Measurement and Analysis of Lengthwise Rail Shock

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Study Conducted by

ASSOCIATION OF AMERICAN RAILROADS
Operations and Maintenance Department
Damage Prevention and Loading Services
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Executive Summary

The purpose of this study is to define significant attributes in the measurement and analysis of rail shock accelerations.

Rail shocks resulting from yard switching of cars were measured under a variety of circumstances, some controlled , some not. Measurements were taken from both standard draft gear cars and cushioned cars. Impact speed was recorded for each impact measured. Car body accelerations were measured at a sample rate of 256 samples per second, analog filtered at 60 Hz. For analysis, the measured acceleration time histories were both low pass and band pass filtered to evaluate significant frequency components.

Conclusions:

- Peak acceleration alone is not an accurate representation of rail shocks. Pulse duration must also be defined. Change of velocity, computed from time domain acceleration histories, provides the most accurate comparative measure of shock severity.

- Peak acceleration amplitudes and pulse durations are defined most accurately by low pass filtering time domain acceleration histories at 10 Hz.

- Change of velocity computations are most accurate when based on acceleration time histories low pass filtered at 3 Hz.

- G-RMS measurements exhibit the lowest variance when derived from data low pass filtered at 3 Hz. (G-RMS computations are time dependent, i.e., the length of the acceleration time history will influence the computation.)

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REPORT OF RESEARCH STUDY

SUBJECT: **Measurement and Analysis of Lengthwise Rail Shock.**

1.0 Introduction

A shock pulse is defined by Cyril M. Harris in Shock & Vibration Handbook as "a substantial disturbance characterized by a rise of acceleration from a constant value and decay of acceleration to a constant value in a short period of time." Lengthwise shocks occur in normal rail handling as a result of yard classification of cars and train slack action. The result of rail shock can be quite graphic in terms of lading damage. But shock characteristics and their measurement is the subject of frequent debate; i.e. just what is a 'substantial disturbance' and a 'short period of time'? And the advent of programmable shock machines to conduct laboratory analysis of product response to shock has made the need for accurate pulse portrayal imperative. This study evaluated a variety of rail shocks that resulted from yard handling impacts of rail cars in an attempt to define meaningful parameters.

The purpose of this study is to define significant attributes in the measurement and analysis of rail shock accelerations.

2.0 Shock Theory

Shock is graphically portrayed as a plot of acceleration as a function of time. Newtonian physics defines acceleration, or deceleration, as the change in velocity of an object divided by the change in time that the object is (de)accelerating, and is expressed by the equation:

$$a = \text{delta } V/\text{delta } t = \Delta V/\Delta t$$

For example, a rail car moving at a constant rate of speed of 4 miles per hour (5.87 feet/sec) impacts a stationary car and comes to rest in 1/4 second. The moving cars' velocity changed from 4 mph to 0 mph in .25 seconds, or 250 milliseconds. If the shock pulse resembled the theoretical square wave, the acceleration could be computed by:

$$a = (5.87-0)/0.25 = 23.5 \text{ ft/sec/sec}$$

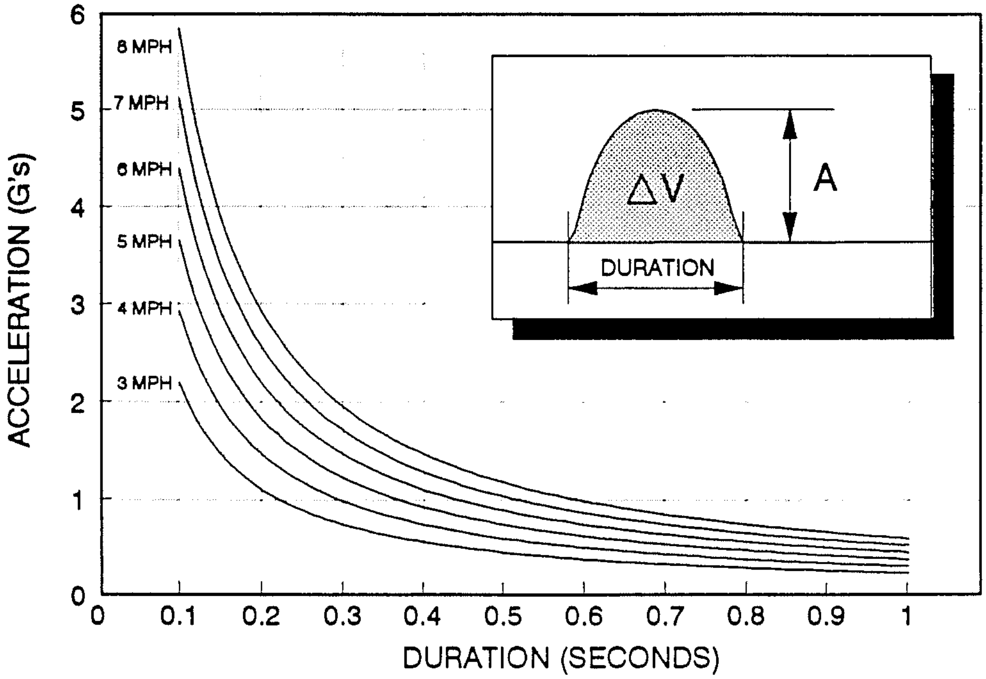
Gravitational acceleration, commonly referred to as "g", is equal to 32.2 ft/sec/sec. So our theoretical acceleration equals 23.5 ft/sec/sec divided by 32.2 feet/sec/sec, or 0.73 g's.

Unfortunately, rail shocks do not generally resemble a square wave shape. The shape of a rail shock acceleration time history can be very complex, as a result of 'imperfect' rail car deceleration (i.e. the struck car moving after the impact), friction and/or hydraulic cushioning, elastic bending of the rail car and structural resonation of the rail car. These influences tend to mask the shock, making its' measurement unclear.

The uninitiated may measure a rail shock with an unfiltered signal digitally sampled at 1,000 samples per second and report a peak longitudinal acceleration of 70 g's - and be accurate! But the significance of the measurement must be predicated on the method of recording and analyzing the acceleration signal.

As previously illustrated, an objects' deceleration can be computed by dividing its' change in velocity by the change in time. Conversely an objects' change in velocity can be computed by multiplying its' peak acceleration by the change in time. Or practically speaking, an objects change in velocity is equal to the area bounded by the acceleration time history as shown in Figure 1.

FIGURE 1
THEORETICAL ACCELERATION LEVELS
AS A FUNCTION OF DURATION
FOR IDEALIZED HALF-SINE PULSE



FOR IDEALIZED SQUARE WAVE
AND SAWTOOTH PULSES

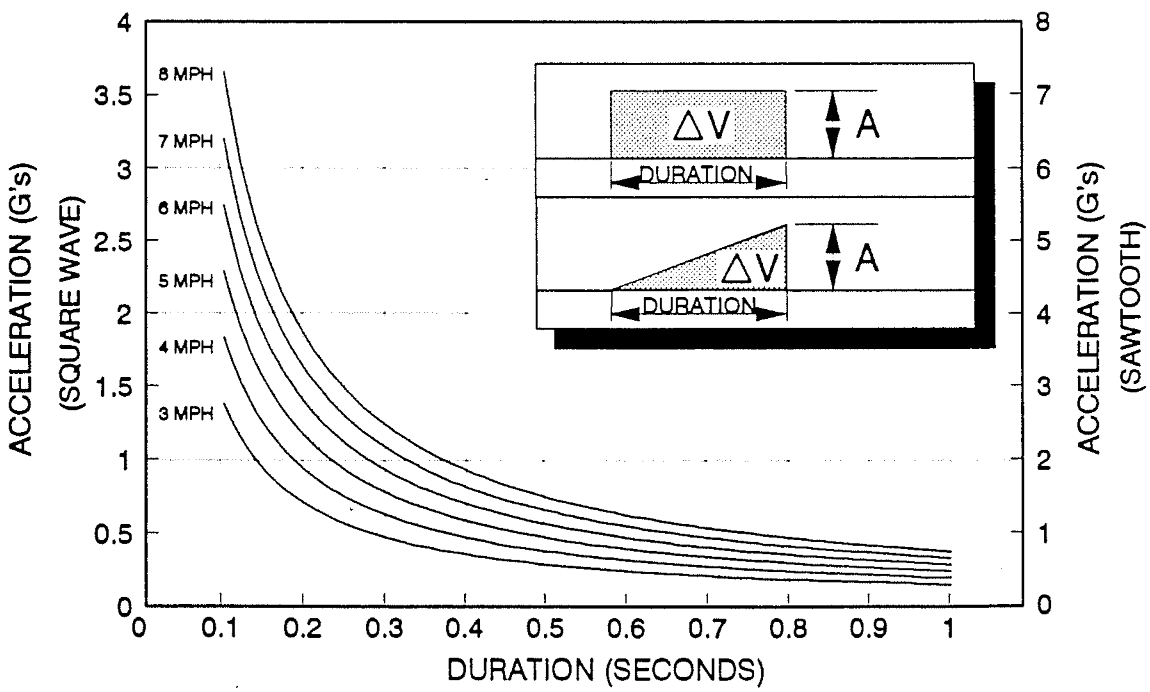
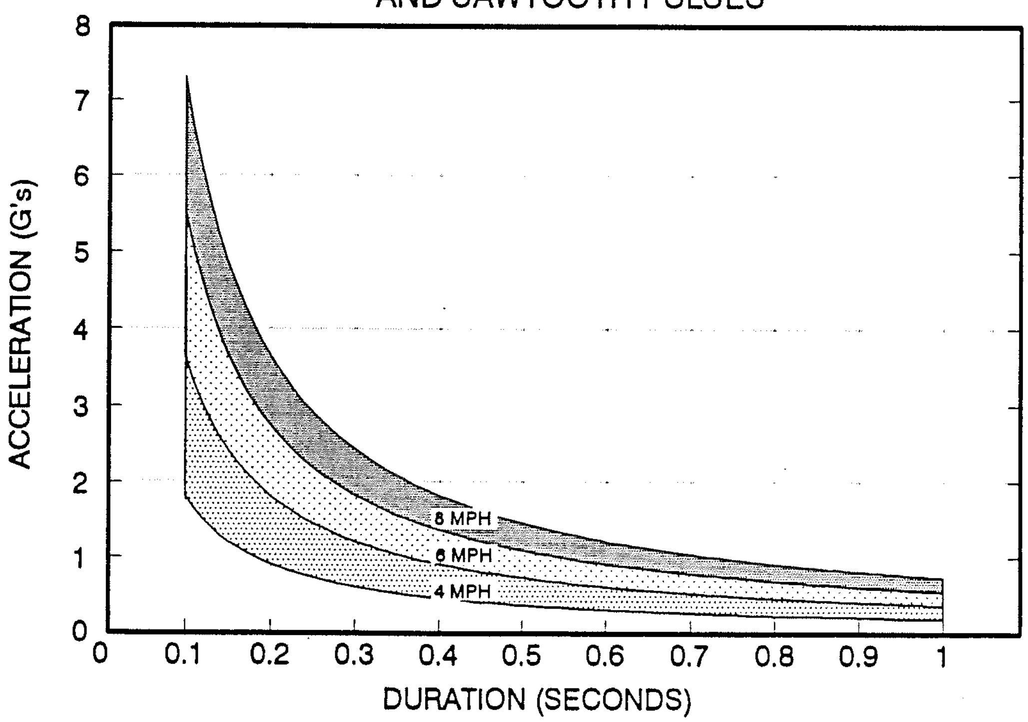


Figure 1 plots this relationship of acceleration, change in velocity and change in time (or duration) for idealized half-sine, square wave and sawtooth pulses. (These 3 wave shapes are frequently used as program inputs for programmable shock machines.) For a constant change in velocity, as the pulse duration increases, the corresponding acceleration decreases.

Rail shocks have been empirically proven to last between 0.1 - 1.0 second due to the cushioning effects of spring/friction elements in standard draft gears and hydraulic units in cushioned cars.

These theoretical accelerations delineate the 'ball park' we're playing in when evaluating rail shock; the vast majority of which result from rail car change in velocity of less than 8 mph. Figure 2 illustrates the fields defined by the theoretical boundaries of the square and the sawtooth pulses. (The half-sine accelerations fall mid-range to the square and the sawtooth.)

FIGURE 2
THEORETICAL ACCELERATION LEVELS
FOR IDEALIZED SQUARE WAVE
AND SAWTOOTH PULSES



It becomes obvious then that a measurement of longitudinal acceleration resulting from rail shock should be (at the very least) something less than 10 g's. And a measurement of 70 g's is an indication that something more then the primary shock pulse is being measured. (Again operating under the assumption that the shock was of at least 0.1 second duration.)

3.0 Methodology

3.1 - General: For this study, rail shocks resulting from yard switching of cars were measured in the field under a variety of circumstances, some controlled, some not. Measurements were taken from standard draft gear cars as well as cushioned cars. For each impact measured, the impact speed of the subject car was recorded with a radar gun or similar device.

3.2 - Instrumentation: The acceleration measurements were made with an Environmental Data Recorder (EDR-3) manufactured by Instrumented Sensor Technology, Inc. Time domain acceleration histories were recorded at a sample rate of 256 samples/second, anti-alias filtered at 60 Hz. For each impact a 2 second long time window was recorded. (The first assumption made was that rail shocks that affect lading occur at frequencies less than 60 Hz. Rail car response to shock input may indeed be higher than 60 Hz, but these responses are structural resonances. Additionally, products shipped via rail are typically packaged in such a way that high frequency inputs are attenuated by packaging material.)

3.3 - Rail Car Types: Car types, for purposes of this report, will be categorized by the cushioning mechanism used between the rail car coupler and the car sill.

Standard draft gear rail cars utilize friction and/or spring elements to control coupler movement. These draft gears offer little shock damping, having only about 3 1/2" of travel, or displacement. Still, these gears extend the duration of a shock (and thereby diminish its' acceleration amplitude) through the limited travel of the gear.

Cushion equipped rail cars utilize hydraulic cylinders to control coupler movement. These may be mounted at either end of the car behind the couplers (referred to as E.O.C., or end of car cushioning) or in the middle of the car, using one cylinder for both couplers (referred to as C.O.C., or center of car cushioning). No C.O.C. cushioned cars were measured during this analysis. E.O.C. cushioning may have 10", 15" or (somewhat infrequently) 20" of travel. E.O.C. units are further defined by the amount, if any, of pre-load applied to the cylinder at the time of manufacture; AAR Mechanical designation M921 is a cushion unit with no pre-load; M921D is a cushion unit with a minimum 55,000 lb pre-load.

4.0 Data Presentation and Analysis

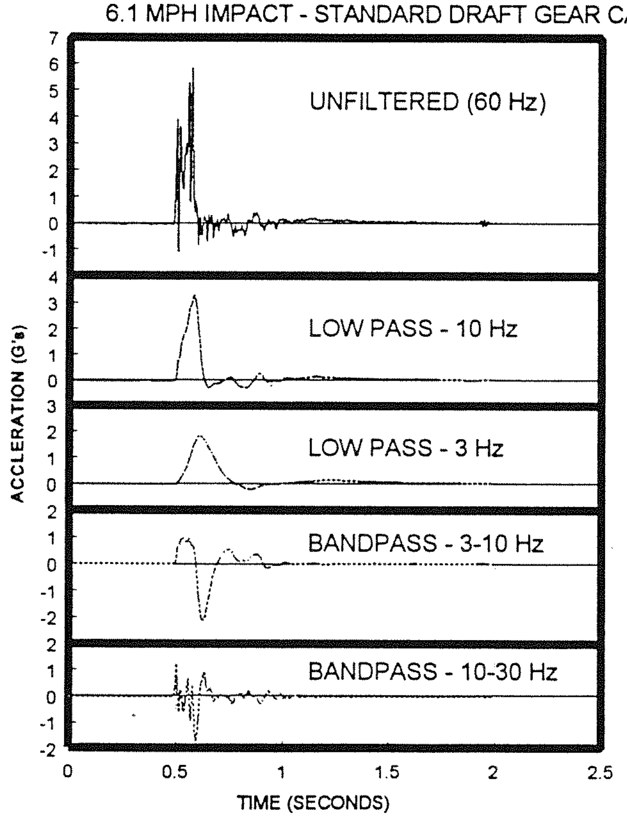
Filtering of data presented in this report was with a second order Butterworth digital filter.

Tabulated data is Appendix A. Graphed waveforms for all recorded pulses are available upon request.

4.1 Shock Pulses Measured from Standard Draft Gear Cars

An example of an unfiltered acceleration time history plot of a 6.1 mph impact (recorded at 256 samples per second) is illustrated in the top frame of Figure 3.

FIGURE 3
ACCELERATION TIME HISTORY
6.1 MPH IMPACT - STANDARD DRAFT GEAR CAR



Notice how the acceleration waveform abruptly changes direction many times over the course of the time history. The peak acceleration level was 5.8 g's, somewhat higher than one would expect from our theoretical estimation. The duration of the shock pulse is open to interpretation, since the waveshape crosses zero many times from start to finish. Subsequently the change in velocity computed from this waveform would under-estimate the actual change in velocity.

The second frame in Figure 3 shows the same shock pulse low pass filtered at 10 Hz. Here the primary pulse appears to be clearly delineated, but the waveform still crosses zero a number of times. These crossings are a result of the anvil car slipping during the impact. Filtering the waveform at 3 Hz generates a wave shape closely approximating a half-sine, but the peak acceleration level appears somewhat below our theoretical estimate.

The frames in Figure 3 showing bandpass (between two discrete frequencies) waveforms are presented to illustrate the activity in these ranges. (Note particularly that the 'stick/slip' action of the friction elements appear clearly in the 10-30 Hz band.)

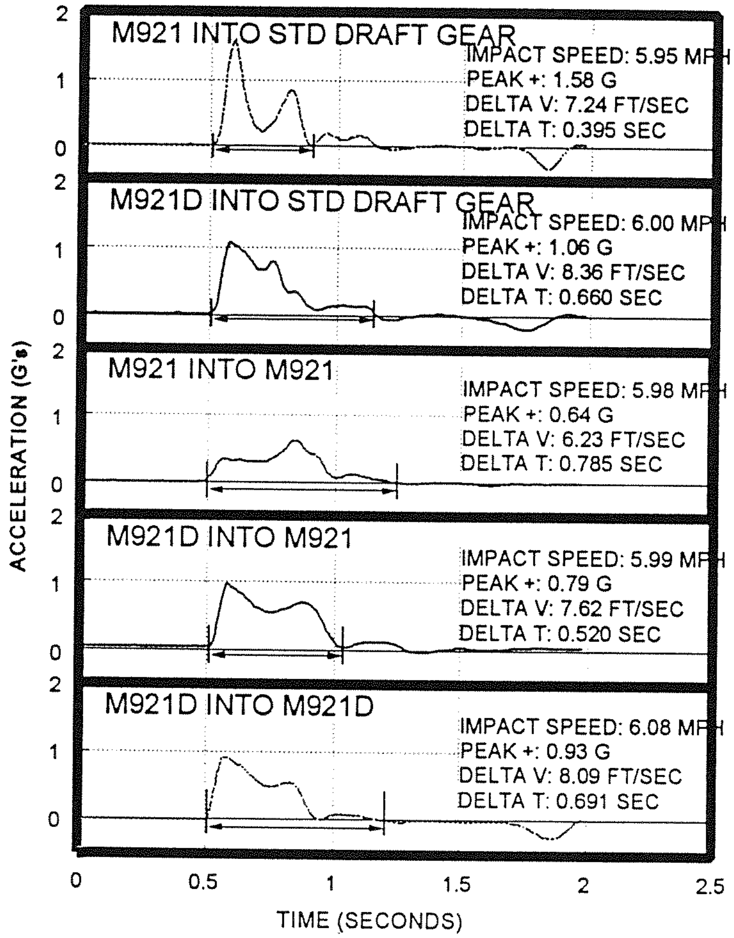
The acceleration time history shown in Figure 3 was taken from a series of impacts having relatively 'clean' waveforms. (These impacts were conducted under very controlled conditions.) All of the acceleration time histories from this impact series were similar in shape when filtered at 10 Hz.

The 10 Hz waveforms were imported into a computerized curve fitting routine to define arithmetically the acceleration as a function of time, for programming or parametric modelling purposes. A non-linear equation (complimentary error function peak) was derived that yields a high degree of statistical confidence. This information is Appendix 2.

4.3 Shock Pulses Measured from Cushioned Cars

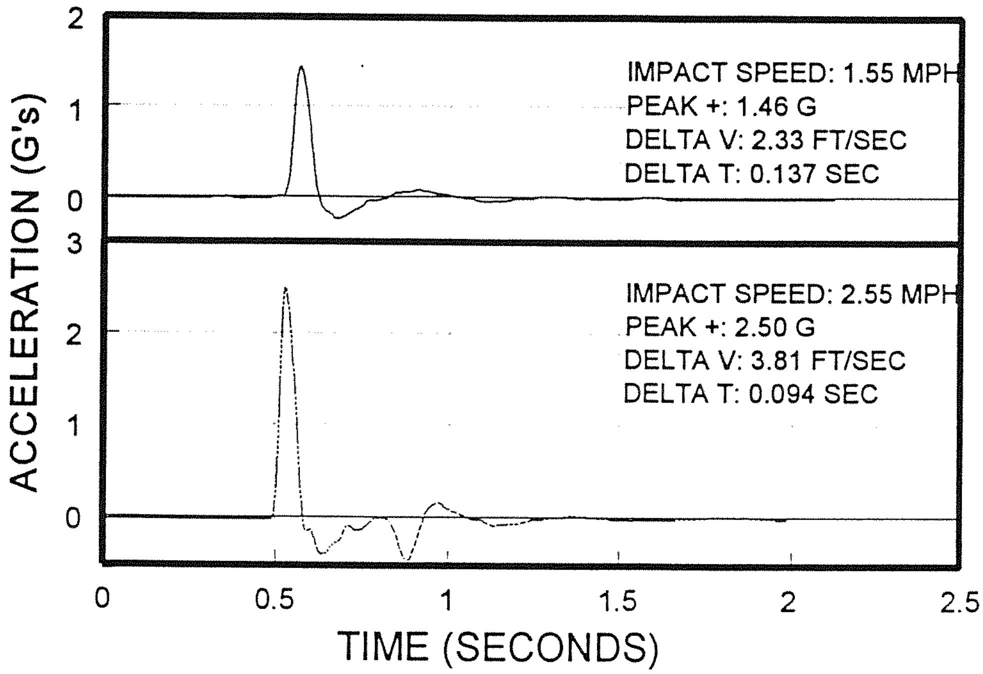
Acceleration data collected from cushion equipped cars were also analyzed by a number of low pass filter selections. Again, 10 Hz filtering appeared to give results within our 'ballpark'. Figure 4 shows acceleration time histories (filtered at 10 Hz) from a number of different cushioned equipment types. All of these impacts were in the 6 mph range.

FIGURE 4
ACCELERATION TIME HISTORIES
6.1 MPH IMPACTS - VARIOUS CUSHIONED CARS



Draft impacts were conducted using a special fixture that translates impact load to the opposite direction so that the hydraulic cushion is loaded in draft (cylinder extending). These impacts are representative of train slack action in draft. Generally draft impacts are of much shorter duration and higher amplitude. See Figure 5.

FIGURE 5
ACCELERATION TIME HISTORIES
DRAFT IMPACTS

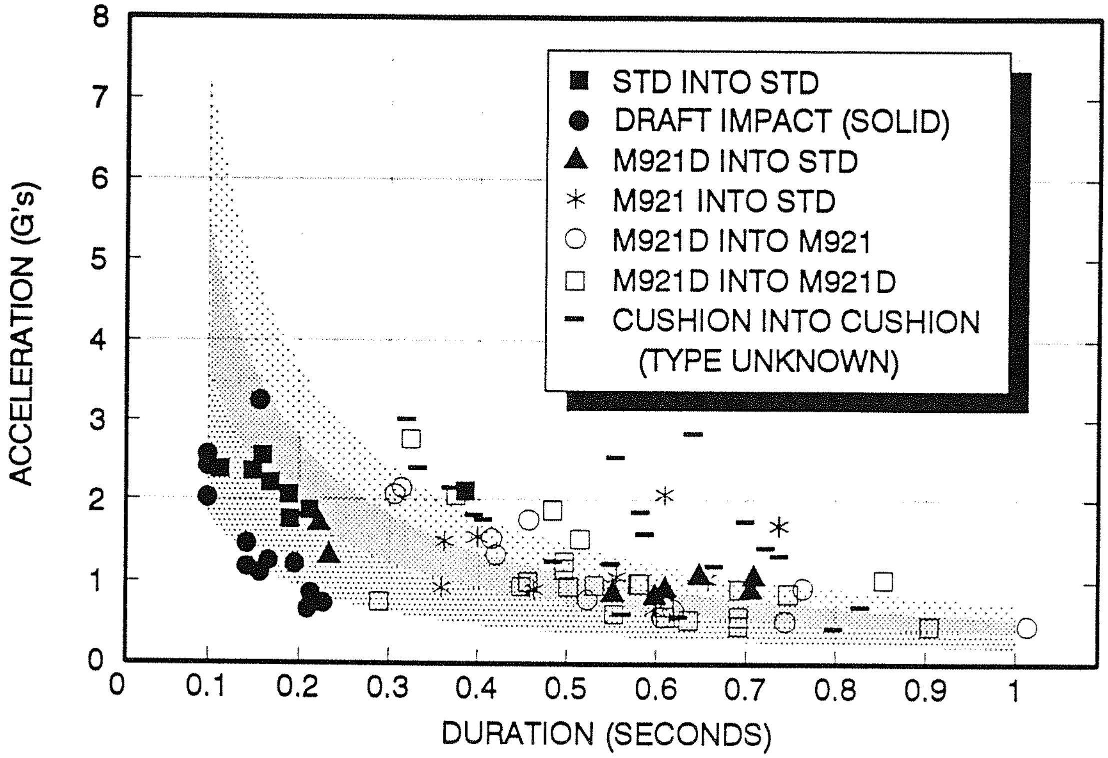


4.4 Data Overview

The remaining overview references data low pass filtered at 10 Hz unless otherwise noted.

Figure 6 plots peak acceleration versus duration for all impacts measured. There is generally good correlation between the 10 Hz data and our theoretical ballpark ranges. Outlying data is predominantly from impacts measured but over which little control was exercised. (In these cases the struck (or anvil) car may or may not have had brakes applied; the anvil may have been multiple cars in the string; and other possible explanations.)

FIGURE 6
PEAK ACCELERATION vs. DURATION
FOR ALL MEASURED IMPACTS
(DATA FILTERED AT 10 Hz)



For impacts between standard draft gear cars, pulse durations ranged from 0.113 to 0.211 seconds, mean 0.167 seconds. The average peak acceleration for a (nominal) 6 mph impact was 2.4 g's.

For impacts between M921 cushioned cars and standard draft gear cars, pulse durations ranged from 0.359 to 0.734 seconds, mean 0.526 seconds. Only two 6 mph impacts were measured; average peak acceleration was 1.4 g's.

For impacts between M921D cushioned cars and standard draft gear cars, pulse durations ranged from 0.551 to 0.707 seconds, mean 0.637 seconds, for impacts 6 mph and under. For impacts over 6 mph, durations ranged from 0.215 to 0.254 seconds, mean 0.23 seconds.

For impacts between cushioned cars (all types), pulse durations ranged from 0.285 to 1.098 seconds, mean 0.584 seconds. Again, pulse durations were shortest for M921D equipped cars impacting into M921D cars when impact speeds exceeded 6 mph.

Table 1 summarizes this statistical analysis.

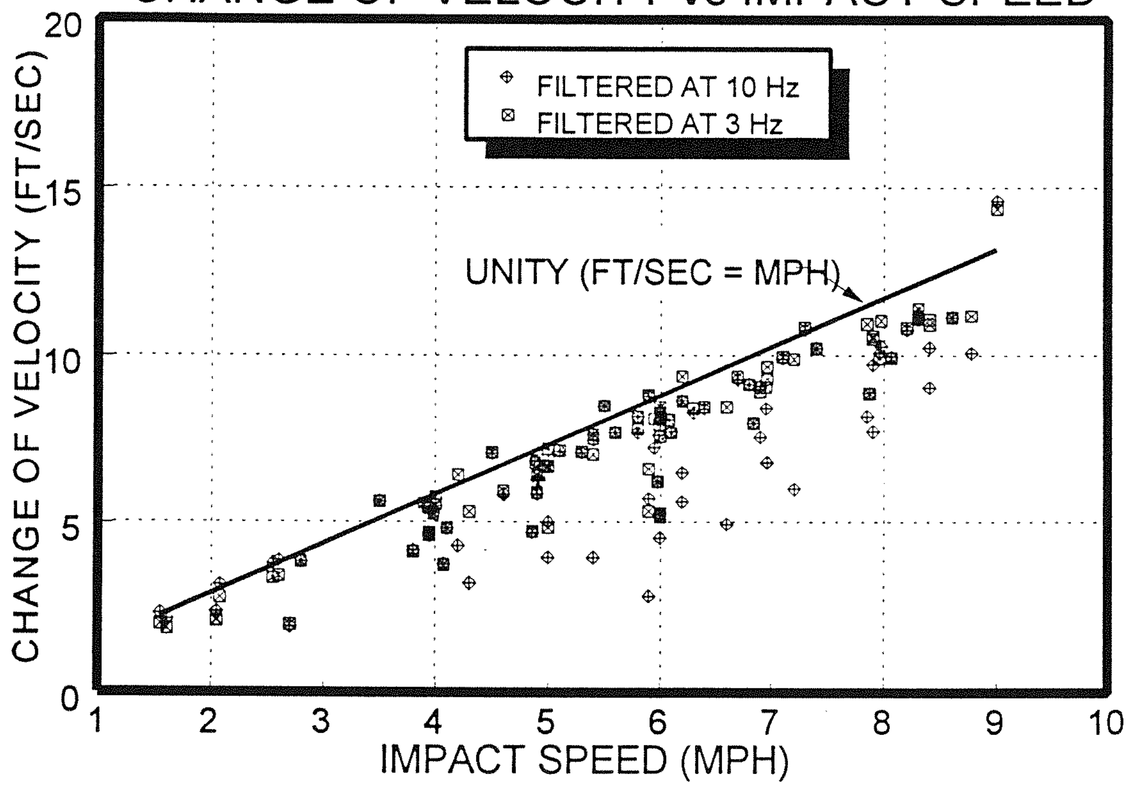
Table 1
Longitudinal Acceleration Measurement Summary
(10 Hz Data Unless Otherwise Noted)

Impact Speed (mph)	Peak G Range	G-RMS Range	Crest Factor (Peak G:GRMS)		Duration (Seconds)		Ratio Delta V/Impact Speed	
			Avg	Std Dev	Avg	Std Dev	10 Hz	3 Hz
1 - Standard Draft Gear Cars into Standard Draft Gear Cars								
4.2-6.2	1.78-3.26	0.31-0.51	6.26	0.50	0.20	0.08	0.63	0.77
2 - M921 Cushioned Cars into Standard Draft Gear Cars								
3.9-8.6	0.69-2.12	0.14-0.45	4.54	0.50	0.526	0.121	0.87	0.90
3 - M921D Cushioned Cars into Standard Draft Gear Cars * Impacts Less Than or Equal to 6.0 mph								
3.9-6.0	0.85-1.06	0.19-0.28	3.99	0.34	0.637	0.057	0.83	0.93
3 - M921D Cushioned Cars into Standard Draft Gear Cars * Impacts Greater Than 6.0 mph								
7.0-7.9	1.23-1.58	0.37-0.45			0.232	0.014		
4 - M921 Cushioned Cars into M921 Cushioned Cars								
3.9-7.9	0.36-0.91	0.11-0.27	3.70	0.29	0.737	0.030	0.75	0.75
5 - M921D Cushioned Cars into M921 Cushioned Cars								
3.8-8.3	0.45-2.17	0.12-0.46	3.95	0.65	0.580	0.172	0.89	0.91
6 - M921D Cushioned Cars into M921D Cushioned Cars								
4.1-8.8	0.76-2.77	0.19-0.47	4.32	0.82	0.509	0.194	0.84	0.86
7 - Cushioned Cars into Cushioned Cars (Type Unknown)								
2.8-9.0	0.55-3.04	0.08-0.55	5.84	1.39	0.579	0.150	0.83	0.94
8 - Draft Impacts								
1.6-2.6	1.16-2.59	0.17-0.35	7.04	0.40	0.122	0.025	0.094	0.83

The severity of shocks which are intermittent or contain occasional high peak values and have crest factors in excess of 6.0 will often be underestimated by rms measures.[2] (The crest factor is calculated by dividing the peak acceleration by the g-rms acceleration.) Even when filtered at 10 Hz, crest factors can exceed 6.0, especially for non-cushioned equipment shocks.

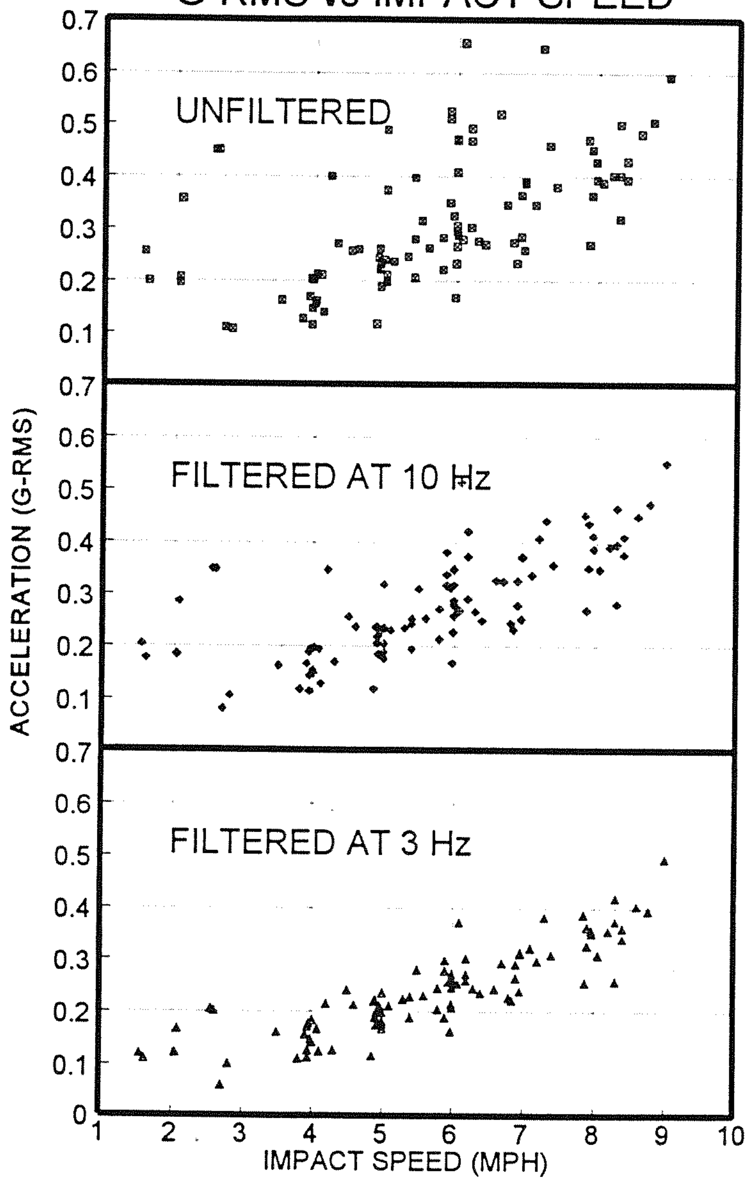
Velocity computations were performed with the data unfiltered, and with the data filtered at 10 and 3 Hz. Filtering time domain acceleration data tends to smooth the waveform, and reduces the frequency of zero crossings. The net effect is that the lower the waveform is filtered, the more accurate is the change of velocity computation, when compared to the radar recorded impact speed. Low pass filtering does not diminish the accuracy of the change of velocity computation, but rather improves it. See Figure 7.

FIGURE 7
CHANGE OF VELOCITY vs IMPACT SPEED



G-rms (root mean square) computations were also performed with the data unfiltered, and with the data filtered at 10 and 3 Hz. Filtering has a significant effect on g-rms measurement, especially transient acceleration measurements. See Figure 8. Note that the variance of the g-rms measurements decreases proportionately with the low pass filtering.

FIGURE 8
G-RMS vs IMPACT SPEED



5.0 Discussion

The goal of this research has been to define meaningful parameters for the measurement and analysis of rail longitudinal shock. Based on this investigation:

1) Peak acceleration amplitudes and pulse durations are defined most accurately by low pass filtering time domain acceleration histories at 10 Hz.

2) Change of velocity computations are most accurate when based on acceleration time histories low pass filtered at 3 Hz.

3) G-rms measurements exhibit the lowest variance when derived from data low pass filtered at 3 Hz.

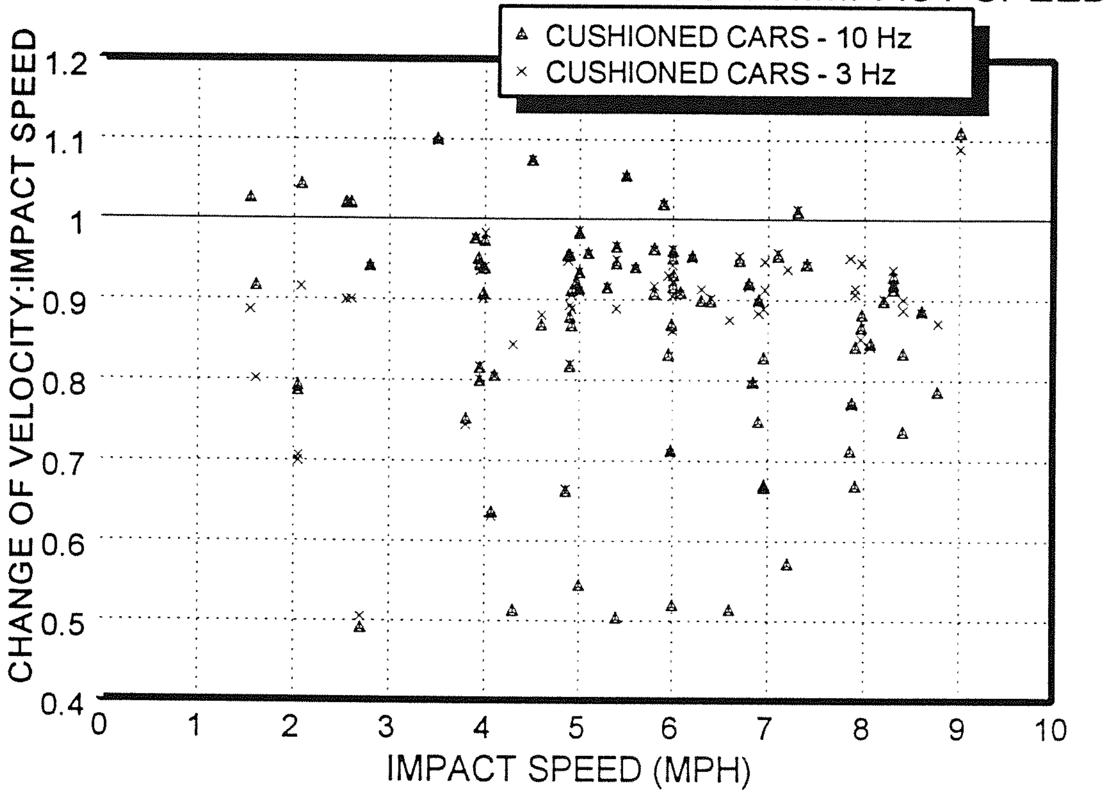
Sample frequency must be at least twice that of the highest significant frequency component of the acceleration signal to avoid frequency aliasing.[1] In practice it has been shown that a sampling frequency of 8 to 10 times the highest significant frequency component yields accurate representations of rail shocks. It follows then if our highest significant frequency is 10 Hz, our recommended digital sample frequency would be not less than 80 samples per second.

Sample frequency must also be 4 to 5 times greater than any anti-aliasing (single pole) filter frequency to prevent aliasing of the data and accurately capture magnitude.

Peak acceleration alone is not an accurate representation of rail type shocks. Pulse duration must also be defined. Sample frequency and filtering frequency(s) are also significant attributes which need be reported to define contextual parameters of the data.

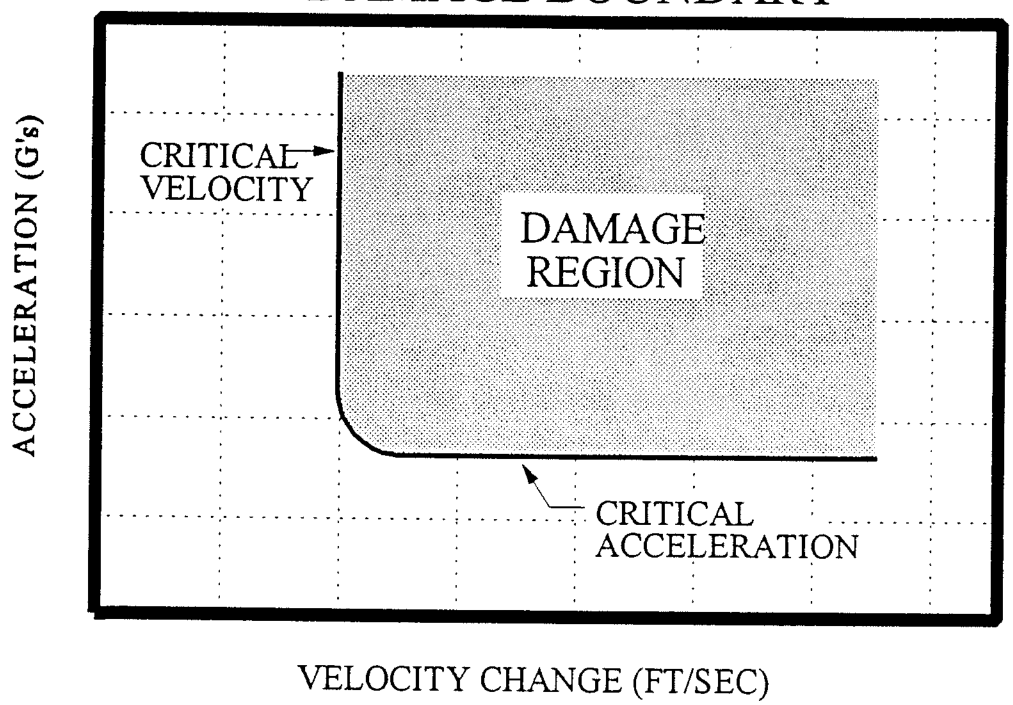
If the purpose of shock monitoring and measurement is to determine equivalency to yard handling impacts, the most logical measurement is change of velocity. For time domain accelerations low pass filtered at 3 Hz, computed change of velocity measurements have at least a 90% accuracy for cushioned equipment. See Figure 9.

FIGURE 9
RATIO CHANGE OF VELOCITY:IMPACT SPEED



The packaging industry acknowledges the interrelationship between peak acceleration and change of velocity in assessment of product fragility (reference ASTM 3332-92, " Mechanical Shock Fragility of Products, Using Shock Machines"). Basically, a products 'damage boundary region' is defined by critical change of velocity and peak acceleration levels, above which the product will be susceptible to damage, but below which the product will remain unharmed. See Figure 10.

FIGURE 10
DAMAGE BOUNDARY



Let's return to our friend who measured 70 g's from a rail car during an impact. Certainly any product shipped by rail (as well as the rail car) would be seriously damaged by such a pulse, provided that the change of velocity in the frequency range considered falls within the damage boundary region. In reality, the change of velocity computed from high frequency components of rail shock is quite small, because the duration is short. Which stands to reason since filtering acceleration time histories does not negatively influence change of velocity computations. Had the 70 g pulse been at low frequency, the result would have been cataclysmic!

High frequency vibration overlays most rail shocks as shown in the first frame of Figure 3. This vibration is primarily structural resonance, which is usually apparent via power spectral analysis. Because this vibration is a normal part of the random vibration spectra it is not considered to be a significant element to shock measurements. (These same resonant peaks appear in the power domain of both vibration and shock acceleration time histories.) It should always be considered when evaluating the effects of vibration response to excitation.

Thomas E. Feltault
Manager Damage Prevention Engineering

References:

1 - Haris, Cyril M.,"Shock and Vibration Handbook", Third Edition.

2 - American Society of Testing and Materials, Annual Book of Standards, Section 15.

3 - British Standards Institution, BS 6841:1987, "Guide to Measurement and Evaluation of Human Exposure to Whole-Body Mechanical Vibration and Repeated Shock."

APPENDIX 1

1 - Standard Draft Gear Cars Into Standard Draft Gear Cars
1-1 Thru 1-5: Field Impacts (Little Control)
1-6 Thru 1-9: Test Center Impacts (Great Control)

LONGITUDINAL ACCELERATION MEASUREMENTS													
Ref #	Impact Speed (mph -radar)	Peak G+			Peak G-			G-RMS			Crest Factor		
		Unf	10 Hz	3 Hz	Unf	10 Hz	3 Hz	Unf	10 Hz	3 Hz	Unf	10 Hz	3 Hz
1-1	5.9	3.66	2.13	0.79	-2.47	-0.52	-0.01	0.51	0.31	0.18	7.17	6.80	4.29
1-2	5.0	4.30	1.78	1.01	-2.13	-0.34	-0.09	0.49	0.32	0.23	8.77	5.66	4.38
1-3	6.0	3.63	2.23	1,17	-1.13	-0.27	-0.06	0.47	0.34	0.26	7.70	6.46	4.56
1-4	5.9	3.74	2.08	1,23	-1.60	-0.53	-0.12	0.53	0.38	0.27	7.10	5.52	4.50
1-5	6.0	3.15	1.89	1.07	-0.79	-0.31	-0.01	0.41	0.31	0.24	7.72	6.02	4.41
1-6	4.2	3.61	2.40	1.08	-0.72	-0.34	-0.04	0.40	0.34	0.21	9.02	6.99	5.16
1-7	6.2	4.35	2.38	1.53	-1.11	-0.57	-0.01	0.49	0.42	0.30	8.83	5.69	5.13
1-8	6.2	4.28	2.57	1.29	-1.00	-0.24	-0.01	0.47	0.37	0.27	9.12	6.97	4.80
1-9	6.1	5.87	3.26	1.83	-1.09	-0.27	-0.18	0.66	0.51	0.37	8.95	6.38	4.98
Summary of 6 MPH Impacts (7):													
Average >		4.10	2.36	1.27	-1.31	-0.39	-0.06	0.51	0.38	0.27	8.08	6.26	4.67
Std Dev >		0.82	0.42	0.31	0.52	0.13	0.06	0.07	0.06	0.05	0.80	0.50	0.29

Ref #	Duration			Velocity			Impact Speed	Ratio: Delta V/ Impact Speed	
	Delta T (rise)	Delta T	Delta T	Delta \v	Delta V	Delta V (measured)			
	10 Hz	10 Hz	3 Hz	10 Hz	3 Hz	10 Hz	(Ft/Sec)	10 Hz	3 Hz
1-1	0.055	0.383	1.027	2.83	6.60	6.68	8.65	0.33	0.76
1-2	0.031	0.188	0.262	5.02	4.86	6.08	7.33	0.68	0.66
1-3	0.062	0.168	0.277	5.27	5.28	6.91	8.80	0.60	0.60
1-4	0.078	0.188	0.262	5.72	5.35	6.76	8.65	0.66	0.62
1-5	0.090	0.211	0.297	5.25	5.18	6.68	8.80	0.60	0.59
1-6	0.039	0.113	0.125	4.32	6.43	6.49	6.16	0.70	1.04
1-7	0.074	0.148	1.320	6.50	9.38	9.39	9.09	0.71	1.03
1-8	0.055	0.160	1.410	5.63	8.65	8.66	9.09	0.62	0.95
1-9	0.074	0.156	0.289	7.71	7.69	10.04	8.95	0.86	0.85
Summary of 6 MPH Impacts (7):									
Average	0.07	0.20	0.70	5.56	6.88	7.87	Average >	0.63	0.77
Std Dev	0.01	0.08	0.49	1.37	1.60	1.34	Std Dev >	0.15	0.17

Note: Change of Velocity Measurements Were Performed Manually From the Time Histories In an Attempt to Improve

2- M921 Cushioned Cars into Standard Draft Gear Cars
2-1 Thru 2-5: Field Impacts (Little Control)
2-6 Thru 2-10: Test Center Impacts (Great Control)

LONGITUDINAL ACCELERATION MEASUREMENTS

Ref #	Impact Speed (mph -radar)	Peak G+			Peak G-			G-RMS			Crest Factor		
		Unf	10 Hz	3 Hz	Unf	10 Hz	3 Hz	Unf	10 Hz	3 Hz	Unf	10 Hz	3 Hz
2-1	4.9	1.76	0.98	0.68	-0.20	-0.02	-0.01	0.26	0.23	0.22	6.72	4.19	3.12
2-2	5.4	1.99	1.09	0.72	-0.13	-0.03	-0.03	0.28	0.25	0.22	7.09	4.37	3.21
2-3	4.6	1.87	0.95	0.73	-0.24	-0.02	-0.02	0.26	0.23	0.21	7.19	4.07	4.39
2-4	6.0	1.80	0.95	0.91	-0.13	-0.03	-0.03	0.31	0.28	0.26	5.87	3.42	3.51
2-5	8.6	2.67	2.12	1.54	-1.14	-0.03	-0.02	0.48	0.45	0.40	5.54	4.75	3.86
2-6	3.9	0.88	0.69	0.45	-0.07	-0.04	-0.04	0.15	0.14	0.12	5.92	4.91	3.67
2-7	4.9	1.36	1.07	0.67	-0.16	-0.05	-0.02	0.22	0.22	0.18	6.08	4.97	3.67
2-8	6.0	2.13	1.58	0.92	-0.38	-0.33	-0.23	0.33	0.31	0.25	6.54	5.13	3.67
2-9	6.9	2.48	1.49	0.97	-0.59	-0.27	-0.21	0.37	0.32	0.29	6.78	4.64	3.41
2-10	8.1	2.56	1.71	1.05	-0.70	-0.38	-0.31	0.39	0.34	0.30	6.57	4.96	3.46
										Average >	6.43	4.54	3.51
										Std Dev >	0.52	0.50	0.21

Ref #	Duration			Velocity		Impact Speed	Ratio: Delta V/ Impact Speed	
	Delta T (rise)	Delta T	Delta T	Delta \v	Delta V			
	10 Hz	10 Hz	3 Hz	10 Hz	3 Hz	(Ft/Sec)	10 Hz	3 Hz
2-1	0.033	0.551	0.562	6.85	6.86	7.19	0.95	0.95
2-2	0.041	0.555	0.578	7.63	7.65	7.92	0.96	0.97
2-3	0.037	0.363	0.438	5.85	5.94	6.75	0.87	0.88
2-4	0.043	0.457	0523	8.05	8.11	8.80	0.91	0.92
2-5	0.051	0.609	0.668	11.17	11.16	12.61	0.89	0.88
2-6	0.047	0.594	0.684	4.61	4.63	5.78	0.80	0.80
2-7	0.051	0.645	0.816	6.30	6.42	7.19	0.88	0.89
2-8	0.047	0.395	0.707	7.24	8.11	8.73	0.83	0.93
2-9	0.074	0.359	0.746	7.56	8.94	10.12	0.75	0.88
2-10	0.090	0.734	0.797	9.98	9.95	11.82	0.84	0.84
Average >	0.051	0.526	0.652			Average >	0.87	0.90
Std Dev >	0.017	0.121	0.117			Std Dev >	0.06	0.05

3 - M921D Cushioned Cars Into Standard Draft Gear Cars
3-1 Thru 3-10: Test Center Impacts (Great Control)

LONGITUDINAL ACCELERATION MEASUREMENTS													
Ref #	Impact Speed (mph -radar)	Peak G+			Peak G-			G-RMS			Crest Factor		
		Unf	10 Hz	3 Hz	Unf	10 Hz	3 Hz	Unf	10 Hz	3 Hz	Unf	10 Hz	3 Hz
3-1	4.0	1.43	0.86	0.64	-0.11	-0.07	-0.05	0.20	0.19	0.17	7.06	4.53	3.72
3-2	4.9	1.55	0.92	0.71	-0.16	-0.07	-0.04	0.23	0.22	0.20	6.62	4.30	3.62
3-3	6.0	1.49	1.06	0.86	-0.30	-0.21	-0.19	0.30	0.28	0.27	5.04	3.71	3.23
3-4	7.0	1.95	1.32	1.23	-0.34	-0.21	-0.14	0.39	0.37	0.31	4.99	3.58	3.99
3-5	7.9	2.28	1.73	1.52	-0.47	-0.36	-0.27	0.45	0.43	0.36	5.02	3.99	4.24
3-6	3.9	1.41	0.85	0.64	-0.09	-0.06	-0.04	0.21	0.19	0.17	6.89	4.54	3.83
3-7	4.9	1.43	0.92	0.74	-0.37	-0.30	-0.23	0.25	0.23	0.22	5.83	3.95	3.44
3-8	6.0	1.66	1.06	0.88	-0.30	-0.24	-0.19	0.29	0.27	0.25	5.77	3.85	3.48
3-9	7.0	1.91	1.31	1.24	-0.36	-0.28	-0.24	0.39	0.37	0.31	4.95	3.54	4.06
3-10	7.9	2.18	1.75	1.58	-0.38	-0.29	-0.24	0.47	0.45	0.38	4.62	3.90	4.12
								All Impacts:	Average >		5.68	3.99	3.77
									Std Dev >		0.85	0.34	0.31

Ref #	Duration			Velocity		Impact Speed	Ratio: Delta V/ Impact Speed	
	Delta T (rise)	Delta T	Delta T	Delta \v	Delta V			
	10 Hz	10 Hz	3 Hz	10 Hz	3 Hz	(Ft/Sec)	10 Hz	3 Hz
3-1	0.039	0.551	0.605	5.45	5.42	5.79	0.94	0.94
3-2	0.043	0.605	0.652	6.56	6.53	7.22	0.91	0.90
3-3	0.043	0.660	0.703	8.36	8.29	8.80	0.95	0.94
3-4	0.043	0.230	0.719	6.79	9.67	10.21	0.67	0.95
3-5	0.047	0.215	0.715	7.73	10.59	11.59	0.67	0.91
3-6	0.047	0.598	0.660	5.47	5.45	5.76	0.95	0.94
3-7	0.051	0.703	0.746	6.82	6.78	7.16	0.95	0.95
3-8	0.045	0.707	0.742	8.18	8.14	8.81	0.93	0.92
3-9	0.043	0.254	0.793	6.82	9.31	10.21	0.67	0.91
3-10	0.043	0.230	0.750	8.19	10.96	11.51	0.71	0.95
Average >	0.044					Average >	0.83	0.93
Std Dev >	0.003					Std Dev >	0.13	0.02

pacts $\leq$ 6 mph:	Average >	0.637	0.685
	Std Dev >	0.057	0.051
Impacts > 6 mph:	Average >	0.232	0.744
	Std Dev >	0.014	0.031

4 - M921 Cushioned Cars Into M921 Cushioned Cars
4-1 Thru 4-5: Test Center Impacts (Great Control)

LONGITUDINAL ACCELERATION MEASUREMENTS

Ref #	Impact Speed (mph-radar)	Peak G+			Peak G-			G-RMS			Crest Factor		
		Unf	10 Hz	3Hz	Unf	10 Hz	3 Hz	Unf	10 Hz	3 Hz	Unf	10 Hz	3Hz
4-1	3.9	0.40	0.36	0.32	-0.07	-0.01	-0.01	0.12	0.11	0.11	3.42	3.18	2.92
4-2	4.9	0.40	0.38	0.35	-0.03	-0.02	-0.01	0.12	0.12	0.11	3.33	3.25	3.09
4-3	6.0	0.70	0.64	0.52	-0.09	-0.03	-0.02	0.17	0.17	0.16	4.15	3.85	3.28
4-4	6.8	0.89	0.81	0.71	-0.14	-0.06	-0.03	0.24	0.23	0.22	3.80	3.52	3.27
4-5	7.9	1.03	0.91	0.80	-0.13	-0.03	-0.01	0.27	0.27	0.25	3.79	3.43	3.17
										Average >	3.70	3.44	3.15
										Std. Dev >	0.29	0.24	0.13

Ref #	Duration			Velocity		Impact Speed	Ratio: Delta V/ Impact Speed	
	Delta T (rise)	Delta T	Delta T	Delta V	Delta V			
	10 Hz	10 Hz	3 Hz	10 Hz	3 Hz	(Ft/Sec)	10 Hz	3 Hz
4-1	0.387	0.715	0.777	4.70	4.72	5.78	0.81	0.82
4-2	0.391	0.703	0.766	4.71	4.74	7.13	0.66	0.66
4-3	0.328	0.785	0.809	6.23	6.22	8.77	0.71	0.71
4-4	0.344	0.758	0.781	7.99	7.98	10.03	0.80	0.80
4-5	0.305	0.723	0.742	8.90	8.88	11.54	0.77	0.77
Average >	0.351	0.737	0.775			Average >	0.75	0.75
Std Dev >	0.033	0.030	0.22			Std Dev >	0.06	0.06

5 - M921D Cushioned Cars Into M921 Cushioned Cars
5-1 Thru 5-21: Field Impacts (Little Control)
5-22 Thru 5-28: Test Center Impacts (Great Control)

LONGITUDINAL ACCELERATION MEASUREMENTS

Ref #	Impact Speed (mph-radar)	Peak G+			Peak G-			G-RMS			Crest Factor		
		Unf	10 Hz	3Hz	Unf	10 Hz	3 Hz	Unf	10 Hz	3 Hz	Unf	10 Hz	3Hz
5-1	4.9	1.33	0.98	0.68	-0.05	-0.01	-0.02	0.22	0.20	0.19	5.95	4.83	3.67
5-2	4.0	1.35	0.96	0.63	-0.20	-0.02	-0.02	0.21	0.20	0.18	6.31	4.94	3.50
5-3	5.3	1.27	0.96	0.78	-0.05	-0.01	-0.01	0.25	0.23	0.22	5.15	4.16	3.54
5-4	6.4	1.62	0.98	0.77	-0.05	-0.01	-0.01	0.27	0.25	0.23	6.01	3.98	3.32
5-5	8.2	2.24	1.90	1.38	-0.05	-0.01	-0.01	0.40	0.39	0.35	5.57	4.91	3.93
5-6	4.1	0.73	0.46	0.37	-0.09	-0.05	-0.05	0.14	0.13	0.12	5.18	3.61	3.07
5-7	5.0	1.18	0.54	0.51	-0.05	-0.02	-0.02	0.20	0.19	0.18	5.88	2.92	2.83
5-8	6.0	1.19	1.00	0.84	-0.05	-0.01	-0.01	0.27	0.26	0.24	4.48	3.93	3.45
5-9	5.0	0.86	0.71	0.60	-0.05	-0.03	-0.03	0.21	0.20	0.19	4.06	3.51	3.11
5-10	7.1	1.41	1.27	1.13	-0.05	-0.01	-0.03	0.35	0.33	0.32	4.07	3.82	3.56
5-11	8.3	1.66	1.56	1.36	-0.05	-0.03	-0.02	0.40	0.39	0.37	4.11	3.98	3.69
5-12	8.3	2.34	1.05	0.75	-0.50	-0.03	-0.03	0.32	0.28	0.25	7.33	3.78	2.95
5-13	4.0	0.98	0.47	0.39	-0.07	-0.02	-0.02	0.16	0.15	0.14	6.07	3.20	2.82
5-14	5.4	1.08	0.54	0.47	-0.15	-0.02	-0.02	0.21	0.19	0.18	5.23	2.80	2.54
5-15	5.8	1.16	0.60	0.55	-0.09	-0.03	-0.02	0.22	0.21	0.20	5.19	2.88	2.72
5-16	6.3	1.35	1.16	0.84	-0.05	-0.03	-0.03	0.28	0.26	0.24	4.88	4.41	3.49
5-17	3.8	0.79	0.45	0.35	-0.11	-0.05	-0.05	0.13	0.12	0.11	6.19	3.90	3.29
5-18	6.8	1.93	0.98	0.69	-0.07	-0.04	-0.03	0.28	0.24	0.22	7.00	4.07	3.07
5-19	5.0	1.19	0.57	0.41	-0.07	-0.03	-0.03	0.20	0.17	0.16	5.97	3.28	2.52
5-20	6.7	1.77	1.36	1.04	-0.13	-0.05	-0.07	0.35	0.32	0.29	5.13	4.26	3.60
5-21	8.3	2.69	2.10	1.61	-0.32	-0.10	-0.09	0.50	0.46	0.41	5.38	4.54	3.89
5-22	4.0	0.74	0.54	0.45	-0.05	-0.03	-0.02	0.16	0.15	0.14	4.71	3.54	3.13
5-23	4.9	0.97	0.68	0.54	-0.07	-0.06	-0.04	0.19	0.18	0.17	5.10	3.74	3.15
5-24	6.0	1.12	0.79	0.63	-0.16	-0.06	-0.05	0.23	0.22	0.21	4.81	3.52	3.01
5-25	7.0	1.49	0.86	0.71	-0.13	-0.03	-0.02	0.26	0.25	0.24	5.73	3.43	3.02
5-26	7.9	1.85	1.56	1.12	-0.16	-0.13	-0.11	0.37	0.35	0.32	5.08	4.48	3.49
5-27	8.4	2.18	1.78	1.28	-0.14	-0.13	-0.09	0.40	0.37	0.32	5.51	4.76	3.81
5-28	8.4	2.62	2.17	1.46	-0.14	-0.10	-0.10	0.43	0.41	0.36	6.07	5.32	4.10
										Average >	5.43	3.95	3.30
										Std. Dev >	0.79	0.65	0.41

Ref #	Duration			Velocity		Impact Speed	Ratio: Delta V/ Impact Speed	
	Delta T (rise)	Delta T	Delta T	Delta V	Delta V			
	10 Hz	10 Hz	3 Hz	10 Hz	3 Hz	(Ft/Sec)	10 Hz	3 Hz
5-1	0.191	0.457	0.527	5.86	5.90	7.19	0.82	0.82
5-2	0.230	0.453	0.539	5.70	5.76	5.87	0.97	0.98
5-3	0.207	0.504	0.570	7.10	7.11	7.77	0.91	0.92
5-4	0.152	0.531	0.629	8.42	8.47	9.39	0.90	0.90
5-5	0.168	0.484	0.586	10.79	10.84	12.03	0.90	0.90
5-6	0.039	0.906	0.984	4.83	4.84	6.01	0.80	0.80
5-7	0.039	0.637	0.656	6.83	6.86	7.33	0.93	0.93
5-8	0.266	0.578	0.625	8.44	8.47	8.80	0.96	0.96
5-9	0.324	0.609	0.645	7.19	7.23	7.33	0.98	0.99
5-10	0.223	0.500	0.543	9.92	9.99	10.41	0.95	0.96
5-11	0.193	0.516	0.566	11.17	11.19	12.17	0.92	0.92
5-12	0.043	0.855	0.914	11.10	11.11	12.17	0.91	0.91
5-13	0.055	0.691	0.715	5.50	5.52	5.87	0.94	0.94
5-14	0.039	0.691	0.719	7.47	7.52	7.92	0.94	0.95
5-15	0.051	0.555	0.684	7.70	7.80	8.51	0.91	0.92
5-16	0.348	0.500	0.602	8.29	8.44	9.24	0.90	0.91
5-17	0.051	1.098	1.129	4.18	4.15	5.57	0.75	0.74
5-18	0.035	0.762	0.852	9.16	9.14	9.97	0.92	0.92
5-19	0.035	0.609	0.703	6.69	6.69	7.33	0.91	0.91
5-20	0.316	0.422	0.527	9.30	9.38	9.83	0.95	0.95
5-21	0.219	0.309	0.426	11.28	11.41	12.17	0.93	0.94
5-22	0.043	0.742	0.770	5.28	5.26	5.84	0.90	0.90
5-23	0.051	0.617	0.844	6.25	6.41	7.22	0.87	0.89
5-24	0.043	0.520	0.809	7.62	7.94	8.79	0.87	0.90
5-25	0.40	0.520	0.793	8.43	9.06	10.19	0.83	0.89
5-26	0.230	0.414	0.809	9.74	10.52	11.59	0.84	0.91
5-27	0.203	0.453	0.824	10.25	10.93	12.32	0.83	0.89
5-28	0.195	0.309	0.777	9.06	11.10	12.32	0.73	0.90
Average >	0.144	0.580	0.706			Average >	0.89	0.91
Std Dev >	0.102	0.172	0.155			Std Dev >	0.06	0.05

6 - M921D Cushioned Cars Into M921D Cushioned Cars
6-1 Thru 6-7: Test Center Impacts (Great Control)

LONGITUDINAL ACCELERATION MEASUREMENTS

ef #	Impact Speed (mph-radar)	Peak G+			Peak G-			G-RMS			Crest Factor		
		Unf	10 Hz	3Hz	Unf	10 Hz	3 Hz	Unf	10 Hz	3 Hz	Unf	10 Hz	3Hz
6-1	4.1	1.58	0.76	0.63	-0.26	-0.10	-0.02	0.21	0.19	0.16	7.46	3.96	3.85
6-2	5.0	1.24	0.87	0.71	-0.50	-0.22	-0.17	0.24	0.23	0.21	5.15	3.86	3.43
6-3	6.1	1.39	0.93	0.79	-0.28	-0.25	-0.21	0.28	0.27	0.25	4.97	3.50	3.16
6-4	6.9	1.26	0.97	0.83	-0.26	-0.17	-0.09	0.29	0.28	0.26	4.42	3.51	3.21
6-5	8.0	2.00	1.69	1.18	-0.24	-0.22	-0.20	0.40	0.38	0.35	5.06	4.40	3.41
6-6	8.0	2.70	2.10	1.32	-0.35	-0.24	-0.18	0.43	0.41	0.35	6.30	5.12	3.74
6-7	8.8	4.09	2.77	1.63	-0.35	-0.24	-0.21	0.51	0.47	0.39	8.08	5.88	4.19
										Average >	5.92	4.32	3.57
										Std. Dev >	1.29	0.82	0.35

Ref #	Duration			Velocity		Impact Speed	Ratio: Delta V/ Impact Speed	
	Delta T (rise)	Delta T	Delta T	Delta V	Delta V			
	10 Hz	10 Hz	3 Hz	10 Hz	3 Hz	(Ft/Sec)	10 Hz	3 Hz
6-1	0.070	0.285	0.363	3.79	3.77	5.97	0.63	0.63
6-2	0.043	0.746	0.789	6.70	6.70	7.29	0.92	0.92
6-3	0.043	0.691	0.746	8.09	8.09	8.92	0.91	0.91
6-4	0.047	0.750	0.781	9.09	9.08	10.12	0.90	0.90
6-5	0.277	0.402	0.832	10.29	11.06	11.69	0.88	0.95
6-6	0.246	0.371	0.457	10.09	9.95	11.67	0.86	0.85
6-7	0.203	0.320	0.785	10.09	11.20	12.86	0.78	0.87
Average >	0.133	0.509	0.679			Average >	0.84	0.86
Std Dev >	0.097	0.194	0.174			Std Dev >	0.09	0.10

7 - Cushioned Cars Into Cushioned Cars (Type Unknown)
7-1 Thru 7-20: Field Impacts (Little Control)

LONGITUDINAL ACCELERATION MEASUREMENTS													
Ref #	Impact Speed (mph-radar)	Peak G+			Peak G-			G-RMS			Crest Factor		
		Unf	10 Hz	3Hz	Unf	10 Hz	3 Hz	Unf	10 Hz	3 Hz	Unf	10 Hz	3Hz
7-1	2.8	0.55	0.43	0.33	-0.05	-0.02	-0.01	0.11	0.10	0.10	5.04	4.17	3.40
7-2	3.9	0.91	0.71	0.50	-0.03	-0.02	-0.01	0.17	0.16	0.15	5.32	4.31	3.25
7-3	5.1	1.35	1.06	0.69	-0.03	-0.01	0.00	0.24	0.23	0.21	5.66	4.68	3.32
7-4	5.8	1.75	1.33	0.79	-0.03	-0.01	0.00	0.28	0.27	0.24	6.16	4.95	3.31
7-5	5.6	1.58	1.21	0.74	-0.03	0.00	0.00	0.26	0.25	0.23	5.98	4.84	3.25
7-6	6.2	1.74	1.44	0.86	-0.03	-0.01	0.00	0.30	0.29	0.26	5.75	5.01	3.36
7-7	7.4	2.56	1.77	1.07	-0.05	-0.04	-0.03	0.38	0.35	0.31	6.74	5.03	3.50
7-8	2.7	1.23	0.59	0.24	-0.24	-0.05	-0.01	0.11	0.08	0.06	11.08	7.53	4.27
7-9	5.4	4.88	1.83	0.75	-1.46	-0.09	-0.01	0.40	0.24	0.18	12.26	7.65	4.09
7-10	4.3	3.41	1.27	0.52	-0.85	-0.08	0.00	0.27	0.17	0.12	12.55	7.61	4.24
7-11	5.0	4.57	1.79	0.73	-1.07	-0.09	0.00	0.37	0.23	0.17	12.20	7.71	4.25
7-12	6.0	5.54	2.18	0.88	-1.66	-0.11	0.00	0.47	0.28	0.20	11.72	7.89	4.32
7-13	6.6	6.51	2.42	1.02	-1.40	-0.14	0.00	0.52	0.32	0.24	12.51	7.50	4.25
7-14	7.2	7.65	3.04	1.28	-1.72	-0.20	0.00	0.65	0.40	0.29	11.84	7.53	4.39
7-15	4.5	1.38	1.24	0.88	-0.07	-0.03	-0.02	0.26	0.25	0.24	5.32	4.90	3.70
7-16	3.5	0.63	0.58	0.50	-0.07	-0.04	-0.03	0.16	0.16	0.16	3.82	3.60	3.18
7-17	5.5	2.01	1.62	1.01	-0.07	-0.03	-0.03	0.32	0.31	0.28	6.35	5.30	3.67
7-18	5.9	2.31	1.86	1.12	-0.13	-0.03	-0.03	0.35	0.33	0.29	6.61	5.58	3.84
7-19	7.3	3.31	2.56	1.42	-0.07	-0.07	-0.04	0.46	0.44	0.38	7.19	5.85	3.78
7-20	9.0	4.40	2.87	1.89	-0.07	-0.07	0.00	0.59	0.55	0.49	7.45	5.24	3.86
										Average >	8.08	5.84	3.76
										Std. Dev >	3.00	1.39	0.42

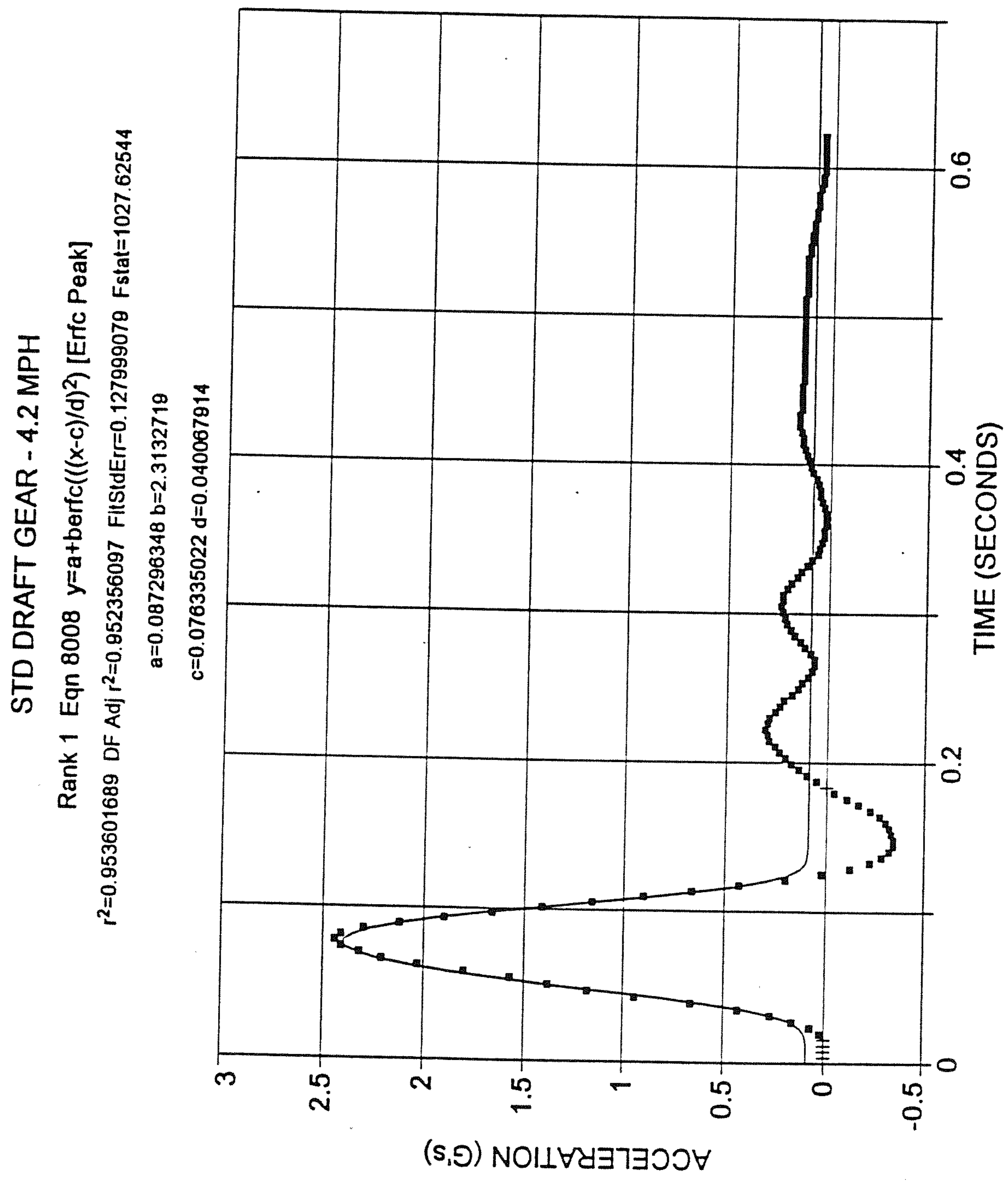
Ref #	Duration			Velocity		Impact Speed	Ratio: Delta V/ Impact Speed	
	Delta T (rise)	Delta T	Delta T	Delta V	Delta V			
	10 Hz	10 Hz	3 Hz	10 Hz	3 Hz	(Ft/Sec)	10 Hz	3 Hz
7-1	0.031	0.797	0.879	3.86	3.86	4.11	0.94	0.94
7-2	0.039	0.828	0.875	5.57	5.58	5.72	0.97	0.98
7-3	0.035	0.715	0.762	7.15	7.16	7.48	0.96	0.96
7-4	0.031	0.738	0.797	8.18	8.18	8.51	0.96	0.96
7-5	0.031	0.664	0.727	7.70	7.71	8.21	0.94	0.94
7-6	0.031	0.723	0.789	8.66	8.66	9.09	0.95	0.95
7-7	0.027	0.699	0.738	10.23	10.23	10.85	0.94	0.94
7-8	0.316	0.562	0.688	1.94	2.00	3.96	0.49	0.50
7-9	0.131	0.398	0.891	3.98	7.04	7.92	0.50	0.89
7-10	0.180	0.484	1.293	3.22	5.33	6.31	0.51	0.84
7-11	0.1443	0.402	1.203	3.98	6.67	7.33	0.54	0.91
7-12	0.125	0.371	1.270	4.56	7.58	8.80	0.52	0.86
7-13	0.105	0.332	1.246	4.96	8.48	9.68	0.51	0.88
7-14	0.090	0.320	1.344	6.02	9.90	10.56	0.57	0.94
7-15	0.094	0.551	0.621	7.08	7.09	6.60	1.07	1.07
7-16	0.133	0.625	0.680	5.64	5.63	5.13	1.10	1.10
7-17	0.070	0.586	0.668	8.49	8.49	8.07	1.05	1.05
7-18	0.066	0.582	0.656	8.80	8.81	6.65	1.02	1.02
7-19	0.049	0.555	0.672	10.79	10.84	10.71	1.01	1.01
7-20	0.059	0.641	0.633	14.62	14.39	13.20	1.11	1.09
Average >	0.089	0.579	0.872			Average >	0.83	0.94
Std Dev >	0.069	0.150	0.244			Std Dev >	0.23	0.12

8 - Draft Impacts - Test Center (Great Control)

LONGITUDINAL ACCELERATION MEASUREMENTS													
Ref #	Impact Speed (mph-radar)	Peak G+			Peak G-			G-RMS			Crest Factor		
		Unf	10 Hz	3Hz	Unf	10 Hz	3 Hz	Unf	10 Hz	3 Hz	Unf	10 Hz	3Hz
8-1	1.6	2.99	1.46	0.59	-0.44	-0.23	-0.09	0.26	0.20	0.12	11.71	7.29	5.04
8-2	2.1	3.90	2.08	0.81	-0.69	-0.33	-0.15	0.36	0.28	0.16	10.91	7.37	5.03
8-3	2.6	4.92	2.59	0.99	-0.99	-0.37	-0.18	0.45	0.34	0.20	10.91	7.53	5.02
8-4	1.6	1.97	1.19	0.54	-0.35	-0.20	-0.09	0.20	0.17	0.11	9.87	6.83	5.03
8-5	2.1	1.43	1.19	0.59	-0.27	-0.21	-0.09	0.20	0.18	0.12	7.25	6.53	4.96
8-6	2.6	4.60	2.50	0.97	-1.18	-0.44	-0.21	0.45	0.35	0.20	10.21	7.26	4.84
8-7	2.1	1.82	1.16	0.58	-0.35	-0.21	-0.09	0.21	0.18	0.12	8.75	6.46	4.93
										Average >	9.94	7.04	4.98
										Std. Dev >			

Ref #	Duration			Velocity		Impact Speed	Ratio: Delta V/ Impact Speed	
	Delta T (rise)	Delta T	Delta T	Delta V	Delta V			
	10 Hz	10 Hz	3 Hz	10 Hz	3 Hz	(Ft/Sec)	10 Hz	3 Hz
8-1	0.025	0.137	0.199	2.33	2.01	2.27	1.02	0.89
8-2	0.023	0.094	0.195	3.18	2.79	3.05	1.04	0.92
8-3	0.020	0.094	0.199	3.88	3.43	3.81	1.02	0.90
8-4	0.033	0.152	0.215	2.16	1.89	2.36	0.91	0.80
8-5	0.035	0.137	0.215	2.38	2.12	3.01	0.79	0.71
8-6	0.023	0.094	0.195	3.81	3.36	3.74	1.02	0.90
8-7	0.039	0.148	0.219	2.36	2.10	3.01	0.78	0.70
Average >	0.028	0.122	0.205			Average >	0.94	0.83
Std Dev >	0.007	0.025	0.010			Std Dev >	0.10	0.09

APPENDIX 2


STD DRAFT GEAR - 4.2 MPH
Rank 1 Eqn 8008 y=a+berfc(((x-c)/d)²) [Erfc Peak]
r²=0.953601689 DF Adj r²=0.952356097 FitStdErr=0.127999079 Fstat=1027.62544
a=0.087296348 b=2.3132719
c=0.076335022 d=0.040067914
ACCELERATION (G's)
TIME (SECONDS)
3
2.5
2
1.5
1
0.5
0
-0.5
0
0.2
0.4
0.6

STD DRAFT GEAR - 6.1 MPH IMPACT

Rank 1 Eqn 8008 $y=a+b\,\mathrm{erfc}(((x-c)/d)^2)$ [Erfc Peak]

r^2=0.954574472 DF Adj r^2=0.952922634 FitStdErr=0.218620214 Fstat=777.51997

a=-0.038698031 b=3.0488138

c=0.094788817 d=0.058703653