Submission No 17

INQUIRY INTO PRESSURES ON HEAVY VEHICLE DRIVERS AND THEIR IMPACT IN NEW SOUTH WALES

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Submission to the NSW Legislative Council Inquiry into PRESSURES ON HEAVY VEHICLE DRIVERS AND THEIR IMPACT IN NEW SOUTH WALES chaired by Ms Cate Faehrmann MLC, Chair of Portfolio Committee No. 6 – Transport and the Arts

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Executive Summary

This submission discusses a major omission in truck and bus driver fatigue management practises. To counter the stated gross deficiencies paramount recommendations are advanced for immediate instigation. Once instigated improved road safety and reduced road accident trauma will result for truck and bus drivers, all road users, vulnerable road users and near road occupants alike. Further advantage for the introduction of the stated recommendations include reduced indirect road transportation costs particularly the cost of truck and bus driver worker compensation insurance premiums.

Existing Heavy Vehicle Driver Fatigue Management Practice

Existing heavy vehicle and omnibus[1] driver fatigue management practice assumes drivers conduct duties seated in a perfectly insulator perfectly ergonomic travelling lounge chair with the vehicle travelling along a perfectly smooth road pavement. Hence the existing management practice assumes driver fatigue is solely dependent on duration of driving.

Evidence to the Contrary

Readily available evidence countering the foregoing postulation is plentiful. These sources, include and are not limited to:

- the number of single heavy vehicle and omnibus serious and fatal accident per annum,
- over 10,000 truck and bus drivers, per annum, submit worker's compensation claims due to back injuries[2],
- the generally poor health and physic of long term truck and bus drivers (both long distance and regional),
- a high fraction of truck and bus drivers exhibit specific ailments including non stationary (or vibrating) eye pupils when standing stationary, steering wheel grip palm calluses, pear shaped physic and are typically over weight,
- truck drivers exhibit a 50% higher incidence of diabetes relative to the general population (based on US statistics)[3],
- typically 15% of trucks drivers suffer type II diabetes (based on the same US statistics)[4] with this statistic exacerbated by the fact a high fraction of trucks drivers are overweight and/or smoke heavily,

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1 Here the description buses also extends to include coaches (within the definition of a heavy omnibus (i.e. ADR vehicle categories ME and OM4))

2 Dr Ting Xia, et.al. on Work-Related Injury and Disease in Australian Truck Drivers # 2 National Transport and Logistic Industry Health and Wellbeing Study, Monash University, Insurance Work and Health Group, May 2018, 32p

3 https://www.freightwaves.com/news/driversissues/trucking-lifestyle-diabetes

4 Ditto

- truck and bus drivers due to their sedentary occupation exhibit a higher incidence of varicose veins than do the general public[5] (Unfortunately, it is expected this incidence rate will increase due to the increased adoption of automatic transmissions within the road haulage and omnibus fleet.),
- some heavy vehicle makes and models, especially those with adverse axle number and spacings, are blatantly known and reported within the industry to associate with adverse pitching and vibration characteristics,
- a significant fraction of trucks (and buses) exhibit irregular tyre wear, premature driver seat wear and premature parts failure,
- the increasing use of high productivity cab over engine (COE) prime movers with twin steer and tandem drive rear axle groups (and higher number of axles) are blatantly known within the industry to associate with adverse pitching and vibration characteristics,
- performance based standards (PBS), for high productivity vehicles, omit requirements for and consideration of driver exposure to whole body vibration, and,
- indirectly the increasing shortage of truck and bus drivers.

Completely ignored is the extent of whole body vibration incident on the driver via the vehicle's cab floor, the vehicle's steering column / steering wheel, (and in some cases manual transmission selector gear stick), the drivers seat pad and in some cases seat head and arm rests. Due to heavy vehicle suspension and drive line characteristics the whole body vibration dose incurred by heavy vehicle drivers primarily comprise seat pad transmitted vertical and fore-aft vibration components.

Road Transport Industry Conveniently Ignored Standard

The much neglected ISO International Standard governing the health and comfort (and hence indirectly fatigue) of workers exposed to mechanical vibrations is the:

ISO 2631-1: 1997 (E) Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 1: General requirements.

This ISO standard, which was first published in 1985, is applied vigorously in most industrial environments especially in mining and manufacturing. Interestingly it is not applied locally with the same vigour and rigour to truck and bus driver environs despite the fact the required steering column, cab floor and seat pad accelerometers and data logging equipment is now commonplace, relatively low cost, readily available and relatively straight forward to install and use. In fact some German made, mobile equipment dedicated, data logging equipment is specifically programmed to output the ISO 2631-1(1997) required worker environs total weighted vibration dose observations as a convenient switchable option. In comparison should standard, yet high quality, data logging equipment be utilised substantial time consuming highly laborious competent proficient operator supervised data file post processing using extensive computer hardware and specialised costly software resources is required (e.g. including Fast Fourier Transform (FFT) algorithms).

5 https://www.theveininstitute.com.au/vein-health-for-truckers-and-professional-drivers/

Paramount Need For Increased Heavy Vehicle Driver Work Environs Monitoring

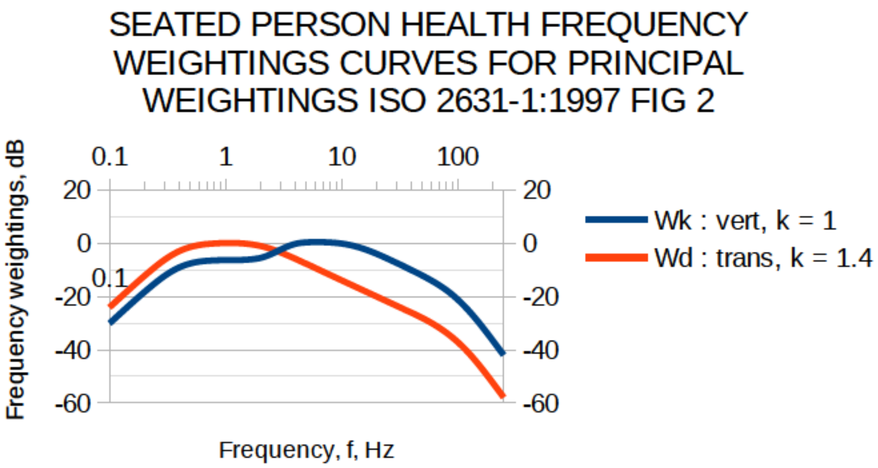
Increased ongoing monitoring of heavy vehicle driver work environs monitoring is necessary for the following reasons:

- the majority of the national heavy vehicle fleet utilise air suspensions. **Unfortunately air suspensions installed on heavy vehicles expose drivers to relatively harmful low frequency vibrations. In comparison yesteryear vehicles were installed with mechanical suspensions. These mechanical suspensions exposed heavy vehicle drivers to relatively less harmful high frequency vibrations.**

- Examination of ISO 2631-1(1997) vividly makes apparent the most adverse vibration frequency spectrum for seated workers is, in the vertical plane 4 to 10 Hz, whereas, for transverse seat pad vibrations the most adverse vibration frequency range is from 0.6 to 1.6 Hz. These adverse vibration frequency spectra, as declared in ISO 2631-1(1997), are most evident in the following figure.

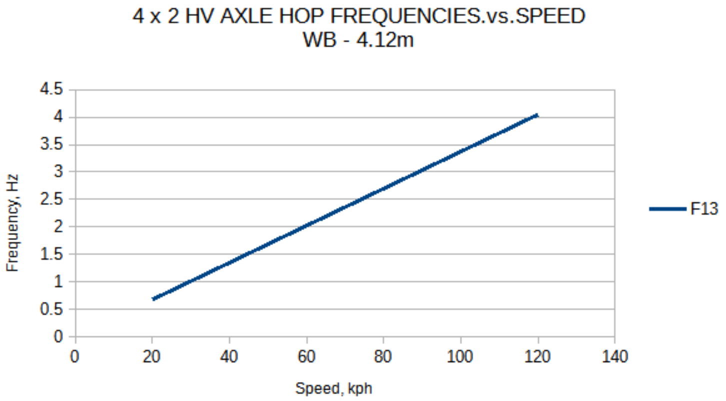
The essential purpose for presenting the following Figure is to highlight, for seat pad vertical (vert) vibrations for which weighting variation (Wk or w_k), and for which multiplier k = 1 applies, the most damaging vibration to the driver's health is when the vibration has a frequency in the range 4 to 10 Hertz (Hz) corresponding to the frequency weighting ordinate, in dB, of $\log_{20}(1)$ (root mean power ratio basis), that is, 0 in the Figure.

Whereas, in the fore-aft vibration or transverse (trans) direction, for which weighting variation (Wd or w_d), and for which multiplier k = 1.4 applies, the most damaging vibration to the driver's health is when the vibration has a frequency in the range 0.6 to 1.6 Hertz (Hz) corresponding to the frequency weighting ordinate, in dB, of $\log_{20}(1)$ (root mean power ratio basis), that is, 0 in the Figure.

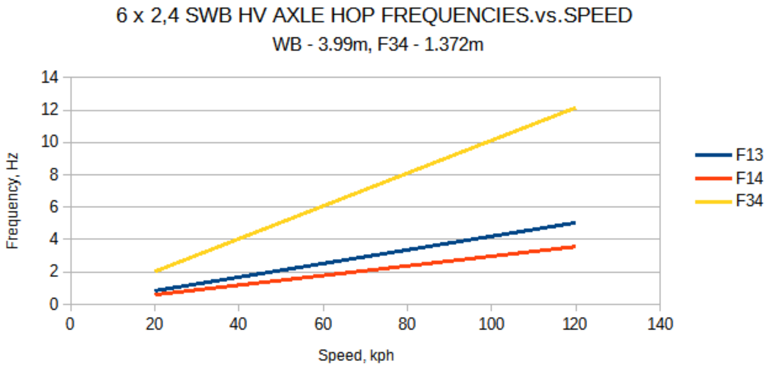


- Every paired sequence of axles, in the longitudinal direction, on a heavy vehicle generate a distinctive axle hop vibration frequency at the particular operating speed. This axle hop generated vibration, in turn, is transmitted to the driver's seat along various transmission paths each displaying differing extent of gain or annulment. In regard the axle legend for the following axle hop frequency figures the lead steer axle is F1, the second steer axle (if fitted) is F2, the lead rear axle is F3 and the next rearward axle F4 and the most rearward axle F5. Hence variation F13 is the variation of axle hop frequency with speed for the axle pair F1 to F3. Likewise F34 is the variation of axle hop frequency with speed for the axle pair F3 to F4, and so on.

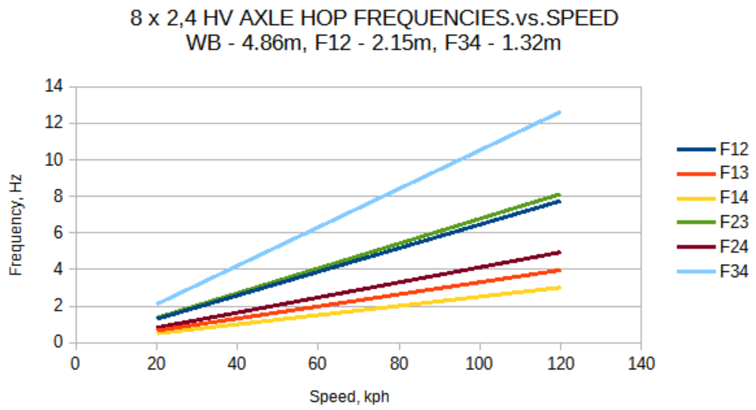
- As a direct consequence 2 axle (one steer and one rear drive) or 4 x 2 prime movers, as utilised in Europe, display a single axle hop generated vertical vibration frequency to drivers seat as depicted in the following figure. Examination of the following figure clearly reveals 4 x 2 heavy vehicles of typical wheelbase dimension (both rigid (or truck) and prime mover) do not expose drivers to adverse vertical seat pad vibrations in the adverse frequency range of 4 to 10 Hz when operating at typical speeds. A further reason by 4 x 2 prime movers display relatively low levels of driver seat vibration results from the fact the vertical turntable load always acts forward of the rear axle. Subsequently, the favourable lower vibration dose incident on the cab and hence drivers of 4 x 2 prime movers so allows European operators to adopt cab over engine prime movers, to a greater extent, in lieu of normal control vehicles. In comparison normal control prime movers were the majority configuration of the traditional local road freight vehicle fleet. Unfortunately, these normal control prime movers, and rigid trucks for that matter, associate with lower productivity and reduced driver visibility of vulnerable road users.



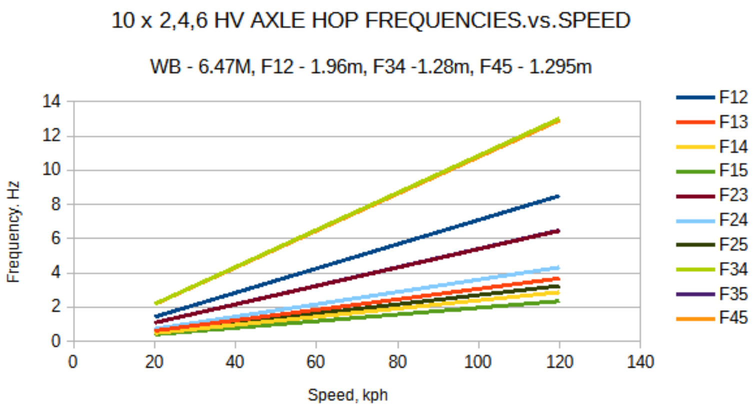
- For increased productivity local prime movers utilise relatively close spaced tandem drive rear axle groups in typical 3 axle or 6 x 2,4 heavy vehicle configurations. Here the 6 x 2,4 indicates the vehicle has one steer axle and two rear axles with either one (6x2) or both (6 x 4) powered or driven. Such close spaced tandem rear axle groups generate, for typical operation speeds, adverse axle hop generated seat pad vertical vibrations onto the driver as evident in the following figure. Notably examination of the following figure, for axle hop frequency variation for axle group F34, vividly indicates drivers of 6 x 2,4 heavy vehicles are exposed to cab and seat pad vertical vibrations in the adverse frequency spectra from 4 to 10 Hz, whenever, the vehicle operates between 40 to 95 kph. Unfortunately, this operation speed range is the norm on local roads!



- Should, for higher productivity again, a prime mover utilise a twin steer axle group in combination with a tandem drive suspension the axle hop generated seat pad vertical vibration dose spectra exposed onto the driver (of 8 x 2,4 prime movers, that is, both 8 x 2 or 8 x 4 prime movers) becomes significantly more adverse, in terms of both multi modal sources and frequency spectra, as shown in the following figure. Notably, as examination of the following figure reveals not only is the driver exposed to the adverse rear axle group axle hop frequency (F34 variation) over the speed range 40 to 95 kph but also two additional and significantly compounding adverse axle hop frequencies due to axle group F12 (that due to the steer axle group) and F23 (that due to the second steer axle and the lead rear axle pair) when operating between 60 to 90 kph.



- It therefore follows prime movers attracting higher productivity by using an additional axle in a 10 x 2(4) prime mover configuration expose drivers to a grossly more adverse, again in terms of both the modal sources and frequency spectra, axle hop generated seat pad vertical vibration dose spectra at typical highway speed operation as shown in the following figure. Notably examination of this figure indicates when operating between 35 to 100 kph the driver is dosed with axle hop frequencies sourced from multiple axle pairs. Including F34 and F45 (drive axle pairs: (near coincident traces apply)), F12 (steer axle pair (55 – 100 kph)) and F23 (rear steer to lead rear axle pair (75 -100 kph)).



- Due to the payload centre of gravity location forward of the rear axle on rigid vehicles the same exhibit lower cab / driver's seat vibration relative to that inflicted to turntable articulated combination prime mover cab / driver seats. Hence typically rigid trucks and the truck cabs of hitch articulated truck dog trailer combinations are more friendly in terms of driver health relative to the prime mover cabs of turntable articulated combinations. Unfortunately, due to productivity reasons and eased reversing characteristics in the local road transport industry turntable articulated combinations significantly out number hitch articulated truck dog trailer combinations.

- **Grossly ignored is the fact air suspended axles off load when passing over concave road surface deviations**. (This behaviour is significantly different to that exhibited by mechanical suspended axles where, more or less the opposite pavement surface discontinuity interaction applies.)

- Typically the turntable on prime movers is located between the location of axle F3 (corresponding to a turntable lead of some 50% of F34) and the centroid of the axle group pair (F34) (corresponding to a turntable lead of zero). Typically due to the increasing tare, resulting, in turn, to the use of large capacity engines and complex multi speed transmissions, on heavy vehicle steer axles subject to a prescriptive maximum allowable steer axle load the turntable lead of most modern prime mover's is near zero. In comparison yesteryear the typical turntable lead was some 10% of the vehicle's wheelbase.

- As a consequence of the foregoing mentioned off loading phenomena and the action of the turntable load prime movers incur a pitching action at the same frequency as the rear axle group axle hop vibration frequency (i.e. axle hop frequency variation denoted by F34 in the foregoing figures) for the particular vehicle operation speed. Most adversely this prime mover pitching action associates with a significant variation in the magnitude of the steer axle tyre to pavement contact force. The same, implies, a significant variation in the lateral steering force occurs for a particular steering lock. At those instants at which the lateral steer force reduce there is, most dangerously, increased risk of vehicle loss of control. The same variation in steer axle loads associates with increased steering column and wheel vertical vibration.

- Furthermore most adversely the magnitude of the foregoing pitching action increases with decreasing vehicle wheel base and decreasing turntable lead. Unfortunately vehicle productivity pressure requirements and increasing steer axle tare mass associates with decreasing prime mover wheel bases (or short wheel base (SWB)) and decreasing turntable leads.

- Thus far only driver seat pad vertical vibration components have been discussed. Unfortunately heavy vehicle driver seat pads also incur significant and equally adverse fore aft vibration components. Luckily, in comparison, typically driver seat pads incur minimal transverse or side to side vibration. Hitherto the source of these most adverse fore aft driver seat pad vibration component is little understood. Notably the fore aft seat pad vibration component is generated by the vehicle's drive line geometry changing due to the (mainly) variation of the ride height of the lead drive axle. It so happens on heavy vehicle the drive line primary section (and each subsequent section) incorporate two universal joints, a lead and a rear joint, respectively. Typical drive lines incorporate at least one or more sections with each having phased universal joint pairs. However, some heavy vehicle with non standard wheelbases adversely utilise three off universal joints in the primary drive line section. Such vehicle's can exhibit particularly adverse fore-aft and transverse seat pad vibration components. It so happens when a single universal joint, with a non zero working angle, rotates at invariant angular speed the angular speed of the output shaft varies periodically. The extent of this angular speed variation increases as the joint working angle increases. Obviously when drive lines are set up the match paired universal joints are suitably phased to cancel the rotational speed variation. However, in operation the working angle of the universal joint closest to the rear drive axle will deviate, with the axle / suspension vertical movement, from that of the lead universal joint (typically the drive line universal joint immediately aft of the vehicle's transmission) working angle. Subsequently, as the suspension moves vertically the output speed of the driveline varies increasingly. The same causing, in turn, the vehicle's forward velocity to instantaneously vary. The time rate of change of the vehicle's instantaneous forward velocity (resulting from the drive line rotational speed variation into the differentials) gives rise to the driver's seat pad fore-aft vibration component.

- It so happens due to the increased compliance of air suspensions air suspended axles deviate in ride height to a greater extent relative to the ride height variation exhibited by mechanical suspended vehicles. Hence heavy vehicles with air suspended drive axles exhibit greater extent of fore-aft driver seat pad vibration than do seemingly identical heavy vehicles with mechanical sprung drive axles.

- Unbeknown to most air springs cannot tolerate tension. Subsequently in operation the ride height of air suspended vehicles is governed by the instantaneous counter play of the vertical load acting on the drive axle group and the reaction to the drive torque delivered to the drive axle/s via the drive line. The same acts to cause the air pressure in the air springs supporting the rear axle group to depress below the static values. The extent of air spring air pressure depression increases with increasing extent of drive torque hence increasing vehicle GCM. The in service depressed air spring air pressures, in the rear axle group air suspensions, associate with an increased ride height variation for the air suspended drive axle/s. This frame rise phenomena, incurred with powered or driven air suspended axles, therefor further exacerbates the magnitude of the driver's seat pad fore-aft vibration component.

- Most unrecognised is the existence of a particularly adverse feedback mechanism which greatly exacerbates the extent of adverse vibration dose (both vertical and fore-aft) incurred by drivers of air suspended vehicles. This feedback mechanism first involves tandem and tri axle group air suspensions inflicting long wave length corrugation damage to road pavements especially on grades (both incline (drive axle groups subject to positive torque) and decline (drive axle groups subject to negative torque (engine braking)) and on pavements laid on flexible (or clayey) sub-bases.

- Hence when an air suspended heavy vehicle subsequently passes over air suspended heavy vehicle corrugation damaged road surface suspension response resonance occurs. In turn, this suspension resonance and, in turn, drive line resonance is transmitted in the form of excessive vertical and fore-aft vibrations to the vehicle's cabin / driver's seat pad.

- Adverse and in some cases grossly incorrect oem air suspension details further exacerbate air suspended axle group generated driver seat pad vibration characteristics. So much so the involved vehicle/s displays excessive seat pad vibrations and grossly difficult handling characteristics so rendering the vehicle unsafe.

Hence the appropriate conclusion to this discussion is to state heavy vehicles with air suspended rear axle groups expose drivers to grossly more adverse harmful health wise low frequency vibrations relative to that incurred by driver's of heavy vehicles with mechanical sprung rear axle groups.

The foregoing discussion highlights the introduction of air suspensions technology onto heavy vehicles occurred without adequate prior evaluation compounded by a complete lack of understanding. These major deficiencies were, in turn, further compounded by both oem and non-oem commercial compromises and trial and error experimentation. The latter was effected at the cost of driver health, well being and sadly in a blatantly grossly excessive number of cases driver lifes.

How Bad is Bad?

It is appropriate to examine the lumbar health impacts inflicted to the drivers of the prime mover's (both complainant (F3, F4, F6 and F26)[6] and benchmark (BM1, BM2 and BM3)) vehicles tested in the FORS 2000[7] report presented for both 8 hour and 14 hour duration evaluated in accord with ISO 2631-1(1997) as depicted in the following Figure 2T. Here it should be noted the data points for 8 hour driver duration simply correspond to the combinations of FORS 2000 report Figure 27 (weighted vertical seat pad vibration dose (a_{wx})) and FORS 2000 report Figure 28 (weighted fore-aft seat pad vibration pad (a_{wk}) data for each respective test vehicle in accord with the stated ISO 2631-1(1997) procedure. The same evaluated values are simply repeated at the 14hr duration abscissa. Here it should be noted the subscript T, attached to the data legend, simply indicates the observed **T**otal weighted acceleration dosage observed on the seat pad of the driver's seat. Here for convenience only the data point for the worst test complainant vehicle ($F3_T$) and the best benchmark vehicle (a normal control Volvo NH prime mover) $BM3_T$ are plotted as the data points for each of the 5 off remaining vehicle population located within this range.

Investigation into the Specification of Heavy Trucks and Consequent Effects on Truck Dynamics and Drivers: Final Report

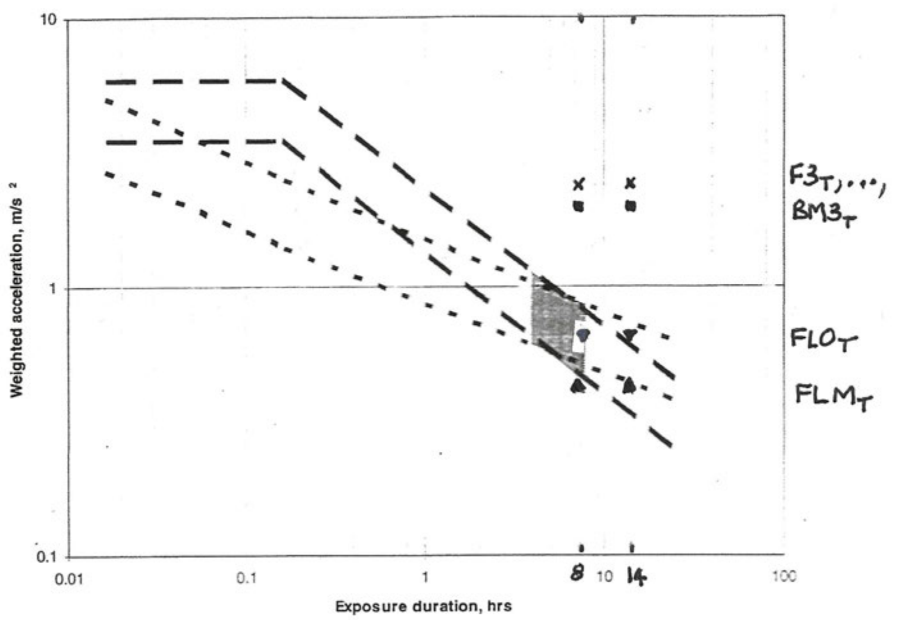


Figure 2T Health guidance caution zones (ISO 2631 Annex B) LUMBAR HEALTH

Figure 2T Total Weighted Vibration Dose compared to the ISO 2631 Annex B Health Guidance Caution Zones: LUMBER HEALTH evaluated using k_x = 1.4 and k_z = 1 (Eqn (10) ISO 2631).

Examination of foregoing Figure 2T reveals:

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6 Accurate inclusion of data for complainant test vehicle $F1_{awT}$ was not possible due to the author only having assess to monotone copies of FORS 2000 report Figures 27 and 28. Unfortunately in monotone for the stated legend symbol it was not possible to identity data points $F1_{awx}$ and $F1_{awk}$ in the respective FORS 2000 report Figures.

7 Sweatman, P.F. and McFarlane, S., 2000, Investigation into the Specification of Heavy Trucks and Consequent Effects on Truck Dynamics and Drivers: Final Report, Report Prepared for FORS by Roaduser International Pty Ltd, April.

- the total weighted observed driver seat pad acceleration for test complainant vehicle F3 was some 2.38 m/s^2,
- all complainant test vehicles were indeed vehicles of genuine driver unhealthy ride complaint,
- the observed driver total weight acceleration dose plotted for complainant test vehicles (F3, F4, F6 and F26) is indeed consistent with physiological and health damage inflicted to the drivers[8] of these vehicles hence these operators elected to both submit a formal complaint to FORS and to park their vehicles for both their and other road user safety,
- most concerning the test benchmark vehicles (BM1, BM2 and BM3) although not attracting driver unhealthy ride complaint exhibited only marginal improved driver total weighted vibration exposure,
- the total weighted observed driver seat pad acceleration for the least vibrating bench mark vehicle BM3 was some 1.97 m/s^2 an improvement of only some 18% on that for complainant vehicle F3.

Hence it can be confidently stated **all** (that is 100%) drivers driving trucks identical to those tested in the FORS 2000 investigation (depicted by the data point range: $F3_T$, … $BM3_T$) are exposed to extremely high risk of lumbar damage. This most serious outcome is evidenced by the fact the evaluated total weighted acceleration doses experienced by the test vehicle drivers plotted for both 8 hour and 14 hour (say Advanced Fatigue Management (AFM) maximum allowed driving duration) locate significantly above the recommended upper bound for worker health vibration exposure. The latter recommended exposure bound is indicated by the upper heavy dashed line in Figure 2T.

This same observation hence correlates well with the in excess of over 10,000 heavy vehicle driver worker compensation claims submitted to iCare per annum for back related injuries.

It may be noted foregoing Figure 2T so depicts the total weighted vibration dose experienced by the driver of a 6 x 4 Freightliner rigid tipper tested and reported in Road User International Report # 99-549-02 November 1999 with both the original tandem drive axle group air suspension (FLO_T) and tandem drive axle group modified air suspension (FLM_T).

Comparison of the relative location of the data points for the 6 x 4 rigid truck highlight rigid trucks and hence hitch articulated heavy vehicle combinations associate with vastly lower risk to driver lumbar damage than do turntable articulated heavy vehicles (prime movers). Notably the rigid heavy vehicle driver's seat vibrates only some 33% of the driver's seat vibrations observed of the vehicles tested in the FORS 2000 investigation. Subsequently, even when reported for 14 hour exposure both the original and modified air suspensions, on the tandem axle group, the Freightliner 6 x 4 rigid exposed the driver to a vibration dose only within the caution health risk zone. The latter zone represented by the band between the upper recommended health bound and lower recommended health bound. With the upper and lower health bound represented by the respective heavy dashed line in Figure 2T.

At this point it is most appropriate to note the drivers total seat pad vibration acceleration reduced some 35% for the Freightliner rigid with the modified drive air suspension relative to that observed for the same vehicle with the original suspension.

8 The majority operator / drivers of the formal complainant vehicle population listed in Table 1 p11 FORS 2000 were known to the author via professional engagement as were over at least 150 non formal complainant owner / operators.

Further correlation of Figure 2T driver's seat acceleration observations

In passing it is most appropriate to highlight details relating to complainant test vehicle F6 which is representative of a fleet of 5 off identical vehicles.
When first involvement with this vehicle occurred the driver reported significant physiological and health issues. So much so that at the termination of each daily duty he would arrive home to collapse into bed without participating with the family evening meal.
Due to the FORS2000 adverse findings relating to this vehicle Recommendation (2) p127 FORS 2000 required '*the vehicle should be rectified through appropriate means of mechanical intervention*.'
Subsequently vehicle F6 and the complete fleet were modified with the fundamentally identical modification to each vehicle's drive axle group air suspension as the drive axle group air suspension modification effected to the Freightliner 6 x 4 rigid mentioned previous.

Post modification vehicle F6 and sister fleet vehicles became most comfortable and predictable prime movers to drive. Unfortunately post modification F6 was not retested. However, it is suffice to declare the allocated driver post his daily driving duty attended his home to effect hobby gardening and engage in the evening meal family activities. So impressed with the modified vehicle behaviour the owner without hesitation frequently took opportunity to exhibit the modified vehicle at road safety conference venues and trade exhibitions in both Tasmania and on the mainland. So favourable were the vehicle's operational characteristics the fleet was readily and eagerly purchased by another operator when the first operator's log haulage contract ceased.

It is also most appropriate here to declare both the during and post FORS 2000 investigation operation of test vehicle F3. Immediately post test driving complainant vehicle F3 the test driver forwarded a letter to FORS stating the particular test vehicle was, in his opinion and qualitative assessment, totally unroad worthy and unsafe. The vehicle's OEM on receipt of the test driver's letter from FORS immediately initiated litigation action. Subsequently, the test driver's letter was confiscated as a Commonwealth Secret and the test driver was relieved of all further FORS 2000 test driving duties. Furthermore some twelve months post the FORS investigation this vehicle was on sold with the new owner specifically warned of the vehicle's adverse behaviour. Within three months of operation the second owner complained of the vehicle's adverse behaviour to the vehicle's OEM. The OEM subsequently confiscated the specific vehicle and took commercial liberty to issue the operator with a replacement prime mover.

Whereas, to the author's knowledge complainant test vehicle F1 was immediately confiscated by the OEM post the FORS 2000 investigation. The OEM apparently effected significant strengthening to the vehicle's chassis. It is unknown what operation, if indeed any, occurred with this vehicle post this OEM chassis strengthening.

In regard post FORS 2000 investigation operation of complainant test vehicle: F4 the author is not specifically informed of such. However, the undersigned is most confident the involved vehicle would be either parked for spare parts, confiscated by the OEM or it's operation prematurely terminated by involvement in a serious accident.

In comparison, the author, is aware complainant test vehicle F26, was on sold to a live sheep export haulage contractor servicing the Port of Adelaide. Post this knowledge, in turn, the author is confident the vehicle's operation, due to operation at high centre of gravity, prematurely terminated by involvement in a serious accident.

Extrapolation of driver's seat pad acceleration observations to that of cab over engine prime movers

It is most concerning to predict the driver's seat pad acceleration observed for cab over engine (COE) prime movers would be some 15% to 25% more adverse than the worst test complainant vehicle driver seat pad vibration observed in the FORS 2000 investigation. Notably some 15% to 25% more adverse than the observed acceleration for test complainant vehicle F3. That is, for a typical cab over engine (COE) prime movers it is expected the driver's total weighted seat pad acceleration would be observed to be some 2.74 to 2.98 m/s^2.

This prediction correlates well with the qualitatively observed seat pad vibrations, premature vehicle component breakages and loosening occurring on the vehicle and more concerning the premature severe physiological and health damage inflicted to the driver of the initially S/W Sydney then NSW Southern Tableland based complainant vehicle F25[9]. In fact so adverse were the driver's seat pad vibrations the owner / operator restricted the vehicle's operation to the Hume Highway only as the vehicle's ride was excessively rough and the vehicle's handling excessively erratic and difficult when driven on any other route including the Newell, New England and Pacific Highways (circa 1998). Subsequently, the vehicle's operation became so adverse the owner / operator elected to park the vehicle for good.

The implication of this prediction is that the majority of driver worker compensation claims involving back injuries will associate with the operation of COE prime movers.

Heavy Vehicle Seat Vibration and Driver Fatigue

Unfortunately, as stated in the introduction:

'*The primary purpose of this part of ISO2631 is to define methods of quantifying whole-body vibration in relation to*
human health and comfort;
the probability of vibration perception;
the incidence of motion sickness.'

Notably ISO 2631-1(1997) does not directly provide guidance as to the relation between vehicle driver incurred vibration level and driver fatigue.

To date the most comprehensive discussion of the possible relation between Heavy Vehicle Seat Vibration and Driver Fatigue is that presented by Mabbott N., Foster G. and McPhee B. in Australian Transport Safety Bureau (ATSB) Road Safety Research Report CR203 dated July 2001[10].

Due to relevance of this report to this Inquiry the Abstract of ATSB Report CR203 is presented here for completeness:

'*In studies and in anecdotal evidence a relationship between vibration in heavy vehicles and driver fatigue has been assumed, without supporting evidence. A literature review identified a few studies showing a possible association between fatigue and low frequency vibration that is typical of the vibration frequencies experienced by heavy vehicle drivers. An experimental study would be needed*

9 FORS 2000 Table 1 page 11 List of Complainant Vehicles and Complaints
10 ISBN 0 642 25562 8 ISSN 1445-4467

to determine whether the effect of vibration would be noticeable among known contributors to fatigue (eg. time awake, time on task, rest and sleep, circadian factors).

Research has also associated whole body vibration exposure with adverse health effects on the human body. Limited available data suggests that exposure to vibration of Australian heavy vehicle drivers may be high, putting drivers at risk to health. A field study of vibration levels experienced by Australian truck drivers would be necessary to determine actual vibration exposure levels and establish standards for trucks sold in Australia.'

It is most disappointing the authors of ATSB report CR203 did not elect to report all reported vibration exposure values presented in Table 3 page 11, in terms of a single total weighted acceleration dose, in accord with ISO 2631-1 (1997) section 6.5 (Combining vibrations in more than one direction for improved comparison and interpretation).

For assessment of vibration in relation effect on Health ISO 2631-1 (1997) p13 in Section 7.2 Health: Evaluation of the Vibration expressed here for completeness:

'*7.2.1 The weighted r.m.s acceleration (see 6.1) shall be determined for each axis (x,y and z) of translational vibration on the surface which support the person.*

7.2.2 The assessment of the effect of a vibration on health shall be made independently along each axis. The assessment of the vibration shall be made with respect to the highest frequency-weighted acceleration determined in any axis on the seat pan.

Note – When vibration in two or more axes is comparable, the vector sum is sometimes used to estimate health risk[11].

7.2.3 The frequency weightings shall be applied for seated persons as follows with the multiplying factors k as indicated (here the axes are defined in Figure 1 a) Seated position page 3 Basicentric axes of the human body.)
x-axis: W_d*, k = 1.4 (vertical)*
y-axis: W_d*, k = 1.4 (transverse side to side)*
z-axis: W_k *, k=1. (fore-aft)*

7.3 Guidance on the effects of vibration on health

Guidance on the effects of vibration on health can be found in annex B'.

Returning to Table 3 in CR203 with particular attention to the FORS 2000 reported driver vibration exposure values:
z-axis (vertical) - 0.64 to 1.60 m/s^2 mean 0.88 m/s^2; x-axis (fore-aft) - 0.50 to 1.12 m/s^2 mean 0.78 m/ s^2.

Noting the reported mean accelerations along the z and x axis **only differ by 13%** it was appropriate the FORS 2000 authors evaluated the vector sum of the individual components to fully assess the health effects of the observed vibrations as was evaluated to arrive at Figure 2T of this submission.

11 The authors elected emphasis.

Furthermore in the comments section of Table 3 in CR203 relevant for the FORS 2000 investigation it is stated:

'*Study of vibration characteristics of selected heavy transport trucks under operating conditions.'*

Here it should be noted only normal control configuration prime movers were examined, the vehicles were tested some 3 tonne sub to their allowable GCM, the vehicles were operated at sub commercial speeds and the testwork was conducted with copious number and duration of rest breaks along the test route with the actual testing for each vehicle completed within an 8 hour test driver shift.

'*All measurements above ISO comfort level (0.315 m/s^2)*'
Noted with the stated numeric assumed applicable for that at 8 hour exposure.

'*All vehicle rides were in the ISO caution zone and three were in the likely health risk zone for an 8 hour exposure.*'

The author poses the simple blatant question most appropriate for drivers operating in the National Road Transport industry. Namely:

"**Within the stated National industry how many truck drivers limit their daily vibration exposure to 8 hour duration?**"

Federal Court of Australia Erroneous Decision

In the F26 owner driver vs OEM litigation case[12] heard by Justice Kenny of the Federal Court of Australia the grossly unprepared and inexperienced legal team acting for the Plaintiff failed to recognise the FORS 2000 vibration data presentation was not completed as per the requirements of ISO 2631-1(1997).

Notably had the Plaintiff's legal team presented the vibration data observed for the plaintiff's vehicle F26 as that presented in Figure 2T, of this report, it is expected Justice Kenny would have handed down a judgement strongly in favour of the Plaintiff.

However, notwithstanding Justice Kenny's actual decision going against the Plaintiff a highly confidential out of Court settlement between the Plaintiff and the OEM resulted in the OEM paying all the Plaintiff's Legal and Court attendance expenses including expert witnesses (excepting those of the undersigned) and a financial compensation payment exceeding some $380,000!

Grossly Overrated Suspension Rating Contribution to Excessive Driver Seat Pad Vibrations

Private Owned Vehicle Experience

The author purchased a 6.5 T GVM 4 x 2 Mitsubishi Canter tipper second hand indirectly from Mt Isa City Council. On the instant of collecting the vehicle's keys the salesperson informed it was the roughest truck he had ever driven. Indeed the vehicle well maintains its horrid ride reputation. As highlighted by need to operate sub 80kph on the Hume highway and a return trip between Wollongong and the Bankstown area requires at least a day of recuperation. There is suggestion the front and rear suspensions are at least two GVM models heavier than required. On purchase plans

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were set in motion to air suspend (with a state-of-the-art system) the vehicle all round. Unfortunately, due to work commitments such plans were put on hold and remain so.

FORS 2000 Complainant Vehicle Example

Known to the author was that custom specified mechanical drive suspended complainant vehicle (FORS 2000) 'F29'[13] was installed with grossly overrated steer and drive axle suspensions. So gross was the rating of the drive suspension and double railed chassis the vehicle exhibited extremely adverse unsafe flag poling vehicle chassis vibration characteristics when in service on public roads at highway speed.
Fortunately, the owner operator elected to park the vehicle and subsequently on sell the vehicle. The vehicle subsequently operated off road as a low loader haulage prime mover in a large open cut mine.

Certified Vehicle Experience

The undersigned was requested to certify a fleet of HINO 700 Series 8 x 4 trucks modified by conversion of the oem mechanical twin steer axle suspensions to state-of-the-art air suspensions. This steer axle suspension modification was effected in response numerous driver (both male and female) excessively rough ride complaints especially when the vehicles are operated remote from urban areas, on typical low quality unsealed roads and over or along railway lines (as per the fleet's specific railway maintenance and construct contract requirements). It so happened the oem non load sharing steer axle group 15,000 kg rating exceeded the maximum allowable GML by some 50%!

Reported and Observed Adverse Vehicle / Driver Excess Vibration Situations

Prior to and during the FORS 2000 investigation the undersigned was aware of and had received and maintained contact with the owner operators of over 200 complainant air suspension vehicles. Further in one complainant case a fleet of some 50 vehicles were involved and subsequently parked by the large fleet operator.

The undersigned inspected numerous air suspended heavy vehicles and buses installed with grossly inappropriate and poorly chosen chassis to cab and cab floor to driver seat suspension details and parameters. Notably the driver may became exposed to significantly adverse vibration spectra should in addition to the axle to chassis air suspension the chassis to cab and the cab floor to driver's seat be air suspended. This was particularly serious where it was blatantly obvious at least one of the non axle suspension system parameters and natural frequency were grossly incorrect.

With the increasing steer axle tare higher rated mechanical steer axle suspensions are being installed. These higher rated mechanical steer axle suspensions are reported by drivers to generate particularly harsh rides especially when operated along unsealed strongly corrugated roads.

The undersigned was requested to inspect a particular prime mover which was reported by the driver to exhibit excessive cab and seat vibrations. The driver informed he had reported the excessive vibration to the owner to which apparently the owner replied:

***"Get in the vehicle and drive it you sissy"*!**

13 This complainant vehicle was not tested in the FORS 2000 investigation as it was installed with a mechanical tandem drive OEM six rod suspension. Notably the FORS 2000 investigation was restricted to normal control long wheel based heavily fuelled tandem drive prime movers installed with air suspensions.

The driver subsequently continued to drive the vehicle for several weeks before gaining employment with another road transport company.

The undersigned is also aware of a large number of drivers post complaining to the owner of excessive cab and seat pad vibration electing to park the vehicle roadside fully laden and walk away from it opting to gain employment with another road transport operator. Indeed some of the reported parked vehicles included fully laden stock crates.

The undersigned also observed first hand numerous drivers and/or owner drivers incurring premature health damage and gross ageing. These adverse effects were highlighted when the driver or owner / driver elected to park the vehicle and the undersigned had opportunity some months later to reengage with the individual face to face. In the majority of re-engagement situations the driver was not immediately recognisable. Notably, typically on first contact when the driver was operating the complainant vehicle, the driver appeared to be some 15 years the undersigned’s senior. However, and with considerable and comforting surprise, at the instant of the subsequent contact the true age of the driver became evident which was typically some 15 years junior to the undersigned’s age! Most encouraging from these experiences was the fact that short term exposure and inflicted health damage to the driver’s was reversible in some part.

Recommendations

1. International Code ISO 2631-1(1997) should be immediately incorporated into a ADR for specifying the heavy vehicle driver environs vibrations daily dosage as assessed by a commercial Sydney – Melbourne haulage operation (or equivalent).

2. At every heavy vehicle inspection stations both vehicle road worthiness and driver health should be simultaneously assessed.

3. In regard vehicle road worthiness, in addition, the vehicle should be examined for irregular tyre wear patterns, premature adverse driver seat wear and tear and premature loosening of components. Should such be identified the subject vehicle should be issued with a defect notice requiring the vehicle's driver vibration environs be tested in accord with ISO 2631-1 within 14 days of receiving the defect.

4. Should the driver exhibit adverse physic (or in crude terms pear shaped physic) and / or exhibit non stationary eye pupils or steering wheel palm calluses the (majority) driven vehicle should be issued with a defect notice requiring the vehicle's driver vibration environs be tested in accord with ISO 2631-1 (1997) within 14 days of receiving the defect.

5. The driver of every heavy vehicle reporting to an inspection station should be requested to reply to the following question:

   'Ranked on a scale of 1 to 5 where rank 1 corresponds to comfortable whereas rank 5 corresponds to grossly uncomfortable what ranking would you describe your driver environs in regard pitching and vibration experienced during the major trip leg to attend this inspection station'.

   Should the driver respond with a ranking of 5, to the above posed question, the driven vehicle should be issued with a defect notice requiring the vehicle's driver environs be tested in accord with ISO 2631-1 (1997) within a 14 days of receiving the defect.

6. The requirements of ISO 2631-1(1997) should be incorporated into the provisions demanded of advanced fatigue practices[14].

7. The requirements of ISO 2631-1(1997) should be incorporated into the provisions demanded of Performance Based Standard (PBS) vehicles. Satisfaction of this requirement should be assessed by testing to ISO 2631-1(1997) requirements with 14 days of the vehicle commencing operation with the testing conducted at both the vehicle's designed GVM and GCM on a return leg haulage operation along the Hume Highway at commercial highway speed operation.

8. For every characteristic model released by heavy vehicle manufacturers the OEM should declare the expected typical driver environs total weighted vibration dose (in accord within ISO 2631-1(1997)) for the typical most adverse model configuration and specifications operating as a prime mover combination at allowable GCM observed for a typical commercial Sydney – Melbourne Hume Highway haulage operation.

14 https://www.nhvr.gov.au/safety-accreditation-compliance/fatigue-management/work-and-rest-requirements/advanced-fatigue-management-afm

9. Furthermore the observed driver total weighted vibration dose experienced (in accord within ISO 2631-1(1997)) during trade journal test drives should be declared within any subsequent published media article.

10. Manufacturers should not market nor custom build (other than for non public road operation) heavy vehicle/s or vehicle models with grossly over rated axle group suspension ratings. Particularly the suspension rating for the steer axle group should not be grossly excessive. To ensure optimal driver vibration environs installed heavy vehicle suspension ratings should not exceed 10% of the applicable road authority's legislated allowable axle group mass loading for the particular axle group.

11. Manufacturers should not market nor custom build (other than for non public road operation) heavy vehicle/s or vehicle models exhibiting axle spacings such that any particular axle pair spacing is not an integral multiple of the closest axle pair spacing (other than that of the identical axle pair) installed to the vehicle. Alternatively, the manufacturer must prove each axle group suspension incorporate 15% in service inherent critical damping.

12. Icare (or SIRA) truck and bus driver worker compensation claims should be rigorously analysed to identify claim adverse configuration populations (prime mover or rigid (both prescriptive or PBS)), types (forward or normal control), makes, models (cab, axle numbers, axle spacings, turn table lead (if prime mover) and front and rear suspension make and model, respectively.

13. Should an adverse cluster be identified from this analysis a bias selected vehicle should be selected from each identified cluster group or sub population to be tested for the driver's environs in accord with ISO 2631-1(1997) as soon as practical (if appropriate).

14. The heavy vehicle or bus associated with each driver worker compensation claim assessed to be significantly premature and severe in regard back injury damage and /or deteriorated driver health should be tested for the driver's vibration environs in accord with ISO 2631-1(1997) within 14 days of the claim submission date.

15. The vehicle corresponding to every 99th truck and bus driver compensation claim submission should be randomly selected for testing of the driver's vibration environs in accord with ISO 2631-1(1997) within 14 days of the claim submission date.

16. The ISO 2631-1(1997) driver total weighted vibration dose observations of the above listed vehicle test population should be regularly made known to the appropriate Government Authority /ies and be 'media' released for publication in trade journals. Furthermore to ensure scientific merit the same should be regularly published in peer reviewed journals.

17. All vehicles displaying driver total weighted vibration dose observations exceeding the worker health bounds presented in ISO 2631-1(1997) shall be suitably modified to satisfy the specified health bounds for the specific daily vibration exposure duration. Confirmation of satisfaction of a particular vehicle's driver vibration environs to ISO 2631-1(1997) health bounds should be proven via retesting in accord with ISO 2631-1(1997) during commercial haulage operation conducted on the Hume Highway Sydney Melbourne return.

What Heavy Vehicle Modifications Are Possible to Allay Driver Vibration Exposure

Fortunately relatively simple, easy to install and low cost inherently stable and reliable suspension modifications exist to transform truck and buses exhibiting excessive total weighted whole body vibration driver environs levels, in excess of the ISO 2631-1 (1997) health bounds, to vehicles which exhibit acceptable (in accord with ISO 2631-1 (1997) health bounds) driver environs total vibration dose levels. The reduction in the extent of vibration is highlighted by way of comparison of test data points for the original rigid test vehicle, as depicted by data point (FLO_T) to that of the rear suspension modified vehicle, as depicted by data point (FLM_T) in foregoing Figure 2T.

Due to brevity and focus considerations the required suspension modifications are not detailed here. Suffice to declare the required modification involve conversion of each axle group to exhibit dynamic load sharing and ensuring each axle is inherently orifice damped with the ride height of the axle group or single axle controlled by a unitary ride height control valve receiving feedback of the axle group's mean ride height or receiving feedback from a particular axle at sub 50% gain with the ride height control valve so positioned to be insensitive to vehicle lean. Further details of the required suspension modifications and the suggested priority of application are available from the author on request.

In other cases improved driver health environs, in regard vibration dosage, may be attainable by improved choice of cab to chassis and driver seat to cab suspension parameters and frequency characteristics.

Conclusion

Truck and bus driver work environs should be considered work environs like any other employee work environs and fatigue management practices. Hence it is totally incorrect for truck and bus driver work environs to be considered insulated from ISO 2631-1(1997) provisions. Systematic application of ISO 2631-1 (1997) to truck and bus driver work environs and fatigue management considerations will generate a safer road system and, in the longer term, yield reductions in driver worker compensation insurance premiums much to the benefit of the paramount road transport industry and the community at large. Unfortunately the recommended driver vibration environs monitoring will be grossly too late for the large number of deceased drivers involved in fatigue related single vehicle accidents and for the significant numbers of drivers exiting the industry due to premature poor health particularly those incurring major back and other musculoskeletal injury/ies. Unfortunately the status of all road pavements have deteriorated significantly recently. Consequently, as suggested in this discussion, there will be a significant increase in truck driver resignations due to health issues especially back injuries resulting from the current extremely poorly maintained and rain / flood damaged roads.

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