Ergonomic Status, Whole Body Vibration and Health Assessment of U.S. Railroad Locomotives & Operators

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Aim of study:

- Ergonomic factors in relationship to whole-body vibration (WBV) exposure in US locomotives
- Cab and seats in use
- Mitigating effects (WBV)

Background:

- Low back disorder occupational risk factors
  - Bending, twisting, lifting,
  - **Awkward posture & WBV**
- Rail vehicles:
  - Unique environment
    - Multi-axis whole-body vibration and shocks (WBV)
    - Lateral acceleration
    - Frequent irregular shocks
    - Events often unpredictable

Epidemiology of neck and lower back disorders :

- Method:
  - self-administered 200-item survey (cross-section)
    - Musculoskeletal diseases (back, neck, large joints)
    - Working conditions and ergonomic factors
    - Psycho-social stress (Karasak et al Model)
  - US & Canada randomly selected group of active railroad engineers and a comparison group (civil engineers)
  - Response rate: 47% for railroad engineers (n= 1195) and 41% for controls (n=323).

Journal of Transportation Research Board; No 1899, 2004, p145-155

Epidemiology of neck and lower back disorders - Results:

- Serious LBP and neck/shoulder complaints among locomotive engineers was ~ double c/w control group
- Adjusted* OR for sciatic pain (a back condition with neurological complications) was 2.17 (95% CI 1.33-3.56) *Age, gender, race, smoking, non-occupational WBV exposure
- Attenuation of risk after controlling for psychosocial work factors, time sitting at work, and time at work being bothered by vibration

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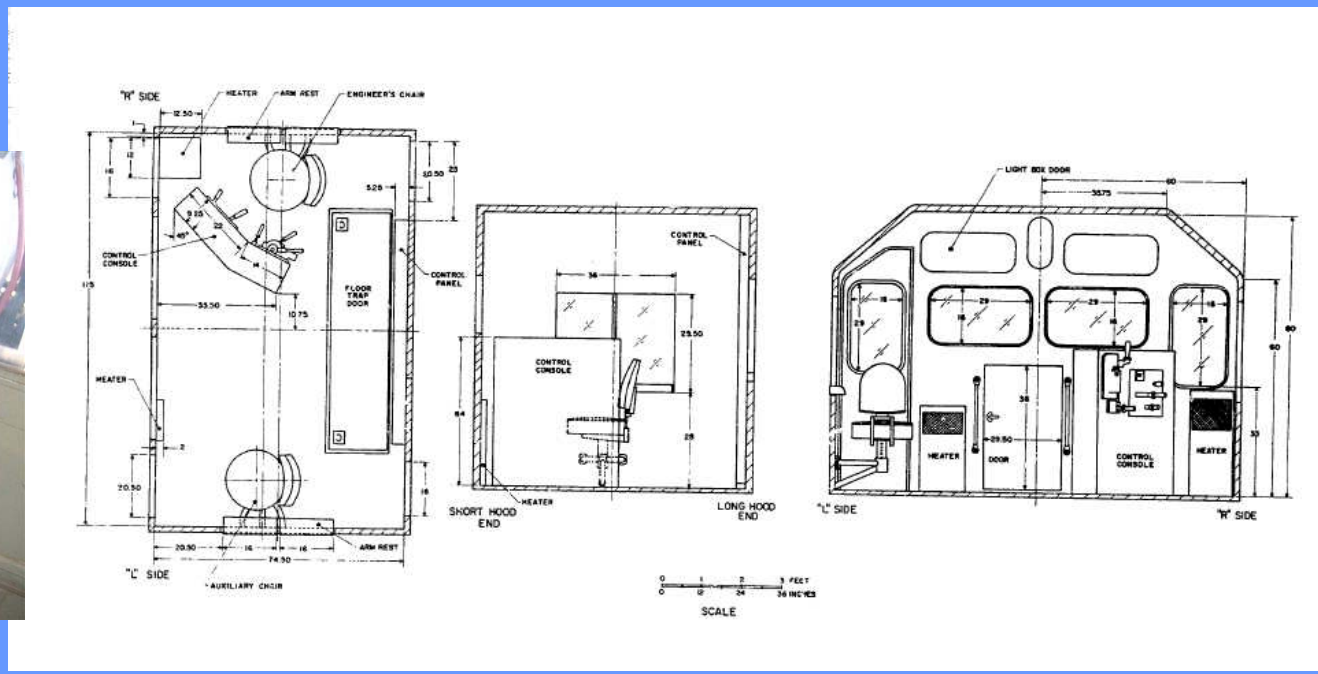
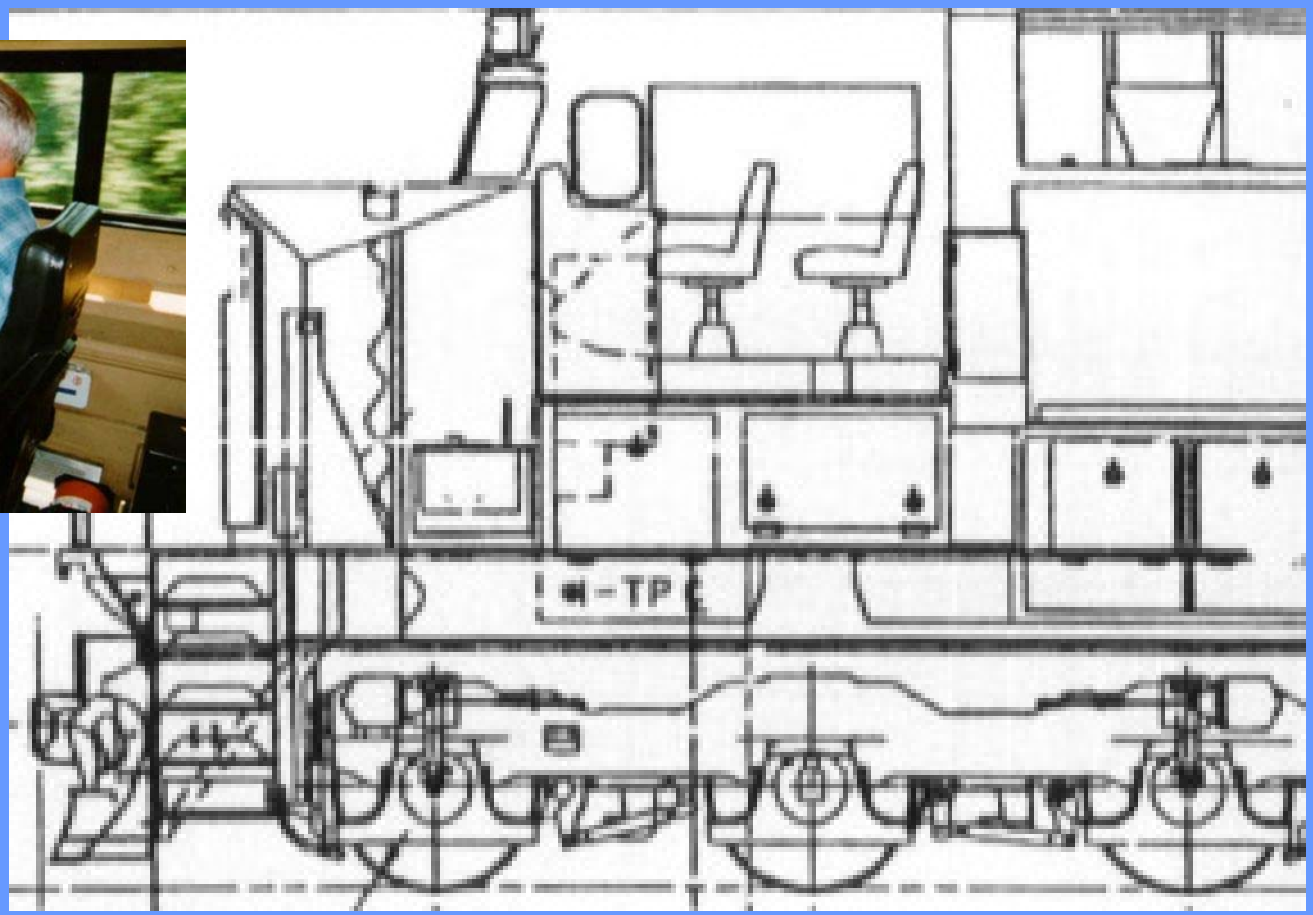
Method:

- Standardized cross-sectional questionnaire survey of North-American locomotive engineers (n= 1195) and controls (n=323).
- Comparison with a non-exposed control group (sedentary office worker)
- 50+ locomotive cab and seat inspections
- Observation of tasks and body movements of locomotive operators during routine revenue service

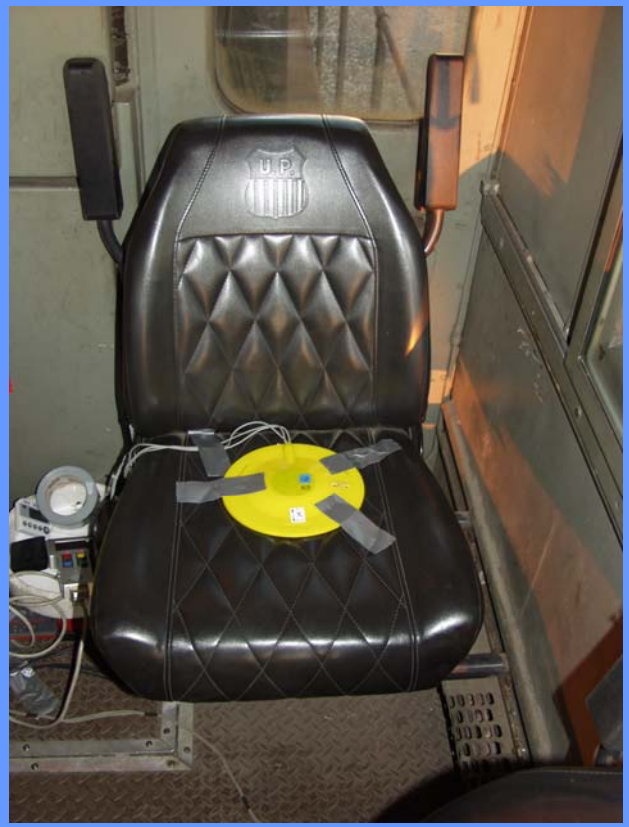
Traditional cab and seat design ("AAR Control Stand")



New Generation “Wide body” locomotive cab and seating



Yard switcher GP40-2



Field observations:

Model GE C41-8, 4135 hp, built in 1991 (UP 9077) – USSC Seat retrofitted (2001)

Whole body vibration results (ISO 2631-1; 1997)

Axis	x	y	z	Vector sum	x	y	z
(n)	51	51	51	51	42	42	42
Mean	**0.14**	**0.22**	**0.28**		**1.43**	**1.21**	**0.97**
Min	0.05	0.05	0.09	0.13	1.00	1.03	0.61
Max	0.72	0.71	0.50	1.44	2.32	1.51	1.56
SD	0.14	0.12	0.08	0.22	0.32	0.11	0.17
Mode	0.07	0.14	0.32	N/A	1.20	1.25	0.92

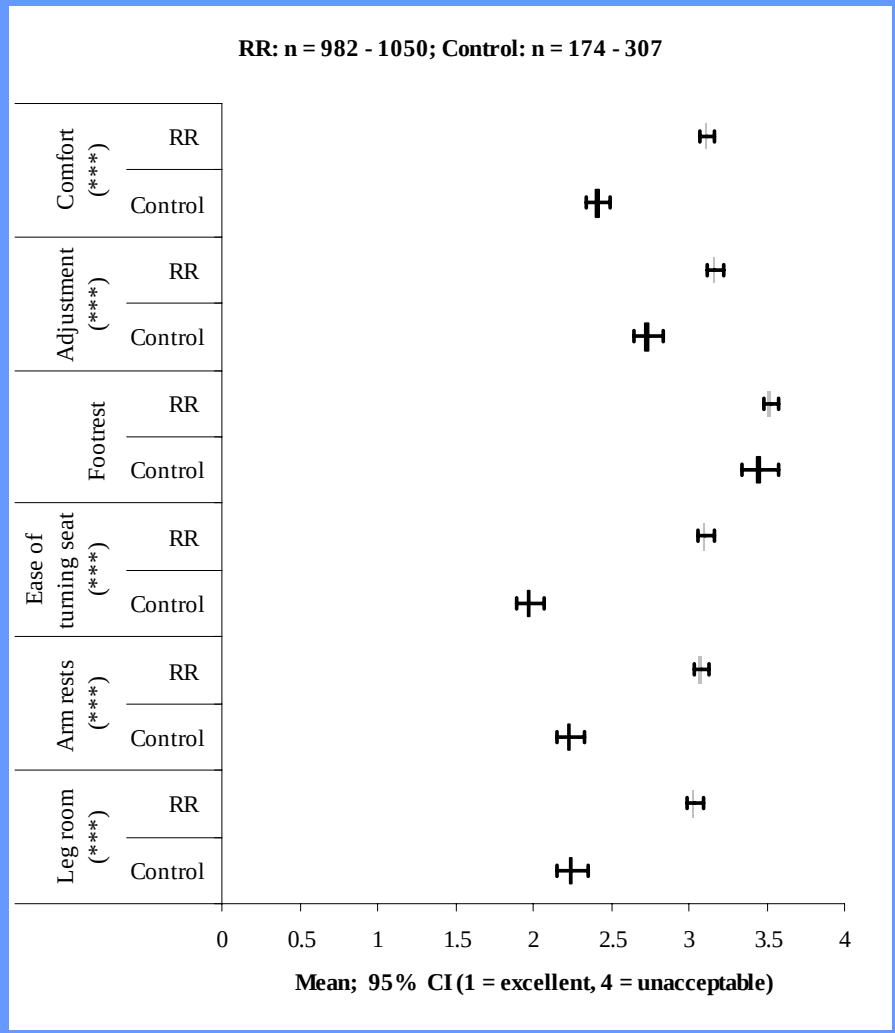
Shock indicator (non-sinusoidal vibration)

	Crest Factor			$MTVV/a_w$			$VDV/a_wT^{1/4}$		
	x	y	z	x	y	z	x	y	z
Mean	15.95	10.91	14.42	7.37	6.12	5.59			
Min	6.60	3.80	6.30	3.20	2.90	2.10	1.44	1.44	1.44
Max	67.26	28.07	45.74	26.16	14.38	10.29	4.27	2.48	2.09
SD	11.39	4.94	7.03	4.15	2.11	1.75			
Mode	7.90	8.30	9.30	4.70	N/A	4.40			

Seat characteristics (n=1419)

	Locomotive operator		Control			
	(%)	N	(%)	N	χ^2	$p(\chi^2)$
Arm rest	**82.3**	**1011**	**89.1**	**313**	**8.29**	**0.004**
Any back support	**78.7**	**1043**	**90.3**	**310**	**21.24**	**<0.001**
Adjustable back support	**30.5**	**1026**	**14.7**	**299**	**29.33**	**<0.001**
Air cushion system	**11.1**	**1026**	**37.4**	**297**	**112.55**	**<0.001**
Round seat pad (toad stool)	**20.0**	**985**	**23.1**	**303**	**1.36**	**0.244**
Footrest available?	**34.1**	**954**	**5.6**	**305**	**94.83**	**<0.001**

Evaluation of seat features and comfort rating (*** p < 0.001)



Odds ratios of vibration, seating and other factors and musculoskeletal disorders

		Model 4			Model 5			Model 6		
		OR ; CI (Lower – Upper); p			OR ; CI (Lower – Upper); p			OR ; CI (Lower – Upper); p		
1	**Back pain lasting more than 1 day in the past 12 months (n = 1059)**	**1.19**	**1.12 – 1.27**	**< 0.001**	**1.19**	**1.12 – 1.27**	**< 0.001**	**1.19**	**1.12 – 1.27**	**< 0.001**
2	**Neck or shoulder pain lasting a day or more during the past 12 months (n = 853)**	**1.16**	**1.10 – 1.23**	**< 0.001**	**1.16**	**1.10 – 1.23**	**< 0.001**	**1.16**	**1.10 – 1.23**	**< 0.001**
		Following only for engineers who reported back pain lasting more than 1 day in the past 12 months:								
3	**Sciatica pain at least once a week in past year (n = 765)**	**1.19**	**1.11 – 1.28**	**< 0.001**	**1.19**	**1.11 – 1.27**	**< 0.001**	**1.19**	**1.11 – 1.27**	**< 0.001**

Model : Time at work being bothered by vibration (hours/day), Adjusted for gender, racial origin (Caucasian vs. other), currently smoking (Y/N), vibration exposure second job (Y/N), spare time vibration exposure (min), adjusted for seating characteristics (Arm rests, any kind of back support, special adjustable lower back support, air cushion system, availability of footrest) and engineers seat rating (comfort, adjustment, turning seat, arm rests, leg room).

Model 4: In addition, adjusted for time sitting at work (hours/day)

5: In addition, adjusted for employment duration (10 year increments).

6: In addition, adjusted for age.

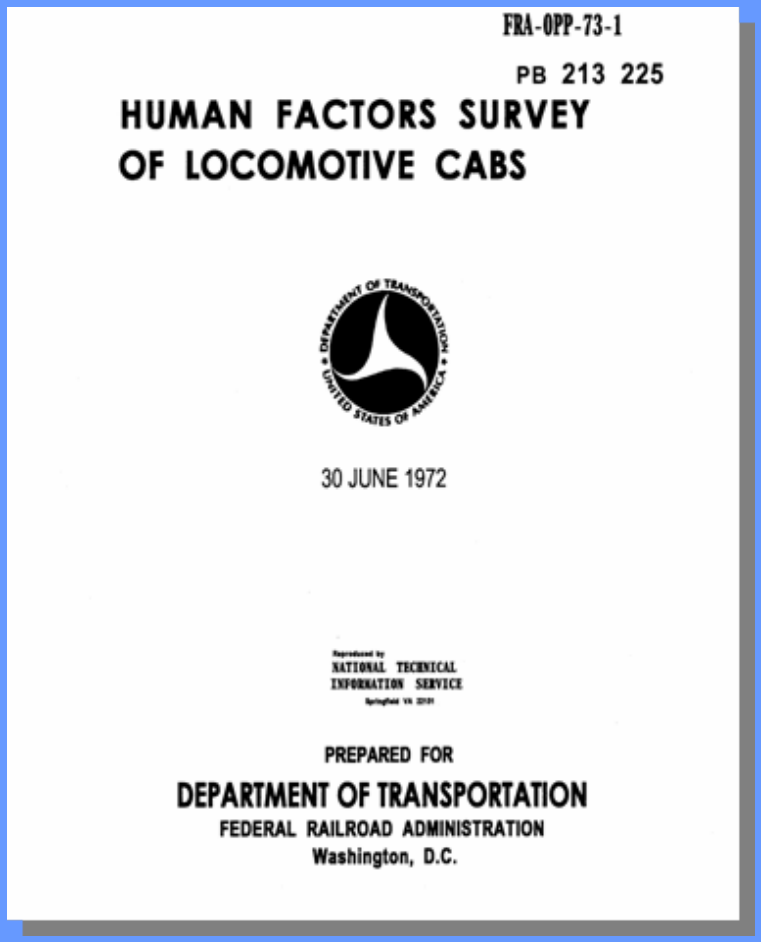
Important vibration risk assessment factors:

- Vibration basic values
- Crest factor, MTVV, VDV etc.
- Resonance range (hertz) (PSD)?
- Exposure duration
- Seating Posture
- Adequate rest periods
- Consider all facts in overall analysis

Other discussion points

- Locomotive engineers are working often overtime and long hours (+60 h/week)
- Seats in use are often defective, loose and poorly adjustable
- Seat position and mounting contributes to ergonomic postural stress (back).
- A health survey indicates high MSD risk

The FEDERAL GOVERNMENT Studied Shock & Vibration in Locomotives in Order to Protect Rail Employees



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HUMAN FACTORS SURVEY OF LOCOMOTIVE CABS

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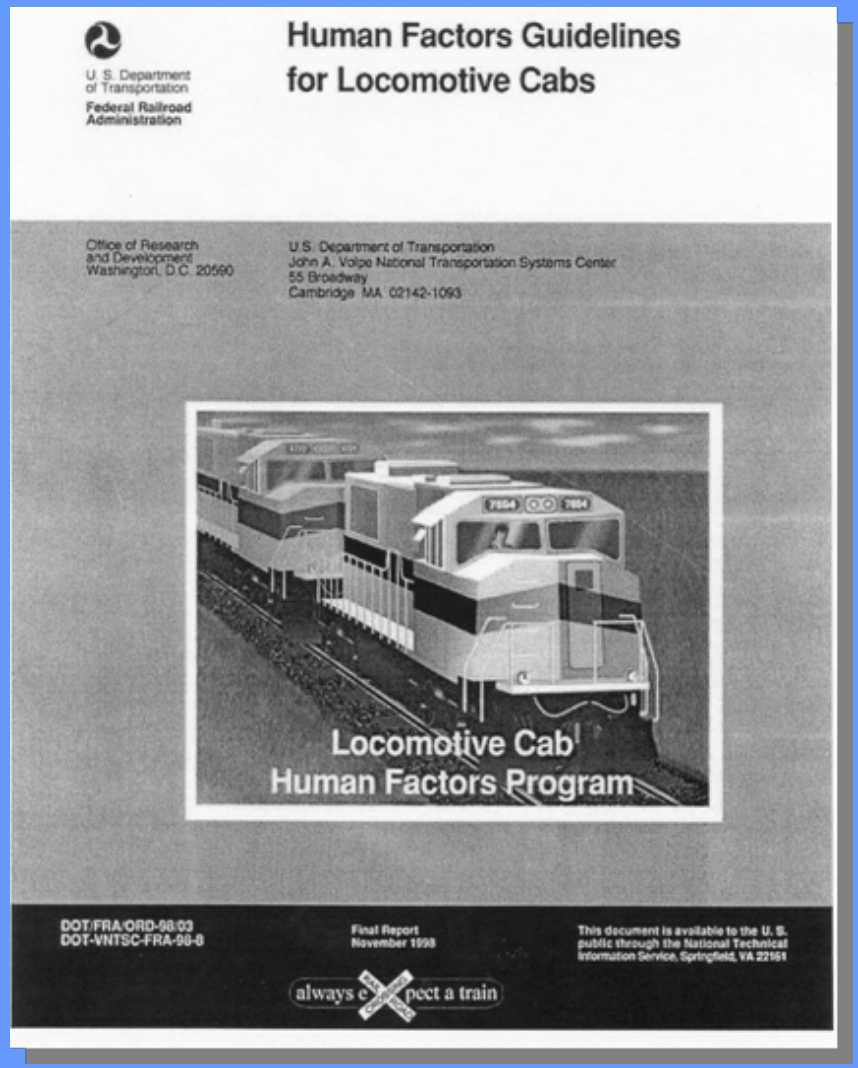

U.S. Department of Transportation

Federal Railroad Administration

Human Factors Guidelines for Locomotive Cabs

Office of Research and Development Washington, D.C. 20590

U.S. Department of Transportation John A. Volpe National Transportation Systems Center 55 Broadway Cambridge MA 02142-1093

Locomotive Cab Human Factors Program

DOT/FRA/ORD-98/03 DOT-VNTSC-FRA-98-8

Final Report November 1998

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Railroad Industry Studies:

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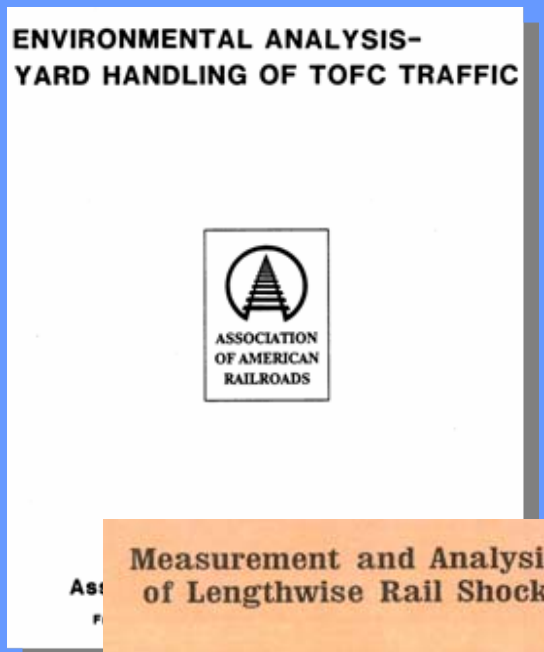

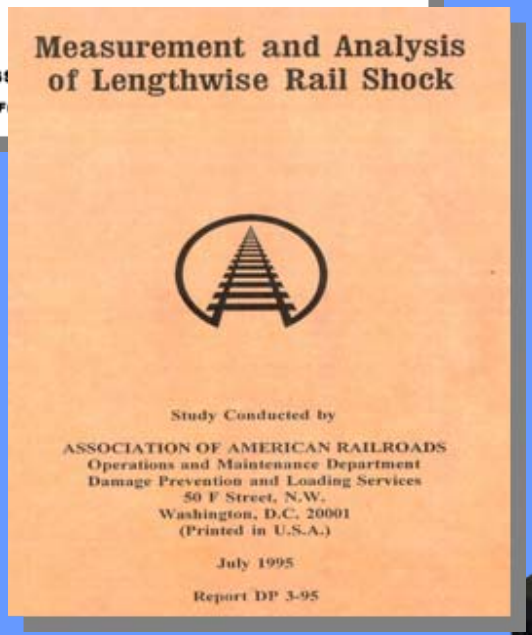

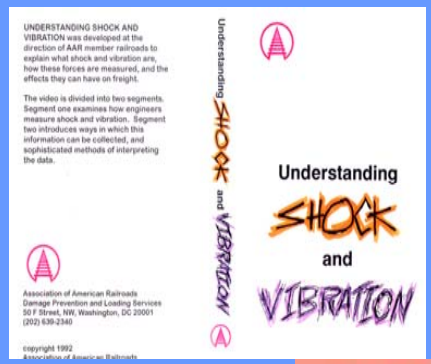

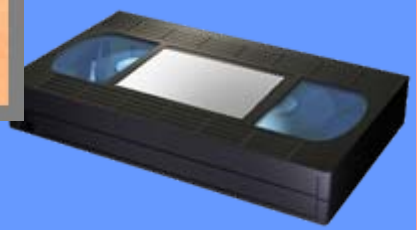

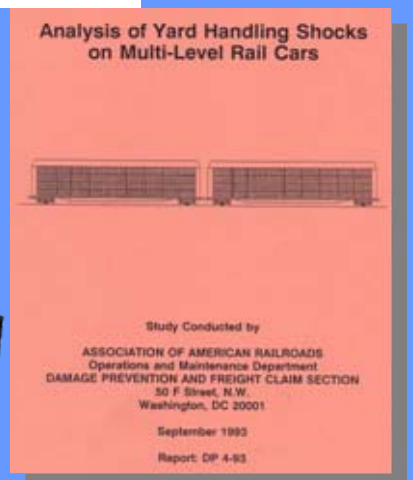

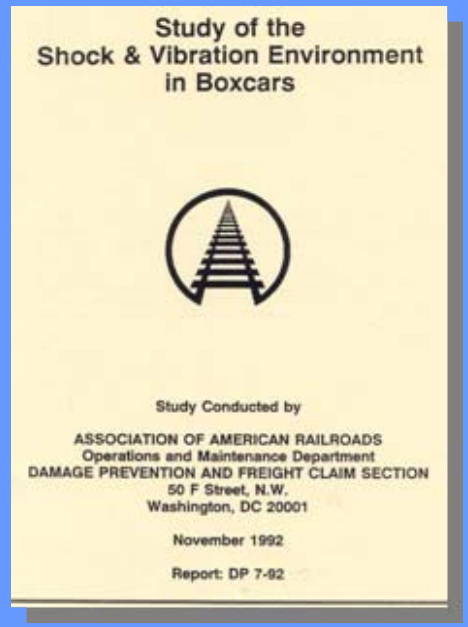

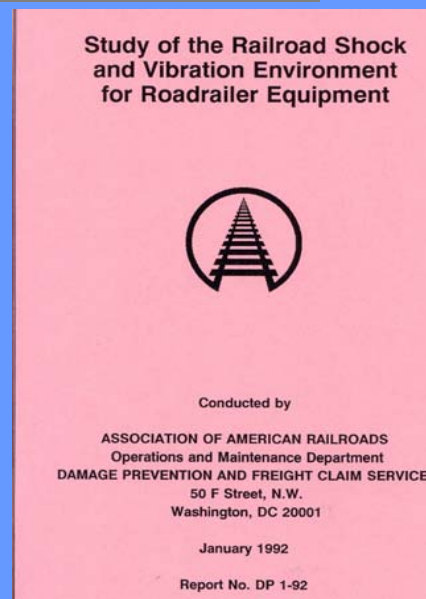

Summary and Conclusion

- Seated locomotive engineers are exposed to unique vibration and shock in all three direction.
- Lateral vibration and unpredictable irregular shocks are of concern.
- Current seats, including newer type seats appear inadequate to reduce vibration and provide sufficient postural support.
- Combined ergonomic risk factors and WBV exposure
- Preventive engineering and interventions utilizing current technology and medical knowledge appear prudent

Outlook – Real time postural measurements