

# **National Shipbuilding Research Program**

## **Final Report**

### **Noise Control for Portable Ventilation Blowers**

#### **Panel Project 2014-424**

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## 1.0 Introduction

Portable Ventilation Blowers (PVB) used in shipboard construction and repair present many noise control challenges. In addition to the noise generated by motors, fans and air movement, noise control in this work environment is complicated by noise and vibration-conductive mounting surfaces on metal hulls and deck plates, equipment that is mobile with possible relocation on a daily or weekly basis, rugged handling and maintenance.

Previous work at shipyards and through NSRP has demonstrated these PVBs to be a major contributor to shipboard noise levels during construction and overhaul. Experience, observation and testing has suggested that several practical control options such as vibration isolators, acoustical jackets, duct silencers and enclosure partitions have the potential to offer feasible noise reduction solutions. No published studies or reports are available to demonstrate how these noise control strategies may be achieved in the shipbuilding industry.

The methodology that was employed to evaluate and recommend practical noise control strategies for this study included the following steps.

1. A systematic and methodical acoustical measurement approach was utilized to determine what practical measures may be applied to offer effective noise mitigation strategies in the use of the PVB units at Newport News and Electric Boat shipyards.
2. A variety of noise mitigation strategies were applied to the primary PVB model used at each participating shipyard.
3. Follow up testing was conducted to measure the effectiveness of the selected noise mitigation strategies.
4. Delivery of a written report to define the methods, cost, application and noise reduction benefits of the selected treatments.

One PVB unit (brand, model, size) was selected from each shipyard. It is the intent of this research to provide findings and recommendations that are “scalable” with application to similar pieces of equipment in future noise reduction efforts. The larger sized PVB units at each shipyard were selected for testing.

The specific acoustical measurement methodology (measurement protocol) that was utilized is American National Standards Institute, *Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Engineering method for an essentially free field over a reflecting surface.*<sup>1</sup> This standard allows for the measurement of the sound emissions from the selected PVB units under evaluation and, as such, a comparison can be made of the baseline sound emission levels with the sound emission levels associated with the PVB units equipped with various noise reduction treatments. The net sound reduction is the primary basis for determining which noise control application will be most effective. In addition, sound level measurements were conducted at a distance of five and ten feet from the acoustical

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<sup>1</sup> ANSI/ASA S12.54-2011 / ISO 3744:2010, *Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Engineering method for an essentially free field over a reflecting surface.*

center of the PVB unit along an X- and Y-axis grid that was applied to the test location. These data provide an assessment of the various noise reduction treatments on a directional basis. The sound emission levels are disproportionately reduced as a function of the specific component(s) of the PVB (i.e., motor, fan housing, intake and exhaust) targeted by the noise reduction treatment (i.e., device and/or material). For example, in the case of the selected PVB at Electric Boat, where one of three intake flanges is typically un-ducted; the result of the un-ducted flange being fitted with an intake silencer is reduced sound emission levels from intake area of the PVB. We will also consider, in conjunction with each shipyard, other parameters in determining whether a particular noise reduction treatment is viable for permanent use. These parameters include effects on volumetric flow rate, flammability ratings, durability, size constraints, etc.

## **2.0 Project tasks and objectives**

The study was divided into five tasks which are:

### **Task 1: Complete Background Research and Develop Field Testing Plan**

- Establish contact with shipyard participants at Newport News and Electric Boat shipyards. Throughout the project, the defined point of contact representatives will serve as the on-site shipyard representatives to coordinate schedule; PVB equipment access, mechanical operation and maintenance of PVB as needed; visitor access badges and photography passes; and the receipt and review of reports and test data.
- Define the type, size and models of portable ventilation blowers (PVB) that will be used in the noise evaluation and control studies at each respective site. One unit (brand, model, size) will be selected from each shipyard. It is the intent of this research to provide findings and recommendations that are “scalable” with application to similar pieces of equipment in future noise reduction efforts.
- Evaluate and review the published and available technical information on previous testing and noise control work conducted on similar or comparable pieces of equipment
- Develop the scope and schedule for the preliminary noise testing, observation, measurement to be conducted in Task 2.

### **Task 2: Field Testing and Analysis**

- Conduct a site visit to each participating shipyard (EB and NNS) for two days of observation and testing to measure and define baseline noise levels of the PVB units selected by each site for the study. In addition, observations will be conducted of how the PVB units are utilized under real-world conditions to inform the selection of workable noise mitigation strategies. Dimensional and operating parameters will also be measured as they related to the selection of appropriate noise mitigation strategies.
- Measurements will be conducted under a standardized set of conditions which may be replicated at a later date. The comparison of pre and post-treatment measurements will provide the basis for the assessment of the efficacy of an individual noise reduction control strategy or combination of strategies.
- Following a review of the noise test data and on site observations, the research team will define and recommend a series of specific, practical noise reduction treatments for follow-up application and testing on the selected PVB from each site. Potential

treatments may include: in-line silencers, vibration damping mounting platforms, resilient seal fan gaskets, modified ductwork and motor housings, sound dampening jackets or other measures.

### **Task 3: Application and Testing of Selected Noise Reduction Treatments**

- Prepare a series of noise reduction treatments for use with the PVB units tested at the respective shipyard sites.
- Schedule shipyard site visits to install and evaluate selected noise reduction treatments.
- Visit each participating shipyard (EB and NNS) for two days of observation and testing to measure and define post-treatment noise levels produced by the PVB selected by each site for the study. The post-treatment noise testing regimen will be completed under conditions comparable to the earlier baseline analysis. Testing may include noise measurements with the treatments individually and in combination, as appropriate and feasible.

### **Task 4: Prepare Draft Report**

- Compile a summary report that includes background research, a detailed description of the representative PVB selected for the study, preliminary pre-treatment test data, descriptive methods for the fabrication, selection and installation of the noise reduction treatments, follow up test data with application of noise reduction treatments, analysis of the findings and recommendations for the most effective application of these treatments for practical noise reduction in shipyards.
- Distribute Draft Report to participating shipyard representatives and Risk Management Panel leadership for review and comment.

### **Task 5: Deliver Final Report**

- Discuss Draft Report with participating shipyard representatives to ensure the presentation and summary provides worthwhile and constructive data for the reduction of PVB noise.
- Review, discuss and summarize Draft Report edits and comments into a Final Report.
- **Technology Transfer:** *The participating shipyards will receive custom-fitted and validated prototypes, with site specific build specifications to fabricate additional noise control modifications. This represents a unique opportunity for immediate technology transfer and practical application of the research findings.* The data collected and recommendations will be available for use by all shipyards and ship repair activities. Project progress reports will be made to appropriate panels of the NSRP during and at the completion of the project. Reports will be distributed via “nsrp.org” and other electronic media.

## **3.0 Baseline field testing and observations of PVB in-use at each shipyard**

### **3.1 HI-Newport News, Newport News, Virginia on March 17-19, 2014**

The research team conducted a site visit to NNS on March 17-19, 2014 to make observations and undertake testing to measure and define baseline noise levels produced by the PVB selected by

NNS for the study. The research team received dedicated escort and logistical support for our visit.

The PVB selected for evaluation was a 10 HP Robinson Blower. It was initially thought that there was not much variability of sound emission levels among PVB of the same size and make. As such, it was decided that due to logistical issues during this site visit to NNS and in order to avoid duplication of efforts that sound level measurements that were to be collected as part of an in-house NNS acoustical study, for the selected PVB, would be used as the baseline data for the NSRP Study. It was subsequently realized that there is significant variability in sound emissions from like-PVB units and, as such, it would be necessary to compare pre- and post-treatment measurements for identical PVB units to properly assess the effectiveness of the selected noise reduction treatments.

Observations were made of PVB in-use on an aircraft carrier undergoing overhaul at NNS. Many of the PVB in-use for carrier construction and overhaul at NNS are located within interior deck spaces and, as such, due to hard metal reverberant surfaces, have a much greater impact on the acoustical work environment than PVB located outdoors. PVB were observed under various conditions; some units were configured for individual use and others are arranged in-series with a second PVB of the same size (e.g., 10 HP). The 10 HP PVB utilizes a 12 inch diameter duct on the inlet and outlet of the blower. The outlet air from the PVB is either exhausted to the hanger deck through a short length of duct (approximately 5-10 feet) or ducted directly to the exterior of the ship (up to approximately 100 feet of duct) depending on the material(s) the PVB are ventilating. Those units which exhaust directly into the hanger deck contribute considerably more noise to the acoustical work environment than those that exhaust to the exterior of the ship.

Observations of PVB in-use also included a qualitative assessment of the vibrational energy being transferred from PVB to the ship deck. The extent to which vibrational energy is transferred to the deck is a function of the characteristics of the PVB as well as those of the ship deck (e.g., deck thickness, location of support structures, etc.). As such, it is not possible to recreate actual in-use conditions at the test location (off-ship). Therefore, to the extent possible, vibration-isolation treatments must be assessed on a PVB that is onboard a ship and at a location onboard that is conducive to vibrational energy transfer. To assist in selecting appropriate sized vibration-isolation mounts for future testing, measurements were made of the clearance between the lower frame of approximately 10 PVB and the ship deck. These were PVB in-use onboard a ship. It was determined the Robinson Blower units ranged from approximately 2.75 to 3.5 inches and the New York Blower units were approximately 5.5 inches.

To ensure potential noise reduction treatments to the PVB will be serviceable we consulted with the supervisor of the NNS Repair Shop. The key points of discussion included: durability of treatment materials; adequate clearance below the main support frame to allow for PVB to be lifted by a skid-steer loader (particularly related to adding vibration-isolation mounts); concern related to significant increase in overall weight; and, concern for treatments that result in significant increase of the "foot-print" or overall dimensions of the PVB and would make it more difficult to maneuver PVB in the typical tight-quarters aboard a ship.

To fully understand the process of how PVB are setup and deployed we also consulted with the supervisor of the shop responsible for this mobilization. We were particularly interested in knowing whether noise treatments, such as a silencer, had been used in the past and, if so, were they effective and workable in the ship construction and repair environment. According to the supervisor, their only effort to lessen the noise from the PVB, to his knowledge, was to attach a 5-10 foot length of duct to the exhaust of the PVB. This short length of duct is (i.e., tubing) referred to as “stack.”

NNS does not have engineering drawings of the Robinson 10 HP PVB. Therefore, a sketch was made of the PVB to facilitate the documentation of dimensional measurements. The selected PVB was also weighed to obtain an overall weight and the weight at the four corners of the unit to inform the proper selection of vibration-isolation mounts. The individual weights measured at the four corners of the PVB were 73, 120, 124 and 175 lbs. The overall weight measured for the same PVB unit was approximately 497 lbs. and is consistent with the sum of the individual weights (within 5 lbs.). This information was used to purchase properly sized noise reduction treatments and vibration-isolation materials and devices.

A top-view and side-view sketch of the PVB is provided in Attachment 1 of this report.

Photographs were taken by our NNS escort of PVB in-use, under representative conditions, and also the selected PVB under test conditions. Representative examples are provided as Attachment 2 to this report.

### **3.2 General Dynamics Electric Boat, Groton, CT on April 7-9, 2014**

The research team conducted a site visit to Electric Boat (EB) on April 7-9, 2014 to make observations and undertake testing to measure and define prevailing noise levels produced by the Portable Ventilation Blower (PVB) selected by EB for the study. The research team received dedicated escort and logistical support for our visit.

The PVB selected for evaluation is a Coppus, Inc. TM-8 (15 HP) unit. This unit was located at the dock area near the “Temp Vent” shop. This is a suitable outdoor test location that has features that are consistent with the requirements of the measurement methodology which will be utilized in this study, ANSI/ASA S12.54-2011 / ISO 3744:2010, *Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Engineering method for an essentially free field over a reflecting surface (ANSI Standard)*.

Observations were made of PVB units that were located at the base of the dry dock alongside a submarine under construction and along the top catwalk area of the dry dock. The surface these PVB sit upon is concrete and, as such, there is no significant vibrational energy being transferred to this surface. However, the use of rubberized “feet” on the PVB, as opposed to metal “feet”, may serve to reduce vibrational noise that might otherwise occur.

The TM-8 PVB units are typically equipped with a multi-inlet adapter which can accommodate 3-4 ventilation ducts (8” diameter flexible duct). It is also typical for one of the duct inlets to be

left open (no duct attached). The other ducts are active and are providing ventilation to the work areas in need of fresh air exchange. Each 8' diameter duct, at approximately 50 feet from the PVB, branch into two 4" ducts which then enter various sections of the submarine (e.g., tanks and other spaces undergoing painting, welding, etc.). The open inlet is equipped with a safety guard ("screen") to assist in preventing objects and body parts from being drawn into the PVB. Some PVB, so equipped, emitted a whistle-type sound due to the aerodynamic effect of the inlet safety guard.

While most employees were not working continuously in close proximity to the operating PVB, some work is required in the vicinity of this equipment for extended periods. One example is the safety monitor, known as a "tank watcher," who is assigned to a stationary location to observe others while they are working in the lower level tanks of a submarine in dry dock. Due to the close proximity (approximately 10-20 feet) to two operating PVB, this work location has a relatively high exposure to noise and; therefore, would benefit greatly from effective noise control of this equipment. Other employees who are in close proximity to the same two PVB units, for an extended period of time, are those that work on scaffolding (staging) on the exterior of the submarine. These employees, are at times, directly above (a few feet to the left or right) of the PVB units and; therefore, would benefit greatly from effective noise control of this equipment.

The TM-8 PVB units at EB are equipped with a dissipative-type silencer which is installed at the exhaust of the unit. As such, the initial baseline, pre-abatement sound level measurements were conducted with and without the silencer installed to assess the effectiveness of the silencer. When the broadband sound power levels (dBA values) for the PVB equipped with and without the silencer are compared, the difference in levels is approximately 7 dBA. This is an appreciable difference and represents a perceived halving of the loudness of the PVB when the silencer is in-use. On an energy basis, a 7 dB reduction represents approximately a two-fold decrease. That said, the data also indicates that the inlet that is typically left open (no duct attached) is a significant contributor to the overall sound emissions from the PVB. As was discussed for the initial baseline measurements that were conducted for the selected PVB at NNS, it was subsequently realized that there is significant variability in sound emissions from like-PVB units and, as such, it would be necessary to compare pre- and post-treatment measurements for identical PVB units to properly assess the effectiveness of the selected noise reduction treatments.

To ensure potential noise reduction treatments to the PVB will be serviceable we consulted with those responsible for the maintenance and repair and installation ("Temp Vent") of these units. The key points of discussion included: durability of treatment materials; do not increase the height of the units since any additional height would not allow the units to be brought through the doorway to the maintenance shop, anything that would make it more difficult to move the PVB units with a skid-steer loader; concern related to significant increase in overall weight; and, concern for treatments that result in significant increase of the "foot-print" or overall dimensions of the PVB and would make it more difficult to maneuver or set-up PVB.

Engineering drawings of the selected PVB were not readily available. Therefore, a sketch was made of the selected PVB to facilitate the documentation of dimensional measurements. This information will be needed to purchase properly sized noise reduction treatments and devices.

A top-view and side-view sketch of the PVB is provided as Attachment 1 to this report.

Photographs were taken by the EB photographer of PVB in-use, under representative conditions, and also the selected PVB under test conditions. Several photographs are provided as Attachment 3 to this report.

#### **4.0 Summary of Pre- and Post-Treatment Sound Level Testing and Observations**

##### **4.1 Robinson 10HP Blower (NNS)**

The research team measured the pre- and post-treatment sound levels produced by a Robinson 10HP Blower on July 21-23, 2014. The shipyard provided dedicated escort and logistical support for this work.

The PVB provided for this evaluation (Shipyard ID 727-90) was a different unit than the PVB evaluated in Task 2 (Shipyard ID 721-90). This PVB is shown as tested under baseline conditions in Figure 1.



Figure 1 – Robinson 10HP Blower in baseline test

An outdoor platen area was provided as a suitable test location. This area met the requirements of the measurement methods used in this study; ANSI/ASA S12.54-2011 / ISO 3744:2010, *Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Engineering method for an essentially free field over a reflecting surface*. The



test area provided a flat concrete surface and no significant vertical reflective surfaces within 30 feet of the tested equipment. A measured grid was established as shown in Figure 2.

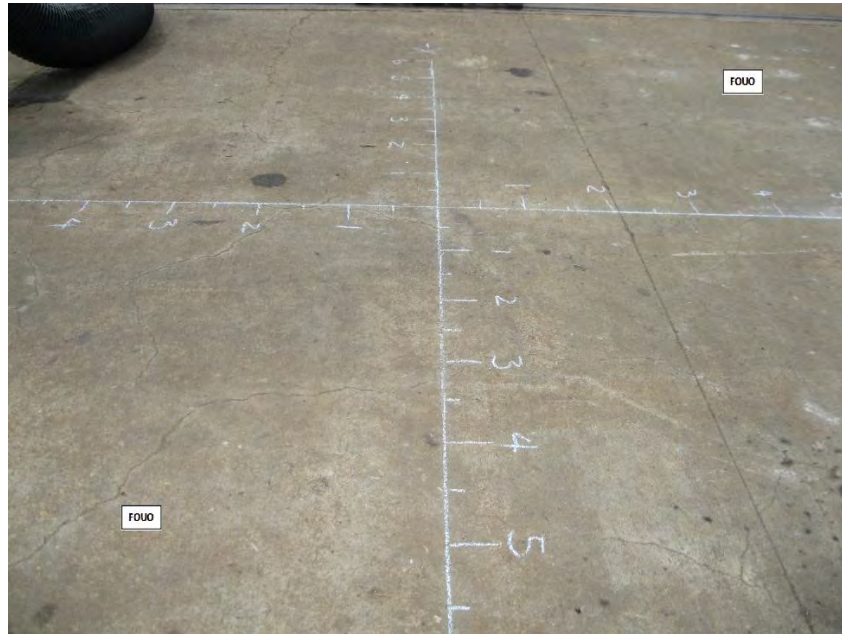


Figure 2 – Measured grid for sound level testing per ANSI/ASA S12.54-2011

The noise reduction treatments evaluated included:

- Exhaust silencer (dissipative-type) which was attached to the outlet (exhaust) flange of the PVB. A dissipative silencer is designed to have a minimal pressure drop and, as such, the effect on the flow rate is also minimal. To the extent possible, flow rate measurements were conducted during the noise testing. Many of the PVB in use during the construction and overhaul of surface ships were observed to be located within interior spaces or lower decks. In some cases, on larger ships, these PVB exhaust directly into these interior spaces. Baseline testing confirmed that the noise emitted at the exhaust is one of the primary contributors to the overall noise emissions from the PVB. The use of a silencer in this application should measurably reduce the sound emission levels from the PVB. Exterior and interior views of the silencer are shown in Figure 3.



Figure 3 –Exhaust Silencer: Interior view (left photo) and the exterior view (right photo).

The specific silencer that was evaluated in this study is a Lindab-USA, Inc. Model SLGU-12-06, purchased through the distributor, Stillwell-Hansen, Inc., Edison, NJ at a cost of \$439 plus freight. This unit, in addition to providing a high level of acoustical performance, is manufactured with an acoustical lining material that conforms to ASTM E84- 91a and NFPA 90A and will not exceed flame spread and smoke developed ratings of 25/50. A detailed specification sheet for this unit is provided as Attachment 4 to this report.

- Acoustical “jacket” was installed around the fan housing to increase the *insertion loss* of fan housing and thereby reduce the sound emission levels from this portion of the PVB. A sheet of *acoustical-jacket* material was custom-cut onsite and fitted to the fan housing. The *acoustical-jacket* panels were secured in place with tape supplied by the manufacturer for this purpose. The *acoustical-jacket*, as installed, is shown in Figure 4.



Figure 4 – Acoustical Jacket, as installed on the surface of the fan housing

The acoustical jacket material that was evaluated in this study is “acoustical pipe and duct lagging: B-10 LAG/QFA-3” which was purchased from Sound Seal Acoustical Products, Agawam, MA, at a cost of \$85 plus freight. This material, in addition to providing a high level of acoustical performance, is manufactured to conform to ASTM E84-91a and NFPA 90A with a flame spread and smoke developed ratings of 12.5/19.5. A detailed specification sheet for this material is provided as Attachment 5 to this report.

- Vibration-isolation mounts were installed for testing on the four corners of the lower frame of the PVB to interrupt the path that currently allows vibrational energy of the PVB to be transferred to the deck of the ship. The PVB is currently configured with wheels, in contact with the ship deck, which are non-resilient. The vibration-isolation mounts are a “housed-spring” type of mount that is both durable and effective. A neoprene pad is adhered to the base of the mount. A spring type mount is effective at reducing low- and mid- frequency vibration; while a neoprene pad is effective for high-frequency vibration. The vibration-isolation mounts are shown in Figure 5.



Figure 5 – Vibration Isolation mounts (left photo) are sized for the weight at each corner of the PVB and the photo on the right shows one mount with the full weight of the PVB on the spring mounts – wheels off the ground.

The four vibration-isolation mounts that was evaluated in this study are Mason Industries, Inc. (1) Model C-A-75, (2) Model C-A-125 and (1) Model C-A-200 purchased through Zoro Industrial Supplies ([www.zoro.com](http://www.zoro.com)) at a cost of \$149.11 plus shipping. A detailed specification sheet for these units is provided as Attachment 7 to this report.

A series of five noise reduction treatments and/or system configurations were tested. A description of these test configurations are as follows:

- **Configuration 1:** Represents one of two baseline (pre-treatment) configurations tested and included a length of 25 feet of flexible duct attached to the intake and exhaust flanges.
- **Configuration 2:** Represents the second baseline (pre-treatment) configuration tested and included a length of 25 feet of flexible duct attached to the intake flange and a 10 foot length of flexible duct attached to the exhaust flange.
- **Configuration 3:** Represents post-treatment testing with the inline dissipative silencer attached to the exhaust flange and the flexible duct set-up as described in Configuration 2.
- **Configuration 4:** Represents post-treatment testing with the inline dissipative silencer attached to the exhaust flange, the fan housing fitted with the *acoustical-jacket* and the flexible duct set-up as described in Configuration 2.
- **Configuration 5:** Represents post-treatment testing with the fan housing fitted with the *acoustical-jacket* and the flexible duct set-up as described in Configuration 2.

For each of these configurations a set of sound level measurements were conducted based on the ANSI/ASA S12.54-2011 standard as well as a series of additional measurements to further evaluate the efficacy of the noise treatments, individually and in combination. The same methodology and procedures were utilized for the baseline (pre-treatment) testing and for the testing with the noise reduction treatments. In addition, ambient sound level measurements were conducted to assess the contribution from adjacent noise sources and to “correct” for these

sources as part of the data analysis. A diagram of the X and Y-axis lines applied for this testing grid is shown as Figure 6.

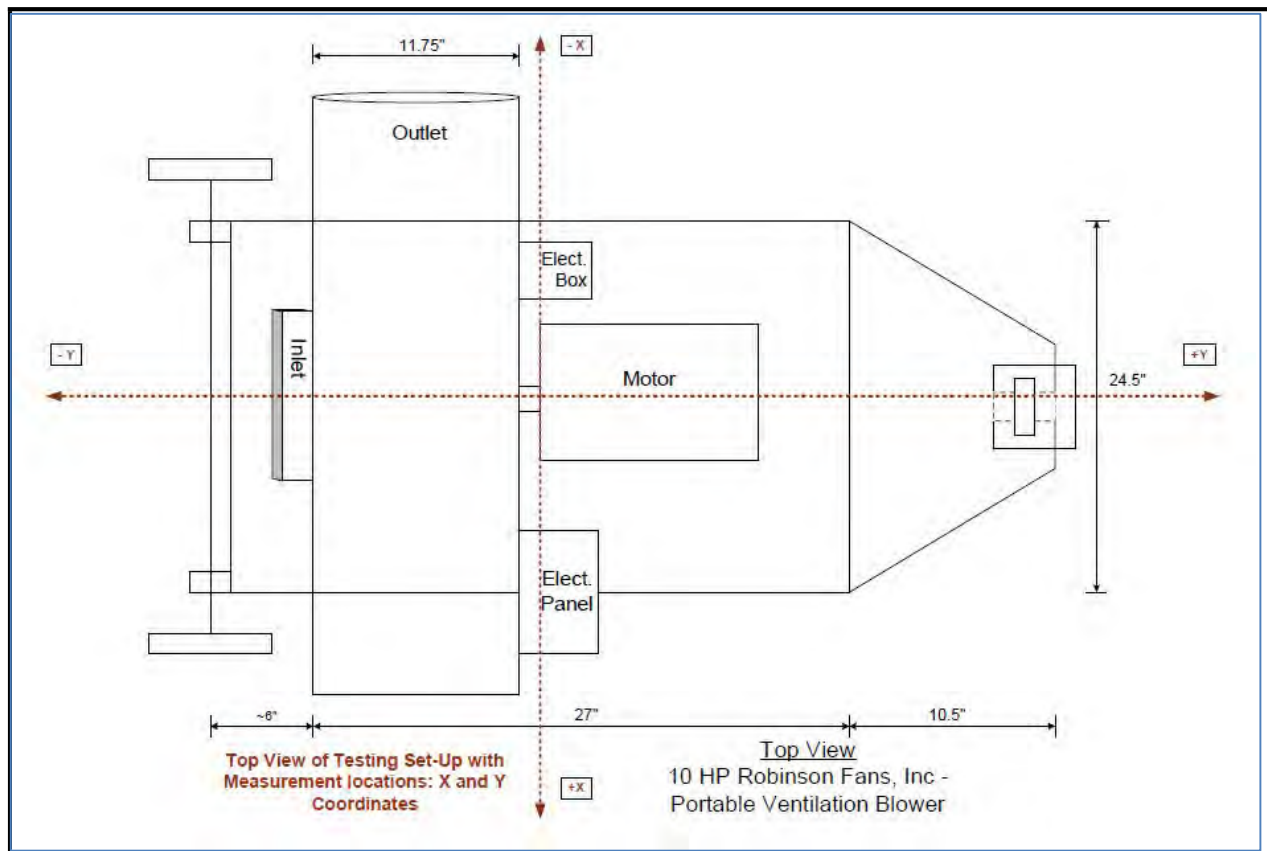


Figure 6 – Sound level testing grid for 10HP Robinson Blower with X and Y axis lines

The selected Robinson 10 HP PVB used a 12 inch diameter duct on the inlet and outlet of the blower. The outlet air from the PVB is either exhausted to an interior deck of the ship through a short length of duct (approximately 6-10 feet and referred to as a “stack”) or ducted directly to the exterior of the ship (typically 100 feet of duct or more) depending on the material(s) the PVB is ventilating. Those units which exhaust directly into the interior decks contribute considerably more noise to the work environment than those that exhaust to the exterior of the ship and represent a worst-case scenario. This is the basis for the flexible duct setup described in Configuration 2 that was used for the baseline and post-treatment testing.

Photographs were taken by the shipyard photographer, showing the PVB in-use and under test conditions.

Following installation and testing, all noise reduction treatment materials and devices were left with the shipyard for ongoing use and evaluation.

#### 4.2 Coppus TM-8 15HP Blower (EB)

The research team evaluated the pre- and post-treatment sound levels produced by a Coppus TM-8, 15HP blower on August 5-7, 2014. The shipyard provided dedicated escort and logistical support for this work.

The PVB provided for the Task 3 evaluation (Shipyards ID 822) which included pre- and post-treatment measurements was a different unit than the PVB initially evaluated in Task 2 (Shipyards ID 615); although, it was the same brand, model and size. The PVB tested is shown in Figure 7.



Figure 7 – Coppus TM-8 Blower (Shipyards ID 822)

An outdoor platen area was provided as a suitable test location. This area met the requirements of the measurement methods used in this study; ANSI/ASA S12.54-2011 / ISO 3744:2010. This work area has a flat concrete base and no significant vertical reflective surfaces within 30 feet of the test equipment. To accommodate the testing, the shipyard set up scaffolding (i.e., staging) above and around the PVB to closely simulate the layout within the dry dock area. A second scaffolding was also set-up to allow for the support of an acoustical curtain which was being evaluated for its effectiveness at reducing noise levels for the “tank watcher” work location in the dry dock. The scaffolding also allowed for a representative assessment of the effectiveness of the noise reduction treatments for employees that are working on the scaffolding above the PVB units. The test area, as configured, is shown in Figure 8.



Figure 8 – Coppus TM-8 Test Area

The TM-8 PVB units observed in-use in the shipyard were typically equipped with a multi-inlet manifold which can accommodate 3-4 ventilation ducts (8" diameter flex duct). It is also typical with this model for one of the duct inlets to be left open with no duct attached. The TM-8 PVB units, as currently configured, are equipped with a dissipative-type silencer on the discharge only. As such, baseline, pre-treatment sound level measurements were conducted with this silencer in place.

The noise reduction treatments evaluated included:

- Inlet silencer (dissipative type) was applied to the inlet flange of a multi-inlet manifold that is typically left “open” with no duct attached. A dissipative silencer is designed to have a minimal pressure drop and, as such, the effect on the volumetric flow rate is also expected to be minimal. To the extent possible, flow rate measurements were conducted during the noise testing. The use of a silencer in this application is anticipated to reduce the sound emission levels from the PVB since the “open” inlet represents a significant contribution to the total noise associated with PVB, as demonstrated in baseline testing. Exterior and interior views of the silencer are shown in Figure 9.



Figure 9 – Intake Silencer for Coppus TM-8: Exterior View (left photo) and Interior View (right photo)

The specific silencer that was evaluated in this study is a Lindab-USA, Inc. Model SLGU-8-06, purchased through the distributor, Stillwell-Hansen, Inc., Edison, NJ at a cost of \$296 plus freight. This unit, in addition to providing a high level of acoustical performance, is manufactured with an acoustical lining material that conforms to ASTM E84- 91a and NFPA 90A and will not exceed flame spread and smoke developed ratings of 25/50. A detailed specification sheet for this unit is provided as Attachment 4 to this report.



- Acoustical-curtain was installed to interrupt the direct sound path between the location of the PVB and the location which is representative of the “tank watcher” work station. In addition to serving as a barrier to the direct sound path it also serves to absorb a portion of the sound that would otherwise reverberate within the acoustically “hard” surfaces found in a dry dock. The acoustical curtain tested was 10 feet wide by 8 feet in height. The job title of “Tank Watcher” has been used in the presentation of this data to represent the potential noise exposure of a shipyard employee positioned in dry dock near a comparable PVB in use. The acoustical-curtain, as tested, is shown in Figure 10.



Figure 10- Acoustical curtain for Coppus TM-8, as tested

The custom acoustical curtain that was evaluated in this study is “BSC-25-2” Noise Barrier/Sound Absorber Composite” which was purchased from Sound Seal Acoustical Products, Agawam, MA, at a cost of \$500 plus freight. The acoustical curtain, in addition to providing a high level of acoustical performance, is manufactured to conform to ASTM E84-91a and NFPA 90A with a flame spread and smoke developed ratings of 22.78/30.56. A detailed specification sheet for this unit is provided as Attachment 6 to this report.

- *Acoustical-jacket* was installed on the surface of the fan housing to increase the *insertion loss* of fan housing and thereby reduce the sound emission levels from this portion of the PVB. The *acoustical-jacket* was custom cut and fitted from a sheet of acoustical lagging material. The *acoustical-jacket* panels were secured in-place with lagging tape supplied by the manufacturer. The *acoustical-jacket*, as tested, is shown in Figure 11.



Figure 11 – *Acoustical-jacket* for Coppus TM-8, as tested

The acoustical jacket material that was evaluated in this study is “acoustical pipe and duct lagging: B-10 LAG/QFA-3” which was purchased from Sound Seal Acoustical Products, Agawam, MA, at a cost of \$85 plus freight. This material, in addition to providing a high level of acoustical performance, is manufactured to conform to ASTM E84-91a and NFPA 90A with a flame spread and smoke developed ratings of 12.5/19.5. A detailed specification sheet for this unit is provided as Attachment 5 to this report.

- Acoustical-curtain as a partial-enclosure for the motor assembly – a 4 feet by 8 feet section of the acoustical curtain material was “tented” over the motor housing, as depicted in Figure 12, to assess the performance of this material to reduce the sound emission levels from this portion of the PVB. This was not a test condition that was initially anticipated to be conducted. However, it provided an opportunity to collect data for a noise reduction treatment that may have merit. The placement of the acoustical curtain material was done with consideration for the needs of the air-cooled electric motor. This is a concern that would need to be considered more fully if this noise reduction approach were to be implemented. It would also be necessary to design the curtain material to be of a proper size and be equipped with adequate means for fastening it to the PVB.

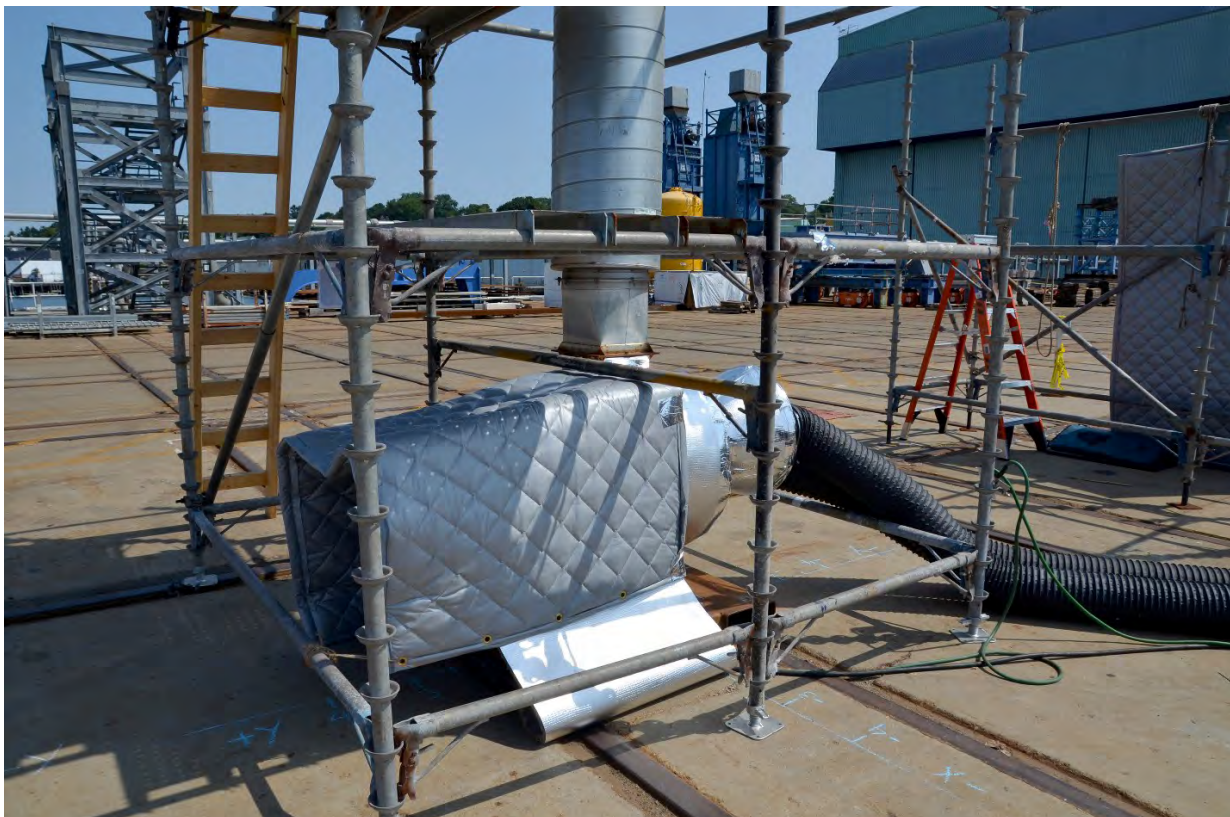


Figure 12 – *Acoustical-curtain* material “tented” over the motor housing of the Coppus TM-8, as tested.

A series of five noise reduction treatments and/or system configurations were tested. A description of these test configurations are as follows:

- **Configuration 1:** Represents the baseline (pre-treatment testing) configuration tested and included two 22’ lengths of 8” flexible duct attached to 2 of the 3 inlet flanges of the multi-flange inlet adapter while the other inlet flange was left “open.” Also installed on the PVB was the typical pre-existing inline exhaust silencer with no inner acoustical lining remaining in-place. The inner acoustical lining of the older exhaust silencers currently in-use were observed to be damaged or, in many cases, completely missing due to corrosion.

- **Configuration 2:** Represents conditions in Configuration 1 with the addition of the inline inlet silencer on the otherwise open inlet flange of the multi-flange inlet adapter and the *acoustical-curtain* in-place approximately 20 feet from and in line with the inlet side of the PVB. The far-side of the *acoustical-curtain* represents the location of the employee referred to as the “tank watcher.”
- **Configuration 3:** Represents conditions in Configuration 1 with the addition of the inline inlet silencer on the otherwise open inlet flange of the multi-flange inlet adapter, the *acoustical-curtain* in-place approximately 20 feet from and in line with the inlet side of the PVB and the *acoustical-jacket* fitted onto the fan housing of the PVB.
- **Configuration 4:** Represents conditions in Configuration 1 with the addition of the *acoustical-curtain* in-place approximately 20 feet from and in line with the inlet side of the PVB and the *acoustical-jacket* fitted onto the fan housing of the PVB. The inlet silencer is not attached in this Configuration.
- **Configuration 5:** Represents conditions in Configuration 1 plus the *acoustical-jacket* fitted onto the fan housing of the PVB and a portion of the acoustical curtain material was positioned over the motor housing of the PVB to assess the effectiveness of a *partial-enclosure* of the motor. The *acoustical-jacket* and acoustical–curtain material “tented” over the PVB motor housing, serving as a partial-enclosure.

Figure 13 is a schematic of the testing grid used to conduct the sound level measurements for calculation of the sound power level pursuant to the ANSI Standard and in the collection of sound level data at distances of 5 feet and 10 feet from the acoustical center of the PVB along the X and Y-axis lines.

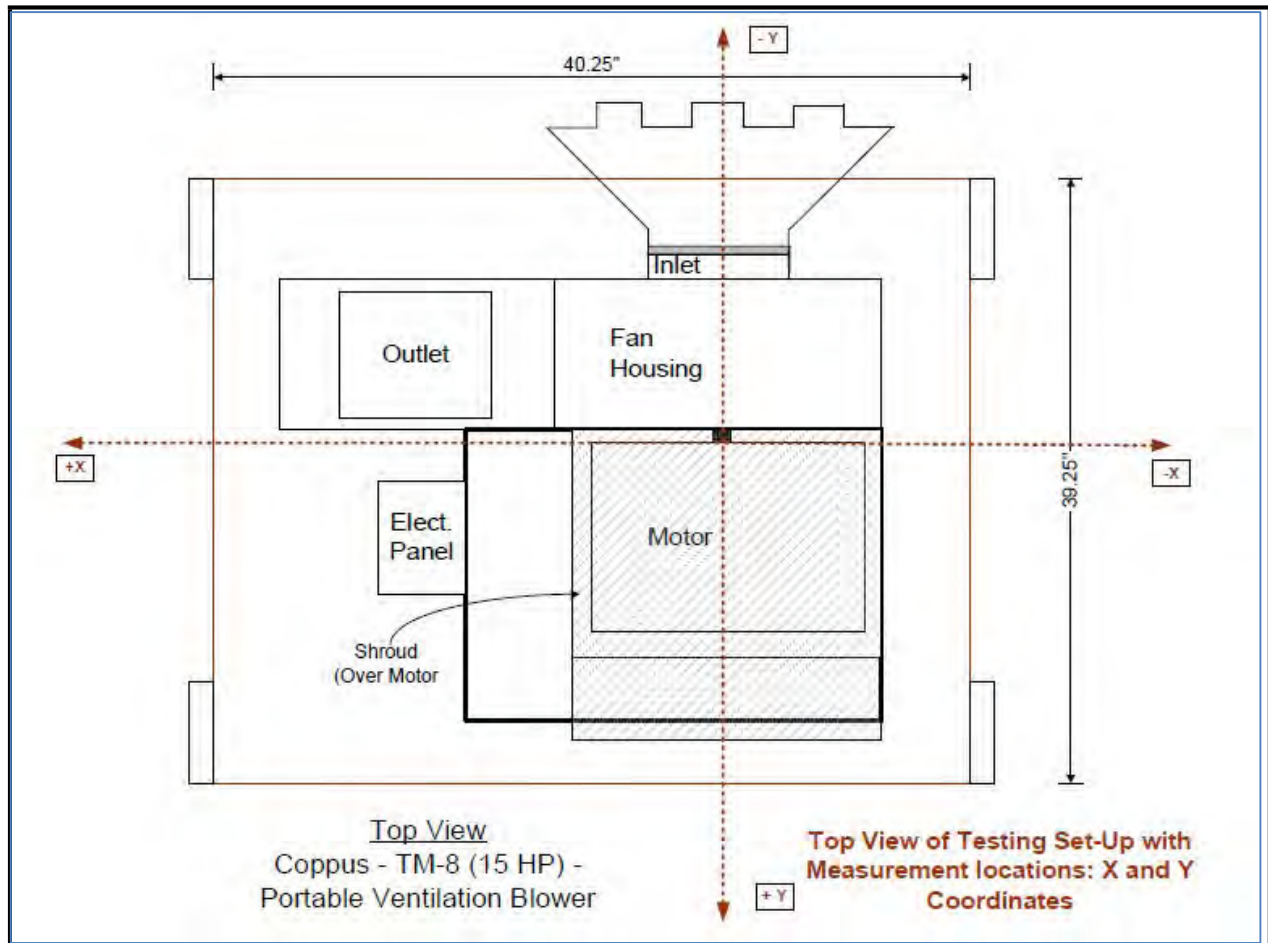


Figure 13 – Sound Level Testing Grid for Coppus TM-8 Blower with X and Y-axis Lines.

Photographs were taken by the shipyard photographer, showing the PVB in-use and under test conditions.

At the completion of testing, all noise reduction treatment materials and devices were left with the shipyard for their ongoing use and evaluation.

## 5.0 Collection of sound level data and results

Sound level data collected during field testing was used to calculate the spectral and ultimately the broadband sound power levels according to *ANSI/ASA S12.54-2011*. The objective of the sound power level determination is to be able to report a single value (L<sub>wA</sub>, A-weighted, Sound Power Level) to represent the sound energy of a sound source, in this case, the PVB. The comparison of the pre- and post-abatement sound levels will provide the primary measure of the

effectiveness of the noise reduction treatments applied individually and in combination, as appropriate.

It was subsequently realized that there is significant variability in sound emissions from PVB units of the same brand, model and size and, as such, it would be necessary to compare pre- and post-treatment measurements for the same PVB unit to properly assess the effectiveness of the selected noise reduction treatments. Since the PVB units available for Task 3 testing were different than those tested as part of Task 2 (baseline measurements), a complete set of new baseline measurements were collected on each PVB unit as part of the Task 3 testing.

All sound level measurements were conducted with a Bruel and Kjaer (B&K) Model 2250 integrating sound level meter (s/n 2473227) which is an ANSI *Type 1* instrument. It measures and stores all standard acoustic parameters simultaneously including 1/3 octave band frequency analysis. The instrument is laboratory certified annually. The most recent laboratory certification was conducted on June 12, 2014. The sound level meter is equipped with a B&K Model 4189 - 1/2-inch free-field microphone which has a **dynamic range** of 14.6 – 146 dB and a **frequency range** of 6.3 Hz to 20 kHz.

Each set of field measurements were "bracketed" by pre- and post-measurement session field calibrations using the B&K 4231 Sound Calibrator (s/n 2394128). This instrument also is laboratory certified annually; most recently on June 12, 2014.

The sound level meter was set to measure and store data based on the following parameters:

- broadband levels with A-weighting and C-weighting;
- frequency levels in third octaves between 50-10,000 hertz, with Z-weighting;
- one-second sampling rate; and,
- sample duration of a minimum of 20 seconds

The above instrument settings and measurement parameters are consistent with the requirements of the measurement methodology which was utilized in this study, ANSI/ASA S12.54-2011 / ISO 3744:2010.

The measured sound level data was stored to the meter and later downloaded using B&K utility software for the Model 2250 known as BZ5503, **Measurement Partner Suite**. The data was then exported to Microsoft EXCEL for post-processing according to the requirements of ANSI/ASA S12.54-2011 for the determination of sound power levels for each of the PVB configurations.

A variety of noise reduction treatments have been applied and tested on a PVB unit at each shipyard. The sound level data collected during this testing was analyzed to determine the spectral and broadband sound power levels for the selected PVB units under the described test configurations.

It is important to recognize that the pre- and post-abatement testing evaluated actual in-service PVB units selected from shipyard inventory at the date and time of measurement. While the Task 3 post-treatment testing summarized in this report evaluated noise reduction treatments on the same size and model of PVB tested in Task 2 (initial baseline, pre-treatment testing) the follow up testing – conducted four months later – did not allow for the use of the same piece of equipment. As a result, pre-treatment testing was repeated in conjunction with the post-treatment testing conducted in Task 3. The research value of this distinction is twofold. First, the differences between the Task 2 and the Task 3 sound level values demonstrate the potential for a wide fluctuation in the noise generated by different PVB of the same brand and model under comparable conditions. Secondly, the variable noise levels generated by different PVB units of the same type emphasizes the practical value of ongoing maintenance such as lubrication, cleaning and balancing, replacement of resilient seals and gaskets, and the tightening of bolts as a low-cost, in-house noise reduction measure. The comparison of pre- and post-treatment sound levels will provide the primary measure of the effectiveness of the noise reduction treatments applied individually and in combination, as appropriate.

The sound power levels were measured and calculated based on the procedures in the ANSI/ASA S12.54-2011 / ISO 3744:2010 standard and are provided in Tables 1 and 3 for the 15 HP Coppus TM-8 PVB (EB) and the 10 HP Robinson PVB (NNS), respectively. The sound level data provided in Table 2 (Coppus TM-8) and Table 4 (Robinson 10HP) represents additional measurements conducted at various distances and locations (representative of work locations) relative to the PVB, under test, to further assess the efficacy of the noise reduction treatments.

Table 1: Sound Power Emission Levels of 15 HP Coppus™-8 PVB – Baseline and With Selected Noise Reduction Treatments. Testing Conducted August 5-7, 2014.

Freq.	Sound Power Emission Level PVB Noise Reduction Treatments & System Configuration				
	1	2	3	4	5
	Baseline	Intake Silencer & acoustical curtain <sup>1</sup>	Intake Silencer & Acoustical Curtain <sup>1</sup> & Acoustical Jacket	Acoustical Curtain <sup>1</sup> & Acoustical Jacket	Acoustical Jacket & Acoustical Curtain over motor housing
(Hz)	(dB)	(dB)	(dB)	(dB)	(dB)
50	92.87	84.80	85.66	89.05	n/a
63	98.81	93.11	93.28	96.84	
80	95.38	87.75	89.16	93.97	
100	93.05	85.09	86.42	93.08	
125	92.97	88.32	87.39	91.36	
160	94.54	91.23	90.91	92.46	
200	96.13	94.06	92.60	92.97	
250	95.91	95.15	93.57	94.34	
315	99.10	98.56	97.10	97.33	
400	103.35	103.92	102.09	102.41	
500	99.88	96.57	98.09	97.29	
630	100.12	95.69	96.15	96.11	
800	94.14	92.16	91.14	92.06	
1000	95.77	94.62	92.55	93.33	
1250	93.99	93.47	92.18	91.96	
1600	94.44	93.95	93.54	93.33	
2000	93.60	92.59	93.39	92.54	
2500	94.36	93.35	93.16	91.94	
3150	93.22	91.08	90.26	90.25	
4000	91.03	89.71	86.38	88.73	
5000	91.21	91.87	86.96	87.18	
6300	87.62	87.45	84.18	84.99	
8000	82.30	81.57	77.13	78.48	
10000	78.60	77.90	73.02	74.84	
LwA	106.72	105.51	104.61	104.57	n/a

Note 1: The acoustical curtain was installed at the location of the *tank watcher*, at approximately 15 feet from the PVB and, as such, the acoustical curtain had no influence on the measurements other than those conducted at the *tank watcher* position.



Table 2: Sound Pressure Emission Levels of the 15 HP Coppus TM-8 PVB at Select Measurement Distances and Locations – Baseline and With Selected Noise Reduction Treatments. Testing conducted August 5-7, 2014.

Measurement locations <sup>1</sup>	Sound Pressure Emission Level PVB Noise Reduction Treatments & System Configuration				
	1	2	3	4	5
	Baseline	Intake Silencer & acoustical curtain <sup>2</sup>	Intake Silencer & Acoustical Curtain <sup>2</sup> & Acoustical Jacket	Acoustical Curtain <sup>2</sup> & Acoustical Jacket	Acoustical Jacket & Acoustical Curtain over motor housing
	(dBA)	(dBA)	(dBA)	(dBA)	(dBA)
Exhaust	101.19	102.01	102.19	102.55	101.61
Intake 1	96.61	97.02	95.93	95.59	95.53
Intake 2	96.07	97.78	95.86	97.61	96.65
Intake at Silencer	n/a	88.49	88.71	98.17	n/a
Hearing Hgt. on staging	94.51	93.45	93.69	93.70	93.46
Tank watcher	84.17	73.51	71.19	73.92	n/a
-x @ 5'	91.56	91.01	89.21	88.51	86.58
-x @ 10'	86.77	86.94	85.45	86.14	83.42
-y @ 5'	96.92	90.17	89.77	97.33	96.73
-y @ 10'	90.55	86.01	85.57	89.77	89.24
x @ 5'	91.95	90.93	90.35	90.02	88.27
x @ 10'	85.97	85.87	85.53	85.17	84.10
y @ 5'	92.13	93.93	91.33	92.21	91.10
y @ 10'	87.06	87.16	86.30	85.93	84.84

Note 1: See Figure 13 which provides a diagram of the PVB and relative measurement locations

Note 2: The acoustical curtain was installed at the location of the *tank watcher*, at approximately 20 feet from the PVB and, as such, the acoustical curtain had no influence on the measurements other than those conducted at the *tank watcher* position.

Table 3: Sound Power Emission Levels of 10 HP Robinson PVB – Baseline and With Selected Noise Reduction Treatments. Testing conducted July 22-23, 2014.

Frequency	Sound Power Emission Level PVB Noise Treatment & System Configuration				
	1	2	3	4	5
	Baseline w/ 25' length duct on intake & exhaust	Baseline w/ 25' length duct on intake & 10' length on exhaust	Exhaust Silencer	Exhaust Silencer & Acoustical Jacket	Acoustical Jacket
(Hz)	(dB)	(dB)	(dB)	(dB)	(dB)
50	81.56	84.62	79.31	81.31	83.45
63	84.41	85.25	82.36	89.55	86.65
80	86.11	86.19	83.61	82.97	84.55
100	81.67	86.98	78.71	81.85	85.71
125	83.31	86.88	81.17	82.30	87.20
160	83.82	87.97	82.73	83.64	88.79
200	84.21	89.71	83.26	83.88	90.06
250	84.54	86.84	83.87	81.22	87.32
315	83.65	86.47	83.55	81.57	86.49
400	87.24	88.25	85.96	85.36	88.28
500	85.87	87.40	84.00	83.17	87.17
630	84.43	85.47	82.73	81.17	85.27
800	84.06	85.79	80.11	78.08	83.84
1000	78.81	79.22	77.97	77.25	78.95
1250	79.40	79.59	80.50	79.11	79.51
1600	78.06	79.07	77.80	76.91	78.93
2000	76.37	76.89	75.65	74.54	76.64
2500	75.71	75.86	73.51	73.72	75.17
3150	73.33	73.09	71.99	71.05	72.60
4000	73.97	73.17	72.00	72.66	73.43
5000	76.97	76.31	73.01	73.49	74.46
6300	66.37	64.93	63.01	63.67	65.05
8000	61.70	59.38	60.61	59.02	59.99
10000	59.20	56.68	57.90	56.10	57.19
LwA	91.37	92.62	89.03	88.96	92.23

Note: Comparisons of sound levels to assess noise treatment efficacy were made relative to the Configuration 2, baseline condition, since it represents the in-use configuration that is widely in use and currently is associated with the highest sound emission levels.

Table 4: Sound Pressure Emission Levels of 10 HP Robinson PVB at Select Measurement Distances and Locations – Baseline and With Selected Noise Reduction Treatments. In addition, flow rate (Q) data is provided for the intake and exhaust for each test condition. Testing conducted July 22-23, 2014.

Measure location <sup>1</sup>	Sound Pressure Emission Level PVB Noise Treatment & System Configuration				
	1	2	3	4	5
	Baseline w/ 25' length duct on intake & exhaust	Baseline w/ 25' length duct on intake & 10' length on exhaust	Exhaust Silencer	Exhaust Silencer & Acoustical Jacket	Acoustical Jacket
	(dBA)	(dBA)	(dBA)	(dBA)	(dBA)
Exhaust	93.27	94.86	83.93	84.18	98.02
Intake	88.94	89.28	90.62	91.01	91.86
-x @ 5'	77.07	79.19	76.74	74.34	80.93
-x @ 10'	75.40	80.72	72.02	70.99	83.39
-y @ 5'	77.03	78.51	76.29	73.86	79.55
-y @ 10'	76.37	76.71	74.88	74.27	79.84
x @ 5'	76.87	77.28	77.48	73.66	77.16
x @ 10'	74.26	74.99	74.12	71.16	74.48
y @ 5'	78.63	80.16	80.32	78.68	80.97
y @ 10'	74.79	76.79	73.94	73.25	78.18
Q, Intake (fpm) <sup>2</sup>	4950	4900	4600	5200	5300
Q, Exhaust (fpm) <sup>2</sup>	6150	5100	5200	5000	5300

Note 1: See Figure 6 which provides a diagram of the PVB and relative measurement locations.

Note 2: Flow rate measurements were conducted with an Alnor Compuflow meter, Model CF8596, Serial 55010220 REV. M.

## 6.0 Data Analysis and Findings/Conclusions

The components of the PVB that are the primary contributors to the sound emission levels include:

1. Intake
2. Exhaust
3. Fan Housing
4. Motor

These components are common to the PVBs utilized at both NNS and EB. The intake and exhaust are the components, when uncontrolled (e.g., no silencer, no significant length of ducting), represent the greatest noise emissions. The fan housing (including the internal fan/impeller unit) and the electric motor appear to be appreciably similar in the magnitude of their noise emission levels.

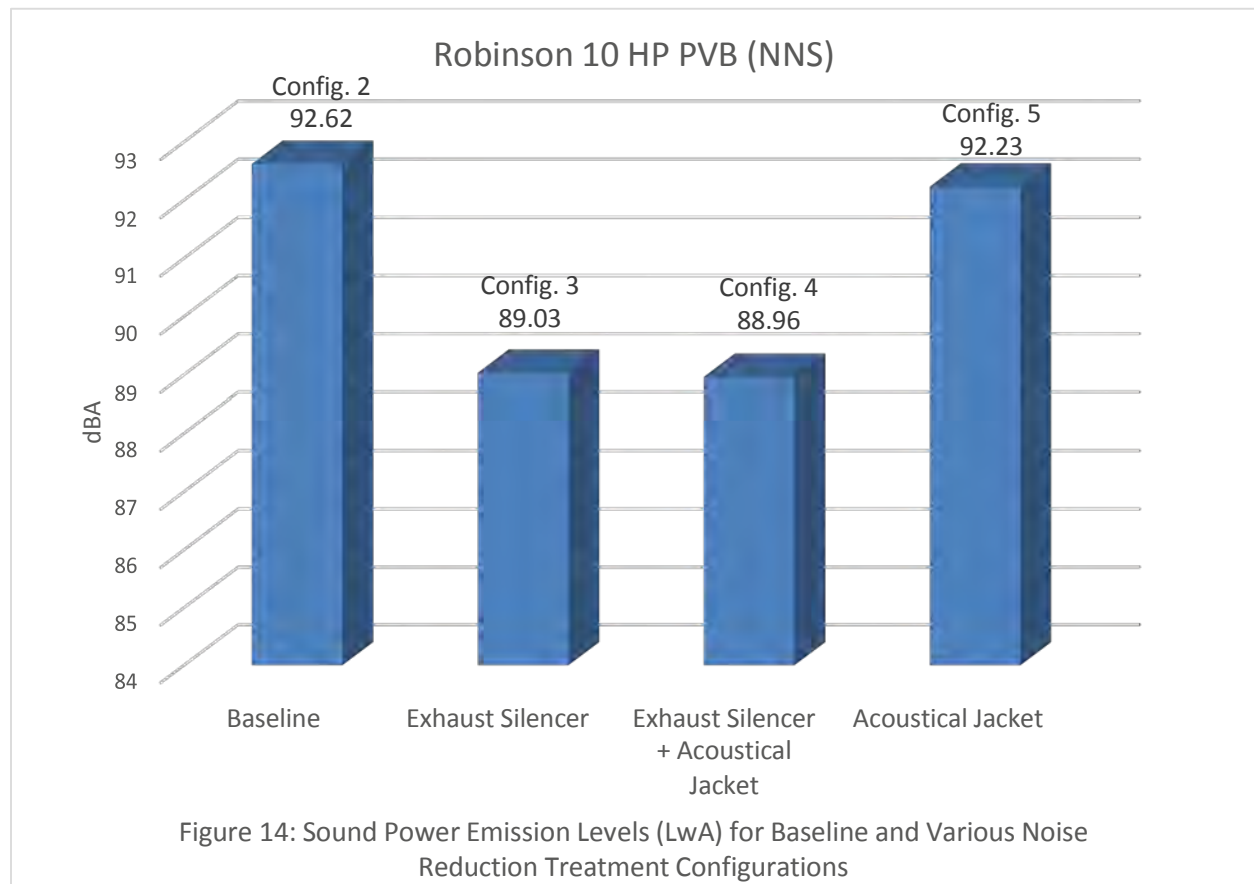
## **6.1 Robinson 10HP Blower (NNS)**

### **6.1.1 Typical in-use operational conditions**

The Robinson 10 HP PVB is typically outfitted with a 12 inch diameter duct on the inlet and outlet of the blower. The outlet air from the PVB is either exhausted to an interior deck through a short length of duct (approximately 6-10 feet and referred to as a “stack”) or ducted directly to the exterior of the ship (typically 100 feet of duct or more) depending on the material(s) the PVB are exhausting. Those units which exhaust directly into the interior decks contribute considerably more noise to the acoustical work environment than those that exhaust to the exterior of the ship and represent a worst-case scenario for the use of PVBs in interior sections of a ship. On occasion, two PVB have been observed to be connected in series with one another; however, this was not a configuration that was included in this study. That said, it is reasonable to assume that the noise reduction treatments investigated in this study can be utilized for PVB connected in series with similar benefit being realized.

### **6.1.2 Analysis of selected noise reduction treatments**

The data presented in Figure 14, is a graphical presentation of the data provided in Table 3, Section 5.0 (Results) of this report.



Note: The baseline condition represented by Configuration 2 was the basic configuration include in each subsequent configuration.

As shown in Figure 14, when the baseline sound power level (Configuration 2) is compared to the same PVB unit equipped with an exhaust silencer and fitted with an *acoustical-jacket* on the fan housing (Configuration 4) the difference in pre- and post-treatment sound power levels is approximately 3.5 decibels. A reduction of 3.5 decibels represents approximately a halving of the sound energy (actual reduction 56.9%).

The data presented in Figure 14 were determined based on the measurement and calculation procedures in the ANSI/ASA S12.54-2011 Standard and represent an acoustically averaged value for the PVB, on an overall basis, at a relatively close distance (within 4.72 feet). As such, it does not fully evaluate the noise reduction benefits of the silencer at greater distances from the PVB and also at specific directions from the PVB unit than were evaluated based on the ANSI Standard.

In order to assess the effectiveness of the noise reduction treatments at greater distances than those considered in the ANSI Standard and to also consider the directionality of the sound emissions additional sound level measurements were conducted and are presented in Figure 15 which is a graphical presentation of the data provided in Table 4, Section 5.0 (Results) of this report.

Figure 15: 10HP Robinson PVB (NNS) – Sound levels at 10 feet from acoustical center of unit, at the outlet of 10 feet of exhaust duct for baseline conditions (Configuration 2), and with noise reduction treatments installed on the PVB. The original data is presented in Table 4 of this report.

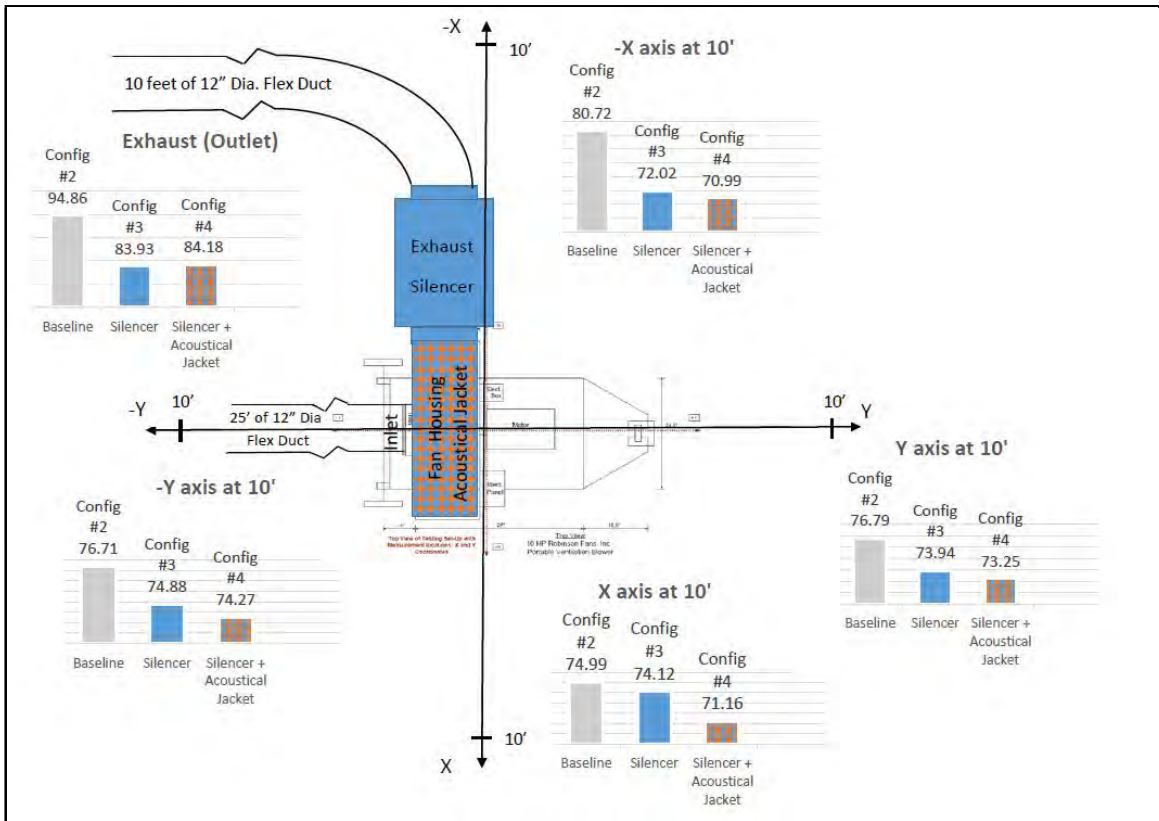


Figure 15 provides sound level data at 10 feet from the acoustical center of the PVB with noise reduction treatments installed on the unit and also at the exhaust outlet. The data indicates that the exhaust silencer provide significant reductions in noise emissions from the PVB.

Specifically, the more notable data are:

1. For the measurements at the “exhaust” where the difference between the baseline data for Configuration 2 and post-treatment data for Configurations 3 and 4, with the exhaust silencer in-place, represents a reduction of approximately 10 decibels (dB). A difference of 10 dB is an order of magnitude reduction in acoustical energy and a halving of the perceived loudness which is very significant and will result in a significant reduction in the noise contribution in the surrounding work environment. An appreciable improvement in speech intelligibility will also be realized due to the reduced noise levels resulting in improved communication among employees in the area.
2. For the measurements at 10 feet in the “-X-axis” direction from the PVB, where the difference between baseline for Configuration 2 and post-treatment data for Configuration 3, with the exhaust silencer in-place, represents an approximately 9 dB reduction which is consistent with the data measured at the “exhaust.”

The data also indicates the acoustical jacket installed on the surface of the fan housing of the PVB provides a significant reduction in noise, albeit not to extent of the exhaust silencer. Specifically, the more notable data supporting this conclusion is for the data measured at 10 feet from the PVB along the “X-axis” where the difference between Configuration 3, with both the silencer and acoustical jacket are in-place and the data for Configuration 4, with only the acoustical jacket in-place, represents a reduction of approximately 3 dB. These data, being that they were measured on the side of the PVB where the fan housing is located, indicated that the acoustical jacket is effective when other components of the PVB are not acoustically dominant.

The noise reductions in the “Y-axis” and “-Y-axis” directions indicate less benefit from the exhaust silencer and acoustical jacket because in these directions from the PVB measured sound levels are dominated by either the PVB motor or the inlet and associated “break-out” noise radiating from the intake flexible duct.

As an additional treatment, vibration isolation mounts were applied to the four corners of the PVB. This involved removing an existing bolt from each corner, locating the mount under the PVB support frame and replacing the bolt that was removed with a bolt supplied with the mount that secures it in-place and allows for adjustment to the spring portion of the mount. The extent to which vibrational energy is transferred to the deck is a function of the characteristics of the PVB as well as those of the ship deck (e.g., deck thickness, location of support structures, etc.). As such, it is not possible to recreate actual in-use conditions at the test location (off-ship). Therefore, vibration-isolation treatments must be assessed on a PVB that is onboard a ship and at a location onboard that is conducive to vibrational energy transfer. Unfortunately, we were unable to conduct this testing. With concern for safety, it was determined that a PVB in-operation onboard could not be fitted with the mounts without being “powered-down.” Since those PVB units that were candidates for testing needed to be onboard, and hence in-use, it was not possible to take them out of service even for a short period. It may be possible to do this type of evaluation during off-hours, but that was not an option during the scheduled visit.

## **6.2 Coppus TM-8 15HP Blower (EB)**

### **6.2.1 Typical in-use operational conditions**

The PVB at EB is typically equipped with a multi-flange intake where all but one of the intake flanges has 50 feet or more of flexible ducting attached to these flange(s); while one intake flange typically remains “open” (i.e., no duct attached).

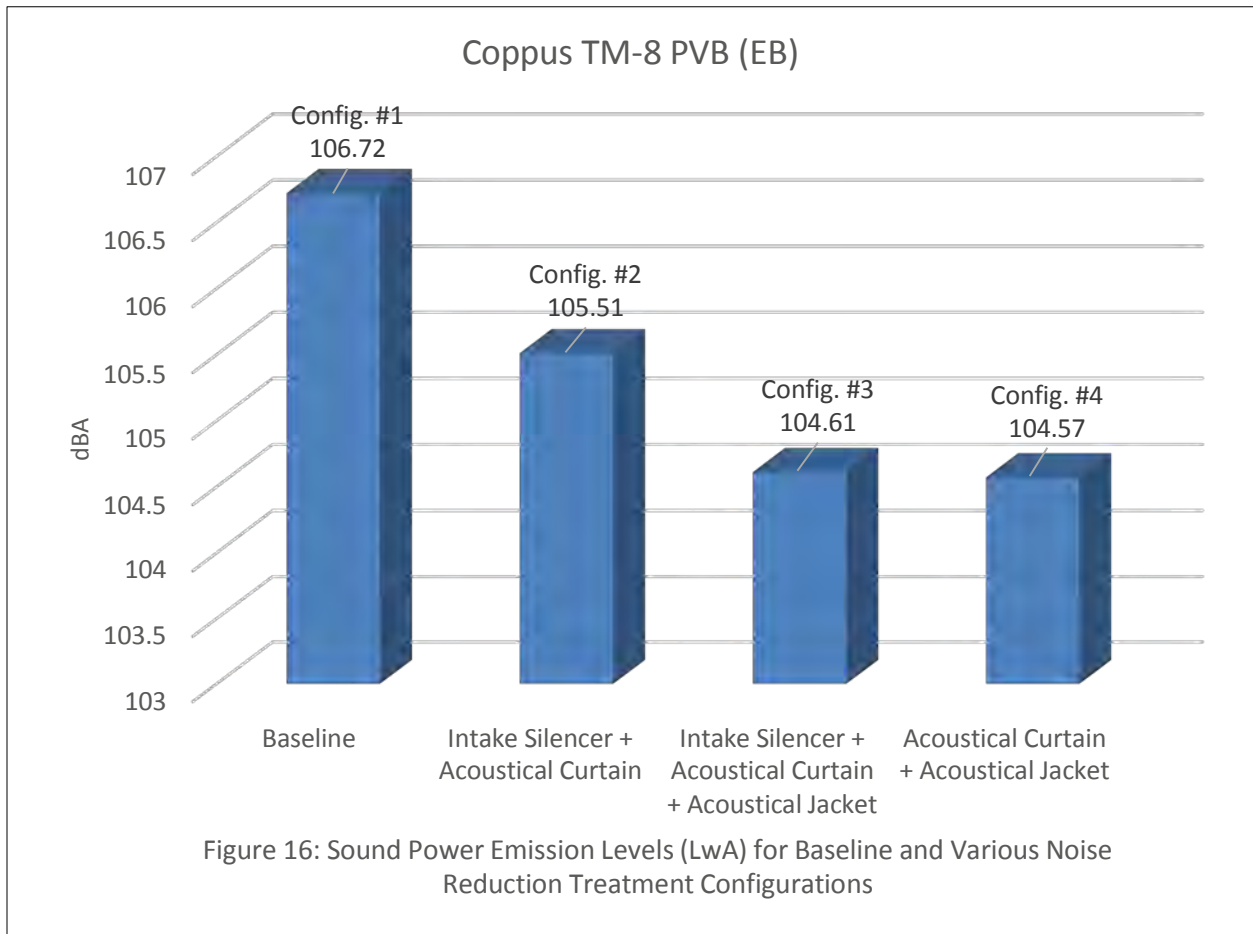
The “open” intake flange is fitted with an inlet safety guard “screen” device to keep materials from being drawn into the intake. This device was observed on PVB unit 819 to create a high-frequency, high-intensity whistling sound of 103-104 dB at 10k hertz. Other PVB of the same size and using a similar inlet safety guard did not exhibit the same whistling sound. It is likely that this effect is a function of flow rate across the guard and the width of the gaps between the solid portions of the guard (i.e. guard “pattern”). A guard with a different “pattern” could be on-hand to use as an alternative in circumstances when the whistle effect is occurring.

The ducting that is attached to PVB -- from an acoustical perspective -- serves to attenuate the sound mainly by means of acoustical absorption at the inner walls of the ducting. It also serves to distribute the noise that would otherwise contribute to the collective noise emissions of the PVB at a distance which reasonably results in reduced noise exposure from a qualitative perspective. As such, longer length of ducting can be beneficial to reducing noise exposure levels; however, it will also result in greater “resistance” through the blower system which diminishes the volumetric air flow (i.e., reduced ventilation capacity). PVBs, in all observed cases, were equipped with silencers on the exhaust of the units. However, when we inspected the exhaust silencers on a number of PVB units, in all cases, the inner acoustical lining was damaged or missing all together. Since the inner acoustical lining is an essential component to the performance of a silencer, the noise reduction for these units is greatly diminished.

### **6.2.2 Analysis of selected noise reduction treatments**

The Coppus TM-8 15HP blower when configured with an intake silencer and *acoustical-jacket* on the fan housing (Configuration 4) the difference in pre- and post-treatment sound power levels is approximately 2 decibels. See Figure 16 which is a graphical presentation of the data provided in Table 1, Section 5.0 (Results) of this report.





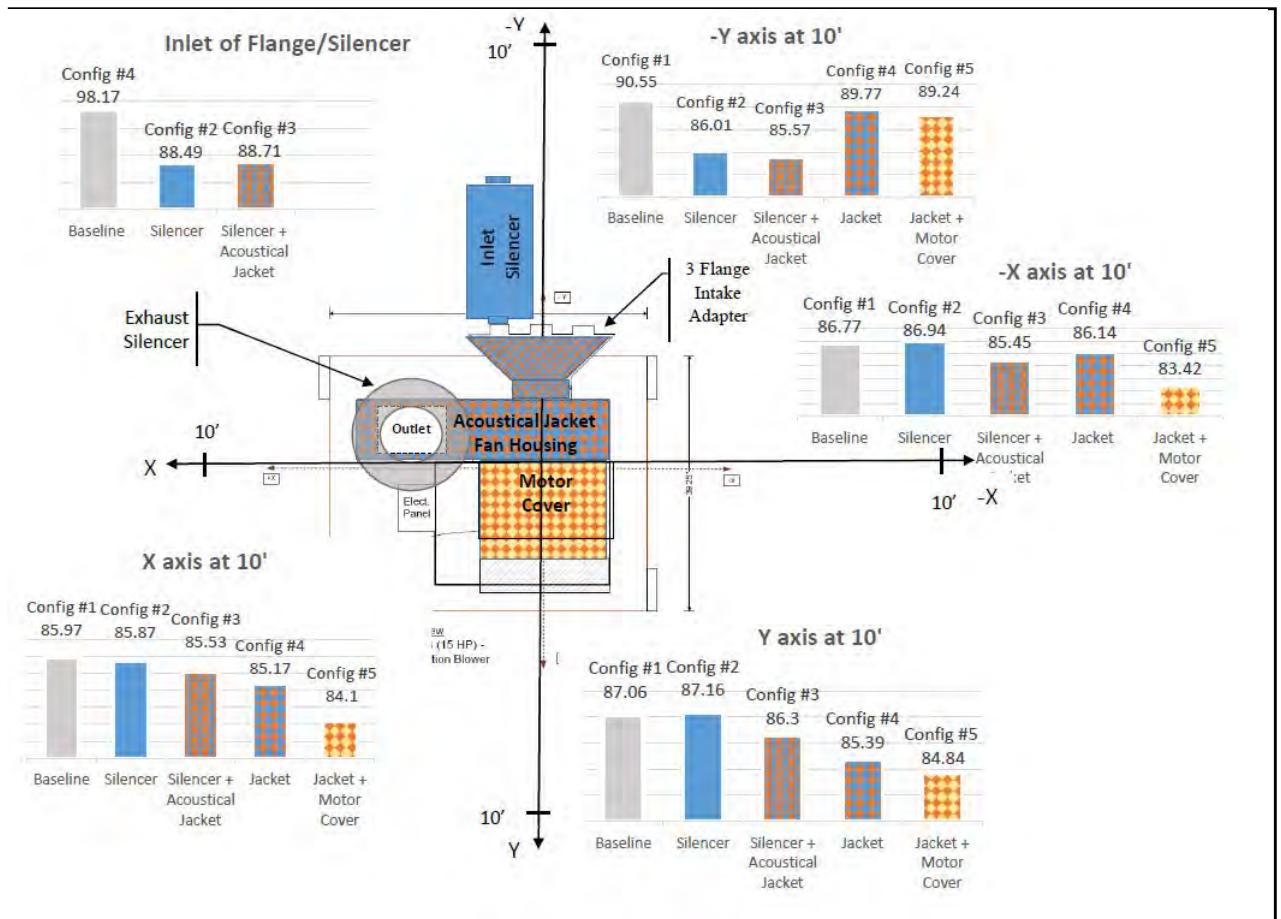
Note: The acoustical curtain has no effect since it is approximately 20 feet from the PVB and outside the measurement domain for this data set.

A reduction of 2 decibels represents an approximately 33% reduction of the total sound energy. It is important to note that the outlet of the silencer was beyond the measurement locations as determined by the ANSI Standard.

The data presented in Figure 16 were determined based on the measurement and calculation procedures in the ANSI/ASA S12.54-2011 Standard and represent an acoustically averaged value for the PVB, on an overall basis, at a relatively close distance (within 4.72 feet). As such, it does not fully evaluate the noise reduction benefits of the silencer at greater distances from the PVB and also at specific directions from the PVB unit than was evaluated based on the ANSI Standard.

In order to assess the effectiveness of the noise reduction treatments at greater distances than those considered in the ANSI Standard and to also consider the directionality of the sound emissions additional sound level measurements were conducted and are presented in Figure 17 which is a graphical presentation of the data provided in Table 2, Section 5.0 (Results) of this report.

Figure 17: 15HP Coppus PVB (EB) – Sound levels (dBA) at 10 feet from acoustical center of the PVB unit, at the inlet of the intake silencer or open flange for baseline conditions, and with noise reduction treatments installed. The two intake flanges of the “3 Flange Intake Adapter” that are not fitted with the Inlet Silencer or “open” have 25 feet of 8 inch diameter flexible duct attached. The original data is presented in Table 2 of this report.



The data presented in Figure 17 demonstrates that each of the noise reduction treatments, except the acoustical jacket, when compared with the baseline sound levels provide a significant reduction in noise levels at the inlet flange and at a distance of 10 feet from the acoustical center of the PVB in the direction representative of the PVB component being “controlled.”

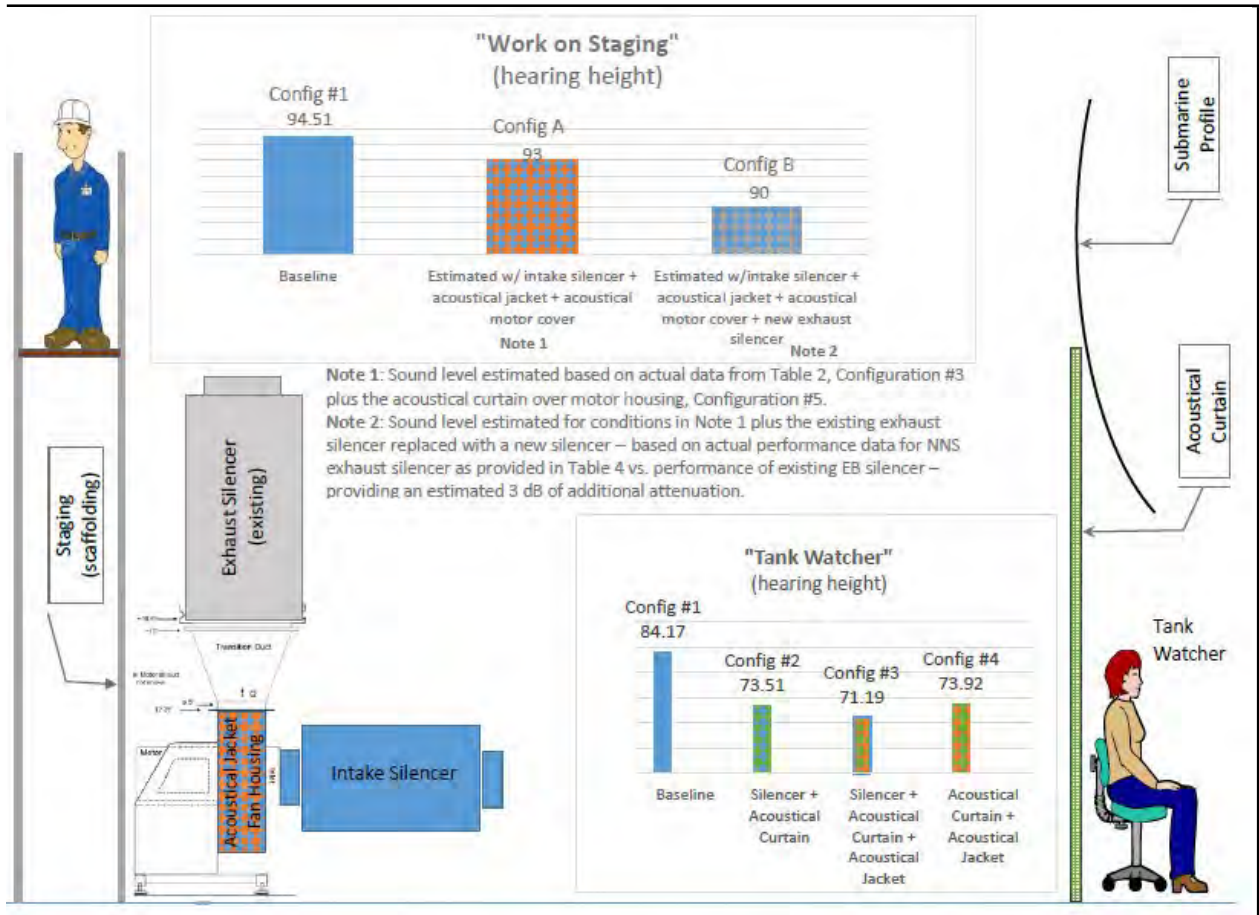
The silencer installed on the otherwise “open” inlet flange of the PVB (Configuration 2) provides approximately 10 dB of noise reduction when compared to the sound levels of the “open” inlet flange (Configuration 4). For the measurements at 10 feet in the “-Y-axis” direction from the PVB, where the difference between the baseline sound level (Configuration 1) and post-treatment data for Configuration 2, with the exhaust silencer in-place, represents an approximately 4.5 dB reduction which represents an approximately 66% reduction in acoustical energy and approximately a 25% reduction in perceived loudness. This represents the direction of the “tank watcher” work location for those PVBs located in that area of the dry dock. The noise reduction to the “tank watcher” work area will also benefit from the acoustical curtain which will be discussed later.

The data indicated that the noise reduction associated with the acoustical jacket as fitted to the surface of the fan housing of the PVB was not significant. It is important to realize that the component of the PVB (fan housing, motor, exhaust, intake, etc.) which is the dominant source of noise will demonstrate the greatest noise reduction when controlled with an effective noise reduction treatment. This will then be the case for the component of the PVB that is rated as the second most dominant noise source and so on. It is reasonable, based on the fact that the data for the acoustical jacket fitted to the NNS PVB demonstrated a significant degree of noise reduction that once other components of the EB PVB are more fully “controlled” the benefit of the acoustical jacket may become significant. Extending the acoustical jacket onto the transition duct located between the fan housing and the exhaust silencer would likely improve the overall performance of this noise reduction treatment.

A section of the acoustical-curtain that was initially only intended to interrupt the sound path between the PVB and the “tank watcher” position was used as a partial-enclosure to investigate the benefit of such a treatment to reduce the noise emission from the PVB motor. A 4 foot by 8 foot section of the acoustical curtain material was “tented” over the motor housing, as depicted in Figure 12, to assess the performance of this material to reduce the sound emission levels from this portion of the PVB. The placement of the acoustical curtain material was done with consideration for the needs of the air-cooled electric motor. This is a concern that would need to be considered more fully if this noise reduction approach were to be implemented. It would also be necessary to design the curtain material to be of a proper size and be equipped with adequate means for fastening it to the PVB. That said, the data as presented in Figure 17 indicates that the partial-enclosure at the motor, coupled with the acoustical jacket on the fan housing resulted in a noise reduction of up to approximately 3 dB in the “-X-axis” direction. Approximately 2 dB of noise reduction was also measured in the “X- and Y-axis” directions.

The directivity of the noise from the PVB is a particularly important consideration when the PVB is located in the outdoors and the position and directional orientation of the PVB is in relatively close proximity to a work location such as the “tank watcher” in the dry dock area.

Figure 18: 15 HP Coppus PVB (EB) – Sound levels at locations for two work positions – “work on staging” at hearing height (5’ above staging platform) and “tank watcher” at hearing height (3’ above grade) seated behind acoustical curtain.



### **“Tank Watcher” Work Location**

The “tank watcher” typically remains in this position throughout their work shift. This position is approximately 15-20 feet from where two continuously operating 15 HP Coppus Blowers are located. It is particularly worth noting that the sound levels, shown in Figure 18, as received at the simulated location for the “tank-watcher” with the PVB equipped with the inlet silencer and *acoustical-jacket* and having the *acoustical-curtain* in-place (Configuration 3) demonstrate a noise reduction of approximately 13 decibels when compared to the baseline sound levels of Configuration 1. This represents a very significant reduction in noise for this work area. A difference of 13 dB is more than an order of magnitude reduction in acoustical energy and greater than a halving of the perceived loudness which is also very significant. An appreciable improvement in speech intelligibility will also be realized due to the reduced noise levels resulting in improved communication in this work area.

### **“Work on Staging” Location**

The work platform on the staging above exhaust of PVBs may be occupied for an entire work shift. The affected hearing zone is approximately 5-15 feet above two continuously operating 15 HP Coppus Blowers depending on which level of staging they are working on. The existing exhaust silencer installed on these PVB are typically not providing their full-measure of noise reduction due to the inner lining of the silencer being either damaged or missing all together. A PVB equipped with an intake silencer, acoustical jacket on the fan housing, a partial-enclosure (acoustical curtain) “tented” over the motor housing (Configuration A – based on data for Configurations 2 and 3) and the existing exhaust silencer demonstrates a noise reduction of approximately 1.5 dB for this location. While this reduction is not particularly significant, it can be greatly enhanced if the existing exhaust silencer is replaced with an exhaust silencer with the same acoustical performance as the one evaluated for the exhaust silencer used for the Robinson blower. An estimated noise reduction of 4.5 dB as shown on Figure 18 for Configuration B when compared to Configuration 1 is based on a conservative estimation of the enhanced attenuation provided by a new silencer which is less prone to “break-out” noise and with an intact sound absorbing inner liner.

## **6.3 Data analysis and findings common to the Robinson 10 HP Blower and the Coppus TM-8 Blower**

### **6.3.1 Potential impact of noise reduction treatments on the ventilation system flow rate**

The only noise control treatment evaluated in this study that could potentially have an impact on the ventilation system flow rate is the silencer, as installed on the intake or exhaust of the PVB, since it is the only treatment put in-line and the ventilation air must pass through it. Although only a few flow rate measurements were collected in this study, it is clear from that data that the flow rate is not significantly affected by the intake or exhaust silencers, as evaluated. This is completely expected since the silencers are dissipative-type units. Unlike a reactive-type silencer which internally redirects air flow multiple times, a dissipative silencer has the same internal diameter as the PVB intake or exhaust flange, and that of the flexible ducting attached to

it, and absorbs sound energy (i.e., noise) into the side wall lining of the silencer. All of things being equal, the static pressure of a straight-line dissipative silencer is equal to or less than a similar straight-line length of flexible duct.

### **6.3.2 Full-Enclosure verses a Partial-Enclosure**

A full-enclosure was not investigated for this study. Although it is technically feasible to design and construct a full-enclosure, there are practical considerations that make this approach to noise control challenging to put into use. The potential benefit could be that the sound emissions from all the components of the PVB unit, except for the exhaust and intake ducts, would be subject to the attenuation of enclosure. If designed and fitted properly this approach could provide greater noise attenuation when compared to the partial-enclosure that was investigated in this study. However, since the PVBs are equipped with an air cooled motor, any full-enclosure must have a means of providing adequate ventilation to the motor. As such, the enclosure would need to be designed with an active ventilation system consisting of a motorized fan unit and a fresh air intake vent. The “penetrations” in the walls of the enclosure created by the ventilation system (i.e., fresh air intake and exhaust) become areas where noise can escape the enclosure and must be controlled with acoustical louvers to maintain the effectiveness of the enclosure. Air exchange is needed to satisfy the cooling requirements of the PVB motor. Furthermore, there are a number of other practical considerations that make a full-enclosure a less than desirable noise control strategy including cost to design and construct the enclosure, weight and bulkiness, need for electrical power to operate the ventilation system, time needed to properly install the enclosure on and around the PVB with specific attention to minimizing openings where the intake and exhaust ducting penetrate the enclosure. For all these reasons it was determined that a full-enclosure would not be a good choice to control noise from these type of units when operated in shipyard conditions.

## **7.0 Recommendations**

The noise reduction treatments applied in this evaluation can be feasibly used in shipyards with significant noise reduction benefits. These noise reduction treatments are scalable to other similar-type PVB units used at these and other shipyards.

### **7.1 Robinson 10HP Blower**

The application of the noise reduction treatments for the 10 HP Robinson PVB including the exhaust silencer and acoustical “jacket” fitted to the fan housing demonstrate significant noise reduction and their use should be considered for noise sensitive work areas. These noise reduction treatments are scalable to the smaller PVB units used in shipyards. In order to have an appreciable reduction in the noise levels within interior deck spaces it is necessary to install the recommended controls on all or nearly all PVB operating in this area due to the reverberant environment. At a minimum, those units clustered together or those PVB units in somewhat distinct sections of deck spaces must all be similarly controlled for a significant improvement to be realized. The reduced noise levels will benefit those that are working in these spaces by

lessening their level of noise exposure and improving their speech intelligibility when communicating with each other.

The use of a silencer at the exhaust of the PVB provides a greater benefit for those PVB that exhaust into the interior deck spaces, as opposed to those ducted to the exterior of the ship. That said, the exhaust ducting does not “contain” all the noise within it as it travels to the exterior of the ship. This is known as “break-out” noise. As such, those PVB units that exhaust to the exterior of the ship would also benefit from an exhaust silencer. On occasion, two or more PVB have been observed to be connected in series with one another; however, this was not a configuration that was included in this study. That said, it is reasonable to assume that the noise reduction treatments investigated in this study can be applied for PVB connected in series with similar benefit being realized.

The PVB that are used on the interior and exterior of the ship have been observed to transfer a significant amount of vibrational energy to the deck surfaces in the vicinity of the PVB unit. If the PVB are fitted with properly sized vibration isolation mounts at the four corners of the units the amount of vibration transfer may be significantly reduced. The “housed-spring” mount type units specified in this study are both effective and should be sufficiently durable to withstand the shipyard environment. It is recommended that PVB units that are operating on a ship deck or other similar conductive surfaces be equipped with vibration isolation mounts when control is needed.

Acoustical curtains were not investigated as a potential noise reduction treatment for the Robinson blower since the primary research application for this study was directed to operation in the interior spaces of the larger surface ships under construction or overhaul. These interior spaces are acoustically “hard” (i.e., reverberant) as characterized by the lack of any significant acoustically absorptive surfaces. As such, there are a multitude of reflected noise paths that would “cancel-out” the “barrier” effect provided by the acoustical curtain and would diminish any significant benefit of the curtain. That said, for those PVB operated outdoors or in interior spaces with limited vertical reflective surfaces and ceiling heights in excess of 30 feet, the noise reduction benefits described for an acoustical curtain could be realized.

## **7.2 Coppus TM-8 15HP Blower**

The noise reduction treatments applied to the 15 HP Coppus PVB including the exhaust silencer and acoustical “jacket” fitted to the fan housing demonstrate significant noise reduction. Their use in noise sensitive areas is recommended. In addition, the acoustical curtain was shown to provide a significant reduction in the noise received from the PVB at the work location of the “tank watcher.” In this case, the acoustical curtain was located between the PVB and the work location. It is important to note that the performance of the acoustical curtain is a function of its relative proximity to the noise source and the receiver location. It is also important to note that it was assumed for the purpose of the testing that the “tank watcher” remained stationary for the entire shift. Some lateral movement should be expected. In order to not diminish the curtain’s

acoustical performance, the curtain length should be sufficient to ensure the “tank watcher” is not located closer than three feet from either end of the curtain.

Based on observation of the existing exhaust silencers in use, the inner acoustical lining was damaged by corrosion or missing. Since the inner acoustical lining is an essential component to the performance of a silencer, the noise reduction for these units is greatly diminished. A comparison of the noise reduction achievable for the new exhaust silencer with that of the older corroded exhaust silencer demonstrates how a properly designed and maintained silencer can provide significantly greater noise reduction than one that is of a poorer design and not properly maintained. The damaged or corroded exhaust silencers should be replaced or repaired where effective noise control is needed.

The inlet safety guards that are currently used on the “open” inlet flange of the multi-flange inlet adapter, in some cases, produces an intense “whistle-type” noise. Due to its intensity and “pure-tone” frequency it is both annoying and is potentially significant in terms of noise exposure. If an intake silencer is not being used in place of the inlet safety guard, it is important to select a guard that will not cause a significant “whistle” effect. A device with slightly wider spacing would likely continue to serve as a safety guard while minimizing the “whistle” effect.

A section of the acoustical-curtain was used as a partial-enclosure to investigate the benefit of such a treatment to reduce the noise emission from the PVB motor. A 4 foot by 8 foot section of the acoustical curtain material was “tented” over the motor housing, as depicted in Figure 12, to assess the performance of this material to reduce the sound emission levels from this portion of the PVB. The placement of the acoustical curtain material was done with consideration for the needs of the air-cooled electric motor. This is a concern that would need to be considered more fully if this noise reduction approach were to be implemented. It would also be necessary to design the curtain material to be of a proper size and be equipped with adequate means for fastening it to the PVB. The acoustical curtain material can be ordered with grommets, for example, to facilitate its attachment to the PVB motor housing. The testing shows that the acoustical curtain as a partial-enclosure at the motor housing, coupled with the acoustical jacket on the fan housing resulted in a noise reduction of approximately 3 dB in the lateral “-X-axis” direction and approximately 2 dB of noise reduction “X- and Y-axis” directions. This is significant and when coupled with the other noise reduction treatments would result in reduced noise levels in the work area. The testing results for the location of the work on the staging above the PVB, as depicted in Figure 18, indicates that the combined noise treatments provide only a modest reduction in noise at this location (approximately 1.5 dB). However, if the exhaust silencers that are currently in-use at EB, are repaired or replaced, the noise reduction at the “work on staging” location is estimated to be 4.5 dB.

### **7.3 Recommendation common to all PVB**

#### **7.3.1 Preventive maintenance program**

In addition to installing cost-effective treatments, it is also recommended that shipyards implement a regular preventive maintenance program for noise reduction benefits. Based on observations and discussions with mechanical specialists at participating shipyards, it is apparent that PVBs that are in need of maintenance and repair may generate more noise than well maintained and regularly serviced equipment. Due to operational demands, these PVB, when used for shipyard applications, may be put in-use in rugged indoor and outdoor environments to run on a 24-hour schedule for several months or more without a defined maintenance interval.



A defined comprehensive preventative maintenance program could be a very effective measure to further reduce noise and vibration generated by these PVB units. Some of the observations associated with increased noise/vibration generation included failing bearings, dust loaded impeller fans, loose bolts, missing lining material in silencers and missing resilient gaskets between metal assemblies.

A preventive maintenance program should include, at a minimum, the following activities:

1. Clean the fan/impeller at regular intervals so dusts and other materials do not accumulate and cause the fan/impeller to be out of balance resulting in premature wear of the bearings;
2. Tighten loose bolts;
3. Install/reinstall gaskets between components of the PVB, such as the inlet/exhaust flanges, to minimize noise emissions and vibrations;
4. Inspect the inner lining of silencers to determine if it is intact;
5. Inspect the water-weep holes in the fan housing to ensure they are not clogged; and,
6. Check bearings for wear and replace before a worn bearing results in increased noise emission levels.

#### **Acknowledgements:**

The research team would like to thank the following organizations and individuals for their assistance in making this project a success.

**Participating Shipyards** – The staff at these facilities with the support of their management provided extensive assistance in time and effort and without whom this project could not have been completed.

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Department 027 Safety  
4101 Washington Avenue  
Newport News, VA 23607

**General Dynamics Electric Boat**

Safety and Industrial Hygiene -- Stacy Herritt and Don Peterson  
75 Eastern Point Road  
Groton, CT 06340

**Navy and Marine Corps Public Health Center**

Portsmouth, VA  
Michael A. Miller and Leslie Crowder

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Sound Seal Acoustical Products – Maryellen Riemenschneider and Michael Parisi  
50 H.P. Almgren Dr.  
Agawam, MA 01001  
[mremo@soundseal.com](mailto:mremo@soundseal.com)  
(413) 789-1770

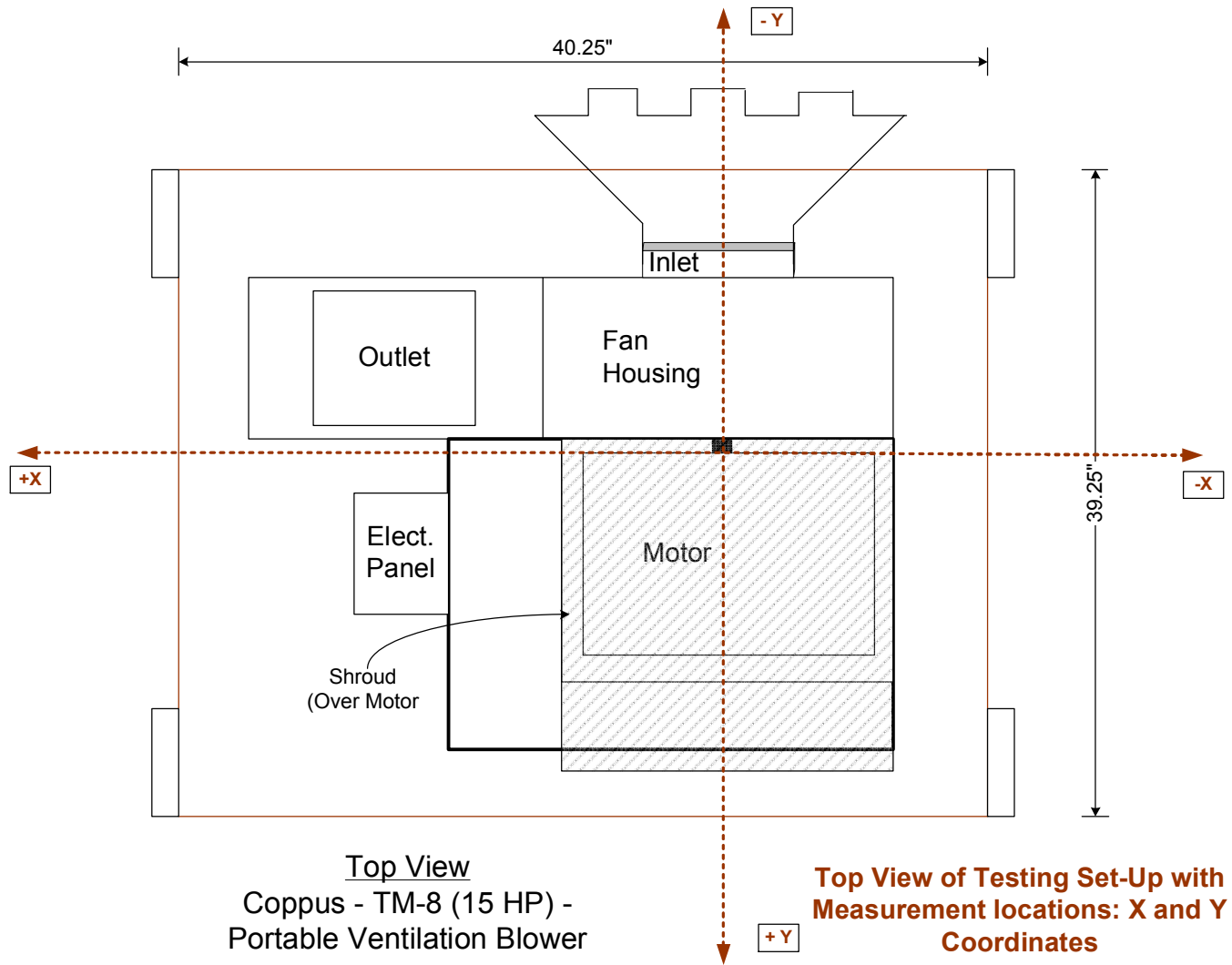
Supplied the acoustical curtain and acoustical “lagging” jacket materials

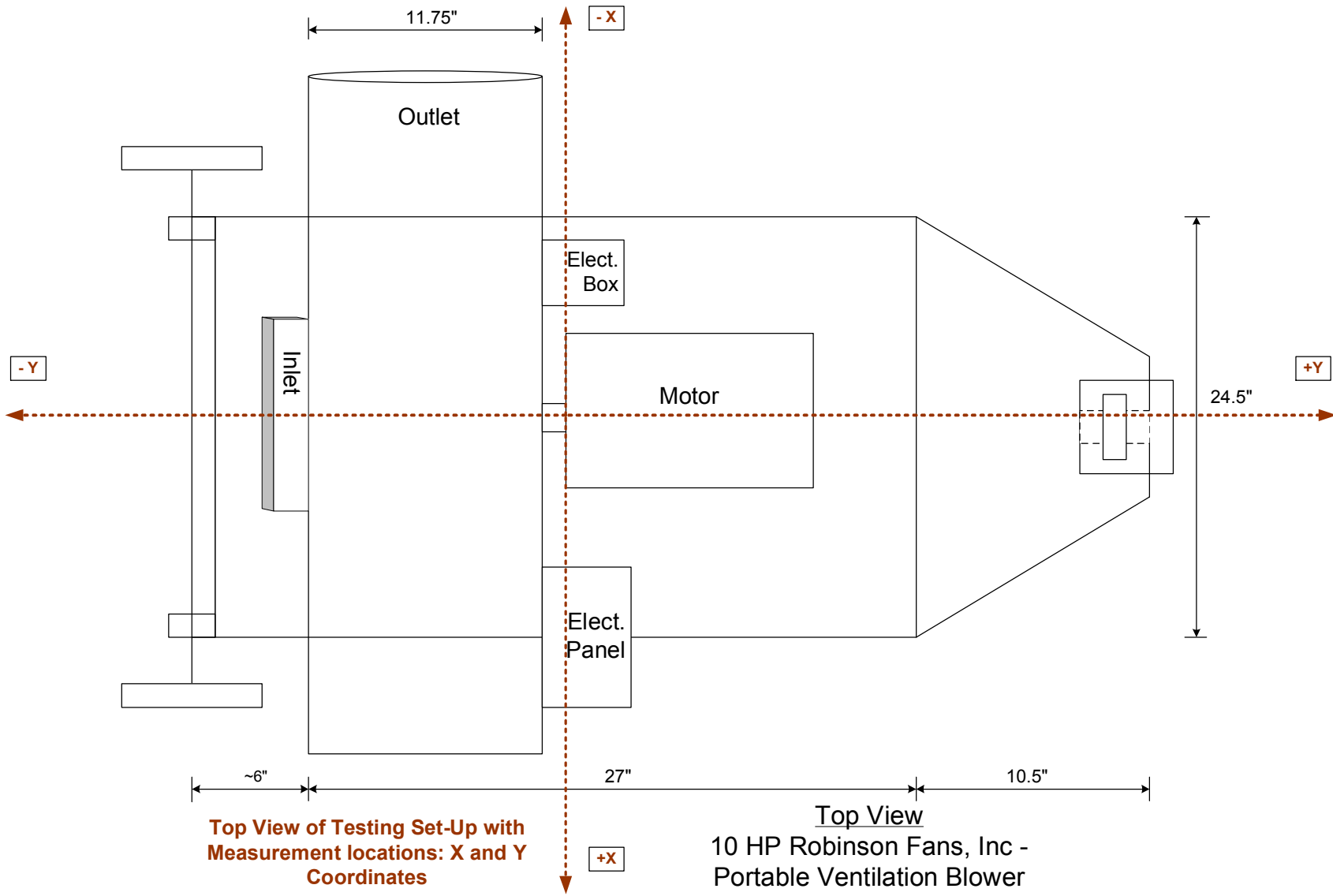
Stillwell-Hansen, Inc. – Tyler Tjong  
3 Fernwood Avenue  
P.O. Box 7820  
Edison, NJ 08818-7820  
Phone: 732-225-7474

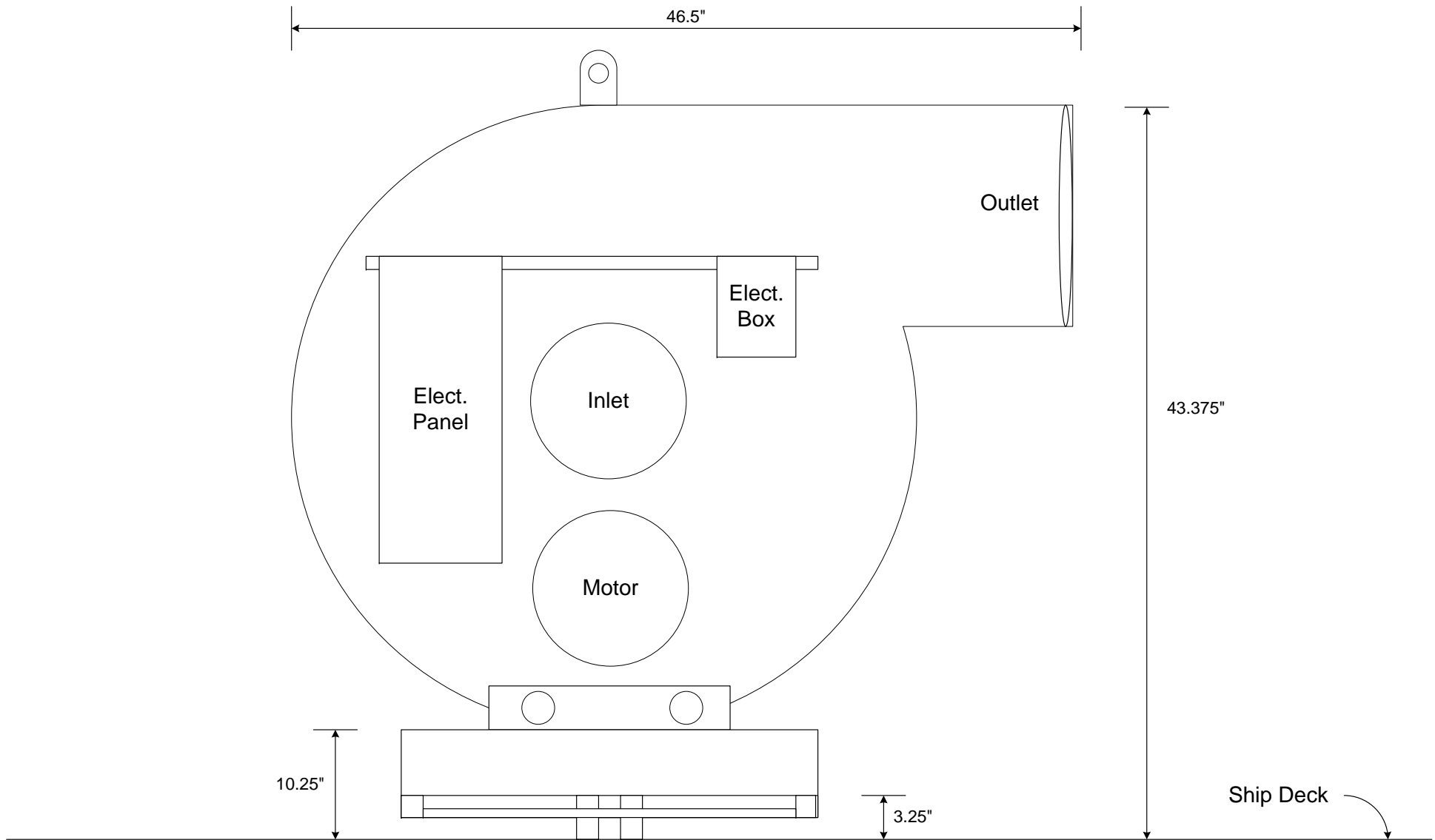
Supplied the inline acoustical silencers

## **Attachment 1**

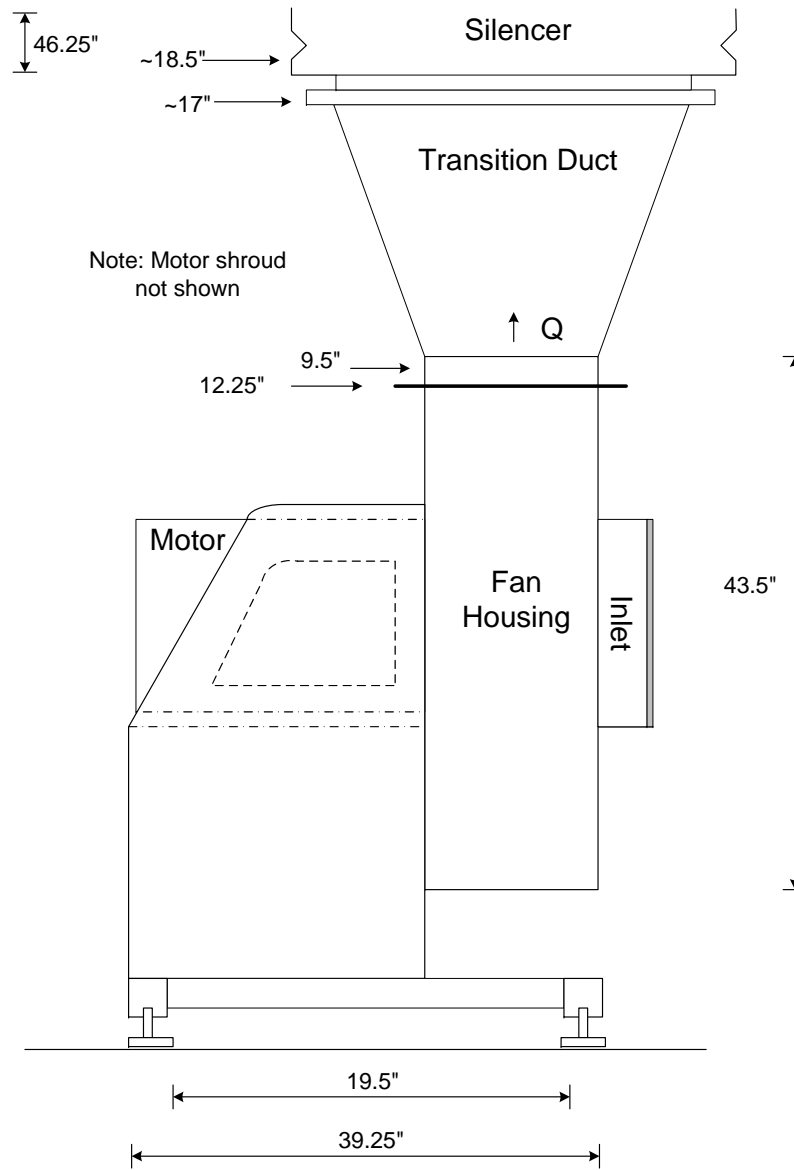
### **Top and side-view sketch of the PVB**







Side View  
10 HP Robinson Fans, Inc - Portable Ventilation  
Blower



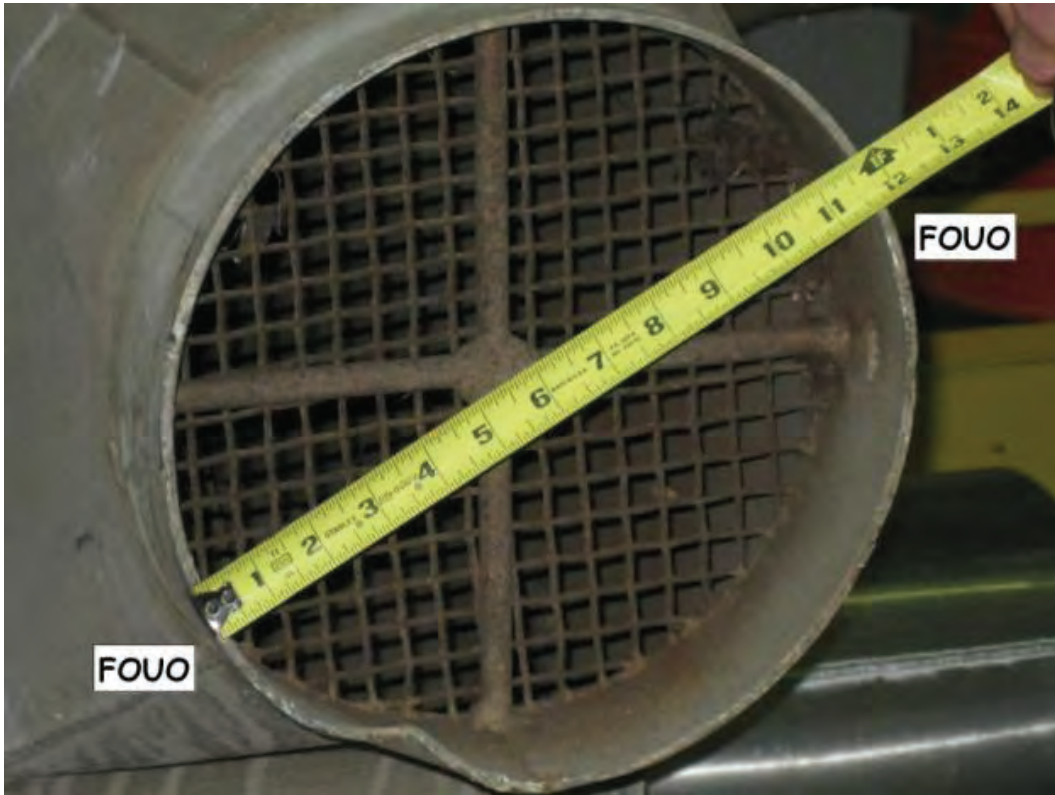
Side View

Coppus, Inc - TM-8 (15HP) Portable Ventilation Blower

## **Attachment 2**

### **Photographs of PVB in-use and under test conditions at NNS**





Exhaust Air Discharge



New PVB Unit Awaiting Evaluation  
Approved for public release – unlimited distribution



Weight Measurement on Scale



Shipboard PVB System In Use

Approved for public release – unlimited distribution

## **Attachment 3**

### **Photographs of PVB in-use and under test conditions at EB**



Top View, PVB Units in Drydock



PVB Unit with Discharge Silencer Removed



Examination of Silencer Baffle System



Sound Measurement at Exhaust Discharge

Approved for public release – unlimited distribution

**Attachment 4**

**Silencer, SLGU-12-06 detailed specification sheet**



Single Wall Round

Double Wall Round

Flat Oval

Comfort

Silencer

Industrial



# Content - Silencers

General information on noise ..... 3  
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## Silencers for spiral systems

### Straight silencers



SLGU ..... 9  
 SLGU 04 ..... 10  
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### Baffle silencers



SLBGU 04..... 20

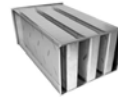
### Elbow silencers



BSLGU..... 30

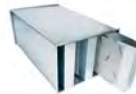
## Silencers for rectangular systems

### Rectangular silencers



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### General information on noise

Noise is generally accepted as unwanted sound. Noise in a ventilation system is a very complex and diverse phenomenon. There are often many noise sources occurring at the same time, which affects our perception of noise. It can be difficult to separate these noise sources from each other; however, it is very important to be able to separate them so that the appropriate sound attenuator can be installed.

### Noise sources

In principle, the noise sources in a ventilation system can be roughly divided into the following main areas:

1. fan noise  
Noise from the fan can be divided into air flow noise and operating noise. Air flow noise is a function of the velocity and pressure. Operating noise comes from the fan motor, belt drives, bearings, etc. The air flow noise is usually the worst problem. The critical frequency is often the fan impeller frequency,  $f_s$ .  
 $f_s = n/60 \cdot s$  (Hz)  
 $n$  = number of revolutions (rpm)  
 $s$  = number of blades
2. Duct noise  
Duct noise is generated primarily when the air flow passes sharp edges, dampers, turning vanes in rectangular elbows and poorly installed saddle taps. Any obstruction to the air flow will cause turbulence and noise. Secondary duct noise may also originate from the transmission of noise through the duct from room to room.
3. Damper noise, valve noise, etc.  
Noise may also be caused near valves, dampers as the air flow passes through relatively small holes. Noise may also be caused by poor joints or leaks.
4. Building noise  
Building noise is the noise which is transmitted through parts of a building: walls, floors, ceilings and other components.

### Noise or sound attenuation

It is desirable and often required that noise be attenuated or removed. Silencers are specially designed for attenuating noise originating from the sources specified in items 1 and 2 above. Before investing in sound attenuating products, it is very important to determine the origin of the noise.

### What is sound?

Small changes in the normal atmospheric pressure which accompany a sound wave is called the sound pressure. When measuring the sound pressure, a total value for the strength of the sound can be obtained. As an example, the weakest sound the human ear can detect has a sound pressure of  $20 \cdot 10^{-6}$  Pa at 1000 Hz. This is defined as the hearing threshold. A sound pressure around 100 Pa would be strong enough that it hurts the human ear. A sound pressure scale using measurements in Pa would become extremely long and cumbersome. For practical reasons the decibel system has been introduced.

#### Sound pressure level, $L_p$

The sound pressure level which is measured in dB is an expression of the perception of noise.

$$L_p = 20 \cdot \log\left(\frac{p}{p_o}\right) \quad (\text{dB}) \quad (4.1)$$

Where:

- $p$  = the sound pressure in question (Pa)
- $p_o$  = reference pressure =  $20 \cdot 10^{-6}$  (Pa)

#### Sound power level, $L_w$

The sound power level which is measured in dB is an expression of the sound power which the system gives off.

$$L_w = 10 \cdot \log\left(\frac{p}{p_o}\right) \quad (\text{dB}) \quad (4.2)$$

Where:

- $p$  = sound power in question, W
- $p_o$  = reference power  $10^{-12}$ , W

#### Calculation of sound power level, $L_p$

$$L_p = L_w + 10 \cdot \log\left(\frac{Q}{4\pi l^2} + \frac{4}{R}\right) \quad (\text{dB}) \quad (4.3)$$

Where:

- $L_w$  = the sound power level of the sound source, dB
- $Q$  = direction factor
- $l$  = distance between sound source and measuring point, ft
- $R = \frac{S \cdot a}{(a-1)}$  = room constant (ft<sup>2</sup>)
- $S$  = total absorption surface of the room (ft<sup>2</sup>)
- $a$  = the room's mean absorption coefficient

#### Octave bands

As it is rarely possible to attenuate low frequencies and high frequencies with the same device, it is necessary to divide the noise into octave bands. This facilitates analysis of the area where the noise is prevalent. The octave bands used in this division are often designated as a given band's mean frequency,  $f_m$ . In ventilation systems the bands used are usually those between 1 and 8.

Octave band	1	2	3	4	5	6	7	8
$f_m$ Hz	63	125	250	500	1000	2000	4000	8000



### General information on sound attenuation

Sound attenuation is usually required in order to comply with project specifications or to fulfill a wish for a better environment. See Table 5.1. These acceptable noise levels are the result of all sound and noise sources (ventilation, electrical fittings, water pipes, fans in computer equipment, etc.).

#### Calculation of sound in ventilation systems

A precondition for sizing sound attenuators is to obtain an accurate sound calculation of the system. The sound calculation is based on the sound power level, which is then converted to the sound pressure level. (See Formula 4.3, page 4). In general, the sound power level of the fan must be known. The following must also be available before the sound attenuation calculation can be made:

- Octave band analysis (frequency analysis)
- Definition of desired end result

#### The A-weighted sound level

It has been found that humans do not perceive two sound pressures of the same magnitude but with different frequencies identically. However, it is possible to make the individual frequencies comparable through appropriate correction (A-filter) of the linear sound pressure level. The value achieved is called the A-weighted sound pressure level,  $L_{pA}$ , which is the sum of the corrected sound pressure levels in the individual octave bands. Instruments are available in which the A-filter can be inserted when measuring the individual octave bands. The measurement results are designated: Whole octave A-weighted values, measured in dB.

#### Specification of requirements

There are 2 methods for specifying the noise requirement:

1. by means of NC
2. by means of  $L_{pA}$

### Recommended maximum values for sound pressure levels

Below is a table which indicates the recommended maximum values for sound pressure levels in N-value and  $L_{pA}$ . There is no fixed ratio between the various sound specifications, but as long as the noise in question is ventilation noise without pure tones, the following rule of thumb applies:  $L_{pA} = NC + 5$

Building type	Room type	NC	$L_{pA}$
Dwellings	Kitchens	30	35
	Living rooms	25	30
Child-care	Kindergardens	30	35
Institutions	Day nurseries	30	35
Meeting facilities	Lecture halls	25	30
	Libraries	30	35
	Cinemas	30	35
	Concert halls	20	25
	Courtrooms	25	30
Shops	Theaters	25	30
	Retail	35	40
	Department stores	35-45	40-50
Hospitals	Supermarkets	35-45	40-50
	Corridors	30	35
	Operating rooms	25	30
Hotels	Patient rooms	20	25
	Lobbies	35	40
Churches	Function rooms	30	35
	All rooms	25	30
Offices	Conference rooms	30	35
	Large offices	30	35
	Computer rooms, large	40	45
	Computer rooms, small	40	45
Restaurants	Cafeterias	40	45
	Dining rooms	40	45
Schools	Lecture halls	25	30
	Corridors	30	35
	Gymnasiums	30	35
	Staff rooms	30	35
Sports	Gymnasiums	35	40
	Swimming pools	35	40



### General information on sound attenuation

The  $L_{pA}$  value can be determined as follows:

1. two random A-weighted octave values (usually the two highest) are added logarithmically by means of the curve.
2. the result is added logarithmically to a random third A-weighted octave value.
3. the addition continues and the  $L_{pA}$ -value is obtained when the addition includes all A-weighted octave values.

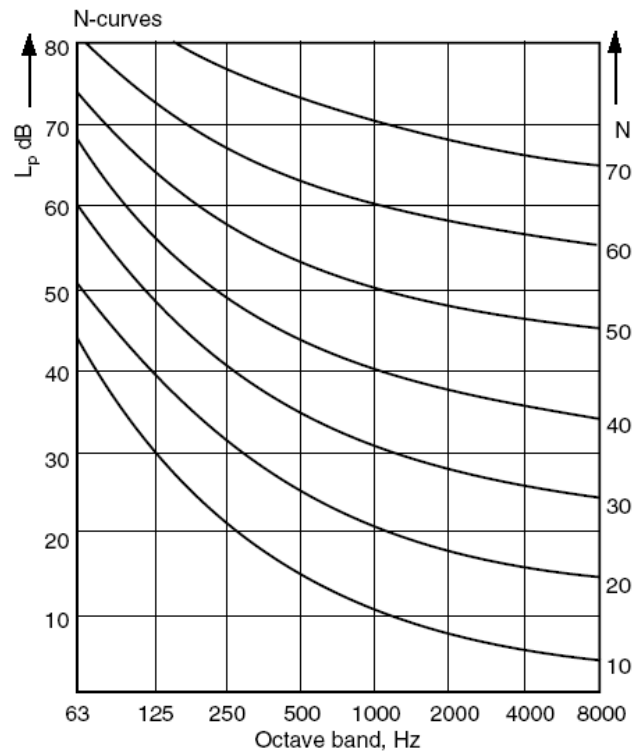
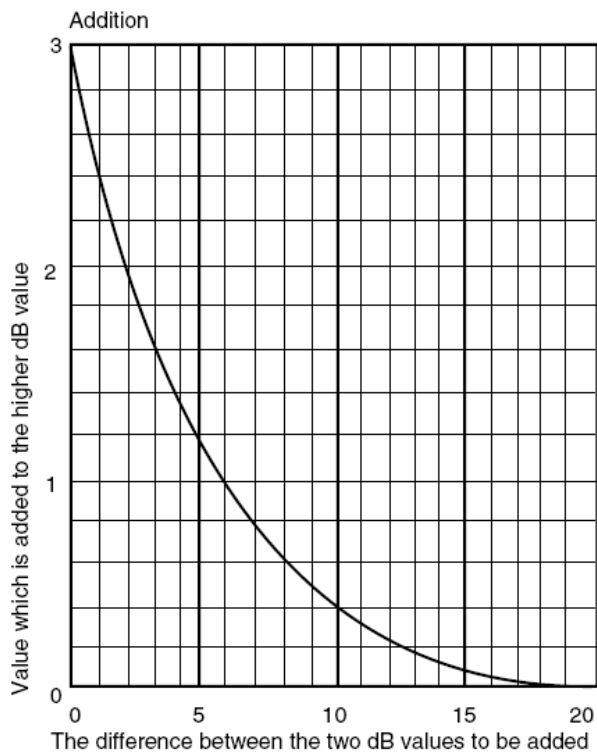
Example: 53 dB + 53 dB + 54 dB:

$$53 \text{ dB} + 53 \text{ dB} = 53 \text{ dB} + 3 = 56 \text{ dB}$$

$$56 \text{ dB} + 54 \text{ dB} = 56 \text{ dB} + 2 = 58 \text{ dB}$$

When determining the N-value, the sound levels in question are plotted and the points connected.

NC is determined as the N-curve which touches the spectrogram for the noise entered.





# Technical description

## Design

The straight silencers in the Lindab Silencer range are designed with a spiral seam outer shell and an inner perforated shell. The space between is filled with inorganic glass fiber sound absorption material. There is a fiber retention system between the perforated inner shell and the glass fiber material in order to prevent the erosion of fiberglass into the airstream.

## Connection

All silencers are supplied with Lindab Safe® end treatment as standard.

## Size Range

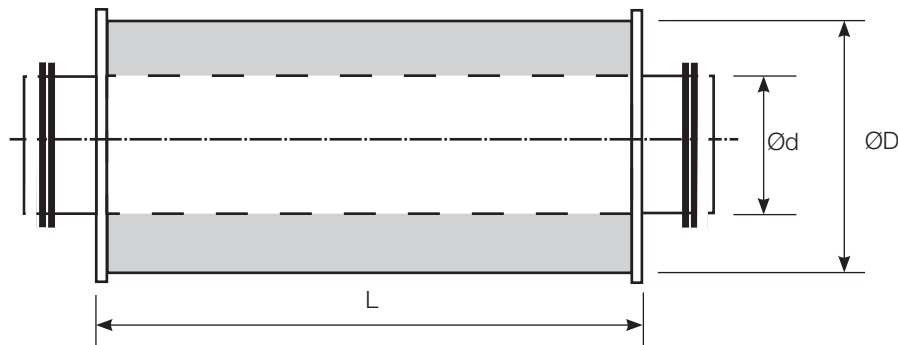
All straight silencers are available from 3" to 50" diameter and in standard lengths of 12", 24", 36", 48", 60", 72", 84" and 96", depending on the connection diameter. Please contact the manufacturer for larger diameters.

Elbow silencers are available from 4" to 12" diameter in 2" thickness and from 4" to 24" diameter in 4" thickness.

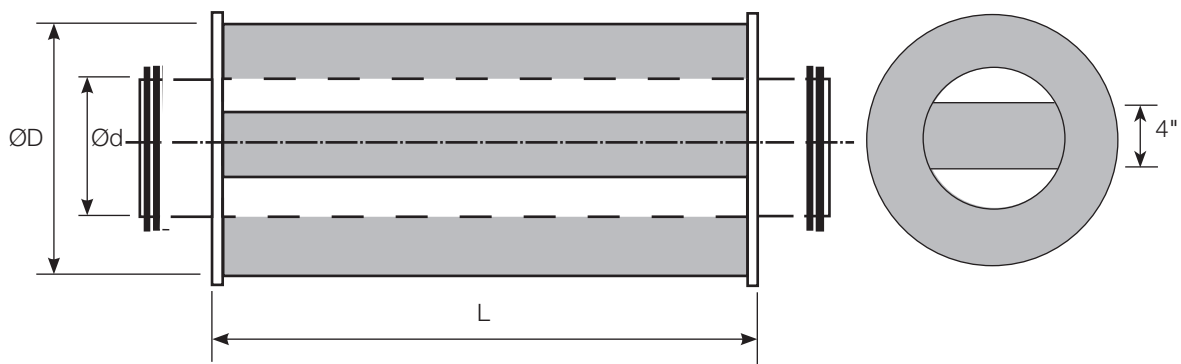
## Technical data

For information on dimensions, weight, insertion loss, self noise and pressure drop refer to the appropriate section for each individual silencer type.

Dimensional sketch for SLGU



Dimensional sketch for SLBGU





# Specification

## General

1. All round silencers shown on plans or scheduled shall be manufactured by Lindab, Inc. (800) 797-7476 or approved equal. All silencers shall meet manufacturer's published performance data tested according to ASTM E477.
2. The contractor may, at his option, convert any or all double wall or sound lined duct work to silencers provided that the intended sound attenuation is matched or exceeded, the project space limitations are properly addressed and that the overall system design static pressure is not exceeded.

## Materials

1. Unless otherwise noted, all silencers shall be a minimum of G-60 galvanized steel in accordance with ASTM A-653 and A-924. Perforated inner liner shall consist of 1/8" perforations on 1/4" staggered centers corresponding to an overall open area of 23%.
2. When stainless steel is specified on contract documents, outershells of silencers manufactured using stainless steel type 304 or type 316 in accordance with ASTM A-240 shall be provided.
3. Absorption filler material shall be glass fiber of adequate density to meet the specified acoustic performance. Filler material density shall be high enough so as to eliminate voids caused by settling.
4. Glass fiber material shall conform to ASTM E84- 91a and NFPA 90A and not exceed flame spread and smoke developed ratings of 25/50.
5. Fiber retention fabric shall be 0.008" thick, 15.6 lbs ft<sup>3</sup> density with an air permeability rate of 9.2 ft<sup>3</sup>/ft<sup>2</sup>-s.

## Construction

1. Unless otherwise noted, all silencers shall be constructed per gauges in the following table:

Diameter (Inches)	Straight Silencer			Elbow Silencer	
	Inner	Outer	Baffle	Inner	Outer
3 - 14	28	28	22	24	24
16 - 24	26	26	22	24	22
26 - 42	24	24	22	NA	20
44 - 50	20	20	22	NA	18

2. The inner and outer shells of the straight silencers shall be spiral lockseam construction. The cavity formed by the two shells shall be filled with inorganic glass fiber sound absorption material. All silencers shall contain a fiber retention system which utilizes a non-woven polyester fabric integrated within the spiral seam of the inner shell and tightly secured to avoid fiberglass from eroding into the airstream.
3. The entry profile of the interior baffle shall be aerodynamically efficient thereby yielding minimum self-generated noise characteristics.
4. The outer shell of all straight silencers 8" diameter and larger shall be corrugated for added strength and rigidity. The corrugations also decrease the amount of surface area perpendicular to the noise source, adding to the effectiveness of the silencer and decreasing potential breakout noise.
5. Spiral seam slippage shall be prevented by means of a flat seam and a mechanically formed indentation evenly spaced along the spiral seam.
6. The inner and outer shells of all elbow silencers shall be a minimum of 5 gore construction. The inside of all outer shell gores shall be sealed to meet ASHRAE's Leakage Class 3 requirements. The cavity formed by the two shells shall be filled with inorganic glass fiber sound absorption material. The fiber retention system is integrated around the inner perforated shell and tightly secured to avoid fiberglass from eroding into the airstream.



# Specification

7. All silencer ends shall come factory equipped with a double lipped, EPDM rubber gasket and shall be calibrated to the manufacturer's published dimensional tolerance standard. This ensures consistent performance with Lindab's Safe® Duct System. Gasket shall be classified by Underwriter's Laboratories to conform to ASTM E84-91a and NFPA 90A flame spread and smoke developed ratings of 25/50.
8. Silencers shall not leak or fail structurally when exposed to a maximum differential pressure of 8 inch water gauge.

## Performance

1. ACOUSTIC: All silencer ratings shall be determined by testing performed in accordance with ASTM specification E477-96 which utilizes the duct-to-reverberant room test method and provides for airflow in both directions. Acoustic ratings shall include Dynamic Insertion Loss (DIL) and Self Generated Noise (SN) for both forward and reverse flow conditions. Data shall be presented for testing on the following sizes: 6", 12", 18", 24", 30", 36" and 42".
2. AERODYNAMIC: Static pressure drop of silencers shall not exceed those listed in the silencer schedule or specifications. Pressure drop data shall be presented for the same sizes as the acoustic data.

## Certification

All silencer ratings shall be conducted by a nationally recognized acoustic test laboratory. The testing laboratory shall be completely independent of the manufacturer.



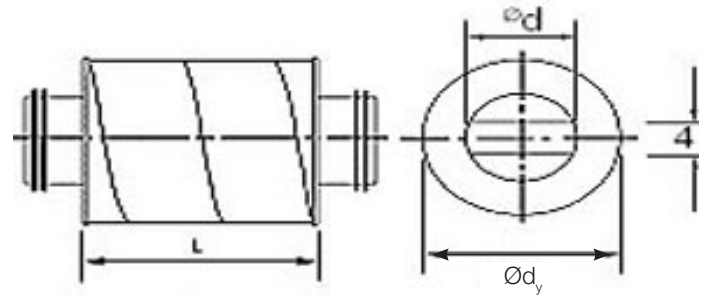
# Straight silencers

# SLGU

9



## Dimensions

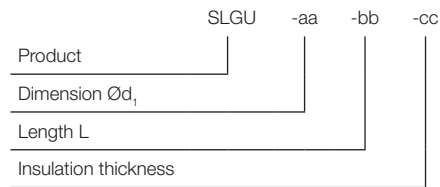


SLGU 04:  $\text{Ød}_y = \text{Ød}_1 + 8$   
 SLGU 06:  $\text{Ød}_y = \text{Ød}_1 + 12$

## Description

The SLGU silencer is a straight through silencer with no obstructions to the air flow. It is available with 4" and 6" thick insulation.

## Ordering example





# Straight silencers

# SLGU 06

## Acoustical Performance – Net Insertion Loss

15

Octave band	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
Frequency (Hz)	63	125	250	500	1K	2K	4K	8K	63	125	250	500	1K	2K	4K	8K	63	125	250	500	1K	2K	4K	8K	
Ød <sub>1</sub> (in)	Net Insertion Loss (Decibels)								Net Insertion Loss (Decibels)								Net Insertion Loss (Decibels)								
Velocity (fpm)	Net Insertion Loss (Decibels)								Net Insertion Loss (Decibels)								Net Insertion Loss (Decibels)								
L (in)	12								24								36								
3	-6000	7	8	12	17	19	26	22	19	9	13	21	29	33	39	32	23	10	18	29	41	46	51	42	27
	-4000	6	7	12	16	18	25	22	19	8	12	20	28	32	38	32	24	10	17	27	40	45	51	42	29
	-2000	6	7	11	16	18	25	22	20	8	12	18	27	32	38	33	26	10	16	25	38	45	51	43	31
	0	6	7	10	15	17	25	22	20	8	11	17	26	30	38	33	27	9	15	23	37	42	50	43	33
	+2000	5	7	10	15	17	24	22	20	7	11	16	26	29	35	32	27	9	14	21	36	40	45	42	33
	+4000	4	6	10	15	16	24	21	18	6	10	15	25	28	34	32	26	8	13	19	35	39	44	42	33
	+6000	3	5	10	14	16	24	20	17	6	9	14	24	27	33	30	25	8	12	18	34	37	42	40	33
4	-6000	6	7	11	15	17	23	19	16	8	12	19	27	30	34	28	21	9	17	27	39	43	45	37	24
	-4000	5	6	11	14	16	22	19	16	8	11	18	26	30	34	28	22	9	16	25	38	42	45	37	26
	-2000	5	6	10	14	16	22	19	17	7	10	17	26	29	34	28	23	9	15	23	36	42	45	38	28
	0	5	6	9	13	15	22	19	17	7	10	15	25	28	33	28	24	8	14	21	35	40	45	38	30
	+2000	4	6	9	13	14	21	19	17	6	9	15	25	27	32	28	24	7	13	20	34	38	43	37	30
	+4000	4	5	9	13	14	21	19	16	6	9	14	24	26	31	28	24	7	12	18	33	37	42	37	30
	+6000	3	5	9	13	14	21	19	15	5	8	13	23	25	30	28	24	6	11	17	32	35	40	36	30
5	-6000	5	6	10	13	15	20	16	13	7	11	18	25	28	29	24	17	8	16	26	37	41	39	32	21
	-4000	4	5	10	13	14	19	17	13	6	10	17	24	27	31	25	18	8	15	24	36	40	43	33	23
	-2000	4	5	9	12	14	19	17	14	6	9	15	23	26	31	25	19	7	14	22	34	39	43	34	25
	0	4	5	8	12	13	19	17	14	6	9	14	22	25	31	25	20	7	13	20	33	38	43	34	27
	+2000	4	5	8	11	12	18	17	14	5	8	13	22	24	30	25	20	6	12	19	32	36	42	33	27
	+4000	3	4	8	11	12	18	16	13	4	8	12	21	23	29	25	20	6	11	17	31	35	40	33	27
	+6000	2	4	7	11	12	18	16	12	3	7	12	20	22	27	24	19	5	10	17	29	33	36	32	27
6	-6000	4	5	8	11	13	17	13	10	6	10	16	23	26	25	20	14	7	15	24	35	38	32	26	17
	-4000	3	4	8	11	12	16	14	10	5	9	15	23	25	29	22	15	6	13	22	34	38	41	29	19
	-2000	3	4	7	10	11	16	14	10	4	8	14	21	24	29	22	16	5	12	21	32	36	41	29	21
	0	3	4	7	10	11	15	14	11	5	8	13	21	23	28	22	17	6	12	19	31	35	41	30	23
	+2000	3	3	6	9	10	15	14	11	4	7	12	20	22	28	22	17	5	11	18	30	33	40	29	23
	+4000	2	3	6	9	10	15	13	10	3	7	11	19	21	27	21	17	4	10	16	29	32	38	29	23
	+6000	1	3	5	8	9	15	13	9	2	6	11	17	20	24	20	16	3	9	16	26	30	32	27	23
7	-4000	4	9	15	21	24	27	20	14	5	13	21	31	36	37	27	19	6	16	28	41	47	47	33	23
	-3000	4	9	14	21	23	27	20	15	5	12	21	30	35	37	27	19	6	16	28	40	46	47	33	24
	-2000	4	9	13	20	23	27	20	15	5	12	20	30	34	37	27	20	6	15	27	39	45	47	33	25
	0	4	8	13	19	22	27	21	16	5	11	19	29	33	37	28	22	6	15	25	38	44	47	35	27
	+2000	4	7	12	18	21	26	20	16	4	10	18	28	31	36	27	22	5	14	24	37	42	45	33	27
	+3000	3	6	11	17	20	25	19	16	4	9	17	26	30	33	26	22	4	13	23	35	40	42	32	28
	+4000	2	6	11	17	19	23	19	15	3	9	16	25	29	31	25	22	4	12	22	34	38	38	32	28
8	-4000	4	9	14	20	23	25	18	14	5	12	21	29	33	33	24	18	5	15	27	37	43	41	30	22
	-3000	4	9	13	20	23	25	18	14	5	12	20	28	33	33	24	19	5	14	26	36	42	40	30	23
	-2000	3	9	12	19	22	25	19	15	4	12	19	27	32	33	25	20	5	14	26	35	41	40	30	24
	0	3	8	12	18	21	25	19	15	4	11	19	26	31	33	25	20	4	13	25	34	40	40	31	25
	+2000	3	7	12	17	20	24	18	15	4	10	18	26	30	31	24	20	4	12	24	34	39	38	30	25
	+3000	2	6	12	16	20	24	18	14	3	9	18	25	29	30	24	20	3	11	23	33	37	36	30	25
	+4000	2	5	11	16	19	23	18	14	3	8	17	24	27	29	24	20	3	11	22	32	35	35	29	26





# Straight silencers

# SLGU 06

## Acoustical Performance – Net Insertion Loss

Octave band	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
Frequency (Hz)	63	125	250	500	1K	2K	4K	8K	63	125	250	500	1K	2K	4K	8K	63	125	250	500	1K	2K	4K	8K	
Ød <sub>1</sub> (in)	Net Insertion Loss (Decibels)								Net Insertion Loss (Decibels)								Net Insertion Loss (Decibels)								
Velocity (fpm)	Net Insertion Loss (Decibels)								Net Insertion Loss (Decibels)								Net Insertion Loss (Decibels)								
L (in)	12								24								36								
9	-4000	4	8	14	18	23	23	16	13	4	11	20	26	31	30	22	16	4	13	26	34	40	37	27	20
	-3000	4	8	13	18	23	23	16	13	4	10	19	25	31	30	22	16	4	13	25	33	40	37	27	20
	-2000	3	8	12	17	21	23	17	13	3	10	18	25	30	30	22	17	4	13	25	32	39	37	28	21
	0	3	7	12	16	20	23	17	14	3	9	18	24	29	30	23	18	3	12	24	32	38	37	28	22
	+2000	3	7	12	16	19	23	16	14	3	9	17	23	28	29	22	18	3	11	23	31	37	36	27	23
	+3000	2	6	12	15	19	22	16	13	2	8	17	22	27	28	22	18	2	10	22	30	36	34	27	23
	+4000	2	5	11	15	18	22	16	13	2	7	16	22	26	28	21	18	2	10	21	30	34	34	26	23
10	-4000	3	7	13	16	22	21	14	11	3	9	19	24	30	27	19	14	3	11	24	31	37	33	24	17
	-3000	3	7	12	15	22	21	14	11	3	9	18	23	30	27	19	14	3	11	24	30	37	33	24	17
	-2000	2	7	12	15	20	21	14	11	3	9	18	22	28	27	20	15	3	11	23	29	36	33	25	18
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	+2000	2	6	11	14	18	21	14	12	2	8	17	21	27	27	19	16	2	9	22	28	35	33	24	20
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+4000	1	5	10	13	17	20	14	11	1	7	15	20	25	26	19	16	1	8	20	27	33	32	23	20	
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	0	0	4	10	11	17	17	12	9	0	6	16	17	25	22	16	12	0	7	21	23	32	27	19	15
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	+3000	0	3	10	11	17	16	11	8	0	5	15	17	24	22	15	12	0	7	19	22	30	28	18	15
+4000	0	3	9	10	16	16	11	8	0	5	14	16	23	22	15	12	0	7	18	21	30	28	18	15	
14	36								48								60								
	-2000	3	6	12	14	18	16	14	11	4	8	16	19	22	19	16	14	4	9	19	23	25	21	18	16
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	+1000	2	5	11	14	18	16	14	11	2	6	14	17	22	18	16	12	3	7	17	21	26	20	17	13
	+2000	2	5	11	14	17	16	13	11	2	6	14	17	21	18	15	12	3	7	17	21	26	20	17	13
+3000	2	5	11	14	17	15	13	10	2	6	13	17	21	17	15	11	3	7	16	20	26	20	17	13	
18	-2000	1	6	14	17	20	17	15	12	3	7	18	21	25	20	17	14	4	8	21	25	30	22	19	15
	-1500	1	6	13	16	20	17	15	11	3	7	17	20	25	20	17	13	4	8	20	24	29	22	19	15
	-1000	1	6	13	16	19	17	15	11	2	7	16	20	24	20	17	13	3	8	19	24	29	22	19	15
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## **Attachment 5**

# **Acoustical jacket material, B-10 LAG/QFA-3 detailed specification sheet**

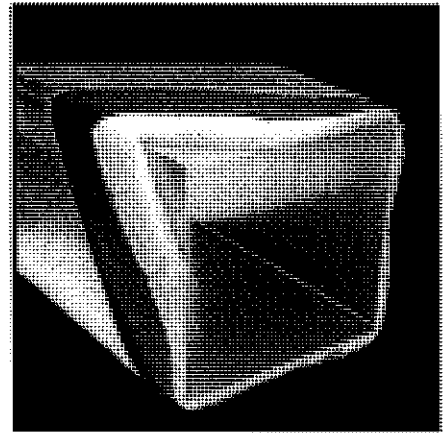
Spec Data Sheet

**B 10 -SERIES**  
FLEXIBLE NOISE BARRIERS

**Acoustical Pipe and Duct Lagging:  
B-10 LAG/QFA-3**

A composite material featuring a flexible one-pound per square foot reinforced-foil faced loaded vinyl noise barrier bonded to a 1" thick quilted fiberglass decoupler. Used to wrap noisy pipes, ducts, valves and fan housings.

- Easy to cut, wrap and install with matching lag tape
- Class A (or 1) flammability rating per ASTM E-84
- Standard roll is 54" wide x 30' long



**Applications:**

Used to wrap the exterior of ducts and pipes to block the noise that transmits through its walls as air or other contents move through it. The quilted fiberglass decoupler improves the performance of the noise barrier and provides sound absorption and thermal insulation around the duct or pipe. The reinforced foil facing on the barrier readily accepts a matching lag tape for easy installation. Suitable for both indoor and outdoor applications.

**Product Data:**

<b>Description</b>	1 lb. psf reinforced-foil faced loaded vinyl barrier bonded to a 1" thick scrim faced quilted fiberglass absorber
<b>Nominal thickness</b>	1.0 inch
<b>Roll size</b>	54" x 30 feet
<b>Weight</b>	1.2 lb psf
<b>Temperature range</b>	-20° to + 220° F
<b>Thermal Conductivity</b>	0.24 BTU-in. ft <sup>2</sup> °F per (ASTM C518) @ 75°F
<b>Flammability</b>	Class A (or 1) Per ASTM E-84 Smoke Density index 19.5 Flame spread index 12.5

**Acoustical Performance:**

**Sound Transmission Loss:**

Product	OCTAVE BAND FREQUENCIES (Hz)						
	125	250	500	1000	2000	4000	STC
B-10 Lag/QFA-3	18	18	23	30	39	46	29

Per ASTM E-90 & E 413



## **Attachment 6**

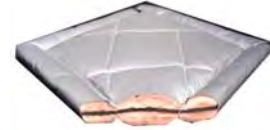
### **Custom acoustical curtain, BSC-25-2 detailed specification sheet**

**BSC-SERIES**

NOISE BARRIERS/SOUND ABSORBER  
COMPOSITES

**BSC-25-2" Noise Barrier/Sound Absorber Composite**

The barrier septum configuration offers the benefits of sound absorption and noise barriers. A non-reinforced 1-lb psf loaded vinyl barrier is sandwiched between 1" and a 2" layer of quilted fiberglass absorbers. Curtain panels are constructed with grommets across the top and hook and loop fasteners along the vertical edges. Rolls are available 4' wide up to 25' long and can be either bound or unbound.



- Class 1 or A per ASTM E84
- STC rating 32
- NRC rating 0.85
- Available colors: gray, white, black, or tan

**Applications:**

Typical uses include modular curtain panels in acoustical curtain walls or enclosures. Also used as separator walls or divider partitions, or to line the perimeter walls or ceiling of a room or building to both reduce noise inside and outside of the room or building.

**Product Data:**

<b>Description</b>	2" vinyl faced quilted fiberglass/ 1LB-psf non-reinforced loaded vinyl barrier/ 1" vinyl faced quilted fiberglass
<b>Nominal thickness</b>	2.0"
<b>Temperature range</b>	-20° to +180° F
<b>Standard roll size:</b>	48" wide x 25' long
<b>Weight</b>	1.7 LB psf
<b>Flammability</b>	Class A: Flame Spread: 22.78 Smoke density: 30.56

**Acoustical Performance:**

Sound Transmission Loss Data

PRODUCT	OCTAVE BAND FREQUENCIES (Hz)						STC
	125	250	500	1000	2000	4000	
BSC-25-2"	13	20	29	40	50	55	32

Sound Absorption Data :

PRODUCT	OCTAVE BAND FREQUENCIES (Hz)						NRC
	125	250	500	1000	2000	4000	
BSC-25-2"	.19	.99	.96	.80	.57	.33	.85

## **Attachment 7**

**Vibration-isolation mounts, Models; (1) C-A-45,  
(2) C-A-125, (3) C-A-200, detailed specification sheet**



## MASON INDUSTRIES, Inc.

Manufacturers of Vibration Control Products

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Hauppauge, NY 11788  
631/348-0282  
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Anaheim, CA 92801  
714/535-2727  
FAX 714/535-5738  
Info@MasonAnaheim.com  
www.MasonAnaheim.com

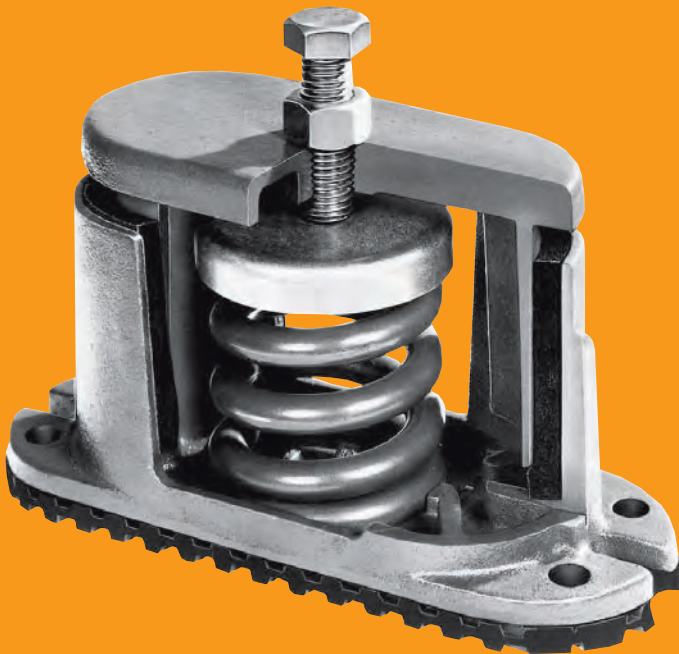
HOUSED  
SINGLE and  
MULTIPLE  
SPRING MOUNTS

TYPE

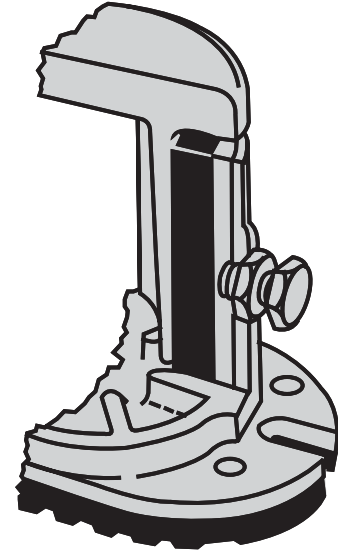
C

C-210-2 BULLETIN

**TYPE "C"** Spring Mountings provide a packaged solution to troublesome vibration problems. Since the static deflection of the spring element is much greater than that provided by most rubber materials, these units will perform where it is necessary to establish low natural frequencies or to use a mounting that is more yielding than the supporting floor. Type "C" mountings are specifically designed for noise and vibration free application in critical areas on light concrete or wooden floors.



Semi-circular Neoprene sponge inserts limit movement during start and stop and prevent contact between the projections of the upper and lower semi-steel castings. These inserts are designed for a minimum of damping in all directions to allow the springs to function properly and develop installed efficiencies that are very close to the theoretical. Non-adjustable inserts are recommended for all air conditioning applications under compressors, air handling units, centrifugal fans and most other constant frequency vibration problems.



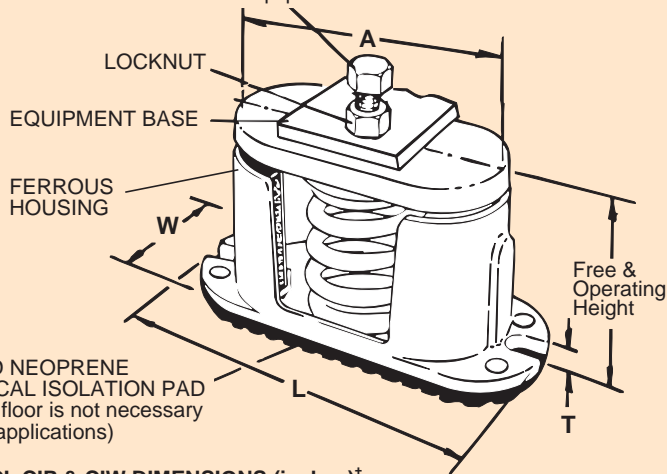
**TYPE "CS"** mountings have built in adjustable snubbers for shock absorbing and high horizontal thrust applications. The damping, or housing drag, is varied by means of end adjustment bolts which change the pressure on the solid neoprene inserts. Tightening the snubbers reduces vertical movement and limits bounce. The same adjustment controls side motion and rock. Wear is negligible as damping is provided by the viscous-distortion of the neoprene inserts rather than by friction. Adjustable snubbers are recommended for applications under punch presses, drop hammers, clickers and other industrial equipment.

**EXTERNAL** adjustment mountings are used when equipment mounting holes are well centered and the mounting leveling and adjustment bolt is accessible from above.

**INTERNAL** adjustment mountings provide a means of attachment when it is preferable to shift the center of the mounting in relation to the equipment mounting hole or where there is no access for adjustment from above. Attachment to the equipment may be made either by an individually located tapped hole or by a type "W" friction pad cemented on top of the mounting. The internal spring adjustment bolt is reached through the side opening by means of an open end wrench. Both external and internal adjustment mountings are provided with type "W" acoustical friction pads on bottom to eliminate the need for bolting down on most installations.

## 1" & 2" Deflection SINGLE and MULTIPLE SPRING MOUNTS

**C** TOP ACCESS ADJUSTMENT BOLT— Turn clockwise to load spring and maintain Free & Operating Height. Bolt length is suitable for 1" maximum Equipment Base thickness.



NON-SKID NEOPRENE ACOUSTICAL ISOLATION PAD (Bolting to floor is not necessary on indoor applications)

### TYPE C, CI, CIP & CIW DIMENSIONS (inches)<sup>†</sup>

Type	Size	CI Only			L	T	W	SW	HCL	HCW	MBD	SBC	Type C	1" Free & Op. Ht.			2" Free & Op. Ht.		
		A	B	C									Adj. Bolt	C	CI&CIP	CIW	C	CI&CIP	CIW
C- CI- CIP- CIW-	A	4	3/8	1	53/4	1/2	21/8	5/16	43/4	1	1/4	5	3/8 x 4	41/2	47/8	51/8	—	—	—
	B & B2	53/4	1/2	11/4	81/4	1/2	23/4	7/16	61/2	11/2	3/8	71/4	1/2 x 4	55/8	61/8	63/8	53/4	61/8	63/8
	C & C2	65/8	1/2	11/4	87/8	9/16	31/2	7/16	71/4	13/4	3/8	77/8	5/8 x 41/2	55/8	61/8	63/8	61/2	63/4	7
	D & D2	93/4	5/8	††	12	9/16	31/2	7/16	103/8	13/4	3/8	11	5/8 x 41/2	61/8	61/2	63/4	67/8	71/2	73/4
	E & E2	121/8	5/8	2	123/4	5/8	65/8	—	113/8	51/8	1/2	—	3/4 x 5	61/8	61/2	63/4	67/8	71/2	73/4
	F	16	3/4	††	16	5/8	7	—	141/2	51/8	5/8	—	Internal	63/8	63/4	7	71/8	73/4	8
	G	193/4	3/4	††	193/4	3/4	10	—	183/8	81/4	5/8	—	Adj. Only	63/8	63/4	7	71/8	73/4	8

<sup>†</sup> Casting Dimensions vary  $\pm 1/8"$ . <sup>††</sup> Hole is in center.

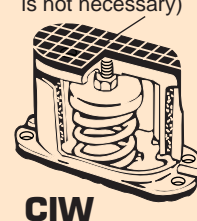
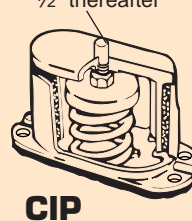
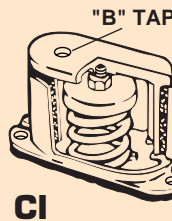
### TYPE 1" DEFL. C, CI, CIP & CIW RATINGS

Type	Size	Rated Capacity (lbs)	Rated Defl (in)	Mount Constant (lbs/in)	Spring Color/Stripe
1" Defl.	A-45	45	1.60	28	Blue
	A-75	75	1.50	50	Orange
	A-125	125	1.33	94	Brown
	A-200	200	1.15	174	Black
	A-310	310	1.00	310	Yellow
	A-400	400	1.00	400	Green
	A-510	510	1.00	510	Red
	A-625	625	1.00	625	White
	B-65	65	2.10	31	Brown
	B-85	85	2.10	40	White/Black
	B-115	115	2.00	57	Silver
	B-150	150	2.00	75	Orange
	B-280	280	1.60	174	Green
	B-450	450	1.31	344	Red
B-750	750	1.12	670	White	
C- CI- CIP- CIW-	B-1000	1000	1.00	1000	Blue
	B-1250	1250	1.00	1250	Gray
	B-1650	1650	1.00	1650	Black
	C-1000	1000	1.00	1000	Black
	C-1350	1350	1.00	1350	Yellow
	C-1750	1750	1.00	1750	Black
	C-2100	2100	1.00	2100	Yellow*
	C-2385	2385	1.00	2385	Yellow**
	C-2650	2650	1.00	2650	Red*
	C-2935	2935	1.00	2935	Red**
	D-3500	3500	1.00	3500	Black*
	D-4200	4200	1.00	4200	Yellow*
	D-4770	4770	1.00	4770	Yellow**
	D-5300	5300	1.00	5300	Red*
D-5870	5870	1.00	5870	Red**	
E-7000	7000	1.00	7000	Black*	
E-8400	8400	1.00	8400	Yellow*	
E-9540	9540	1.00	9540	Yellow**	
E-10600	10600	1.00	10600	Red*	
E-11740	11740	1.00	11740	Red**	
F-12600	12600	1.00	12600	Yellow*	
F-14310	14310	1.00	14310	Yellow**	
F-15900	15900	1.00	15900	Red*	
F-17610	17610	1.00	17610	Red**	
G-18900	18900	1.00	18900	Yellow*	
G-21465	21465	1.00	21465	Yellow**	
G-23850	23850	1.00	23850	Red*	
G-26415	26415	1.00	26415	Red**	

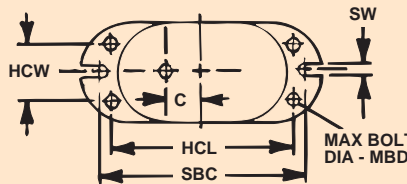
\*with RED core spring \*\*with GREEN core spring

Dowel Pin is 3/8" dia for CIP-A & 1/2" thereafter

FRICION PAD - (Bolting to Equipment is not necessary)



CI, CIP & CIW Mounts have SIDE ACCESS INTERNAL ADJUSTMENT BOLTS. Turn clockwise to load spring and maintain Free & Operating Height.



BASE PLATE DIMENSIONS FOR C, CI, CIP & CIW (Top Plate Dim. for CI Only)

CS & CSI sizes start at C-1000. A & B sizes are not manufactured. Type C dimensions below apply.

### TYPE 2" DEFL. C, CI, CIP & CIW RATINGS

Type	Size	Rated Capacity (lbs)	Rated Defl (in)	Mount Constant (lbs/in)	Spring Color/Stripe
2" Defl.	B-20	20	2.40	8	Tan
	B-26	26	2.18	12	White/Blue
	B-35	35	2.20	16	Purple
	B-50	50	2.20	24	White/Red
	B-65	65	2.10	31	Brown
	B-85	85	2.10	40	White/Black
	B-115	115	2.00	57	Silver
	B-150	150	2.00	75	Orange
	B2-210	210	2.12	99	Silver
	B2-290	290	2.00	144	Blue
C- CI- CIP- CIW-	B2-450 <sup>†</sup>	450	2.00	224	Tan
	B2-680 <sup>†</sup>	680	2.00	340	Gray
	C2-125	125	2.50	50	Purple
	C2-170	170	2.40	70	Brown
	C2-210	210	2.30	90	Red
	C2-260	260	2.20	120	White
	C2-330	330	2.00	165	Black
	C2-460	460	2.00	230	Blue
	C2-610	610	2.00	305	Green
	C2-880 <sup>†</sup>	880	2.00	440	Gray
	C2-1210 <sup>†</sup>	1210	2.00	605	Silver
	C2-1540 <sup>†</sup>	1540	2.00	770	Gray*
	C2-1870 <sup>†</sup>	1870	2.00	935	Silver*
	D-C2-2420 <sup>†</sup>	2420	2.00	1210	Silver*
D-C2-3080 <sup>†</sup>	3080	2.00	1540	Gray*	
D-C2-3740 <sup>†</sup>	3740	2.00	1870	Silver*	
E-C2-3520 <sup>†</sup>	3520	2.00	1260	Gray	
E-C2-4840 <sup>†</sup>	4840	2.00	2420	Silver*	
E-C2-6160 <sup>†</sup>	6160	2.00	3080	Gray*	
E-C2-7480 <sup>†</sup>	7480	2.00	3740	Silver*	

All springs without "†" have additional travel to solid equal to 50% of the rated deflection.

\*with RED core spring

<sup>†</sup>Published ratings allow minimum 25% additional travel to solid. For a full 50% specified minimum use the following ratings:

Size	Derated Capacity (lbs)	Defl (in)	Size	Derated Capacity (lbs)	Defl (in)
B2-450	410	1.83	D-C2-3080	2570	1.67
B2-680	565	1.66	D-C2-3740	3120	1.67
C2-880	800	1.82	E-C2-3520	3200	1.82
C2-1210	1010	1.67	E-C2-4840	4040	1.67
C2-1540	1285	1.67	E-C2-6160	5145	1.67
C2-1870	1500	1.67	E-C2-7480	6245	1.67
D-C2-2420	2020	1.67			