ATTACHMENT B

NOISE ANALYSIS REPORT AND MEMO

Noise Analysis

Proposed Aggregate Mining Operation
17825 Valley View Drive
Sand Creek Township, Scott Co., Minnesota

Prepared for

Jordan Aggregate, LLC

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Noise Analysis

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1.0 Introduction

This report presents an analysis of noise levels expected from operation of the proposed Jordan Aggregate, LLC sand and gravel mine in Sand Creek Township, Scott County, Minnesota. Section 2 describes the layout of the mining operation and surrounding properties, equipment to be used for the mining operation, noise sources, and distances to receptors. The regulatory requirements for noise levels and noise controls are outlined in Section 3. Section 4 presents a discussion and definitions relating to sound and noise, and describes the methods of analysis used for predicting noise levels at nearby receptors. Results of the analysis for mining operations are provided in Section 5. Results of the analysis for truck traffic are provided in Section 6. Section 7 discusses noise monitoring and mitigation.

2.0 Mining Layout and Operations

Mining operations are proposed on approximately 84.7 acres of land on a 100-acre parcel located at 17825 Valley View Drive in Sand Creek Township, Scott County, Minnesota. The site location, surrounding properties, and mining and processing operations area within the site are shown in Figure 1.

2.1 Mining Layout

The mining operations area is bounded by Valley View Drive to the northwest, the Scott Juvenile Alternative Facility and SCALE training facility to the north, a residence to the west, and by the Sand Creek floodplain to the south and east. Five properties were evaluated for noise impacts from the proposed mining operation and associated truck traffic:

1) SCALE training facility, located at 17706 Valley View Drive (nearest NAC-2 property to mine site) (Figure 1)
2) Scott County Juvenile Alternative Facility located at 17681 Valley View Drive (nearest NAC-1 property to north/east side of mine site) (Figure 1)
3) Residence at 18020 Valley View Drive (nearest NAC-1 property to west side of mine site) (Figure 1)
4) Valley View Assisted Living Facility (nearest NAC-1 property for traffic noise on Route 1) (Figure 2)
5) Residence at 230 Valley View Drive East (nearest NAC-1 property for traffic noise on Route 2) (Figure 3)

2.2 Noise Sources

Noise emissions due to mining operations will occur from five generalized sources:

1) Excavating, loading, and hauling aggregate materials at the active mine face for mining above the water table. Mining equipment will include a combination of excavators, loaders, and haul trucks. Not more that two pieces of equipment would be operating at any given time.
2) Dredge operations for mining aggregate materials from below the water table.
3) Processing equipment (e.g. rock crusher and classifying screens) as shown in Figure 1.
4) Portable asphalt plant located at the east edge of the plant site as shown in Figure 1.
5) Truck traffic on 173rd Street and Valley View Drive.

Estimated noise levels produced from the mining operations, at a reference distance of 50 feet (15 meters) from the noise source, are summarized in the following table. The estimated noise levels for mining equipment (loader, excavator, trucks) are taken from "FHWA Highway Construction Noise Handbook," Federal Highway Administration, August 2006. The noise levels for processing equipment (crusher, screen, and generator) are based upon noise ratings published by the manufacturers for the types of equipment proposed for use in the project (adjusted for the standard reference distance of 50 feet used in the analysis). Manufacturer's noise ratings are provided in Appendices B and C.

Equipment	Noise Level at 50 feet (dBA)
Front End Loader/Excavator	80
Off-Road Hauling Trucks	76
Dredge Operations	80
Crusher	87.2
Classifying Screens	84.0
Generator	67.5
On-Road Haul Trucks	80
Portable Asphalt Plant	87.5

The noise level for on-road dump trucks was based on EPA standards, which were subsequently codified in Minnesota Rule 7030.1040. The table and discussion below was obtained from the FHWA:

The Noise Control Act of 1972 gives the Federal Environmental Protection Agency (EPA) the authority to establish noise regulations to control major sources of noise, including transportation vehicles and construction equipment. In addition, this legislation requires EPA to issue noise emission standards for motor vehicles used in Interstate commerce (vehicles used to transport commodities across State boundaries) and requires the Federal Motor Carrier Safety Administration (FMCSA) to enforce these noise emission standards.

The EPA has established regulations which set emission level standards for newly manufactured medium and heavy trucks that have a gross vehicle weight rating (GVWR) of more than 10,000 pounds and are capable of operating on a highway or street. Table 3 shows the maximum noise emission levels allowed by the EPA noise regulations for these vehicles.

Table 3
Maximum Noise Emission Levels
as Required by EPA for Newly Manufactured Trucks
with GVWR Over 10,000 pounds

Effective Date	*Maximum Noise Level 50 feet from Centerline of Travel**
January 1, 1988	*80 dBA*

**Using the Society of Automotive Engineers, Inc. (SAE), test procedure for acceleration under 35 mph*

2.3 Distances from Noise Sources to Receptors

The distances from noise sources to receptor will vary as mining operations move around the site. For this analysis, “threshold” distances were calculated for the combined noise sources. The threshold distances are the closest distances between noise sources and receptors for which the mining operations will be in compliance with noise regulations.

Noise distances are shown as circles on Figure 1. Red and blue circles represent the distance from processing and asphalt plants, respectively, to receptors. The cyan circle represents the threshold distance for above-water-table mining operations. When mining operations are occurring inside the cyan circles, operation of the processing plant and/or asphalt plant will be curtailed for noise regulations compliance.

Distances for truck traffic noise impacts are discussed in Section 6.

3.0 Noise Regulations

State of Minnesota noise regulations are contained in Minnesota Rules Chapter 7030. “Noise Area Classifications” are defined in 7030.0050, subp. 2. The assisted living facility and juvenile alternative facility located northeast of the proposed mining operation fall in Noise Area

Classification 1 (Group quarters, Other residential). The Mosquito Control District facility falls in Noise Area Classification 2 (Government services, Miscellaneous services).

Noise standards applicable to these Noise Area Classifications are defined in 7030.0040, subp. 2, and are summarized below.

Minnesota Noise Standards				
Noise Area Classification	Daytime		Nighttime	
	L_{50} dBA	L_{10} dBA	L_{50} dBA	L_{10} dBA
1	60	65	50	55
2	65	70	65	70

Mining and trucking operations will be conducted only during daytime hours (7 am to 10 pm) and as may be further restricted by County requirements. The daytime noise standards, listed above, are applicable to these operations.

4.0 Definitions and Methods of Analysis

This section provides a general discussion and definitions relating to sound and noise, followed by a description of the methods used to analyze noise for the proposed mining operation.

4.1 Discussion and Definitions

Sound is defined as any pressure variation that the human ear can detect. When considered as an environmental condition, sound is often considered to be "noise." For this study, sound or noise pressure levels are measured in the decibel scale, denoted as "dB." Where the primary concern is the noise effects on humans, sound readings are usually compensated by an "A"-weighted filter, which accounts for human's limited hearing response in the upper and lower frequency bands. Sound pressure level measurements using the A-weighted filter are denoted dBA. Sound levels that are exceeded 50 percent of the time during a one-hour measuring period are denoted as "L_{50}" sound levels. Sound levels that are exceeded 10 percent of the time during a one-hour measuring period are denoted as "L_{10}" sound levels.

The smallest noise level change that the human ear can detect is approximately 3 dB. A doubling of the static air pressure amounts to a change of 6 dB, and an increase of 10 dB is equivalent to a doubling of the perceived sound level. Sound is known to decrease at a rate of 6 dB for each doubling of distance. Decibel levels of common noise sources are provided in the following table ("Guide to Noise Control in Minnesota," Minnesota Pollution Control Agency, March 1999).

Sound Pressure Level (dBA)	Noise Source
140	Jet Engine (at 25 meters)
130	Jet Aircraft (at 100 meters)
120	Rock and Roll Concert
110	Pneumatic Chipper
100	Jointer/Planer
90	Chainsaw
80	Heavy Truck Traffic
70	Business Office
60	Conversational Speech
50	Library
40	Bedroom
30	Secluded Woods
20	Whisper

4.2 Methods of Analysis

The noise analysis presented in this report is based upon the procedures set forth in ISO 9613-1:1993 (Acoustics—Attenuation of Sound during Propagation Outdoors—Part 1: Calculation of the absorption of sound by the atmosphere) and ISO 9613-2:1996(E) (Acoustics—Attenuation of Sound during Propagation Outdoors—Part 2: General methods of calculation). These standards specify methods for summing the noise produced by multiple point sources, and calculating the attenuation of sound for the following attenuation effects:

- Geometrical divergence
- Atmospheric absorption
- Ground effect
- Reflection from surfaces
- Screening by obstacles

For this study, the attenuation effects from geometrical divergence, atmospheric absorption, and ground effects were considered. There are no flat, hard vertical surfaces in the area (such as buildings) that would result in sound reflection, therefore attenuation due to reflection does not apply. The attenuation effects of screening by obstacles (such as berms, trees, and depression of the mining area below surrounding ground elevations) were ignored, even though these screening features will be present and will provide some attenuation effect. Ignoring the screening effect results in conservative noise level predictions, with a slight overestimate of the noise levels.

Summation of noise from multiple point sources and attenuation of noise due to geometrical divergence, atmospheric absorption, and ground effect were calculated according to the formulas in Sections 6, 7.1, 7.2, and 7.3, respectively, of ISO 9313-2 (see Appendix A). The calculations assume that two pieces of mining equipment (excavators, loaders, haul trucks) will be operating at the same time at the active mining face, and that the dredging equipment will be operating. The calculations assume that a rock crusher, classifying screens, and loader will be operating at the processing area.

5.0 Results for Mining Operations

The results indicate that the noise from mining operations at the Noise Area Classification 1 receptors located west of the site will be below the L_{50} regulatory daytime noise standard of 60 dBA when mining operations are located more than 175 meters from the receptors (See Fig. 1). When mining operations are closer than 175 meters, the processing and/or asphalt plant operations will be curtailed to comply with noise regulations.

The results indicate that the noise from mining operations at the Noise Area Classification 1 receptor located north of the site will be below the L_{50} regulatory daytime noise standard of 60 dBA when mining operations are located more than 121 meters from the receptors (See Fig. 1). The mining operations boundary is farther than 121 meters from this receptor.

The results indicate that the noise from mining operations at Noise Area Classification 2 receptor will be below the L_{50} regulatory daytime noise standard of 65 dBA when mining operations are located more than 145 meters from the receptors (See Fig. 1). When mining operations are closer than 145 meters, the processing and/or asphalt plant operations will be curtailed to comply with noise regulations.

More detailed results, including the data used for the variables in the referenced ISO 9613 formulae, are provided in Tables 1 through 10.

6.0 Results for Traffic Noise

This section addresses traffic noise impacts along the proposed haul route due to aggregate truck traffic traveling to and from the mining operation. Noise impacts are calculated relative to the L_{10} and L_{50} daytime and nighttime standards for Noise Area Classification 1 (NAC-1) codified in Minnesota Rules 7030.0040 subp. 2. These noise standards are summarized in Section 3 above.

Two truck routes are proposed: Valley View Drive north of the Project site to 17rd Street to Highway 169 (Route 1), and Valley View Drive south of the Project site to Co. Rd. 9 to Highway 169 (Route 2). These routes are shown on the Haul Route Map andwill be used as follows:

- Outbound traffic with a destination south of the Project will exit the Project site northbound on Valley View Drive to 173rd Street to southbound Hwy 169. This route is estimated to carry an average of 11 trips per day and a peak of 22 trips per day (1 trip and 2 trips per hour, respectively).
- Outbound traffic with a destination north of the Project will exit the Project site southbound on Valley View Drive to County Road 9 to northbound Hwy 169. This route is estimated to carry an average of 43 trips per day and a peak of 88 trips per day (4 trips and 10 trips per hour, respectively).
- Inbound traffic from both northbound and southbound Hwy 169 will enter the Project site via 173rd Street to southbound Valley View Drive to the Project entrance. This route is estimated to carry an average of 54 trips per day and a peak of 110 trips per day (6 trips and 12 trips per hour, respectively)
- Combined outbound and inbound trips:
    - Route 1—Valley View Drive/173rd Street north of Project site: Average 64 trips per day, peak 132 trips per day (7 trips and 14 trips per hour, respectively)
    - Route 2—Valley View Drive/Co. Rd. 9 south of Project site: Average 43 trips per day, peak 88 trips per day (4 trips and 10 trips per hour, respectively).

Existing traffic on Valley View Drive was also taken into consideration for the daytime truck traffic noise analysis. Based on the MnDOT Municipal State Aid (MSA) Traffic Volume Map (available on the MnDOT website) traffic along Valley View drive between County Road 9 and Syndicate Road was 860 trips per day. This stretch of road includes the location of Receptor 2. Of greatest concern for noise calculations are the number of heavy commercial vehicle trips. The MSA map does not include a breakdown of light versus heavy vehicle volumes so it was estimated that the 860 trips consists of approximately 3% heavy commercial vehicles, resulting in approximately 26 heavy vehicle trips per day, or 3 per hour. This is based on the fact that this area of Valley View is mostly a residential area with limited industry. For comparison, the MnDOT Trunk Highway Volume Map for 2006 (available on the MnDOT website) shows that traffic is comprised of approximately 6% heavy commercial vehicles. By including this background noise into the daytime noise calculations, the peak traffic increases to 17 trips per hour for Route 1 and 13 trips per hour for Route 2.

Truck traffic noise impacts were evaluated for the Valley View Assisted Living Facility (NAC-1 land use) located on the corner of Valley View Drive and 173rd Street, as the nearest noise receptor for the Valley View Dr/173rd St route (Route 1). The noise impact boundary was established based upon observed human activity in the yard area. The boundary is located 60 feet from the road centerline, as shown on Figure 4. Potential noise impacts for this receptor relative to the L_{10} and L_{50} standards were evaluated for both daytime and nighttime conditions, since trucks may possibly arrive at the mine site entrance prior to its opening time of 7:00 am.

Truck traffic noise impacts were evaluated for the residence located at 230 Valley View Drive E in the City of Jordan (NAC-1 land use) as the nearest noise receptor for the Valley View Dr/Co Rd 9 route (Route 2). The boundary for noise impact analysis was established at the house since the yard area where activity would occur is located on the opposite side of the house from Valley View Drive. This distance from the house to the road centerline is 24 feet, as shown on Figure 5. Potential noise impacts for this receptor relative to the L_{10} and L_{50} standards were evaluated for both daytime and nighttime conditions, since trucks may possibly arrive at the mine site entrance prior to its opening time of 7:00 am.

Other receptors along the routes are located farther away from the road and thus will experience a lesser noise level than the two receptors selected for evaluation.

The results of the analysis indicate that noise from truck traffic will be in compliance with the daytime L_{10} and L_{50} standards and L_{50} nighttime standard for the peak traffic rate under the highest noise frequency scenario. Noise from truck traffic will also be in compliance with the L_{10} nighttime standard if 9 or fewer trucks arrive along one route during the hour preceding the 7:00 am mine opening time. These results are summarized in the following table. Details of the analysis are provided Tables 3 through 10.

Summary of Noise Analysis for Truck Traffic				
	Daytime		**Nighttime**	
Route	L_{10} (1)	L_{50}	L_{10} (1)	L_{50}
Route 1				
Calculated Non-Attainment	5.8%	10.3%	9.3%	16.5%
Allowable Non-Attainment	10%	50%	10%	50%
Route 2				
Calculated Non-Attainment	4.5%	17.9%	9.5%	16.6%
Allowable Non-Attainment	10%	50%	10%	50%

(1) Results for a traffic rate of 9 trips per hour prior to 7:00 am

7.0 Noise Monitoring and Mitigation

It is expected that noise monitoring will be included as a condition of the Scott County Interim Use Permit for the Site. If noise monitoring demonstrates that applicable noise thresholds at nearby receptors are exceeded due to noise generated by the project, there are a number of mitigation measures that can be implemented to reduce noise emissions and achieve compliance with noise regulations.

Noise generated by the mining and plant operations can be mitigated using one or more of the following measures:

- Operational modifications – for example, halting processing operations while working the active mine face closest to receptors
- Engine mufflers
- Dampers for excavating and processing equipment (eliminate vibration and rattle)
- Liners for processing equipment to reduce stone-on-metal noise
- Sound barriers – can be constructed to deflect the noise away from receptors

Noise generated by truck traffic can be mitigated by reducing the truck volume along Valley View Drive. This can be accomplished by metering the trucks exiting the Site through the use of a stoplight or barrier arm, such that only a certain number of trucks can leave the Site every hour.

Tables

Table 1

Threshold Distance Calculation for Mining Operations

Proposed Mining Operation, Sand Creek Township, Scott County

17-Aug-10

Noise Analysis Data	Class 1 Receptor (to west)				Class 1 Receptor (to east)				Class 2 Receptor			
	Threshold Mining Operation Distance	Closest Dredging Operation	Asphalt Plant Operation	Processing Plant Operation	Threshold Mining Operation Distance	Closest Dredging Operation	Asphalt Plant Operation	Processing Plant Operation	Threshold Mining Operation Distance	Closest Dredging Operation	Asphalt Plant Operation	Processing Plant Operation
Distances, Factors, Functions												
Reference Distance from Source (d_o, meters)	15	15	15	15	15	15	15	15	15	15	15	15
Sound Propogation Distance-Source to Receptor (d_p, meters)	175	295	401	322	121	380	420	545	145	395	302	435
Attenuation Coeficient for Air Absorption (alpha, dB/meter)	0.000869	0.000869	0.00869	0.000869	0.000869	0.000869	0.00869	0.000869	0.000869	0.000869	0.00869	0.000869
Ground Attenuation Factor, near source (G_s)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Ground Attenuation Factor, near receptor (G_r)	1	1	1	1	1	1	1	1	1	1	1	1
Ground Attenuation Factor, between source and receptor (G_m)	1	1	1	1	1	1	1	1	1	1	1	1
Ground Factor Function-Source Area ($c'(h_s)$)	3.7	3.7	3.7	3.7	3.5	3.7	3.7	3.7	3.6	3.7	3.7	3.7
Ground Factor Function-Receptor Area ($c'(h_r)$)	6.3	6.5	6.5	6.5	6.0	6.5	6.5	6.5	6.2	6.5	6.5	6.5
Height of Source (H_s, meters)	2	2	2	2	2	2	2	2	2	2	2	2
Height of Receptor (H_r, meters)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Sound Levels at Reference Distance from Source (Leq, dBA)												
Mining Operations												
Excavator or Loader	80.0	NA	NA	NA	80.0	NA	NA	NA	80.0	NA	NA	NA
Haul Truck or Dozer	76.0	NA	NA	NA	76.0	NA	NA	NA	76.0	NA	NA	NA
Dredge	NA	80.0	NA	NA	NA	80.0	NA	NA	NA	80.0	NA	NA
Processing Operations												
Rock Crusher	NA	NA	NA	87.2	NA	NA	NA	87.2	NA	NA	NA	87.2
Screening System	NA	NA	NA	84.0	NA	NA	NA	84.0	NA	NA	NA	84.0
Customer Loading	NA	NA	NA	80.0	NA	NA	NA	80.0	NA	NA	NA	80.0
Asphalt Plant	NA	NA	87.5	NA			87.5				87.5	
Combined Sound Level from Multiple Sources ($Leq_{s\text{-}comb}$, dBA)	**81.5**	**80.0**	**87.5**	**89.4**	**81.5**	**80.0**	**87.5**	**89.4**	**81.5**	**80.0**	**87.5**	**89.4**
Sound Attenuation												
Attenuation due to Geometric Divergence (A_{div}, dBA)	21.3	25.9	28.5	26.6	18.1	28.1	28.9	31.2	19.7	28.4	26.1	29.2
Attenuation due to Atmospheric Absorption (A_{atm}, dBA)	0.2	0.3	3.5	0.3	0.1	0.3	3.6	0.5	0.1	0.3	2.6	0.4
Attenuation due to Ground Effect (A_{gr}, dBA)	5.2	5.3	5.3	5.3	4.8	5.3	5.3	5.3	5.0	5.3	5.3	5.3
Sound Level at Receptor (L_r, dBA)	**54.8**	**48.6**	**50.1**	**57.2**	**58.4**	**46.3**	**49.6**	**52.4**	**56.6**	**45.9**	**53.5**	**54.5**
Combined Sound Level at Receptor due to Mining, Processing, and Asphalt Operations ($Leq_{r\text{-}comb}$, dBA)	**60.0**				**60.0**				**60.0**			

Table 2

Threshold Distance Calculation for Noise from Customer Loading Operations Daytime L50 Sound Level

Proposed Mining Operation, Sand Creek Township, Scott County

17-Aug-10

Noise Analysis Data	Class 1 Receptor L50<60 dB Loading Only	Class 2 Receptor L50<65 dB Loading Only
Distances, Factors, Functions		
Reference Distance from Source (d_o, meters)	15	15
Sound Propogation Distance-Source to Receptor (d_p, meters)	**90**	**57**
Attenuation Coeficient for Air Absorption (alpha, dB/meter)	0.000869	0.000869
Ground Attenuation Factor, near source (G_s)	0.5	0.5
Ground Attenuation Factor, near receptor (G_r)	1	1
Ground Attenuation Factor, between source and receptor (G_m)	1	1
Ground Factor Function-Source Area ($c'(h_s)$)	3.4	3.0
Ground Factor Function-Receptor Area ($c'(h_r)$)	5.7	4.9
Height of Source (H_s, meters)	2	2
Height of Receptor (H_r, meters)	1.5	1.5
Sound Levels at Reference Distance from Source (Leq, dBA)		
Mining Operations		
Excavator or Loader	80	80
Haul Truck or Dozer	0	0
Processing Operations		
Rock Crusher	NA	NA
Screening System	NA	NA
Combined Sound Level from Multiple Sources ($Leq_{s\text{-}comb}$, dBA)	**80.0**	**80.0**
Sound Attenuation		
Attenuation due to Geometric Divergence (A_{div}, dBA)	15.6	11.6
Attenuation due to Atmospheric Absorption (A_{atm}, dBA)	0.1	0.0
Attenuation due to Ground Effect (A_{gr}, dBA)	4.3	3.4
Sound Level at Receptor (L_r, dBA)	**60.0**	**65.0**
Threshold Distance (meters)	**90**	**57**

Table 3

L_{10} Daytime Truck Noise Calculation

Valley View Assisted Living Facility

Proposed Mining Operation, Sand Creek Township, Scott County

17-Aug-10

	Truck Noise Frequency		
Noise Data	250 Hz	500 Hz	1000 Hz
Source Noise Level (dBA, 50 feet)	80	80	80
Noise Standard (L_{10} Daytime, dBA)	65	65	65
Required Attenuation (dBA)	15	15	15
Distance Data			
Receptor Distance from Road Centerline (feet)	60	60	60
Distance from Receptor at which Required Attenuation is Achieved (feet)	148	174	276
Corresponding Road Distance from Receptor (feet)	136	163	269
Time Duration Calculations			
Travel Speed (mph)	30	30	30
Travel Time per Trip within Non-Attainment Zone (hours)	0.00171	0.00206	0.00340
Trips per Hour [mining(14) + background(3)]	17	17	17
Total Travel Time within Non-Attainment Zone (hours)	0.0291	0.0350	0.0577
Results			
Non-Attainment Percent of one-Hour Period	2.9%	3.5%	5.8%
Maximum Allowable Non-Attainment Percentage	10%	10%	10%

Noise Attenuation Calculations			
Distances, Factors, Functions			
Source Noise Level (dBA)	80	80	80
Reference Distance from Source (d_o, meters)	15.24	15.24	15.24
Sound Propogation Distance-Source to Receptor (d_p, meters)	45.2	53	84
Attenuation Coeficient for Air Absorption (alpha, dB/meter)	0.000869	0.000869	0.000869
Ground Attenuation Factor, near source (G_s)	0.5	0.5	0.5
Ground Attenuation Factor, near receptor (G_r)	1	1	1
Ground Factor Function-Source Area (A_s)	5.7	4.8	2.0
Ground Factor Function-Receptor Area (A_r)	5.7	4.8	2.0
Height of Source (H_s, meters)	1.5	1.5	1.5
Height of Receptor (H_r, meters)	1.5	1.5	1.5
Sound Attenuation			
Attenuation due to Geometric Divergence (A_{div}, dBA)	9.4	10.8	14.8
Attenuation due to Atmospheric Absorption (A_{atm}, dBA)	0.0	0.0	0.1
Attenuation due to Ground Effect (A_{gr}, dBA)	5.5	4.1	0.1
Total Attenuation at Distance "d_p" (dBA)	**15**	**15**	**15**

Table 4

L_{50} Daytime Truck Noise Calculation

Valley View Assisted Living Facility

Proposed Mining Operation, Sand Creek Township, Scott County

17-Aug-10

	Truck Noise Frequency		
Noise Data	250 Hz	500 Hz	1000 Hz
Source Noise Level (dBA, 50 feet)	80	80	80
Noise Standard (L_{50} Daytime, dBA)	60	60	60
Required Attenuation (dBA)	20	20	20
Distance Data			
Receptor Distance from Road Centerline (feet)	60	60	60
Distance from Receptor at which Required Attenuation is Achieved (feet)	221	269	482
Corresponding Road Distance from Receptor (feet)	213	262	479
Time Duration Calculations			
Travel Speed (mph)	30	30	30
Travel Time per Trip within Non-Attainment Zone (hours)	0.00269	0.00331	0.00604
Trips per Hour [mining(14) + background(3)]	17	17	17
Total Travel Time within Non-Attainment Zone (hours)	0.0458	0.0563	0.1027
Results			
Non-Attainment Percent of one-Hour Period	4.6%	5.6%	10.3%
Maximum Allowable Non-Attainment Percentage	50%	50%	50%

Noise Attenuation Calculations			
Distances, Factors, Functions			
Source Noise Level (dBA)	80	80	80
Reference Distance from Source (d_o, meters)	15.24	15.24	15.24
Sound Propogation Distance-Source to Receptor (d_p, meters)	67.5	82	147
Attenuation Coeficient for Air Absorption (alpha, dB/meter)	0.000869	0.000869	0.000869
Ground Attenuation Factor, near source (G_s)	0.5	0.5	0.5
Ground Attenuation Factor, near receptor (G_r)	1	1	1
Ground Factor Function-Source Area (A_s)	6.7	5.5	2.1
Ground Factor Function-Receptor Area (A_r)	6.7	5.5	2.1
Height of Source (H_s, meters)	1.5	1.5	1.5
Height of Receptor (H_r, meters)	1.5	1.5	1.5
Sound Attenuation			
Attenuation due to Geometric Divergence (A_{div}, dBA)	12.9	14.6	19.7
Attenuation due to Atmospheric Absorption (A_{atm}, dBA)	0.1	0.1	0.1
Attenuation due to Ground Effect (A_{gr}, dBA)	7.1	5.3	0.2
Total Attenuation at Distance "d_p" (dBA)	**20**	**20**	**20**

Table 5

L_{10} Nighttime Truck Noise Calculation

Valley View Assisted Living Facility

Proposed Mining Operation, Sand Creek Township, Scott County

17-Aug-10

	Truck Noise Frequency		
Noise Data	250 Hz	500 Hz	1000 Hz
Source Noise Level (dBA, 50 feet)	80	80	80
Noise Standard (L_{10} Nightime, dBA)	55	55	55
Required Attenuation (dBA)	25	25	25
Distance Data			
Receptor Distance from Road Centerline (feet)	170	170	170
Distance from Receptor at which Required Attenuation is Achieved (feet)	335	430	840
Corresponding Road Distance from Receptor (feet)	288	395	823
Time Duration Calculations			
Travel Speed (mph)	30	30	30
Travel Time per Trip within Non-Attainment Zone (hours)	0.00364	0.00498	0.01039
Trips per Hour	9	9	9
Total Travel Time within Non-Attainment Zone (hours)	0.0328	0.0449	0.0935
Results			
Non-Attainment Percent of one-Hour Period	3.3%	4.5%	9.3%
Maximum Allowable Non-Attainment Percentage	10%	10%	10%

Noise Attenuation Calculations			
Distances, Factors, Functions			
Source Noise Level (dBA)	80	80	80
Reference Distance from Source (d_o, meters)	15.24	15.24	15.24
Sound Propogation Distance-Source to Receptor (d_p, meters)	102	131	256
Attenuation Coeficient for Air Absorption (alpha, dB/meter)	0.000869	0.000869	0.000869
Ground Attenuation Factor, near source (G_s)	0.5	0.5	0.5
Ground Attenuation Factor, near receptor (G_r)	1	1	1
Ground Attenuation Factor, between source and receptor (G_m)	1	1	1
Ground Factor Function-Source Area (b', c', d')	7.6	6.1	2.2
Ground Factor Function-Receptor Area (b', c', d')	7.6	6.1	2.2
Ground Factor Function-Between Source and Receptor (q)	0.1	0.3	0.6
Height of Source (H_s, meters)	1.5	1.5	1.5
Height of Receptor (H_r, meters)	1.5	1.5	1.5
Sound Attenuation			
Attenuation due to Geometric Divergence (A_{div}, dBA)	16.5	18.7	24.5
Attenuation due to Atmospheric Absorption (A_{atm}, dBA)	0.1	0.1	0.2
Attenuation due to Ground Effect (A_{gr}, dBA)	8.4	6.2	0.2
Total Attenuation at Distance "d_p" (dBA)	**25**	**25**	**25**

Table 6

L_{50} Nighttime Truck Noise Calculation

Valley View Assisted Living Facility

Proposed Mining Operation, Sand Creek Township, Scott County

17-Aug-10

	Truck Noise Frequency		
Noise Data	250 Hz	500 Hz	1000 Hz
Source Noise Level (dBA, 50 feet)	80	80	80
Noise Standard (L_{50} Nightime, dBA)	50	50	50
Required Attenuation (dBA)	30	30	30
Distance Data			
Receptor Distance from Road Centerline (feet)	170	170	170
Distance from Receptor at which Required Attenuation is Achieved (feet)	528	719	1,463
Corresponding Road Distance from Receptor (feet)	500	698	1,453
Time Duration Calculations			
Travel Speed (mph)	30	30	30
Travel Time per Trip within Non-Attainment Zone (hours)	0.00631	0.00881	0.01835
Trips per Hour	9	9	9
Total Travel Time within Non-Attainment Zone (hours)	0.0568	0.0793	0.1652
Results			
Non-Attainment Percent of one-Hour Period	5.7%	7.9%	16.5%
Maximum Allowable Non-Attainment Percentage	50%	50%	50%

Noise Attenuation Calculations			
Distances, Factors, Functions			
Source Noise Level (dBA)	80	80	80
Reference Distance from Source (d_o, meters)	15.24	15.24	15.24
Sound Propogation Distance-Source to Receptor (d_p, meters)	161	219	446
Attenuation Coeficient for Air Absorption (alpha, dB/meter)	0.000869	0.000869	0.000869
Ground Attenuation Factor, near source (G_s)	0.5	0.5	0.5
Ground Attenuation Factor, near receptor (G_r)	1	1	1
Ground Attenuation Factor, between source and receptor (G_m)	1	1	1
Ground Factor Function-Source Area (b', c', d')	8.2	6.4	2.2
Ground Factor Function-Receptor Area (b', c', d')	8.2	6.4	2.2
Ground Factor Function-Between Source and Receptor (q)	0.4	0.6	0.8
Height of Source (H_s, meters)	1.5	1.5	1.5
Height of Receptor (H_r, meters)	1.5	1.5	1.5
Sound Attenuation			
Attenuation due to Geometric Divergence (A_{div}, dBA)	20.5	23.1	29.3
Attenuation due to Atmospheric Absorption (A_{atm}, dBA)	0.1	0.2	0.4
Attenuation due to Ground Effect (A_{gr}, dBA)	9.4	6.6	0.2
Total Attenuation at Distance "d_p" (dBA)	**30**	**30**	**30**

Table 7

L_{10} Daytime Truck Noise Calculation

Closest Receptor on Valley View Drive South of Mine

Proposed Mining Operation, Sand Creek Township, Scott County

17-Aug-10

	Truck Noise Frequency		
Noise Data	250 Hz	500 Hz	1000 Hz
Source Noise Level (dBA, 50 feet)	80	80	80
Noise Standard (L_{10} Daytime, dBA)	65	65	65
Required Attenuation (dBA)	15	15	15
Distance Data			
Receptor Distance from Road Centerline (feet)	24	24	24
Distance from Receptor at which Required Attenuation is Achieved (feet)	148	174	276
Corresponding Road Distance from Receptor (feet)	146	172	275
Time Duration Calculations			
Travel Speed (mph)	30	30	30
Travel Time per Trip within Non-Attainment Zone (hours)	0.00185	0.00217	0.00347
Trips per Hour [mining(10) + background(3)]	13	13	13
Total Travel Time within Non-Attainment Zone (hours)	0.0240	0.0283	0.0451
Results			
Non-Attainment Percent of one-Hour Period	2.4%	2.8%	4.5%
Maximum Allowable Non-Attainment Percentage	10%	10%	10%

Noise Attenuation Calculations			
Distances, Factors, Functions			
Source Noise Level (dBA)	80	80	80
Reference Distance from Source (d_o, meters)	15.24	15.24	15.24
Sound Propogation Distance-Source to Receptor (d_p, meters)	45.2	53	84
Attenuation Coeficient for Air Absorption (alpha, dB/meter)	0.000869	0.000869	0.000869
Ground Attenuation Factor, near source (G_s)	0.5	0.5	0.5
Ground Attenuation Factor, near receptor (G_r)	1	1	1
Ground Factor Function-Source Area (b', c', d')	5.7	4.8	2.0
Ground Factor Function-Receptor Area (b', c', d')	5.7	4.8	2.0
Height of Source (H_s, meters)	1.5	1.5	1.5
Height of Receptor (H_r, meters)	1.5	1.5	1.5
Sound Attenuation			
Attenuation due to Geometric Divergence (A_{div}, dBA)	9.4	10.8	14.8
Attenuation due to Atmospheric Absorption (A_{atm}, dBA)	0.0	0.0	0.1
Attenuation due to Ground Effect (A_{gr}, dBA)	5.5	4.1	0.1
Total Attenuation at Distance "d_p" (dBA)	**15**	**15**	**15**

Table 8

L_{50} Daytime Truck Noise Calculation

Closest Receptor on Valley View Drive South of Mine

Proposed Mining Operation, Sand Creek Township, Scott County

17-Aug-10

	Truck Noise Frequency		
Noise Data	250 Hz	500 Hz	1000 Hz
Source Noise Level (dBA, 50 feet)	80	80	80
Noise Standard (L_{50} Daytime, dBA)	60	60	60
Required Attenuation (dBA)	20	20	20
Distance Data			
Receptor Distance from Road Centerline (feet)	24	24	24
Distance from Receptor at which Required Attenuation is Achieved (feet)	221	269	482
Corresponding Road Distance from Receptor (feet)	220	268	482
Time Duration Calculations			
Travel Speed (mph)	30	30	30
Travel Time per Trip within Non-Attainment Zone (hours)	0.00278	0.00338	0.00608
Trips per Hour [mining(10) + background(3)]	13	13	13
Total Travel Time within Non-Attainment Zone (hours)	0.0361	0.0440	0.0791
Results			
Non-Attainment Percent of one-Hour Period	3.6%	4.4%	7.9%
Maximum Allowable Non-Attainment Percentage	50%	50%	50%

Noise Attenuation Calculations			
Distances, Factors, Functions			
Source Noise Level (dBA)	80	80	80
Reference Distance from Source (d_o, meters)	15.24	15.24	15.24
Sound Propogation Distance-Source to Receptor (d_p, meters)	67.5	82	147
Attenuation Coeficient for Air Absorption (alpha, dB/meter)	0.000869	0.000869	0.000869
Ground Attenuation Factor, near source (G_s)	0.5	0.5	0.5
Ground Attenuation Factor, near receptor (G_r)	1	1	1
Ground Factor Function-Source Area (b', c', d')	6.7	5.5	2.1
Ground Factor Function-Receptor Area (b', c', d')	6.7	5.5	2.1
Height of Source (H_s, meters)	1.5	1.5	1.5
Height of Receptor (H_r, meters)	1.5	1.5	1.5
Sound Attenuation			
Attenuation due to Geometric Divergence (A_{div}, dBA)	12.9	14.6	19.7
Attenuation due to Atmospheric Absorption (A_{atm}, dBA)	0.1	0.1	0.1
Attenuation due to Ground Effect (A_{gr}, dBA)	7.1	5.3	0.2
Total Attenuation at Distance "d_p" (dBA)	**20**	**20**	**20**

Table 9

L_{10} Nighttime Truck Noise Calculation

Closest Receptor on Valley View Drive South of Mine

Proposed Mining Operation, Sand Creek Township, Scott County

17-Aug-10

	Truck Noise Frequency		
Noise Data	250 Hz	500 Hz	1000 Hz
Source Noise Level (dBA, 50 feet)	80	80	80
Noise Standard (L_{10} Nightime, dBA)	55	55	55
Required Attenuation (dBA)	25	25	25
Distance Data			
Receptor Distance from Road Centerline (feet)	24	24	24
Distance from Receptor at which Required Attenuation is Achieved (feet)	335	430	840
Corresponding Road Distance from Receptor (feet)	334	429	840
Time Duration Calculations			
Travel Speed (mph)	30	30	30
Travel Time per Trip within Non-Attainment Zone (hours)	0.00421	0.00542	0.01060
Trips per Hour	9	9	9
Total Travel Time within Non-Attainment Zone (hours)	0.0379	0.0488	0.0954
Results			
Non-Attainment Percent of one-Hour Period	3.8%	4.9%	9.5%
Maximum Allowable Non-Attainment Percentage	10%	10%	10%

Noise Attenuation Calculations			
Distances, Factors, Functions			
Source Noise Level (dBA)	80	80	80
Reference Distance from Source (d_o, meters)	15.24	15.24	15.24
Sound Propogation Distance-Source to Receptor (d_p, meters)	102	131	256
Attenuation Coeficient for Air Absorption (alpha, dB/meter)	0.000869	0.000869	0.000869
Ground Attenuation Factor, near source (G_s)	0.5	0.5	0.5
Ground Attenuation Factor, near receptor (G_r)	1	1	1
Ground Attenuation Factor, between source and receptor (G_m)	1	1	1
Ground Factor Function-Source Area (b', c', d')	7.6	6.1	2.2
Ground Factor Function-Receptor Area (b', c', d')	7.6	6.1	2.2
Ground Factor Function-Between Source and Receptor (q)	0.1	0.3	0.6
Height of Source (H_s, meters)	1.5	1.5	1.5
Height of Receptor (H_r, meters)	1.5	1.5	1.5
Sound Attenuation			
Attenuation due to Geometric Divergence (A_{div}, dBA)	16.5	18.7	24.5
Attenuation due to Atmospheric Absorption (A_{atm}, dBA)	0.1	0.1	0.2
Attenuation due to Ground Effect (A_{gr}, dBA)	8.4	6.2	0.2
Total Attenuation at Distance "d_p" (dBA)	**25**	**25**	**25**

Table 10

L_{50} Nighttime Truck Noise Calculation

Closest Receptor on Valley View Drive South of Mine

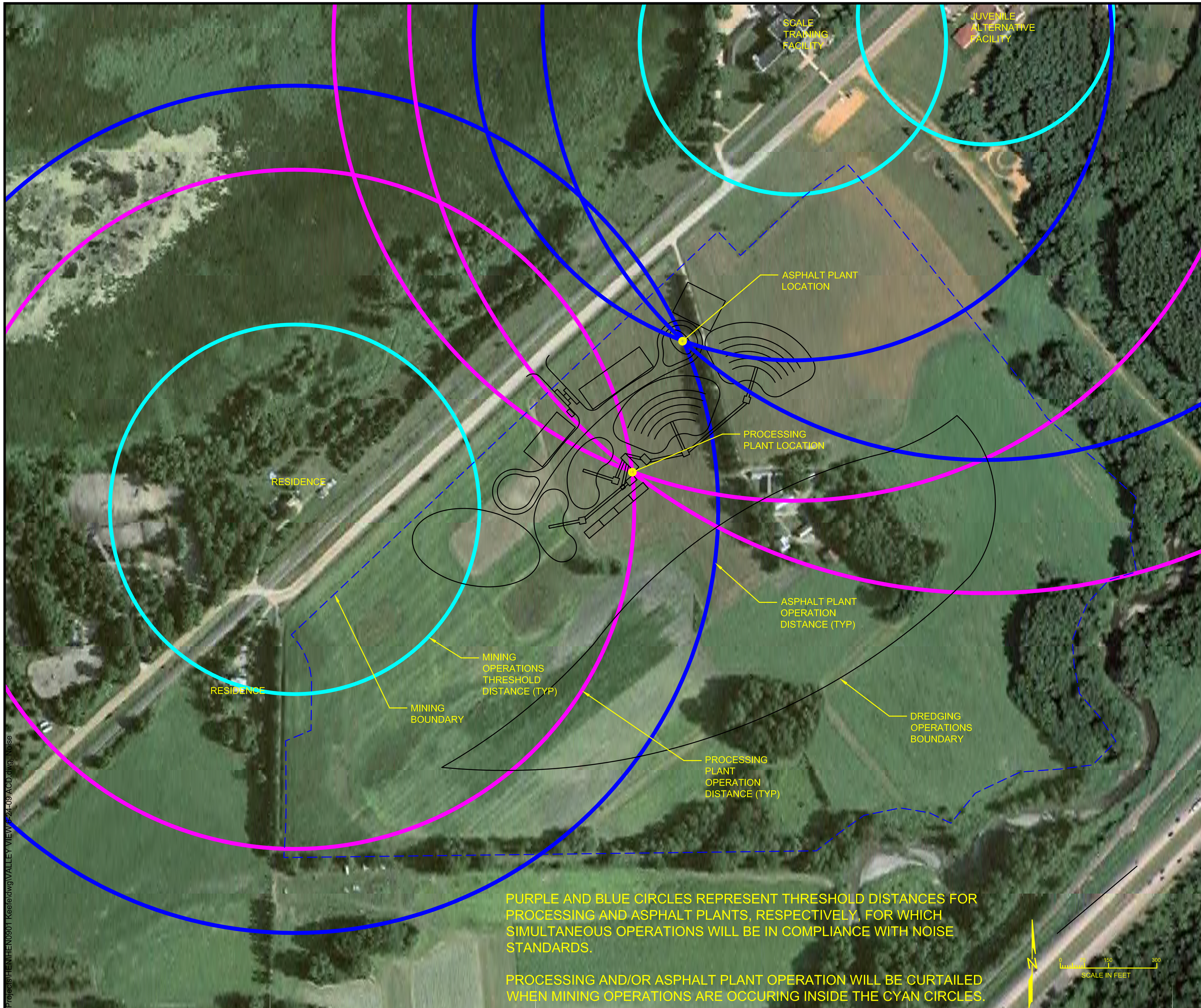
Proposed Mining Operation, Sand Creek Township, Scott County

17-Aug-10

	Truck Noise Frequency		
Noise Data	250 Hz	500 Hz	1000 Hz
Source Noise Level (dBA, 50 feet)	80	80	80
Noise Standard (L_{50} Nightime, dBA)	50	50	50
Required Attenuation (dBA)	30	30	30
Distance Data			
Receptor Distance from Road Centerline (feet)	24	24	24
Distance from Receptor at which Required Attenuation is Achieved (feet)	528	719	1,463
Corresponding Road Distance from Receptor (feet)	528	718	1,463
Time Duration Calculations			
Travel Speed (mph)	30	30	30
Travel Time per Trip within Non-Attainment Zone (hours)	0.00666	0.00907	0.01847
Trips per Hour	9	9	9
Total Travel Time within Non-Attainment Zone (hours)	0.0600	0.0816	0.1663
Results			
Non-Attainment Percent of one-Hour Period	6.0%	8.2%	16.6%
Maximum Allowable Non-Attainment Percentage	50%	50%	50%

Noise Attenuation Calculations			
Distances, Factors, Functions			
Source Noise Level (dBA)	80	80	80
Reference Distance from Source (d_o, meters)	15.24	15.24	15.24
Sound Propogation Distance-Source to Receptor (d_p, meters)	161	219	446
Attenuation Coeficient for Air Absorption (alpha, dB/meter)	0.000869	0.000869	0.000869
Ground Attenuation Factor, near source (G_s)	0.5	0.5	0.5
Ground Attenuation Factor, near receptor (G_r)	1	1	1
Ground Attenuation Factor, between source and receptor (G_m)	1	1	1
Ground Factor Function-Source Area (b', c', d')	8.2	6.4	2.2
Ground Factor Function-Receptor Area (b', c', d')	8.2	6.4	2.2
Ground Factor Function-Between Source and Receptor (q)	0.4	0.6	0.8
Height of Source (H_s, meters)	1.5	1.5	1.5
Height of Receptor (H_r, meters)	1.5	1.5	1.5
Sound Attenuation			
Attenuation due to Geometric Divergence (A_{div}, dBA)	20.5	23.1	29.3
Attenuation due to Atmospheric Absorption (A_{atm}, dBA)	0.1	0.2	0.4
Attenuation due to Ground Effect (A_{gr}, dBA)	9.4	6.6	0.2
Total Attenuation at Distance "d_p" (dBA)	**30**	**30**	**30**

Figures



REV	DATE	BY	DESCRIPTION

I HEREBY CERTIFY THAT THIS PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

JOHN R. MCCAIN

SIGNATURE ____________

DATE ________ REG. NO. 21835

McCain and Associates, Inc.
5300 Highway 12
Maple Plain, MN 55359
ph 952-346-3900
fx 952-346-3901

DWN JRM	DATE 09/01/09
DGN'R JRM	CHK'D NRB
PROJECT NO. HEN0901	
DRAWING NO. MINING_PLAN.DWG	

Figure 1
NOISE THRESHOLD DISTANCES
PROPOSED MINE SITE
SAND CREEK TOWNSHIP, SCOTT COUNTY, MINNESOTA

JORDAN AGGREGATES, LLC

SHT 1 of 1 SHTS

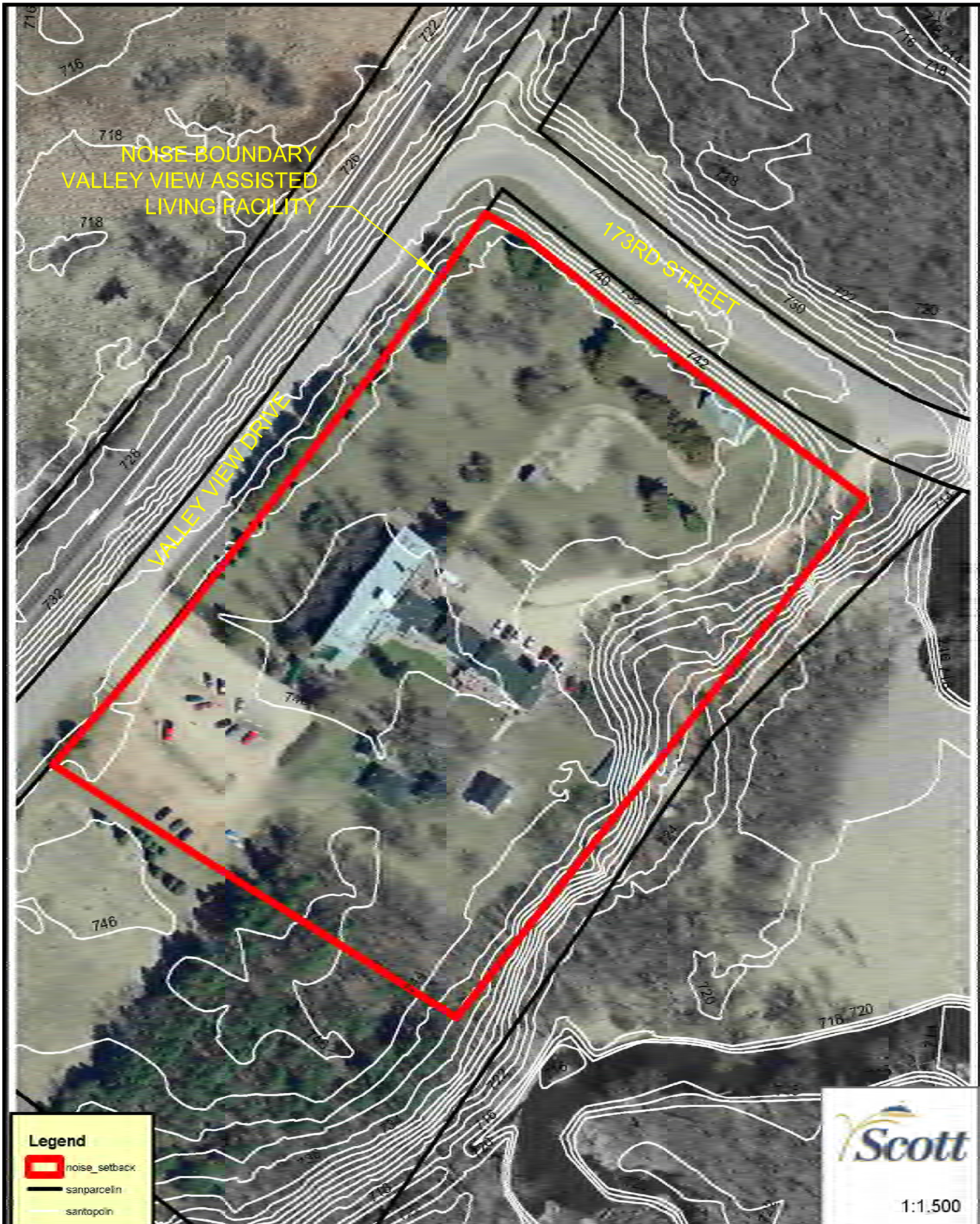


FIGURE 2
CLOSEST RECEPTOR
ROUTE 1
TRUCK TRAFFIC NOISE ANALYSIS
PROPOSED HENTGES MINE

McCain
and Associates, Inc.
5300 Highway 12, Maple Plain, MN 55359
ph 952-346-3900 fx 952-346-3901

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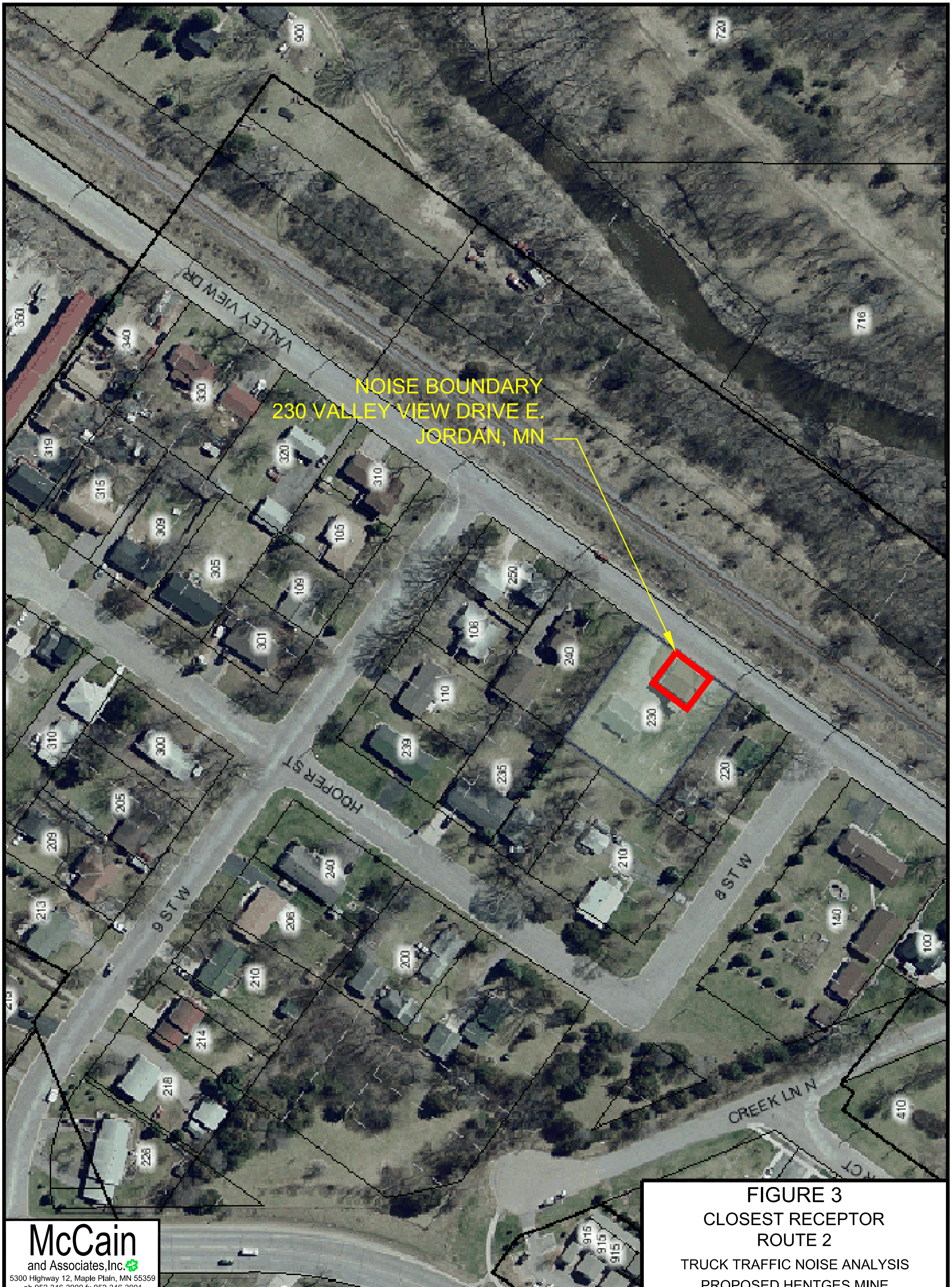

FIGURE 3
CLOSEST RECEPTOR
ROUTE 2
TRUCK TRAFFIC NOISE ANALYSIS
PROPOSED HENTGES MINE

McCain and Associates, Inc.
5300 Highway 12, Maple Plain, MN 55359
ph 952-346-3900 fx 952-346-3901

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Appendix A

ISO 9613-2, Acoustics—Attenuation of sound during propagation outdoors

Part 2: General Method of Calculation

INTERNATIONAL STANDARD

ISO 9613-2

First edition
1996-12-15

Acoustics — Attenuation of sound during propagation outdoors —

Part 2:
General method of calculation

Acoustique — Atténuation du son lors de sa propagation à l'air libre —

Partie 2: Méthode générale de calcul

Reference number
ISO 9613-2:1996(E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 9613-2 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

ISO 9613 consists of the following parts, under the general title *Acoustics — Attenuation of sound during propagation outdoors:*

— *Part 1: Calculation of the absorption of sound by the atmosphere*

— *Part 2: General method of calculation*

Part 1 is a detailed treatment restricted to the attenuation by atmospheric absorption processes. Part 2 is a more approximate and empirical treatment of a wider subject — the attenuation by all physical mechanisms.

Annexes A and B of this part of ISO 9613 are for information only.

International Organization for Standardization
Case Postale 56 • CH-1211 Genève 20 • Switzerland
Printed in Switzerland

Introduction

The ISO 1996 series of standards specifies methods for the description of noise outdoors in community environments. Other standards, on the other hand, specify methods for determining the sound power levels emitted by various noise sources, such as machinery and specified equipment (ISO 3740 series), or industrial plants (ISO 8297). This part of ISO 9613 is intended to bridge the gap between these two types of standard, to enable noise levels in the community to be predicted from sources of known sound emission. The method described in this part of ISO 9613 is general in the sense that it may be applied to a wide variety of noise sources, and covers most of the major mechanisms of attenuation. There are, however, constraints on its use, which arise principally from the description of environmental noise in the ISO 1996 series of standards.

Acoustics — Attenuation of sound during propagation outdoors —

Part 2:
General method of calculation

1 Scope

This part of ISO 9613 specifies an engineering method for calculating the attenuation of sound during propagation outdoors in order to predict the levels of environmental noise at a distance from a variety of sources. The method predicts the equivalent continuous A-weighted sound pressure level (as described in parts 1 to 3 of ISO 1996) under meteorological conditions favourable to propagation from sources of known sound emission.

These conditions are for downwind propagation, as specified in 5.4.3.3 of ISO 1996-2:1987 or, equivalently, propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs at night. Inversion conditions over water surfaces are not covered and may result in higher sound pressure levels than predicted from this part of ISO 9613.

The method also predicts a long-term average A-weighted sound pressure level as specified in ISO 1996-1 and ISO 1996-2. The long-term average A-weighted sound pressure level encompasses levels for a wide variety of meteorological conditions.

The method specified in this part of ISO 9613 consists specifically of octave-band algorithms (with nominal midband frequencies from 63 Hz to 8 kHz) for calculating the attenuation of sound which originates from a point sound source, or an assembly of point sources. The source (or sources) may be moving or stationary. Specific terms are provided in the algorithms for the following physical effects:

— geometrical divergence;
— atmospheric absorption;
— ground effect;
— reflection from surfaces;
— screening by obstacles.

Additional information concerning propagation through housing, foliage and industrial sites is given in annex A.

This method is applicable in practice to a great variety of noise sources and environments. It is applicable, directly or indirectly, to most situations concerning road or rail traffic, industrial noise sources, construction activities, and many other ground-based noise sources. It does not apply to sound from aircraft in flight, or to blast waves from mining, military or similar operations.

To apply the method of this part of ISO 9613, several parameters need to be known with respect to the geometry of the source and of the environment, the ground surface characteristics, and the source strength in terms of octave-band sound power levels for directions relevant to the propagation.

NOTE 1 If only A-weighted sound power levels of the sources are known, the attenuation terms for 500 Hz may be used to estimate the resulting attenuation.

The accuracy of the method and the limitations to its use in practice are described in clause 9.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 9613. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 9613 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1996-1:1982, *Acoustics — Description and measurement of environmental noise — Part 1: Basic quantities and procedures.*

ISO 1996-2:1987, *Acoustics — Description and measurement of environmental noise — Part 2: Acquisition of data pertinent to land use.*

ISO 1996-3:1987, *Acoustics — Description and measurement of environmental noise — Part 3: Application to noise limits.*

ISO 9613-1:1993, *Acoustics — Attenuation of sound during propagation outdoors — Part 1: Calculation of the absorption of sound by the atmosphere.*

IEC 651:1979, *Sound level meters*, and Amendment 1:1993.

3 Definitions

For the purposes of this part of ISO 9613, the definitions given in ISO 1996-1 and the following definitions apply. (See table 1 for symbols and units.)

3.1 equivalent continuous A-weighted sound pressure level, L_{AT}: Sound pressure level, in decibels, defined by equation (1):

$$L_{AT} = 10 \lg \left\{ \left[(1/T) \int_0^T p_A^2(t)\,\mathrm{d}t \right] \Big/ p_0^2 \right\} \text{ dB} \qquad \ldots (1)$$

where

$p_A(t)$ is the instantaneous A-weighted sound pressure, in pascals;

p_0 is the reference sound pressure (= 20×10^{-6} Pa);

T is a specified time interval, in seconds.

The A-frequency weighting is that specified for sound level meters in IEC 651.

NOTE 2 The time interval T should be long enough to average the effects of varying meteorological parameters. Two different situations are considered in this part of ISO 9613, namely short-term downwind and long-term overall averages.

Table 1 — Symbols and units

Symbol	Definition	Unit
A	octave-band attenuation	dB
C_{met}	meteorological correction	dB
d	distance from point source to receiver (see figure 3)	m
d_p	distance from point source to receiver projected onto the ground plane (see figure 1)	m
$d_{s,o}$	distance between source and point of reflection on the reflecting obstacle (see figure 8)	m
$d_{o,r}$	distance between point of reflection on the reflecting obstacle and receiver (see figure 8)	m
d_{ss}	distance from source to (first) diffraction edge (see figures 6 and 7)	m
d_{sr}	distance from (second) diffraction edge to receiver (see figures 6 and 7)	m
D_I	directivity index of the point sound source	—
D_z	screening attenuation	—
e	distance between the first and second diffraction edge (see figure 7)	m
G	ground factor	—
h	mean height of source and receiver	m
h_s	height of point source above ground (see figure 1)	m
h_r	height of receiver above ground (see figure 1)	m
h_m	mean height of the propagation path above the ground (see figure 3)	m
H_{max}	largest dimension of the sources	m
l_{min}	minimum dimension (length or height) of the reflecting plane (see figure 8)	m
L	sound pressure level	dB
α	atmospheric attenuation coefficient	dB/km
β	angle of incidence	rad
ρ	sound reflection coefficient	—

3.2 equivalent continuous downwind octave-band sound pressure level, L_{fT}(DW): Sound pressure level, in decibels, defined by equation (2):

$$L_{fT}(\mathrm{DW}) = 10 \lg \left\{ \left[(1/T) \int_0^T p_f^2(t)\,\mathrm{d}t \right] \Big/ p_0^2 \right\} \ \mathrm{dB} \qquad \ldots (2)$$

where $p_f(t)$ is the instantaneous octave-band sound pressure downwind, in pascals, and the subscript f represents a nominal midband frequency of an octave-band filter.

NOTE 3 The electrical characteristics of the octave-band filters should comply at least with the class 2 requirements of IEC 1260.

3.3 insertion loss (of a barrier): Difference, in decibels, between the sound pressure levels at a receiver in a specified position under two conditions:

a) with the barrier removed, and

b) with the barrier present (inserted),

and no other significant changes that affect the propagation of sound.

4 Source description

The equations to be used are for the attenuation of sound from point sources. Extended noise sources, therefore, such as road and rail traffic or an industrial site (which may include several installations or plants, together with traffic moving on the site) shall be represented by a set of sections (cells), each having a certain sound power and directivity. Attenuation calculated for sound from a representative point within a section is used to represent the attenuation of sound from the entire section. A line source may be divided into line sections, an area source into area sections, each represented by a point source at its centre.

However, a group of point sources may be described by an equivalent point sound source situated in the middle of the group, in particular if

a) the sources have approximately the same strength and height above the local ground plane,

b) the same propagation conditions exist from the sources to the point of reception, and

c) the distance d from the single equivalent point source to the receiver exceeds twice the largest dimension H_{max} of the sources ($d > 2H_{max}$).

If the distance d is smaller ($d \leqslant 2H_{max}$), or if the propagation conditions for the component point sources are different (e.g. due to screening), the total sound source shall be divided into its component point sources.

NOTE 4 In addition to the real sources described above, image sources will be introduced to describe the reflection of sound from walls and ceilings (but not by the ground), as described in 7.5.

5 Meteorological conditions

Downwind propagation conditions for the method specified in this part of ISO 9613 are as specified in 5.4.3.3 of ISO 1996-2:1987, namely

— wind direction within an angle of ± 45° of the direction connecting the centre of the dominant sound source and the centre of the specified receiver region, with the wind blowing from source to receiver, and

— wind speed between approximately 1 m/s and 5 m/s, measured at a height of 3 m to 11 m above the ground.

The equations for calculating the average downwind sound pressure level L_{AT}(DW) in this part of ISO 9613, including the equations for attenuation given in clause 7, are the average for meteorological conditions within these limits. The term average here means the average over a short time interval, as defined in 3.1.

These equations also hold, equivalently, for average propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs on clear, calm nights.

6 Basic equations

The equivalent continuous downwind octave-band sound pressure level at a receiver location, L_{fT}(DW), shall be calculated for each point source, and its image sources, and for the eight octave bands with nominal midband frequencies from 63 Hz to 8 kHz, from equation (3):

$$L_{fT}(\mathrm{DW}) = L_W + D_c - A \qquad \ldots (3)$$

where

L_W is the octave-band sound power level, in decibels, produced by the point sound source relative to a reference sound power of one picowatt (1 pW);

D_c is the directivity correction, in decibels, that describes the extent by which the equivalent continuous sound pressure level from the point sound source deviates in a specified direction from the level of an omnidirectional point sound source producing sound power level L_W; D_c equals the directivity index D_I of the point sound source plus an index D_Ω that accounts for sound propagation into solid angles less than 4π steradians; for an omnidirectional point sound source radiating into free space, D_c = 0 dB;

A is the octave-band attenuation, in decibels, that occurs during propagation from the point sound source to the receiver.

NOTES

5 The letter symbol A (in italic type) signifies attenuation in this part of ISO 9613 except in subscripts, where it designates the A-frequency weighting (in roman type).

6 Sound power levels in equation (3) may be determined from measurements, for example as described in the ISO 3740 series (for machinery) or in ISO 8297 (for industrial plants).

The attenuation term A in equation (3) is given by equation (4):

$$A = A_{div} + A_{atm} + A_{gr} + A_{bar} + A_{misc} \quad \ldots (4)$$

where

A_{div} is the attenuation due to geometrical divergence (see 7.1);

A_{atm} is the attenuation due to atmospheric absorption (see 7.2);

A_{gr} is the attenuation due to the ground effect (see 7.3);

A_{bar} is the attenuation due to a barrier (see 7.4);

A_{misc} is the attenuation due to miscellaneous other effects (see annex A).

General methods for calculating the first four terms in equation (4) are specified in this part of ISO 9613. Information on three contributions to the last term, A_{misc} (the attenuation due to propagation through foliage, industrial sites and areas of houses), is given in annex A.

The equivalent continuous A-weighted downwind sound pressure level shall be obtained by summing the contributing time-mean-square sound pressures calculated according to equations (3) and (4) for each point sound source, for each of their image sources, and for each octave band, as specified by equation (5):

$$L_{AT}(\mathrm{DW}) = 10 \lg \left\{ \sum_{i=1}^{n} \left[\sum_{j=1}^{8} 10^{0,1\left[L_{fT}(ij) + A_f(j)\right]} \right] \right\} \ \mathrm{dB} \quad \ldots (5)$$

where

n is the number of contributions i (sources and paths);

j is an index indicating the eight standard octave-band midband frequencies from 63 Hz to 8 kHz;

A_f denotes the standard A-weighting (see IEC 651).

The long-term average A-weighted sound pressure level L_{AT}(LT) shall be calculated according to

$$L_{AT}(\mathrm{LT}) = L_{AT}(\mathrm{DW}) - C_{met} \quad \ldots (6)$$

where C_{met} is the meteorological correction described in clause 8.

The calculation and significance of the various terms in equations (1) to (6) are explained in the following clauses. For a more detailed treatment of the attenuation terms, see the literature references given in annex B.

7 Calculation of the attenuation terms

7.1 Geometrical divergence (A_{div})

The geometrical divergence accounts for spherical spreading in the free field from a point sound source, making the attenuation, in decibels, equal to

$$A_{div} = \left[20 \lg(d/d_0) + 11\right] \ \mathrm{dB} \quad \ldots (7)$$

where

d is the distance from the source to receiver, in metres;

d_0 is the reference distance (= 1 m).

NOTE 7 The constant in equation (7) relates the sound power level to the sound pressure level at a reference distance d_0 which is 1 m from an omnidirectional point sound source.

7.2 Atmospheric absorption (A_{atm})

The attenuation due to atmospheric absorption A_{atm}, in decibels, during propagation through a distance d, in metres, is given by equation (8):

$$A_{atm} = \alpha d / 1\,000 \qquad \ldots (8)$$

where α is the atmospheric attenuation coefficient, in decibels per kilometre, for each octave band at the midband frequency (see table 2).

For values of α at atmospheric conditions not covered in table 2, see ISO 9613-1.

NOTES

8 The atmospheric attenuation coefficient depends strongly on the frequency of the sound, the ambient temperature and relative humidity of the air, but only weakly on the ambient pressure.

9 For calculation of environmental noise levels, the atmospheric attenuation coefficient should be based on average values determined by the range of ambient weather which is relevant to the locality.

7.3 Ground effect (A_{gr})

7.3.1 General method of calculation

Ground attenuation, A_{gr}, is mainly the result of sound reflected by the ground surface interfering with the sound propagating directly from source to receiver. The downward-curving propagation path (downwind) ensures that this attenuation is determined primarily by the ground surfaces near the source and near the receiver. This method of calculating the ground effect is applicable only to ground which is approximately flat, either horizontally or with a constant slope. Three distinct regions for ground attenuation are specified (see figure 1):

a) the source region, stretching over a distance from the source towards the receiver of $30h_s$, with a maximum distance of d_p (h_s is the source height, and d_p the distance from source to receiver, as projected on the ground plane);

b) the receiver region, stretching over a distance from the receiver back towards the source of $30h_r$, with a maximum distance of d_p (h_r is the receiver height);

c) a middle region, stretching over the distance between the source and receiver regions. If $d_p < (30h_s + 30h_r)$, the source and receiver regions will overlap, and there is no middle region.

According to this scheme, the ground attenuation does not increase with the size of the middle region, but is mostly dependent on the properties of source and receiver regions.

The acoustical properties of each ground region are taken into account through a ground factor G. Three categories of reflecting surface are specified as follows.

Table 2 — Atmospheric attenuation coefficient α for octave bands of noise

Temperature	Relative humidity	Atmospheric attenuation coefficient α, dB/km							
		Nominal midband frequency, Hz							
°C	%	63	125	250	500	1 000	2 000	4 000	8 000
10	70	0,1	0,4	1,0	1,9	3,7	9,7	32,8	117
20	70	0,1	0,3	1,1	2,8	5,0	9,0	22,9	76,6
30	70	0,1	0,3	1,0	3,1	7,4	12,7	23,1	59,3
15	20	0,3	0,6	1,2	2,7	8,2	28,2	88,8	202
15	50	0,1	0,5	1,2	2,2	4,2	10,8	36,2	129
15	80	0,1	0,3	1,1	2,4	4,1	8,3	23,7	82,8

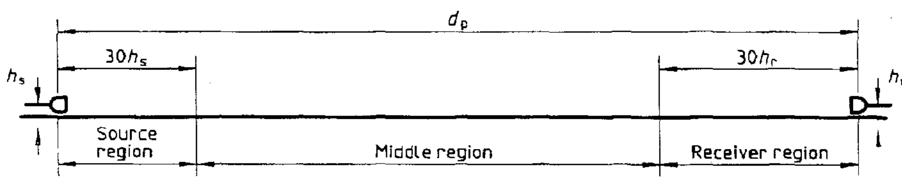


Figure 1 — Three distinct regions for determination of ground attenuation

a) **Hard ground,** which includes paving, water, ice, concrete and all other ground surfaces having a low porosity. Tamped ground, for example, as often occurs around industrial sites, can be considered hard. For hard ground $G = 0$.

NOTE 10 It should be recalled that inversion conditions over water are not covered by this part of ISO 9613.

b) **Porous ground,** which includes ground covered by grass, trees or other vegetation, and all other ground surfaces suitable for the growth of vegetation, such as farming land. For porous ground $G = 1$.

c) **Mixed ground:** if the surface consists of both hard and porous ground, then G takes on values ranging from 0 to 1, the value being the fraction of the region that is porous.

To calculate the ground attenuation for a specific octave band, first calculate the component attenuations A_s for the source region specified by the ground factor G_s (for that region), A_r for the receiver region specified by the ground factor G_r, and A_m for the middle region specified by the ground factor G_m, using the expressions in table 3. (Alternatively, the functions a', b', c' and d' in table 3 may be obtained directly from the curves in figure 2.) The total ground attenuation for that octave band shall be obtained from equation (9):

$$A_{gr} = A_s + A_r + A_m \qquad \ldots (9)$$

NOTE 11 In regions with buildings, the influence of the ground on sound propagation may be changed (see A.3).

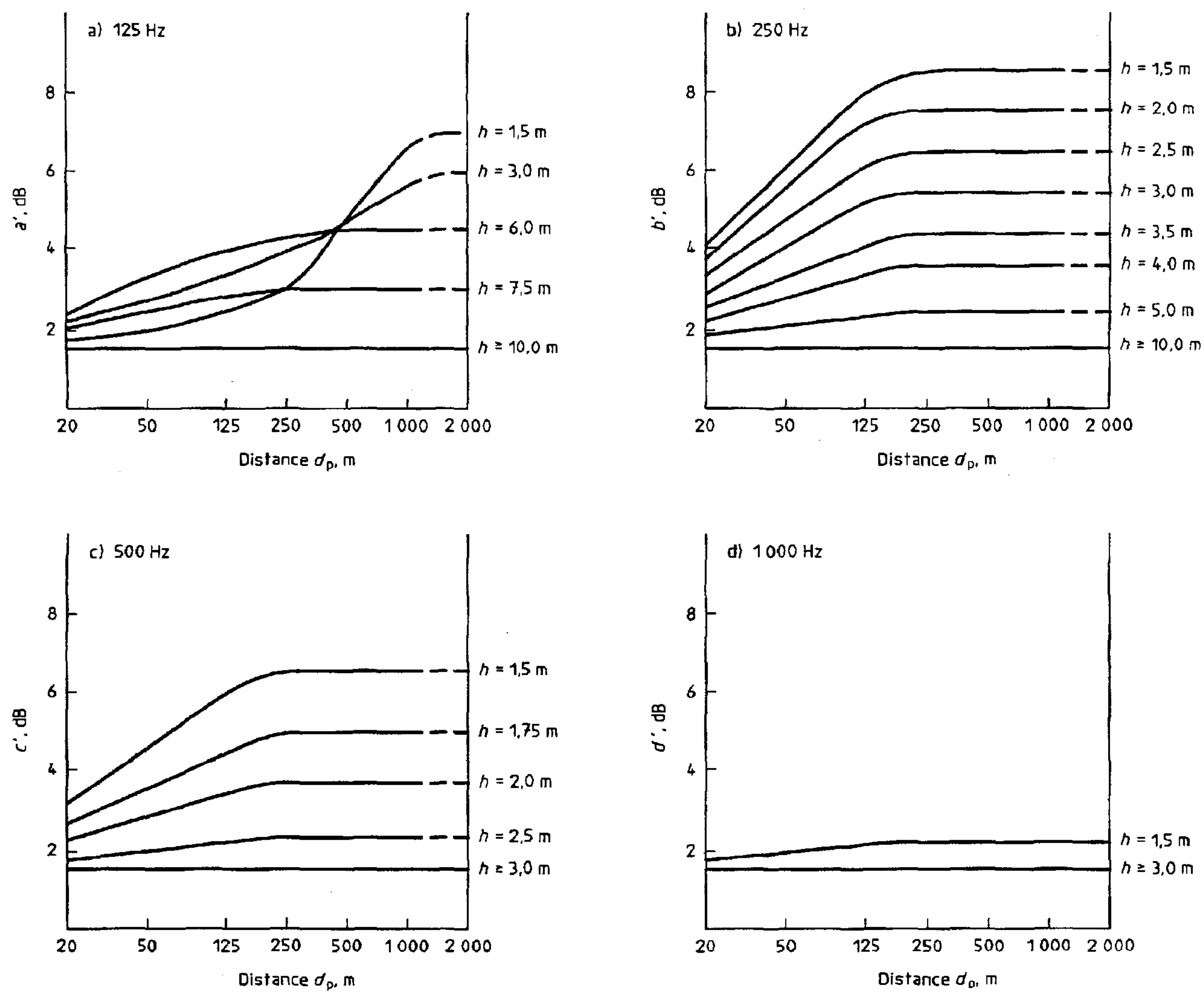


Figure 2 — Functions a', b', c' and d' representing the influence of the source-to-receiver distance d_p and the source or receiver height h, respectively, on the ground attenuation A_{gr} (computed from equations in table 3)

Table 3 — Expressions to be used for calculating ground attenuation contributions A_s, A_r and A_m in octave bands

Nominal midband frequency Hz	A_s or A_r 1) dB	A_m dB
63	$-1,5$	$-3q$ 2)
125	$-1,5 + G \times a'(h)$	
250	$-1,5 + G \times b'(h)$	
500	$-1,5 + G \times c'(h)$	
1 000	$-1,5 + G \times d(h)$	$-3q(1 - G_m)$
2 000	$-1,5(1 - G)$	
4 000	$-1,5(1 - G)$	
8 000	$-1,5(1 - G)$	

NOTES

$$a'(h) = 1,5 + 3,0 \times e^{-0,12(h-5)^2}\left(1 - e^{-d_p/50}\right) + 5,7 \times e^{-0,09h^2}\left(1 - e^{-2,8 \times 10^{-6} \times d_p^2}\right)$$

$$b'(h) = 1,5 + 8,6 \times e^{-0,09h^2}\left(1 - e^{-d_p/50}\right)$$

$$c'(h) = 1,5 + 14,0 \times e^{-0,46h^2}\left(1 - e^{-d_p/50}\right)$$

$$d'(h) = 1,5 + 5,0 \times e^{-0,9h^2}\left(1 - e^{-d_p/50}\right)$$

1) For calculating A_s, take $G = G_s$ and $h = h_s$. For calculating A_r, take $G = G_r$ and $h = h_r$. See 7.3.1 for values of G for various ground surfaces.

2) $q = 0$ when $d_p \leqslant 30(h_s + h_r)$

$$q = 1 - \frac{30(h_s + h_r)}{d_p} \quad \text{when } d_p > 30(h_s + h_r)$$

where d_p is the source-to-receiver distance, in metres, projected onto the ground planes.

7.3.2 Alternative method of calculation for A-weighted sound pressure levels

Under the following specific conditions

— only the A-weighted sound pressure level at the receiver position is of interest,

— the sound propagation occurs over porous ground or mixed ground most of which is porous (see 7.3.1),

— the sound is not a pure tone,

and for ground surfaces of any shape, the ground attenuation may be calculated from equation (10):

$$A_{gr} = 4,8 - (2h_m/d)\left[17 + (300/d)\right] \geqslant 0 \text{ dB} \quad \ldots (10)$$

where

h_m is the mean height of the propagation path above the ground, in metres;

d is the distance from the source to receiver, in metres.

The mean height h_m may be evaluated by the method shown in figure 3. Negative values for A_{gr} from equation (10) shall be replaced by zeros.

NOTE 12 For short distances d, equation (10) predicts no attenuation and equation (9) may be more accurate.

When the ground attenuation is calculated using equation (10), the directivity correction D_c in equation (3) shall include a term D_Ω, in decibels, to account for the apparent increase in sound power level of the source due to reflections from the ground near the source.

$$D_\Omega = 10 \lg \left\{1 + \left[d_p^2 + (h_s - h_r)^2\right] \Big/ \left[d_p^2 + (h_s + h_r)^2\right]\right\} \text{dB} \quad \ldots (11)$$

where

h_s is the height of the source above the ground, in metres;

h_r is the height of the receiver above the ground, in metres;

d_p is the source-to-receiver distance projected onto the ground plane, in metres.

7.4 Screening (A_{bar})

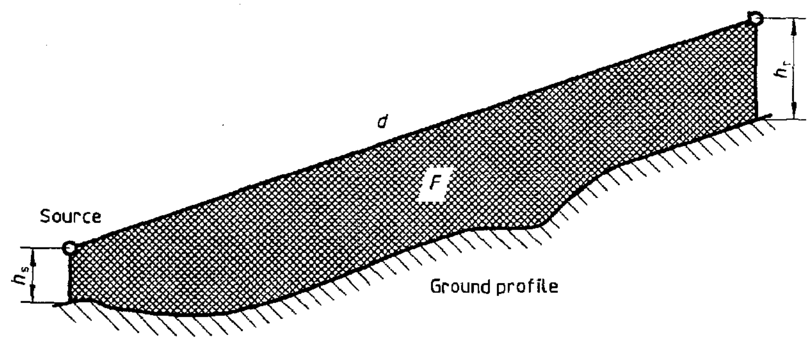
An object shall be taken into account as a screening obstacle (often called a barrier) if it meets the following requirements:

— the surface density is at least 10 kg/m²;

— the object has a closed surface without large cracks or gaps (consequently process installations in chemical plants, for example, are ignored);

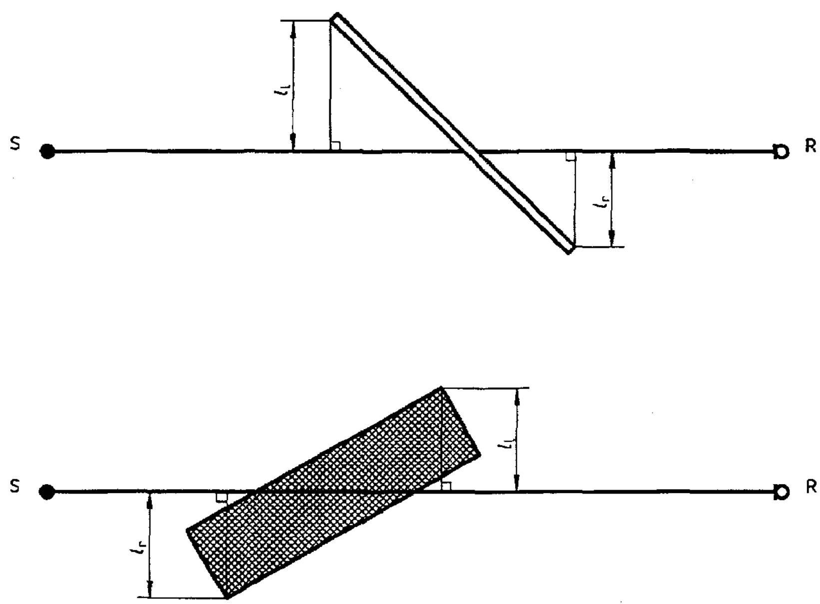
— the horizontal dimension of the object normal to the source-receiver line is larger than the acoustic wavelength λ at the nominal midband frequency for the octave band of interest; in other words $l_l + l_r > \lambda$ (see figure 4).

Each object that fulfils these requirements shall be represented by a barrier with vertical edges. The top edge of the barrier is a straight line that may be sloping.



$h_m = F/d$, where F is the area

Figure 3 — Method for evaluating the mean height h_m



NOTE — An object is only considered to be a screening obstacle when its horizontal dimension perpendicular to the source-receiver line SR is larger than the wavelength: $(l_l + l_r) > \lambda$

Figure 4 — Plan view of two obstacles between the source (S) and the receiver (R)

For the purposes of this part of ISO 9613, the attenuation by a barrier, A_{bar}, shall be given by the insertion loss. Diffraction over the top edge and around a vertical edge of a barrier may both be important. (See figure 5.) For downwind sound propagation, the effect of diffraction (in decibels) over the top edge shall be calculated by

$$A_{bar} = D_z - A_{gr} > 0 \quad \ldots (12)$$

and for diffraction around a vertical edge by

$$A_{bar} = D_z > 0 \quad \ldots (13)$$

where

D_z is the barrier attenuation for each octave band [see equation (14)];

A_{gr} is the ground attenuation **in the absence of the barrier** (i.e. with the screening obstacle removed) (see 7.3).

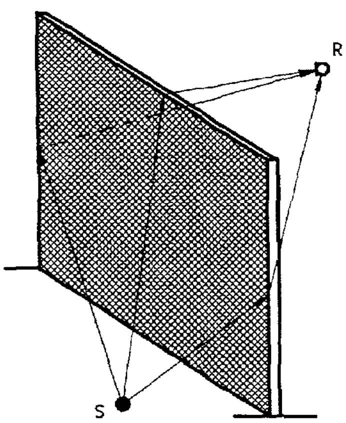


Figure 5 — Different sound propagation paths at a barrier

NOTES

13 When A_{bar} as defined by equation (12) is substituted in equation (4) to find the total attenuation A, the two A_{gr} terms in equation (4) will cancel. The barrier attenuation D_z in equation (12) then includes the effect of the ground in the presence of the barrier.

14 For large distances and high barriers, the insertion loss calculated by equation (12) is not sufficiently confirmed by measurements.

15 In calculation of the insertion loss for multisource industrial plants by high buildings (more than 10 m above the ground), and also for high-noise sources within the plant, equation (13) should be used in both cases for determining the long-term average sound pressure level [using equation (6)].

16 For sound from a depressed highway, there may be attenuation in addition to that indicated by equation (12) along a ground surface outside the depression, due to that ground surface.

To calculate the barrier attenuation D_z, assume that only one significant sound-propagation path exists from the sound source to the receiver. If this assumption is not valid, separate calculations are required for other propagation paths (as illustrated in figure 5) and the contributions from the various paths to the squared sound pressure at the receiver are summed.

The barrier attenuation D_z, in decibels, shall be calculated for this path by equation (14):

$$D_z = 10 \lg \left[3 + (C_2/\lambda) C_3 z K_{met}\right] \text{ dB} \quad \ldots (14)$$

where

C_2 is equal to 20, and includes the effect of ground reflections; if in special cases ground reflections are taken into account separately by image sources, $C_2 = 40$;

C_3 is equal to 1 for single diffraction (see figure 6);

$$C_3 = \left[1 + (5\lambda/e)^2\right] \Big/ \left[(1/3) + (5\lambda/e)^2\right] \quad \ldots (15)$$

for double diffraction (see figure 7);

λ is the wavelength of sound at the nominal midband frequency of the octave band, in metres;

z is the difference between the pathlengths of diffracted and direct sound, as calculated by equations (16) and (17), in metres;

K_{met} is the correction factor for meteorological effects, given by equation (18);

e is the distance between the two diffraction edges in the case of double diffraction (see figure 7).

For single diffraction, as shown in figure 6, the pathlength difference z shall be calculated by means of equation (16):

$$z = \left[(d_{ss} + d_{sr})^2 + a^2\right]^{1/2} - d \quad \ldots (16)$$

where

d_{ss} is the distance from the source to the (first) diffraction edge, in metres;

d_{sr} is the distance from the (second) diffraction edge to the receiver, in metres;

a is the component distance parallel to the barrier edge between source and receiver, in metres.

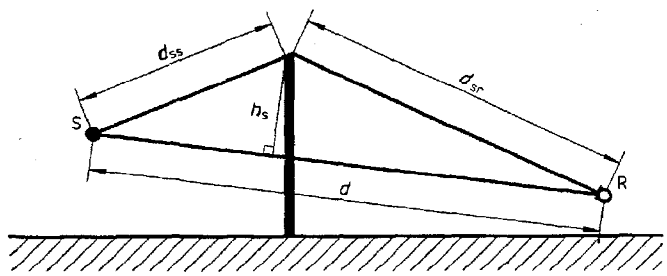


Figure 6 — Geometrical quantities for determining the pathlength difference for single diffraction

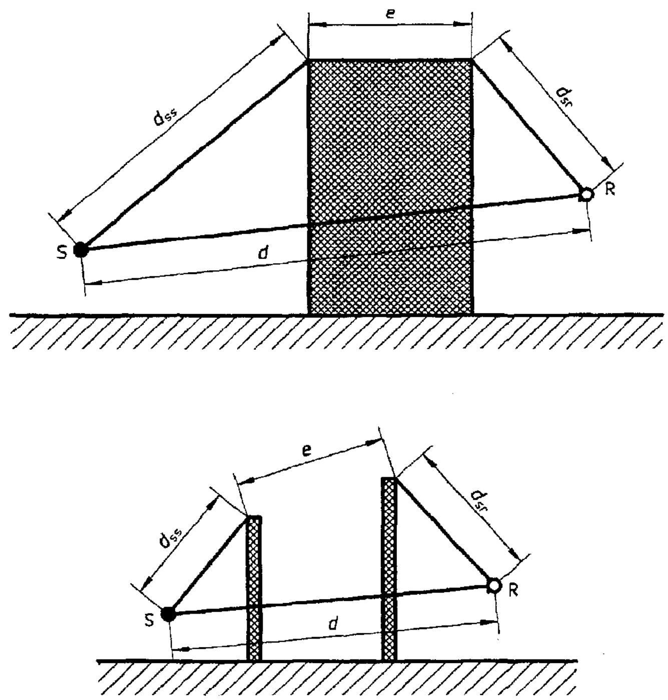


Figure 7 — Geometrical quantities for determining the pathlength difference for double diffraction

If the line of sight between the source S and receiver R passes above the top edge of the barrier, z is given a negative sign.

For double diffraction, as shown in figure 7, the pathlength difference z shall be calculated by

$$z = \left[\left(d_{ss} + d_{sr} + e \right)^2 + a^2 \right]^{1/2} - d \qquad \ldots (17)$$

The correction factor K_{met} for meteorological conditions in equation (14) shall be calculated using equation (18):

$$K_{met} = \exp\left[- (1/2000) \sqrt{d_{ss} d_{sr} d/(2z)} \right] \quad \text{for } z > 0 \qquad \ldots (18)$$

$$K_{met} = 1 \quad \text{for } z \leqslant 0$$

For lateral diffraction around obstacles, it shall be assumed that $K_{met} = 1$ (see figure 5).

NOTES

17 For source-to-receiver distances less than 100 m, the calculation using equation (14) shows that K_{met} may be assumed equal to 1, to an accuracy of 1 dB.

18 Equation (15) provides a continuous transition from the case of single diffraction ($e = 0$) where $C_3 = 1$, to that of a well-separated double diffraction ($e \gg \lambda$) where $C_3 = 3$.

19 A barrier may be less effective than calculated by equations (12) to (18) as a result of reflections from other acoustically hard surfaces near the sound path from the source to the receiver or by multiple reflections between an acoustically hard barrier and the source.

The barrier attenuation D_z, in any octave band, should not be taken to be greater than 20 dB in the case of single diffraction (i.e. thin barriers) and 25 dB in the case of double diffraction (i.e. thick barriers).

The barrier attenuation for two barriers is calculated using equation (14) for double diffraction, as indicated in the lower part of figure 7. The barrier attenuation for more than two barriers may also be calculated approximately using equation (14), by choosing the two most effective barriers, neglecting the effects of the others.

7.5 Reflections

Reflections are considered here in terms of image sources. These reflections are from outdoor ceilings and more or less vertical surfaces, such as the façades of buildings, which can increase the sound pressure levels at the receiver. The effect of reflections from the ground are not included because they enter into the calculation of A_{gr}.

The reflections from an obstacle shall be calculated for all octave bands for which all the following requirements are met:

— a specular reflection can be constructed, as shown in figure 8;

— the magnitude of the sound reflection coefficient for the surface of the obstacle is greater than 0,2;

— the surface is large enough for the nominal midband wavelength λ (in metres) for the octave band under consideration to obey the relationship

$$1/\lambda > \left[2/\left(l_{min}\cos\beta\right)^2\right]\left[d_{s,o}d_{o,r}/\left(d_{s,o}+d_{o,r}\right)\right] \quad \ldots (19)$$

where

λ is the wavelength of sound (in metres) at the nominal midband frequency f (in hertz) of the octave band $\left(\lambda = \dfrac{340\ \text{m/s}}{f}\right)$;

$d_{s,o}$ is the distance between the source and the point of reflection on the obstacle;

$d_{o,r}$ is the distance between the point of reflection on the obstacle and the receiver;

β is the angle of incidence, in radians (see figure 8);

l_{min} is the minimum dimension (length or height) of the reflecting surface (see figure 8).

If any of these conditions is not met for a given octave band, then reflections shall be neglected.

The real source and source image are handled separately. The sound power level of the source image $L_{W,im}$ shall be calculated from

$$L_{W,im} = L_W + 10\lg(\rho)\ \text{dB} + D_{Ir} \quad \ldots (20)$$

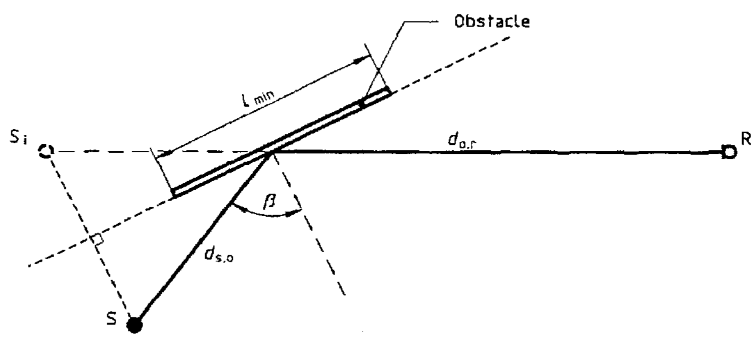
where

ρ is the sound reflection coefficient at angle β on the surface of the obstacle ($\geqslant 0,2$) (see figure 8);

D_{Ir} is the directivity index of the source in the direction of the receiver image.

If specific data for the sound reflection coefficient are not available, the value may be estimated using table 4.

For the sound source image, the attenuation terms of equation (4), as well as ρ and D_{Ir} in equation (20), shall be determined according to the propagation path of the reflected sound.



NOTE — A path $d_{s,o} + d_{o,r}$ connecting the source S and receiver R by reflection from the obstacle exists in which β, the angle of incidence, is equal to the angle of reflection. The reflected sound appears to come from the source image S_i.

Figure 8 — Specular reflection from an obstacle

Table 4 — Estimates of the sound reflection coefficient ρ

Object	ρ
Flat hard walls	1
Walls of building with windows and small additions or bay	0,8
Factory walls with 50 % of the surface consisting of openings, installations or pipes	0,4
Cylinders with hard surfaces (tanks, silos)	$\frac{D \sin(\phi/2)}{2d_{sc}}$ *) where D is the diameter of the cylinder; d_{sc} is the distance from the source to the centre C of the cylinder; ϕ is the supplement of the angle between lines SC and CR.
Open installations (pipes, towers, etc.)	0

*) This expression applies only if the distance d_{sc} from the source S to cylinder C is much smaller than the distance d_{cr} from the cylinder to receiver; see figure 9.

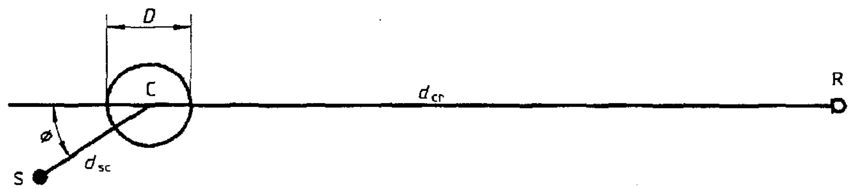


Figure 9 — Estimation of sound reflection coefficient for a cylinder

8 Meteorological correction (C_{met})

Use of equation (3) leads directly to an equivalent continuous A-weighted sound pressure level L_{AT} at the receiver for meteorological conditions which are favourable for propagation from the sound source to that receiver, as described in clause 5. This may be the appropriate condition for meeting a specific community noise limit, i.e. a level which is seldom exceeded (see ISO 1996-3). Often, however, a long-term average A-weighted sound pressure level L_{AT}(LT) is required, where the time interval T is several months or a year. Such a period will normally include a variety of meteorological conditions, both favourable and unfavourable to propagation. A value for L_{AT}(LT) may be obtained in this situation from that calculated for L_{AT}(DW) via equation (3), by using the meteorological correction C_{met} in equation (6).

A value (in decibels) for C_{met} in equation (6) may be calculated using equations (21) and (22) for the case of a point sound source with an output which is effectively constant with time:

$$C_{met} = 0 \quad \ldots (21)$$

if $d_p \leqslant 10(h_s + h_r)$

$$C_{met} = C_0 \left[1 - 10(h_s + h_r)/d_p\right] \quad \ldots (22)$$

if $d_p > 10(h_s + h_r)$

where

h_s is the source height, in metres;

h_r is the receiver height, in metres;

d_p is the distance between the source and receiver projected to the horizontal ground plane, in metres;

C_0 is a factor, in decibels, which depends on local meteorological statistics for wind speed and direction, and temperature gradients.

The effects of meteorological conditions on sound propagation are small for short distances d_p, and for longer distances at greater source and receiver heights. Equations (21) and (22) account approximately for these factors, as shown in figure 10.

Values in metres

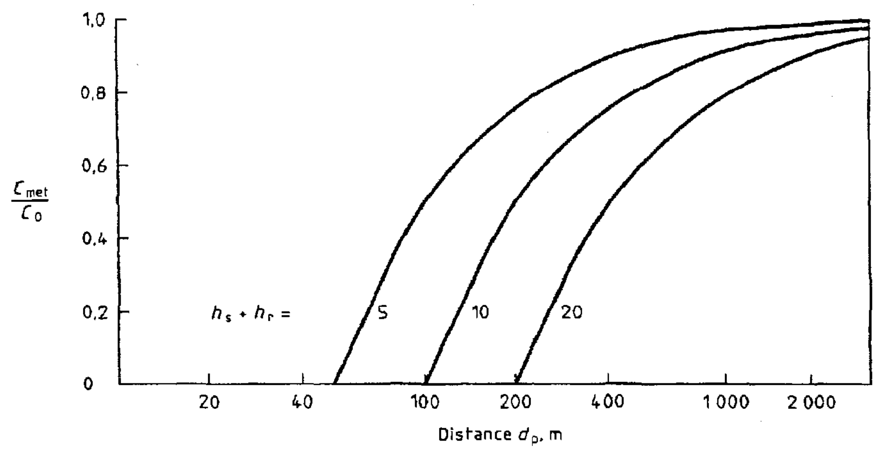


Figure 10 — Meteorological correction C_{met}

NOTES

20 A value for C_0 in equations (21) and (22) may be estimated from an elementary analysis of the local meteorological statistics. For example, if the meteorological conditions favourable to propagation described in clause 5 are found to occur for 50 % of the time period of interest, and the attenuation during the other 50 % is higher by 10 dB or more, then the sound energy which arrives for meteorological conditions unfavourable to propagation may be neglected, and C_0 will be approximately + 3 dB.

21 The meteorological conditions for evaluating C_0 may be established by the local authorities.

22 Experience indicates that values of C_0 in practice are limited to the range from zero to approximately + 5 dB, and values in excess of 2 dB are exceptional. Thus only very elementary statistics of the local meteorology are needed for a ± 1 dB accuracy in C_0.

For a source that is composed of several component point sources, h_s in equations (21) and (22) represents the predominant source height, and d_p the distance from the centre of that source to the receiver.

9 Accuracy and limitations of the method

The attenuation of sound propagating outdoors between a fixed source and receiver fluctuates due to variations in the meteorological conditions along the propagation path. Restricting attention to moderate downwind conditions of propagation, as specified in clause 5, limits the effect of variable meteorological conditions on attenuation to reasonable values.

There is information to support the method of calculation given in clauses 4 to 8 (see annex B) for broadband noise sources. The agreement between calculated and measured values of the average A-weighted sound pressure level for downwind propagation, L_{AT}(DW), supports the estimated accuracy of calculation shown in table 5. These estimates of accuracy are restricted to the range of conditions specified for the validity of the equations in clauses 3 to 8 and are independent of uncertainties in sound power determination.

NOTE 24 The estimates of accuracy in table 5 are for downwind conditions averaged over independent situations (as specified in clause 5). They should not necessarily be expected to agree with the variation in measurements made at a given site on a given day. The latter can be expected to be considerably larger than the values in table 5.

The estimated errors in calculating the average downwind octave-band sound pressure levels, as well as pure-tone sound pressure levels, under the same conditions, may be somewhat larger than the estimated errors given for A-weighted sound pressure levels of broad-band sources in table 5.

In table 5, an estimate of accuracy is not provided in this part of ISO 9613 for distances d greater than the 1 000 m upper limit.

Throughout this part of ISO 9613 the meteorological conditions under consideration are limited to only two cases:

a) moderate downwind conditions of propagation, or their equivalent, as defined in clause 5;

b) a variety of meteorological conditions as they exist over months or years.

The use of equations (1) to (5) and (7) to (20) (and therefore also table 5) is limited to case a): meteorological conditions only. Case b) is relevant only to the use of equations (6), (21) and (22). There are also a substantial number of limitations (non-meteorological) in the use of individual equations. Equation (9) is, for example, limited to approximately flat terrain. These specific limitations are described in the text accompanying the relevant equation.

Table 5 — Estimated accuracy for broadband noise of L_{AT}(DW) calculated using equations (1) to (10)

Height, h *)	**Distance, d *)**	
	$0 < d < 100$ m	100 m $< d < 1\ 000$ m
$0 < h < 5$ m	± 3 dB	± 3 dB
5 m $< h < 30$ m	± 1 dB	± 3 dB

*) h is the mean height of the source and receiver.
d is the distance between the source and receiver.

NOTE — These estimates have been made from situations where there are no effects due to reflection or attenuation due to screening.

Annex A
(informative)

Additional types of attenuation (A_{misc})

The term A_{misc} in equation (4) covers contributions to the attenuation from miscellaneous effects not accessible by the general methods of calculating the attenuation specified in clause 7. These contributions include

— A_{fol}, the attenuation of sound during propagation through foliage,

— A_{site}, the attenuation during propagation through an industrial site, and

— A_{hous}, the attenuation during propagation through a built-up region of houses,

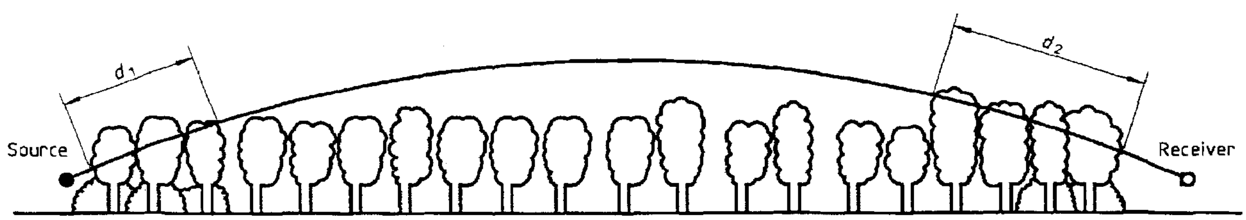
which are all considered in this annex.

For calculating these additional contributions to the attenuation, the curved downwind propagation path may be approximated by an arc of a circle of radius 5 km, as shown in figure A.1.

A.1 Foliage (A_{fol})

The foliage of trees and shrubs provides a small amount of attenuation, but only if it is sufficiently dense to completely block the view along the propagation path, i.e. when it is impossible to see a short distance through the foliage. The attenuation may be by vegetation close to the source, or close to the receiver, or by both situations, as illustrated in figure A.1. Alternatively, the path for the distances d_1 and d_2 may be taken as falling along lines at propagation angles of 15° to the ground.

The first line in table A.1 gives the attenuation to be expected from dense foliage if the total path length through the foliage is between 10 m and 20 m, and the second line if it is between 20 m and 200 m. For path lengths greater than 200 m through dense foliage, the attenuation for 200 m should be used.



NOTE — $d_f = d_1 + d_2$

For calculating d_1 and d_2, the curved path radius may be assumed to be 5 km.

Figure A.1 — Attenuation due to propagation through foliage increases linearly with propagation distance d_f through the foliage

Table A.1 — Attenuation of an octave band of noise due to propagation a distance d_f through dense foliage

Propagation distance d_f m	**Nominal midband frequency** Hz 63	125	250	500	1 000	2 000	4 000	8 000
$10 \leq d_f \leq 20$	Attenuation, dB: 0	0	1	1	1	1	2	3
$20 \leq d_f \leq 200$	Attenuation, dB/m: 0,02	0,03	0,04	0,05	0,06	0,08	0,09	0,12

A.2 Industrial sites (A_{site})

At industrial sites, an attenuation can occur due to scattering from installations (and other objects), which may be described as A_{site}, unless accounted for under A_{bar}, or the sound source radiation specification. The term installations includes miscellaneous pipes, valves, boxes, structural elements, etc.

As the value of A_{site} depends strongly on the type of site, it is recommended that it is determined by measurements. However, for an estimate of this attenuation, the values in table A.2 may be used. The attenuation increases linearly with the length of the curved path d_s through the installations (see figure A.2), with a maximum of 10 dB.

A.3 Housing (A_{hous})

A.3.1 When either the source or receiver, or both are situated in a built-up region of houses, an attenuation will occur due to screening by the houses. However, this effect may largely be compensated by propagation between houses and by reflections from other houses in the vicinity. This combined effect of screening and reflections that constitutes A_{hous} can be calculated for a specific situation, at least in principle, by applying the procedures for both A_{bar} and reflections described in 7.4 and 7.5. Because the value of A_{hous} is very situation-dependent, such a calculation may be justified in practice. A more useful alternative, particularly for the case of multiple reflections where the accuracy of calculation suffers, may be to measure the effect, either in the field or by modelling.

A.3.2 An approximate value for the A-weighted attenuation A_{hous}, which should not exceed 10 dB, may also be estimated as follows. There are two separate contributions

$$A_{hous} = A_{hous,1} + A_{hous,2} \qquad \text{... (A.1)}$$

A.3.3 An average value for $A_{hous,1}$ (in decibels) may be calculated using the equation

$$A_{hous,1} = 0{,}1 B d_b \quad \text{dB} \qquad \text{... (A.2)}$$

where

- B is the density of the buildings along that path, given by the total plan area of the houses divided by the total ground area (including that covered by the houses);
- d_b is the length of the sound path, in metres, through the built-up region of houses, determined by a procedure analogous to that shown in figure A.1.

The path length d_b may include a portion d_1 near the source and a portion d_2 near the receiver, as indicated in figure A.1.

The value of A_{hous} shall be set equal to zero in the case of a small source with a direct, unobstructed line of sight to the receiver down a corridor gap between housing structures.

NOTE 25 The A-weighted sound pressure level at specific individual positions in a region of houses may differ by up to 10 dB from the average value predicted using equations (A.1) and (A.2).

Table A.2 — Attenuation coefficient of an octave band of noise during propagation through installations at industrial plants

Nominal midband frequency, Hz	63	125	250	500	1 000	2 000	4 000	8 000
A_{site}, dB/m	0	0,015	0,025	0,025	0,02	0,02	0,015	0,015

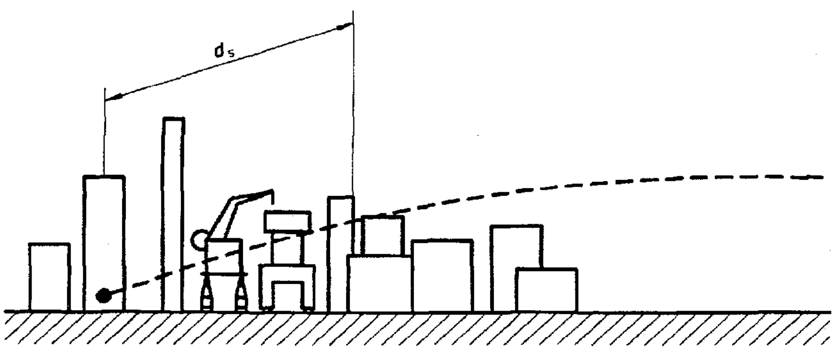


Figure A.2 — The attenuation A_{site} increases linearly with the propagation distance d_s through the installations at industrial plants

A.3.4 If there are well-defined rows of buildings near a road, a railway, or a similar corridor, an additional term $A_{hous,2}$ may be included (provided this term is less than the insertion loss of a barrier at the same position with the mean height of the buildings):

$$A_{hous,2} = -10 \lg[1 - (p/100)] \text{ dB} \qquad \ldots \text{(A.3)}$$

where p (the percentage of the length of the façades relative to the total length of the road or railway in the vicinity) is $\leqslant 90$ %.

A.3.5 In a built-up region of houses, the value of $A_{hous,1}$ [as calculated by equation (A.2)] interacts as follows with the value for A_{gr}, the attenuation due to the ground [as calculated by equation (9) or equation (10)].

Let $A_{gr,b}$ be the ground attenuation in the built-up region, and $A_{gr,0}$ be the ground attenuation if the houses were removed [i.e. as calculated by equation (9) or equation (10)]. For propagation through the built-up region in general, $A_{gr,b}$ is assumed to be zero in equation (4). If, however, the value of $A_{gr,0}$ is greater than that of A_{hous}, then the influence of A_{hous} is ignored and only the value of $A_{gr,0}$ is included in equation (4).

The interaction above is essentially to allow for a range of housing density B. For low-density housing, the value of A_{gr} is dominant, while for high-density housing A_{hous} dominates.

Annex B
(informative)

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1) To be published. (Revision of ISO 266:1975)

ICS 17.140.01

Descriptors: acoustics, noise (sound), airborne sound, wave propagation, attenuation, rules of calculation.

Price based on 18 pages

Appendix B

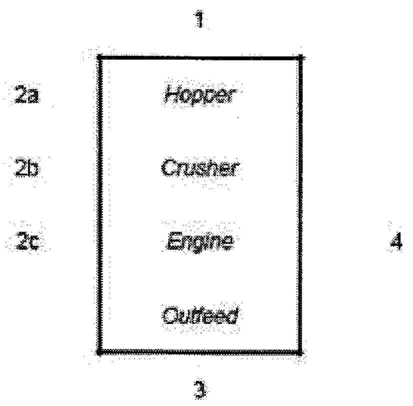
Processing Equipment Manufacturer's Noise Ratings

Crusher

Sound Pressure Level Measurement Results

Test Conditions and Set-Up:

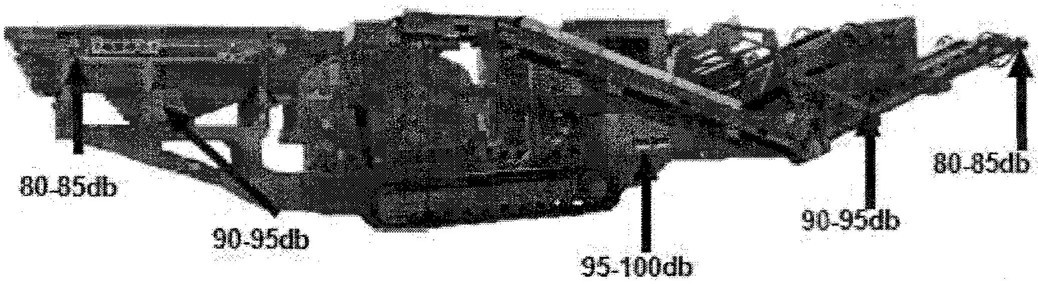
Temperature (°C)	26°C
Humidity (%)	50%rh
Background Noise (db[A])	40 dB(A)
Distance Between Microphone and Machine (m)	5
Distance from Floor to Microphone (m)	1.5



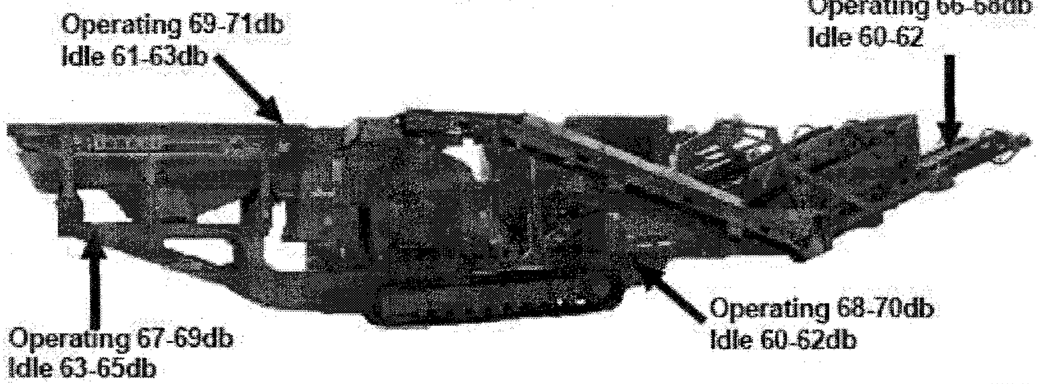
Measuring Point	Position	Sound Level dB(A) Idle	Sound Level dB(A) Full Operation
1	Bystander, 5m Horizontal, 1.5m vertical	–	80.4
2a	Bystander, 5m Horizontal, 1.5m vertical	–	89.4
2b	Bystander, 5m Horizontal, 1.5m vertical	–	91.6
2c	Bystander, 5m Horizontal, 1.5m vertical	80.2 85.0 w/beeper	94.2 96.7 w/beeper
3	Bystander, 5m Horizontal, 1.5m vertical	–	81.4
4	Bystander, 5m Horizontal, 1.5m	84.0	93.7

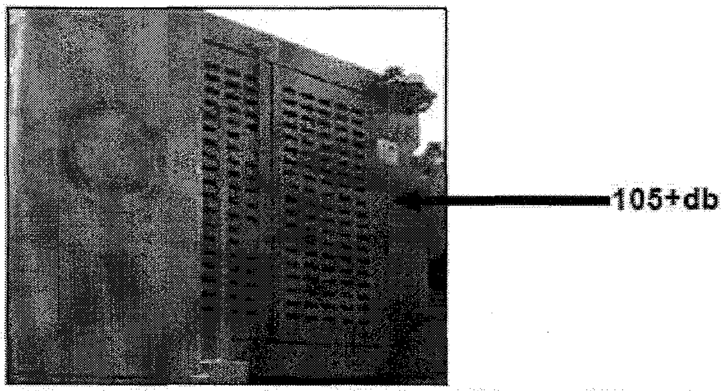
Emissions **17-10**

Noise Levels
3 feet from machine/5 feet from ground



At 200 feet





*Levels were taken while machine was at operating speed, no material being processed.

17

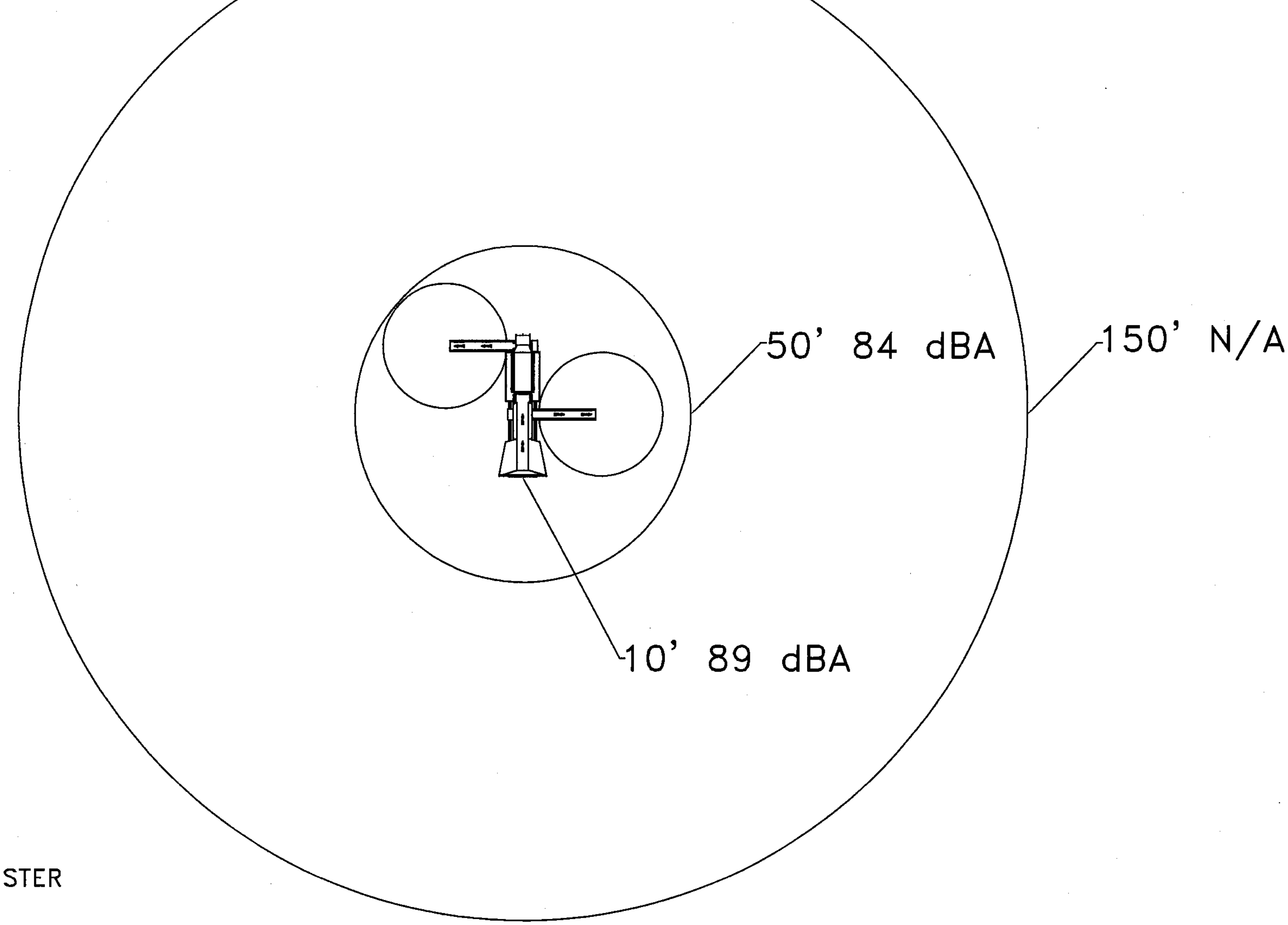
**Decibal readings shown are approximate. Noise levels will vary depending on work site, weather conditions, material being processed and other factors.

****

DISCLAIMER:

This transmission from Astec Industries or one of its subsidiaries is confidential and solely for the use of the intended

SOUND LEVEL READINGS TAKEN AT SPECIFIED DISTANCES FROM OPERATING EQUIPMENT.
(ANSI and OSHA METER AND SCALE)



Screen

NOTE:
N/A = DID NOT REGISTER ON METER.

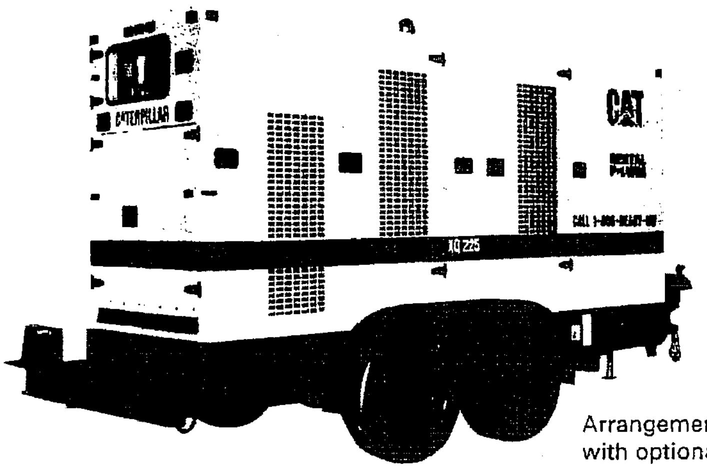
Construction Equipment Company Crushing and Screening Specialists	THIS DRAWING AND ITS CONTENTS IS THE PROPERTY OF "CONSTRUCTION EQUIPMENT COMPANY". ISSUED IN STRICT PERMISSION OF ABOVE STATED COMPANY, BE REPRODUCED FOR ANY PURPOSE WHATSOEVER EXCEPT THE MANUFACTURE OF ARTICLES FOR "CONSTRUCTION EQUIPMENT COMPANY". IT IS LOANED SUBJECT TO "RETURN UPON DEMAND".	Drawing Title "CEC" SCREEN-IT "Mdl. 512-I" SOUND LEVEL READINGS	File No.: DA2189-0 Date:10-5-1999 Scale: NONE Drawn By: CEB App'd By: CEB

XQ Line Rental Package

Generator

Sound Attenuated

350 kW
225 kW
125 kW
Prime Power including 10% overload



Arrangement shown with optional trailer with pintle hitch.

FEATURES

- **ENCLOSURE – SOUND ATTENUATED**
  Made with 12 gauge steel. Includes single point lifting eye. Sound levels – low 70s dbA @ 7 m (22 ft) at no load. See chart on page 2 for specifics. Generator Set/ EMCP II Repower Kits available for repower.
- **RUGGED DESIGN FOR RENTAL ENVIRONMENT**
  Packages designed to survive in rugged and maintenance starved environments.
- **EMCP II CONTROL PANEL**
  Shock mounted with panel lights.
- **RELIABLE, FUEL EFFICIENT DIESEL**
  The compact, four-stroke-cycle diesel engine combines durability with minimum weight while providing dependability and economy.
- **MULTI-VOLTAGE DISTRIBUTION PANEL WITH LOCKABLE DOORS**
  Rust-free hinges on side opening doors. Adequate space for line and plug connection without interference when door is closed.
- **EPA AND CARB CERTIFIED**
  XQ350, XQ225, and XQ125 emission certified for non-road mobile applications.

XQ350, CATERPILLAR® 3406 ENGINE

I-6, Four-Stroke-Cycle Watercooled Diesel

Bore—mm (in)	137 (5.4)
Stroke—mm (in)	165 (6.5)
Displacement—L (cu in)	14.6 (893)
Compression Ratio	14.5:1
Aspiration	Turbocharged-Aftercooled

XQ225, CATERPILLAR® 3306 ENGINE

I-6, Four-Stroke-Cycle Watercooled Diesel

Bore—mm (in)	121 (4.75)
Stroke—mm (in)	152 (6.0)
Displacement—L (cu in)	10.5 (638)
Compression Ratio	15:1
Aspiration	Turbocharged-Aftercooled

XQ125, CATERPILLAR® 3304 ENGINE

I-4, Four-Stroke-Cycle Watercooled Diesel

Bore—mm (in)	121 (4.75)
Stroke—mm (in)	152 (6.5)
Displacement—L (cu in)	7.0 (425)
Compression Ratio	16:1
Aspiration	Turbocharged-Aftercooled

Voltages available –
60 Hz 3406
120/208, 277/480, 600, 139/240
3306 & 3304
120/208, 139/240, 277/480, 600
(Adjustable a minimum of ±10%).
Some voltages require derating.

Caterpillar EMCP II Control Panel 24 Volt DC Control
Vibration isolated
NEMA 12 enclosure
Dead front
Lockable hinged door
Generator instruments meet ANSI C-39-1

CATERPILLAR

XQ LINE RENTAL PACKAGE

STANDARD EQUIPMENT

Generator Set Package
Air cleaner, dual element
Alternator, charging battery and mounting
Base, fuel tank skidable, 8 hour min., full load fuel capacity
Breather, crankcase oil, lubricating
EMCP II control panel
Enclosure, 12-gauge steel with foam sound suppression
Fuel level gauge
Generator with VR3 voltage regulator
Guards, protection alternator, fan, belts
Radiator, 112° F coolant, 50% glycol
Turbocharged-aftercooled on XQ125, XQ225 & XQ350
Woodward electronic 524 governor on XQ125, XQ225 & XQ350

Distribution Panel
Bus bar connections
easy access for connections through bottom of unit, even when it is lowered to the ground
Lockable doors
side hinged lockable doors with rust-free pinned hinges. Designed with adequate space to allow for connection of the 250 volt twist lock plug with the door closed.

Receptacles with Individual Circuit Breakers
1 - 240V, 50 amp
2 - 120V, 15 amp duplex
2 - 120V, 20 amp twist lock
Remote start/stop contacts

Main Circuit Breakers
Current transformers, hard mounted built-in quick change 240/480V voltage board on XQ350
Separate 240V and 480V bus bar sets on XQ225 & XQ125 with both voltages available simultaneously
240V and 480V or 600V, CSA approved

OPTIONAL EQUIPMENT

Trailer with adjustable hitches on XQ225 & XQ125
Air inlet shutoff
Battery charger
CSA approval
Jacket water heater
Space heater
Trailer with pintle hitch on XQ350

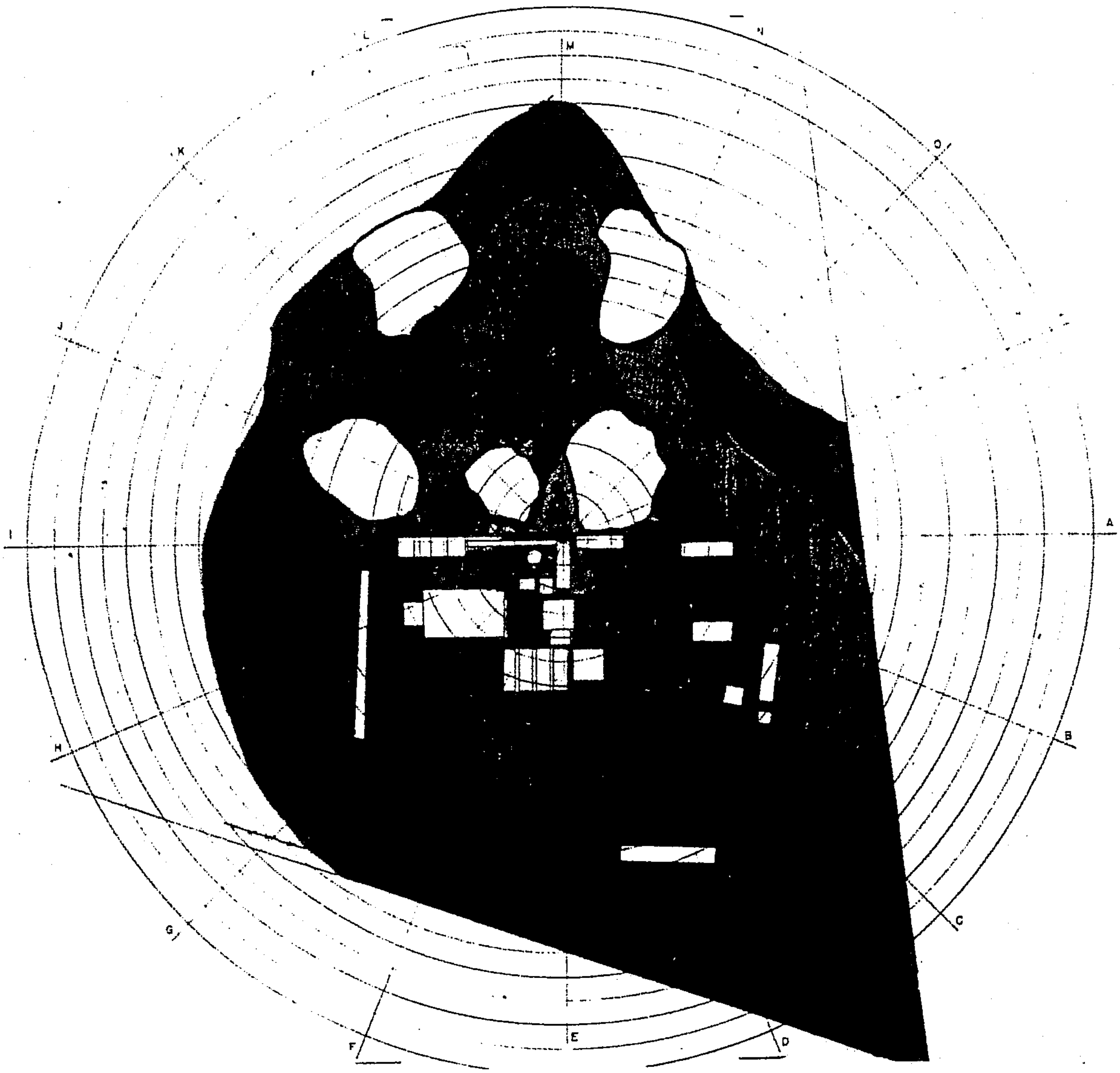
TECHNICAL DATA

3406, 3306, 3304 Generator Sets		XQ350	XQ225	XQ125
Engine		3406	3306	3304
Prime power rating (w/10% overload) @ 0.8PF with fan	kW	350	225	125
Engine horsepower	bhp	519	316	196
Aspiration		TA	TA	TA
Dimensions with Trailer				
Length	mm (in)	6147 (248)	5385 (221)	5385 (220)
Width	mm (in)	2388 (95)	1956 (75)	1956 (75)
Height (with lifting eye)	mm (in)	3531 (140)	2612 (103)	2612 (103)
Shipping weight (wet)	kg (lb)	6356 (14 000)	4990 (11 000)	4404 (9800)
Engine lubricating oil capacity	L (qts)	37.9 (40.0)	29.0 (31.0)	21.8 (23.0)
Engine coolant capacity w/radiator	L (gal)	89.1 (23.5)	45.5 (12.0)	31.8 (8.4)
Fuel tank capacity	L (gal)	758 (200)	530 (140)	530 (140)
Fuel consumption prime +10% load w/fan	L/hr (gph)	100.8 (26.6)	66.2 (17.5)	37.3 (9.9)
Fuel consumption (100% prime) w/fan	L/hr (gph)	92 (24.3)	59.9 (15.8)	33.8 (9.0)
Fuel consumption (75% prime) w/fan	L/hr (gph)	70.4 (18.6)	44.8 (11.9)	25.6 (6.8)
Running time @ 75% prime	hr	10.8	11.8	20.6
Sound level — Prime +10%	dbA	74.1	72.3	68.8
Prime @ 7 meters	dbA	73.2	71.1	68.4
No Load @ 7 meters	dbA	69.6	70.8	64.9

Appendix C

Portable Asphalt Plant Noise Ratings

ENVIRONMENTAL NOISE IN AND AROUND HOT-MIX ASPHALT PLANTS



— A First Report

napa

IS-63

National Asphalt Pavement Association • 6811 Kenilworth Avenue, • Riverdale, Maryland 20840

Introduction

No one has ever attempted to publish a pamphlet written specifically about environmental noise around Hot-Mix plants. This pamphlet is made possible through the sponsorship and assistance of the National Asphalt Pavement Association Environmental Committee, and the support of Hot-Mix asphalt producers. It contains useful information and facts carefully gathered by the NAPA Environmental Task Force on Noise.

We request you read this pamphlet in its entirety so that you will have a better understanding of the industry's problems concerning noise. If you find unfamiliar terminologies, skip over them—BUT DO CONTINUE reading the *entire* pamphlet.

This brochure was written to clarify much of the misunderstandings about noise problems in and around asphalt plants. It points out some of the problems and offers some general guidelines towards their most expedient and economical solutions.

I. Noise Theory

Noise by definition is unwanted sound. More specifically, it is sound which annoys, is unpleasant, or irritating to us. It may be as gentle as a dripping faucet which robs us of our sleep, or as ear-shattering as a sonic boom, capable of shattering glass windows and cracking walls. But in all cases, it is undesirable.

Sound is defined as any pressure variation in a gaseous or liquid medium that the human ear can detect. The speed with which the pressure varies is known as frequency, measured in cycles per second, or hertz (Hz). The frequency range of human hearing extends from approximately 20 Hz to 20,000 Hz. Pressure variations outside of this range would normally be considered as vibrations rather than sound since they are beyond the range of human hearing.

An equally important term which is used to describe the quality of sound is intensity. Sound intensity, or loudness, is the magnitude of pressure changes.

The human ear is an amazing instrument. The weakest sound intensity that the ear can detect is about 20 micro pascals; the highest intensity sound which the ear can perceive without pain is approximately 100,000,000 micro pascals. Thus if we were to work with sound in micro pascals, we would encounter very large unmanagable numbers. To simplify computations and reduce the size of the numbers encountered in sound work, a unit called "The Decibel" is used. While the pascal units are expressed in linear form, dB's are determined by a logarithmic scale (Figure 1).

	dB Logarithmic	Linear
Sound Studio	20 dB	200 micro pascals
Quiet Office	40 dB	2,000 micro pascals
Conversation (3 ft)	60 dB	20,000 micro pascals
Noisy restaurant	80 dB	200,000 micro pascals
Printing press	100 dB	2,000,000 micro pascals
50 HP siren (100 ft)	120 dB	20,000,000 micro pascals
Jet Plane	140 dB	200,000,000 micro pascals

Figure 1 Representative Noise Levels

A. Sound Loudness

The factors determining the loudness we hear are extremely complex and well beyond the scope of this report. One factor we must address, however, is the human ear's unequal sensitivity to frequencies. The ear is not equally sensitive to all frequencies or to the same frequency at widely varying sound intensities. Figure 2 shows the relative response of the human ear near the threshold of hearing at various frequencies. Since we are interested in sound measurements representing the human ear's response to sound intensity, we must design an instrument which approximates the curve shown in Figure 2. The manufacturers of sound meters have developed a device known as the A weighting network (A-Scale) also shown in Figure 2. This weighted measure of sound intensity is known as the dBA and is the accepted criteria for sound measurements on which most noise regulations are based.

B. Sound Power Level

Sound power level (PWL) is a theoretical value representing the sound energy being emitted from any sound source. It assumes an idealized condition of being a point source of acoustic energy in a free field. In actual practice, it is a value which is calculated from sound pressure level (SPL) and distance data. It is of great value in calculating the sound pressure level at various distances from a sound source. The relationship between the sound power level (PWL), distance (r), and sound pressure level (SPL) is as follows:

$$PWL^{*} = SPL + 20 \log_{10} r \quad - 2.5$$

*for hemispherical conditions.

Sound pressure level (SPL) is the sound level expressed in dB or dBA. Sound pressure is sound we actually hear or to which a sound level meter responds. Sound pressure level is affected by the distance from the sound source. Sound pressure level can also be affected by other sound sources, reflections, and a variety of other factors. The unit of measure of sound pressure level which is normally used is the dBA which most nearly approximates the response of the human ear to sound.

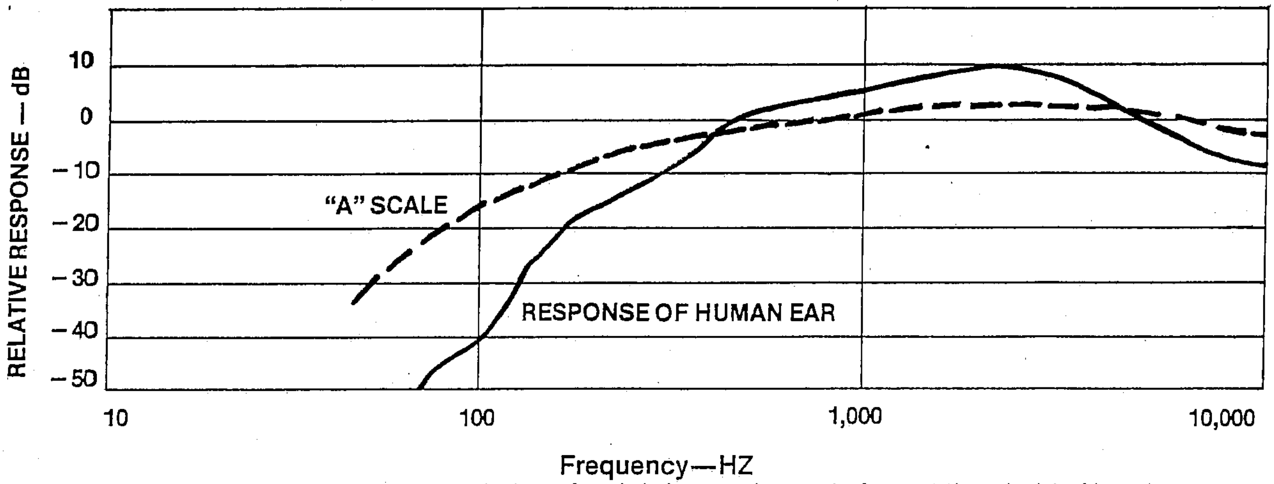


Figure 2 Response characteristics of weighting scales and of ear at threshold of hearing.

If one desires to find the resulting noise level of two or more pieces of equipment running simultaneously, the sound levels in dB cannot be added arithmetically. A simple method of making the addition without using logs is to use the correction factor in Figure 3, which is added to the larger of the two sound levels to find the resulting sound level.

Example

Machine 1	100 dBA
Machine 2	94 dBA
Difference	6 dBA
Correction Factor (from Fig. 3 at 6 dB)	1 dBA
Highest Level	100 dBA
Resultant Noise Level	101 dBA

In a free field environment, the sound pressure (SPL) varies with the distance (d). As distance increases away from the sound source, the sound pressure level diminishes. The relationship between sound pressure level (SPL) and distance (d) is:

$$SPL\ 2 = SPL\ 1 - 20\,(\log_{10} d_1 - \log_{10} d_2)$$

It is interesting to note that each time the distance is doubled, the sound pressure level (SPL) diminishes by 6 dB (Figure 4).

Example: The sound pressure level at point 1, which is 10 feet from the sound source, is 80 dB. Find the sound pressure at point 2 which is 40 feet from the sound source, and at point 3 which is 80 feet from the sound source.

$$SPL\ 2 = 80 - 20\,(\log_{10} 40 - \log_{10} 10) = 68\ dB$$

Since the distance from the source to point 3 is double the distance of from the source to point 2, we only need to deduct 6 decibels from the sound pressure level at 2 to find the sound pressure level at point 3.

$$SPL\ 3 = 68 - 6 = 62\ dB$$

II. Legal Implications

Legislation to control noise is not new. Because noise bothered him, Julius Caesar banned chariot driving at night. The first documented legal action relating to noise dates back to the year 1800. At that time, a group of irate citizens filed a complaint against the local blacksmith whose shop contained a large forging hammer that was used throughout the night. The court ruled that the shop could not operate between the hours of 8:00 P.M. and 6:00

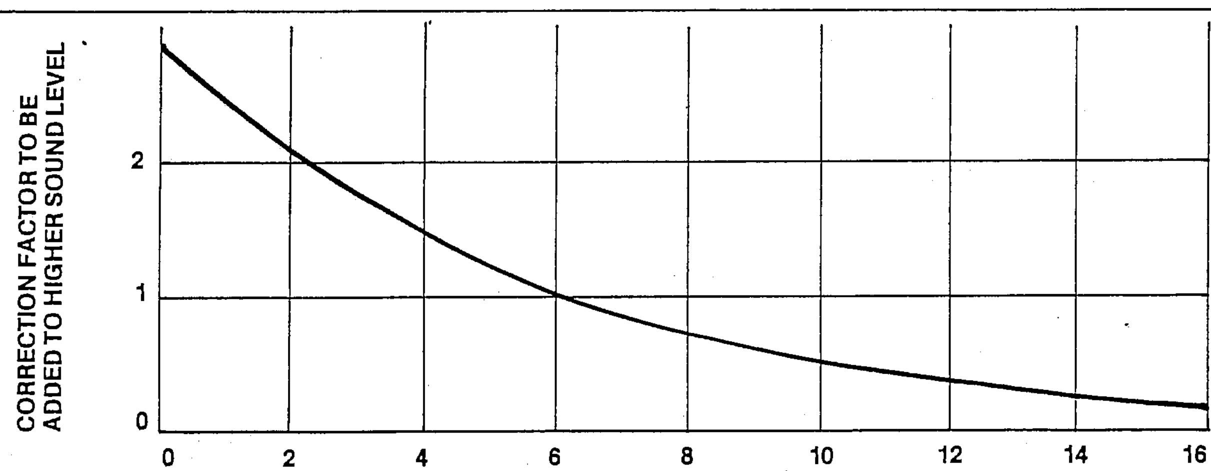


Figure 3 Difference in sound levels.

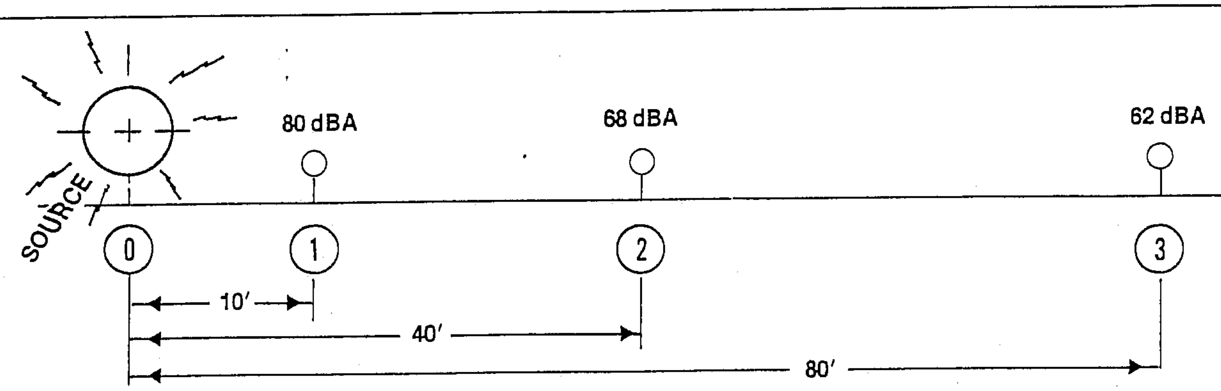


Figure 4 Distance-Sound Pressure Relationship.

A.M. Since Caesar's time many cases have been heard and numerous decisions handed down. However, it has only been in the past ten years that any significant legislation has been passed. Much of this legislation was based on emotion rather than on attainable goals.

Although nearly all of the 50 states had prepared and passed legislation pertaining to noise, the first momentous step was made on May 20, 1969, with the passage of the so-called Walsh-Healey Public Contracts Act. This Act was truly the forerunner of all important noise legislation. Yet it failed to accomplish the job for which it was designed.

With the ever-increasing cry for more protection for workers, Congress passed the Occupational Safety and Health Act (OSHA), of 1970, which provides enforcement procedures with sufficient power to compel compliance with its edicts. The OSHA Act covers a variety of subjects including noise. Section 1910.95, entitled Occupational Noise Exposure, is the section that concerns us. (See Figure 5.)

The OSHA Act is not concerned with ambient noise but with the exposure of the worker to that noise; meaningful exposure measurement can only be accomplished by individual dosemeter readings.

The U.S. Environmental Protection Agency (EPA) is also involved in writing model noise legislation. The EPA initially wrote noise legislation which was essentially limited to the noise at and beyond the property line rather than on-site noise. Now the EPA is encouraging state and local governments to take over the job of writing this legislation and is involving itself only in writing model legislation for its own use.

The EPA is very actively working on a program of setting noise standards for various types of equipment. As time permits, they will be setting standards for individual pieces of equipment selected from a list of major sources of noise pollution. The significant difference between this legislation and OSHA's is that the manufacturer will be held responsible for seeing that his equipment meets the EPA standard.

The U.S. Bureau of Mines, Mining Enforcement Safety Administration, also has powers similar to those of OSHA. Although their activities are generally limited to mining operations, they may, under some circumstances, involve themselves in operations not directly connected with mining.

The enactment of state and city noise ordinances continues to grow in the United States. In 1976 there was an increase of 21% in the noise legislation written by municipalities. These ordinances cover a wide variety of topics such as nuisance, zoning, vehicle, recreational vehicles, railroad, aircraft, construction, building, etc. The types of legislation are so varied that it would be impossible to summarize them. For detailed information it is suggested that you contact the local, city or state agency involved.

III. NAPA Sound Tests

NAPA has sponsored a noise test program which attempted to develop a general picture of the noise problem in hot-mix plants. For purposes of this test program, 10 asphalt plants of diverse manufacturing origin and sizes, and equipped with burners of different makes operating on both oil and gas, were selected. A series of sound tests were conducted and isodyne diagrams prepared for each plant. Figure 6 shows the basic information on each of the ten plants. With the exception of plant four, which contains some erroneous data, test results showed trends indicating the noise level from any plant may be predicted based on its firing rate, type of fuel, and type of burner equipment. Figure 7 shows a chart which may be used to predict the sound power level of a burner from the actual heat release, or firing rate. This chart is based primarily on low pressure air atomizing burners and may be somewhat difficult to use for other types of equipment. When used in conjunction with Figure 8, the sound pressure level in dBA may be predicted at any distance from the burner. It should be noted that these charts only give representative values for hot-mix plants; one must understand that there will be slight variations from plant to plant.

The following examples show how these charts can be used to predict noise levels due to asphalt plant burner systems.

Problem: Assume your plant burns 50 million Btu's per hour using fuel oil. You are going to relocate your plant near the edge of your property and note that it will be 300 feet from the property line. You would like to know the approximate noise level in dBA at the boundary line of your property.

Known quantities $Q = 50$ Million Btu/hr.
$R = 300$ Feet

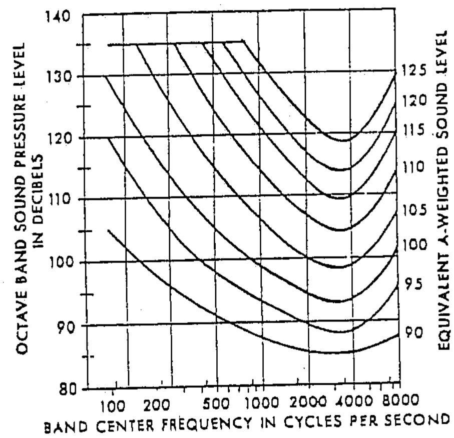
Find SPL at 300 feet.

1. Enter chart Figure 7 at 50 Million BTU/Hr and draw

§ 1910.95 Occupational noise exposure.

(a) Protection against the effects of noise exposure shall be provided when the sound levels exceed those shown in Table G–16 when measured on the A scale of a standard sound level meter at slow response. When noise levels are determined by octave band analysis, the equivalent A-weighted sound level may be determined as follows:

Figure G-9



Equivalent sound level contours. Octave band sound pressure levels may be converted to the equivalent A-weighted sound level by plotting them on this graph and noting the A-weighted sound level corresponding to the point of highest penetration into the sound level contours. This equivalent A-weighted sound level, which may differ from the actual A-weighted sound level of the noise, is used to determine exposure limits from Table 1.G–16.

(b) (1) When employees are subjected to sound exceeding those listed in Table G–16, feasible administrative or engineering controls shall be utilized. If such controls fail to reduce sound levels within the levels of Table G–16, personal protective equipment shall be provided and used to reduce sound levels within the levels of the table.

(2) If the variations in noise level involve maxima at intervals of 1 second or less, it is to be considered continuous.

(3) In all cases where the sound levels exceed the values shown herein, a continuing, effective hearing conservation program shall be administered.

TABLE G–16—PERMISSIBLE NOISE EXPOSURES [1]

Duration per day, hours	*Sound level dBA slow response*
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼ or less	115

[1] When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the following fractions: $C_1/T_1 + C_2/T_2$ C_n/T_n exceeds unity, then, the mixed exposure should, be considered to exceed the limit value. Cn indicates the total time of exposure at a specified noise level, and Tn indicates the total time of exposure permitted at that level.

Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

Figure 5 Reprint of Section 1910.95

Plant No.	Type Fuel	Burner Size Million BTU's	Plant Output TPH	Fan Size CFM	Avg. PWL dB	Avg. SPL at 60 dBA	Acoustic Power Watts	Heat Release Millions BTU/Hr
1	Oil	170	160	58000	128	95	6.3	41
2	Oil	50	125	40000	122	89	1.6	35
3	Gas	200	280	64000	132	99	15.8	78
4	Gas	80	120	36000	123	90	2.0	33
5	Oil	40	120	32000	117	84	0.5	30
6	Oil	130	300	60000	115	82	0.31	80
7	Oil	90	250	44000	127	94	4.0	50
8	Oil	80	180	39000	114	80	0.2	53
9	Gas	50	180	44000	123	90	2.0	32
10	Oil	167	240	60000	125	92	3.2	58

Figure 6 Asphalt Hot-Mix Plant Data

a horizontal line intersecting the oil-fired line. At this point drop a vertical line and read the sound power level equal to 125 dBA.

2. Enter Curve Figure 8 at a distance of 300 feet and draw horizontal line to intersect the curve, then drop a vertical line and read a correction factor K equal to 47 dBA.
3. The sound pressure level at 300 feet from the dryer will be equal to

$$SPL = PWL - K$$
$$SPL = 125 - 47 = 78 \text{ dBA}$$

If we had to have a reading of 70 dBA or less at that point on the property line, we could try to increase the distance, thereby reducing the sound pressure level. In order to find the approximate distance we would need to proceed as follows:

4. The sound power from the burner chart Figure 7 is equal to 125 dBA as previously determined in Step 1. If we require 70 dBA, then we must determine what sound pressure correction factor is necessary to get down to 70 dBA.

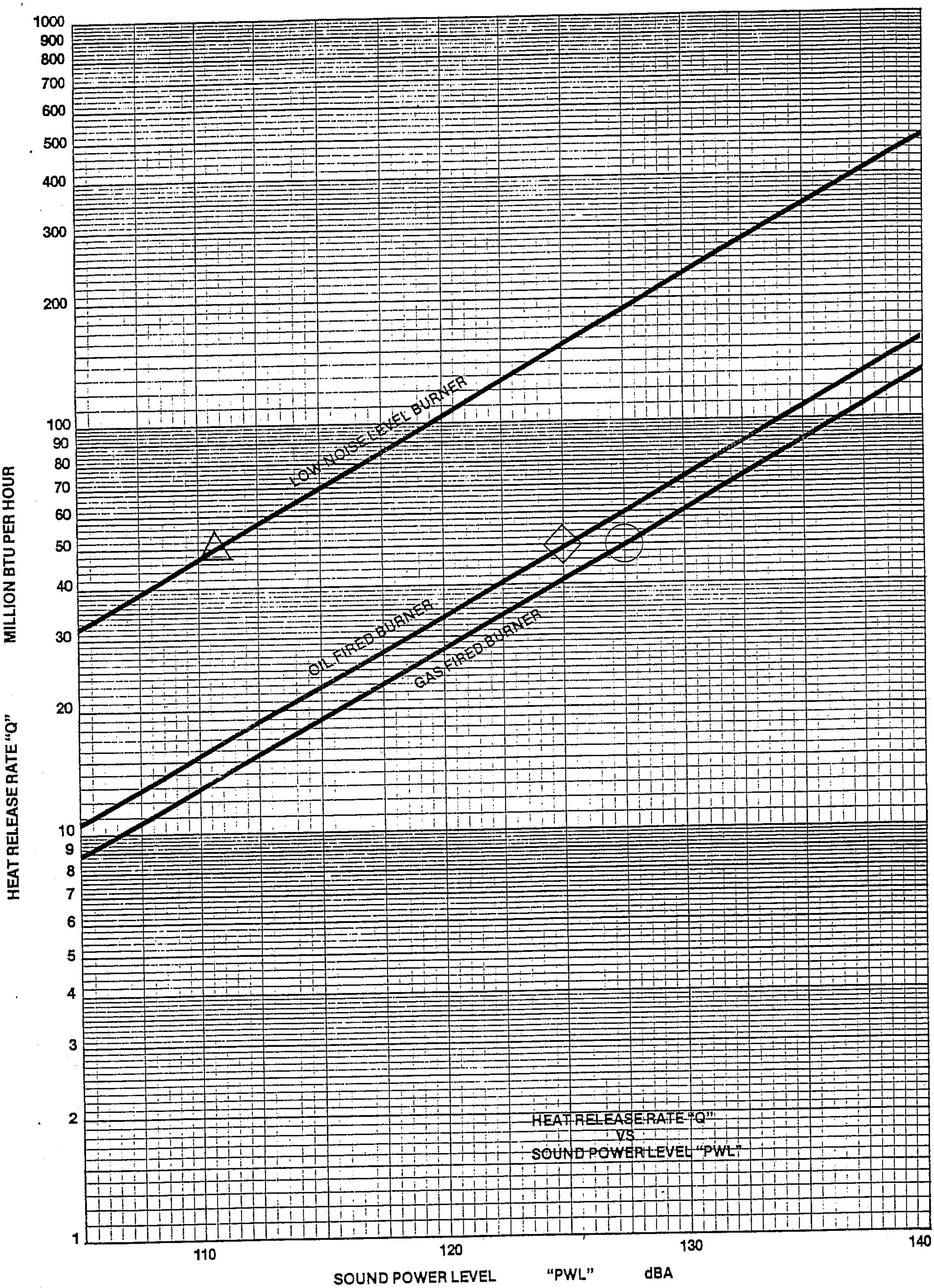
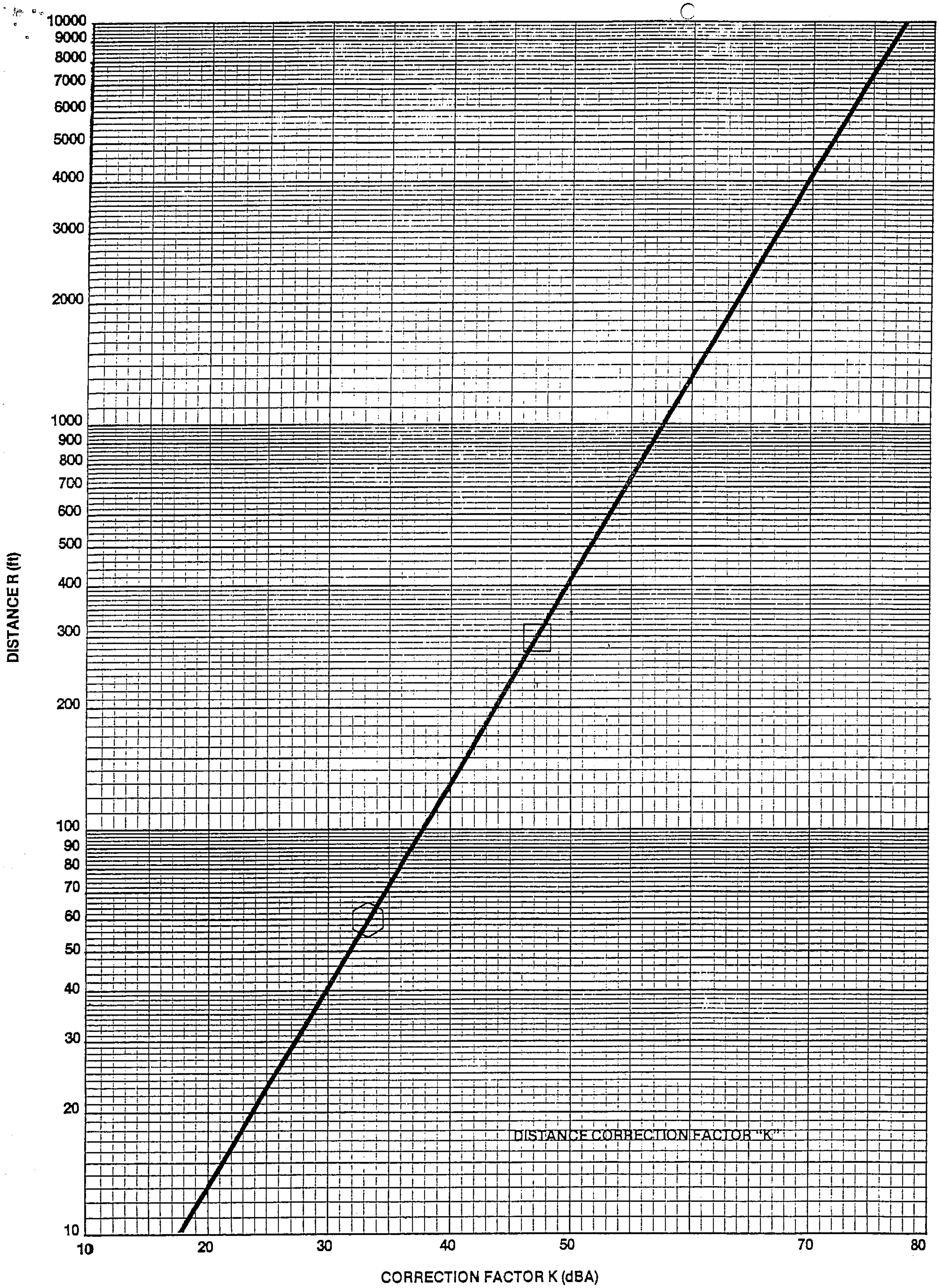

HEAT RELEASE RATE "Q" MILLION BTU PER HOUR
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
LOW NOISE LEVEL BURNER
OIL FIRED BURNER
GAS FIRED BURNER
HEAT RELEASE RATE "Q"
VS
SOUND POWER LEVEL "PWL"
110
120
130
140
SOUND POWER LEVEL "PWL" dBA

Figure 7



10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
DISTANCE R (ft)
DISTANCE CORRECTION FACTOR "K"
10
20
30
40
50
70
80
CORRECTION FACTOR K (dBA)

Figure 8

$K = PWL - SPL$
$K = 125 - 70 = 55$ dBA

We need a distance correction factor of 55. Enter chart Figure 8 at a correction factor equal to 55, read vertically to intersect the curve, then draw a horizontal line and read 750 feet from the burner to the property line to get 70 dBA.

5. If it were not practical to increase the distance from the burner to the property line to 750 feet, we could consider the use of a low-noise level, or silent type of burner. To check the sound pressure level at 300 feet for the low-noise level burner, proceed as follows:
Take similar steps to steps 1 and 2 in the previous example. Enter curve Figure 7 at 50 million Btu and read horizontally to the silent burner line. Read vertically to show a sound power level of 111 dBA.
To find the sound pressure level at 300 feet using a silent type of burner, we can use the same correction factor determined for 300 feet, found in Step 2.

$SPL_{300\ Ft.} = PWL - K$
$SPL_{300\ Ft.} = 111 - 47$ which equals 64 dBA

The 64 dBA is well below the 70 dBA required at the property line. It would be safe to locate the dryer at 300 feet from the property line.

Certain other generalized conclusions may be drawn from the test work:

1. Gas burners, at the same heat release rate, are generally noisier than oil burners. This may be seen from Figure 6.
2. The burner, or firing system, is generally the most noisy stationary piece of equipment on the site.
3. Sound intensity emerging from an open fired burner is generally higher than the sound level emerging from the exhaust stack.
4. The sound intensity emerging from the exhaust stack is generally directed upwards and, therefore, less of a problem than the open burner end. However, the noise from the stack may cause problems where low-noise level burners have been used to reduce sound intensities on the site.
5. Fan intakes and turbo compressor intakes prove to be a significant source of noise, the intensity of which is proportional to fan horsepower.
6. Noise from the dryer drum can be significant when large size aggregate or stone is being run without fine aggregate to absorb the impact of falling rock on the steel shell.
7. Aggregate stockpiles, when properly located, can greatly aid in reducing noise problems. The stockpiles act as absorbers and also as deflectors, and in some cases, as reflectors. When judiciously used, they may serve as very effective tools in reducing noise levels at specific locations.
8. Buildings and large objects may serve as barriers or deflectors to reduce noise at certain locations. However, it must be realized that they can also act as reflectors, intensifying sound in other areas. Groups of buildings or other large objects will generally intensify the sound field on the side facing the burner, or noise source, and will generally reduce the sound intensity on the side facing away from the noise source.

IV. Method of Controlling Noise Exposure

There are numerous methods and combinations of methods which may be used to control noise. Most of these methods can be grouped into five basic categories:

1. Move it.
2. Absorb it.
3. Block it.
4. Reduce it.
5. Reduce exposure time.

Move it.

The offending sound source may be moved to a new location where the noise does not affect employees or other persons. An alternative method would be to relocate the work stations of employees so that they are remotely located from the noise source thereby reducing the exposure.

Absorb it.

Materials such as glass or mineral wool, cork, felt, etc. have the ability to absorb and dissipate sound pressure waves. These materials may be used to line walls, enclosures, screens, and barriers, thereby absorbing the offending sounds. Attenuators, or mutes, may also be used to contain and absorb noise.

Block it.

Sound waves can be blocked by walls, or barriers made of or lined with dense material such as lead, or the absorbing materials referred to above. The noise source may be enclosed by materials having low transmission properties, thereby preventing the escape of the noise. An alternative method would be to enclose employees in protective booths, thereby reducing exposure. Ear protectors, such as earplugs or earmuffs, would also fall within this category.

Reduce it.

The offending piece of machinery may be redesigned to reduce its noise output. The installation of quiet burners and low noise level motors to replace conventional burners and/or motors is a typical method.

Reduce exposure time.

In severe cases, where it is impractical to use the methods previously discussed, it may be useful to reduce operator exposure time by rotating operating personnel, reducing their overall exposure time and, as a result, be able to expose them to higher intensities. (See Figure 9)

There are a wide variety of products on the market which can be used to reduce noise.

Duration per day, hours	Sound level dBA slow response
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼ or less	115

[1] When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the following fractions: $C_1/T_1+C_2/T_2$ C_n/T_n exceeds unity, then, the mixed exposure should be considered to exceed the limit value. Cn indicates the total time of exposure at a specified noise level, and Tn indicates the total time of exposure permitted at that level.

Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

Figure 9 Permissible Noise Exposures

V. Procedure to Follow

Up to now authorities have given priority to model regulations rather than the enforcement of existing legislation. In the future one can expect ever-increasing pressure will be brought to bear on industry to comply with present noise legislation. We think it wise to take advantage of the lead time and attempt to gain control of our noise problems while time permits, before being forced to take actions which may be economically detrimental to our industry.

If you operate an asphalt plant, you probably should plan to correct it in the near future. Do it before you receive a citation and face the possibility of being shut down, having to take immediate action without a chance to investigate the variety of solutions available to you. If you act now, you can probably save yourself considerable money in fines, equipment costs and loss of production.

Once you have decided to correct your problem, consider the following plan of action:

1. Conduct a walk-around survey of your plant. Listen to the various noises and try to determine which are the loud, offensive pieces of equipment. If available, the A-scale sound level meter readings could prove to be helpful, but it is not absolutely necessary to use a sound level meter in doing this.
2. Employ a noise consultant to run sound tests on your plant. It is important that you employ a man who is qualified to do noise studies and who has already done similar studies on asphalt plants or similar types of equipment. Significant savings in consulting costs can be made by employing someone having a familiarity with the industry and the procedures which must be followed. Your national or state association should be able to recommend such an individual.
3. Prior to making the study, discuss with your consultant your ideas developed during your walk-around survey. Make it very clear that your ideas are intended to help him make his study, but that the responsibility for a complete and thorough test will rest with him.
4. Have the consultant run a complete dBA survey of your plant site, mapping his findings on an isodyne diagram of at least five dBA isodyne increments. This map will be used for evaluating your compliance with noise laws.
5. Have an octave band analysis run on all mobile and stationary equipment considered prime noise offenders. This octave band analysis will give clues as to the methods which can be used to silence the equipment.
6. Study the isodyne map to locate areas of high noise level. This study must be done with federal, state, and local ordinances in mind since they will vary from place to place.
7. Consider the five methods of controlling noise:
    1. Move it.
    2. Absorb it.
    3. Block it.
    4. Reduce it.
    5. Reduce exposure time.

    The 1st and 5th methods can be considered by yourself, using your isodyne plot to locate the magnitude and location of your trouble areas. The 2nd, 3rd and 4th methods should only be used in conjunction with a competent consulting engineer.
8. Care should be exercised to get ambient background noise measurements along property lines, with the Hot-Mix plant SHUT DOWN. These measurements will set the minimum noise level which can be achieved.
9. One last caution. This paper is intended to give to you a basic understanding of noise, noise legislation, and methods of controlling noise, resulting in a working knowledge of the subject so that you can intelligently appraise your noise problem. It gives criteria for selecting a qualified consultant so that you can work with him and assist him in defining your noise problem and find the least expensive, yet acceptable, solution to it. It is not, nor is it intended to be, a do-it-yourself guide to noise control.

ADM ASPHALT DRUM MIXERS, INC.

SOUND LEVELS/dba

ITEM	50ft.	100ft.	300ft.	500ft.
Burner 41m	85	79	69	65
Exhaust Stack	85	79	69	65
Drum (approx)	50	44	34	30
Turbo-Blower	68	62	52	48
Air Compressor	58	52	42	38
Resulting noise level of all equipment running simultaneously.	87.5	81.5	71.5	67.5

Permissible noise exposure in accordance with OSHA regulations:

Duration per day, hours	Sound level, dba
8	90
6	92
4	95
3	97
2	100
1	102

Representative noise levels that you are accustomed to hearing are as follows:

Sound Studio	20db
Quiet Office	40db
Conversation (3ft.0)	60db
Noisy Restaurant	80db
Printing Press	100db
50 H.P. Siren	120db
Jet Plane	140db

1 ADM PARKWAY — HUNTERTOWN, INDIANA 46748 — PH. 219-637-5729 — FAX 219-637-3164

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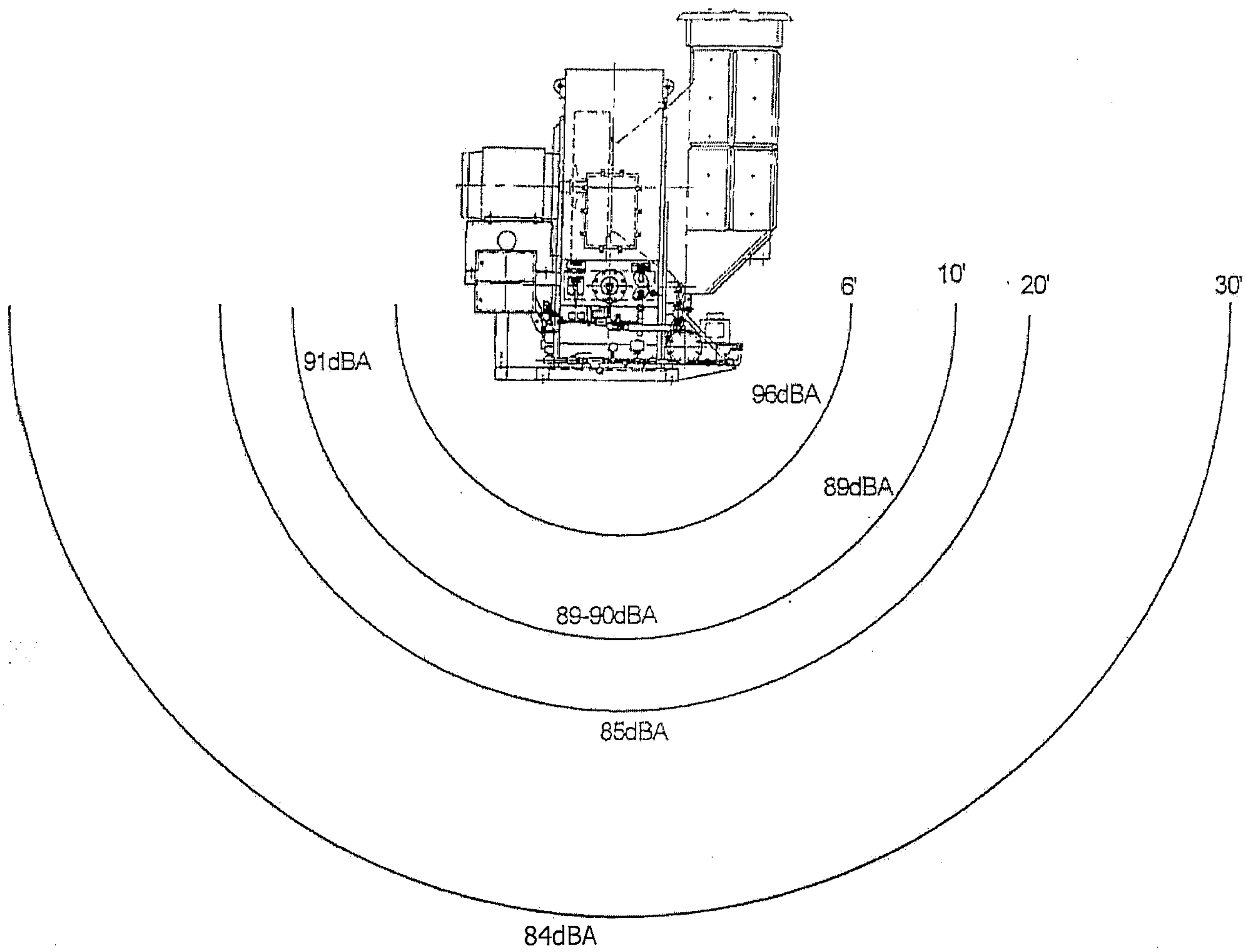

SOUND PRESSURE LEVELS WILL DROP BY APPROXIMATELY 6dBA EACH TIME THE DISTANCE FROM THE SOUND SOURCE IS DOUBLED.

THE APPROXIMATE DECIBEL LEVEL AT 980' IS 54 Dba

Representative Noise Levels You Are Accustomed To Hearing:

Sound Studio	20dBA
Quiet Office	40dBA
Conversation(3 ft)	60dBA
Noisy Restaurant	80dBA