APPENDIX D. COMPUTING SOURCE REFERENCE LEVELS FROM MEASUREMENTS

This appendix contains the procedures for computing source reference levels (SEL_{ref}) from source measurements in cases where the Source Reference Tables in Chapter 6 indicate measurements are preferred.

For vehicle passbys, the closeby source measurements may be either of the vehicle's sound exposure level (SEL) or of its maximum noise level (L_{max}). Both these descriptors can be measured directly by commonly available sound level meters. L_{max}'s are allowed here for several reasons. Often L_{max} measurements are available from transit-equipment manufacturers. For some transit systems, equipment specifications will limit closeby L_{max}'s to some particular value. And in some situations, closeby source measurements may be taken as part of the environmental study for more precision than is possible with the reference-level table.

For non-passby sources, the closeby source measurements must be of the source's SEL over one source "event." The source "event" duration may be chosen for measurement convenience; it will subtract out of the computation when the measured value is converted to reference operating conditions later in this section.

This manual does not specify elaborate methods for undertaking such closeby source measurements, nor that these measurements be at the reference conditions discussed in the main text. Required are measurements that conform to good engineering practice, guided by the standards of the American National Standards Institute and other such organizations (see References 1 and 2 of Chapter 6).

For passbys of both highway and rail vehicles, the following conditions are required in addition to good engineering practice:

- Measured vehicles must be representative of project vehicles in all aspects, including representative acceleration and speed conditions for 3-axle buses.
- Track must be relatively free of corrugations and train wheels relatively free of flats, unless these conditions are typical of the proposed project.

- Perpendicular distance between the measurement position and the source's centerline must be 100 feet or less.
- Vehicle speed must be 30 miles per hour or greater, unless typical project speeds are less than that.
- No noise barriers, terrain, buildings, or dense tree zones may break the lines-of-sight between the source and the measurement position.

For sources other than vehicle passbys, the following conditions are required in addition to good engineering practice:

- Measured source operations must be representative of project operations in all aspects.
- The following ratio must be 2 or less:

  distance to the furthest source component
  divided by
  distance to the closest source component

  In addition, the distance to the closest source component must be 200 feet or less. If both these conditions cannot simultaneously be met, then separate closeby measurements must be made of individual components of this source, for which these distance conditions can be met.

- The following ratio must be 2 or less:

  lateral length of the source area, measured perpendicular to the general line-of-sight between source and measurement position
  divided by
  distance to the closest source component

  If this condition cannot be met, then separate closeby measurements must be made of individual components of this source, for which this condition can be met.

- No noise barriers, terrain, buildings, or dense tree zones may break the lines-of-sight between the source and the measurement position.

When closeby source measurements are made under non-reference conditions, the equations in Table D-1 are used to convert the measured values to Source Reference Levels. Detailed procedures follow. Note that each vehicle type must be measured and converted separately. Note that this computation requires that all measured vehicles be of the same type. For trains of mixed consists, see Appendix E. For rail vehicles, measure/convert a group of locomotives **or** a group of cars separately.

If SEL was measured for a highway-vehicle passby, or a passby of a group of identical rail vehicles:

- Collect the following input information:
  - SEL_{meas}, the measured SEL for the vehicle passby

- N, the consist of the measured group of rail cars or group of locomotives
- T, the average throttle setting of the measured diesel-powered locomotive(s)
- S_{meas}, the measured passby speed, in miles per hour
- D_{meas}, the closest distance between the measurement position and the source, in feet

- Compute the Source Reference Level -- SEL_{ref} -- from the **first** equation in Table D-1.

Example D-1. Computation of SEL_{ref} from SEL Measurement of Fixed-Guideway Source

A passby of two diesel-powered locomotives was measured at

SEL_{meas} = 90.

For this measurement,

N = 2

T = 6

S_{meas} = 55 miles per hour, and

D_{meas} = 65 feet.

The resulting SEL_{ref} = 86.5 dB.

End of Example D-1

If SEL was measured for a stationary noise source:

- Collect the following input information:
  - SEL_{meas}, the measured SEL for the noise source, for whatever source "event" is convenient to measure
  - E_{meas}, the event duration, in seconds
  - D_{meas}, the closest distance between the measurement position and the source, in feet
- Compute the Source Reference Level -- SEL_{ref} -- from the **second** equation in Table D-1.

Example D-2. Computation of SEL_{ref} from SEL Measurement of Stationary Source

A signal crossing was measured for a 10-second "event" at

SEL_{meas} = 70.

For this measurement,

E_{meas} = 10 seconds and

D_{meas} = 25 feet.

The resulting SEL_{ref} = 71.8 dB.

End of Example D-2

If L_{max} was measured for a passby of a group of identical rail vehicles:

- Collect the following input information:
  - L_{max}, measured for the group passby
  - N, the consist of the measured group of rail cars or group of locomotives
  - T, the average throttle setting of the measured diesel-powered locomotive(s)
  - S_{meas}, the measured passby speed, in miles per hour
  - D_{meas}, the closest distance between the measurement position and the source, in feet
  - L_{meas}, the total length of the measured group of locomotives or group of rail cars, in feet
- Compute the Source Reference Level -- SEL_{ref} -- from the **third or fourth** equations in Table D-1, depending on whether the sources are locomotives or rail cars.

Example D-3. Computation of SEL_{ref} from L_{max} Measurement of Fixed-Guideway Source

A passby of a 4-car consist of 70-ft long rail cars was measured at

L_{max} = 90.

For this measurement,

N = 4

S_{meas} = 70 miles per hour

D_{meas} = 65 feet, and

L_{meas} = 280 feet.

Using the fourth equation in Table D-1,

α = 1.14

and the resulting SEL_{ref} = 86.7 dB.

End of Example D-3

If L_{max} was measured for a highway-vehicle passby:

- Collect the following input information:
  - L_{max}, measured for the highway-vehicle passby
  - S_{meas}, the vehicle speed, in miles per hour
  - D_{meas}, the closest distance between the measurement position and the source, in feet
- Compute the Source Reference Level -- SEL_{ref} -- from the **fifth** equation in Table D-1.

Example D-4. Computation of SEL_{ref} from L_{max} Measurement of Highway Vehicle Source

A 3-axle bus was measured at

L_{max} = 78, under full throttle, accelerating conditions.

For this measurement,

S_{meas} = 22 miles per hour and

D_{meas} = 80 feet.

Using the fifth equation in Table D-1, the resulting SEL_{ref} = 83.8 dB.

End of Example D-4

Table D-1 Conversion to Source Reference Levels at 50 feet for Transit Noise Sources

Measured Quantity	Noise Source	Equation
SEL	Vehicle passby	$SEL_{ref} = SEL_{meas} + 10\log\left(\frac{S_{meas}}{50}\right) + 10\log\left(\frac{D_{meas}}{50}\right) + C_{consist} + C_{emissions}$
	Stationary noise source	$SEL_{ref} = SEL_{meas} - 10\log\left(\frac{E_{meas}}{60}\right) + 20\log\left(\frac{D_{meas}}{50}\right)$
L_{max}	Rail-vehicle passby, locomotives	$SEL_{ref} = L_{max} + 10\log\left(\frac{L_{meas}}{50}\right) + 10\log\left(\frac{D_{meas}}{50}\right) - 10\log(2\alpha) + C_{consist} + C_{emissions} + 3.3$
	Rail-vehicle passby, cars only	$SEL_{ref} = L_{max} + 10\log\left(\frac{L_{meas}}{50}\right) + 10\log\left(\frac{D_{meas}}{50}\right) - 10\log[2\alpha + \sin(2\alpha)] + C_{consist} + C_{emissions} + 3.3$
	Highway-vehicle passby	$SEL_{ref} = L_{max} + 20\log\left(\frac{D_{meas}}{50}\right) + C_{emissions} + 3.3$

Vehicle Type		Expression for $C_{consist}$	Expression for $C_{emissions}$
Locomotives		$-10\log(N)$	0 for $T < 6$; $-2(T-5)$ for $T \geq 6$
Rail Cars		$-10\log(N)$	$-30\log\left(\frac{S_{meas}}{50}\right)$
Three-axle (commuter) Buses	accelerating	0	-1.6
	not accelerating	0	$-24.6 \times \log\left(\frac{S_{meas}}{50}\right)$
Two-axle (city) Buses		0	$-33.9 \times \log\left(\frac{S_{meas}}{50}\right)$
Automobiles		0	$-38.1 \times \log\left(\frac{S_{meas}}{50}\right)$

N = consist, (number of locomotives *or* rail cars in the measured group)

T = average throttle setting of measured diesel - electric locomotive(s)

D_{meas} = closest distance between measurement position and source, in feet

E_{meas} = event duration of measurement, in seconds

L_{meas} = total length of measured group of locomotives *or* rail cars, in feet

S_{meas} = speed of measured vehicle(s), in miles per hour

$\alpha = \arctan\left(\frac{L_{meas}}{2D_{meas}}\right)$, in radians