Noise Control in Large Gas Handling Plants

The law has been written to reduce noise levels in operating plants. An engineering approach is the only way to assure that operations will comply with the regulations.

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The general engineering approach to noise control in large gas handling plants, though somewhat complicated, provides the only scientific method of achieving the environmental criteria today specified in the law.

More than four years have passed since the present noise criteria limiting the exposure of employees to industrial noise levels of 90 dBA for eight hours and related level-time equivalents became law. To meet the intent and requirements of this law, it is necessary to understand the environmental noise exposure in terms of the contributions of the many sources that synthesize to produce the sound pressure levels measured at the points of exposure throughout typical industrial areas.

The development of this engineering approach will consider the typical problem noise sources common to gas handling processes, such as gas vents, valves, turbines, compressors, oil and gas burners, fans, pressure blowers, gear boxes, and motors. This article discusses the requirements for a noise control survey and analysis, solutions to the noise control of problem sources, and methods for anticipating and incorporating noise control for noise sources during the design phase.

To properly assess the noise exposure of employees, the law requires that a standard sound level meter be used in the survey (Type II per ANSI S1.4, as suggested in Department of Labor Bulletin No. 334) set on "A" scale, slow response.

Once it has been determined that there are points within the environment that exceed the criteria level for employee exposure, a noise control survey must be conducted to identify the noise sources contributing to these exposure survey levels and determine the nature of each quantitatively.

Precise sound level meter is required

Such an engineering control survey requires at least a precision sound level meter with an octave band (or finer bandwidth) frequency analyzer and a microphone having a flat response to at least 16,000 hertz (Hz). The sound pressure level vs. frequency data is vital to pinpoint each source by its characteristic noise signature and further to break down the noise into its component parts. The purpose of the latter is to develop engineering criteria for control of each source that will result in an environmental level below the criteria limit when the sources are re-synthesized.

The important point to realize is that this survey is essential in the determination of criteria for each equipment, which must be less than 90 dBA in each case, so as to result in an environmental level less than 90 dBA, using well-known methods for adding decibels.

Consider an example of a typical area with a background noise level of 78 dBA and follow the effect upon the environmental noise level (assuming a highly reverberant area) as the noise from three equipments is superimposed (see Figures 1 through 4). To reduce the environmental level below 90 dBA one can work on (in effect change the equipment noise criteria for) source 2 or 3, or both as desired.

Then consider some of the techniques employed in a noise control survey. Along with a thorough familiarity with the acoustical instrument, it is essential to recognize the key characteristics of noise source types. A few examples follow:

For such equipment types as fans, compressors, gear

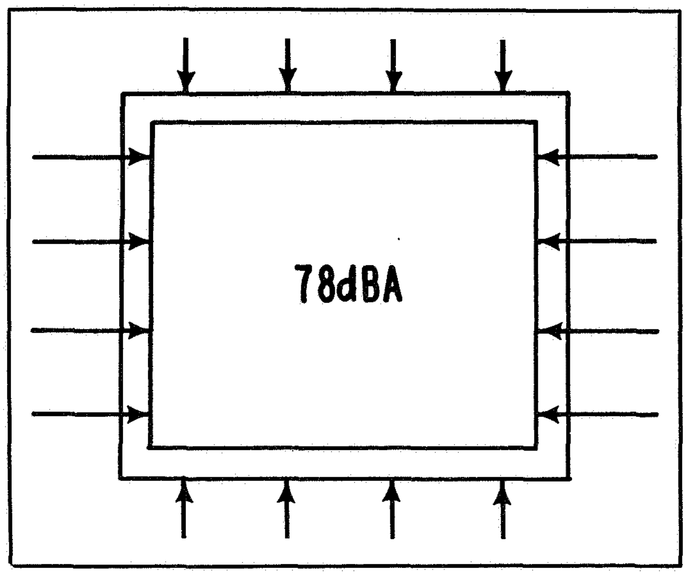

Figure 1. Entire volume is at 78 dBA, with no equipment installed (noise coming through block wall boundaries).

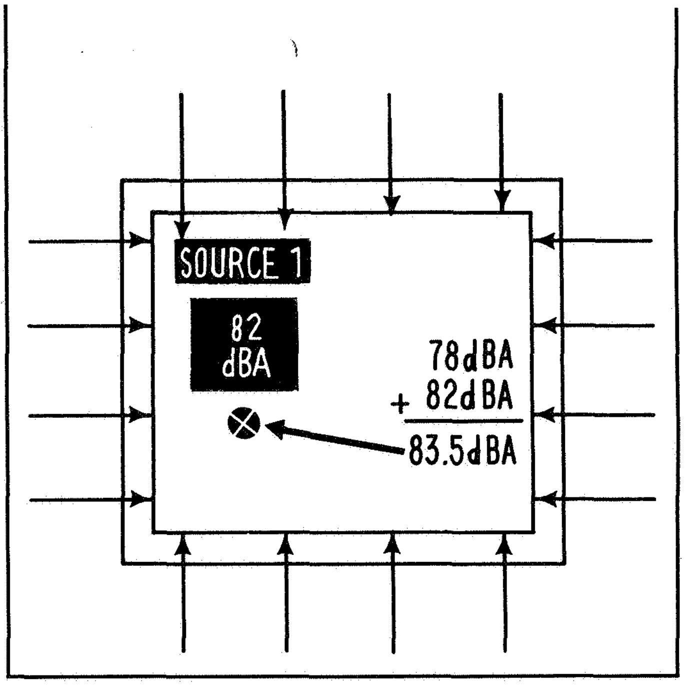

Figure 2.
Source 1, which is 82 dBA by itself, is added to the room, and the resultant level in the area becomes 83.5 dBA.

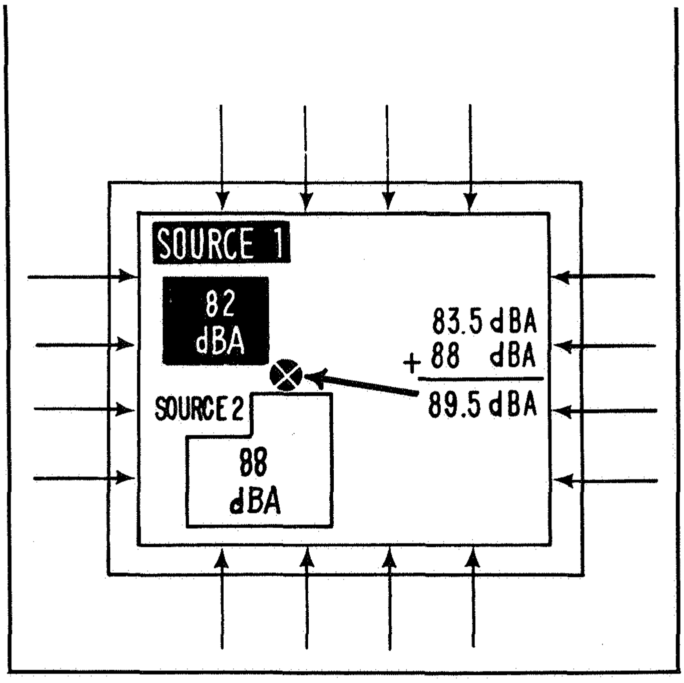

Figure 3.
Source 2, which is 88 dBA by itself, is added to the room with Source 1, and the resultant level in the area becomes 89.5 dBA.

boxes, motors, pressure blowers, and pumps, these are the key noise characteristics:

Blade frequency—fundamental and higher harmonics where noise peaks at a frequency given by

$$f = \frac{N \times RPM}{60K} \qquad (1)$$

where:
f = frequency, in Hz.
N = number of rotating elements (e.g. blades).
K = number of fixed edges which rotating elements pass.
RPM = rotating speed, revolutions per minute.

For equipment types such as vents, jets, and orifices below the critical pressure drop, key noise characteristics are:

Frequency peak of noise spectrum given by

$$f = 0.2 \frac{V}{d} \qquad (2)$$

where:
f = frequency, in Hz.
V = velocity, in ft./sec.
d = characteristic dimension, in ft.
0.2 = the Strouhal number.

This noise is also characterized by high-frequency peaks, i.e., above 500 Hz.

For such equipment types as valves, key noise characteristic is as follows:
When the pressure ratio across the valve exceeds 1.89/1.00 (assuming a perfect gas, e.g., air) and/or when the Mach number of the flow exceeds 0.7, a high level of high-frequency noise over several octave bands is to be expected.

For such equipment types as oil and gas burners, key noise is generally characterized by low-frequency pulsations caused by instabilities in the combustion process with some high-frequency noise due to shear in the mixing region and aspiration of air.

Checking back with the vendor for noise data at this time may also produce necessary information, in that he may have evaluated a similar model or type. Recognizing the key noise characteristics is most important when the noise control survey must be conducted without the privilege of starting and stopping equipment at will. This situation infers that the resultant estimates of noise from each source are based on experience and the judicious use of the various available techniques for mathematically eliminating background noise. For these purposes, background noise is all noise other than that from the sources being considered. A conservative treatment of the estimates is essential to the successful achievement of noise control and compliance with the exposure criteria.

Having estimated the individual contributions of all equipments affecting the environment in terms of sound pressure level as a function of frequency, the next step to noise control is to set up the criteria for each equipment involved such that the difference between estimated contribution and criteria represents the attenuation, or noise control, required. Of course, all separate equipment criteria must be compatible with the 90 dBA criteria for the employee exposure points in the area.

Throughout this entire analysis one is constantly reminded that there is no unique expression of dB sound pressure level vs. frequency that gives 90 dBA. There are many such curves available. This flexibility is fortuitous because it permits some optimization in engineering the controls. For example, interchanging the equipment criteria between two units is one alternative available where these two sources are solely responsible for problem noise in a given area (again assuming that it is highly reverberant).

Six basic elements of noise control

Now consider the general approaches to the noise control hardware required to suppress the noise from the previously mentioned typical sources in gas handling plants, such as those which produce ammonia and methanol. The six basic elements of noise control are: 1) vibration isolation (including balancing and alignment; 2) transmission loss (massive barriers); 3) absorption; 4) damping (resonance); 5) seals and fasteners; and 6) silencers. They will be discussed by application to the problems now considered.

Gas vents. Noise from gas vents, as previously noted, is a strong function of the gas velocity at the exit orifice. Also included may be some airborne noise gen-

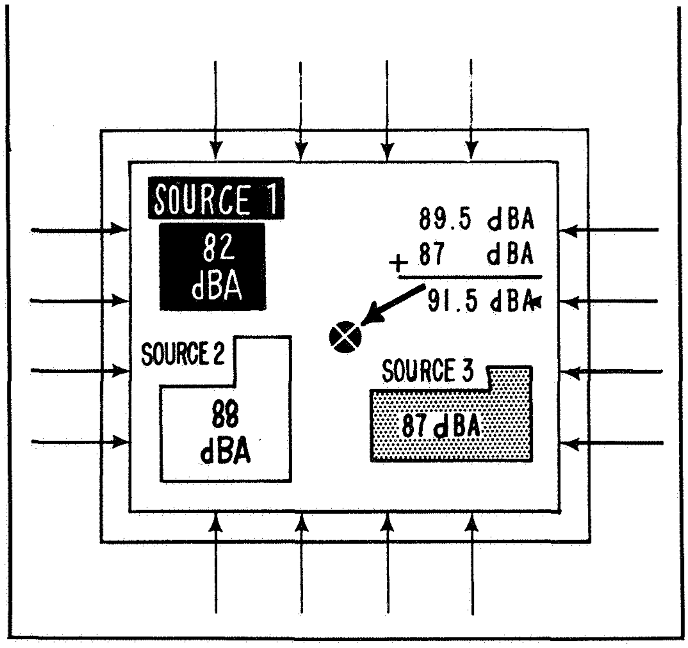

Figure 4. Source 3, which is 87 dBA by itself, is added to the room with Sources 1 and 2, and the resultant level in the area becomes 91.5 dBA (1.5 dBA in excess of criteria).

erated by upstream sources other than the discharge orifice itself.

The solution to this problem generally comprises one or more of the following:

1. Silencers of various types: including packed, pulsation control—chamber type, laminar absorbers, reactive and radial diffuser type.
2. Velocity control valves with stacked, multi-ported discs which use the "porous plug" principle of adiabatic flow with friction.
3. Multi-ported orifice plates which also use the "porous plug" principle of adiabatic flow with friction (but with fixed C_v, valve sizing coefficient).

The selection of the type of silencer is based upon a number of factors including:

1. Insertion loss required in dB as a function of frequency depends on noise generated and where the vent orifice is located relative to potential auditors.
2. The characteristics of the gas including temperature, pressure, contamination and corrosion properties.
3. The nature of the flow: whether it is pulsating (generally below 500 Hz) as is the case when the source is, for example, a lobe-type pressure blower or axial compressor; or if it is relatively smooth flow (e.g., pulsation frequencies are generally greater than 1,000 Hz) as is the case for most centrifugal fans, blowers and compressors that operate at high speed.

There are many unique methods for application of commercial silencers to vent noise problems. One of the more interesting for large vents is the use of parallel arrays. The cost of silencers in a parallel array with the same overall attenuation and flow-handling characteristics is significantly less than the equivalent single unit. Further, the arrangement is much more compact and is simpler to install and maintain.

A simple comparison for a typical case may be drawn in the following example: Cross-sectional area required for flow is 393 sq. in., which can be obtained using five 10 in. diameter silencers in parallel, each having an approximate length of 47 in. To accomplish this same task with a single unit requires a 22 in. diameter silencer, 97 in. long. The cost comparison shows a $300 savings for the multiple array.

Valves. The noise from valves can be reduced by velocity control devices which employ stacked, multiport discs. They permit pressure let-down through adiabatic flow with friction in the manner of a porous plug, with a full range of flow control.

Also applicable for some installations are the multiported, tortuous-path plates which can be installed downstream of the noise generating control valve to back up pressure (below the critical ratio of 1.89/1) on the valve and also on one or more of the plates as may be required. This hardware is somewhat limited by the fact that the labyrinthian plates are fixed orifices (i.e., constant valve sizing coefficient, C_v) and may reduce the range of flow control for the valve.

Other, less satisfactory, techniques from a long term installation standpoint are insulation of valve body and pipe, or insulation of the valve body and use of a downstream silencer on the discharge port. Upstream silencing is not needed when these techniques are used, as long as the valve orifice is choked (i.e., sonic velocity or greater at the orifice).

Turbines. Manufacturers of large turbines now provide completely packaged units which incorporate noise control to levels specified by the customer. These generally comprise enclosures and silencers designed to confine the noise inside the enclosures.

It is essential that noise generated by mechanical misalignment and unbalance not be simply covered by an enclosure. This portion of the noise source can, and should, be eliminated if only for the inherent benefits in equipment operation and maintenance.

Smaller turbines, whose noise spectra are characterized by high frequency screech, should be similarly enclosed and muffled.

Compressors. Noise control of compressors can generally be broken down into two categories, with one or more of the noise control devices being required. Axial and reciprocating types would require pulsation control vessels, silencers, insulation, vibration isolation, and enclosures. The other, the centrifugal types, would need silencers, vibration isolation, and insulation.

In addition to the use of these treatments, compressor units should be balanced and aligned to tight tolerance levels with particular regard for system compatibility with coupling, gear box and driver. For new installations, consideration should be given to the hermetically-sealed units which usually generate much less noise than their counterparts of equivalent horsepower. It should also be noted that for compressor trains having a gear box, that this element can be a significant part of what may be generally termed compressor noise.

Oil and gas burners. The primary source of noise with present oil and gas burners is the manner in which secondary and tertiary air is induced by aspiration into the burner unit and the degree to which there must be openings in the front wall to provide this air.

The secondary and tertiary air should be supplied by forced-air sources, thus permitting the installation of sealed burners and noise-control barriers across these open areas.

Some consideration must also be given to the burner type and controls as well as the moisture content of the fuel-air mixture. These factors contribute to the low-frequency pulsations and rumble which normally accompany the combustion process. For example, moisture content contributes significantly to the pulsations due to the nature of the sudden expansions and contractions that relate to the time varying moisture levels in the combustible mixture. Closed type burners are of significant benefit in reducing noise.

The nature, composition, and location of the ignition tile is also an important factor in consideration of the various types of fuels that may be used in the burners.

Fans and pressure blowers. Noise control for this equipment should be considered comparable, except in the case of lobe-type pressure blowers. In general, manufacturers of this kind of equipment can provide accurate sound power level or sound pressure level data upon which decisions can be based.

The general case would consider the suction noise, so-called housing noise (everything but the suction and discharge), and discharge noise. It could be of further interest to define the fan operating mode as to whether the suction and/or discharge are open or ducted, and where the flow (and noise) originates and terminates.

The resulting matrix of conditions determines the use of suction silencers, discharge silencers, pipe insulation, flexible connections, and vibration isolation. The lobe-type pressure blowers of present commercial configuration also require an enclosure around the case for most installations.

Gear boxes. The typical gear box generally appears to be an acoustical anomaly. It is difficult at first glance to believe that such a sturdy looking housing could radiate such excessive noise. This radiation of excessive noise is, of course, readily explainable in terms of the manner in which gear boxes are typically made with heavy and thin walled sections. It is the latter, under the heavy forced vibrations produced by the meshing gears and bearing excitations, that produce and radiate the high noise levels.

A fact not generally considered is the extremely high internal noise levels (>160 dB). There are a number of noise control solutions, and some are basic guidelines for gear box operation regardless of the noise problem. They include balance and alignment, proper selection of bearings, gear materials and finishes, and gear tooth configurations and tolerances.

From the noise standpoint alone, one generally encloses the gear box. If the choice exists in the design stage, a uniformly heavy walled gear box (high sound transmission loss) can be specified. An alternative to using a gearbox for speed conversion and power transmission in the drive system is to use an equivalent system of independent direct current (d.c.) electric motors (or variable frequency a.c. units) driving each unit with a modern electronic solid state device for control.

Motors. There are many types of motors in use which range from the high noise-producing TEFC (totally enclosed, fan-cooled) type to the newer; relatively low level d.c. motors presently on the market.

The TEFC motor can be taken care of by use of an inlet (air) muffler and a muffler enclosure that ducts the air along the case fins to the discharge side. Some manufacturers now offer low-noise TEFC motors (i.e., down to 78 dBA below 200 h.p.).

Other high noise producing motors (for example, high horsepower and open rotor designs) will generally require a silencer and/or enclosure system that permits free flow of the cooling air along the desired path without permitting propagation of the generated noise. Vibration isolation, for example on a common pad with the driven equipment and coupling, is always worth detailed consideration.

Noise control in the design phase

There is one more aspect of the engineering approach to noise control that must be considered, namely noise control that can be accomplished in the design phase for new facilities, and noise control of new equipment to be added to existing areas. Four basic items should be considered to produce a successful result:

1. A current noise survey of the environment.
2. A complete noise profile of all equipment to be installed in the environment. a) Obtain from vendor if his stock equipment is being evaluated; b) Specify to the vendor if one has a "not-to-exceed equipment" profile that guarantees satisfaction of the environmental criteria.
3. A knowledge of the methods and conditions under which the test data required has been obtained (or sound power data as an alternative).
4. A qualitative and quantitative description of the environmental boundaries (i.e., hard walls, absorptive walls, acoustical ceiling, carpeted floor, etc., including the Room Constant, R (*1*)).

The incorporation of noise control before installation generally results in significant economic benefits, with the prospect that the built-in noise suppression devices are less likely to interfere with operation and equipment maintenance.

The important point in the design stage is to realize that noise from all sources in an area is additive, as explained earlier, and that the equipment criteria must be such that when all noise is superimposed from the various sources, the environmental noise levels are within the criteria limit.

The techniques presented earlier for distinguishing between the various noise signatures of sources in an existing area can also be applied to the prediction of potential problem noise sources in new plant areas.

Conclusions

The general engineering approach to noise control has been discussed, including requirements for a noise control survey and analysis, solutions for noise control of equipments typically found in large gas handling plants, and methods for recognizing and identifying potential noise sources in new installations.

The important aspect in use of the engineering approach to noise control is to realize that the environmental noise profiles of employee exposure points in an area will be completely dependent on the quantity of noise that arrives from each source in the area at these points. Since the law specifies an exposure criteria that pertains to the sound pressure levels measured from point to point in the environment, the implications for individual equipment criteria are clear. These equipment criteria must be less than the environmental criteria. The actual difference is established on an engineering basis by the number of sources, the manner in which they add, and ultimately, what can be done from a noise control hardware standpoint for each source. #

Literature cited

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DISCUSSION

GENE COMEAU, CFCA. You talked about measuring a vendor's equipment to see if it met the guarantee. With all the other noise sources around in an actual installation, how do you measure the noise from the vendor's equipment? How do you establish the source of the noise?

DEAR – This is after it's installed? We use the techniques that I've described earlier. That is, to find the mechanical properties such as rpm, the number of rotating blades. We make near field pressure measurements. We make vibration measurements. We use these detective tools to zero in on the source. For example, if it were a fan, we'd take the number of blades in the fan times the rpm over 60 and if it's got one cut water on it, that would be a denominator of one. We'd make our measurements, look for a peak noise at that level or a series of peak with that fundamental and its harmonics, and we zero on that. Then make measurements near field and far field and we make an attempt to determine how that noise is propagating. Once you draw the map of this area with many sources in it, these isobars tend to isolate the sources by putting cylindrical kinds of shapes around the sources. And this is about the way we do it.

COMEAU: I can't imagine that you could ever prove a case like this.

DEAR – Well, we do have occasions when we can shut down pieces of equipment, and if this is during a start up we will wait until the occasion arises and then we'll go in and run it, with most of the other equipment shut down. Under those conditions of course then you can zero right in on the source. We at this time are trying to get the measurements made in the vendor's plant through our Mechanical & Electrical section so that we don't run into this problem.

In other words, we're making this a part of acceptance just like horsepower, load, and everything else. And we write the specifications accordingly.

COMEAU: I would think that the vendor's shop would be the only place to obtain a legally binding test.

DEAR – That's right. And that's primarily the way they're going. But we have gone back on other cases and we've been able to prove our point. One thing you must remember, is the vendors are interested in this. Manufacturers are interested because they by law in the near future will have to label their equipment. In other words, in addition to telling the power it consumes, the horsepower it develops and all that sort of thing, they're going to have to put a dBA level on it and a dBA level map, and that's under the EPA authority given in the Noise Act of 1972 which is different than OSHA.

DAVE WHITE, Borden Chemical: Just to make it clear, what you say is that if we have enough pieces of equipment, each of them 85 dB, we're going to get over the 90.

DEAR – That's right. It would take about four pieces of equipment at 85 to exceed 90. If you add 85 to itself, well, take four 85's, the sum of two 85's is 88, 88 + 88 is 91; you're over.