NHTSA Roof Crush Tests and Other Tests for Validating Computer Models
## NHTSA 216 Tests

<table>
<thead>
<tr>
<th>Yr</th>
<th>Make</th>
<th>Model</th>
<th>Nr</th>
<th>Pitch</th>
<th>Roll</th>
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<th>Initial Head Clr</th>
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5” Allowable
Observation

All vehicles tested easily passed 216
Roof Force vs. Crush
Typical of 216 Loading

![Graph showing Roof Force vs. Crush with Allowable level indicated.](image)
Roof Force vs. Crush
Typical of 216 Loading

NHTSA Conduced
3 Drop Tests from Heights
To Absorb Energy 1, 2 & 3
NHTSA Drop Test Research

- Dropped 2 vehicle types – with 2 different orientations each and several different drop heights (total of 8 vehicles)
- Drop height based on non-linear static crush test data (Test as in 216, but with 2 test orientations)
- Initial drop test was to achieve the max crush in the crush test (Based on energy 1+2+3)
- Comparative vehicle dropped sequentially three times – Drop heights determined by Energy 1, Energy 2, and Energy 3
## NHTSA Drop Tests
### Nissan Pickup

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<th>Nr</th>
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Initial Roof Clearance 6.15”
## NHTSA Drop Tests

**Dodge Colt**

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*Initial Roof Clearance 7.99”*
Drop Test Characteristics

- Static test results could be used to predict equivalent drop height in first and subsequent roof loadings.
- In drop test, vehicle rotation absorbs energy.
- Vehicle rotation may vary with roof crush.
- In drop test, hood may impact ground.
- Drop test absorbs more energy than the static test.
- Drop test produces higher peak force.
Drop Test vs. Static Test

- Static test is more repeatable
- Static test produces generally similar damage to drop test
- Drop test is more like the real world
- Drop test permits the use of dummy

- Issue for both:
  Relationship to real world; crash severity
Drop Test Characteristics

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# Roof Crush Tests by NHTSA

**Vehicles Tested to 10+ in. of Crush**

### Quasi-Static Tests

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<th>Year</th>
<th>Make</th>
<th>Model</th>
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### Quasi-Static + Dynamic

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Analysis of NHTSA Roof Crush Tests

• Tests with and without glass bonded in the windshield
• Tests of different vehicle classes
• Tests demonstrating different load deflection characteristics
• Tests comparing 216 test and drop test
NHTSA Roof Tests – Honda Civic

Decreased Load Support After 3”
NHTSA Roof Tests – C/K Pickup

Decreased Load Support After 5”

Roof Deflection, in.

Force/Vehicle Weight

Civic  C/K Pickup
NHTSA Tests – Pontiac No Glass

Increasing Load Support After 2”

Force/Vehicle Weight

Roof Deflection, in.

Civic  6000, no Glass
NHTSA Roof Tests - Plymouth

Roof Deflection, in.

Barely Meets 216 w/o Glass

- Civic
- 6000, no Glass
- Vista, no Glass
NHTSA Roof Tests – Range

![Diagram showing roof deflection vs. force/vehicle weight for different models. The Civic, 6000, Vista, and X no Glass are represented. The diagram indicates nearly elastic load support.](image-url)
NHTSA Tests – Explorer and Taurus

Generally Similar Response
NHTSA Tests – Static vs. Dynamic

Dynamic Response Has Higher Stiffness

Roof Crush, In.

Taurus Static
Taurus Dynamic
Dynamic Rollover Tests

- NHTSA 208 Rollovers ~ 30
- NHTSA Roll Cart Rollovers ~ 15
- Rollovers from Litigation ~ 20
- Rollover from ASRI – C/K Pickup
- Crush Test from NHTSA – C/K Pickup
- Drop Test from Litigation – C/K Pickup
- GW FEM Model for NHTSA – C/K Pickup
Other Vehicle FEM Models Developed by GWU

- Taurus
- Caravan
- Neon
- GM C/K Pickup

- Initial Roof Crush Model – GM C/K Pickup
Additional Testing Required

• Quasi-static testing under loading conditions different from 216.
• Drop testing at different orientations from the 216 configuration.
• Roof testing and evaluation of production vehicles believed to have superior roof strength.
• Roof testing and evaluation of modified vehicles with improved roof strength.
Ongoing Research

• Rollover Roof Crush Sponsored by the Santos Family Foundation
NHTSA Rollover Crash Severity Project

- In Dec 2001 NHTSA placed high priority on developing a severity index for rollover.
- Considered a prerequisite for a roof crush standard.
- Assigned personnel to project.
- Initiated a cooperative project with GW.
- GW Roof Crush Research Project slightly broadened to accommodate opportunity to assist NHTSA.
Rollover Severity Research Project
Ms. Eigen

• Analysis of rollover accident data supplemented by modeling to assess distributions by:
  – Number of quarter turns
  – Extent of roof crush
  – Roll rate
  – Vertical velocity
  – Most harmful event
  – MAIS 3+ injuries by body region
Harmful Factors that Contribute to Roof Crush
Mr. Lier and Mr. Godrick

- Conduct vehicle tests and film analysis to calibrate and validate computer models.
  - Instrumented vehicle test conducted Oct 2001
  - Additional data available from other tests (drop tests)

- Develop FEM computer models to study factors that contribute to roof crush.

- Exercise computer models; determine critical values for vehicle orientation, vertical velocity, roll rate
FEM Model Static Test - Pickup
FEM Drop Test
Vehicle/occupant modeling to:

– Determine the contribution of roof intrusion to occupant injury.

– Determine population of injuries that could be mitigated by increased roof strength.

– Determine the recommended vertical and horizontal velocity and vehicle orientation for roof crush testing.
Coordination

• Work is being coordinated with NHTSA
• Briefing to Ford Motor Company staff-
  – Data for model validation requested
• Briefings to Public Citizen and Center for Auto Safety
• Advise from Carl Nash and Don Friedman
  – Subcontract with Don Friedman for Improved Roof Design