

ExxonMobil DESIGN PRACTICES	AIR POLLUTION CONTROL, INDUSTRIAL HYGIENE, AND NOISE CONTROL FLOW-INDUCED NOISE	Section	Page
		XVIII-C1	1 of 34
		March, 2004	

CONTENTS

Changes shown by ↗

Section

Page

SCOPE / BACKGROUND	3
REFERENCES	3
DEFINITIONS	4
<i>Jet Noise</i>	<i>4</i>
<i>Pipe Wall Transmission Loss</i>	<i>4</i>
DECISION TREES FOR VALVE AND FLOW NOISE CONTROL	4
NOISE CRITERIA	4
FLOW NOISE GENERATION	7
BASIC NOISE GENERATING MECHANISMS	7
FLOW RESTRICTIONS	7
FREE JET DISCHARGE	7
FLOW DISCONTINUITY	7
BOUNDARY LAYER NOISE	8
FLOW NOISE PREDICTION	8
VALVE NOISE PREDICTION	8
RESTRICTION ORIFICE NOISE PREDICTION	10
VENT NOISE PREDICTION	10
PIPING VELOCITY LIMIT	12
ACOUSTIC FATIGUE LIMIT	16
SAMPLE PROBLEM	16
DESIGN GUIDE – VALVE AND ORIFICE NOISE ESTIMATION AND CONTROL	17
COMPRESSOR RECYCLE VALVES	17
DEPRESSURING VALVES	17
PRESSURE RELIEF VALVES	18
STEAM DESUPERHEATERS	18
DESIGN GUIDE – VENT NOISE ESTIMATION AND CONTROL	19
STEAM EJECTORS	19
STEAM GENERATION VENTS	19
SELF-STARTING STEAM TURBINES	19
STEAM LINE WARM-UP	19
AIR COMPRESSOR VENTS	20
DEPRESSURING VENTS	20
VESSEL PURGE VENTS	20
VENT SILENCERS	20
ENCLOSURE PURGES	21
LINE STEAM BLOWING	22
DESIGN GUIDE – FCCU REGENERATOR FLUE GAS LINE NOISE ESTIMATION AND CONTROL	24
COMMUNITY NOISE ESTIMATE	25
WORKPLACE NOISE ESTIMATE	29
FCCU FLUE GAS LINE / STACK SILENCER DESIGN	29

Section XVIII-C1	Page 2 of 34	<i>AIR POLLUTION CONTROL, INDUSTRIAL HYGIENE, AND NOISE CONTROL</i>	ExxonMobil
March, 2004		FLOW-INDUCED NOISE	DESIGN PRACTICES

TABLES

Table 1 - Correction Factor for Pipe Size and Wall Transmission Loss, K_v	9
Table 2 - Correction Factor for Insulation Installed on Piping and Valve Body, K_i	9
Table 3 - Vent Directivity Index.....	11
Table 4 - Velocity Limits for Uninsulated Piping Elements to Avoid Excessive Noise from a Continuously Operating System	15
Table 5 - Allowable Increase in Piping System Velocity for External Insulation.....	15
Table 6 - Flow Rate Sizing of Silencers.....	20
Table 7 - Stack Exit Sound Power	25
Table 8 - Stack Exit Noise Radiation Directivity Index (DI), DB	26
Table 9 - Pipe/Stack Wall Transmission Loss (TL), DB	27

FIGURES

Figure 1 - Decision Tree for an Existing Flow or Valve Noise Problem	5
Figure 2 - Decision Tree for Noise Control of Flow and Control Valves in New or Replacement Facilities ...	6
Figure 3 - Allowable Velocities for Uninsulated Straight Piping to Avoid Excessive Noise (Customary Units)	13
Figure 4 - Allowable Velocities for Uninsulated Straight Piping to Avoid Excessive Noise (Metric Units) ...	14
Figure 5 - Example Silencer Design for Line Steam Blowing.....	23
Figure 6 - A Schematic Of A Representative Flue Gas Line And Stack	32
Figure 7 - A Conceptual Silencer Design For FCCU Flue Gas Line And Stack.....	33
Figure 8 - Silencer Design Chart	34

Revision Memo

03/04	Major modifications including a design guide for FCCU regenerator flue gas line noise estimate and control. Noise estimate methods have been presented for community and workplace noise assessment. A silencer design tool for reducing noise from flue gas line / stack is also documented. Both techniques have been improved from the previous methods based on recent project work and R&D effort.
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 DESIGN PRACTICES	AIR POLLUTION CONTROL, INDUSTRIAL HYGIENE, AND NOISE CONTROL FLOW-INDUCED NOISE	Section XVIII-C1	Page 3 of 34
		March, 2004	

SCOPE / BACKGROUND

This section is concerned with the noise generated and transmitted by the flow of gases and vapors within closed piping and emitted from open vent piping systems. Guidelines are provided to enable the design engineer to perform screening estimates of the noise levels generated by various vent, valve, and piping configurations.

It should be noted that liquid flow in piping systems is not covered in this Design Practice because liquid flow generally does not cause noise problems of the magnitude of gaseous and vapor flow. In fact, with the exception of cavitation, the noise levels generated by liquid flow systems are low enough to satisfy most noise criteria. However, if cavitation does occur, then excessive noise levels can be generated and pose both a noise control problem and, more importantly, a potential piping failure due to mechanical fatigue. Normal precautions taken during design, construction, and operation to keep flow below cavitation conditions will eliminate this potentially destructive noise source. If changing operations or equipment wear result in cavitation conditions, then the ExxonMobil Engineering Mechanical Specialist can be contacted for assistance in modifying and/or resizing the associated equipment.

For most plant construction and modifications, the noise abatement measures associated with flowing fluids is the responsibility of the plant engineer and/or contractor who is performing the engineering and equipment procurement for the facility. If questions arise concerning either contractor or manufacturer noise estimates or their proposed noise control techniques, then the ExxonMobil Engineering Noise Specialist should be contacted for guidance.

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Section XVIII-C1		Page 4 of 34		<i>AIR POLLUTION CONTROL, INDUSTRIAL HYGIENE, AND NOISE CONTROL</i> FLOW-INDUCED NOISE	 DESIGN PRACTICES
March, 2004					

DEFINITIONS

Basic Acoustical Terms

See *Guidelines and Considerations for Noise Control*, [Section XVIII-C](#), DEFINITIONS.

Jet Noise

Jet noise is created when a flow stream mixes with a relatively still surrounding fluid. The high shear forces in the mixing layer give rise to periodic compressions of the fluid which propagate as sound.

Pipe Wall Transmission Loss

Pipe wall transmission loss is the difference in decibels between the sound pressure level inside a pipe and sound pressure level at the outside surface of the pipe.

DECISION TREES FOR VALVE AND FLOW NOISE CONTROL

To provide guidance to design engineers, decision trees for controlling the noise generated by gas flow and control valves in gas service are shown in this section. The decision trees show specific suggestions appropriate for flow and valve/orifice noise control and are consistent with the approaches introduced in *Guidelines and Considerations for Noise Control*, [Section XVIII-C](#). For implementing corrective actions to existing facilities, see [Figure 1](#). For purchasing new or replacement equipment, see [Figure 2](#). For those situations that may not fit into these scenarios, such as major capital project equipment, contact the ExxonMobil Engineering noise control specialists for assistance.

NOISE CRITERIA

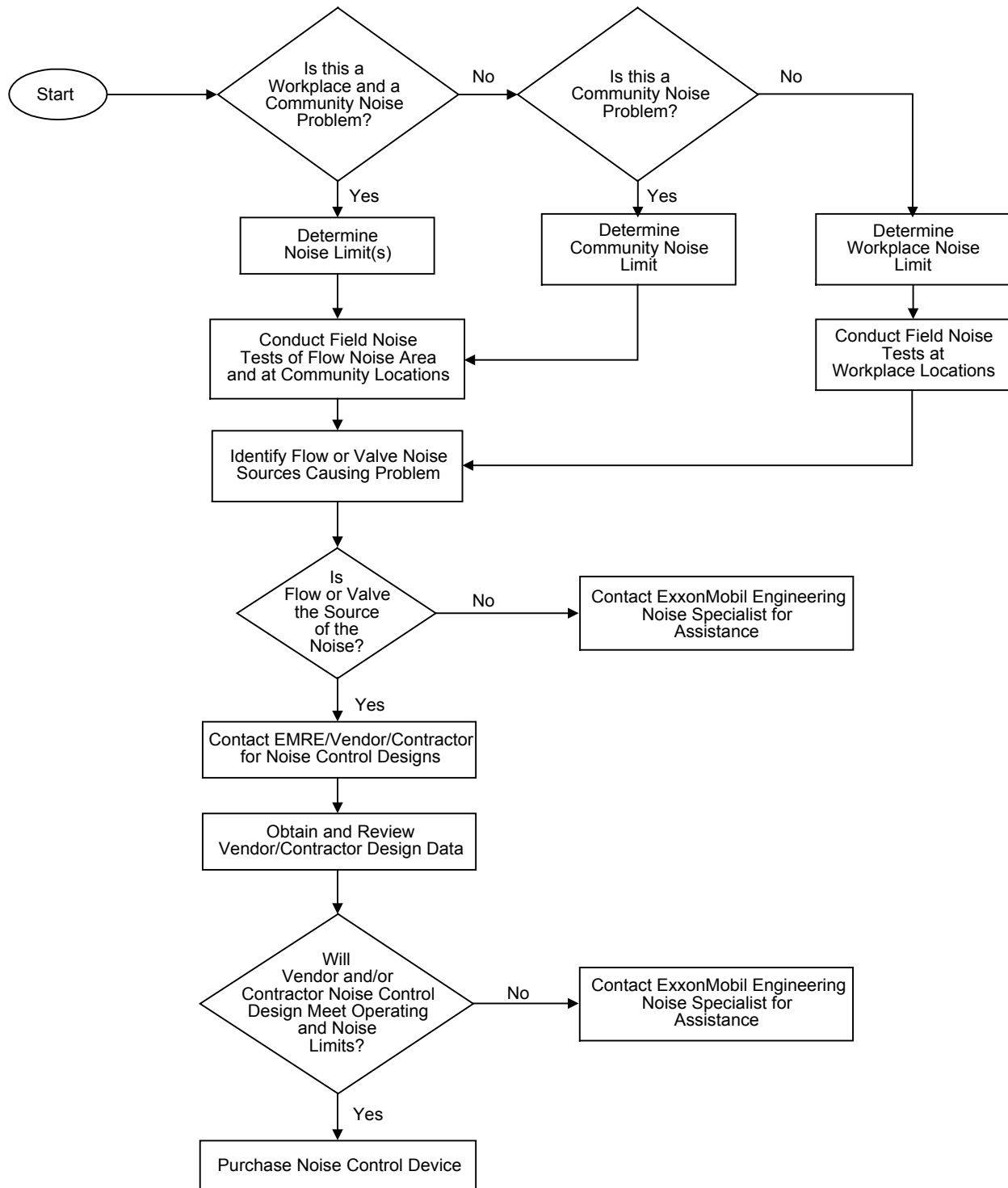
Two general types of noise level criteria are usually applicable to process units: workplace noise limits to minimize worker hearing impairment and community noise limits to prevent annoyance in adjacent communities. Compliance with both of these criteria can be a concern with gas flow and valves/orifices in gas service. The generated noise from these sources can be significant and must receive consideration during new and/or replacement facility designs.

Multiple and intermittent sources (i.e., vents) represent special cases when setting and evaluating noise criteria impacts. For example, allowable noise levels for atmospheric vents must be established for both in-plant and community locations. The criteria levels will be a function of the facility design noise criteria (based on local governmental ordinances and regulations) and the number of sources.

For further discussion and details on general community and workplace noise criterion, please refer to *Guidelines and Considerations for Noise Control*, [Section XVIII-C](#), **PLANT NOISE CRITERIA**.



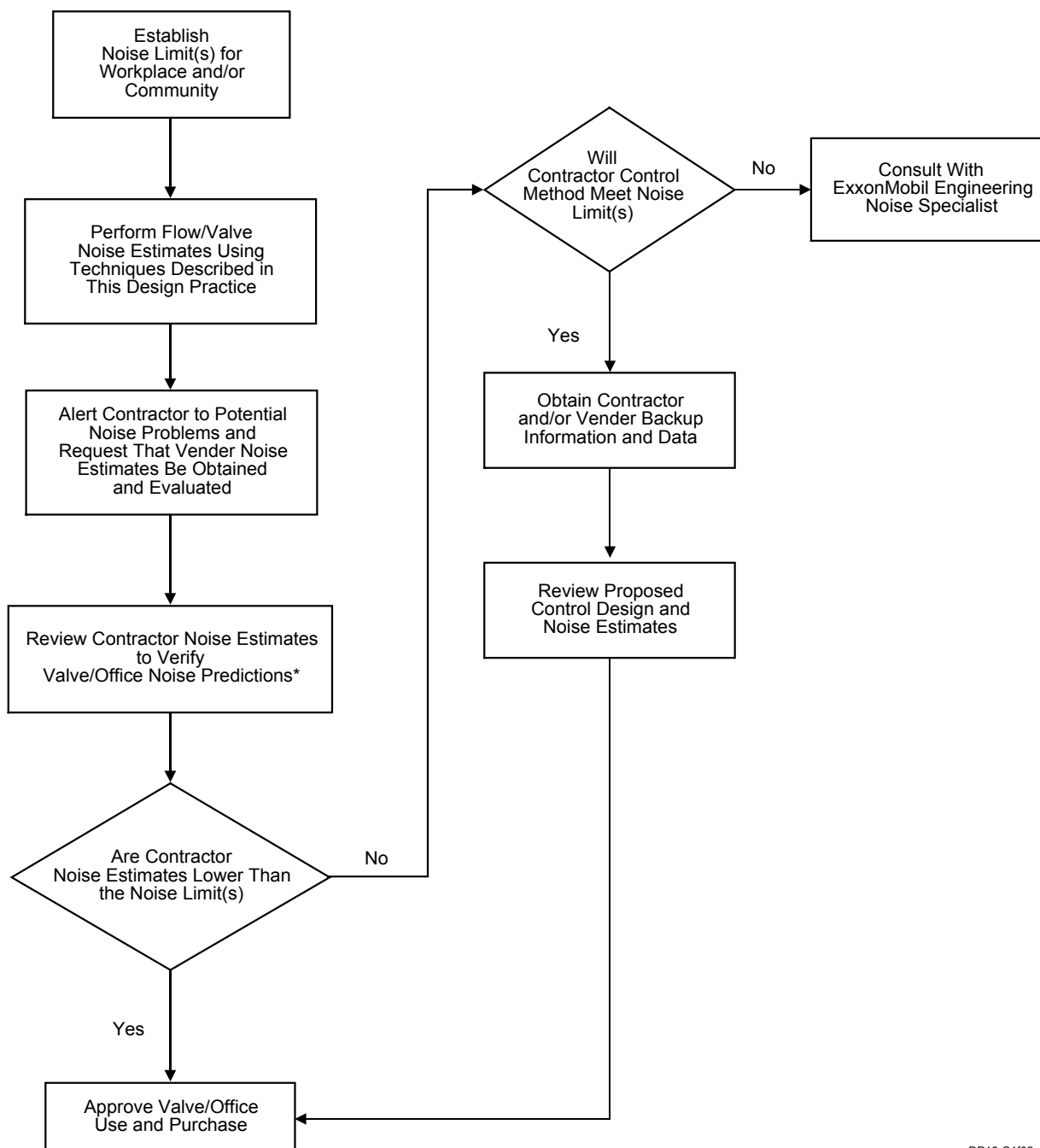
Figure 1 - Decision Tree for an Existing Flow or Valve Noise Problem



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Section XVIII-C1	Page 6 of 34	<i>AIR POLLUTION CONTROL, INDUSTRIAL HYGIENE, AND NOISE CONTROL</i> FLOW-INDUCED NOISE	 DESIGN PRACTICES
March, 2004			

Figure 2 - Decision Tree for Noise Control of Flow and Control Valves in New or Replacement Facilities



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***Note:**

Liquid flow valves/orifices normally do not present a noise problem. If Contractor liquid valve/orifice noise estimates exceed criteria, then contact an ExxonMobil Engineering Noise Specialist for assistance.

 DESIGN PRACTICES	AIR POLLUTION CONTROL, INDUSTRIAL HYGIENE, AND NOISE CONTROL FLOW-INDUCED NOISE	Section XVIII-C1	Page 7 of 34
		March, 2004	

FLOW NOISE GENERATION

BASIC NOISE GENERATING MECHANISMS

There are four basic fluid flow mechanisms encountered in process plants, which can result in the generation of flow noise. These mechanisms/causes are as follows:

1. Flow through restrictions such as valves and orifices.
2. Jet discharges from high velocity vent exits.
3. Flow through discontinuities such as tees, elbows, and reducers.
4. Flow along a solid boundary such as a pipe wall.

Of the above, flow through a restriction is the most prevalent and is responsible for most of the fluid flow noise in process plants. Jet discharge and flow discontinuities cause less noise problems, while flow at a boundary rarely if ever generates significant noise. Each of these flow noise generation situations is discussed below in more detail.

FLOW RESTRICTIONS

Control valves and fixed orifices are the most common sources of fluid flow noise generation in process plants. The contractor is normally aware of the fact that control valves can generate excessive noise and is usually supplied with an estimate of the valve noise from the valve vendor. The contractor then takes the necessary steps to ensure that the control valve noise does not exceed the applicable noise criteria. However, restriction orifices may not be recognized as potential noise sources and may not receive proper consideration by the contractor in the detailed engineering of the plant. Therefore, it would be desirable to alert the contractor to those fixed orifices that have the potential to exceed the plant's noise criteria. The procedure for identifying the potentially noisy orifices is presented below under the section entitled [RESTRICTION ORIFICE NOISE PREDICTION](#).

Some control valves and restriction orifices in high gas flow and/or high-pressure drop service can generate sufficient acoustic energy to cause fatigue cracking of the piping. The procedures for identifying those valves and orifices that have the potential to cause mechanical fatigue failures are presented the section entitled [ACOUSTIC FATIGUE LIMIT](#).

If the reader wishes to undertake an in-depth analysis of the piping system noise associated with a particular control valve or restriction orifice, then please refer to **ER&E Report No. EE.51E.76**, *Prediction of the Generated and Transmitted Noise Levels from Control Valves*.

FREE JET DISCHARGE

Free jet discharge noise is created as a fluid exits from either a pipe or nozzle. The most common example is the discharge of a gas from a vent tailpipe. However, in most situations this jet noise is completely overshadowed by the noise from the vent valve, which propagates along the vent pipe and is radiated from the vent exit. In cases where the vent pipe imposes a very high back pressure, resulting in a high exit velocity, the jet exit noise may be significant. For mechanical and acoustical performance reasons, inline silencers are designed to have an exit velocity that is below the point where the jet exit noise would become significant. To ensure that excessive jet noise is not created downstream of the silencer, the exit tailpipe diameter should not be reduced (or swaged down) downstream of the silencer discharge. Also, increasing the vent pipe diameter just upstream of the exit will not substantially reduce the noise.

Another situation in which jet discharge noise may be encountered is purging of enclosures. Design considerations for this application are discussed below in the **DESIGN GUIDE** section.

FLOW DISCONTINUITY

The noise generated by tees, elbows, and reducers is usually much lower than the noise levels from other piping system sources such as control valves and compressors. Also, except for vent and pressure relief systems, the typical piping design velocities will not cause noise to be generated that is in excess of normally applied criteria levels. Guideline velocities for tees, elbows, and reducers are given below under the section entitled [PIPING VELOCITY LIMIT](#).

In some high-pressure letdown systems, the tee connection where a lateral joins a header can create acoustic energy of sufficient magnitude to warrant investigation of the possibility of acoustic fatigue of the piping elements. This is the same problem that can be created by extremely noisy control valves. Information for evaluating the possibility of acoustic fatigue at a tee is presented in the [ACOUSTIC FATIGUE LIMIT](#) section.

Section XVIII-C1	Page 8 of 34	AIR POLLUTION CONTROL, INDUSTRIAL HYGIENE, AND NOISE CONTROL	ExxonMobil
March, 2004		FLOW-INDUCED NOISE	DESIGN PRACTICES

BOUNDARY LAYER NOISE

As a fluid flows through a pipe, pressure fluctuations are generated in the boundary layer area at the internal surface of the pipe. These pressure fluctuations die out very quickly and have little effect beyond the point at which they are generated. At the point of generation these pressure fluctuations can excite the pipe wall into vibration, which in turn radiates noise to the outside environment. However, the noise generated by fluid-boundary interaction is usually not perceptible over other noise sources in the piping system such as control valves and compressors. Also, the velocities for which continuously operating piping systems are sized will not cause noise in excess of normally applied criteria levels.

Because of its secondary importance, boundary generated noise is difficult to measure and quantify. However, based on published information, guidelines for allowable pipe velocities in relation to noise have been prepared and are included in the section [PIPING VELOCITY LIMITS](#).

FLOW NOISE PREDICTION

VALVE NOISE PREDICTION

Valve Screening Estimates - Early in a project, a screening noise evaluation must be performed to identify those valves which potentially will require noise treatment by the contractor and/or manufacturer. Subsequently, the results should be included in the Design Specification provided to the contractor. To perform a detailed valve noise prediction, the methods described in the ISA standards (*References 2 and 9*) should be used.

Because the project is in its initial stages, no detailed design information is available. Hence, the screening estimates must be simple to perform and require a minimum of operating information. They should provide the design engineer a generalized estimate of the noise expected from most standard (i.e., not equipped with any noise control features) valves regardless of basic valve design. The equations shown below offer all of these advantages.

Sound Power Level Screening Estimates - The sound power level generated by most standard control valves and radiated into the downstream piping can be determined from the following expressions:

For Units in the Customary System:

$$L_W = 10 \log \left[(W)^2 \left(\frac{\Delta P}{P_1} \right)^{3.6} \left(\frac{T}{MW} \right)^{1.2} \right] + 45 \quad \text{Eq. (1)}$$

where: L_W = Sound power level generated by the valve and radiated to the downstream piping, dB re 10⁻¹² watts
 W = Flow rate of the gas, lbs/hr
 ΔP = $P_1 - P_2$ = pressure drop across the control valve, psi
 P_1 = Upstream pressure, psia
 P_2 = Downstream pressure, psia
 T = Temperature of flowing gas, °R
 MW = Molecular weight of flowing gas

For Units in the Metric System:

$$L_W = 10 \log \left[(W)^2 \left(\frac{\Delta P}{P_1} \right)^{3.6} \left(\frac{T}{MW} \right)^{1.2} \right] + 126 \quad \text{Eq. (2)}$$

where: L_W = Sound power level generated by the valve and radiated to the downstream piping, dB re 10⁻¹² watts
 W = Flow rate of the gas, kg/sec
 ΔP = $P_1 - P_2$ = pressure drop across the control valve, kPa
 P_1 = Upstream pressure, kPa
 P_2 = Downstream pressure, kPa
 T = Temperature of flowing gas, °K
 MW = Molecular weight of flowing gas

 DESIGN PRACTICES	AIR POLLUTION CONTROL, INDUSTRIAL HYGIENE, AND NOISE CONTROL FLOW-INDUCED NOISE	Section XVIII-C1	Page 9 of 34
		March, 2004	

Sound Pressure Level Screening Estimates - The sound pressure level at 3 ft (1 m) out from the piping immediately downstream of the control valve is determined from the following expression:

$$L_{PA} = L_W - K_V - K_I \quad \text{Eq. (3)}$$

where: L_{PA} = A-weighted sound pressure level at 3 ft (1 m) out from the pipe wall immediately downstream of the control valve, dBA

L_W = Sound Power Level as calculated from [Eq. \(1\)](#) or [\(2\)](#), dB re 10⁻¹² watts

K_V = Correction factor to account for the pipe size and pipe wall transmission loss from [Table 1](#), dB

K_I = Correction factor to account for insulation on the piping and valve body from [Table 2](#), dB

Table 1 - Correction Factor for Pipe Size and Wall Transmission Loss, K_V

NOMINAL PIPE DIAMETER		PIPE SCHEDULE										
in.	mm	STD	X	XX	5S	10	10S	20	30	40	80	160
1	25	54	58	72	42	—	50	—	—	54	58	65
2	50	50	55	68	38	—	45	—	—	50	55	63
4	100	50	56	67	36	—	41	—	—	50	56	63
6	150	49	54	66	36	—	38	—	—	49	55	63
8	200	48	55	63	37	—	40	45	45	48	55	64
10	250	47	50	—	37	—	40	43	46	47	52	58
12	305	47	49	—	38	—	40	43	46	47	53	59
14	355	45	48	—	37	42	39	44	45	47	52	58
18	455	46	48	—	38	42	39	44	47	49	54	61
24	610	45	47	—	40	41	41	45	48	50	55	62
30	760	43	46	—	40	42	42	46	48	—	—	—
36	915	43	45	—	—	—	—	—	—	—	—	—
42	1065	42	45	—	—	—	—	—	—	—	—	—

Table 2 - Correction Factor for Insulation Installed on Piping and Valve Body, K_I

TYPE OF INSULATION	CORRECTION FACTOR FOR INSULATION, dB
1 in. to 3 in. Calcium Silicate	3
Foam Glass Cold Insulation	0
Fiberglass or Mineral Wool - 1 in. (25 mm) Thick	12 18 21

Note: Fiberglass density should be 6 - 8 lb/ft³ (98 - 128 kg/m³) or mineral wool density should be 8 -10 lb/ft³ (128 - 160 kg/m³) and covered with a metal jacket or insulating cement.

Section XVIII-C1	Page 10 of 34	AIR POLLUTION CONTROL, INDUSTRIAL HYGIENE, AND NOISE CONTROL	ExxonMobil
March, 2004		FLOW-INDUCED NOISE	DESIGN PRACTICES

It is important to note that because of the manner in which the above equations were derived, they can also be used to estimate the noise immediately downstream of a restriction orifice. If an in-depth screening evaluation of a control valve piping system is required, the reader should refer to **ER&E Report No. EE.51E.76**, *Prediction of the Generated and Transmitted Noise Levels from Control Valves*.

Detailed Engineering Estimates of Valve Noise - The detailed engineering estimates of control valve noise are usually handled by the contractor. Typically, the contractor will contact the valve manufacturers to size the process valves and propose an abatement approach to ensure the expected noise levels will meet project noise criteria. Alternatively, the contractor will size the valve and estimate the emitted noise and develop an appropriate noise control approach (low-noise trim, etc.) using the manufacturers sizing computer program. Regardless of which path the contractor chooses the resulting noise estimates should be the same and will produce an acceptable estimate if the manufacturer prediction was determined using either the ISA or IEC methods. If questions arise concerning either the manufacturer prediction method, estimated noise levels, or proposed noise control approach, and then the ExxonMobil Engineering noise control specialist should be contacted for assistance.

RESTRICTION ORIFICE NOISE PREDICTION

The mechanism of noise generation by restriction orifices is basically the same as for standard control valve designs. Therefore, the control valve screening estimate method, [Eqs. \(1\)](#) or [\(2\)](#) and [\(3\)](#), also may be used to perform estimates of the dBA noise level at three (3) ft out from the piping immediately downstream of a restriction orifice.

As in the control valve screening estimates, the results of the restriction orifice evaluation should be used to alert the project contractor to those restriction orifices, which potentially will exceed the in-plant noise criteria and require noise treatment. If questions arise concerning either the contractor noise prediction or the proposed noise control approach, then the ExxonMobil Engineering noise control specialist should be contacted for assistance.

VENT NOISE PREDICTION

The vent valve is almost always the dominant noise source radiated from the discharge of process plant vents. As a general rule, it can be assumed that the free jet noise generated at the vent exit will not be a problem.

Vent Exit Radiation - Special considerations and screening estimate methods for vent valve operations are described in the sections below. For venting operations, the vent sound pressure level radiating from the vent exit may be determined by the procedure given below.

1. Calculate the vent valve sound power level using [Eq. \(1\)](#) or [\(2\)](#).
2. Calculate the sound pressure level from the following expression:

For Distances in Customary Units:

$$L_{PX} = L_W - 20 \log X - 0.0015X - DI + 2 \quad \text{Eq. (4)}$$

where: L_{PX} = A-weighted sound pressure level at distance X ft from the vent exit, dBA
 L_W = Vent valve sound power level from [Eq. \(1\)](#), dB re 10^{-12} watts
 X = Distance from vent exit to point of concern, ft
 DI = Directivity Index for the vent from [Table 3](#), dBA

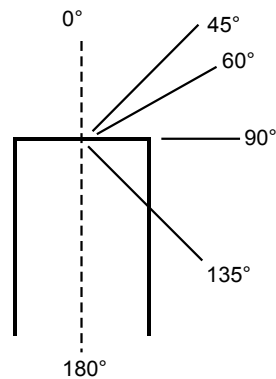
For Distances in Metric Units:

$$L_{PX} = L_W - 20 \log X - 0.0049X - DI - 8 \quad \text{Eq. (5)}$$

where: L_{PX} = A-weighted sound pressure level at distance X m from the vent exit, dBA
 L_W = Vent valve sound power level from [Eq. \(2\)](#), dB re 10^{-12} watts
 X = Distance from vent exit to point of concern, m
 DI = Directivity Index for the vent from [Table 3](#), dB

ExxonMobil DESIGN PRACTICES	AIR POLLUTION CONTROL, INDUSTRIAL HYGIENE, AND NOISE CONTROL FLOW-INDUCED NOISE	Section XVIII-C1	Page 11 of 34
		March, 2004	

Table 3 - Vent Directivity Index



VENT DIAMETER		DIRECTIVITY INDEX, DI, dB				
ft	m	0°	45°	60°	90°	135° - 180°
< 1	< 0.3	- 1	+ 3	+ 5	+ 6	+ 9
2	0.6	- 2	+ 1	+ 6	+ 7	+ 12
4	1.2	- 2	0	+ 7	+ 11	+ 15
> 8	> 2.4	- 2	- 2	+ 8	+ 14	+ 18

Vent Exit Pipe Radiation - The noise radiated by the vent pipe wall is usually substantially less important than the noise from the vent exit. However, if the pipe noise radiation is of concern, then calculate the noise level at 3 ft (1 m) from the pipe surface using Eqs. (1) or (2) and (3). Next, determine the sound pressure level at distance X from the vent exit by substituting the L_{w-p} results of the following expressions into either Eq. (4) or (5) and assuming DI to be zero.

For Distances in Customary Units:

$$L_{w-p} = L_{PA} + 10 \log L + 7 \quad \text{Eq. (6)}$$

where: L_{w-p} = Vent valve sound power level radiated by the vent pipe wall, dB re 10^{-12} watts
 L_{PA} = A-weighted sound pressure level at 3 ft as calculated from Eqs. (1) and (3), dBA
 L = Length of vent pipe radiating a distance X, ft

For Distances in Metric Units:

$$L_{w-p} = L_{PA} + 10 \log L + 17 \quad \text{Eq. (7)}$$

where: L_{w-p} = Vent valve sound power level radiated by the vent pipe wall, dB re 10^{-12} watts
 L_{PA} = A-weighted sound pressure level at 1 meter as calculated from Eqs. (2) and (3), dBA
 L = Length of vent pipe radiating a distance X, m