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Report on:

Investigation of Dumpster Noise Controls

Prepared for:

City of Portland
Office of Neighborhood Involvement
Office of Sustainable Development

c/o Mr. Paul VanOrden
City Hall
1221 SW Fourth Avenue, Suite 110
Portland, OR 97204

DSA Project #: 140031

November 19, 2003

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Daly-Standlee & Associates, Inc.

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Executive Summary

An investigation was conducted to determine noise controls that could feasibly be used to reduce the amount of noise generated by garbage dumpsters when they are picked up by a front loading garbage truck and lifted over the cab of the truck to empty the contents into the truck.

The results of the investigation indicate that a significant reduction in dumpster radiated noise can be achieved by adding a simple damping treatment to the dumpster. A 5 dB reduction in noise was achieved in the laboratory, and a 4 to 5 dB reduction was measured during field demonstrations. Furthermore, the damping treatment changed the nature of the sound radiated from the dumpster in such a way that most people judge it to be a “very significant improvement”.

It is concluded that it is feasible to substantially reduce the amount of impact generated noise typically associated with dumpster dumping.

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1. Introduction

Nighttime noise created during the collection of garbage from 1 to 4 yard dumpsters by front-end loading garbage trucks was identified as a major source of garbage truck noise in the City by the City of Portland Noise Control Task Force and the City of Portland Noise Review Board. In order to address the issue of nighttime front-end loaded dumpster noise, the Bureau of Development Services (BDS) in conjunction with the Office of Neighborhood Involvement (ONI) requested that a study be undertaken to analyze the noise generated by the dumpsters associated with front-end loading garbage trucks. A study was conducted by Daly-Standlee & Associates, Inc. and this report presents the findings of and the conclusions drawn from the study.

2. Scope of Work

Through the contract Scope of Work, DSA was asked to:

1. Determine the characteristics of dumpster related noise created by the rapid movement of a typical 3 or 4 yard dumpster over the front driver's cabin of a garbage truck.
2. Consider various noise reduction methodologies, and based on the feasibility and cost of the various options, develop a specific approach that could be used to treat a typical 3 or 4 yard dumpster and provide a cost effective amount of noise reduction for the community. It was instructed that the cost to apply sound mitigating materials and /or methodologies to a dumpster should include the anticipated labor costs for applying the designated treatment.

3. Bin Size Selection

The contract specified that the dumpster noise reduction work should focus on the treatment of *"an average 3 or 4 yard dumpster"*. In conducting this investigation, DSA chose to focus on a 3-yard dumpster, for the following reasons:

1. It was more practical to transport a 3-yard bin to and from the testing facility (e.g., a 3-yard bin fits in the box of a standard half-ton truck, whereas a 4-yard bin does not).
2. It was assumed that a 3- yard bin would require less noise reduction treatment than would be required with a 4-yard bin and the amount of treatment needed in the study would influence the cost of the study.
3. It was believed that the mechanisms of noise and vibration for both the 3 and 4 yard bins is the same, and therefore it was assumed that a treatment developed for a 3-yard bin would also be effective for a 4-yard bin.

4. Field Testing of Untreated Bins

To help in the identification of viable dumpster related noise reduction treatments, a series of sound recordings were first made with an empty dumpster bin at the Waste Management maintenance facility located at 7727 NE 55th Avenue. The recordings were analyzed later in the lab to characterize the frequency spectrum and level of the sound generated by the dumpster during a typical dumping operation. This section presents a discussion of those recordings and the data obtained from the analysis of the recordings.

4.1. Field Test Procedure and Instrumentation

For these measurements, an empty bin was placed in a relatively open area in the maintenance yard at the site and the sound was recorded continuously from a point 50 feet to the side of the bin as a garbage truck operator simulated cycles of engaging, lifting, emptying, lowering and disengaging the dumpster. The sound recording equipment consisted of an ANSI compliant Type 1 sound level meter connected to a computer-based dynamic signal analyzer system. The computer-based signal analyzer system was also used to playback and analyze the recorded data later in the lab. The microphone was located 5 feet from the ground at the measurement location.

The dynamic signal analyzer used consisted of a Sound Technology ST-190 data acquisition module with SpectraPro software running on a notebook computer. The sound signal was recorded on the computer as a calibrated sound pressure level in 16 bit computer audio (WAV) file format. Once recorded, the data was then played back through an audio amplifier system for the purpose of listening to different segments. Furthermore, the analysis software was used to conduct spectral analysis of segments of the recording, as well as to plot sound levels versus time.

During the field measurements, a video camera was placed at approximately the same position as the microphone and used to video tape the handling of the bin. The tape was later used to help interpret and analyze the sound recordings.

For each test, the fork truck was initially positioned in front of the bin, with the tip of its forks located 1 to 3 feet from the front of the bin. The operator was instructed to move forward, pick up the bin and go through the motion of raising it overhead and dumping it into the truck, then set it on the ground. Sound levels and video were recorded for each test.

It should be noted that the truck operator for the field tests was a supervisor, not a regular driver. It was considered possible that the bin could have been handled less aggressively (i.e., with fewer and less intense impacts) than it would be in normal use. Therefore, the “supervisor” operator was asked to simulate emptying the bin in what he considered to be a “normal” fashion, as well as a “more aggressive” fashion (i.e., to shake the bin one or two more times overhead, as if he was trying to dislodge trash stuck in the bin).

Recordings were made for three “normal” emptying cycles and three “more aggressive” emptying cycles. This was repeated on a second bin. One of these bins was kept aside at Waste Management, and the other was taken by DSA for additional tests and treatment.

4.2. Field Test Results

Figure 1 shows a plot of sound level versus time during the simulation of a “normal” dumpster emptying cycle. This data was generated with the SpectraPro software by stepping through the recorded sound file at intervals of about 0.1 seconds and calculating the average A-weighted sound level (L_{eq}) with an averaging time of about 0.185 seconds. It is approximately equivalent to the Fast time weighting response of a sound level meter (the weighting specified in the City of Portland noise ordinance).

As shown in Figure 1, during a “normal” emptying cycle, “dumpster noise” is the short duration impulsive noise generated when the forks impact against the bin structure. The remaining noise found in the operation is associated with the truck or the hydraulic pump associated with the lift.

Figure 1 shows that the idling truck noise is at a level of about 65 dBA. When the truck moved forward and the hydraulic pump raised the arms, the noise level rose to around 70 to 72 dBA. The high, short duration peaks in Figure 1 are caused by impacts of the forks against the bin. These peaks were all over 80 dBA, and the highest was close to 90 dBA. It is likely that these peaks, which are 10 to 20 dBA higher than the truck noise, make the dumpster emptying noise so intrusive.

Figure 2 shows the sound level versus time for a “more aggressive” dumpster emptying cycle and it shows that in this case, impulsive dumpster sound ranged from 88 to 94 dBA.

Figure 3 shows an octave band noise spectrum for the dumpster noise at the instant in time in Figure 2 corresponding to the maximum peak noise level of 94 dBA. In this case, the spectrum values are A-weighted, to emphasize the contribution of each frequency band to the overall A-weighted noise level. As shown in Figure 3, most of the acoustic energy in the impulsive noise is contained in the octave bands from 250 Hz to 8 kHz, inclusive.

5. *Potential Dumpster Noise Reduction Methodologies*

As stated earlier, dumpster noise is considered to be the impulsive noise generated when the forks on the garbage truck impact the dumpster. This study is intended to determine potential noise reduction treatments that can be used on the dumpster to reduce the amount of sound that radiates from the dumpster when impacted. Treatments such as the addition of materials to the fork to reduce the amount of energy imparted to the dumpster are the subject of another study and will not be discussed in this report.

There are three noise reduction treatment methodologies that can possibly be used to reduce dumpster noise. They are:

1. Applying damping material to the dumpster surface
2. Lagging the dumpster surface
3. Stiffening the dumpster surface

Damping the dumpster surface involves applying a damping material directly to the surface that has a very high rate of energy dissipation. Damping materials can come in the form of a limp sheet of material that is glued directly to a surface or in the form of a slurry material that is applied to a surface using a sprayer or trowel, depending on its density. The use of damping material to reduce dumpster noise is considered to be very feasible from a physical standpoint because it can be easily applied to the dumpster and once applied, it can hold up to the elements for long periods. Therefore, the use of damping materials will be considered further in this study.

Lagging the dumpster surface basically involves enclosing the dumpster surface with a mass material that is held off the dumpster by a vibration isolating material. A prefabricated lagging material such as foam laminated to loaded vinyl could be glued directly to the dumpster surface much in the same manner as the damping material. However, unlike damping materials, lagging materials would very likely not hold up to the working environment of the dumpster due to their inability to resist mechanical strain or impact. Therefore, the lagging approach will not be considered further in this study.

Often, when acoustic energy radiates from a surface, it radiates from that surface because the surface is free to vibrate. Stiffening the surface of the dumpster can reduce the amount of surface vibration due to the fact that it raises the resonant frequency of the surface and it reduces the vibrational energy in the surface. Stiffening the surface involves the mechanical application of a structural stiffener (such as a gusset or brace) to the surface of the dumpster. The stiffener could be welded to the surface or attached with a mechanical fastener such as bolts. Since stiffeners can be made from steel materials and they can be welded or bolted to the surface, it is concluded that they would be feasible to use from a physical standpoint. However, as a retrofit approach to achieve a reduction of sound with a particular dumpster, it is expected that the labor cost to make the modifications to the dumpster would make the approach to burdensome and the benefit might still be unacceptable. Therefore stiffening the dumpster surfaces was not considered further in this study.

6. Dumpster Surface Radiation Tests

As stated above, the use of a damping treatment was considered feasible to reduce dumpster radiated noise levels from a physical standpoint. The only thing left to determine would be how much material was needed and where the material should be placed to achieve an acceptable amount of noise reduction. Obviously, the damping treatment would be most effective if the entire dumpster was covered with damping material. However, this would be both prohibitively expensive and wasteful because experience has shown that a relatively high degree of noise reduction can be achieved by treating a smaller percentage of the surface (e.g. 25% or less) if the material is concentrated on areas with a high level of vibration. Thus, the study needed to determine the answers to these two questions before recommendations could be made relative to the use of damping material in reducing dumpster noise.

It is known that the amount of sound radiation from a plate (such as the surface of a dumpster) is directly proportional to the amount of vibration on that plate. Thus it was concluded that to answer the questions of how much material and where the material should be placed, it would be helpful to have a picture of the amount of vibration on the surfaces of the dumpster when the dumpster was impacted. DSA conducted dumpster vibration measurements and the following sections discuss the measurements and the results of the measurements.

6.1. Dumpster Vibration Test Procedure

To conduct the vibration survey, rectangular grid lines were drawn on the front, back and one side of the dumpster with an erasable marker (see Figure 4). A similar grid was drawn on the dumpster bottom (not shown). After the grid system was drawn, the measurement of vibration on the dumpster surfaces was made using the following procedure:

1. At each grid point, the vibration level was measured while three to five hammer blows were imparted to the dumpster on the rear of one of the dumpster lifting channels near the point where the garbage truck fork would normally impact it.
2. For these tests an instrumented test hammer was used with an accelerometer (vibration sensor) as shown in Figure 5.
3. The instrumented hammer was used to trigger the data acquisition, and to allow the response data to be normalized to the measured impact force. This way, the effect of any variation in the striking force could be removed from the picture.

The vibration measurements were conducted with a Dactron Photon dynamic signal analyzer. The back of the dumpster lifting channel was selected as the impact point, because, from the video analysis it was learned that the back end of the lifting channel is one of the main points where the truck forks strike the dumpster when it is jostled during bin emptying.

6.2. Dumpster Vibration Data Analysis

The measured vibration spectrum found at each grid point was normalized to the measured impact force, and then converted to A-weighted octave band vibration velocity levels. Vibration velocity was used rather than acceleration, because it is well known that there is a good correlation between the vibration velocity of a large surface and the sound pressure level radiated by that surface.

To identify the areas on the various dumpster panels with the highest vibration levels, the measured data was plotted in the form of a vibration contour map for each surface. An example of the plots for the 1000 Hz octave band frequency is shown in Figures 6 through 9. Focus is placed on the 1000 Hz band in this report, because the sound in that frequency was found to be a major contributor to the overall sound radiating from the dumpster and damping treatments are known to be very effective at this frequency. Similar plots may be produced for other octave bands as well as for the overall A-weighted sound level.

The colored areas on the plots represent a range of vibration levels in decibels identified in the legend in each plot. The row and column numbers shown in Figures 6 through 9 correspond to the grid numbers shown in Figure 4.

It should be noted that to reduce the level of effort required in the study, advantage was taken of the fact that the dumpster front, back and bottom panels are symmetric about a plane passing through the middle of the bin. Because of this symmetry, the front, back and bottom surfaces could be tested from the side edge of the dumpster to slightly beyond the midline of each panel and the results could be extended to the other side of the dumpster to account for the impact that occurs on the other side during lifting.

7. Investigation of Damping Treatment

7.1. Damping Material

As stated earlier in the discussion about damping materials, damping treatments can consist of a sheet of material or a slurry material that is sprayed or trowel applied to the surface. Because sheet material is typically easier to apply and easier to control than the slurry material, sheet damping material was used in this study. Damping sheets typically consist of a thin (approximately 1/8" thick) sheet of elastomer material that has an adhesive backing for adhering the material to a surface. The material is normally cut into pieces and glued to the surface of the sheet metal.

Using the thickness of the dumpster surfaces and considering the type of damping approach being used (free layer damping instead of constrained layer damping), a damping sheet product made by Blachford Antivibe™ DS was selected from Barrier Corporation's current stock of materials1. Specifications and pricing for this material (Barrier P/N 031332) are included in Appendix A. The sheet had nominal dimensions of 36" wide by 54" long.

1 Barrier Corporation, 9908 SW Tigard St., Tigard, OR 97223

7.2. Damping Material Application

In an attempt to minimize material waste, a sheet of the damping material was cut into patches 9” x 9” square, and some of these patches were cut in half (4-½“x 9”). The 9 inch dimension was chosen simply because 9 was a common factor of 36 and 54, the damping sheet dimensions. Based on the vibration contour graphs, patches of damping material were applied to selected areas on the various panels, beginning with those areas which had the highest vibration levels.

To evaluate the damping treatment, the untreated dumpster was first tested in a large reverberant room, by tapping on the lifting channel impact point with the instrumented hammer and measuring the sound pressure level at a point in the reverberant sound field of the room. The measured sound pressure level was normalized to the measured impact force, again to remove the influence of any variation in the impact force during the test.

Once the data was collected at each grid point for the untreated condition, damping material was applied to the dumpster and the impact test was repeated. Initially, in an attempt to minimize the amount of material used, the material applied was limited to approximately 50% of one full damping sheet. This achieved about a 3 dB reduction in sound level. Next, additional patches were added to bring the total up to about 75% of a full sheet. This achieved a further 1 dB reduction. Finally, additional patches were added incrementally until all pieces from one sheet were applied to the dumpster, and the test results revealed that a 5 dB reduction in overall A-weighted sound level had been achieved.

Although the measurement results showed that a 5 dB reduction had been achieved in the overall A-weighted sound pressure level, the testers agreed that the sound quality had improved much more than what would have been expected with a 5 dB reduction. Therefore, with a 5 dB reduction in sound level and a “noticeable improvement” in sound quality, the decision was made to not add any additional damping materials.

7.3. Detailed Discussion of Damping Treatment Lab Test Results

Figure 10 shows the approximate position of patches of damping material on the bin front back and sides, when the material application was stopped. There was also one patch of material (approximately 6” x 9”) on the center of the bottom panel (not shown). The material applied amounted to approximately 14 square feet. This is equal to about 18% of the bin surface area.

It should be noted that for this development work, the material was applied to the inside of the bin for convenience in testing only. DSA expects that when applied to bins in the field, the damping material would be applied to the outside surfaces of the bin, and would likely have a coat of paint applied over the patches.

As noted above, this damping treatment achieved a 5 dB reduction in the overall A-weighted sound level, and subjectively, a "noticeable improvement" in sound quality of the noise emanating from the dumpster.

Figure 11 shows the A-weighted sound level spectra measured before and after treatment. From Figure 11, it can be seen that the damping treatment made very little difference at low frequencies, provided reductions of 3 to 4 dB in the mid-frequency range, and provided reductions of from 6 to 15 dB at higher frequencies. It is believed that the reduction of higher frequency noise may explain why the subjectively, many people would rate the change in sound as a "very significant improvement", even though the overall dBA level was only reduced by 5dB.

8. Damping Treated Dumpster Field Sound Tests

To evaluate the effectiveness of the applied damping treatment in the field, another set of field tests were conducted with a fork truck at the Waste Management maintenance facility in northeast Portland.

8.1. Sound Test Procedure and Instrumentation

The test procedure and instrumentation used for the post-treated dumpster field sound tests were essentially the same as those used for the pre-treatment tests described earlier. However, a different truck and operator had to be used for the post-treatment tests but it is believed that the influence on the results by the different truck and operator were eliminated by making measurements with the operator lifting an untreated bin followed by his lifting the treated bin.

For these tests, the operator was instructed to pick each bin up, go through the motions of emptying it aggressively (i.e., jostling it at the top as if to dislodge stuck trash), set it down, and then repeat this operation two more times. During each bin test, sound and video was again recorded from a microphone position 50 feet to the side of the bin.

8.2. Test Results

Due to the highly variable nature of how bins are handled from cycle to cycle, it is difficult to compare sound levels from one test to the next. To facilitate this, DSA staff studied the recorded video tape to identify one cycle from each test set where the treated and untreated bins appeared to have been handled in a very similar manner. These cycles were then located in the audio recording, and analyzed to determine their sound levels. In this case, the analysis consisted of playing the recorded sound pressure signal through a sound level meter set to measure A-Weighted sound pressure level with the Fast Time Weight setting (the metric used by the City of Portland noise code). The output from the sound meter was then captured with a digital data acquisition system to produce a chart of A-weighted sound level versus time (a "strip chart").

Figure 12 shows the sound level versus time traces from the above analysis for the untreated and treated bins. Considering the four highest sound level peaks, the average reduction in measured sound level is approximately 4.5 dB. This is very close to the reduction of 5 dB measured in the laboratory.

During the operating test, it was also observed that the subjective improvement in sound quality was significant – probably more significant than one would infer from the decibel reduction alone. For example, when the treated bin was tested immediately after the untreated bin, the truck operator made an unsolicited comment to the effect that the treated bin was significantly quieter.

9. Further Discussion of Damping Material Approach

9.1. Material Cost

As shown in Appendix A, when purchased in quantities of 4 sheets or more, the sheet type damping material used in this study would cost $42.75 per sheet, or $3.17 per square foot. As noted above, exactly one sheet was used to treat a 3-yard dumpster to achieve a 5 dB reduction in the overall A-weighted impact generated noise level. Hence, the material cost of treating a 3-yard bin would be $42.75. Assuming that the amount of material required to treat a 3-yard bin would increase in proportion to the increase in the bin volume, 33% more material would be required to treat a 4-yard bin. Hence, material costs for a 4-yard bin is projected to be about $57.

The estimated labor required to apply the damping material in the field, including (a) determining where to apply the material, (b) applying it, and (c) applying a coat of paint over top of it, is 4 hours for a 3-yard bin and 5 hours for a 4-yard bin. Assuming a labor cost of $15/this amounts to labor costs of $60 and $75 for a 3 and 4-yard bin, respectively. These cost estimates are summarized in Table 1.

Table 1
Cost Estimate of Sheet Damping Treatments for 3 and 4-Yard Bins

	3-Yard Bin	4-Yard Bin
Material required (sq-ft)	13.5	18.0
Labor (hr)	4.0	5.0
Material cost @ $3.17/sq-ft	$42.80	$57.06
Labor cost @ $15/hr	$60.00	$75.00
Total (material + labor)	$102.80	$132.06

9.2. Alternative Damping Materials

Damping sheet materials similar to the product used in this study are available from other manufacturers. One competitive product also carried by Barrier Corporation of Tigard was considered. However, this material was more than twice the cost of the Antivibe DS material used here, and it did not accept and hold paint as well. It is expected that similar results would be obtained with materials of similar properties. For this reason, and the fact that the one alternative considered was more expensive, damping sheet products other Antivibe DS were not tested in this study.

One alternative to the damping *sheets* used in this study is a liquid damping material that is sprayed or troweled on to the surface. Blachford makes two products of this type called Antivibe DL-10 and DL-30. These are viscous, water-based materials that work well in applications with curved or irregular surfaces, and can be painted after they are dry. Relative to the sheet material used in this study, the cost of these materials is in the range of $2.50 to $3.00 per square feet. Although the water-based materials could be used in this application, they are not recommended, for the following reasons:

1. Waste bins have large flat surfaces that sheet materials can easily be applied to.
2. Water-based materials are messier to work with, require a special spray applicator for best results, and would probably involve more wasted material than the sheet material.
3. The sheet material provides better damping performance at temperatures below room temperature.
4. Water-based materials have less resistance to abrasion and are likely to wear off quicker than sheet material.
5. Water-based materials are prone to crack and become less effective if the metal flexes which is likely in the case of the dumpster metal.

9.3. Damping Material Inside Versus Outside Bin

As mentioned above, for this study, most of the damping material was applied inside the bin, simply for convenience in conducting the tests. DSA expects that in the field, the damping material would be applied to the outside of the bin with a coat of paint applied over top. This way, the damping sheet would be less likely to be affected by moisture and abrasion from the trash.

9.4. Amount of Damping Material Needed

As mentioned above, patches of damping material were incrementally added, until a dumpster noise reduction of 5 dB was achieved. Although no direct work was done to determine if this is the most efficient material arrangement, it should be noted that the locations of damping material patches were guided by an extensive vibration response survey. It is possible that less material area could achieve the same reduction found in this study. However, to determine the answer to that question would require additional testing and it is likely that the amount of material could not be reduced significantly without a corresponding loss in performance. Furthermore, at a material cost of less than $50 per bin, it is questionable whether such additional study is worthwhile.

9.5. Extension of this Work to Other Types of Bin

We expect that the configuration of damping materials developed for the 3-yard dumpster in this study would work equally well on other waste bins, provided that they are not radically different in size or structural design. If the bins are significantly different in size, stiffness, or mass distribution, it is quite possible that the layout developed here would be less than optimum. This could only be determined by additional tests. However, with the test methodology having been developed here, the effort (and corresponding cost) involved should be reasonable.

10. Conclusions

This project confirmed that it is feasible to achieve a significant reduction in dumpster radiated noise by adding a simple damping treatment that can be installed in the field. As described above, a 5 dB reduction in noise was achieved in the laboratory, and a 4 to 5 dB reduction was measured during field demonstrations. Furthermore, the damping treatment changed the nature of the sound radiated from the dumpster in such a way that most people would judge it to be “a significant improvement”.

Appendix A - Specifications and Pricing of Damping Sheet Material Used

BARRIER NOISE AND THERMAL CONTROL MATERIALS

SPECIFICATIONS: DAMPING SHEET

PRODUCT NUMBER: 031331 - .050″ thick

031332 - .125″ thick

A damping treatment for the dissipation of mechanical energy associated with vibration. Damping sheet can significantly reduce noise if applied to a relatively thin metal structure that is excited by vibration or airborne sound. Damping sheet is supplied with a pressure sensitive adhesive, which is protected by a release liner.

Typical Properties:

Color:	Black
Solid Content:	100%
Density, g./c.c.	1.75
Thermal Conductivity BTU in./(hr.sq.ft. degrees F.):	2.1
Hardness, Shore D	52

Standard Sheet	031331	46″ x 54″
	031332	36″ x 54″
Weight: lbs./sq.ft.		
	031331	. 45
	031332	1.1

Flammability:	Meets MVSS-302

Resistance To:

Diesel fuel	Very Good
Mineral spirits	Very Good
Lubricating oil	Very Good
Gasoline	Poor
Toluene	Poor
Methanol	Fair
Water	Excellent

BARRIER NOISE AND THERMAL CONTROL MATERIALS

SPECIFICATIONS: DAMPING SHEET

PRODUCT NUMBER: 031331 - .050" thick X 46" X 54"

031332 - .125" thick X 36" X 54"

	QUANTITY	PRICE/SHEET
P/N 031331 .050" thick	1 SHEET	$38.66
	2-3 SHEETS	$35.66
	4+ SHEETS	$33.66

	QUANTITY	PRICE/SHEET
P/N 031332 .125" thick	1 SHEET	$47.75
	2-3 SHEETS	$44.75
	4+ SHEETS	$42.75

Figure 1
Operating Test - 3 Yard Untreated Bin
Sound Level at 50 Feet During Simulation of Bin Dump
Normal Emptying of Bin (Bin 1, Test 1)

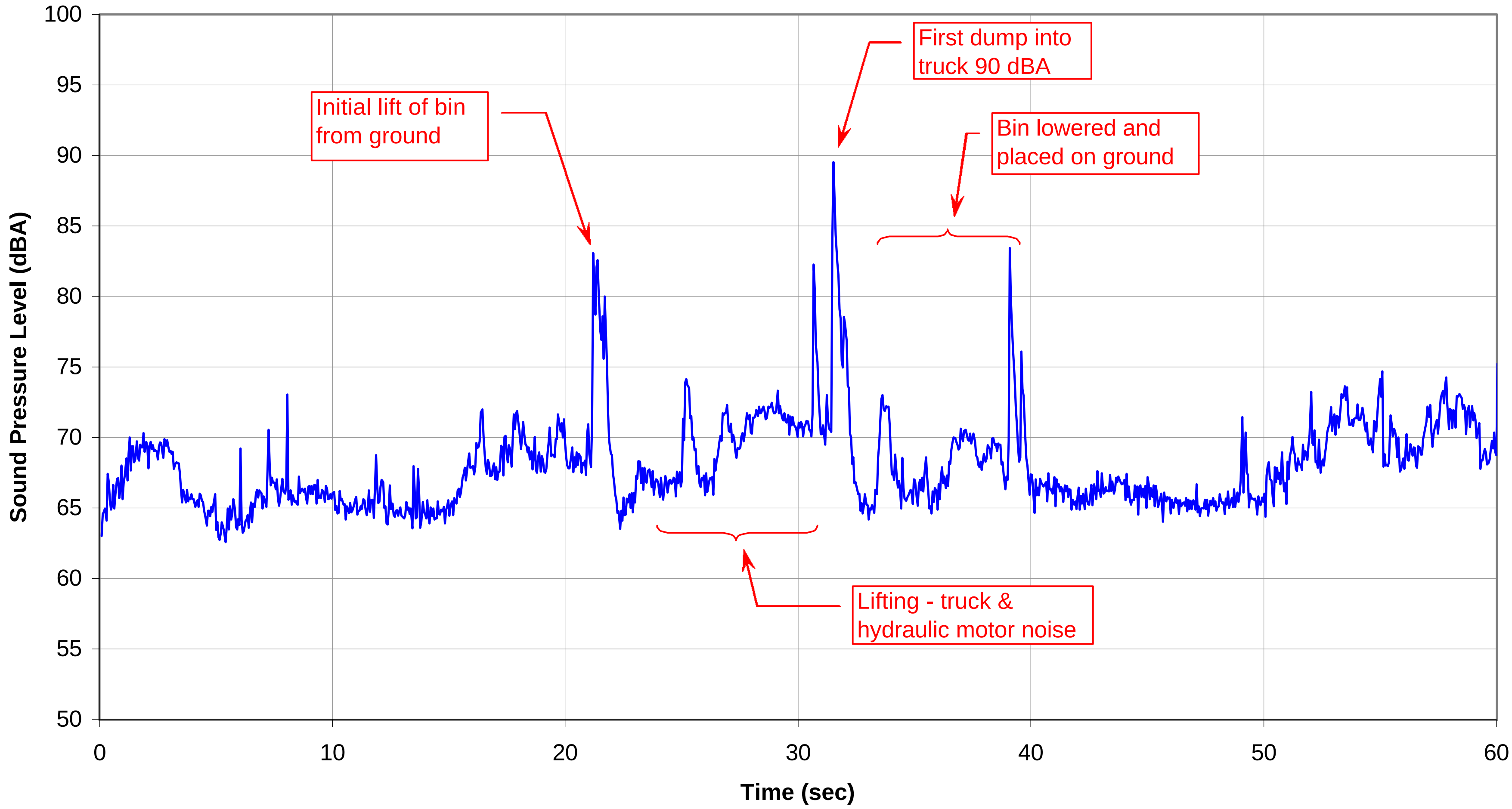


Figure 2
Operating Test - 3 Yard Untreated Bin
Sound Level at 50 Feet During Simulation of Bin Dump
More Aggressive Emptying of (Bin 1, Test 5)

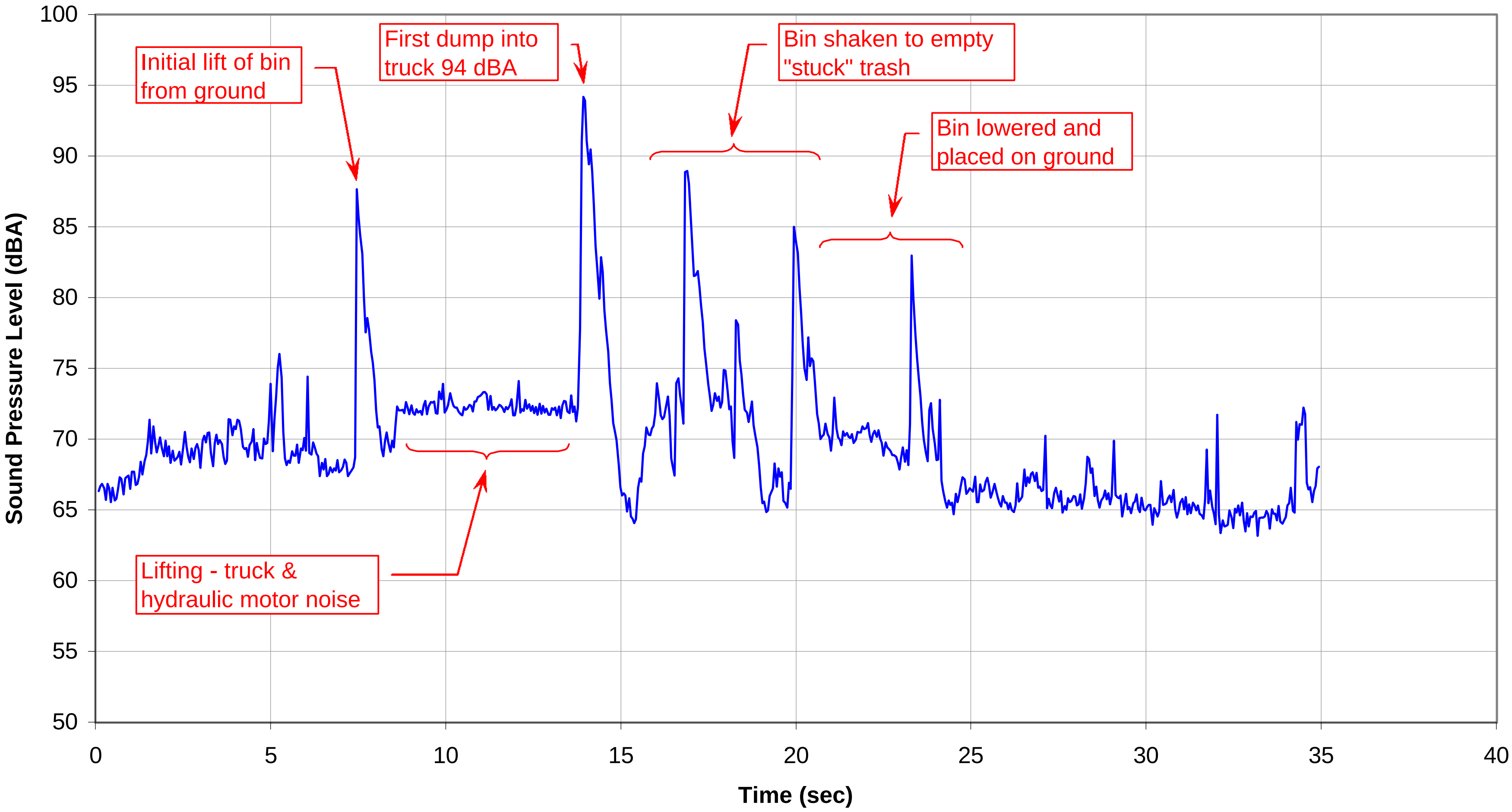
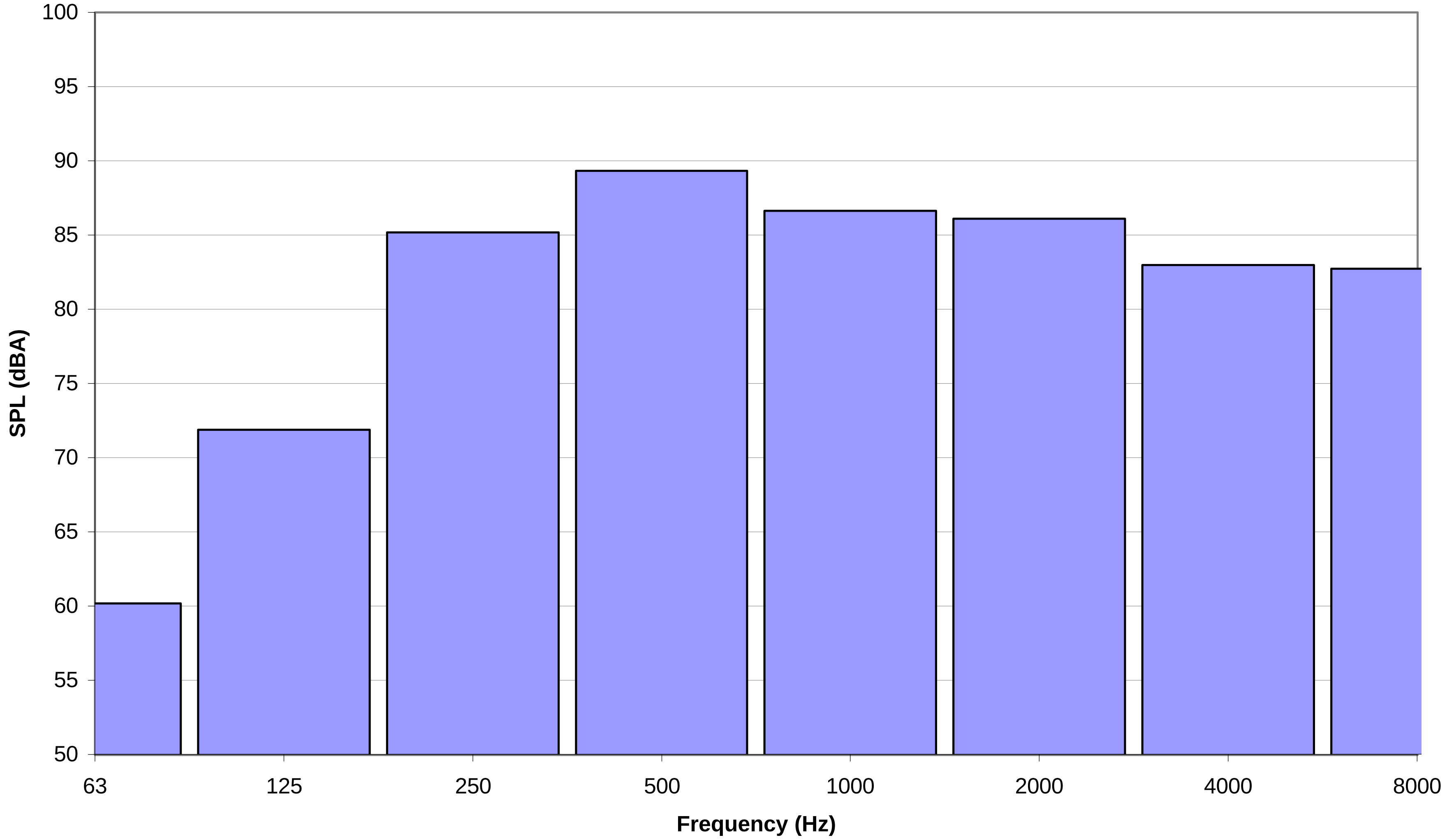


Figure 3
Bin 1, Test 5: A-Weighted Spectrum at Instant of Maximum SPL (93.9 dBA)



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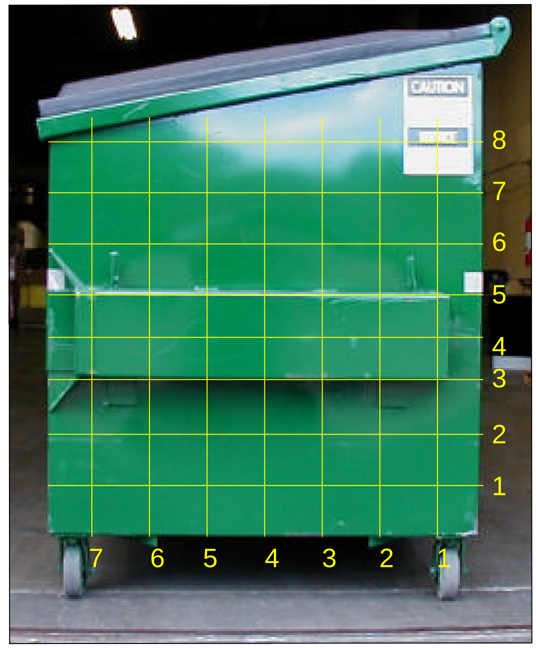

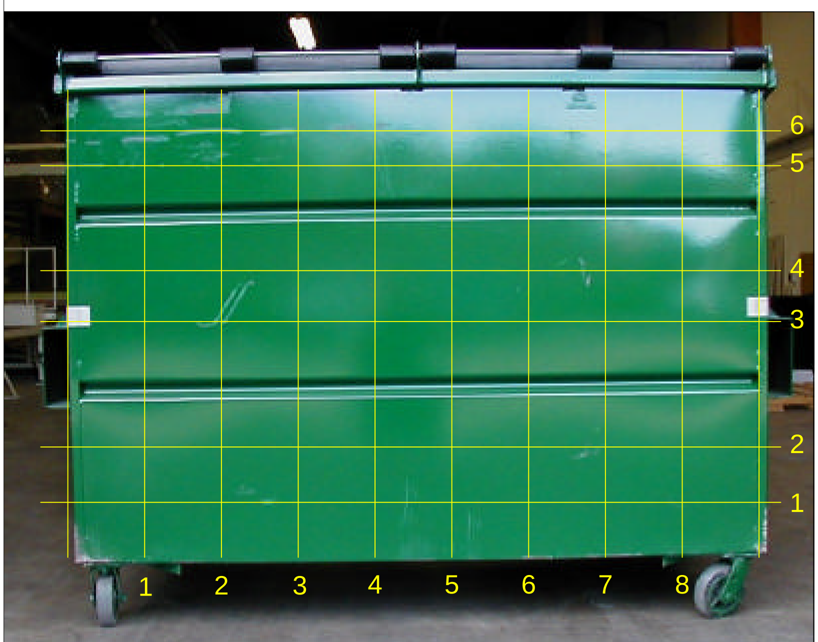

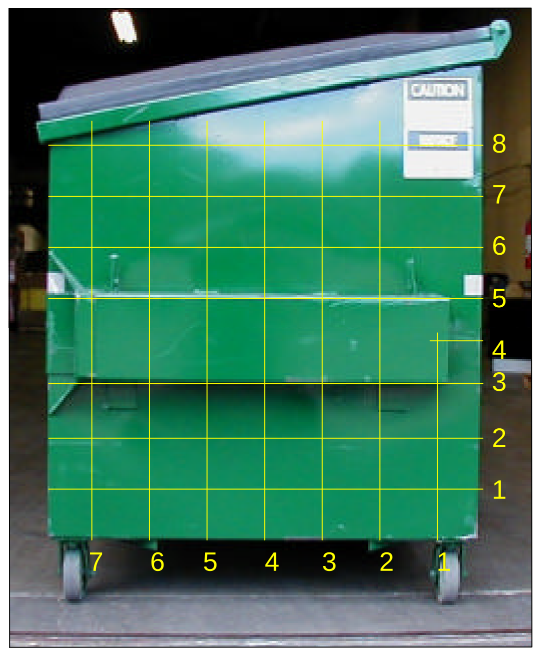

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Waste bin impact response test grid.

DESIGNED BY:	DRAWN BY:	DATE: APRIL 2002	PROJECT NO. 101021	FIGURE 4

140031-grid.dwg

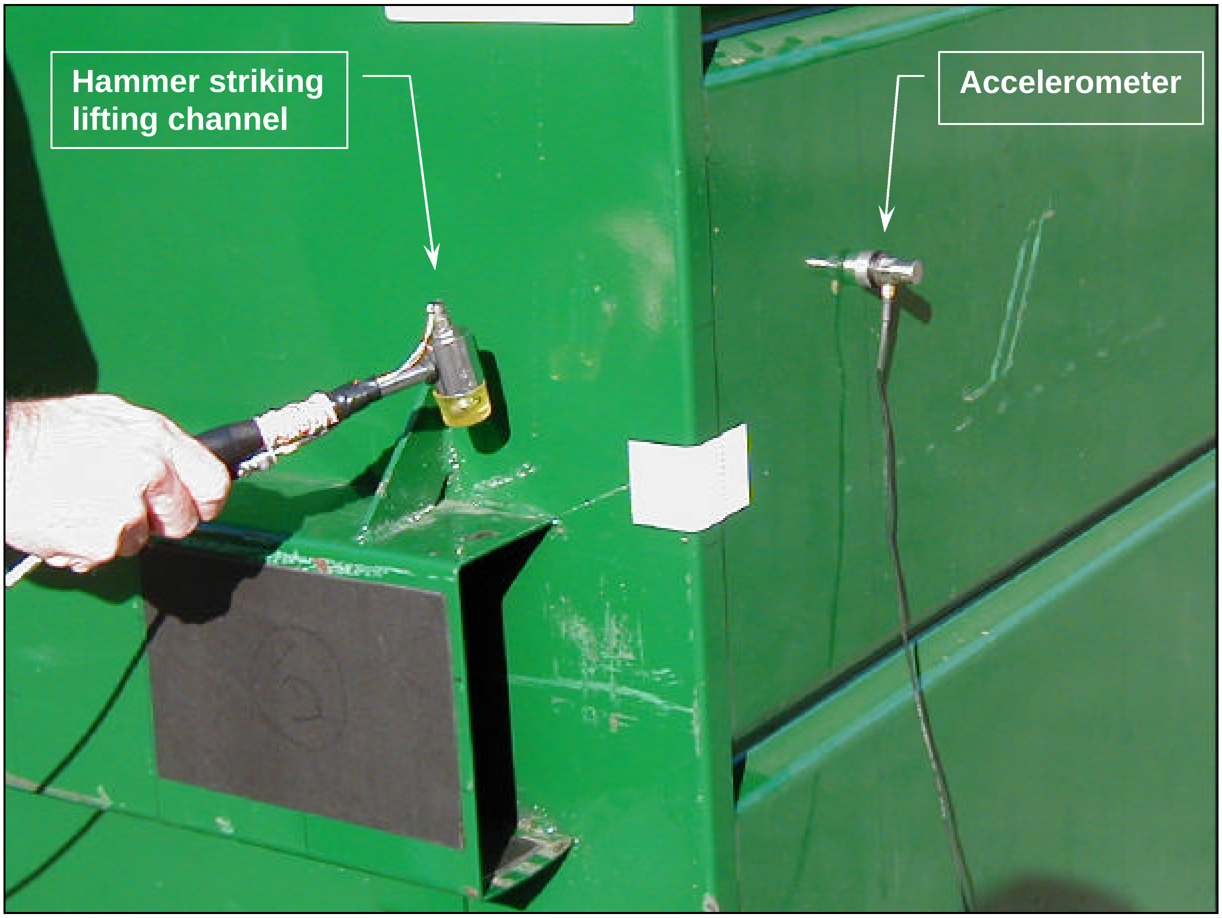


Figure 5. Instrumented hammer and accelerometer.

Figure 6

Front Panel - Normalized A-Wt Velocity 1000 Hz

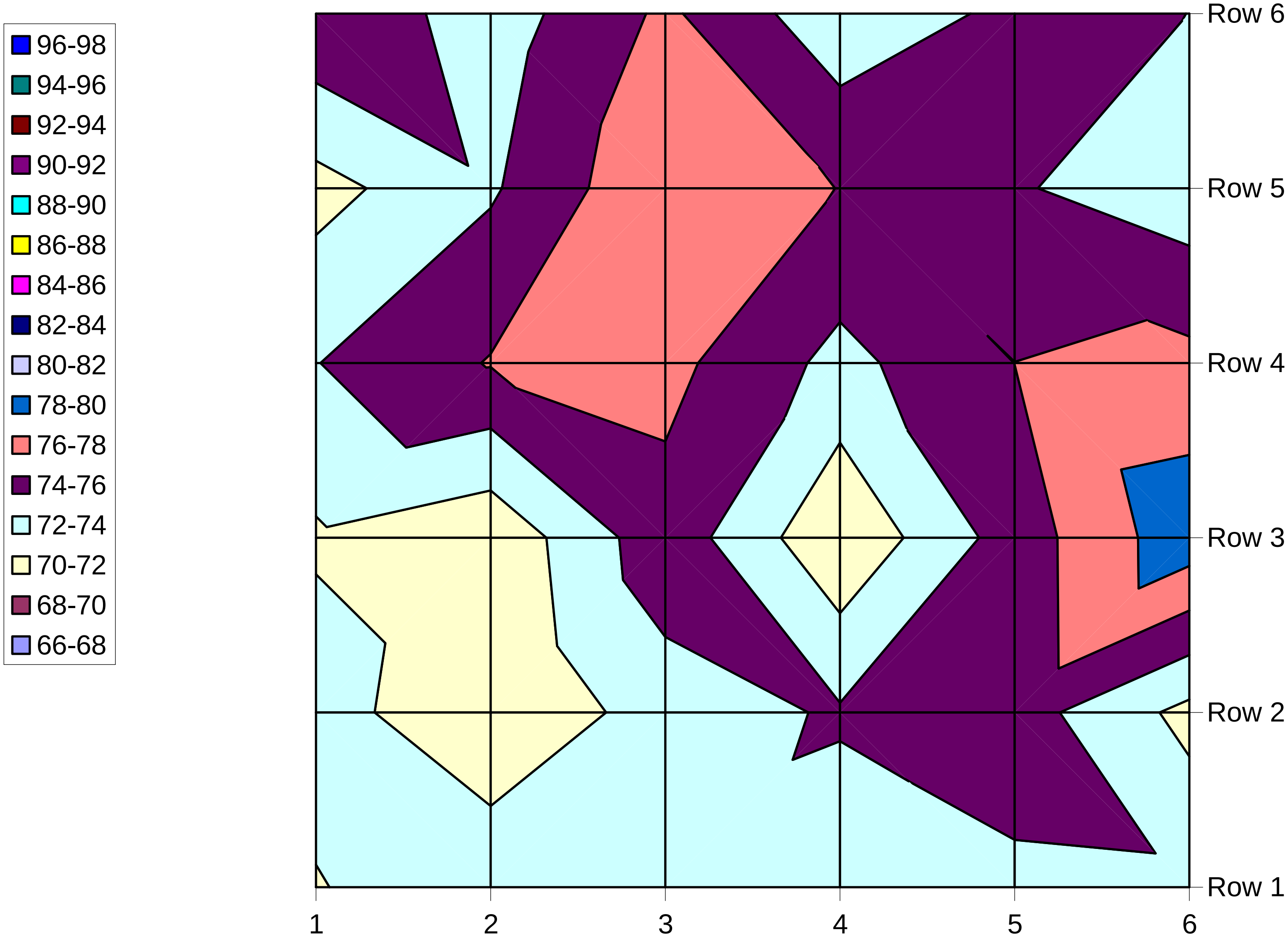


Figure 7

Back Panel - Normalized A-Wt Velocity 1000 Hz

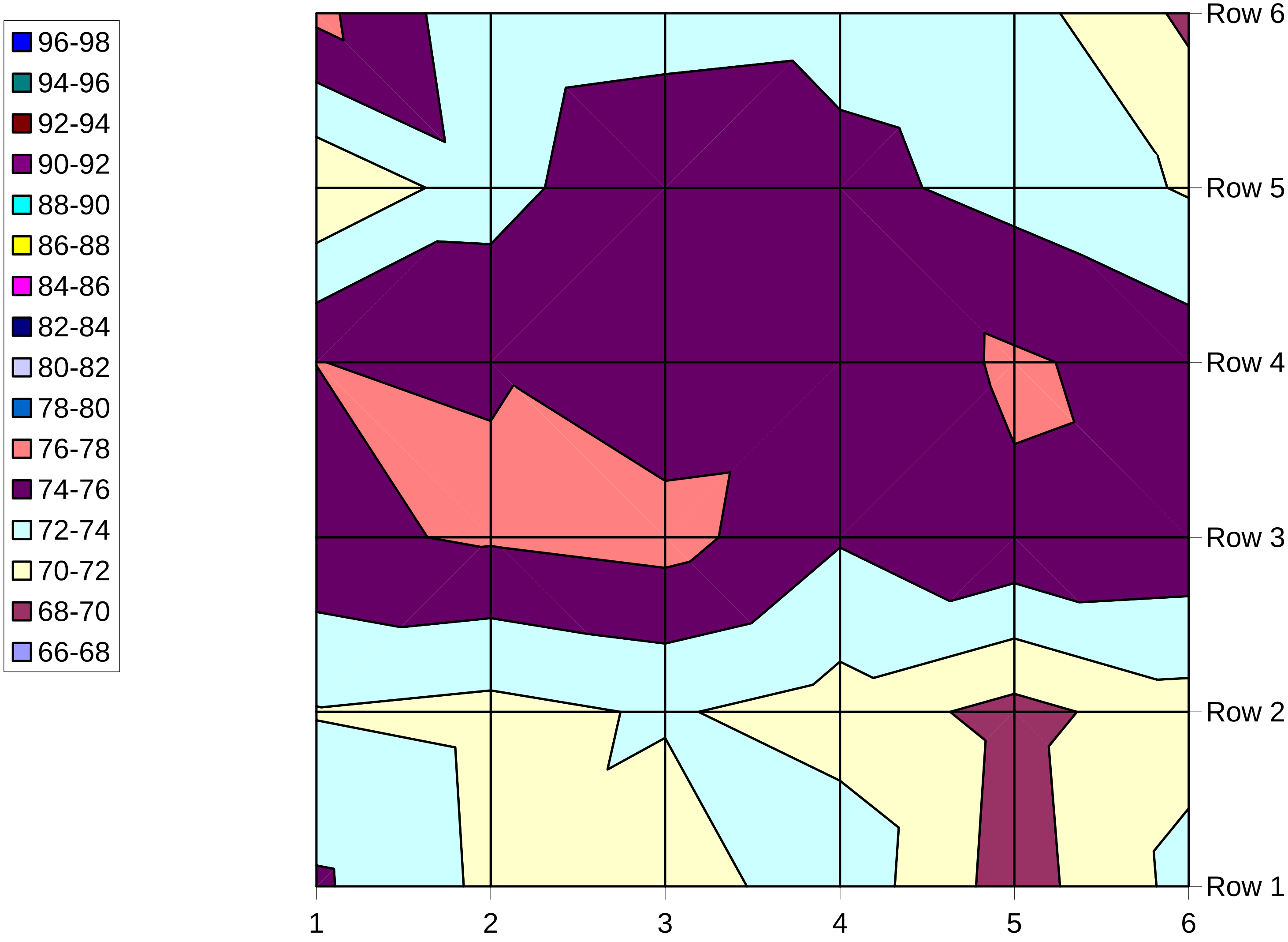


Figure 8

Side Panel - Normalized A-Wt Velocity 1000 Hz

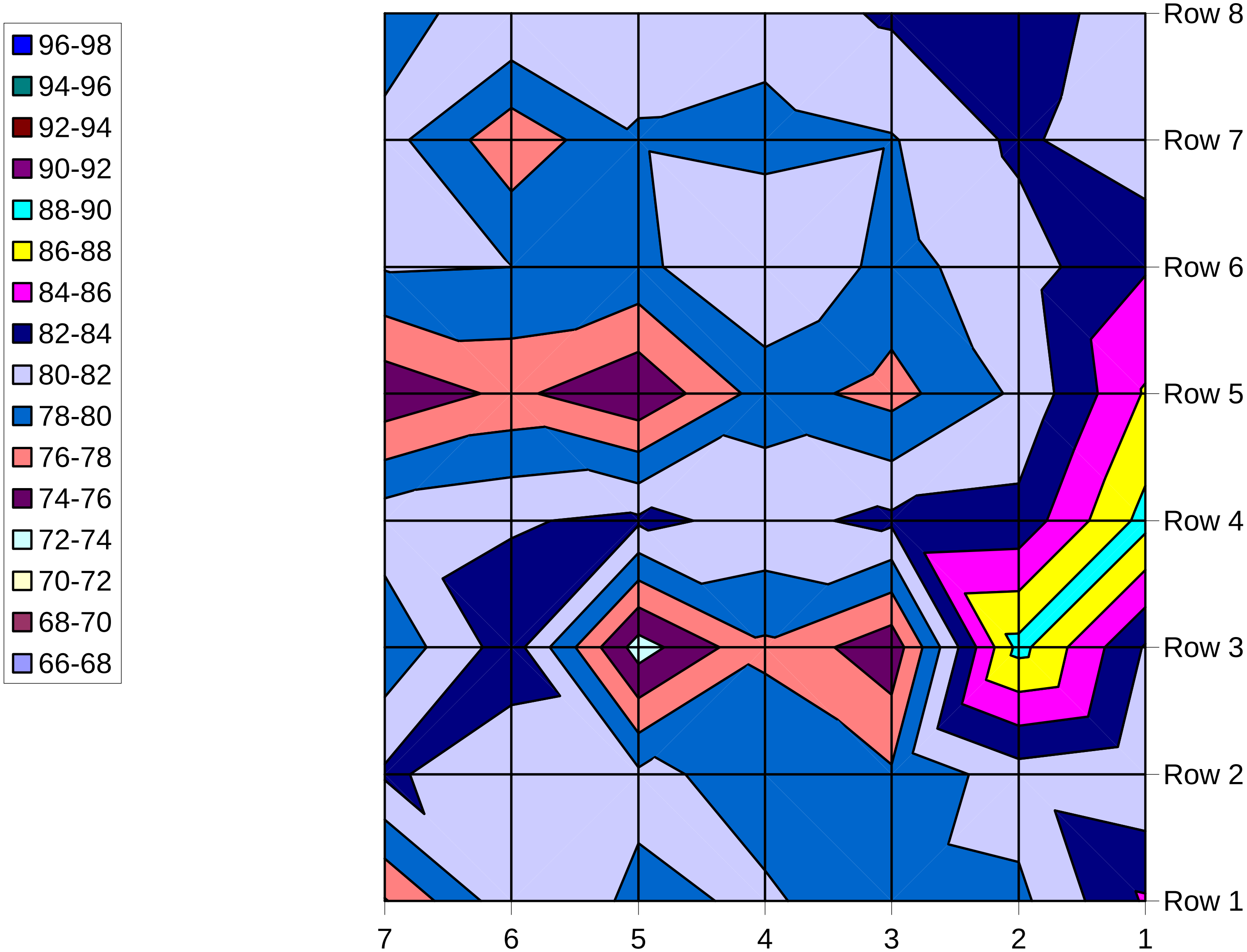
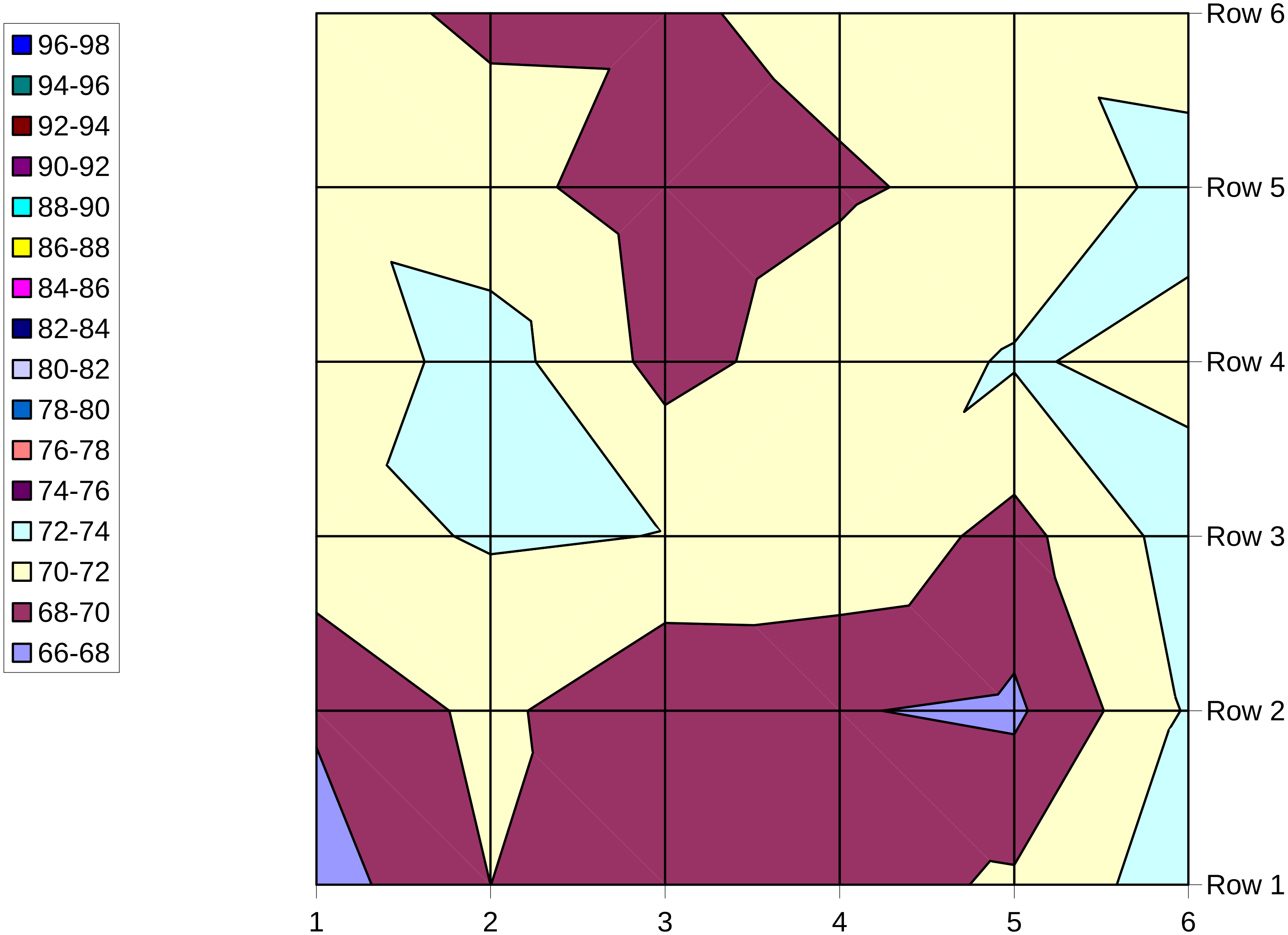
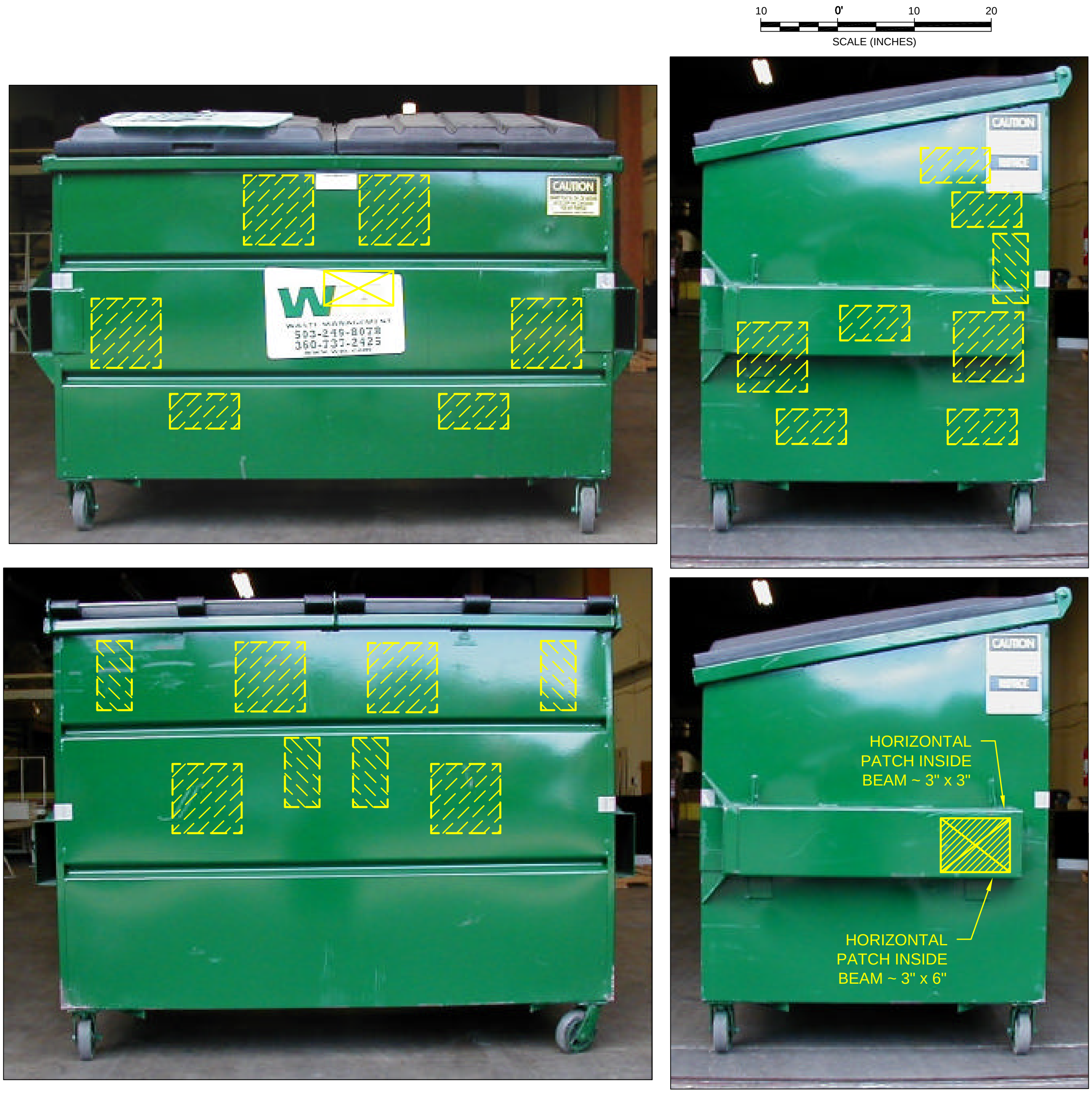


Figure 9

Bottom Panel - Normalized A-Wt Velocity 1000 Hz





Daly-Standlee & Associates, Inc.

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email: DSA@acoustechgroup.com

Waste bin - areas trated with damping sheet (patches were generally 9" x 9" or 4-$\frac{1}{2}$" x 9"). Dashed lines indicate patches on inside surface

DESIGNED BY:	DRAWN BY:	DATE:	PROJECT NO.	
		OCTOBER 2003	140031	FIGURE 10

140031-grid.dwg

Figure 11
Sound Spectrum Due to Bin Impact in Reverberant Room

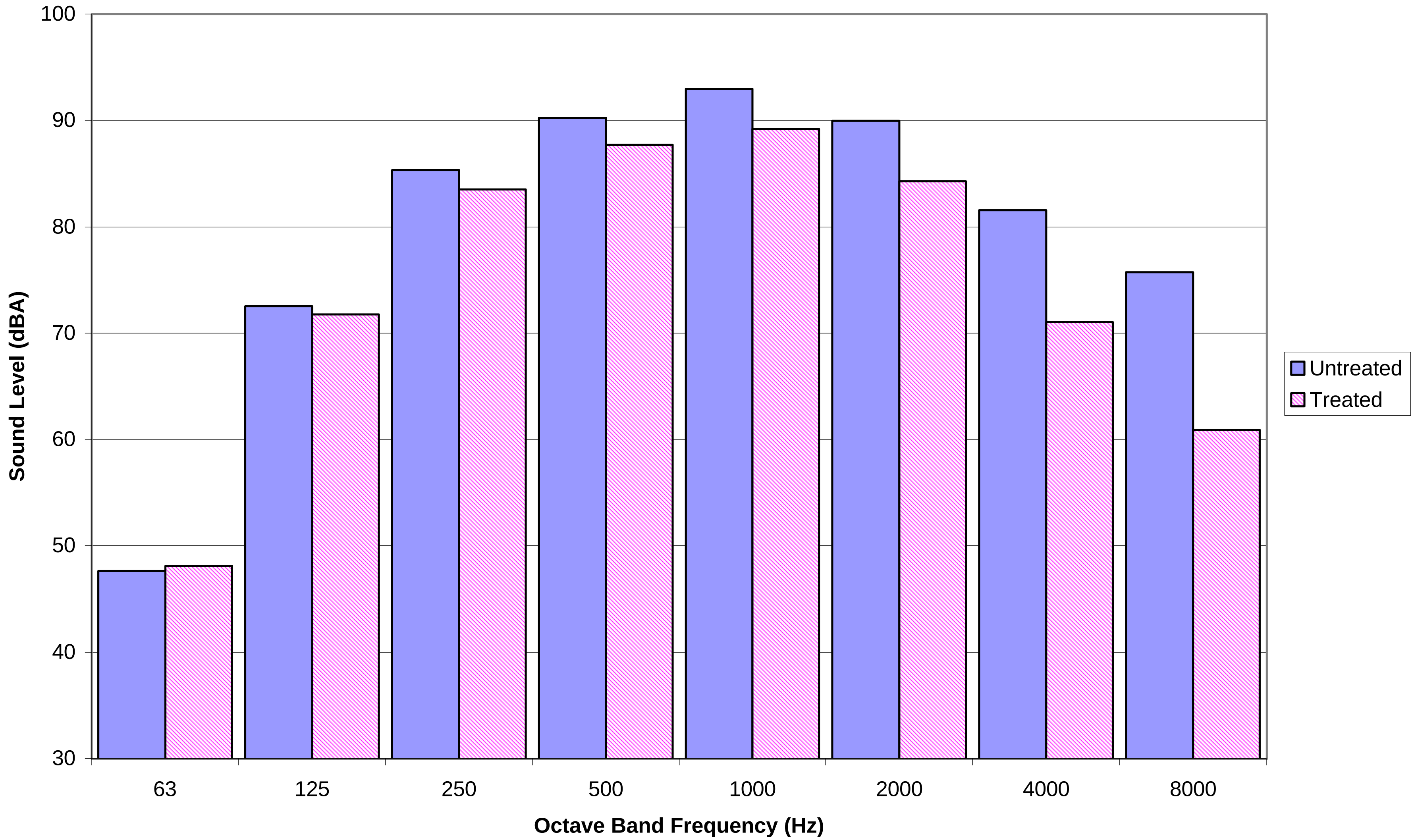

Figure 12
A-weighted Fast Sound Pressure Level VS Time
During Comparable Bin Dumps (Forks at Highest Position Above Truck)