THE ENGINEERING INSTITUTE

Roof Crush

Engineering Analysis of the Proposed FMVSS-216 Requirement

November 21, 2005

Stephen A. Batzer, Ph.D., P.E.
Farmington, Arkansas

This history of roof design is often indifferent

1970
Marquis Brougham

2002 Toyota
4Runner

Strong roofs are not merely a goal but a current reality

Volvo XC-90

Subaru Forester

FMVSS 571.216 Roof Crush Resistance

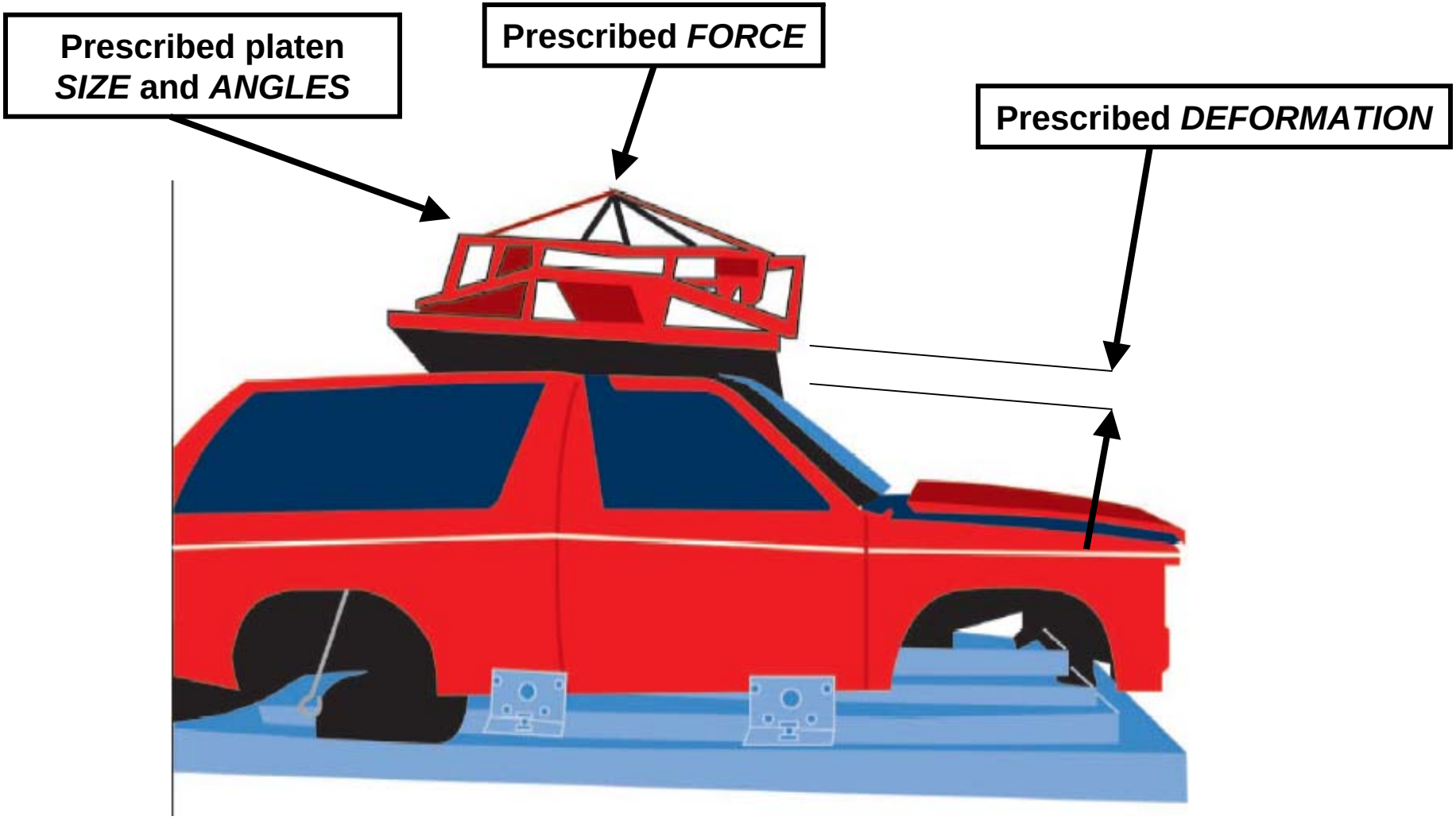
"The purpose of this standard is to reduce deaths and injuries due to the crushing of the roof into the occupant compartment in rollover crashes."

It does not apply to all vehicles

Principles of an Optimum Roof Crush Standard

1. Protects the public:
   - reasonably sized belted occupants will not be injured by roof crush for the vast majority of rollovers.
2. Allows the roof to deform a prescribed amount:
   - compliant roofs bend, but *not too much* and *do not break*.
3. Incorporates an achievable proven technology level:
   - uses low-tech, off the shelf design and manufacturing techniques.
4. Defines realistic certification protocol:
   - repeatable destructive testing methodology.

Current FMVSS 216 Roof Strength Certification

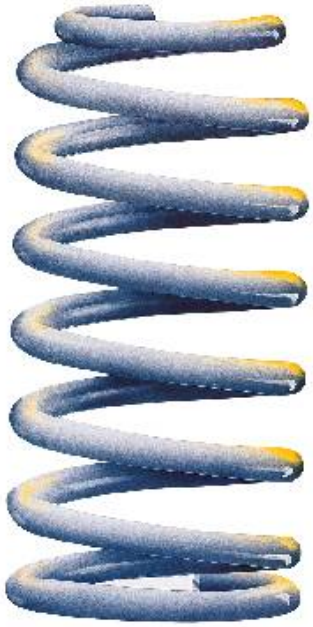


This testing gives an imperfect indication of practical roof strength.
It is, therefore, only a suitable *companion test* to dynamic rollovers

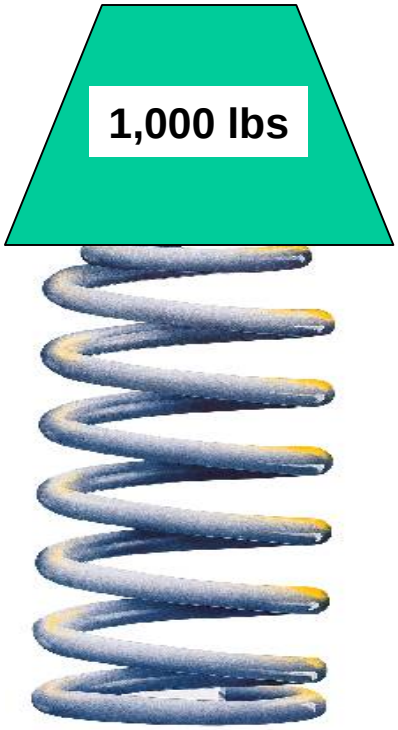
The roof is actually a giant spring

Springs are described by *force per unit distance deformed*

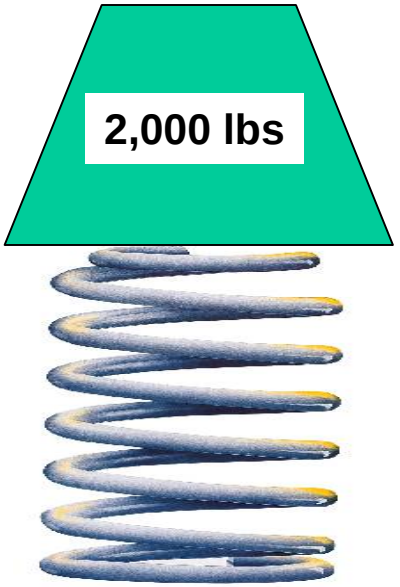
3 Identical Springs…



Undeformed
0 lbs
0” deflection



Deformed
1,000 lbs with
1” deflection



Deformed
2,000 lbs with
2” deflection

The *Spring Constant* is 1,000 $^{lbs}/_{in}$ for all 3 cases
<u>Force</u> and <u>Deflection</u> are both important.

Roof Crush Standards

Existing Standard:

1. Vehicle must resist:
   - 1.5X weight within
   - 5” of travel.
2. Does not take the amount of static headroom into account (vehicle at rest on wheels – seat compressed).
3. Applied to one side of the roof.
4. Vehicle-independent platen angles.

Proposed Standard:

1. Vehicle must resist:
   - 2.5X weight within
   - ~7.63” of travel.
2. Does not take the amount of dynamic headroom into account (vehicle rolling with occupant upside down).
3. Applied to one side of the roof.
4. Vehicle-independent platen angles.

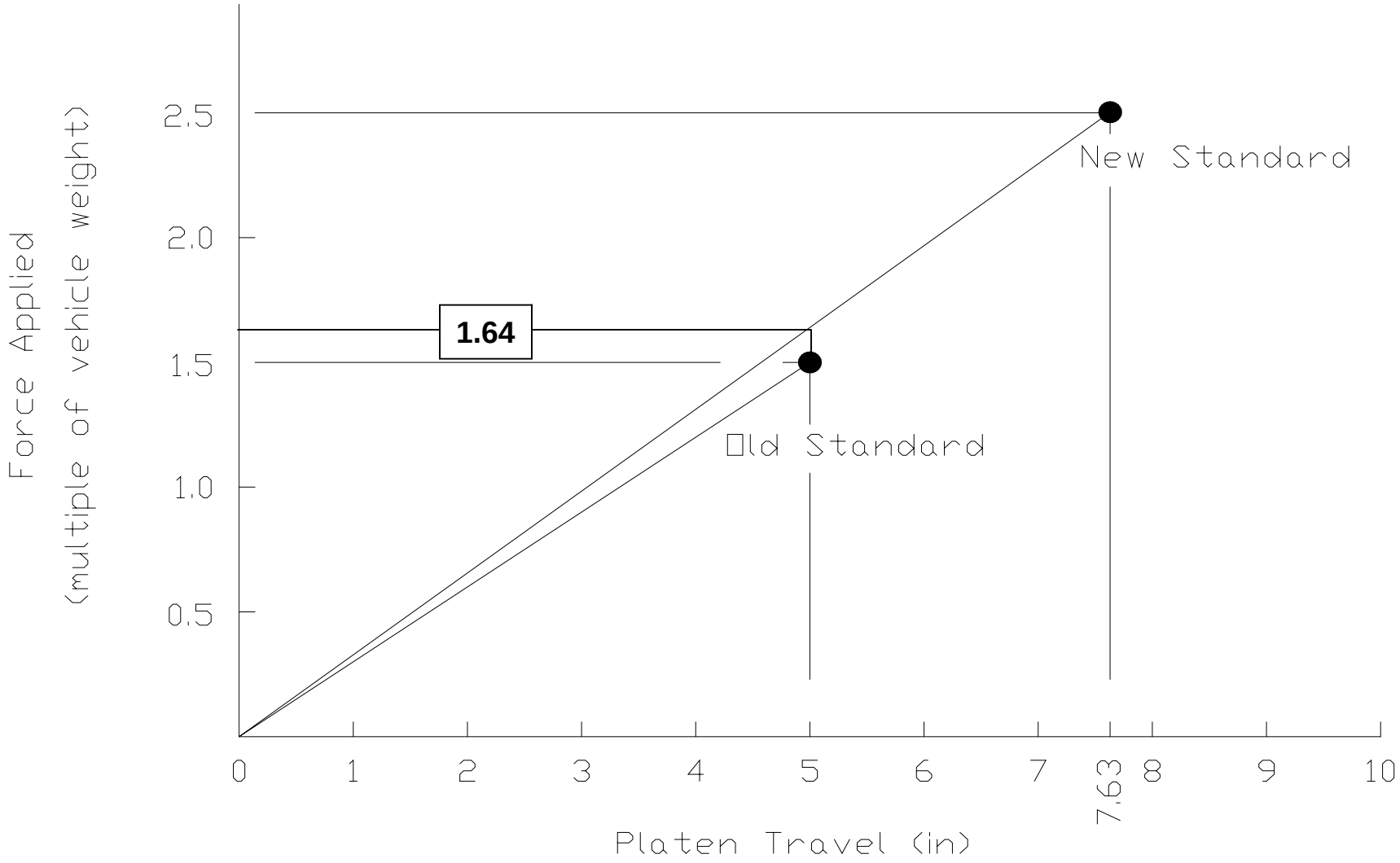
Roof Crush Certification Changes

- The old weight standard of 1.5 X has been TIGHTENED
  to 2.5 X, a change of 67 %.

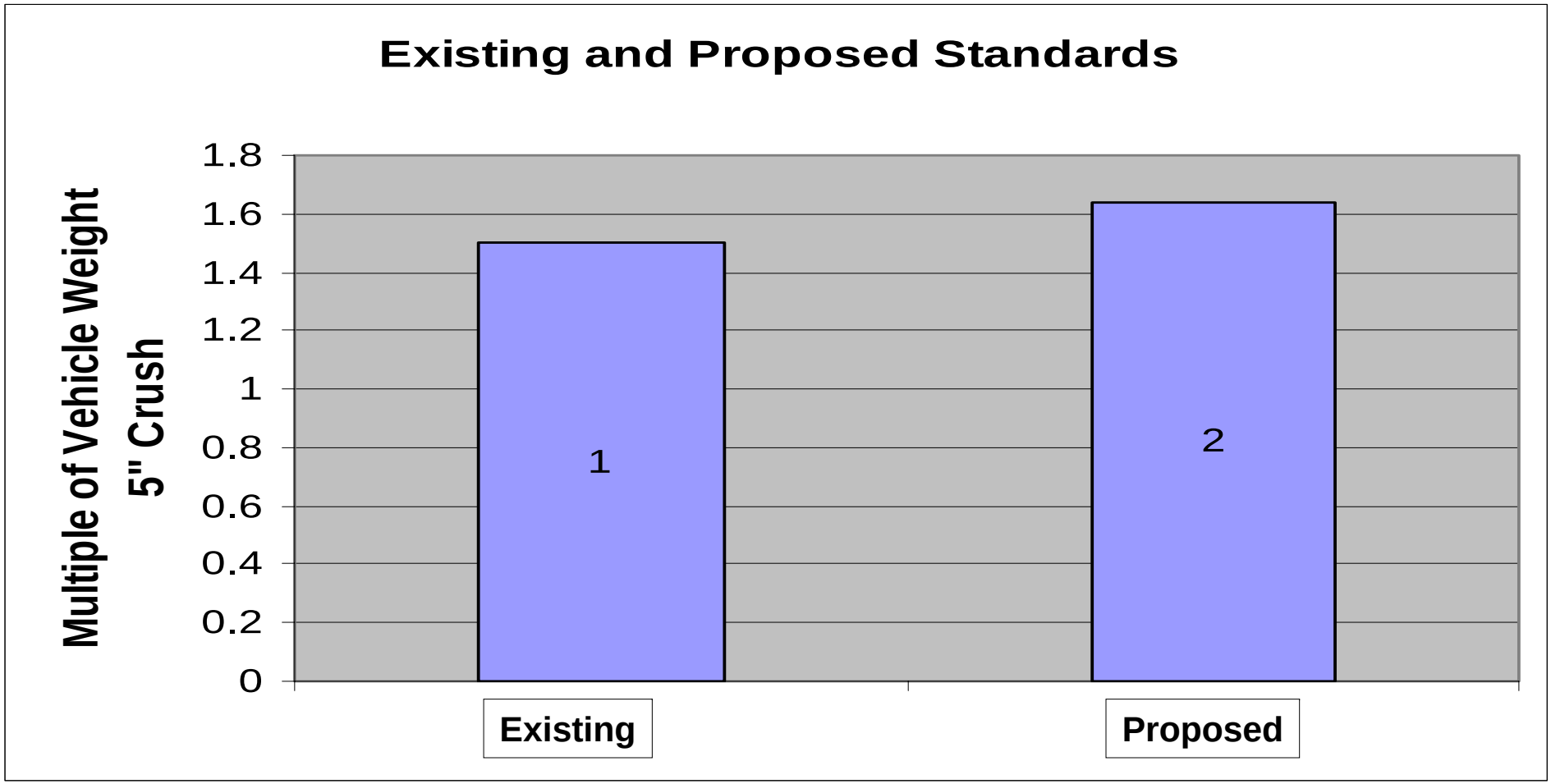
- The old intrusion standard of 5” has been RELAXED
  to an average of 7.63” based upon NHTSA’s measurements, a change of 53 %.

- The strength requirement of the vehicle of 1.5X/5” has been changed to 2.5X/7.63”, which translates to 1.64X/5”, a mere 9% increase.

Schematic of Old and New Standards



70% of existing vehicles pass the new standard.
This represents "business as usual"


Existing and Proposed Standards
Multiple of Vehicle Weight
5" Crush
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
2
Existing
Proposed

Summary

- The current proposal is not based upon solid science to ensure it will protect the public.
- The current proposal:
  - Only increases the roof strength a modest 9%.
  - Does not ensure that at the 5” intrusion level that the old standard of 1.5X is preserved.
  - Only targets the headroom of a 50% male.
  - Does not take the amount of dynamic headroom into consideration.
  - Does not change the platen angles based upon vehicle geometry.
- *The current proposal is not validated by testing.*