Study Summary

Study Title:

Seatbelt Effects on Adult Spinal Compression Loads

Study Performed At:

University of Pennsylvania, School of Engineering and Applied Science, Laboratory for Research on the Structure of Matter (LRSM)

Study Objectives:

To approximate the effects of rough driving on the adult spine and to compare these effects when a typical seatbelt is used without and with a CG-Lock attached

Study Conclusions:

- A standard seatbelt can permit peak spinal loads in on the order of 2.5 times body weight during upward accelerations and loss of driving control due to significant weight reduction (half body weight) as the seat descends
- Use of the CG-Lock device reduced peak spinal loads to 1.75 times body weight and maintained 90% of body weight during the descent phase.

Study Inferences:

- Use of a CG-Lock reduces lofting which should reduce the rate of accidents through better driver control
- Head injuries from lofting and spinal compressions from suspension bottoming out will be reduced or eliminated with the use of a CG-Lock
- The CG-Lock permits modest tension on a seatbelt's lap belt, providing pelvic anchoring (stability). This in turn means better vehicle feedback and reduction of accidents.

- ***The full study follows*** -

Seatbelt Effects on Adult Spinal Compression Loads

Conclusions From Tests Performed At The University of Pennsylvania School Of Engineering

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Bruce Mather, B.S. (Chem), Lap belt Cinch, Inc.

Abstract:

A simulation of the forces acting on the human spine while driving in a heavy vehicle over rough roads was devised by using a servohydraulic actuator to rapidly displace a 100 pound weight vertically. The force was applied through a stiff spring damper system to simulate vehicle suspension and seat springing.

A standard automotive-type seatbelt was used to restrain the weight in the control (baseline) test series. The tests were identically repeated with a commercially available "occupant stability" device (the CG-Lock®) attached to the seatbelt.

Results suggest that rough road driving in a standard seatbelt can permit peak spinal loads on the order of 2.5 times body weight during upward accelerations and loss of driving control due to significant weight reduction (half body weight) as the seat descends. Use of the CG-Lock device reduced peak spinal loads to 1.75 times body weight and maintained 90% of body weight during the descent phase.

The test hypotheses that the CG-Lock could reduce spinal compression injuries in people driving HMMWVs and similar military equipment, and that the CG-Lock would improve driver control, are supported.

This study was supported by a grant from Ben Franklin Technology Partners, SEP

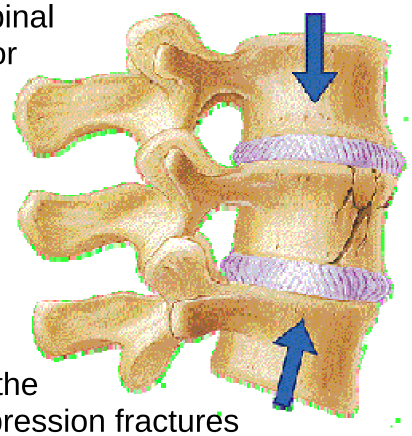
Background:

Solders in Iraq and other places are being injured while driving HMMWVs and other vehicles at high speeds on rough terrain. The injuries are most often due to accident or spinal compression.

Accident: The higher than normal frequency of vehicular accidents in the types of off road situations encountered by soldiers is due – in large measure – to the lack of feedback to the driver and ergonomic difficulties steering and braking. Driving over rough roads "lofts" the driver (bounces the driver off the seat or significantly reduces body weight) resulting in loss of leverage to control the vehicle and loss of feedback from the vehicle. Lack of feedback allows small driving errors to grow before detection, often resulting in correcting too late or over-correcting. Without physical "buttocks-to-seat" tactile feedback, driving is done by visual clues only, resulting in a high rate of accident.

Control of the vehicle is also inhibited by driver "lofting". If the driver is "weightless" and "unattached" to the vehicle, steering and braking ability is significantly inhibited.

Spinal Compression: The spine is made up of strong bones called vertebrae. A vertebra can break, however, just like any other bone in the body. When a vertebra breaks and then collapses, it is called a vertebral compression fracture. Compression fractures happen most commonly in the thoracic spine (the middle portion of the spine). Example causes include falling in the sitting position (such as in off road driving) and osteoporosis. In the worst cases the resulting compression of the spine can put pressure on the spinal cord and nerves, either from the compression itself or from the protrusion of bone into the nerves of the spinal cord.



Fracturing becomes more likely when the spine bends forward at the same time that downward pressure impacts the spine. For example, falling to the floor in a sitting position simultaneously bends the spine and thrusts the head forward. This posture, combined with the traumatic impact on the buttocks, concentrates pressure on the front part of the spine, and this pressure can cause a fracture. Compression fractures due to trauma can come from a fall, a forceful jump, a car accident, or any other event that stresses the spine past its breaking point.

Occupant "lofting" (which includes driver lofting with the concomitant increase in accidents and accident-related injuries) results when the vehicle rises rapidly in response to terrain, which thereby rapidly raises the occupant. The actual "lofting" occurs when the vehicle (and its seat) settles faster than the occupant, leaving the occupant monetarily suspended above the seat (making the driver's perceived weight much lighter than normal).

Spinal compression is presumed to occur when the rising seat and descending occupant meet in some form of constructive interference. When the relative velocities of the ascending seat and descending occupant are high, the forces on the spine when the two meet can be sufficient to cause fatigue, low back pain, distraction through discomfort, and – in the worst cases – spinal injury.

Cases of cranial injury have been reported when lofting results in occupants hitting their head on the vehicle's roof.

Test Objectives:

The test goal was *not* *to replicate the real world environment*, but to experimentally simulate lofting and compression, and to measure a baseline surrogate for the resultant forces on the spine. Secondarily, using a commercially available "occupant stabilization device"[1], the testing protocol compared *by comparison* the relative attenuation of the spinal forces when the CG-Lock device was used.

Endpoints were the comparative measurement of simulated spinal forces seen, and in measurement of the "weightlessness" when rough road driving was simulated. The sole controlled variable in these studies was the use of the CG-Lock.

Test Equipment and Methodology:

All tests were conducted with an instrumented and programmable Instron Model 8501 servohydraulic system.

A very rigid, reinforced "L" shaped platform was mounted rigidly on the Instron hydraulic ram (displacement input shaft). On this platform was mounted a typical automotive style seatbelt[2] with appropriate routing and hardware. The seatbelt installation and positioning was similar to, but not in absolute

1 The CG-Lock ®; Lap Belt Cinch, Inc.; www.LapBeltCinch.com, MSRP is $41.95

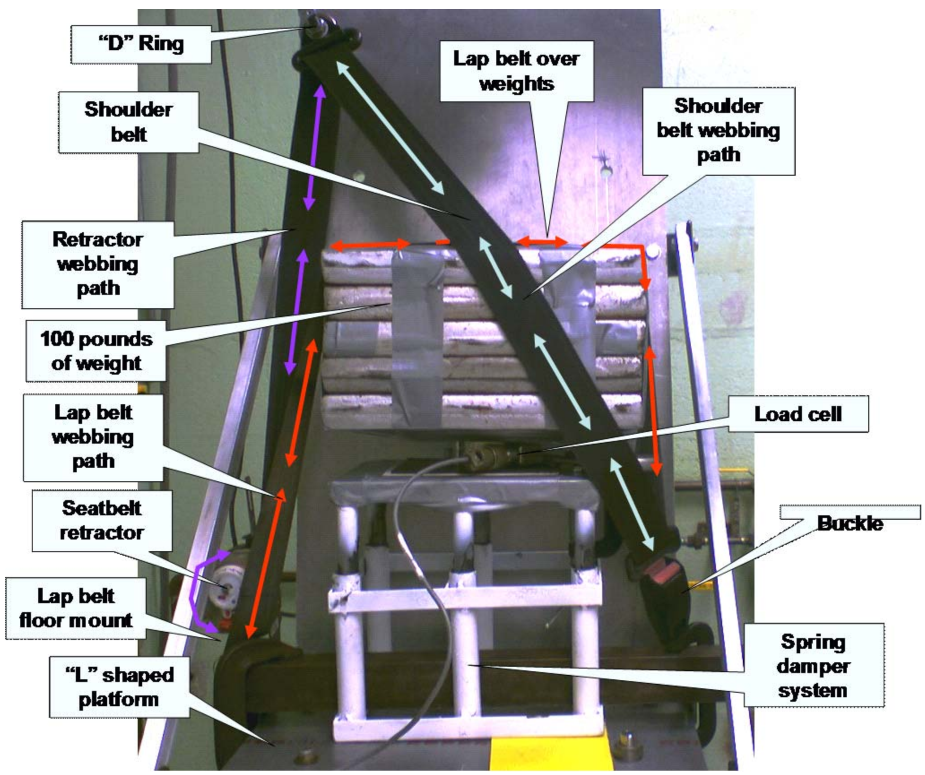
2 Auto-retracting, ALR Inertial reel, continuous through loop slip tongue seatbelt

replication of, the mounting found in typical automotive installations.

A six-tube spring damping system was constructed to simulate both the vehicle suspension (vertical motion with damping and rebound) and the cushioning effects of the vehicle seat. Springs at each corner (inside the tubes) permitted a height compression of about 0.5" with a 100 pound weight resting on the top surface. Total travel under test conditions was about 1.5 inches. Spring damper characterization is in Attachment 1. The yellow square is a shim used for leveling. The spring damper was clamped tightly to the platform.

A calibrated load cell was placed between the simulated seat and the weights that served as the occupant surrogate.

The completed test rig looked like the picture at right. The only difference between runs was the non-use or use of a CG-Lock (attached according to the manufacturer's instructions).



After some preliminary evaluations, it was determined that a displacement of +/- 0.4 inch at a frequency of 0.5 HZ resulted in high forces on upward acceleration and some lofting of the 100 pound weight on descent.

The test device (the CG-Lock) clips onto the existing seatbelt of a vehicle in less than one minute. Once installed, the CG-Lock allows the lap belt to be tightened as much as desired, and the lap belt will retain that tightness until released. The shoulder harness portion is unaffected. Additional data can be found on the manufacturer's web site at www.cg-lock.com and in a basic overview of the CG-Lock in Attachment 2.

Standard Conditions:

- Displacement used: +/- 0.4 inch (total travel = 0.8 inches)
- Frequency: Instron piston reversed direction at 0.5 Hz (cps)
- Load cell: Honeywell SensoTec Model GM; 1.0 volt = 100 pounds
- Total weight used in this test: 100 pounds
- Displacement: 1.0 volt = 1.0 inch

Testing was performed as shown in the following sequence:

Test Number	***101***	***102***	***103***	***104***	***105***	***106***	***107***	***108***	***109***	***110***
Variable: CG-Lock used	No	No	Yes*	Yes	No	No	Yes	Yes**	Yes	Yes
Weight reading with seatbelt in place (weight on load cell without seatbelt in place was 100.0 +/- 0.7 pounds	103.3	101.2	110.4	111.1	100.8	101.7	111.8	101.2	109	111.4

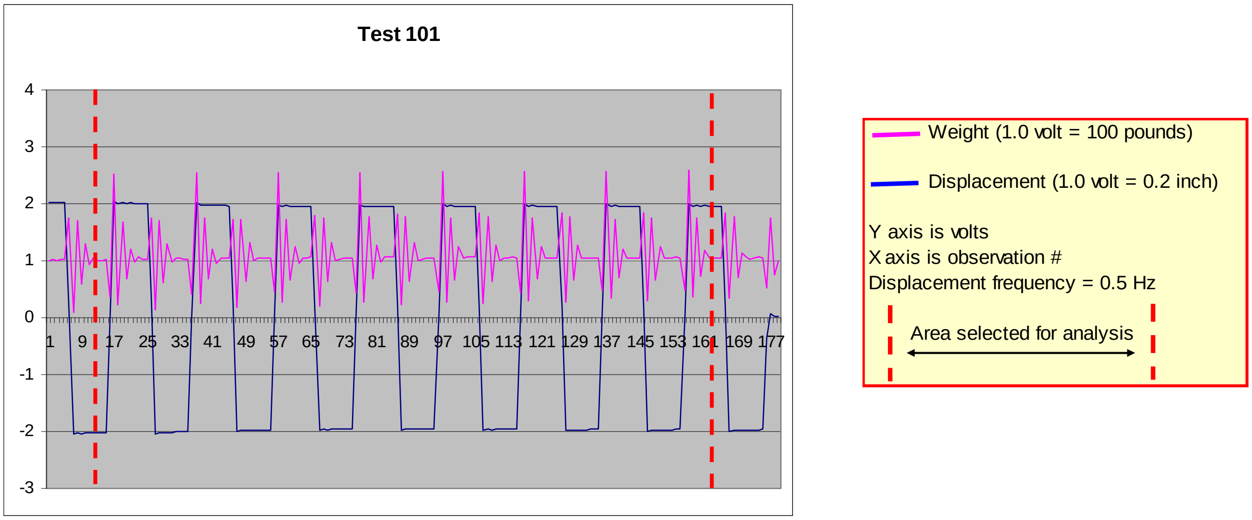
* Data was lost
* * CG-Lock was used, but the lap belt was NOT tightened

Note that the use of the CG-Lock added roughly 10 to 11 pounds to the load cell due to the tightening of the lap belt (see last line of the above table).

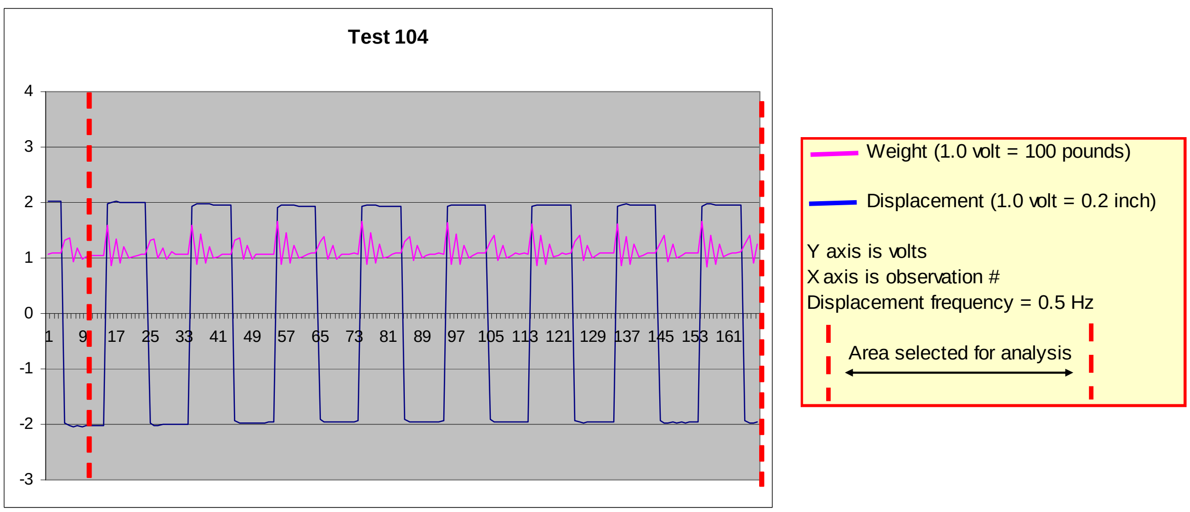
Calibrations are shown graphically in Attachment 1

Resultant Data:

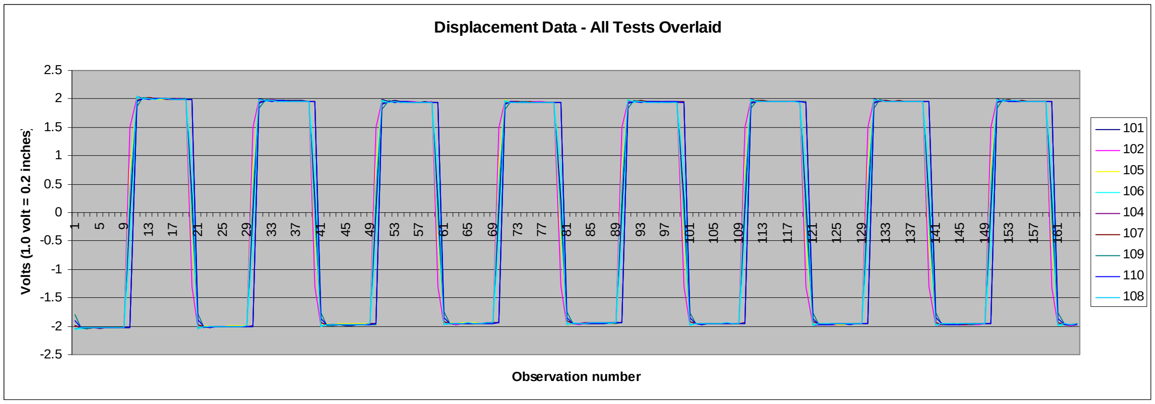
A graphic view of a baseline run (control; without the CG-Lock) is shown below:



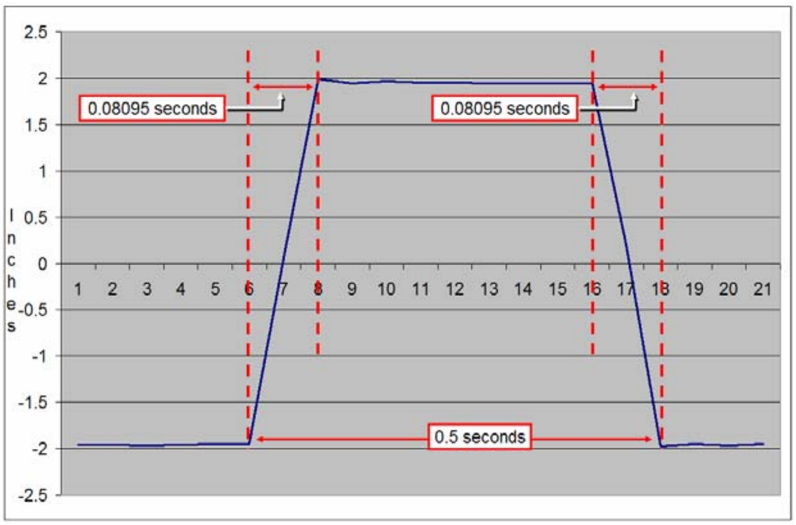
A graphic view of a run with the CG-Lock is shown below:



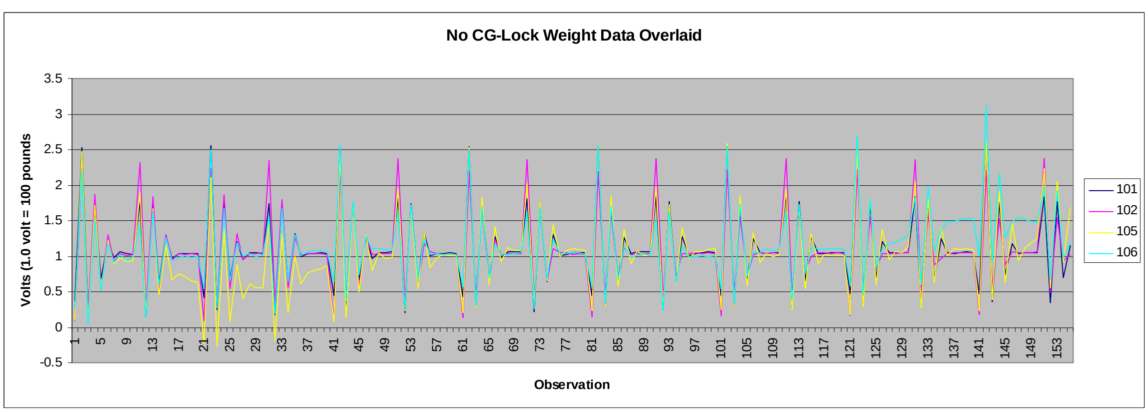
The displacement data for all tests was time phased to overlap and then graphed. The graph below shows that all displacement inputs for all tests in the test series. From this we conclude the inputs were uniform and reproducible.



The speed of the servohydraulic piston was estimated at 9.88 inches per second. A typical displacement cycle waveform is shown below.



The weight measurements for the four baseline (control) tests were time phased and overlaid as shown below.

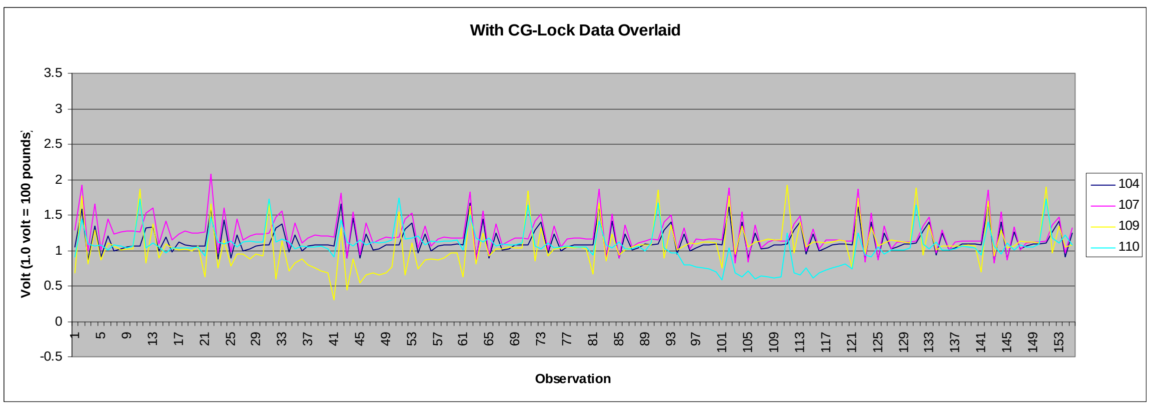


Analysis produced the following summary weight data (all values in pounds:

---------------------- Without CG-Lock ---------------

Test No.	**101**	**102**	**105**	**106**	**Overall Average**
Averaged highest peak weight:	256	235	252	259	251
Averaged lowest peak weight:	89	14	37	35	43
Total weight change average high peak to average low peak:	167	222	216	224	207

The weight measurements for the four CG-Lock tests were time phased and overlaid as shown below (same scaling as for the baseline above).



-------------------- With CG-Lock --------------------

Test No.	**104**	**107**	**109**	**110**	**Overall Average**
Averaged highest peak weight:	163	188	182	167	175
Averaged lowest peak weight:	96	102	85	90	93
Total weight change average high peak to average low peak:	67	86	97	76	82

Conclusions:

Simulation of spinal loads while “rough terrain driving” showed a standard seatbelt can permit peak spinal loads in on the order of 2.5 times body weight during upward accelerations and loss of driving control due to significant weight reduction (half body weight) as the seat descends. Use of the CG-Lock device reduced peak spinal loads to 1.75 times body weight and maintained 90% of body weight during the descent phase.

The test hypotheses that the CG-Lock could reduce spinal compression injuries in people driving HMMWVs and similar military equipment, and that the CG-Lock would improve driver control, are supported by the results of these tests.

At 30 mph, a vehicle travels 44 feet per second. Assuming a 36 inch diameter wheel, a 6 inch high curb or rock or a 6 inch deep pothole can induce a six inch upward vertical displacement in 0.35 seconds. Our testing used a displacement of 0.8 inches occurring in 0.081 seconds (or a rate of 6 inches in 0.61 seconds). It is believed that the test results reported here significantly underestimate the spinal compression effects seen in the real world.

For questions or comments, please contact:

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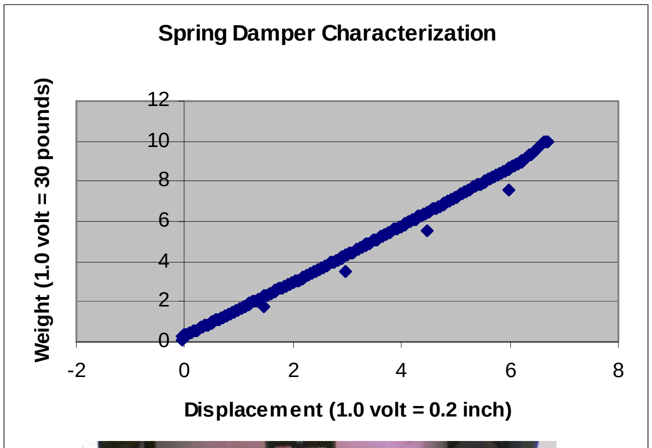
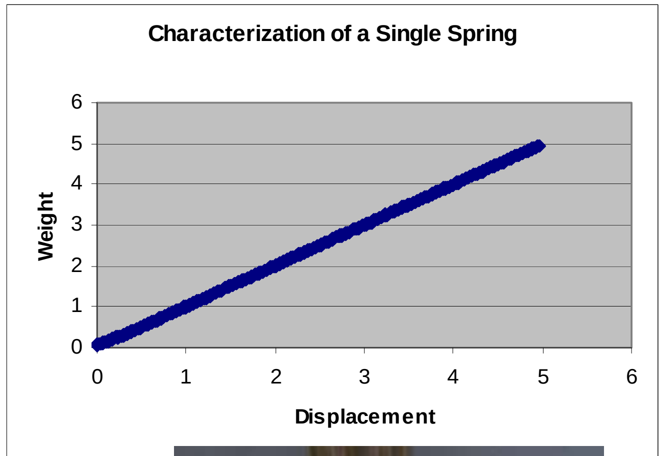
www.CG-Lock.com

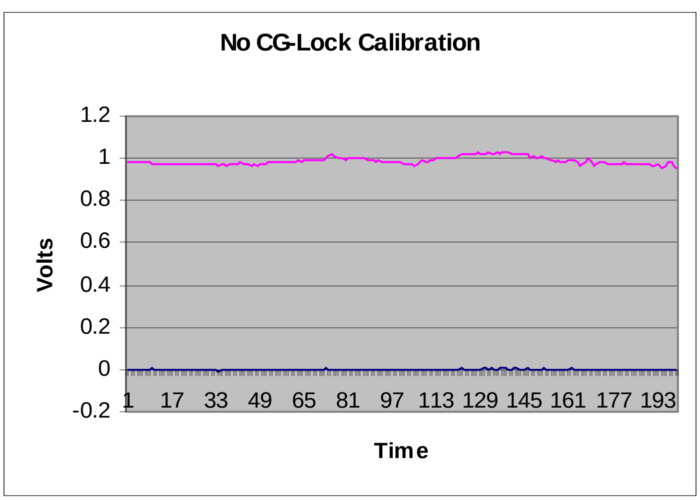
Attachment 1

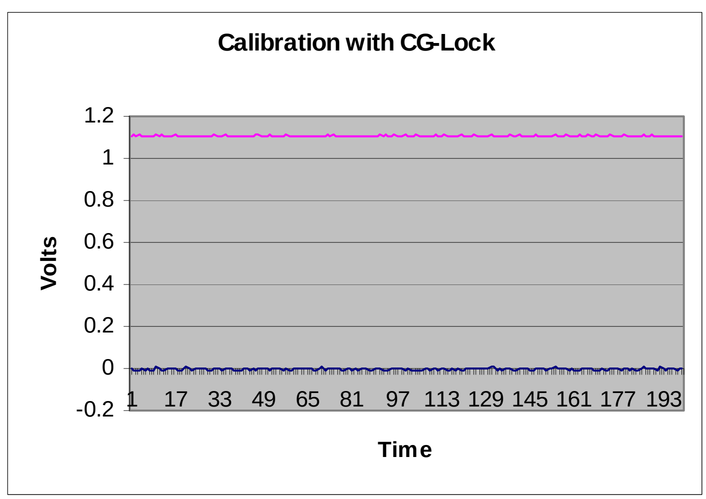
Calibrations

The spring calibrations were performed on an Instron 1331 (see photos below)









Attachment 2

Overview of the CG-Lock

The CG-Lock is a small mechanical device that clips onto the seatbelts of most cars, trucks, vans, and SUVs. Please see Attachment 3 for attachment details.

Once attached, the CG-Lock allows the user to tighten the lap belt portion of the seatbelt as tightly as desired. The shoulder harness is unaffected.

Depending on the lap belt's degree of tightness, different benefits apply to different applications:

CURRENTLY MARKETED APPLICATIONS (please see details at www.CG-Lock.com):

High performance drivers / Recreational off road
Mobility Impaired / Booster Seat Stability
Police, Ambulance, Fire, First Responders & Security

FUTURE APPLICATIONS (please see details at www.LapBeltCinch.com):

Child car seat attachment (aftermarket and original equipment

Original Equipment (vehicular) / Heavy/construction/mining equipment
Military vehicles / Elderly/frail/disabled
Commercial off road / Commuters
Acute and chronic low back pain / Truckers
Light civilian aircraft

The CG-Lock has been "crash tested[3]" and demonstrated to improve vehicle control, not interfere with the seatbelt, and to enhance safety.

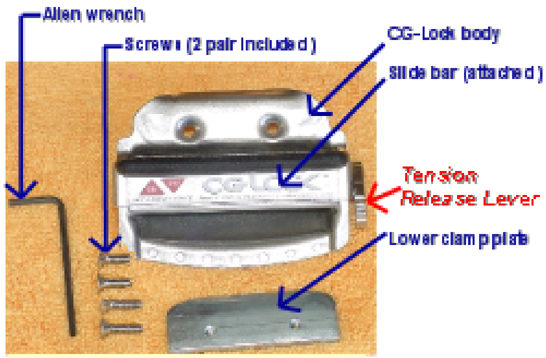
[3] NHTSA FMVSS 208 NCAP, 213-type, and other impact tests

Attachment 3

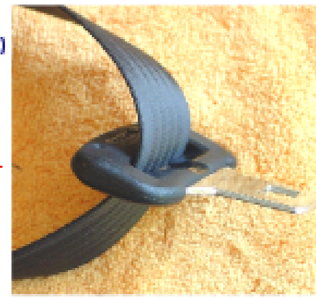
CG-Lock Attachment

CG-Lock - 2 Minute Installation Sequence

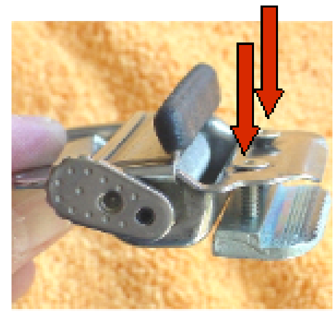
See the "How To Install" video at
http://www.cg-lock.com/multimedia/instructional/InstallVeh.wmv



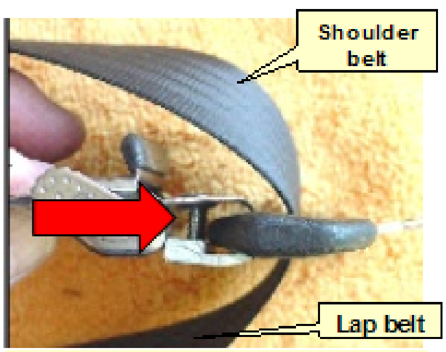
1. The supplied parts



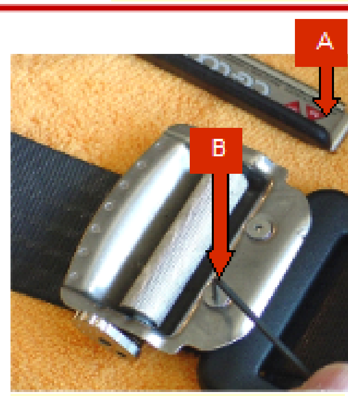
2. A typical single pass tongue



3. Attach the screws to the lower clamp plate

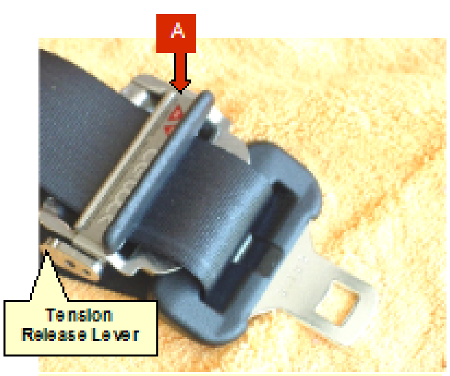


4. Slide the CG-Lock over the tongue



5. Remove the capture bar (A) and tighten the screws using the supplied wrench (B)

6. Lay the shoulder belt over the cam



7. Slide the capture bar over the shoulder belt, depress the lever and slide the bar fully forward

8. Buckle up as usual, then simply pull the slack out of the lap belt by pulling the shoulder belt as shown by the red arrow. If you need more slack to buckle up, depress the lever to let the seatbelt slide through the CG-Lock.

See the Instruction Brochure for complete assembly details and warnings

Attachment 4

Federal Motor Vehicle Safety Standard (FMVSS) Testing:

The CG-Lock was tested in accordance with FMVSS 208 guidelines. The CG-Lock was shown to cause no adverse effects to the safety properties of factory installed 3-point seat belt systems.

-VIA Test Labs

CG-LOCK™
Makes your seat belt racing harness tight

Sports Car Club of America (SCCA) Statement:

"As long as the CG-Lock is installed according to the manufactuer's supplied instructions, the CG-Lock has no effect on the original factory upper body restraint and will be compliant with 3.3.1 of the SCCA National Solo Rules. This includes convertibles without roll bars."

- Doug Gill SCCA Solo Technical Manager