Acoustically Induced Vibration Calculation Method

with Examples

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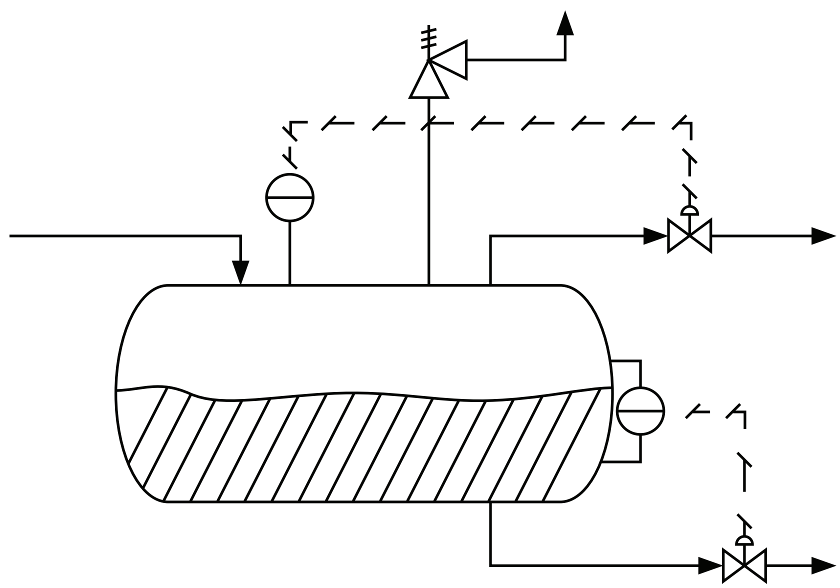

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I. Abstract:

Vibrations associated with high vapor/gas flow rates in flare headers have led to several recent incidents. To prevent such incidents, API STD 521 added a section on Acoustic Fatigue in the 6th Edition (2014). Prior to this addition, relief systems designs would identify areas of high discharge velocities in outlet piping or flare headers. Often, standards and guidelines will place velocity limits on lines in outlet piping and/or flare systems. For many high-pressure relief valves, it is impossible to design a disposal system for which the potential of high velocities in the disposal system is not credible. Thus, processing facilities often have many areas with potential concerns from high velocities, which require additional screening.

This white paper shows a method on how to analyze high velocity concerns related to the Acoustically Induced Vibration. This paper adds onto the simplified screening that is presented in API STD 521 while being completely in agreement with the API requirements. The proposed screening is a conservative approach and follows methodology referred to by API STD 521 for further evaluation. The paper then walks through the methodology for calculating AIV along working several example problems.

II. Background:

High vapor/gas velocities and sonic or near-sonic conditions have generated failures in piping systems, prompting the inclusion in the 6th Ed. of API STD 521 [1] of a section on Acoustic Fatigue (§5.5.12), which provides criteria for a designer to analyze systems for Acoustically Induced Vibration (AIV). Several of the recent failures have been documented and incorporated into **Figure 1**. The new section on Acoustic Fatigue in STD 521 adds new criteria to ensure proper design of relief device disposal systems. While verifying the piping vibration is within recommended design criteria is recommended and not required (i.e., presented as a "should" and not a "shall" in 521), if a facility or company has user specified velocity limits in piping systems, failing to meet those requirements may make some vibrational screening (such as this) a requirement (see also API STD 521 §5.5.3).

To summarize, the methodology presented in this paper:

1. Conservatively reduces the number of installations that require additional screening (as compared to the simple criteria in API as the additional screening methods are incorporated into the base screening).
2. Is consistent with the guidance in API 521 and expanded based on the recommendations for further screening if a system exceeds the listed limit, 155 dB.
3. Is appropriate for the screening of high vapor/gas velocity concerns raised for flare and relief systems.
4. Is simplified yet conservative, and modified for ease-of-use on large scale relief valve and disposal systems analysis.
5. Is based on the API recommendations to review the Carucci and Mueller and Energy Institute guidelines.
6. Is consistent with recent peer-reviewed published articles.

Note: This method is not appropriate for systems that are used more frequently than flare systems as it is dependent on the comparatively low demand/use associated with them.

III. Overly Conservative API Acceptance Criteria:

The listed acceptance criteria in API STD 521 § 5.5.12.2 is presented in equation form below.

$$L_W < 155\ dB \qquad \text{(Equation 1)}$$

This criteria is based on no known failures and is very conservative. From the authors' work, many relief device installations fail this conservative requirement, yet are still safe. Further in this section of API 521 it is stated "A sound power level greater than 155 dB should be further evaluated using methods such as in Bibliographic Items [49] and [56] or a finite element modeling approach." The bibliographic items referenced in API STD 521 are:

[49] CONCAWE, *Acoustic Fatigue in Pipes*, CONCAWE Report 85/52 (1985). Note that this is the work done by Carucci and Mueller which has similar guidance to the significantly more readily available paper from ASME [2]

[56] Energy Institute, *Guidelines for the avoidance of vibration induced fatigue in process pipework*, Second Edition, 2008, ISBN 978-0-85293-463-0 (Energy Institute, 61 New Cavendish Street, London W1G 7AR, United Kingdom, www.energyinst.org.)

The proposed acceptance criteria developed here is a merging of requirements from both sources. The proposed criteria is shown against both (1) Carucci and Mueller's work along with additional data points which have been subsequently published and (2) the Energy Institute's guidelines. Thus, the proposed screening / acceptance criteria meets the stated requirements in API STD 521. Note that this paper follows the API STD 521 recommendation that the user calculate the Sound Power Level (L_W) consistent with the screening criteria proposed (e.g. use the Carucci and Mueller's equation with the Carucci and Mueller's requirements).

IV. Proposed D/t Screening Criteria:

The original Carucci and Mueller work listed the acceptance criteria based on a maximum Sound Power Level (L_W) for each diameter piping. Subsequent work has found that a maximum L_W for a given ratio of pipe "diameter to wall thickness" (D/t) provides a screening criterion that better represents the risk of failure for a piping installation. That is, a ½" thick 24" pipe (Sch XS) is much more resistant to failure than a ¼" thick 24" Pipe (Sch 10). While each pipe has a nominal diameter of 24", the D/t is 48 for the Sch XS pipe compared to 96 for the 24" Sch 10 pipe. As implied by the name, the 24" Schedule Extra Strong pipe resists failure from vibrations better than the thinner Sch 10 pipe.

Since this method is still only a screening procedure, if an installation fails this screening, the designer can either (1) make piping modifications or (2) perform a more detailed analysis (e.g. finite element analysis). The benefit of this method is that the number of concerns identified from screening is reduced from that in API as some screening methods are incorporated into the initial evaluation.

V. Carucci and Mueller's Work:

The first of the two additional screening methods recommended by API STD 521 for determining if a piping system is acceptable if a Sound Power Level (L_W) is greater than 155 dB is the Carucci and Mueller method. This section documents the requirements published by Carucci and Mueller and expands them with published failure data that has been made available after publication of their work. Note that Carucci and Mueller's original work proposed a limit based solely on the diameter of the piping. Subsequent work has shown that a D/t requirement is more predictive of installation hazards (e.g., for the same pipe size, a thicker pipe resists failure more than a thinner pipe). The red curve line in **Figure 1** is the original design curve proposed by Carucci and Mueller, updated and based on D/t (as reported by Bruce, et al. [5]). The black curve is the Carucci and Mueller criteria acceptance curve with a 5 dB safety margin, also proposed by Bruce, et al. [5]). **Figure 1**, in addition to showing the two acceptance curves, has the Carucci and Mueller data points along with additional published points added after Carrucci and Mueller did their original work. All the failures (which are summarized below) have failure LW estimates that were based on Equation 1, consistent with the requirements in API STD 521. Note that the lower limit of the black curve, 155 dB, is the threshold limit in API STD 521.

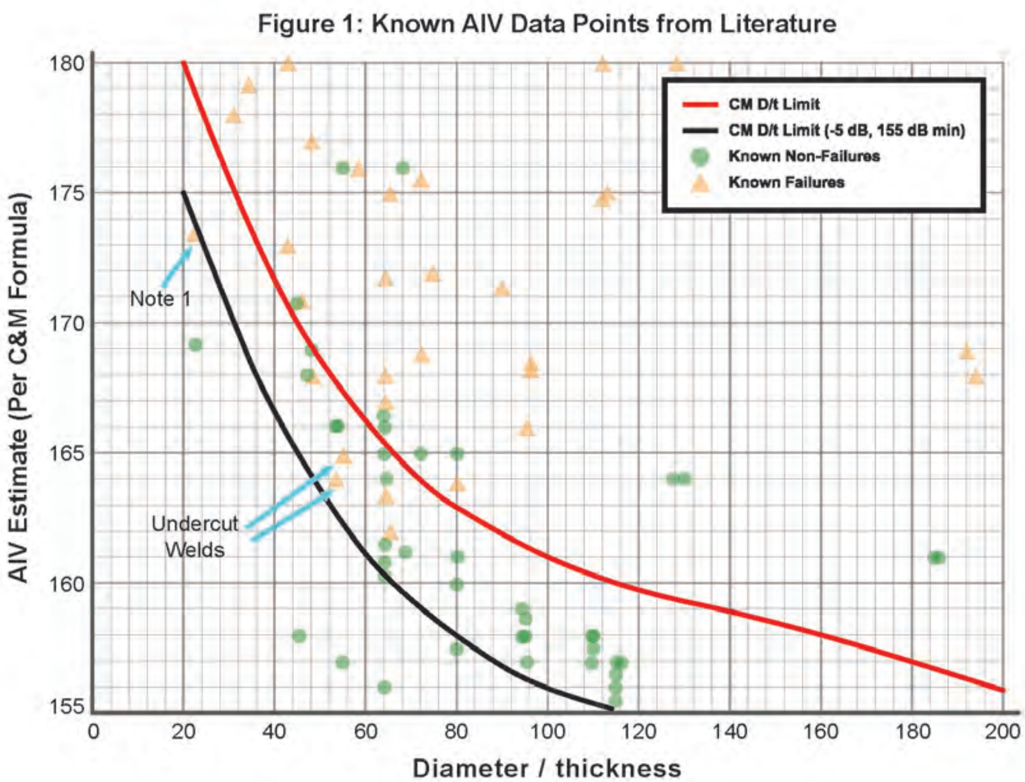


Figure 1: Proposed acceptance (CM, Carucci and Mueller) criteria for AIV
Note 1: This installation operated for 4 hours, which does not meet the definition of intermittent use.

Thus, the -5 dB design curve (black) is proposed by Bruce, et al. [5]), as it provides a reasonable design basis for flare and relief systems that are not in constant operations and account for the other failures in literature In addition to matching the more recent data (as seen in **Figure 2**), the proposed safety margin aligns with the recommendations of the Energy Institute's guidelines.

VI. Additional Known Failure Data:

The following are the sources for the additional known failures that were added to **Figure 1**. Note that the "C&M Failure Points" is the failure data that was originally reported by Carucci and Mueller [2]. The additional failure points are as follows:

Skailes – This paper presented a method for using finite element analysis with two branch fitting (e.g. weldolet) failure case studies. These points are incorporated into the figure above. [4]

Bruce – His paper presented 4 new failure data points and 12 new non-failure data points. The LW was calculated based on the Carucci and Mueller assuming attenuation to the failure point. [5]

Al-Muslim – In an article in the Journal of Pressure Vessel Technology, two vibration failures, from operating facilities were identified, including one at a high flow rate, 132 kg/s. [6]

Evans – In this presentation, an operator lists case studies for two failures. These points were presented at the 2012 INTER-NOISE conference. [7]

Cowling – In a presentation to API, Mr. Cowling presented data that shows five additional failure points. These failures were listed solely on the basis on the nominal pipe size. He also presented two non-failure data points. The author of this paper presented the data assuming that the piping was Sch STD piping. [10]

Swindell – This paper documents the development and use of the 'Energy Institute's screening method one of the figures contains large diameter failure and non-failure data which was incorporated into **Figure 1**. [8]

VII. Energy Institute - Piping Vibration Guidelines:

The second of the two screening methods proposed by API STD 521 for determining if a piping system is acceptable if a Sound Power Level (L_W) greater than 155 dB is identified is the Energy Institute's published Piping Vibration Guidelines [3]. The Energy Institute document lists criteria based on a Likelihood of Failure (LOF). The following cutoff points are given:

LOF ≥ 1.0 – Intolerable, piping must be redesigned, re-supported or a detailed analysis for the main lines and asymmetrical connections should be conducted

1.0 > LOF ≥ 0.5 – Where possible and feasible, the piping should be redesigned, re-supported or a detailed analysis be performed

0.5 > LOF ≥ 0.3 – Check and possibly reinforce small bore and asymmetrical connections

LOF < 0.3 – Ensure small bore connections are sound and installed per standard piping design codes (e.g. ASME Section VIII / B31.3)

To systematically compare the results of the Carucci and Mueller method (and that of the -5 dB safety margin) with the recommendations of the Energy Institute, the authors performed hundreds of calculations on various piping ratios in order to develop a significant data repository of Likelihoods of Failure (LOFs). Since the Energy Institute's work looks at the failure point of a small pipe joining a large pipe, multiple calculations based on a variety of piping configurations were performed using the Energy Institute's screening methods.

Figure 2 summarizes the results of all these calculations and then compares them with the same acceptance criteria as shown in **Figure 1**. The values in **Figure 2** were obtained by the following:

- Specifying piping systems such that the larger diameter pipe ranged from NPS of 3" thru 24".
- Specifying the smaller diameter piping of diameters that ranged from NPS of 2" thru 18".
- The larger and smaller pipe diameters were combined to ensure the resulting d/D ratios ranged from 0.10 thru 0.90.
- The Sound Power Level (L_W) that gave a Likelihood Of Failure (LOF) of 0.49 or 0.99 was then calculated.
- The results were shown for systems with (green/red lines in **Figure 2**) and without branch fittings (e.g. weldolets, blue and orange lines in **Figure 2**).

The ranges of these values are shown as the bands of color in **Figure 2**. This is such that all of the results calculated for a Likelihood Of Failure (LOF) of 0.49 for systems without branch fittings if individually plotted would all appear in the green band (whereas those with a Likelihood Of Failure of 0.49 and a branched fitting would appear in the orange band).

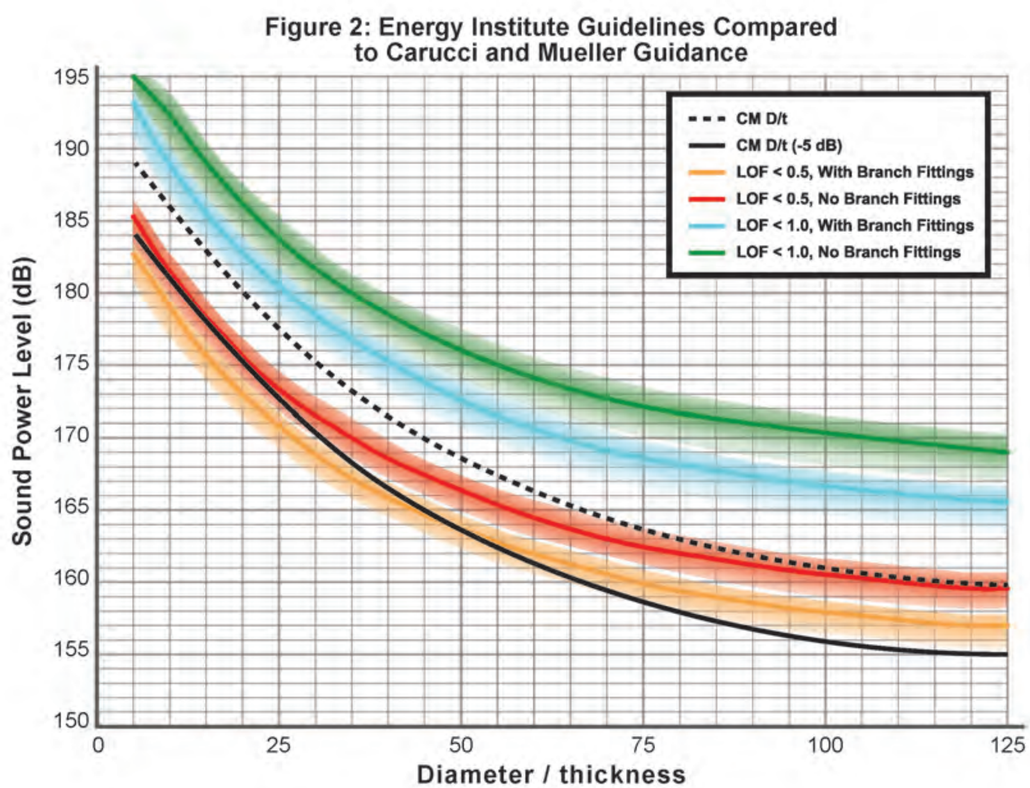


Figure 2: Energy Institute's Likelihood of Failure (LOF) for evaluated piping systems compared to the Carucci and Mueller (CM) Acceptance Criteria.

Note that systems with a D/t less than 50 that also contain branch fittings may require additional screening. The nature of locally manufactured "T" connections (e.g. use of branched fitting) create focus points for vibrational stresses increasing the likelihood of failure and may require additional bracing. Flare systems that are part of large construction projects typically do not contain branch fittings. Relief devices that are added to existing flare systems or are modified to have increased diameter piping are more likely to have branch fittings in the flare piping. Alternatively, operators could create a procedure that would allow them to identify and inspect relief systems piping that contains branch fittings and has an estimated sound power level that is within 10 dB of the Carruci and Mueller D/t. [5]

VIII. Proposed Acceptance Criteria:

Figure 1 shows that using the Carucci and Mueller D/t acceptance curve (as reported by Bruce, et al. [5]) results in several installations that could be identified as acceptable by the Carucci and Mueller acceptance criteria, but are intolerable per the Energy Institute. In addition, the additional failure data added to **Figure 1** shows that the black line, with the safety factor of 5 dB, is acceptable for screening level studies. This requirement meets the requirements for additional screening in API STD 521.

System Frequency Usage Warning:
The criteria in **Figure 1** are for relief systems and elements that are used infrequently (only a few times, for a short duration, in the lifetime of the facility) [5]. Note 1 on **Figure 1** illustrates a system that failed after 4 hours of use. Therefore, if a relief system is expected to be operated frequently, a higher safety margin than proposed in **Figure 1** should be used. These longer duration discharge events will introduce a separate acoustic phenomenon known as Flow Induced Vibration (FIV) which is outside the scope of this paper and the guidance provided in API STD 521. *Providing guidance for pressure let down systems that are frequently used is outside the scope of this paper.*

Examples of systems that typically would not be screened using this method are:

- Emergency depressuring valves on off shore platforms.
- Equipment pressure controllers (e.g. backpressure controllers that discharge to the flare system).
- Normally Operating High pressure letdowns stations
- Relief systems that could be anticipated to be operated for extended periods of time (The author at a facility that received gas from a pipeline, if the inlet feed compressor tripped, the either a pressure control valve or the first relief valve in the facility would vent the feed gas until the compressor was restarted. It then would be reasonable to assume that either this relief device or the pressure control valve would operate for extended periods of time).

Note that relief systems (and Emergency depressuring valves on onshore facilities) may meet the criteria of infrequent use. However, facility owners need to ensure that procedures are in place to monitor these systems in order to perform inspection of small bore piping connections after use (if the estimated sound power level is within 10 dB of the limit in **Figure 1**. [5]

IX. Screening Method:

The relief systems designer can now calculate the Sound Power Level (L_W) levels for the piping systems to compare with the acceptance criteria as shown in **Figure 1**. This section walks the designer through the details of how to calculate the L_W (installation examples are worked in detail in the following sections). After the methodology section, several examples are illustrated.

This section is laid out with the step overview first, followed by the equations that are needed to calculate the numbers in each of the steps.

System Analysis:
The following steps are performed to analyze a system:

Step 1.) Identify the release scenario to be analyzed and determine the system loads for the concurrent system releases. Note multiple release scenarios are utility failures (e.g. power failure or cooling water failure) or systems with more than one relief device (e.g. a column, example 2). *This method assumes that all valves, fittings, and expansions with sonic velocities are vibration sources that must be considered.*

Step 2.) Calculate the Sound Power Level (Equation 2) for each of the sources.

Step 3.) Determine the attenuation as the fluid travels down the piping (Equation 3; note that the L_W travels with the fluid in the pipe).

Step 4.) Once two or more flows join, logarithmically add the two L_Ws together using Equation 4.

Step 5.) Continue steps 2-4 until there is no possibility of additional choking in the system and the L_W is below 155 db.

a.) If an additional secondary sonic point is found, calculate the Sound Power Level (Equation 2) and return to Step 2.

b.) If there is no further risk of sonic flow or streams joining with combined L_W's greater than 155 dB, move to step 6. *Note that two 152 dB streams (or three 150 dB streams, in close succession) joining result in ~ 155 dB.*

Step 6.) Verify that for each of the piping components the estimated L_W is less than the limit in **Figure 1**. Once there are no more streams joining or the potential for further sonic flow (which is determined in the hydraulic profile and not inherent in this proposed methodology), any L_W less than 155 dB can be assumed acceptable per API STD 521 § 5.5.12.2. If there are piping sections where the estimated Sound Power Level (L_W) exceeds the limits, additional screening or piping modifications may be required.

The ending of this paper contains two examples of this methodology. The first is for a system with a single sound power level source and the second is for a system with multiple sources.

Source Sound Power Level (L_W):

For each sonic source (relief valve or choked pipe fitting) calculate the Sound Power Level (L_W) using Equation 2. This is the equation for sound power level from API STD 521 (§ 5.5.12.2). This is the second step of the System Analysis. This may also be done for sonic fittings in the flare system (*System Analysis* step 5).

$$L_W = 10\log_{10}\left[W^2\left(\frac{P_1 - P_2}{P_1}\right)^{3.6}\left(\frac{T_1}{M}\right)^{1.2}\right] + C$$ *(Equation 2)*

where,

- L_W is the sound power level (dB)
- W gas flow rate (lb/hr)
- P_1 is the pressure on the inlet to the source (psia)
- P_2 is the pressure on the outlet to the source (psia)
- T_1 is the temperature at the inlet to the source (°R)
- M relative molecular mass of the gas
- C 51 for all tee fittings (dB)
  45 for all non-tee fittings (dB)

Note: The constant "C" is higher for tees that experience sonic flow "to account for intensified dynamic strain response" per API STD 521 §5.5.12.2.

Attenuation:

Calculate the attenuation as the fluid travels down the piping system, *System Analysis* Step 3. Attenuation is the estimation of the dissipation of the noise energy as the gas travels down the piping from the source to the final terminus. Per both Energy Institute and API, the attenuation is approximately 6 dB per 100 inner pipe diameters. Thus, the following equation is derived from the text in API STD 521 § 5.5.12.2.

$$ATT_{PF} = L\frac{0.72}{d}$$ *(Equation 3)*

where,

- ATT_{PF} Is the sound power level lost (dB)
- d Inner diameter of the pipe (in)
- L Length of pipe segment in question (ft)

Failure to account for the attenuation when reviewing systems will significantly overestimate "problem" areas for detailed review, which results in increased cost with little benefit to the system's overall safety.

Combination of Sound Sources:
Calculate the sound power level as more than one stream combines in a piping network, *System Analysis* Step 4. As the gas flows through the piping system, the acoustical energy travels with the gas. When two gas streams join in a piping network, the L_W's are added logarithmically per Equation 4 below (Equation 4 from API STD 521):

$$L_W = 10\log_{10}\left[10^{\left(L_{W1}/10\right)} + 10^{\left(L_{W2}/10\right)} + \ldots\right] \qquad \textit{(Equation 4)}$$

where,

L_W is the combined sound power level (dB)

$L_{W1,2\ldots}$ is the sound power levels for the gas streams that join together (dB)

In theory, more than two streams could join at a single point; however, piping components that combine more than two streams (e.g. crosses, not tees) are rarely used in the process industry.

Design Verification:
Once the system has been analyzed based on the steps in this section, a Sound Power Level (L_W) has been calculated for each fitting and piping segment. These L_W's are then compared against the limits in **Figure 1** for each piping section / fitting. Any portion of the system that does not meet the requirements in **Figure 1** can be further studied or modified. [10]

This analysis can be simply documented as shown further in this paper in example Tables 1 and 2.

X. Example Problems:

To illustrate how to perform these calculations, the following two examples are given. The first example problem has a single sound source (a pressure relief valve), and the second has multiple relief valves, installed on a single column, that could foresee-ably release simultaneously.

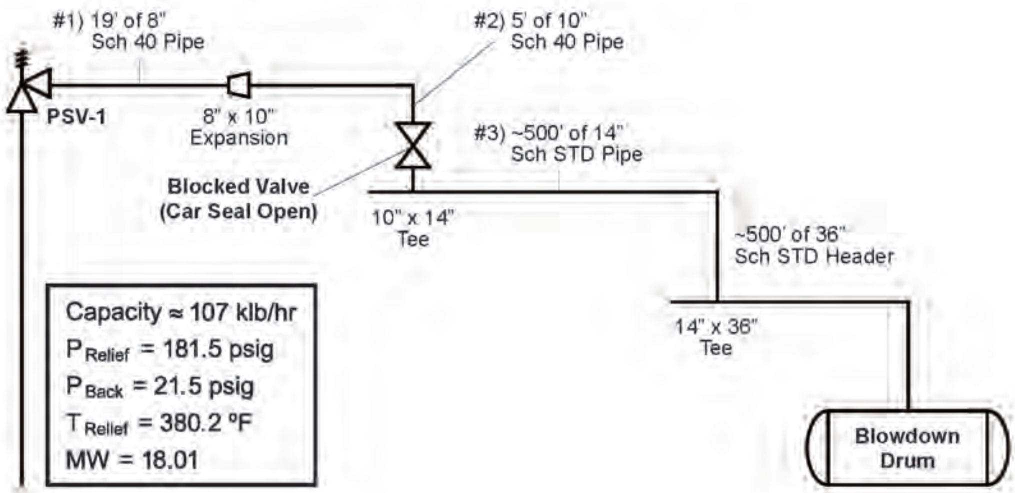
Single L_W Source (Example #1)

It was identified that PSV-1 has high velocities in the discharge line in the event of an external fire. Equation 2 is used to estimate the Sound Power Level (L_W) to verify if the potential for AIV concerns is present. The following calculation was based on the relief device capacity and outlet pressure losses calculated using an industry standard software, SALUS.

The L_W for PSV-1 is calculated as follows for the parameters shown in **Figure 3**.

$$L_W = 10\log_{10}\left[(107{,}000)^2\left(\frac{196.2-36.2}{196.2}\right)^{3.6}\left(\frac{839.9}{18.01}\right)^{1.2}\right] + 45 = 162.4\,\text{dB}$$

Figure 3: Single Source Calculation Basis



Since the Sound Power Level estimate is greater than 155 dB, this method states that we must follow the energy flow from the source to the Blowdown Drum or until the Sound Power Level is below 155 dB. For each point along the way, the sound power level should be checked against the piping D/t ratio to ensure that the limits in **Figure 1** are met. The following table lists the sound power level as it moves through the system with attenuation calculated per Equation 2. The sound power level attenuation as the fluid travels from PSV-1 to the 8x10 expansion is calculated as follows substituting the appropriate parameters into Equation 3:

$$ATT_{PF(Segment\#1)} = 19\frac{0.72}{7.98} = 1.71\, dB$$

The Sound Power Level (L_W) and attenuations are shown for each piping segment in Table 1 (for the example problem illustrated by **Figure 3**). The pipe segments numbered in Table 1 are labeled in **Figure 3**. The L_W calculated in Table 1 as $L_{W\ (In)}$ is the inlet to the piping segment. The attenuation is then calculated and the $L_{W\ (Out)}$ is shown that is the inlet to the next fitting. Since there is only once source for this example, there is no additional of multiple sound power levels. The L_W dissipates as fluid travels from the relied valve to the blowdown drum and no vibration concerns are generated.

Pipe Segment	NPS	Fitting	Sch	L (ft)	d/t	Attenuation	$L_{W\ (In)}$	$L_{W\ (Out)}$	Limit	Criteria Met?
1	8"	Pipe	40	19.0	26.79	1.71	162.42	160.71	172	Yes
2	10"	Pipe	40	5.0	29.45	0.36	160.71	160.35	171	Yes
3	14"	Pipe	Std	~500	37.33	27.28	160.35	***133.07***	168	Yes

At the end of Segment #3 the L_W is ~133 dB, below 155 dB and calculations were not continued per method requirements (consistent with the screening criteria in **Figure 1** and in API STD 521). *Note that per the hydraulic model, the fluid did not choke after this segment.*

Multiple L_W Sources (Item #2):
Relief Devices on a Fractionating Tower, may have high velocities in the discharge line in the event of an external fire. Equation 1 was used to calculate the sound power level (see Example 1 for details). The L_W and attenuation were calculated just as in the previous calculation.

Figure 4: Single Source L_W for Item #2 / Multiple Sources

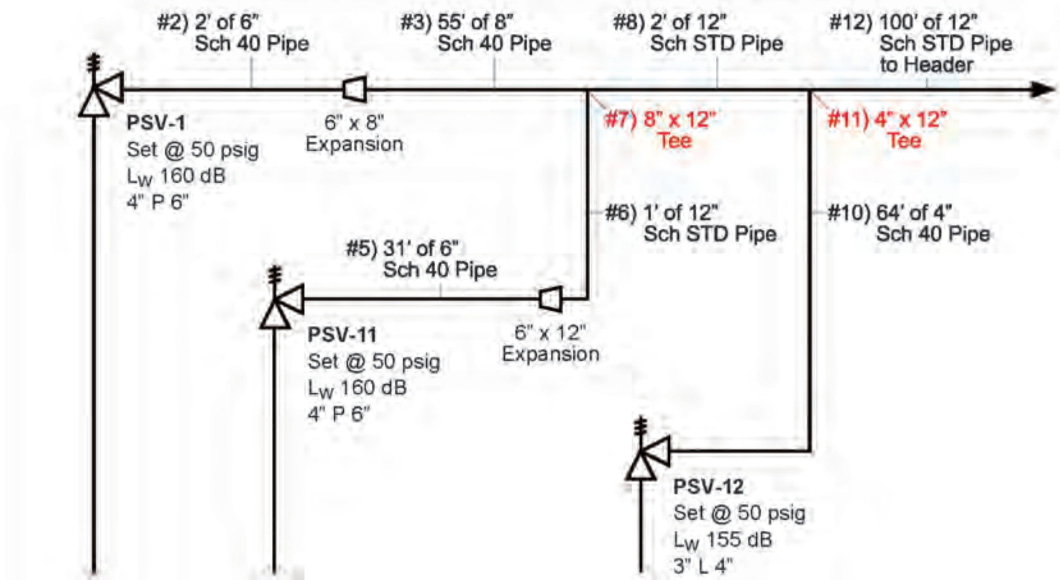


Table 2 contains the analysis for the system shown in **Figure 4**. For this system there are three (3) relief devices which all can be expected to release simultaneously and discharge into common piping. The Sound Power Level (L_W) from the multiple sources will need to be added together at the 8"x12" tee (#7) and the 4"x12" tee (#11). These calculations are performed below and input and results are shown in Table 2.

Combination of Streams in Tee #7:
Estimate of the Sound Power Level for the two streams that converge in Tee #7 (**Figure 4**).

8"x12" tee (#7 in **Figure 4**): This is the addition of the L_W at the end of segments #3 and #6 denoted by a (1) in Table 2.

$$L_{W(Tee\ \#7)} = 10log_{10}\left[10^{\left(154.8/_{10}\right)} + 10^{\left(156.32/_{10}\right)}\right] = 158.64\ dB$$

As shown above, the designer should be aware that two streams near 155 dB can combine to exceed that criteria. In this instance, one ~155 dB stream combined with a L_W of ~156 and resulting in a L_W of 158 dB (higher than either source).

Combination of Streams in Tee #7:
Estimate of the Sound Power Level for the two streams that converge in Tee #1 (**Figure 4**).

4"x12" tee (#11 in **Figure 4**): This is the addition of the L_W at the end of segments #8 and #10 denoted by a (2) in Table 2.

$$L_{W(Tee\ \#11)} = 10log_{10}\left[10^{\left(158.52/10\right)} + 10^{\left(143.55/10\right)}\right] = 158.65\ dB$$

As shown above, the designer should also be aware when combining that two streams of disparate L_W's the additive value of the smaller stream can be negligible. If one stream is 10 dB below the other, the additive value is only 0.4 dB (e.g. adding a 142 dB and 152 dB stream results in a combined stream L_W of 152.4 dB).

Table 2: L_W Calculations for Multiple Source Examples

	NPS	Fitting	Sch	L (ft)	d/t	Attenuation	$L_{W\ (In)}$	$L_{W\ (Out)}$	Limit	Eq. 5 Met?
1	6"	PSV-10	40		23.66	0	160.00	160.00	175.58	Yes
2	6"	Pipe	40	2	23.66	0.24	160.00	159.76	175.58	Yes
3	8"	Pipe	40	55	26.79	4.96	159.76	154.80[1]	174.23	Yes
4	6"	PSV-11	40		23.66	0	160.00	160.00	175.58	Yes
5	6"	Pipe	40	31	23.66	3.68	160.00	156.32[1]	175.58	Yes
6	12"	Pipe	STD	1	34	0.06	156.32	156.26	171.37	Yes
7	12"	8x12 Tee	STD		34	0	158.64	158.64	171.37	Yes
8	12"	Pipe	STD	2	34	0.12	158.64	158.52[2]	171.37	Yes
9	4"	PSV-12	40		18.99	0		155.00	177.73	Yes
10	4"	Pipe	40	64	18.99	11.45	155.00	143.55[2]	177.73	Yes
11	12"	4x12 Tee	STD		34	0	158.54	158.65	171.37	Yes
12	12"	Pipe	STD	100	34	6	160.13	154.13	171.37	Yes

Superscripts [1],[2] are the inputs to calculate the LW for segments #7 and #11, respectively.

Thus, the flow for the last line in Table 2 is not sonic, not expected to become sonic, and below 155 dB; therefore, we can end the analysis. Note that the determination of sonic flow downstream from the system depicted in **Figure 4** is made from the hydraulic profile (not inherent in the proposed method).

XI. Conclusion:

The methods outlined in this paper provide a flare system design tools to quickly screen the many relief devices commonly found in a large petrochemical processing plant. The design criteria in **Figure 1** is conservative and combines the requirements listed in API STD 521 §5.5.12.2 for screening systems when the estimated Sound Power Level (L_W) is greater than 155 dB. The design criteria presented in **Figure 1** is a combination of both the Carucci and Mueller and Energy Institute requirements. The proposed acceptance criteria:

1. Incorporates AIV failures published after Carucci and Mueller published their work and incorporates more recent data which indicate more conservative screening criteria is required.
2. Is consistent with the Energy Institute Vibration Risk Guidance for LOF of 0.49 or less, and these methods can be implemented more quickly for screening than the methods presented in the Energy Institute's guidelines. Systems that contain branch fittings (e.g. weldolets) may require additional screening or monitoring.
3. Meets the specified requirements in API for further analysis when the estimated L_W is greater than 155 dB as it incorporates both additional screening methods into a single verification process.
4. Are valid for typical flare system components that are not used frequently. *Depressuring systems, which are used more frequently, are outside the scope of this paper.*

The outcome of the analysis is relief systems that are segregated into those that are not expected to have any concerns and those that should be further studied or modified. This screening method allows facilities to focus their resources on systems that pose the greatest risk of failure.

XII. References:

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