Noise Exposure

Hazards to gasoline and distillate transport drivers

By William R. Watts and David N. Kudlinski

THIS STUDY CHARACTERIZED the noise exposure of gasoline and distillate transport drivers as it relates to the OSHA action level. Full-shift task and full-shift average noise exposure monitoring were conducted on gasoline and distillate transport drivers to determine which tasks and work conditions resulted in noise exposures above or below the OSHA action level. Routine driver work tasks and work conditions were identified as well.

Previously published studies in this area focus on the noise exposure of over-the-road transport drivers. Gasoline and distillate transport drivers use different delivery routes and methods of loading/unloading from over-the-road transport drivers. Previous noise exposure monitoring data of gasoline and distillate transport drivers has not successfully determined whether these drivers are exposed to noise above or below the OSHA action level. Moreover, the contributory factors to driver noise exposure such as multiple window configurations (as it relates to traffic and wind shear), different transport models, AM/FM radio operation, left versus right ear exposure and fuel pump operation have not been studied.

Multiple test conditions were devised, including driving with different window configurations with radio both on and off, to determine which set of conditions resulted in the greatest risk of full-shift noise exposure above the OSHA action level. In addition, discrete left ear and right ear noise exposure measurements for each task or set of driving conditions were obtained. Finally, instantaneous noise measurements during several tasks in which a driver receives significant exposure were monitored. These tests were developed to target administrative and engineering controls to minimize the risk that drivers will be exposed to noise above the OSHA action level as a full-shift average.

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An informal survey given to transport drivers by the company's health, safety, security and environmental (HSSE) advisor revealed that windows were not being maintained in a closed position over the entire shift. A plan was developed for noise monitoring wherein various up and down (open and closed) window configurations would be tested under routine work conditions.

Background

A literature review yielded six noise studies of transport drivers. Only one of these studies involved drivers performing gas and oil delivery. The other five studies focused on over-the-road drivers of long-haul transports. A summary of each study follows.

Noise levels in oil tanker truck transports were tested with a noise meter by a technician seated in the jump seat (Tyler). Noise levels were found to be 15 dBA higher with the windows down (open) than up (closed). Uninsulated truck transports had interior noise greater than 90 dBA for 30% of the measurements with windows closed. After insulating the cabs, noise levels were reduced below 85 dBA in all transports with the windows closed.

Area noise measurements were obtained in two over-the-road transports at center cab while driving. The driver window was both open and closed during measurements (Behar). All measurements were above the 8-hour OSHA action level. Noise levels were greater with windows down than with windows up.

Personal noise exposure was measured for 20 over-the-road truck transport drivers during 20 trips from San Francisco to San Diego, CA (Kam). Radios were off during this time. Average noise exposure


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with all windows closed (69.6 dBA) was significantly lower than the average noise exposure with all windows open (90.0 dBA).

Eight over-the-road truck transports were tested with noise meters and dosimeters (Hessel, et al). Octave band noise readings indicated that the truck produced noise at lower frequencies, while the CB and AM radios mounted in the cabs produced higher frequency noise. Area noise meter readings in the cab indicated noise below the OSHA permissible exposure limit (PEL) (average 83.4 dBA) while dosimeter readings during driving indicated noise above the PEL (range 72.63-92.98 dBA). This study did not determine the salient cause(s) behind the disparity between area and personal noise exposures.

Sixty over-the-road Canadian transport drivers were monitored with noise dosimeters while driving with different driver window and radio configurations (Seshagiri). With the driver window up and the radio off, the average left ear noise exposure was 80.3 dBA. With the driver window down and the radio on, the average left ear noise exposure was 84.9 dBA.

Overall broadband sound pressure levels inside nine over-the-road transports were measured to be 89.1 dBA (FHWA). The 8-hour and projected 10-hour noise doses experienced by 10 drivers in the study were not excessive as measured against OSHA requirements. The difference between area noise measurements and personal exposure noise measurements was not explained in the article.

Description of Work Environment

Gasoline transport drivers are scheduled for a 10- or 11-hour shift per workday. A typical delivery radius is 20 miles and takes approximately 30 min of drive time.

Tanker trucks fill with gasoline and/or distillate at a terminal load rack. The driver is exposed to noise from adjacent truck engines and when making metal-to-metal fill hose connections at the side of the truck. The driver spends most of the time in a kiosk while the transport is loading. A kiosk is approximately a 4 ft x 5 ft x 8 ft fully enclosed, heated, metal and glass building that is located at one end of the loading rack near the cabs of the transports. A kiosk is located approximately 20 ft away from the swing arms that load the transports.

After loading, the driver transports the gasoline and/or distillate to service stations and other facilities

Abstract: *This study was designed to determine whether gasoline and distillate transport drivers have the potential to be exposed to noise above the OSHA action level. Drivers were monitored for noise exposure during loading/unloading tasks. They were also monitored over their shift for noise exposure during both drive-time tasks and the shift average with the cab radio on and off, and the windows in various configurations.*

with storage tanks. Typical routes may include all highway driving, all city driving or a mixture of the two driving environments. The tanker trucks have speed governors so that a truck does not exceed 55 mph. When windows are down, wind shear, engine noise, exhaust noise, and noise from passing cars and trucks are known to be significant noise sources. To mitigate noise exposures, company policy requires that drivers maintain windows closed at all times. All cabs in the fleet are provided with air conditioning and the manufacturer's sound insulation package.

The truck unloads by gravity drainage through hoses to underground storage tanks or by pumping through hoses to aboveground storage tanks by a truck-mounted pump.

The driver is out of the cab during loading/unloading activities, which may take between 20 min and 1 hour. Noise exposures during unloading resulted from metal-to-metal contact while loading/unloading hoses from the transports, removing and replacing fill caps, and removing and replacing hose helmets into the cabinet underneath the trailer. The truck pump located behind the cab is a significant noise source.

Methods

Noise Monitoring Instrumentation

Quest dosimeter models Q-300 and Noise Pro DLX-1 were used to record personal and area data. Q-300 dosimeters were calibrated at 110.0 dB before and after each use with a Quest CA-12B sound calibrator according to the manufacturer's instructions. At one terminal, Q-300 dosimeters were calibrated at 114.0 dB before and after each use with a Quest QC-10 sound calibrator according to the manufacturer's instructions. Quest Noise Pro DLX-1 noise dosimeters were calibrated at 114.0 dB before and after each use with a Quest QC-10 calibrator. To measure exposures, the noise dosimeter is belt-mounted on the wearer, and its microphone is mounted near the ear on the shoulder.

All measurements were made using the A-weighting network and slow response characteristics incorporating noise levels from 80 to 130 dBA per the OSHA Occupational Noise Exposure Standard. Dosimeters were set for a criterion level of 90 dBA, a threshold level of 80 dBA and an exchange/doubling rate of 5 dBA. The dosimeter records the average noise readings every minute it is engaged in the data logging function.

Noise Monitoring Strategies

Full-Shift Task Monitoring

Full-shift task monitoring of transport drivers was instituted to document the noise levels during specific tasks so that appropriate administrative and engineering controls to lower overall shift-average noise exposure could be developed and targeted. At the time of the study, no task-specific noise monitoring data of transport drivers was identified in the literature review.

Over the duration of the study, two dosimeters were placed on 23 different gasoline and distillate transport drivers. The microphone from one dosimeter was placed on the left shoulder. The microphone from the second dosimeter was placed on the right shoulder. Microphone windscreens were used as directed by the manufacturer.

Researchers rode with drivers in the passenger's seat with a dosimeter microphone on the shoulder of their right ear to record data from the passenger's window. The driver's dosimeters were paused and restarted periodically throughout the day to record data while driving and loading/unloading at the terminals/service stations using the following window configurations:

April 20, 2004, to June 30, 2004

- DU-PU: driver window up; passenger window up;
- D$^{1}/_{3}$-PU: driver window one-third down; passenger window up
- D$^{1}/_{3}$-P$^{1}/_{3}$: driver window one-third down; passenger window one-third down
- DD-P$^{1}/_{3}$: driver window down; passenger window one-third down
- DD-PU: driver window down; passenger window up

Each window configuration was tested once with the AM/FM radio off and then again with the radio on at the volume selected by the driver. Each drive-time testing interval approximated 30 min.

A fourth dosimeter was placed on the visor in the center of each transport's cab to measure area noise levels continuously for the full shift.

After a statistical review of the noise data on June 30, 2004, full-shift noise monitoring of the cab background area noise monitoring (visor dosimeter) and the employee noise exposure monitoring during loading/unloading tasks were discontinued. The data indicate that center cab noise did not approach the OSHA action level at an upper 95% confidence level. Therefore, it is unlikely that a transport driver will be exposed to any values close to 83.4 dBA during loading/unloading tasks since the highest recorded value for any of these tasks was 76.1 dBA. In addition, all future driver personal dosimetry measurements were obtained with the AM/FM radio on with the volume at the driver's preference. The majority of radio volume settings ranged between levels 10 to 14 as viewed on the radio's display. These settings produced radio noise below the 10-hour action level.

Study Limitations

The following limitations of this assessment must be considered while interpreting the collected data:

- Traffic, road, environmental and weather conditions change with each delivery.
- Transport drivers vary in driving methods.
- Individual drivers operate the radio at different volumes.
- Individual drivers handle the equipment differently for loading/unloading tasks.
- Drivers work differently on different shifts (i.e., day vs. night).
- Researchers did not ride with drivers during full-shift monitoring; however, all drivers were checked approximately every 30 min on each trip back to the terminal to load product throughout the entire workday.
- Drivers may have changed the window configurations when not being obseved.
- Drivers may have performed other tasks when not being observed.
- Seat and driver height may have been a factor in relation to microphone position and window openings.

The following new window configurations for drive-time and full-shift average monitoring were developed to determine whether driver noise exposures at these window configurations were below OSHA 8-hour and 10-hour action levels. All previous window opening configurations did not provide an upper 95% confidence level that drive-time noise exposure will be below the OSHA 10-hour action level. Therefore, researchers tested additional window configurations during full-shift task monitoring in an attempt to identify scenarios that would be below the OSHA action levels.

July 13, 2004, to Nov. 4, 2004

- D1"- PU: driver window 1 in. down; passenger window up
- D1"- P1": driver window 1 in. down; passenger window 1 in. down
- DU - P1": driver window up; passenger window 1 in. down

Full-Shift Monitoring

One dosimeter was placed on each of 154 transport drivers. Each driver was assigned one of nine window configurations (these are described later in this article and shown in Table 6 on pg. 30, which contains the breakdown of window configurations per drivers). The cab radio was either on or off prior to July 13, 2004. The AM/FM cab radio was on thereafter, because the focus of the monitoring was on the window configurations as opposed to the effect of the radio. The radio being on would add noise to the worst-case scenario.

Drivers were given large-print reminder signs stating the constant window configuration with radio on or off for the day (April 20, 2004, to June 30, 2004). Beginning July 13, 2004, transport drivers were instructed to use the cab radio at their preferences. The microphones were placed on the driver's left shoulder. Monitoring was conducted for a full shift on each driver.

Researchers checked all drivers as they returned to the terminal to load product. Each driver typically returns to the terminal five to six times per shift. Window configurations, radios and dosimeter operation were verified at this time. Drivers and equipment were found to be in compliance with instructions when inspected at the terminal.

An additional window configuration unique to Manufacturer A, Cab Model 1 was also tested:

- DU-PU (DVO) = driver window up; passenger window up; driver's vent window open.

OSHA Noise Exposure Standard

The OSHA action level (85 dBA) pertains to accumulated noise exposures during a standard 8-hour shift. For shifts longer than 8 hours, an employer must lower the action level to account for a similar total noise dose over the longer shift. For the 10-hour shift driver, the action level can be calculated in accordance with the following equations (AL = action level):

AL (10) = AL (8) + 16.61 log (480 min/600 min) = 85 dBA - 1.6 = 83.4 dBA (1)

For the purposes of this article, 83.4 dBA shall be referred to as the 10-hour OSHA action level. It is noted that most drivers are scheduled for 10-hour shifts.

Results & Discussion

Full-Shift Task Noise Monitoring

The purpose of full-shift task monitoring was to identify those tasks that may contribute to a full-shift average exposure above the OSHA 10-hour action level (83.4 dBA).

Loading/Unloading

Personal noise dosimetry was conducted on transport drivers during loading/unloading tasks at five representative terminals from April 20, 2004, to May 25, 2004. The data are presented in Table 1.

The data indicates that a transport driver will be exposed to considerably less than 83.4 dBA during loading/unloading tasks.

Table 1

Noise Exposure of Transport Drivers During Loading/Unloading Tasks

Scenario	No. of samples	Average noise exposure (dBA)	Upper 95% confidence limit (dBA)
Load tasks left ear	38	72.9	74.6
Load tasks right ear	40	72.0	73.7
Unload tasks left ear	35	74.6	76.4
Unload tasks right ear	37	74.9	76.7

Note. *Time duration of both tasks—product loading/unloading of the trailer—was approximately 20 min each.*

Drive-Time Noise Monitoring

Employee right and left ear noise exposure levels were recorded during driving. The results are presented in Table 2.

Those window configurations producing an upper 95% confidence limit of noise exposure greater than 83.4 dBA (to either the left or right ear) during drive-time are considered unacceptable conditions. The null hypothesis is that the mean noise exposure equals 83.4 dBA, and the alternative hypothesis is that the mean noise exposure is less than 83.4 dBA. For a p value < .05, the null hypothesis is rejected and the alternative hypothesis is accepted. A Type I error occurs when a true null hypothesis is rejected. The risk of this occurring is equal to α (α = significance level) or 1-level of confidence. In all of the statistics, the risk of a Type I error is 5% (0.05).

Statistical power is 1 - β, expressed as a percentage, where β is the probability of making a Type II error. A Type II error occurs when a false null hypothesis is not rejected. The possibility of this

Table 2

Full-Shift Task Monitoring

Scenario	No. of samples	Average noise exposure (dBA)	Upper 95% confidence limit (dBA)	*p* value	Power (%)	Significant (Y/N)
DU-PU left ear	21	78.6	80.445	.0001	*	Y
DU-PU right ear	23	77.4	79.46	.00003	*	Y
D1″-PU left ear	36	80.1	81.258	.0001	*	Y
D1″-PU right ear	36	79.7	81.17	.0008	*	Y
DU-P1″ left ear	30	78.9	79.93	.000002	*	Y
DU-P1″ right ear	30	78.8	80.12	.000001	*	Y
D1″-P1″ left ear	33	80.6	81.82	.00029	*	Y
D1″-P1″ right ear	33	79.86	81.46	.00037	*	Y
D1/3-PU left ear	22	82.6	**83.96**	.157	10.7	**N**
D1/3-PU right ear	24	81.3	82.62	.006	46	Y
D1/3-P1/3 left ear	22	**83.4**	**84.73**	.5	5	**N**
D1/3-P1/3 right ear	23	83.2	**84.36**	.389	5	**N**
DD-PU left ear	20	**85.8**	**86.98**	.999	**	**N**
DD-PU right ear	21	82.9	**84.17**	.245	7.5	**N**
DD-P1/3 left ear	21	**87.3**	**88.56**	1	**	**N**
DD-P1/3 right ear	22	**84.7**	**85.8**	.97	**	**N**

Note. *Left and right ear noise exposures of transport drivers while driving with windows in various configurations. Test value 83.4 dBA.*

**Power has no meaning because the* p *value was low and the application has more than enough samples to make a value significantly different than 83.4 dBA. The null hypothesis is rejected. **If the average noise exposure is above 83.4 dBA (null hypothesis) the* p *value is close to 1 then the power is meaningless.*

occurring is a function of the number of samples taken, significance level and the effect size. Type II errors can only be calculated after the fact. Additional samples may be required if this probability is high. The probability of a Type II error is called β. The value of 1 - β is called the power of the test. The target power was 80% (0.80). Significant (Y/N): Y means that the upper 95% confidence limit was less than the test value of 83.4 dBA. When an upper confidence limit is less than the test value, this is the same statistically as performing a *t* test and showing that the mean value (average noise exposure) is statistically significant and in this case, lower than the test value of 83.4 dBA. The entire 95% confidence interval is below the test value.

As a general trend, steadily higher noise readings were obtained as the opening in the window increased. The left ear experiences higher noise levels than the right ear during driving only in cases where windows were open. The differences between both ears were not statistically significant ($p = .276$) when windows are closed or at 1 in. openings during driving. There were 278 left ear samples and 289 right ear samples.

Noise exposures in bold (Table 2) are those with averages and/or upper 95% confidence limits in excess of the 83.4 dBA 10-hour action level. The data indicate that when the driver window is one third down or more (and at the same time the passenger window is up or down one third), the upper 95% confidence limit for the transport driver's average noise exposure during periods of driving will be above the 10-hour action level. When the driver window is down all the way, the average noise exposure during driving is above the 8-hour action level.

When the driver and/or passenger windows are cracked open no more than 1 in., the upper 95% confidence limit for the transport driver's average noise exposure during driving will be below the 10-hour action level.

Table 3 compares transport drive-time average noise at it applies to four different tractor manufacturers. Based on a comparison of average drive-time noise exposures, Manufacturer B cab produced the highest noise exposure followed by Manufacturer A, Model 1 cab, followed by Manufacturer A, Model 2 cab, then Manufacturer C.

In Table 4, Manufacturer A, Model 2 cab is quieter than both Manufacturer A, Model 1 cab and Manufacturer B cab. This difference is significant in both cases. Manufacturer A, Model 1 cab and Manufacturer B cab are not significantly different.

Table 3
Full-Shift Task Monitoring

	Transports							
	Manufacturer A, cab model 1		Manufacturer A, cab model 2		Manufacturer B		Manufacturer C	
Scenario[a]	Left ear	Right ear	Left ear	Right ear	Left ear	Right ear	Left ear	Right ear
D1/3-P1/3	85.52 (*n*=10)	84.52 (*n*=9)	81.44 (*n*=9)	81.88 (*n*=11)	82.2 (*n*=3)	84.13 (*n*=3)		
D1/3-PU	83.62 (*n*=10)	82.05 (*n*=10)	81.65 (*n*=8)	80.03 (*n*=10)	81.73 (*n*=4)	82.48 (*n*=4)		
DD-P1/3	87.41 (*n*=9)	84.94 (*n*=8)	86.69 (*n*=8)	83.04 (*n*=10)	88.35 (*n*=4)	88.35 (*n*=4)		
DD-PU	85.65 (*n*=8)	83.86 (*n*=7)	85.25 (*n*=8)	81.67 (*n*=10)	87.18 (*n*=4)	84.13 (*n*=4)		
DU-PU	79.89 (*n*=11)	79.81 (*n*=10)	75.9 (*n*=8)	74.3 (*n*=11)	82.3 (*n*=2)	81.8 (*n*=2)		
Total	**84.21 (*n*=48)**	**82.86 (*n*=44)**	**82.17 (*n*=41)**	**80.10 (*n*=52)**	**84.72 (*n*=17)**	**84.46 (*n*=17)**		
D1″-P1″	81.79 (*n*=14)	81.73 (*n*=14)	80.41 (*n*=13)	79.92 (*n*=13)	82.27 (*n*=3)	81.47 (*n*=3)	73.83 (*n*=3)	69.23 (*n*=3)
D1″-PU	81.56 (*n*=16)	81.38 (*n*=16)	78.93 (*n*=14)	79.47 (*n*=14)	84.27 (*n*=3)	82.33 (*n*=3)	73.6 (*n*=3)	68.97 (*n*=3)
DU-P1″	80.71(*n*=12)	81.31 (*n*=12)	78.15 (*n*=11)	78.28 (*n*=11)	79.73 (*n*=3)	79.5 (*n*=3)	75.05 (*n*=4)	71.95 (*n*=4)
Total	**81.39 (*n*=42)**	**81.48 (*n*=42)**	**79.21 (*n*=38)**	**79.28 (*n*=38)**	**82.09 (*n*=9)**	**81.1 (*n*=9)**	**74.25 (*n*=10)**	**70.24 (*n*=10)**

Note. *Driver average noise exposures by transport manufacturer.*

[a]*Average noise exposure (dBA) for each window configuration was 30 min average drive time for each measurement period.*

Table 4
Full-Shift Task Monitoring

Transport manufacturers	No. of samples	Average drive time noise reading	*p* value
Manufacturer A, Model 2	169	80.218	A-2 vs. A-1; p = .0000001
Manufacturer A, Model 1	176	82.524	A-1 vs. B; p = .123
Manufacturer B	52	83.551	A-2 vs. B; p = .000002
Manufacturer C	20	72.245	C vs. A-2; p = .0
			C vs. A-1; p = .0
			C vs. B; p = .0

Note. *Average drive time noise readings by transport manufacturer. Manufacturer C only tested 1 in. window openings.*

Manufacturer C cab had the quietest cab but this is likely due to monitoring only at the 1 in. window openings.

The Manufacturer B and C cabs represent a small percentage of the total fleet and as a result were not tested as frequently as the Manufacturer A cabs. Manufacturer A transports had the following details: six-cylinder diesels; 11 liter; 370 to 410 variable horse power; 12-speed automatic and 10-speed manual transmissions; passenger-side exhaust system mounted on the rear side or behind the rear window; 2-seater nonsleeper cabs; Class 8 tractors; 80,000-lb carrying capacity; gross weight less than 14,000 lb; and three-axle tractors. Manufacturer A, Model 1 had a different engine manufacturer, exhaust system manufacturer and exhaust system mounting (on passenger rear corner) when compared to Model 2 (exhaust system mounting behind the cab) even though the overall transport specifications were very similar. Model 1 was the newer transport.

Manufacturer B transports had the following details: 6-cylinder diesels; 14 liter; 425 horse power; 10-speed manual transmission; exhaust system on passenger side rear corner; 2-seater nonsleeper caps; Class 8 tractors; 120,000-lb carrying capacity; gross weight more than 14,000 lb.

Manufacturer C transports had the following details: 6-cylinder diesels; 11-seater; 400 horse power, 10-speed manual transmission; exhaust system on passenger side rear corner; 2-seater nonsleeper cabs; Class 8 tractors; 80,000-lb carrying capacity; gross weight less than 14,000 lb.

Table 5 shows the effect of the cab radio on drive-time noise exposures of transport drivers. The more the windows are down, the more noise exposure is added by the radio, suggesting that the radio must be louder to compensate for wind shear, exhaust noise, traffic noise and environmental noise.

The left ear drive-time noise exposure is on average 1.02 dBA higher with the radio on, although the dBA difference is not significant (n = 55 ON, n = 51 OFF) at 95% confidence limit by t test statistics. The right ear drive-time noise exposure is on average 2.06 dBA higher with the radio on, and this difference is significant (n = 60 ON, n = 53 OFF). The difference of all measurements taken (right and left ear) of the mean drive-time noise exposure is 1.54 dBA

Table 5

Full-Shift Task Monitoring

Scenario	Window configuration and average noise exposure (dBA) D⅓-P⅓	D⅓-PU	DD-P⅓	DD-PU	DU-PU	Combined
Left ear radio on	84.53 (*n*=12)	83.24 (*n*=10)	87.73 (*n*=11)	85.95 (*n*=11)	78.40 (*n*=11)	83.99 (*n*=55)
Left ear radio off	82.05 (*n*=10)	81.99 (*n*=12)	86.86 (*n*=10)	85.61 (*n*=9)	78.82 (*n*=10)	82.97 (*n*=51)
Difference	2.48	1.25	0.87	0.33	- 0.42	1.02
Right ear radio on	84.58 (*n*=13)	81.79 (*n*=11)	85.22 (*n*=12)	84.08 (*n*=12)	78.08 (*n*=12)	82.80 (*n*=60)
Right ear radio off	81.43 (*n*=10)	80.85 (*n*=13)	84.07 (*n*=10)	81.24 (*n*=9)	76.55 (*n*=11)	80.74 (*n*=53)
Difference	3.15	0.94	1.15	2.84	1.54	2.06
Left ear average	83.40 (*n*=22)	82.56 (*n*=22)	87.31 (*n*=21)	85.78 (*n*=20)	78.6 (*n*=21)	83.49 (*n*=106)
Right ear average	83.21 (*n*=23)	81.28 (*n*=24)	84.69 (*n*=22)	82.86 (*n*=21)	77.35 (*n*=23)	81.83 (*n*=113)
Difference						1.66
Radio on						83.37 (*n*=115)
Radio off						81.83 (*n*=104)
Difference						1.54

Note. *The effect of the AM/FM radio on noise exposures to transport drivers.*

Table 6

Full-Shift Monitoring

Scenario	No. of samples	Average noise exposure (dBA)	Upper 95% confidence limit (dBA)	*p* value	Power (%)	Significant (Y/N)
DU-PU left ear	16	77.7	78.87	.0000002	*	Y
D1″-PU left ear	26	78.5	79.73	.0000003	*	Y
DU-P1″ left ear	25	78.9	79.69	.0000000004	*	Y
D1″-P1″ left ear	26	80.2	81.07	.0000013	*	Y
DD-PU(DVO) left ear	11	79.2	80.85	.0004	*	Y
D⅓-PU left ear	14	78.9	80.58	.00021	*	Y
D⅓-P⅓ left ear	12	80.25	81.99	.004	58.7	Y
DD-PU left ear	12	83.2	**84.5**	.38	5.4	**N**
DD-P⅓ left ear	12	82.69	**84.27**	.218	8.1	**N**

Note. *Left ear noise exposures of transport drivers with windows in various configurations. Test value 83.4 dBA.*

**Reject the null hypothesis. Power has no meaning because the* p *value was low and the application has more than enough samples to make a value significantly different than 83.4 dBA.*

higher with the radio on, and the dBA difference is significant (n = 115 ON, n = 104 OFF).

Full-Shift Noise Monitoring

Employee left ear noise exposure levels were recorded *over the entire shift* at various fixed window configurations and with the radio on. The results are presented in Table 6.

Those window configurations producing an upper 95% confidence limit of noise exposure greater than 83.4 dBA (to the left ear) over the full shift are considered unacceptable conditions. The null hypothesis is that the mean noise exposure equals 83.4 dBA, and the alternative hypothesis is that the mean noise exposure is less than 83.4 dBA. For a p value < .05, the null hypothesis is rejected and the alternative hypothesis is accepted. Statistical power is 1 - β, expressed as a percentage, where β is the probability of making a Type II error. Researchers attempted to attain statistical power greater than 80%. Significant (Y/N): Y means that the upper 95% confidence limit was less than the test value of 83.4 dBA. When an upper confidence limit is less than the test value, this is the same statistically as performing a t test and showing that the mean value (average noise exposure) is statistically significant and in this case, lower than the test value of 83.4 dBA. The entire 95% confidence interval is below the test value.

As a general trend, steadily higher noise readings were obtained as the opening in the window increased.

Noise exposures in bold (Table 6) are those with upper 95% confidence limits in excess of the 83.4

Table 7
Full-Shift Monitoring

Transport manufacturers	No. of samples	Average full-shift noise reading	*p* value
Manufacturer A, model 2	59	79.624	A-2 vs. A-1; p = .534
Manufacturer A, model 1	66	79.986	A-1 vs. B; p = .838
Manufacturer B	16	79.788	B vs. A-2; p = .866
Manufacturer C	13	78.108	C vs. A-2; p = .131
			C vs. A-1; p = .065
			C vs. B; p = .252

Note. *Full-shift monitoring by transport manufacturer. Manufacturer C only tested 1 in. window openings.*

Table 8
Full-Shift Monitoring

	Window configuration and average noise exposure (dBA)					
Scenario	**D$^1/_3$-P$^1/_3$**	**D$^1/_3$-PU**	**DD-P$^1/_3$**	**DD-PU**	**DU-PU**	**Combined**
Left ear radio on	80.82 (n=6)	80.81 (n=7)	83.63 (n=7)	83.90 (n=7)	79.27 (n=9)	81.58 (n=36)
Left ear radio off	79.68 (n=6)	76.17 (n=6)	81.38 (n=5)	82.14 (n=5)	75.71 (n=7)	78.72 (n=29)
Difference	1.14	4.64	2.25	1.76	3.56	2.86

Note. *The effect of the AM/FM radio on noise exposures to transport drivers.*

dBA 10-hour action level. The data indicate that when the driver window is fully down (and at the same time the passenger window is either up or down one third), the upper 95% confidence limit for the transport driver's average noise exposure *over the shift* will be above the 10-hour action level.

When the driver and/or passenger windows are open no more than one third (or when the driver's vent window is open), the upper 95% confidence limit for the transport driver's average noise exposure during the entire shift will be below the 10-hour action level.

In Table 7, none of the average full-shift noise readings of the four manufacturers are significantly different. All readings at various window configurations were pooled.

Table 8 shows the effect of the cab radio being on for full-shift transport driver noise exposures.

The average full-shift noise exposure with the radio on is 2.86 dBA higher than with radio off, and the difference is significant based on a t test at a 95% confidence limit (n = 36 ON and n = 29 OFF). This means that on average the radio adds approximately 3 dBA to transport driver's shift exposure to the left ear when windows are open in various configurations. Drivers are not permitted to use the company cell phone or CB radio while driving the transport. Cell phone calls were made while the transport was parked or outside the cab. Portable CB radios were used by a few drivers tested, but not while driving.

Area Noise Measurements

A dosimeter microphone was attached to the right side of the driver's visor (centered in the cab) during monitoring for six terminal's fleets. The window configurations (DU-PU, D$^1/_3$-PU, D$^1/_3$-P$^1/_3$, DD-PU and DD-P$^1/_3$) were changed during each one-way trip over an entire shift with the radio on and off. The average cab noise levels of 11 samples were measured with windows at various configurations: DU-PU, D$^1/_3$-PU, D$^1/_3$-P$^1/_3$, DD-PU, DD-P$^1/_3$. The average noise exposure was 76.7 dBA, with an upper 95% confidence limit of 77.9 dBA.

The 11 cabs tested include five Manufacturer A, Model 1 cabs, 4 Manufacturer A, Model 2 cabs and two Manufacturer B cabs. None of the 11 measurements exceeded 80 dBA. The results indicate that the 95% limit for shift average cab noise is well below 83.4 dBA. It should also be noted that one Manufacturer C cab was tested at D1"-PU, D1"-P1" and DU-P1" window configurations, and the full-shift average cab noise was 62.2 dBA.

Wide varieties of area sound level measurements (obtained during studies at 5 representative terminals) are summarized in Table 9 and include measurement locations, approximate measurement durations and area noise levels in dBA.

These measurements represent instantaneous noise produced by activities that add to the noise exposure for the entire day. The purpose of these measurements is to identify potential high noise situations the drivers may encounter. The measurements represent all activities that are included in the driver's overall full-shift task monitoring and full-shift monitoring results. It is determined from these measurements that the following situations have the potential to produce area noise levels above the OSHA 8-hour or 10-hour action level:

- The cab radio, truck pump and engine can be significant sources of noise.
- Metal-to-metal contact during loading/unloading produces high noise spikes for brief intervals. It was observed that fatigued drivers tend to create more banging noise toward the end of the shift.
- When the windows are down, wind shear, and passing cars and trucks generate elevated noise levels.

Conclusion

With the exception of one published noise study in 1973, previous noise studies identified in the literature search have concentrated on over-the-road transport drivers who work under different conditions when compared to gasoline and distillate

Table 9

Area Noise Measurements

Location	Scenario/ driver activity	dBA range	Exposure frequency	Exposure duration	Duration
Inside cab	Truck engine off; radio off	65	Many/day	1-15 min	1 min
Inside cab	Truck engine off; radio on, level 11-13	67-69	2/day	5 min	1 min
Inside cab	Truck engine idling; radio off	66-67	2/day	10 min	1 min
Inside cab	Truck engine idling; radio on, level 11-13	69-71	2/day	10 min	1 min
Inside cab	Radio on at maximum volume, level 32	105	0/day	0	15 sec
Outside driver's door	Truck idling	80-81	2/day	15 sec	15 sec
Front of cab grill	Truck idling	86-87	2/day	15 sec	15 sec
Inside kiosk at load rack	Loading at terminal load rack	65	5/day	20 min	15 sec
Side of tank truck at load rack	Connecting/disconnecting loading hoses	80-94	5/day	15 sec	15 sec
Side of tank truck at load rack	Standing near product flow in hoses	82-84	5/day	30 sec	30 sec
Side of tank truck at load rack	Standing near rack meters	82-85	5/day	1 min	1 min
Side of tank truck at service station	Opening/closing 1-3 lid covers to underground storage tank fill caps	80-98	10/day	1 sec/lid	1 sec
Side of tank truck at service station	Removing/loading hoses off/on truck	75-91	5/day	15-60 sec	5 sec
Side of tank truck at service station	Removing/replacing fill pipe caps on trucks	76-86	5-15/day	5 sec	5 sec
Side of tank truck at service station	Loading/unloading fill helmets at cabinet	85-89	5-15/day	5 sec	1 sec
Driver's left ear	Driver window down; 55 mph; no traffic (wind shear only)	85-91	Not determined	Not determined	5 sec
Driver's left ear	Driver window down $^1/_3$; passenger window up	88	Not determined	Not determined	5 sec
Driver's left ear	Driver window down; passenger window up	92-97	Not determined	Not determined	5 sec
Driver's left ear	Driver window down; 55 mph; waste hauler truck passing on left	98	Not determined	Not determined	5 sec
Driver's right ear	Driver window down; 55 mph; truck passing on left	87-96	Not determined	Not determined	5 sec
Driver's left ear	Driver window down; 55 mph; car passing on left	88-95	Not determined	Not determined	5 sec
Driver's right ear	Driver window down; 55 mph; car passing on left	81-92	Not determined	Not determined	5 sec
Passenger's right ear	Passenger window down $^1/_3$; noise from muffler on uphill climb	81-96	Not determined	Not determined	5 sec

Note. *Area noise measurements associated with specific driving, loading/unloading activities.*

transport drivers. The published studies have not determined whether present-day gasoline and distillate transport drivers are exposed to noise above or below the 10-hour OSHA action level of 83.4 dBA.

Both full-shift task and full-shift average noise exposure monitoring were conducted on gasoline and distillate transport drivers to determine which tasks and work conditions resulted in noise exposures above or below the OSHA action level. The data attempted to identify both task and full-shift work conditions where the mean of readings would have an upper 95% confidence limit below the OSHA action level. This methodology was a conservative approach designed to give employers confidence that at least 19 of 20 random employee exposures would likely fall below the OSHA action level under the specified work conditions.

Data analysis indicates that gasoline and distillate loading/unloading tasks do not significantly contribute to time-weighted average noise exposures above the 10-hour OSHA action level. However, it was determined from area measurements that other work tasks have the potential to produce area noise levels above 83.4 dBA.

Based on the nine window configurations tested, when the driver window is one third down or more, the transport driver's task noise exposure *during driving* is at an unacceptable risk of exceeding the 10-hour action level. When the driver window is down all the way, the task noise exposure average *during driving* is above 85 dBA. The data also indicate that when the driver window is fully down, the transport driver's average noise exposure *over the shift* is at an unacceptable risk of exceeding the 10-hour action level. These are considered conditions to be avoided.

Of the nine window configurations tested, the data indicate that when the driver and/or passenger windows are open no more than 1 in., the transport driver's task noise exposure *during driving* will be below the 10-hour action level. The data indicate that when the driver and/or passenger windows are open no more than one third the transport driver's average noise exposure *during the entire shift* will be below the 10-hour action level.

The left ear drive-time (short-term) noise exposure is higher with the radio on, although the data are not significant. The right ear drive-time noise exposure is on average higher with the radio on, and these data are significant. The total of all measurements pooled, right and left ears, produced the mean drive-time noise exposure that is higher with the radio on, and the data is significant. The average full-shift noise exposure to the left ear with the radio on is 2.86 dBA higher than with radio off.

Based on a comparison of average drive-time noise exposures for all window configurations, one of three transport models (Manufacturer A, Model 2) was quieter than the other two, which were statistically similar.

Full-shift cab noise measurements were well below 83.4 dBA, the 10-hour action level.

Recommendations

The recommendations from this study specifically apply to gasoline and distillate transport drivers. In addition, a few of the recommendations can be used by the broader populations of over-the-road transport drivers and even automobile drivers when operating on the freeways and highways.

The following recommendations are for gasoline transport drivers as well as over-the-road long-distance haulers:

- Drivers should stand 20 ft from the truck product pump when it is operating. Ear plugs or ear muffs can be worn if the driver has to stay close to the transport's shut-off valves during pump operation.
- Drivers should not stand near the truck grill for any longer than it takes them to complete their inspection duties.
- The maximum amount of noise-attenuating cab insulation should be specified by each transport manufacturer when ordering the transports to ensure cab noise is maintained below the OSHA action level.
- Additional noise dosimetry monitoring (personal and area) should be conducted when different manufacturers and/or models of cabs are introduced to the workplace to document that the driver's noise exposure is below the OSHA levels.
- Each workplace using transports should have a written policy establishing the driver's responsibility to maintain window and radio configurations at safe levels to protect their hearing. This policy could state the windows are to be closed and/or maintained at 1 in. open. Radio, cell phone and/or CB configurations must be tested by the company's SH&E professionals to determine safe volume settings.

The practice of keeping windows closed and radio volume no higher than the appropriate action level will provide the maximum noise reduction.

The following recommendations could apply to all drivers of any type of motor vehicle:

- AM/FM radio, company radio, CB or cell phone should not be operated at volumes greater than the appropriate action level.
- Windows should be closed or not opened more than 1 in. when driving on the highway at speeds of 55 mph or greater. Having the window(s) open one third or more exposes the driver to potentially hazardous noise exposures.

The practice of keeping windows closed and radio volume no higher than the appropriate action level will provide the maximum noise reduction. Members of the public, families and individuals not connected to the workplace may have a challenge in determining a safe radio and/or window setting. This opportunity would provide SH&E professionals as well as their managements an opportunity to implement another aspect of an off-the-job safety program that would help employees and their families to control and correct unsafe conditions (radio volume and window openings) for themselves and their families. ■

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