# Vibration Attenuation Characteristics of GRINNELL Grooved Couplings

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## Introduction

Vibration within the piping systems used throughout a building can be an issue in that it can lead to unwanted audible noise. This noise results not just from the vibration of the pipe walls themselves, as might be noticeable in mechanical rooms and other such spaces where piping is exposed, but also from the resultant vibration of building elements such as walls, ceilings, beams, etc. that may be in direct contact with the piping itself or the piping support systems. The sources for such vibrations are typically a pump or even just turbulent flow within the pipe due to, for example, flow across a valve or a bend or some other change in geometry. One way to reduce piping related noise is to add in "features" to the pipe walls that help to block and/or absorb the vibration as it attempts to propagate along the pipe away from the source of vibration.

One such feature that can be effective at attenuating this vibration is a coupling element used to join together pipe segments. GRINNELL Grooved Couplings use an elastomeric pressure responsive gasket to seal pipe joints. Shown in Figure 1, this gasket provides a tight seal and works within the housing of the GRINNELL Flexible Coupling to create features that address pipe angular deflection, as well as axial and rotational movement. The gasket is compressed against the pipe sealing surface during installation producing a firm contact between the pipe and the gasket. Among their many other benefits, such couplings have the potential to effectively reduce the amount of vibration transmitted along piping systems, thus leading to less radiated noise associated with sources such as pump motors and flow.


**Figure 1: Section view of a GRINNELL Grooved Coupling**

Some existing elastomeric and braided metal flexible connectors with the primary purpose of vibration attenuation require extra welding of pipe sections and connections with large, heavy flanges to accommodate the flexible elements. This not only increases the weight and complexity of the piping system but also creates more opportunities for leaks to occur. If the GRINNELL pipe coupling design can also mitigate vibration through a piping system, then an alternative exists to the "one-purpose-only" elastomeric or metal flexible connectors. GRINNELL engineers have teamed up with the multi-disciplinary acoustics and vibrations consulting firm Acentech to investigate the vibration attenuation performance of GRINNELL pipe couplings in relation to a rubber flexible connector and a braided metal flexible connector.

## Measurement and Analysis Procedures for In-System Testing

In order to evaluate the vibration attenuation performance of the pipe couplings, a series of measurements under controlled conditions were carried out. The goal of these measurements was to determine the average pipe vibration levels on both sides of a coupling, with a source of vibration located on one side of the coupling, so that the vibration attenuation performance of the couplings could be quantified. These evaluations made use of a flow loop which allowed the use of a pump motor as the source of vibration, as well as a vibration shaker attached to the pipe wall exterior. Figure 2 shows a drawing of the two flow loop setups that were utilized in these tests.

GRINNELL developed two 4 inch diameter side by side piping systems at their training facility in Cranston, Rhode Island. The first system was constructed of all grooved components including three flexible couplings downstream of the pump to act as vibration attenuators. The second piping system was a welded system which incorporated braided metal flex connectors around the pump to act as vibration attenuators. The system was built to illustrate the advantages of a grooved system over a welded system. Some of the criteria tested include the ease and reduced time of installation, incorporation of expansion compensation, and the vibration attenuation characteristics.

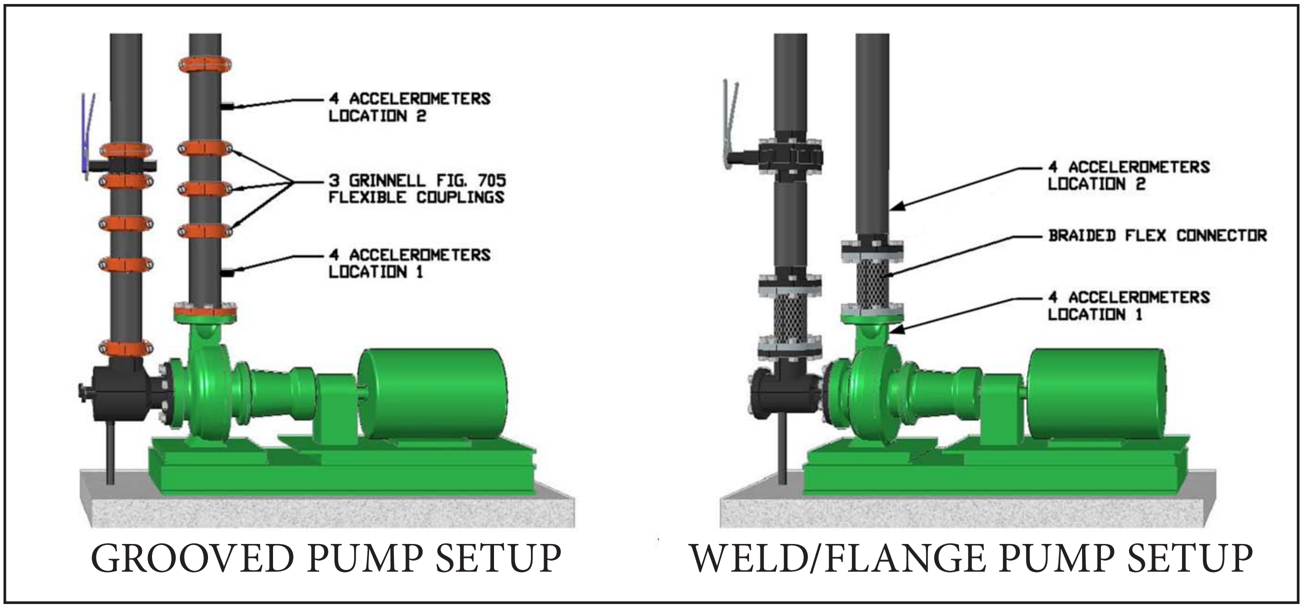



**Figure 2: Piping System used for training and testing purposes**

In this research, we will conclude the results from the vibration attenuation tests. Two types of tests were conducted using the flow loops. In the first, the pump motor was turned on and the flow loops were operated at a number of different pump operating speeds. In the second type of test, an electro-dynamic shaker was used to impart broadband “white noise” vibration into the base of the flow loops (without the pump operating). This was done in order to assess the behavior of the couplings over a broader range of frequencies than may have been possible using only the pump motor (and associated flow) as a source of vibration. For both cases, vibration was measured around the circumference of the pipe. A total of eight accelerometer sensors were used on each flow loop to measure the pipe wall vibration: four locations spaced about the circumference of the pipe on one side of a test coupling, and four locations spaced about the circumference of the pipe on the other side. A list of the instrumentation used for these tests is shown in Table 1.

**Table 1: Instrumentation Used For Pipe Vibration Testing**

| **Vibration Input** | **Labworks Inc. ET-132 Shaker** | |
|---|---|---|
| Recorders | Rion DA-20 | |
| Vibration Sensors | PCB Model 352C65 Accelerometers | |
| | Serial Number | Sensitivity (mV/g) |
| | 28892 | 104.4 |
| | 29389 | 105.9 |
| | 39165 | 100.8 |
| | 39167 | 94.45 |
| | 71764 | 96.73 |
| | LW139217 | 98.80 |
| | LW139218 | 100.0 |
| | LW139219 | 99.20 |

For each test, approximately 15 seconds of the vibration time signal from all the sensors were acquired simultaneously by electronic data recorders. These digitized and stored signals were then post-processed to calculate the 4-channel averaged frequency spectral levels of vibration on both sides of the coupling. Average measurements from the four sensors on either side of the coupling were used because the resulting spatially averaged levels are more correlated to the radiated noise than would be the vibration measured at just a single point on either side of the coupling. The resulting "coupling vibration attenuation" is simply the difference between the averaged vibrations on either side of the coupling, calculated as a function of frequency or given as an overall level. This measurement and analysis procedure was performed with the two flow loop setups shown in Figure 2.

## Results of In-System Testing

The averaged vibration levels obtained on both sides of the GRINNELL Coupling setup, with the pump operating at 1300 rpm, are shown in Figure 3. These vibration velocity levels are shown in terms of frequency spectra, in the twenty-four 1/3 octave bands from 25 Hz to 5000 Hz. Vibration data presented this way is closely associated with the radiated noise that emanates from the pipe walls. A reduction of this vibration would also lead to a reduction in the amount of unwanted sound generated by the flow loop.

Although the fundamental rotation rate of the pump in this case is less than 22 Hz, a frequency generally below what is noticeable by people, the frequency content of the pipe vibration with the pump operating is fairly broadband, due both to tonal components and harmonics associated with the number of pump vanes, and of course to fluid flow. The background vibration levels obtained when the pump was not operating are also shown in Figure 3. It can be clearly seen that the pump increases the pipe vibrations from ambient conditions at all frequencies by as much as 30 to 40 decibels (dB). The same amount of pump induced vibration was also observed in the braided metal flex connector flow loop.

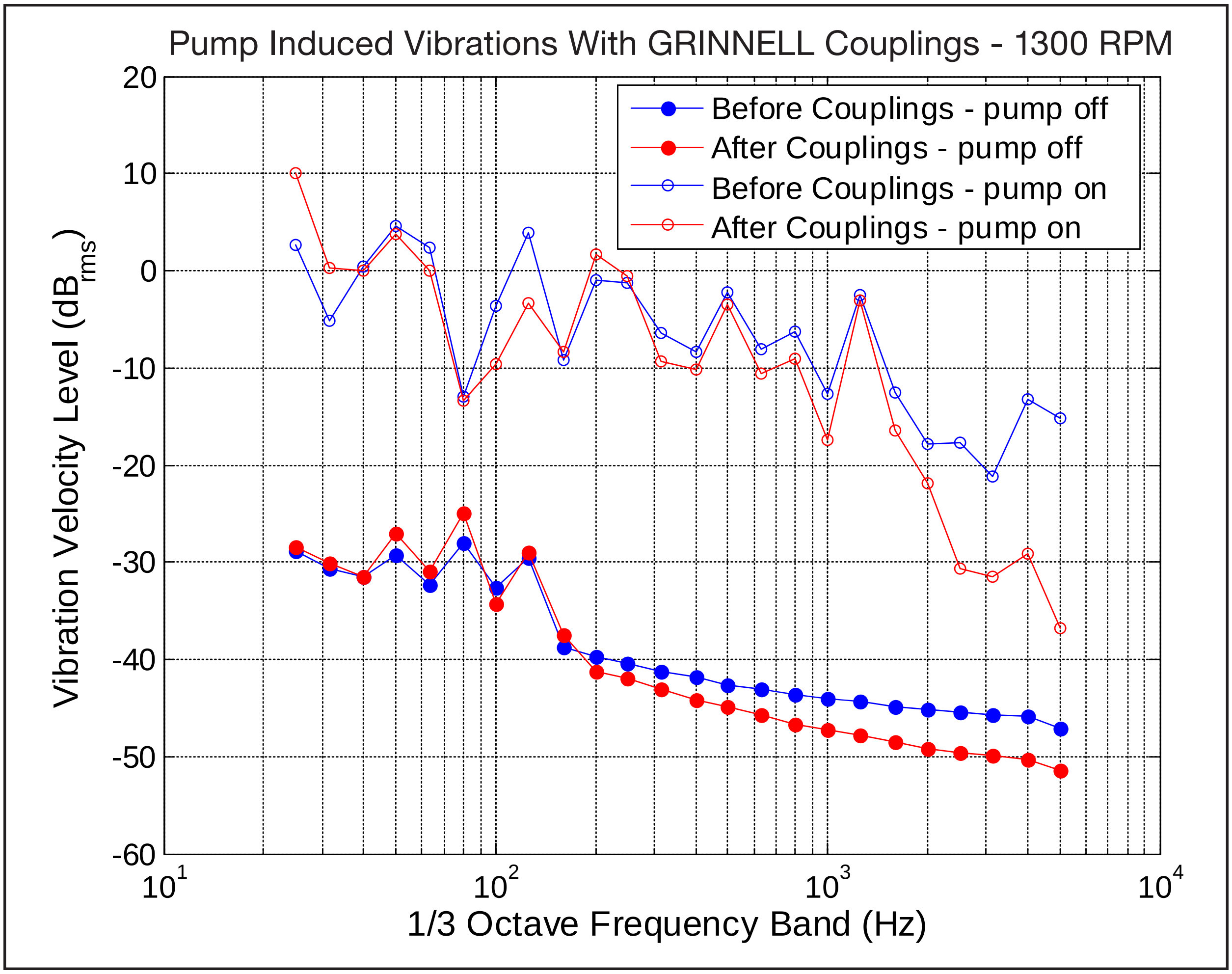



**Figure 3: Spatially Averaged Pipe Vibration Levels on either side of GRINNELL Coupling (with and without Pump Operating at 1300 rpm)**

The vibration reductions obtained across the GRINNELL Couplings and the braided metal flex connector with the pump motor operating at 875 rpm are shown in Figure 4(a). These results are displayed in terms of the reductions calculated in dB (e.g., higher positive values indicate higher reductions), for each of the 1/3 octave frequency bands. These numbers are calculated by simply subtracting the dB vibration levels of the far end of the pipe (location 2) from the levels measured on the pump side of the couplings (location 1). Figures 4(b) and 4(c) show the results obtained for the pump operating at two higher speeds - 1300 rpm and 1750 rpm.

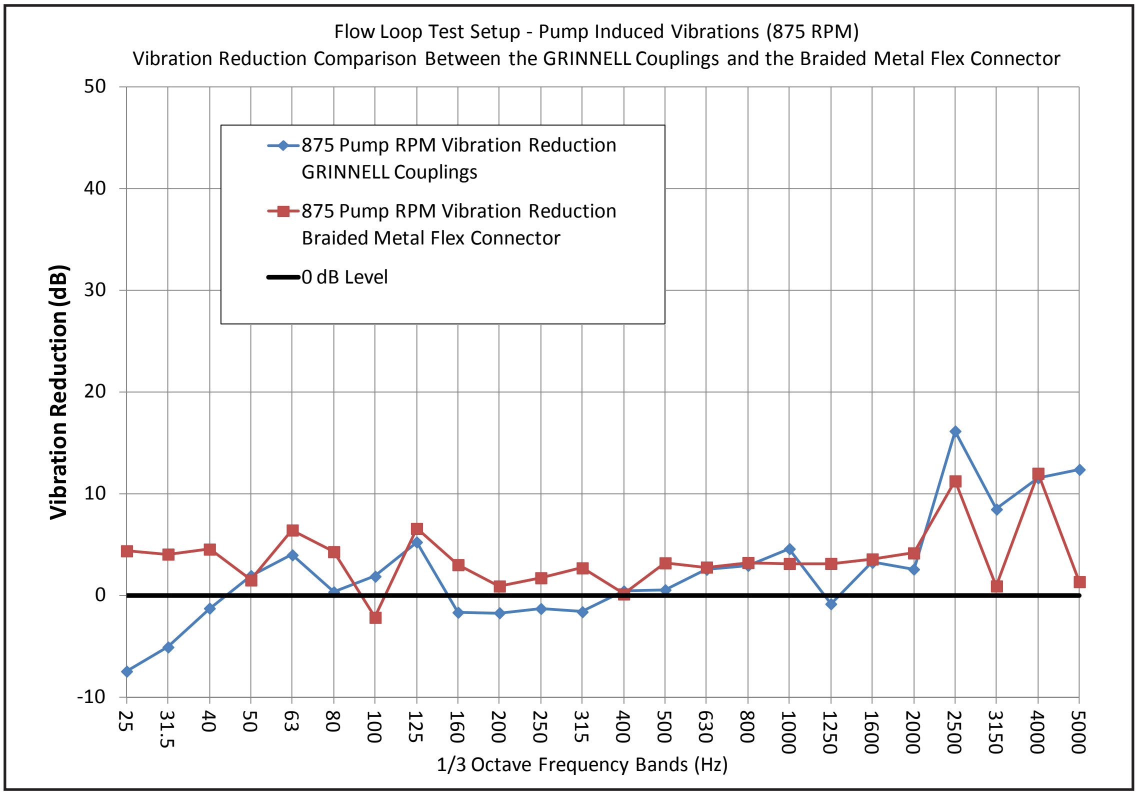



**Figure 4(a): Vibration Reductions Obtained with Pump Operating at 875 rpm**

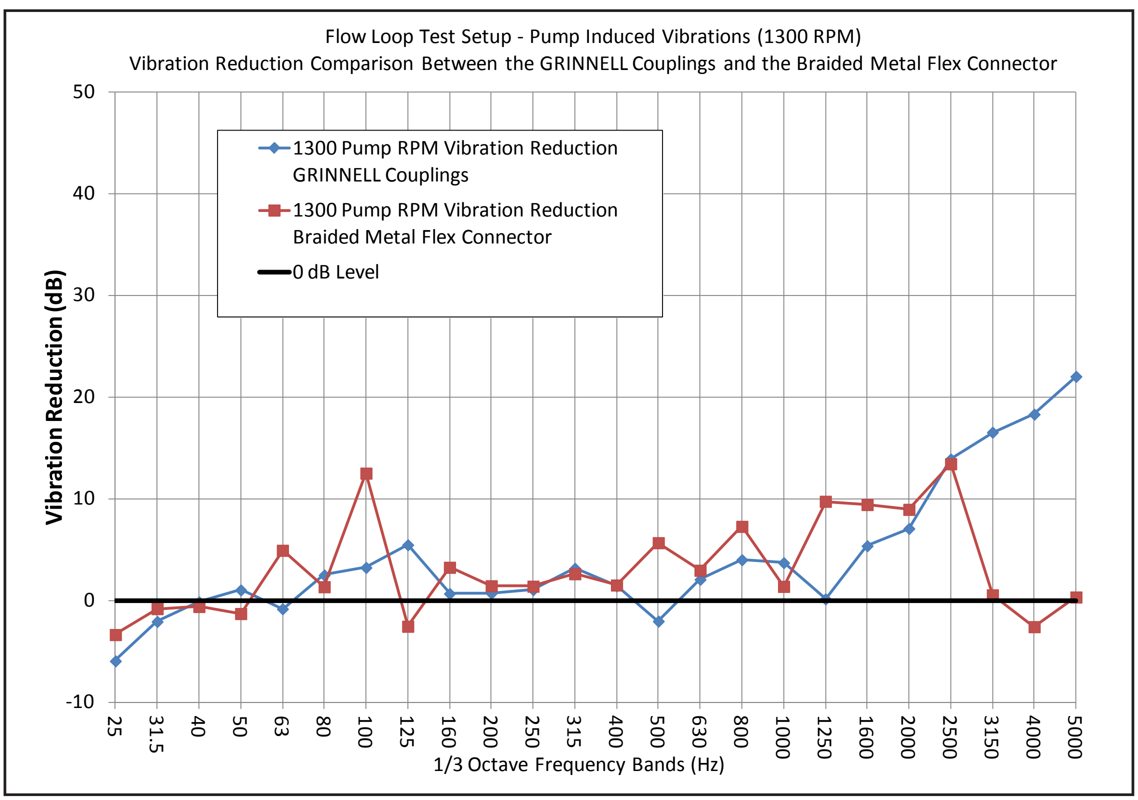



**Figure 4(b): Vibration Reductions Obtained with Pump Operating at 1300 rpm**

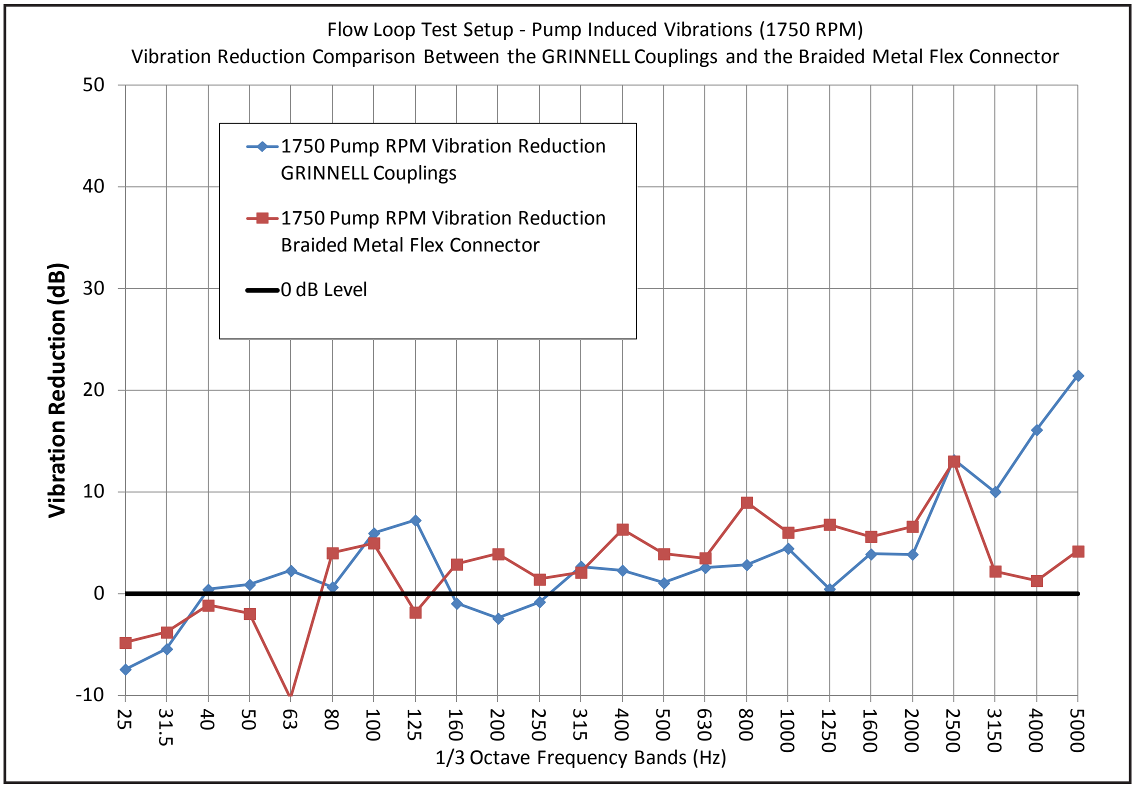



**Figure 4(c): Vibration Reductions Obtained with Pump Operating at 1750 rpm**

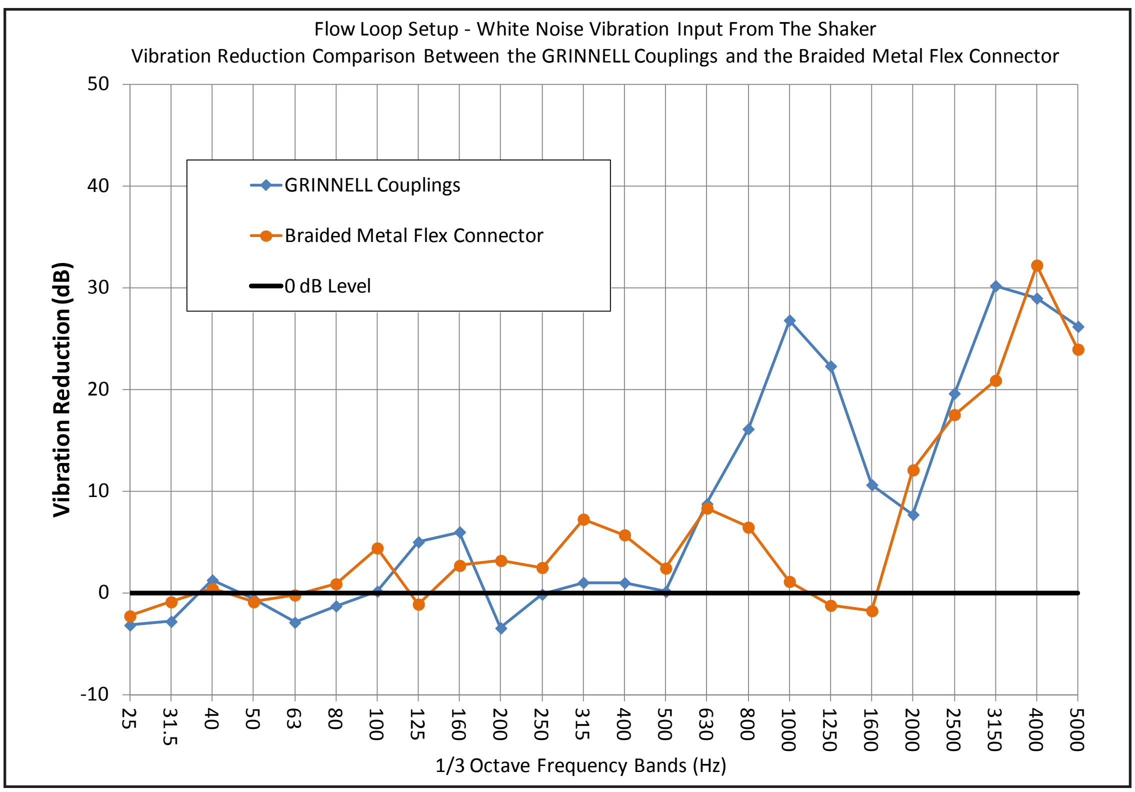



**Figure 5: Results with Shaker Acting as a White Noise Vibration Source**

Figure 5 shows the results of GRINNELL Couplings and the Braided Metal Flex Connector when a shaker was used to impart broadband vibration into the walls of the pipes.

For all cases and for both GRINNELL Couplings and the Braided Metal Connectors, there are a few frequency regions where the vibration levels are greater on the section of pipe opposite the source than they are on the section with the source. This is not unexpected, as there may be certain frequencies where vibration transmission is enhanced in certain locations along the pipe due to boundary conditions and other factors. However, over most of the frequency range the couplings serve as vibration attenuators, and on average the GRINNELL couplings (across three connectors) perform similarly to the single Braided Metal Flex connector. As shown in Figures 4(a), 4(b), and 4(c) at the higher frequencies with the pump as the source, the GRINNELL Couplings generally provide a higher degree of attenuation than does the Braided Metal Flex connector.

Supplemental tests showed that the vibration attenuation performance of the GRINNELL Couplings increased as the number of couplings increased from 1 to 3. This is evident in Figure 6. It would follow that installing even more couplings would further this benefit.

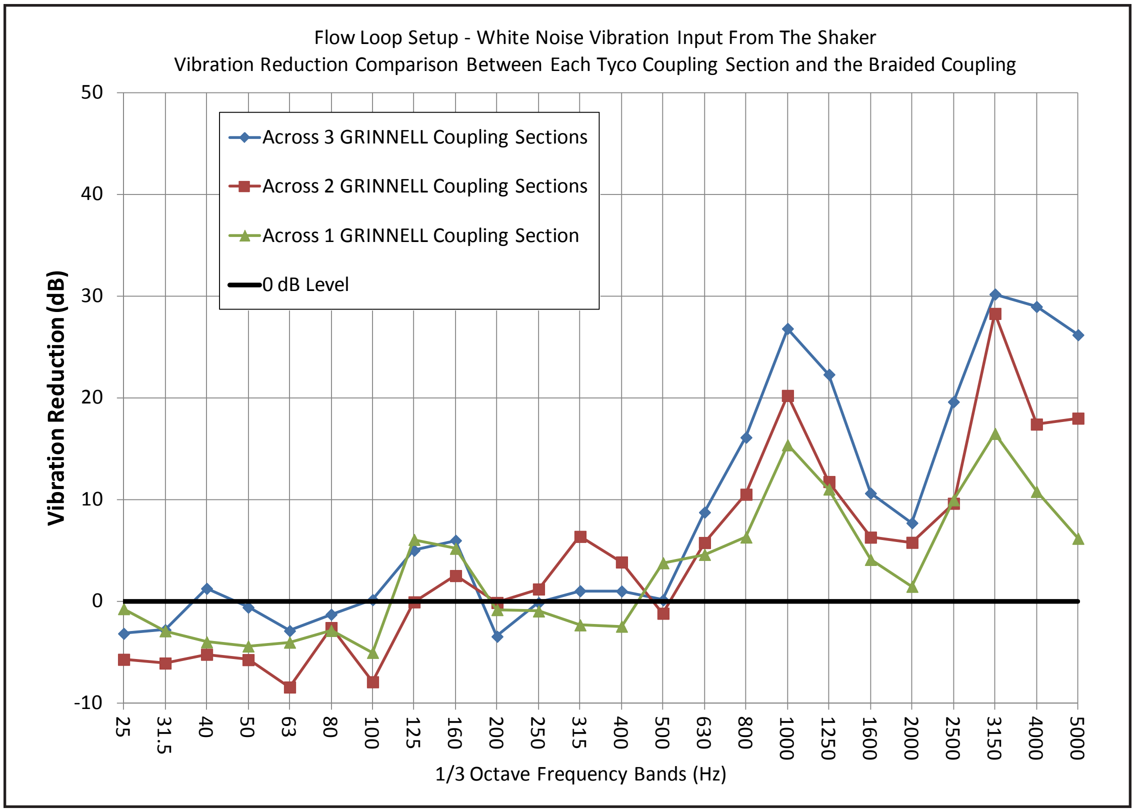



**Figure 6: Attenuation across 1, 2, and 3 GRINNELL Couplings (with the Shaker as a White Noise Vibration Source)**

## Measurements and Results of Out-of-System Testing

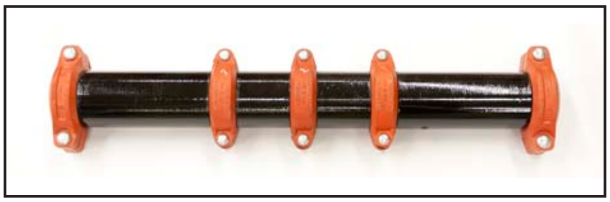
The two types of couplings used in the flow loop along with a third rubber flex connector were evaluated in a bench top test to compare their vibration attenuation properties. Photographs of the three test fixtures used for these out-of-system tests are shown in Figure 7.

**Rubber Flex Connector Assembly**

The rubber flex connector was assembled with the required control units and connected using (8) Grade 5 bolts to ANSI Class 125/150 flanges which were welded to 4” schedule 40 steel pipe. The test assembly was capped with grooved end caps using GRINNELL Couplings. One end cap was provided with an NPT pipe tap connection for the introduction of pressure.

**Braided Metal Flex Connector Assembly**

The braided metal flex connector was connected using (8) Grade 5 bolts to ANSI Class 125/150 flanges which were welded to 4” schedule 40 steel pipe. The test assembly was capped with grooved end caps using GRINNELL Couplings. One end cap was provided with an NPT pipe tap connection for the introduction of pressure.



**GRINNELL Figure 705 Coupling Assembly**

Three GRINNELL Figure 705 Flexible Grooved Couplings were connected to segments of 4” grooved schedule 40 pipe. The test assembly was capped with grooved end caps using GRINNELL Couplings. One end cap was provided with an NPT pipe tap connection for the introduction of pressure.

**Figure 7: The Three Different Pipe Assembly Joints Tested for Vibration Attenuation**

These assemblies were each fitted with 8 accelerometers spaced about the circumference of the pipe on either side of the test component, similar to the flow loop measurements. They were filled with water and pressurized to 50 psi and a mechanical shaker was used to impart broadband “white noise” vibration to the system. The vibration of each pipe assembly was measured on either side of the coupling elements. Table 2 presents the overall vibration attenuation results of these out-of-system bench top tests.

**Table 2: Out-of-System Testing Summary**

| Horizontal Test Setup - White Noise Input Summary | |
|---|---|
| Test Condition | Broadband Vibration Attenuation (dB) |
| Across 1 GRINNELL Coupling Section | 11.6 |
| Across 2 GRINNELL Coupling Sections | 15.1 |
| Across 3 GRINNELL Coupling Sections | 24.3 |
| Braided Metal Flex Connector | 19.0 |
| Rubber Flex Connector | 35.0 |

These overall numbers represent the total amount of vibration reduction across the elements between 25 and 5,000 Hz in each measurement setup. As was the case with the flow loop results, higher numbers indicate better attenuation performance. It can be seen in Table 2 that three GRINNELL Couplings provide more vibration attenuation than the braided metal connection. It is also evident that more grooved coupling segments could be added to the system to increase the amount of vibration reduction to that of the rubber flexible connector.

## Conclusions

The results of this exercise have shown that a series of three GRINNELL Grooved Couplings can provide comparable amounts of vibration reduction to that of a metal braided flexible connector arrangement. It has also been shown that greater vibration attenuation can be achieved with the addition of more GRINNELL grooved flexible pipe coupling elements. This reduction of vibration will result in attenuation of sound transmitted from sources in the piping to nearby listeners or sensitive equipment.

It is standard piping practice to connect grooved check valves, butterfly valves, tee strainers, long radius elbows and short pipe nipples on the suction and discharge sides of pumps. Incorporating the use of GRINNELL Grooved Couplings can address minor angular offset, ease installation and provide effective vibration attenuation without the need for a specialized vibration attenuation component. This translates to a cost savings.

Supporting case studies can be found here **http://grinnell.com/index.php?section=case**.

## About the Authors

With the help of GRINNELL personnel, this testing and analysis was performed by David Bowen and Ethan Brush of Acentech Incorporated. Acentech is a multi-disciplinary consulting firm comprised of experts in the fields of acoustics, noise and vibration, audiovisual and more. With offices in Cambridge, Massachusetts, Trevose, Pennsylvania and Westlake Village, California, their professional staff of more than fifty consultants has expertise in all areas of vibration and acoustics. A direct descendant of the highly regarded Bolt Beranek and Newman (BBN) acoustics consulting group, Acentech is the oldest and largest organization of its type in the U.S.

With over 25 years of experience, David Bowen performs sound and vibration analyses associated with product noise studies. His work includes source and path identification efforts that lead to effective modifications, and the development, implementation and evaluation of various signal processing procedures for use in machinery diagnostics, active noise/vibration control, and remote sensing. Mr. Bowen is a member of the Acoustical Society of America, the Audio Engineering Society, Society of Automotive Engineers, and served as Technical Program Chair for the 127th Meeting of the Acoustical Society of America. He holds both a Master of Science Degree and Engineer's Degree in Mechanical Engineering from MIT.

Drawing from his background in vibration data acquisition and analysis, Ethan Brush has a wide range of experience in structural dynamics. His expertise includes technical projects with dynamic testing and analysis for aerospace and defense applications, as well as studies at university research laboratories. At Acentech, Mr. Brush focuses on real-time remote monitoring systems for construction-related noise and vibration near sensitive facilities. He also applies his sound and vibration testing skills to product noise studies. Mr. Brush received a Master of Science in Mechanical Engineering from Purdue University, and a Bachelor of Science in Mechanical Engineering with a minor in Mathematics from the University of Maine, Orono.

Five GRINNELL Research and Development engineers (Michael Horgan, Gary Bednarz, Bharani Kannan, Ramesh Timasani, Chao Lian) with over 50 years of combined engineering experience have participated in this program. The GRINNELL Research and Development group focuses on the design, development and testing of grooved piping products to meet the requirements of a wide array of industry standards.

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