page

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16. <i>Abstract</i> This SCI-NASS combination report covers an on-site investigation of a crash involving the left side of a 2007 Mercury Mariner (case vehicle) that impacted the back of a 1996 International truck tractor with one semi-trailer. The focus of this investigation is the injuries sustained by the driver and the circumstances surrounding the complete ejection of the back left passenger in the Mercury. The Mercury was traveling eastward in the inside eastbound lane of a rural interstate highway. It was dark with no illumination, raining, and the asphalt road surface was slippery due to ice and frost. As the driver was beginning to negotiate a gentle curve to the right, the Mercury lost traction on the slick road surface and began to rotate clockwise. The International tractor-trailer was stopped, heading east, on the outside (south) shoulder of the eastbound lanes. The International's driver had pulled over because there was another crash a short distance ahead. While sliding in a left-side-leading yaw, the Mercury traveled from the inside lane across the outside lane and onto the outside shoulder. The left side of the Mercury impacted the back of the International's semi-trailer, causing the driver's seat-mounted side impact air bag and the left and right inflatable curtain air bags to deploy. The Mercury rotated sharply counterclockwise away from the semi-trailer and the passenger in the back left seat was completely ejected through the back light. The Mercury came to rest a short distance behind and to the right of the semi-trailer's back end, heading east on the slope of a ditch adjacent to the shoulder. The ejected passenger came to rest in the bottom of the ditch, immediately behind and slightly to the right of the Mercury. The ejected back left passenger was declared dead at the scene. The Mercury's driver, front right passenger and back right passenger were transported via ground ambulance and hospitalized. The Mercury was towed due to disabling damage. The International tractor trailer combination was also towed, but not due to damage.					
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The focus of this investigation is the injuries sustained by the driver and the circumstances surrounding the complete ejection of the back left passenger in a 2007 Mercury Mariner SUV (**Figure 1**) that sustained a left side impact with the back of a semi-trailer. This crash was brought to the National Highway Traffic Safety Administration's attention by sampling activities of the National Automotive Sampling System-Crashworthiness Data System (NASS-CDS). The crash occurred at 1954 hours in January 2009, in Michigan, and was investigated by the applicable state police. The NASS researcher inspected the scene on February 3, 2009 and inspected the Mercury on April 17, 2009. The crash was assigned to this contractor as a Special Crash Investigations (SCI) case on March 25, 2010. Police on-scene and tow yard photos were received on June 15, 2010. This contractor worked with the NASS Zone Center to create this report.



Figure 1: Mercury's left side

CRASH CIRCUMSTANCES

Crash Environment: The Mercury was traveling on a rural interstate highway traversing in a generally east-west direction. The trafficway consisted of two travel lanes in each direction separated by a wide, unprotected grass median, with paved shoulders along the inside and outside edges of the travel lanes. It was dark and raining at the time of the crash, with no illumination near the crash site. The bituminous road surface was slippery due to ice and frost. At the location where the crash occurred, the roadway was level and slightly curved. The speed limit was 113 km/h (70 mph). There were several crashes along this stretch of roadway within less than an hour, due to the hazardous driving conditions.

Pre-Crash: The Mercury was traveling eastward in the inside eastbound lane. As the driver was beginning to negotiate a gentle curve to the right, the Mercury lost traction on the slick road surface and began to rotate clockwise. A 1996 International truck-tractor with a single semi-trailer was stopped, heading east, on the outside (south) shoulder of the eastbound lanes. The International's driver had pulled over because there was another crash a short distance ahead.

Crash: While sliding in a left-side-leading yaw, the Mercury traveled from the inside lane across the outside lane and onto the outside shoulder. The left side of the Mercury impacted the back of the International's semi-trailer, causing the Mercury's left seat-mounted side impact air bag and the left and right inflatable curtain (IC) air bags to deploy. The Mercury rotated sharply counterclockwise away from the semi-trailer and the passenger in the left rear seat was completely ejected through the back light. The Mercury came to rest a short distance behind and to the right of the semi-trailer's back end, heading east on the slope of a ditch adjacent to the shoulder (**Figure 2**). The ejected passenger came to rest in the bottom of the ditch, immediately behind and slightly to the right of the Mercury (**Figure 3**).

Post-Crash: Police and emergency medical services responded to the scene. The ejected left rear passenger was pronounced dead at the scene. The Mercury's remaining three occupants were transported via ambulance to a local hospital. Both vehicles were towed to the police impound lot.

CASE VEHICLE

The case vehicle was a 2007 Mercury Mariner front-wheel-drive, four-door, five-passenger sport utility vehicle (VIN: 4M2CU87157KJ-----), equipped with a V6 3.0 liter gasoline engine and an automatic transmission with a console-mounted selector lever. Four-wheel anti-lock brakes were standard for this model. Electronic Stability Control was not available on this model. The manufacturer has certified that the Mercury is compliant with the Advanced Air Bag portion of Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The front seat row was furnished with two bucket seats, adjustable head restraints, dual stage frontal air bags with an occupant weight sensor in the front right seat, and seat-mounted side impact thorax air bags. The Mercury was also equipped with rollover/side impact inflatable curtain (IC) air bags (the "Safety Canopy System") that provided protection for the front and back outboard seat positions. The two front seats were fitted with lap-and-shoulder manual safety belts with buckle stalk pretensioners. The back seat was a split bench seat with folding backs equipped with manual lap-and-shoulder safety belts. Each second row seat position was originally configured with an adjustable head restraint, but the three head restraints had been removed prior to this crash.

CASE VEHICLE DAMAGE

Exterior Damage: The Mercury sustained direct contact on its left side from its impact with the rear of the semi-trailer, longitudinally from slightly aft of the front door hinges rearward to the rear bumper corner and vertically from the mid-door to the roof rail **Figures 1, 4 and 5**). The Mercury's left side structures above the belt line engaged the back surface of the semi-trailer's cargo box. All of



Figure 2: On-scene view showing roadway with vehicles at final rest positions



Figure 3: Vehicles at final rest; the position of the ejected passenger (covered) is highlighted



Figure 4: On-scene view of Mercury's left side damage, after extrication of the occupants

the left side window glazing, the roof glazing and the back light disintegrated. The left side of the windshield was heavily fractured while the right side of the windshield sustained stress cracks. The back edge of the semi-trailer’s cargo deck engaged the Mercury immediately below the side windows, leaving a distinct linear crease on the front and rear doors and on the quarter panel across the fuel filler cap and the tail light/turn signal assembly to the left edge of the rear liftgate. The lower cross-member of the semi-trailer’s underride guard engaged the Mercury in the mid-door area, also leaving a distinct linear crease from the front door to the leading edge of the rear wheel well. The crush profile was measured along the lower crease, at the mid-door area. Maximum residual crush was measured as 17 cms (6.7 inches) at C-4, slightly aft of the B-pillar. The crush profile is shown in the table below.

Units	Event	Direct Damage		Field L	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	1	290	17	290	0	5	10	17	16	10	-70	-70
in		114.2	6.7	114.2	0.0	2.0	3.9	6.7	6.3	3.9	-27.6	-27.6



Figure 5: Mercury’s back and left side



Figure 6: Mercury’s back and right side

Damage Classification: The Mercury’s Collision Deformation Classification (CDC) is **10LZAW3** (300 degrees). This collision is not eligible for the WinSMASH reconstruction program because the International tractor-trailer combination is an out-of-scope vehicle. The barrier equivalent speed (BES) was calculated based on the Mercury’s measured crush profile. These calculations indicated the Mercury’s BES = 21 km/h (13 mph). This is a borderline calculation and the result seems low.

The manufacturer’s recommended tire size is P235/70R16 and the Mercury was equipped with four tires of this size. The tire data are shown in the table below.

Tire	Measured Pressure		Vehicle Manufacturer's Recommended Pressure		Tread Depth		Damage	Restricted	Deflated
	kPa	psi	kPa	psi	milli-meters	32 nd of an inch			
LF	200	29	207	30	5	6	None	No	No
LR	0	0	207	30	7	9	de-beaded	No	Yes
RR	207	30	207	30	7	9	None	No	No
RF	214	31	207	30	5	6	None	No	No

Vehicle Interior: Inspection of the Mercury's interior revealed evidence of intrusion by left side components and numerous points of occupant contact. Intrusions into the driver's seat area included the left A-pillar (22 cm [8.7 in] laterally), the left roof rail (9 cm [3.5 in] vertically) and the windshield header (4 cm [1.6 in] vertically). Intrusions into the second row left seat area included the forward upper quadrant of the left rear door (15 cm [5.9 in] laterally), the left B-pillar (11 cm [4.3 in] laterally), the left C-pillar (6 cm [2.4 in] laterally) and the left roof rail (4 cm [1.6 in] vertically). There were other left side intrusions of lesser magnitude.

Evidence of contact by the driver was found on the steering wheel rim (chest - bent) and the left lower instrument panel (left knee - cracked). Evidence of contact by the right front passenger was found on the center console (left hip - scuffed and deformed) and the glove box door (left knee - scuffed). Evidence of contact by the left rear passenger was found on the left rear door armrest and on the roof. These included scuffs on the roof upholstery above the left rear seat (left flank and lower extremity) and displacement of the rear dome light (foot). A total of 13 points of contact were documented.

AUTOMATIC RESTRAINT SYSTEM

The Mercury was equipped with a frontal air bag system that is certified by the manufacturer to be in compliance with the Advance Air Bag portion of Federal Motor Vehicle Safety Standard (FMVSS) No. 208, consisting of dual stage frontal air bags for the driver and front right passenger and a weight sensor in the front right seat position. The frontal air bags did not deploy. The Mercury was also equipped with seat-mounted side impact air bags and roof rail-mounted inflatable curtain (IC) air bags. The driver's seat back air bag and both ICs deployed.



Figure 7: Driver's seat-mounted side impact air bag, showing the outboard surface of the air bag and the stub of the driver's safety belt, which was cut by emergency response personnel

The driver's seat-mounted side impact air bag deployed via a pre-stressed seam in the upholstery on the outboard edge of the driver's seat back (**Figure 7**). There was no evidence of damage to the air bag and no evidence of occupant contact.

The left (**Figures 8 and 9**) and right (**Figures 10, 11, 12**) IC air bags deployed from behind a trim panel that runs along the junction of the respective side structures and the roof. Both IC air bags extended down to slightly below the base of the side window glazing. The forward edges of the deployed IC air bags extended to the junction of the respective A-pillars and the roof rails and were approximately perpendicular to the roof rails. The A-pillars slope forward and there was a triangle-shaped gap that was not covered by the deployed IC air bags, between the forward edge of the IC air bags and the A-pillars (**Figure 12**). The front lower corner of each IC was tethered to the respective A-pillars and the back lower corner was tethered to the respective C-pillars. There was no evidence of contact on either IC air bag. The fabric of the left IC air bag was sliced away from the driver's seat area during extrication.



The Mercury was equipped with lap-and-shoulder safety belts in all five seat positions. The two front seat belts consisted of continuous loop webbing with sliding latch plates, height-adjustable D-rings and buckle stalk pretensioners for the two front bucket seats. The front right pretensioner actuated, with the buckle stalk moving a measured distance of 3 cm (1.2 in). The front left pretensioner was not accessible. Based on the vehicle inspection, both the driver and the front right passenger were using their safety belts. The three safety belts in the second seat row consisted of continuous loop webbing with sliding latch plates and fixed upper anchors. Based on the vehicle inspection, neither of the second row occupants were using their safety belts at the time of the crash.

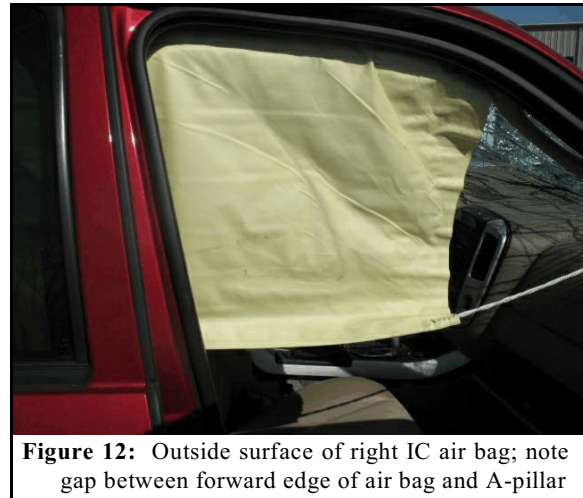


Figure 12: Outside surface of right IC air bag; note gap between forward edge of air bag and A-pillar

CASE VEHICLE KINEMATICS OVERVIEW

The Mercury was negotiating a gentle right curve when it lost traction on the icy road surface. It rotated clockwise and began to yaw, with the left side leading, toward the right shoulder. The slick surface provided little resistance against the Mercury's tires and the rotation/yaw motion probably had little effect on the occupants' seated posture. The Mercury had rotated approximately 70 degrees clockwise when it departed the roadway and entered the shoulder. The left side of the Mercury impacted the back surface of the semi-trailer. All of the left side glazing and the back light disintegrated. The driver's seat back-mounted side air bag and the left and right IC air bags all deployed. All of the occupants moved leftward and forward in response to the 300 degree impact force. The Mercury rebounded from the impact with sharp counterclockwise rotation and the occupants moved rearward and rightward in response to the rebound and rotation. The Mercury came to rest a short distance rearward and to the right of the semi-trailer, heading east.

CASE VEHICLE DRIVER KINEMATICS

The Mercury's driver (19-year-old male, 191 cm [75 inches], 77 kg [170 pounds]) was seated in an unknown posture with his seat track adjusted at the middle position and his seat back slightly reclined. The driver was restrained by the available lap-and-shoulder safety belt system. The driver's seat-mounted side impact air bag and the left roof rail-mounted IC deployed.

The driver moved leftward and forward as the Mercury engaged the semi-trailer. His safety belt retractor locked and he loaded the safety belt webbing. The left A-pillar and the driver's door intruded into the front left seat position. The driver's head impacted the A-pillar and he sustained bi-frontal cerebral contusions, a subarachnoid hemorrhage in the left frontal lobe, diffuse axonal injury, brain edema, cervical strain and an abrasion over his right eyebrow. His chest and abdomen

loaded the safety belt webbing, causing contusions to the chest wall and abdomen. His chest loaded against the forward upper quadrant of the intruding door and he sustained a fracture of the sternum, contusion of the myocardium and pneumothorax. His left elbow impacted the armrest on the driver's door and he sustained a laceration. He moved rightward and rearward as the Mercury rebounded, rotated counterclockwise and came to rest. His position at final rest is not known.

CASE VEHICLE DRIVER INJURIES

The driver was transported via ground ambulance to a hospital, where he was admitted for three days.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source	Source Confidence	Source of Injury Data
1	Contusion, cerebral, bi-frontal lobes, not further specified	serious 140622.3,3	A-pillar, left	Probable	Hospitalization records
2	Hemorrhage, 5 mm (0.2 in) in posterior limb of right internal capsule consistent with diffuse axonal (white matter shearing) injury	critical 140628.5,1	A-pillar, left	Possible	Hospitalization records
	Nonanatomic brain injury with loss of consciousness of unknown short duration, amnesia to event, initial GCS= 14 → 15	Not coded	A-pillar, left	Probable	Hospitalization records
3	Hemorrhage, cerebral, subarachnoid, small, left frontal lobe	serious 140684.3,2	A-pillar, left	Probable	Hospitalization records
4	Fracture xiphoid process of sternum, minimally displaced	moderate 450804.2,4	Left front door panel, forward upper quadrant	Possible	Hospitalization records
5	Pneumothorax, small, left anterior pleural space	serious 442202.3,2	Left front door panel, forward upper quadrant	Possible	Hospitalization records
6	Laceration, 2 cm (0.8 in), posterior left elbow involving joint capsule	moderate 750640.2,2	Left front hardware/armrest, forward upper quadrant	Possible	Hospitalization records
7	Contusion myocardium (cardiac) with minimal effusion, not further specified	minor 441002.1,4	Left front door panel, forward upper quadrant	Possible	Hospitalization records
8	Abrasion, small, on right eyebrow	minor 290202.1,7	A-pillar, left	Possible	Emergency room records

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source	Source Confidence	Source of Injury Data
9	Strain, acute, cervical, not further specified	minor 640278.1,6	A-pillar, left (<i>Indirect injury</i>)	Probable	Hospitalization records
10	Contusion abdomen	minor 590402.1,0	Lap portion of safety belt system	Probable	Interviewee (same person)
11	Brain edema with mild effacement of gyri and sulci	serious 140660.3,9	A-pillar, left	Probable	Hospitalization records
12	Contusion (bruise) over sternum and right chest wall, not further specified	minor 490402.1,0	Torso portion of safety belt system	Probable	Hospitalization records

CASE VEHICLE FRONT RIGHT PASSENGER KINEMATICS

The Mercury's front right passenger (56-year-old female, 160 cm [63 inches], 87 kg [192 pounds]) was seated in an unknown posture with her seat track adjusted between the middle and rear-most position and her seat back slightly reclined. She was restrained by the available lap-and-shoulder safety belt system and the right roof rail-mounted IC deployed.

The front right passenger moved leftward and forward as the Mercury engaged the semi-trailer. Her safety belt retractor locked, her pretensioner actuated and she loaded the safety belt webbing. She sustained a contusion on her left chest, contusions across her lower abdomen and a contusion of her jejunum from loading the safety belt webbing. Her head struck the windshield-mounted rearview mirror and she sustained a laceration near the center of her forehead and a non-anatomic brain injury. Her left elbow struck the center console and she sustained a bruise over her elbow. She moved rightward and rearward as the Mercury rotated counterclockwise and came to rest. Her position at final rest is not known.

CASE VEHICLE FRONT RIGHT PASSENGER INJURIES

The front right passenger was transported via ambulance to a hospital, where she was admitted for two days.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source	Source Confidence	Source of Injury Data
1	Nonanatomic brain injury with brief (unknown) loss of consciousness and amnesia for event; GCS=15	moderate 160410.2,0	Rearview mirror	Probable	Hospitalization records

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source	Source Confidence	Source of Injury Data
2	Laceration, 8 cm (3.1 in), near center of forehead approaching hairline	minor 290602.1,7	Rearview mirror	Probable	Hospitalization records
3	Contusion (bruising) over anterior left chest with pain on palpation	minor 490402.1,2	Torso portion of safety belt system	Probable	Hospitalization records
4	Contusion (bruising) across lower half of abdomen in area of seat belt with tenderness on palpation.	minor 590402.1,8	Lap portion of safety belt system	Certain	Hospitalization records
5	Contusion (hematoma) jejunum, not further specified	moderate 541410.2,8	Lap portion of safety belt system	Certain	Hospitalization records
6	Contusion (bruise) medial left elbow, not further specified	minor 790402.1,2	Interior, center console first row	Probable	Hospitalization records

CASE VEHICLE BACK LEFT PASSENGER KINEMATICS

The Mercury's back left passenger (18-year-old female, 165 cm [65 inches], 116 kg [255 pounds]) was seated in an unknown posture. The bench seat did not have an adjustable seat track or seat back. She was not using the available lap-and-shoulder safety belt. The left roof rail-mounted IC deployed.

The back left passenger moved leftward and forward as the Mercury engaged the semi-trailer. Her chest and abdomen contacted the forward upper quadrant of the left rear door and she sustained a laceration of her left lung, a laceration of the vena cava and multiple bilateral fractured ribs with lacerations of the intercostal muscle tissues on the left. Her face and chest contacted the left IC air bag, causing abrasions overlaying her left zygomatic arch and on her left breast. As the Mercury rebounded and rotated counterclockwise, she was projected rearward over the second row seat back and was completely ejected through the broken-out back light window opening. Her head hit the ground and she suffered brainstem compression and bilateral brain swelling. She also sustained abrasions on the dorsum of her right hand.

CASE VEHICLE BACK LEFT PASSENGER INJURIES

The back left passenger was declared dead at the scene. Her body was transported to the morgue and she was autopsied the next day.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source	Source Confidence	Source of Injury Data
1	Abrasion, 2.5 cm (1 in) overlying left zygomatic arch, not further specified	minor 290202.1,2	Air bag, second row left passenger's IC	Possible	Autopsy
2	Abrasions, 5.1 cm (2 in), irregular, central left breast	minor 490202.1,2	Air bag, second row left passenger's IC	Possible	Autopsy
3	Abrasions, small-less than 2.5 cm (1 in) in area, irregular, on dorsum right hand and overlying medial, proximal, right hand (palmer surface) interphalangeal joints	minor 790202.1,1	Ground	Possible	Autopsy
4	Brainstem compression with symmetrical uncal (transtentorial) and cerebellar tonsillar herniation	critical 140202.5,8	Ground	Possible	Autopsy
5	Laceration, large, deep, vertical, in left lower lobe of lung with massive, bilateral hemothoraces, not further specified	severe 441430.3,2	Left rear door panel, forward upper quadrant	Probable	Autopsy
6	Laceration to inferior vena cava at level of diaphragm, not further specified	serious 421804.3,4	Left rear door panel, forward upper quadrant	Probable	Autopsy
7	Fractured ribs: displaced right posterolateral 10 th and 11 th ; lateral left 2 nd through 7 th with broad lacerations of adjacent intercostal muscle of left 2 nd through 7 th ribs	serious 450250.3,3	Left rear door panel, forward upper quadrant	Probable	Autopsy
8 9	Brain swelling with symmetrical cerebral hemispheres and compressed ventricles	serious 140660.3,1 140660.3,2	Ground	Possible	Autopsy

CASE VEHICLE BACK RIGHT PASSENGER KINEMATICS

The Mercury's back right passenger (18-year-old male, height and weight unknown) was seated in an unknown posture. The bench seat did not have an adjustable track or seat back. He was not using the available lap-and-shoulder safety belt. The right roof rail-mounted IC deployed.

The back right passenger moved leftward and forward in response to the Mercury's impact with the semi-trailer. He sustained a non-anatomic brain injury from an unknown source and lacerations and abrasion on one of his hands (unknown if left or right), probably from flying glass.

As the Mercury rebounded and rotated counterclockwise he moved rightward and rearward. His position at final rest is not known.

CASE VEHICLE BACK RIGHT PASSENGER INJURIES

The back right passenger was transported via ambulance to a hospital, where he was admitted overnight.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source	Source Confidence	Source of Injury Data
1	Nonanatomic brain injury with suspected loss of consciousness of short duration and amnesia for event; GCS=15	moderate 160410.2,0	Unknown injury source	Unknown	Hospitalization records
2 3	Abrasions and lacerations, minor, in hand from where patient was cut by glass, not further specified	minor 790602.1,9 790202.1,9	Noncontact injury: flying glass, unknown source	Possible	Emergency room records

OTHER VEHICLE

The other vehicle was a 1996 International 9200 6x4 truck tractor (VIN: 2HSFMAHR6TC-----) coupled to a single box van semi-trailer (VIN: unknown). Damage to the tractor-trailer was limited to the rear underride guard and the components on the under side of the trailer's cargo deck where the underride guard was attached (**Figures 13 - 16**). The Truck Deformation Classification (TDC) for the International tractor-trailer is **07BDAWA** (200 degrees). The International tractor-trailer was towed to an impound lot, but not due to damage.



Figure 13: Back of semi-trailer, view from left rear



Figure 14: Back of semi-trailer, view from right rear



