LAB TESTING OF SUSPENSION SEATS

Douglas D. Reynolds, Ph.D.
Center for Mechanical & Environmental Systems Technology (CMEST)

University of Nevada, Las Vegas

USA

BACKGROUND

Professor of Mechanical Engineering – Over 46 years experience in areas related to human exposure to mechanical vibration and shock and vibration and shock mitigation

President: ErgoAir, Inc.

Chairman: ANSI S2.39 – Hunan Exposure to Mechanical Vibration and Shock

Chairman: US Technical Advisory Group – ISO TC 108/SC4 - Hunan Exposure to Mechanical Vibration and Shock

Head of US Delegation: ISO TC 108/SC4 - Hunan Exposure to Mechanical Vibration and Shock

REQUIREMENTS FOR DROP TOWER

Provide repeatable laboratory test results that simulate a wave slam event with a vertical shock input that has a time duration of 80 to 120 ms.

Provide an input shock with a peak acceleration amplitude of up to 18 g.

The recorded vertical shock signal must contain frequency information of up to 80 Hz (human vertical frequency response range).

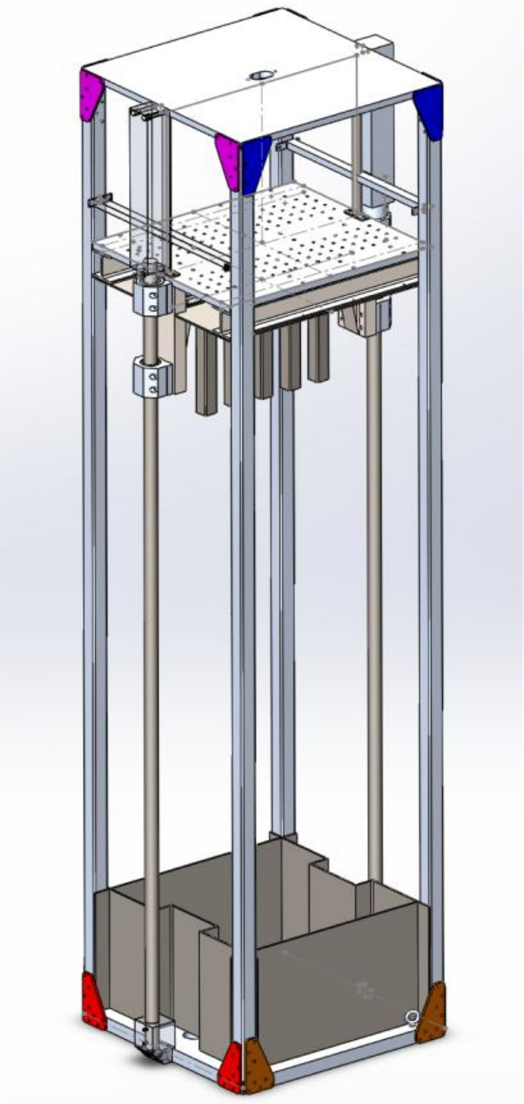
REQUIREMENTS FOR DROP TOWER

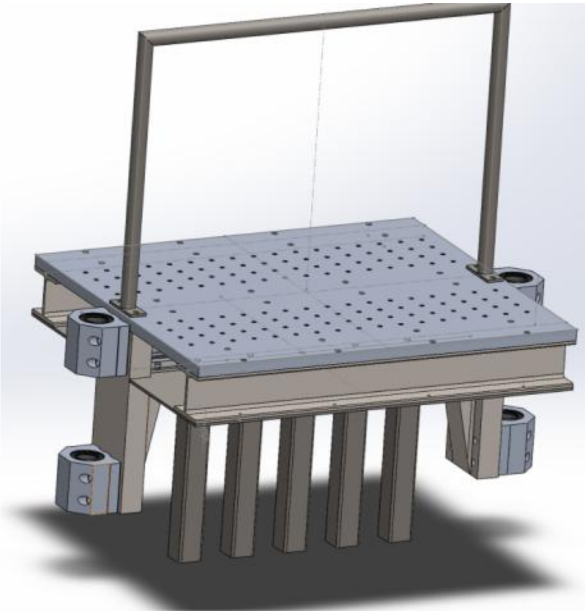
Record shock acceleration signals at the base of the seat frame (deck) and the top of the seat cushion (seat - human interface).

Provide a weight to the top of the seat cushion that simulates the weight of a human sitting on the seat.

Test results must have some correlation to expected human response.

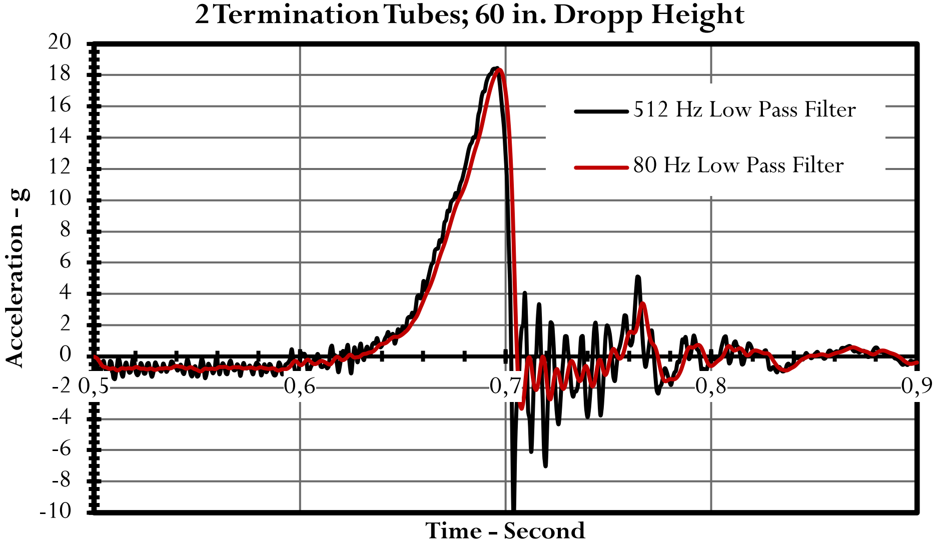
CMEST DROP TOWER





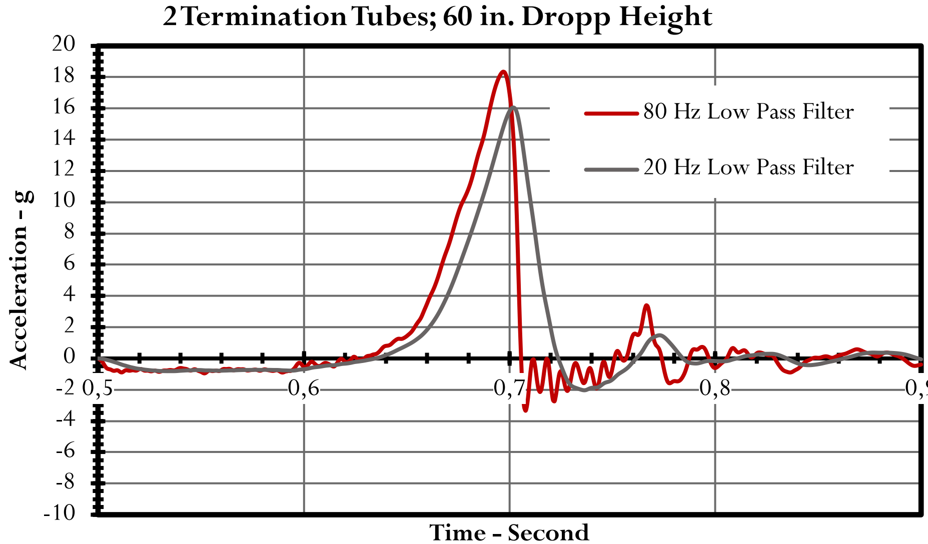
DROP TOWER TEST

UPPER LIMIT OF DROP TOWER



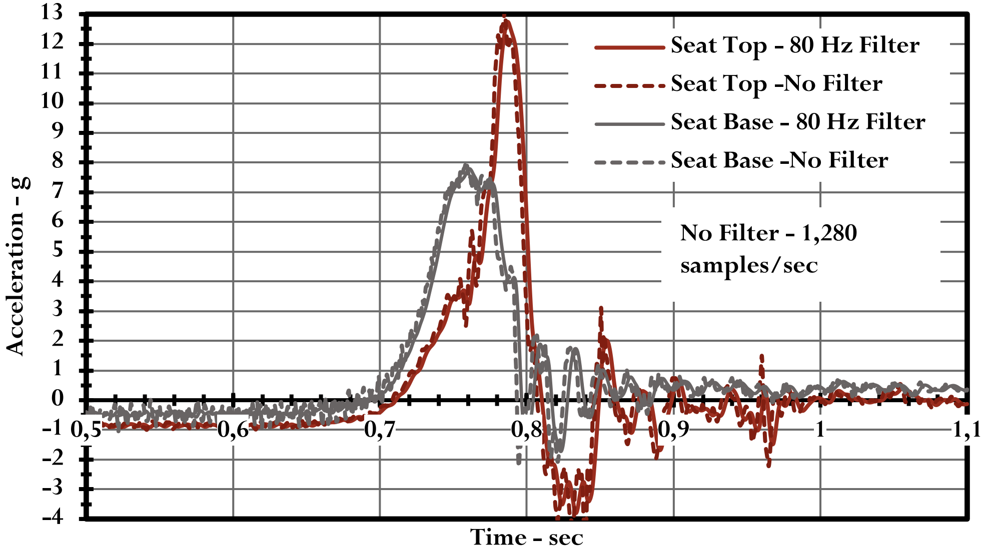
Gook correlation between unfiltered recorded test signal and the signal filtered with an 80 Hz 4-pole Butterworth low-pass filter

Results when the test signal was filtered with a 20 Hz low-pass Butterworth filter: Measured peak acceleration amplitude was decreased by around 2.3 g and the signal time duration was increased.



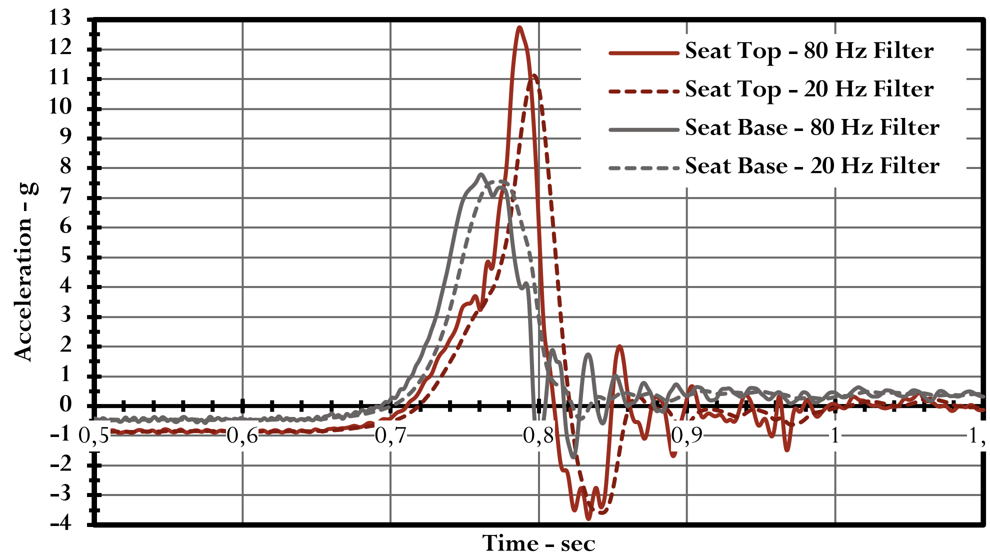
SEAT ACCELERATION TEST RESULTS

Test 2 Seat Acceleration Values



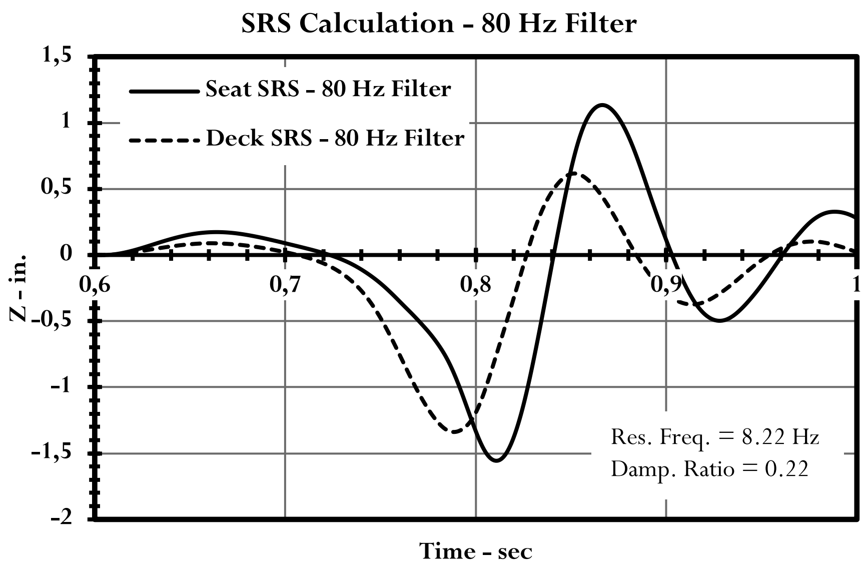
Gook correlation between unfiltered recorded test signals and the signals filtered with an 80 Hz 4-pole Butterworth low-pass filter

Test 2 Seat Acceleration Values

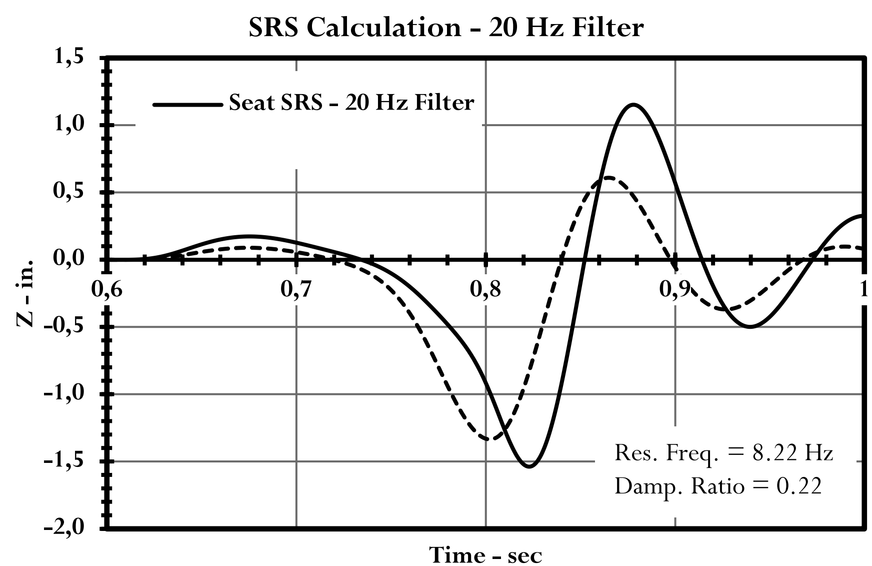


Results when the test signals were filtered with a 20 Hz low-pass Butterworth filter.: Shape of seat base acceleration response was degraded, but the peak value was not significantly reduced. Peak of seat top acceleration was shifted and peak amplitude was decreased by around 1.8 g.

SEAT SHOCK RESPONSE SPECTRUM



There was very little difference between the 80 Hz and 20 Hz 4-pole Butterworth low pass filter results.



SUMMARY OF TEST RESULTS

Peak Seat Acceleration	Peak Accel. - g	Output/Input	% Increase
Seat Base - 80 Hz Filter	7.8		
Seat Top - 80 Hz Filter	12.8	1.64	64
Seat Base - 20 Hz Filter	7.6		
Seat Top - 20 Hz Filter	11.1	1.46	46
Peak Seat Jerk	**Peak Jerk - m/s^3**	**Output/Input**	**% Increase**
Seat Base - 80 Hz Filter	896		
Seat Top - 80 Hz Filter	1,649	1.84	84
Seat Base - 20 Hz Filter	1,032		
Seat Top - 20 Hz Filter	1,410	1.37	37
Seat SRS Response	**SRS Value**	**Output/Input**	**% Increase**
Seat Base - 80 Hz Filter	1.34		
Seat Top - 80 Hz Filter	1.56	1.16	16
Seat Base - 20 Hz Filter	1.34		
Seat Top - 20 Hz Filter	1.54	1.15	15

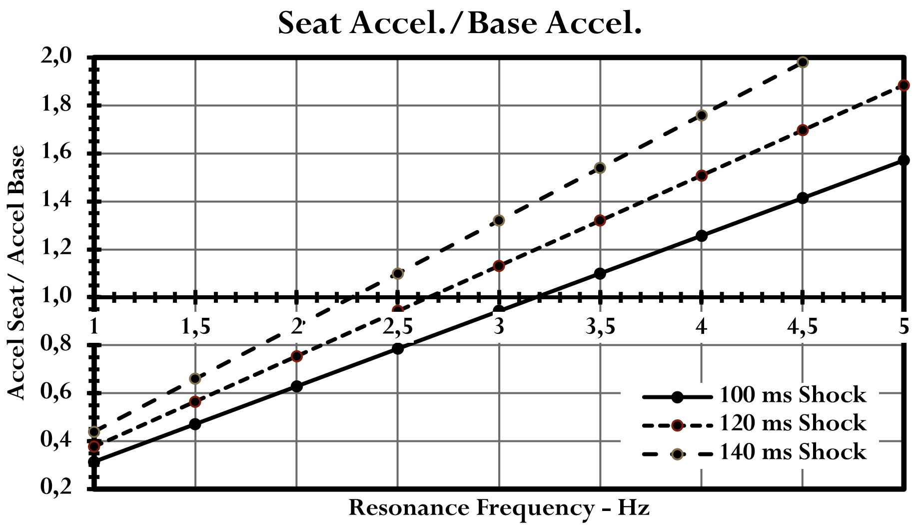
SUMMARY OF TEST RESULTS

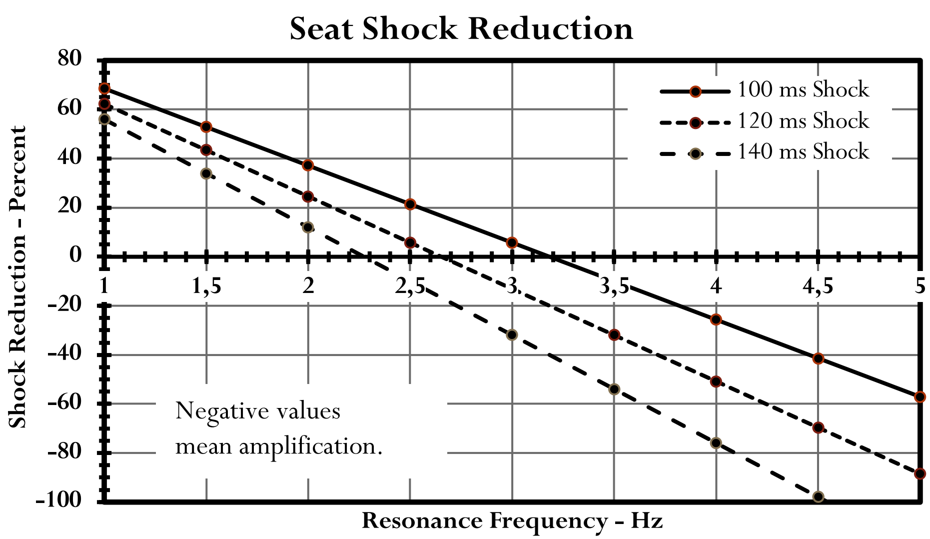
- Drop tower can generate up to an 80 ms 18 g shock pulse and a 100 ms shock pulses at peak amplitudes under 10 g.
- An 80 Hz 4-pole low-pass Butterworth filter captures the relevant frequency information contained in a drop tower shock pulse.
- A 20 Hz Butterworth 4-pole low-pass filter under valued the peak acceleration of shock pulses with a narrow pulse width near the peak of the pulse.
- The peak acceleration and jerk values give good resolution for determining the percent increase or decrease in seat top shock response relative to the seat base.

SUMMARY OF TEST RESULTS

- The shock response spectrum (srs) gives very poor resolution for determining the percent increase or decrease in seat top shock response relative to the seat base. The percent increase obtained with the srs values was 16 percent, as compared to 64 percent for peak acceleration values and 84 percent for jerk values. Therefore, the shock response spectrum can yield misleading results relative to those achieve with the peak acceleration and jerk values. Also, srs values have no correlation with regard to anticipated human response.

WHAT DOES ALL THIS MEAN





	Resonance Frequency - Hz		
	1.0	**1.5**	**2.0**
	Required Spring Defl. - cm		
	24.8	11	6.2
Shock Pulse Duration	**Percent Shock Reducion**		
100 ms Shock	68.5	52.8	37.2
120 ms Shock	62.3	43.4	24.6
140 ms Shock	56.0	34.0	12.0

The resonance frequency of the mannequin on the seat air bladder was around 5 Hz. The resulting percent increase in the seat top acceleration relative to the seat base for a 100 ms shock pulse was 64 percent. This is close to the 68.5 percent increase predicted by the relevant shock response equation for the seat and mannequin configuration in the test. The curves to the left show the predicted seat top accel/seat base accel and the related seat shock reductions for shock pulses of 100, 120 and 140 ms durations and seat system resonance frequencies that range from 1 to 5 Hz.

WHAT DOES ALL THIS MEAN

	Resonance Frequency - Hz		
	1.0	1.5	2.0
	Required Spring Defl. - cm		
	24.8	11	6.2
Shock Pulse Duration	Percent Shock Reducion		
100 ms Shock	68.5	52.8	37.2
120 ms Shock	62.3	43.4	24.6
140 ms Shock	56.0	34.0	12.0

- The seat response dynamics associated with a seat suspension system exposed to a single large wave slam event are different than the seat response dynamics for the same seat suspension systems exposed to repeated lower level shocks.
- Seat suspension system that reduce repeated lower level shock inputs may, in fact, amplify single high level shock inputs associated with wave slam events.
- To achieve a reasonable shock reduction for high level shock pulse durations up to 140 ms, the resonance frequency of the seat suspension system with seat occupant must be between 1 to 1.5 Hz. The required peak to peak displacement for a linear coil spring for a 1.5 Hz resonance frequency is 22 cm and for a 1 Hz resonance frequency is 50 cm. To achieve these resonance frequencies, it will require a transition from seat suspension systems with linear coil springs to system with pneumatic sprints.