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*Report on:*

# Investigation of Garbage Truck Fork Noise Control Treatment

*Prepared for:*

City of Portland
Office of Neighborhood Involvement
Office of Sustainable Development

c/o Mr. Paul VanOrden
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DSA Project #: 140031

December 9, 2003

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## Executive Summary


An investigation was conducted to determine a UHMW treatment design that could be used on the forks of front loading garbage trucks to economically reduce noise generated during the lifting and dumping of front loaded garbage dumpsters. The results of the investigation indicate that a fork sleeve design has a high potential of providing a long lasting UHMW treatment to the forks at a cost of approximately $170 to $180 per truck.

The amount of noise reduction provided by the fork treatment is not as much as that provided by dumpster damping treatment discussed in a November 19, 2003 report entitled, “Investigation of Dumpster Noise Controls”, by Daly-Standlee & Associates, Inc. However, when taken in combination with the damping treatment, it appears the fork treatment can help further reduce the number of impulsive noises generated during the dumping cycle.

Long term testing of the UHMW fork sleeve treatment has not occurred in the field at this time and it is recommended that a final evaluation of the treatment be postponed until the treatment has been sufficiently tested by a garbage hauling company. At that time a final decision can be made as to the viability of fork treatment as a noise reduction measure in reducing garbage collection noise in the City of Portland.

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## 1. Introduction

Nighttime noise created during the collection of garbage from 1 to 4 yard dumpsters by front loading garbage trucks was identified as a major concern of citizens during hearings held by the City of Portland Noise Control Task Force and the City of Portland Noise Review Board. In an effort to address the issue of nighttime garbage collection 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 interaction between the forks on front loading garbage trucks and the dumpsters serviced by those trucks and to determine a fork treatment that could economically reduce garbage collection noise. A study was conducted by Daly-Standlee & Associates, Inc. and this report presents the findings of the study and the conclusions drawn from the study.

## 2. Scope of Work

As a part of the contract document, DSA was asked to:

1. Review the design of mitigation treatment used on the front loading forks of garbage trucks tested by the City and found to fail too quickly to be cost effective.
2. Redesign the fork treatment with a focus on both the cost effectiveness and maximum sound reduction provided by the treatment.

## 3. Fork Design

The forks used on front loading garbage trucks tend to vary by truck manufacturer. Some manufacturers use forks that are generally rectangular in shape with the horizontal cross section of the fork being smaller in dimension than the vertical cross section (see Figure 1). Other manufacturers use forks that are more square in shape such that the horizontal and vertical cross sections are more alike (see Figure 2). On all trucks owned by Waste Management (the garbage hauling company that agreed to assist in the study) the forks are tapered along the bottom from the base of the forks (the point where they connect to the truck) to the tip of the forks such that the forks' vertical dimension is constantly changing along their length. The fork width remains constant along the length of the forks on any particular truck but the width of the forks may vary from manufacturer to manufacturer. And in some instances, the width of the forks on one truck made by a manufacturer may be different from those found on another truck made by the same manufacturer.

Because the study being conducted by Daly-Standlee & Associates, Inc. was intended to be an investigation of the concept of fork treatment rather than to define the "one-size fits all" design for all trucks, it was decided that the investigation would focus on the fork design used on the trucks most recently purchased by

Waste Management. Those forks are rectangular in shape with a taper included along the bottom surface of the forks (see Figure 1).

# 4. Fork Treatment Design

In December 2000 and December 2001, Mr. Paul van Orden, the City of Portland Noise Control Officer, and Mr. Lee Barrett from the City of Portland's Office of Sustainable Development measured the sound generated during the collection of garbage in the City by a front loading garbage truck. In December, 2000, the garbage truck operated with its original equipment but in December 2001, the garbage truck had the top and bottom surfaces of its forks treated with an Ultra-high Molecular Weight (UHMW) plastic. The results of those measurements indicated that the noise generated by the interaction of the forks and the dumpster during the lifting and dumping cycle could be noticeably reduced if the metal to metal contact was eliminated when the forks lifted the dumpsters.

The UHMW treatment was left on the forks of the test truck after the single night of testing in December of 2001 but according to the truck's owner, the material did not hold up to the severe working environment due to the way in which the material had to be attached to the forks. Because the treatment of the forks seemed to have the potential of reducing noise generated during the lifting and dumping of garbage from front loaded dumpsters, the City requested that a study be conducted to determine a fork treatment design that would be cost effective for the industry. Thus, the study looked at the UHMW treatment approach used by Mr. van Orden and how the attachment method could be modified to improve its resistance to damage during normal use in the field.

## 4.1. The Production of Dumpster Lifting Noise

During the initial phase of testing in the dumpster treatment study also being conducted by Daly-Standlee & Associates, Inc., it was noted that much of the noise generated during the lifting of a 3 yard dumpster was the result of metal near the tip of the fork impacting against the metal of the dumpster pocket near the back of the dumpster. This finding was observed to be due to the fact that the dumpster tended to pivot over the base of the fork when it was up in the air and with the tapered fork being smallest at its tip, there was more room between the fork and the dumpster pocket at its tip than there was at its base. Thus, when the dumpster would pivot back and forth on the fork, it would strike the tip of the fork harder than any other place along its length. Consequently, it was concluded that the fork treatment design basically had to insure that the fork treatment remained located where the impact was greatest and that the total length of the fork may not need treatment.

## 4.2. The Modified Fork Treatment Design

The original fork treatment tested by Mr. van Orden included a thin strip of UHMW material attached to each fork in such a way that the material was actually folded around the tip of the fork. The material was banded to the fork along its length with metal bands in an effort to mechanically fasten the material to the fork. With this design, the portion of the UHMW strip curved around the tip of the fork could be subjected to impacts by relatively thin, sharp edges of steel when the truck driver tried to insert the forks into the dumpster pocket and missed. Since the portion of the UHMW material at the tip would not any metal material immediately behind it for support, it could be broken by the impact with an edge of the dumpster pocket or it could be caught and pulled on by any corner of the dumpster. With the material being mechanically fastened to the fork with only metal bands, it could be easily ripped off the fork or the bands could be broken if subjected to high stresses. Thus, to eliminate some of the potential problems found with the original treatment design, it was decided that the design should include a way in which the UHMW material could completely surround the fork instead of being strapped to the top and bottom surface and that this would allow the material to be bolted to the fork and provide a much stronger mechanical means of attachment than that used in the original design.

Since the dumpster treatment study involved the treatment for a 3 or 4 yard dumpster, it was decided that the new fork treatment design would first address the 3 and 4 yard dumpsters. If modifications to that design were needed for other size dumpsters, those could occur once the prototype design was complete and tested.

Measurements were made of the forks on the prototype design vehicle and measurements were made of the pockets on a 3 yard dumpster. Those measurements were then used to determine the dimensions of a UHMW sleeve that could fit over the fork and be positioned such that the material spanned across the point where the edge of the dumpster pocket would impact the fork during a lifting cycle. To help minimize cost, it was decided that the sleeve would be limited to 6 inches in length but that the length could be modified if it was found to be beneficial. Finally, to help the operator during the insertion of the treated fork into the dumpster pocket, it was decided that the front edge of the sleeve should be beveled back. This would reduce the potential of catching the edge of the sleeve on the edge of the dumpster and applying more force on the bolts than necessary.

Figure 3 shows the prototype sleeve developed for the study.

## 5. Testing of Fork Sleeve Prototype

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

### 5.1. Sound Test Procedure and Instrumentation

For these measurements, two empty dumpsters were used; an untreated 3 yard dumpster and the 3 yard dumpster treated with damping material during the dumpster treatment study. To make the measurements, the two bins were placed in a relatively open area in the maintenance yard at the site. The truck operator was asked to first engage the treated dumpster with the treated forks and go through a lifting, dumping and lowering cycle three times. The operator was then asked to engage the untreated dumpster with the treated forks and again go through the lifting, dumping and lowering cycle three times. After the treated forks were used to handle a treated dumpster and an untreated dumpster, the operator was asked to remove the fork treatment and repeat the lifting, dumping and lowering cycles again. The operator was asked to lift and simulate a dump using what he considered to be a normal level of dumping effort and then to do the same series using what he considered to be a more aggressive dumping effort.

During the dumpster dumping tests, the sound level was recorded continuously from a point 50 feet to the side of the dumpster as the garbage truck operator simulated the cycles. The sound recording equipment consisted of an ANSI compliant Type 1 sound level meter connected to a computer-based dynamic signal analyzer system. The microphone was located 5 feet from the ground at the measurement location. 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.

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.

The computer-based signal analyzer system was also used to playback and analyze the recorded data later in the lab. The recorded data was played back through an audio amplifier system for the purpose of listening to different segments and the analysis software was used to conduct spectral analysis of segments of the recording, as well as to plot sound levels versus time. To generate the time histories, the recorded sound was played back through a sound level meter set to measure the A-weighted sound pressure level through the “fast” meter response network. The DC output from the sound meter was then captured with a digital data acquisition system to produce a chart of the A-weighted sound level versus time (a “strip chart”).

### 5.2. Test Results

It should be noted that the truck operator for the field tests was a shop mechanic and not a regular driver and the mechanic was not as experienced at operating the hydraulic levers in a manner that provided a smooth movement from the ground to the dumping position and back down. Therefore, the handling of the dumpsters during the simulated dumping cycles was not very consistent during the test.

Due to the highly variable nature of how the dumpsters were handled from cycle to cycle during the fork treatment tests, it is difficult to compare sound levels from one test to the next. Figures 4 through 7 show the A-weighted sound pressure levels as a function of time for the "aggressive" dumping tests on the un-damped dumpster and the damped dumpster. As can be seen in the data, there is a large variation in the peak sound levels generated from one cycle to the next during a series of three cycles. In addition, there is often a difference in how long it took the operator to lift the dumpster, go through the dumping motion and place it back down on the ground because he often had to make so many extraneous movements in lifting and lowering the dumpster (see Figure 8 for example). Often, those movements were made with a sudden jerky motion causing even more noise to be generated than was made in a previous cycle or than would normally be made if an experienced driver was operating the equipment. Thus, without knowing how much force was imparted from the forks to the dumpster each time they impacted the dumpster, it is difficult to know which peak in one simulated dump cycle to compare with a peak in another simulated dump cycle.

Because of the problem with evaluating individual pulses that occurred within the data, it was decided that it would be best to see if any trends could be seen in the data that could provide any indication of the effect of the fork treatment. To do this, DSA staff studied the recorded video tape to determine those parts of each lift cycle that were a result of the operator's inexperience with operating the controls. Those parts of the data were then excluded from the data set to develop what was considered more consistent data for the lift and dump cycle. The cleaned-up data for each of the four dumpster/fork treatments were then analyzed to determine the sound level exceeded during the cycle 1%, 2%, and so forth, up to 20% of the time. The results of that analysis were then plotted for each dumpster/fork treatment condition to allow a direct comparison of each result. Figure 9 shows the sound levels exceeded the various percentages of time during each of the four test conditions.

The results of the analysis indicate the UHMW fork treatment tends to reduce the maximum noise levels generated during the dumping cycle by 1 to 2 dB which is not a significant amount of reduction. However, it is believed that the measurement results shown in Figures 4 through 7 shows that with the fork treatment, there were fewer times when higher noise levels were generated. While a 2 dB reduction is not a significant amount of noise reduction, it is believed that the total effectiveness of the fork treatment can be seen in how the treatment reduces the number of spikes generated during the dumping cycle. During the test of the untreated dumpster, the untreated forks often caused a loud bang even when the dumpster was being lifted and lowered. There were fewer times when the forks caused extraneous bangs when they were treated with the fork sleeves.

## *6. Fork Sleeve Costs*

The UHMW material used to make the prototype fork treatment was relatively inexpensive; $26.00 for the material needed to make two prototype fork sleeves. However, the material had to be tooled to match the shape of the fork and the cost for that fabrication increased the cost of the treatment to approximately $120.00 per truck.

Fabrication of the prototype fork sleeves for the field tests was handled by Applied Plastics of Portland and according to Mr. Dan Course of that firm, the cost of two fork sleeves for each truck (material and fabrication cost) could be reduced to approximately $60.00 per pair if 50 or more pairs were ordered. With 100 pairs, the cost could be reduced to around $55.00 per set. The final cost to treat each fork on a truck will depend on the amount of material ultimately needed on the fork and the final design of the treatment for the various fork shapes. However, for the rectangular forks on the truck used in the field tests, it is estimated that the treatment costs to allow the forks to handle all sizes of dumpsters will be about 2.1 time that expected for one set of sleeves (there is a 10% increase in the cost for the second set of sleeves because the fork height is larger where the second sleeves are needed thus requiring the use of a larger piece of material. Thus, the final cost per truck is expected to be in the range of $125 to $135 per truck.

The time required to install the fork sleeves on a truck is estimated to be approximately 3 hours once the sleeves are delivered to the shop. Assuming a labor cost of $15/this amounts to labor costs of $45 per truck. Therefore, the total cost per truck for material and labor is estimated to be $170 to $180 per truck.

## 7. Additional Information Regarding Results of Fork Treatment Data

During the time the tests were conducted at Waste Management's maintenance shop on the fork sleeve prototype, the truck operator was asked to operate the truck in a fashion that he though might be considered a normal dump cycle in the field. During most of those events, the sound levels generated by the fork/dumpster interaction were significantly lower than those generated during the "aggressive dump" cycle. For instance, when the treated dumpster was lifted with the treated fork, sound generated by the forks impacting the dumpster was, at times, only 4 to 5 dB above the sound level created by the truck engine (see Figure 10). However, at times, because of jerky maneuverings by the operator, noise levels were generated as high as those generated during the aggressive cycle and the data became even less reliable in assessing the performance of the fork treatment. Therefore, the evaluation of the fork treatment was made using the louder noise levels rather than the quieter noise levels typically found with normal dumping conditions.

Long term testing of the UHMW sleeves on the forks has not occurred at this time. It is recommended that final decisions regarding the acceptability of the sleeve design be delayed until there has been sufficient time to have a hauler use them in the field and see if problems develop that have not been foreseen at this time.

## 8. Conclusions

This project has developed a UHMW fork treatment design that appears to be feasible to assist in reducing the noise generated during the dumping of front loaded dumpsters in the City. The UHMW fork treatment does not appear to significantly reduce the maximum noise levels caused by heavy pulses of the dumpster by the forks but there does seem to be fewer times when high pulses are created with the fork treatment.

It is recommended that further testing of the fork sleeve design be conducted with loaded dumpsters to determine the longevity of the design and determine if the acoustic benefit of the design changes with actual use before a final evaluation of the treatment is made.


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## Photos of Rectangular Garbage Truck Forks

| DESIGNED BY: | DRAWN BY: | DATE: | PROJECT NO. | |
|---|---|---|---|---|
| KGS | | DECEMBER 2002 | 140031 | FIGURE 1 |

140031–Fork–F1.dwg


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## Photos of Square Garbage Truck Forks

| DESIGNED BY: | DRAWN BY: | DATE: | PROJECT NO. | |
|---|---|---|---|---|
| KGS | | DECEMBER 2002 | 140031 | FIGURE 2 |

140031-Fork-F2.dwg

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Fork Sleeve Prototype

| DESIGNED BY: | DRAWN BY: | DATE: | PROJECT NO. | |
|---|---|---|---|---|
| KGS | | DECEMBER 2002 | 140031 | FIGURE 3 |

140031-Fork-F5.dwg

**Figure 4**
**Field Test of Fork Treatment**
**Sound Level Meter at 50 ft. During Simulation of Aggressive Dumpster Dump**
**Untreated Fork - Untreated Dumpster**

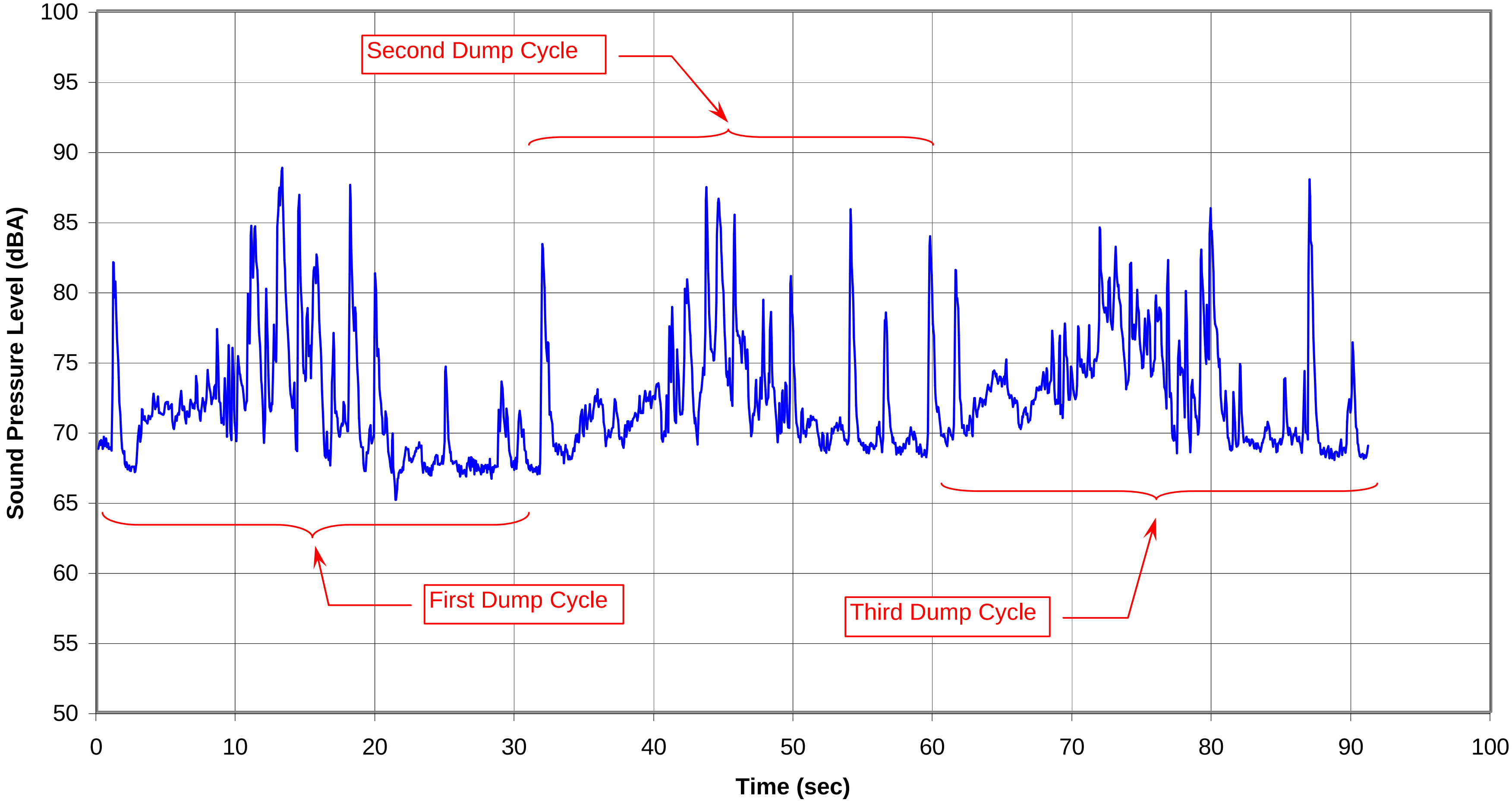

**Figure 5**
**Field Test of Fork Treatment**
**Sound Level Meter at 50 ft. During Simulation of Aggressive Dumpster Dump**
**Untreated Fork - Treated Dumpster**

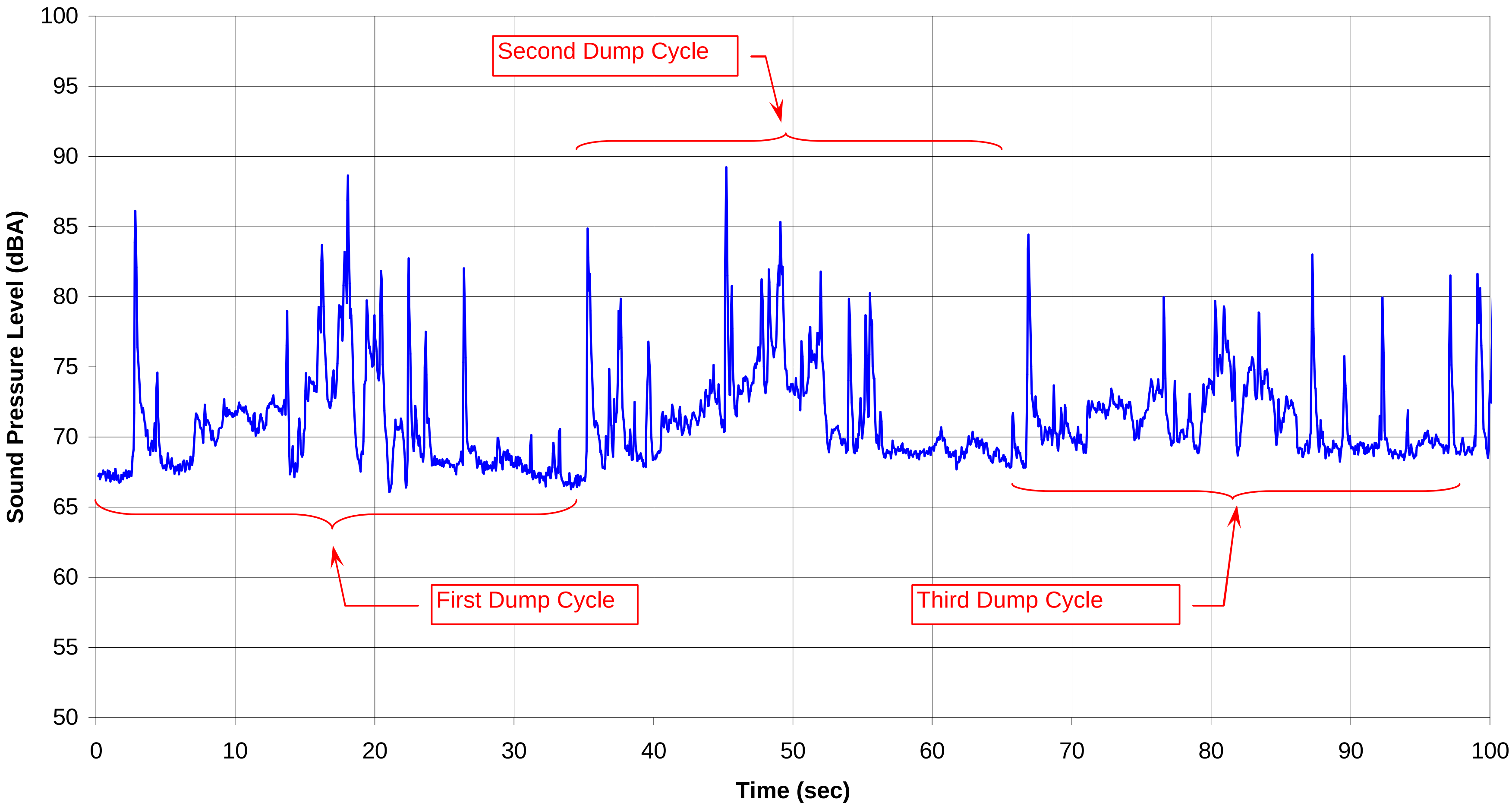

**Figure 6**
**Field Test of Fork Treatment**
**Sound Level Meter at 50 ft. During Simulation of Aggressive Dumpster Dump**
**Treated Fork - Untreated Dumpster**

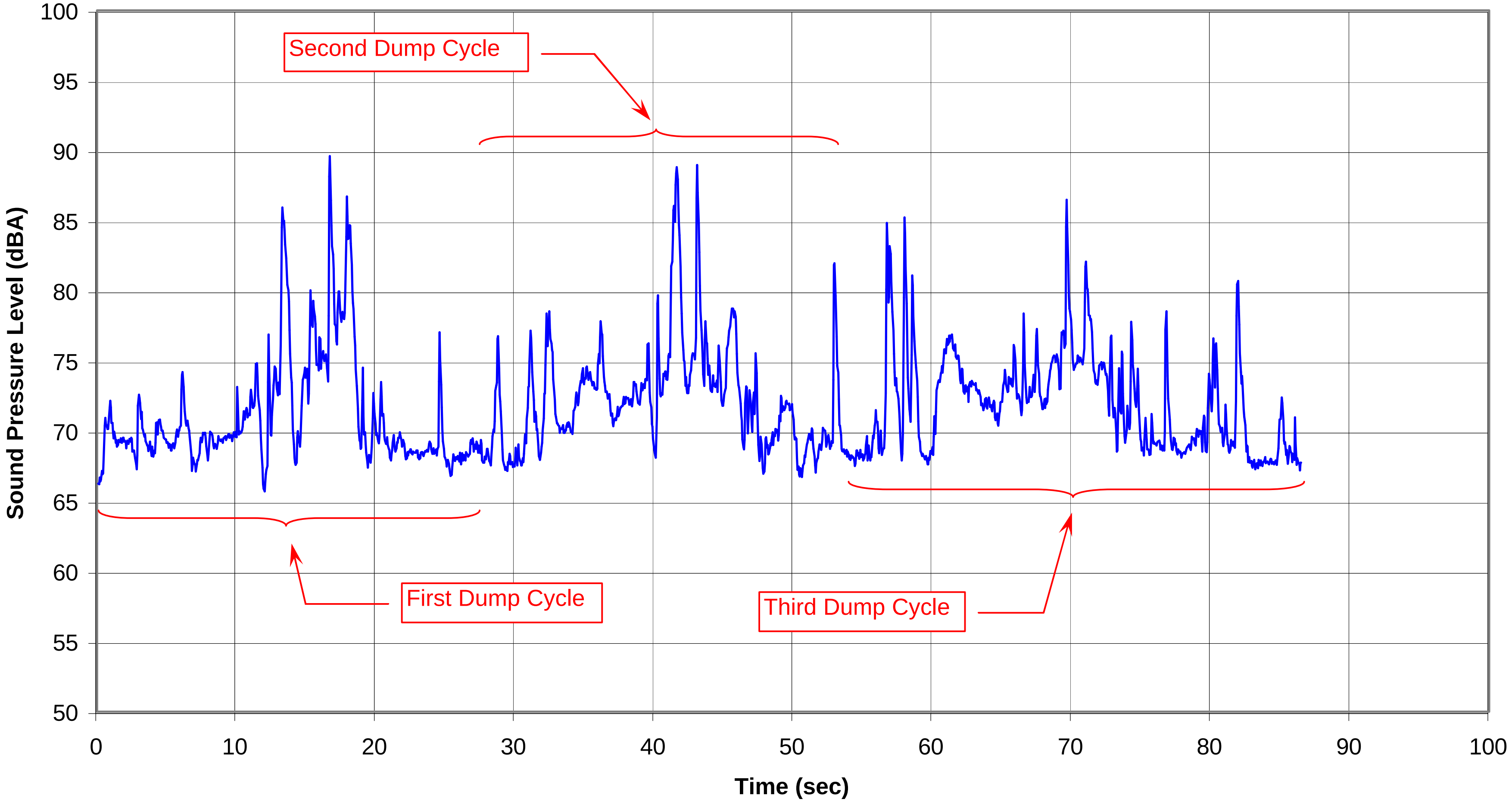

**Figure 7**
**Field Test of Fork Treatment**
**Sound Level Meter at 50 ft. During Simulation of Aggressive Dumpster Dump**
**Treated Fork - Treated Dumpster**

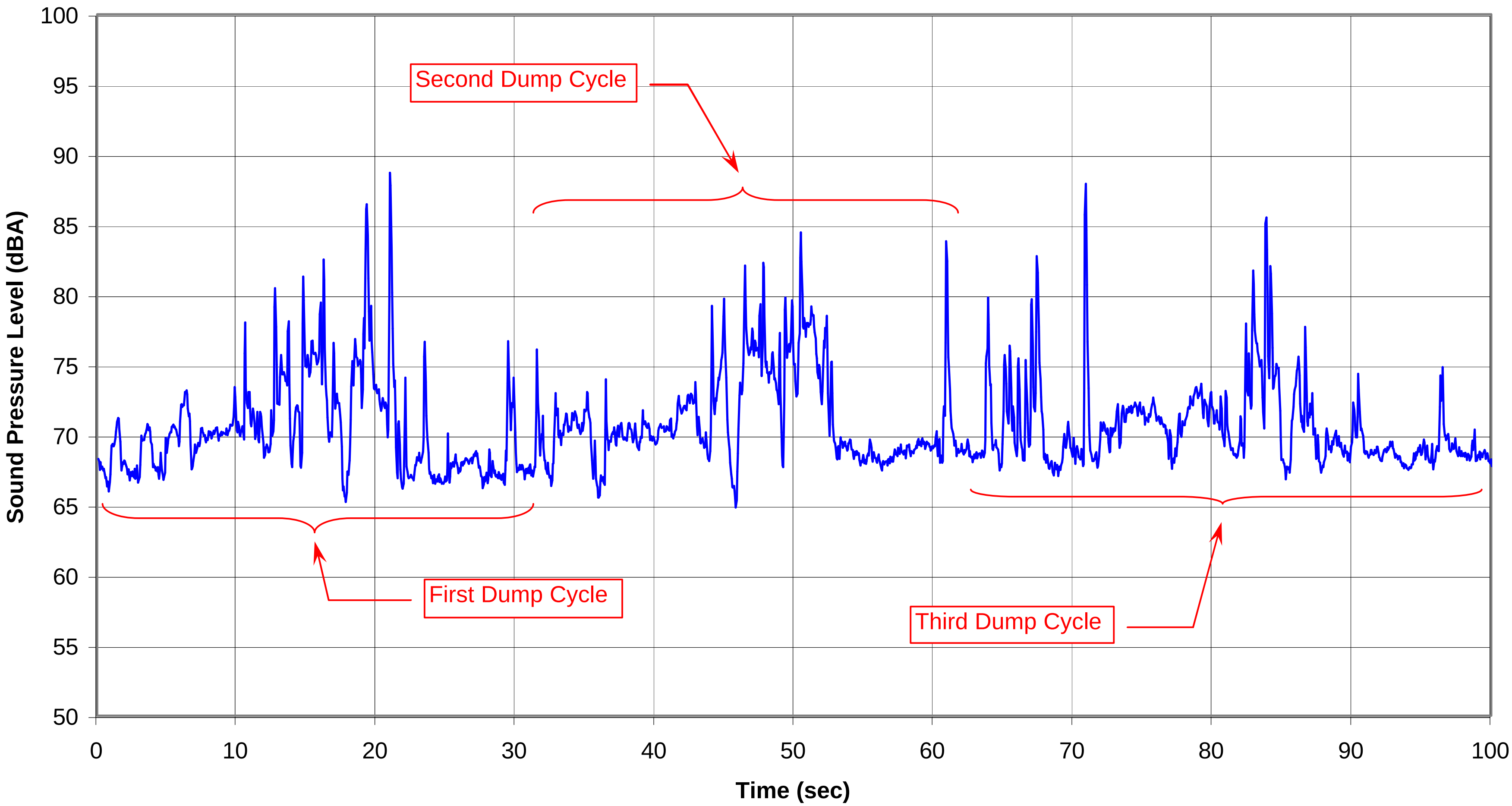

**Figure 8**
**Field Test of Fork Treatment**
**Sound Level Meter at 50 ft. During Simulation of Aggressive Dumpster Dump**
**Treated Fork - Untreated Dumpster - Detail of One Cycle**

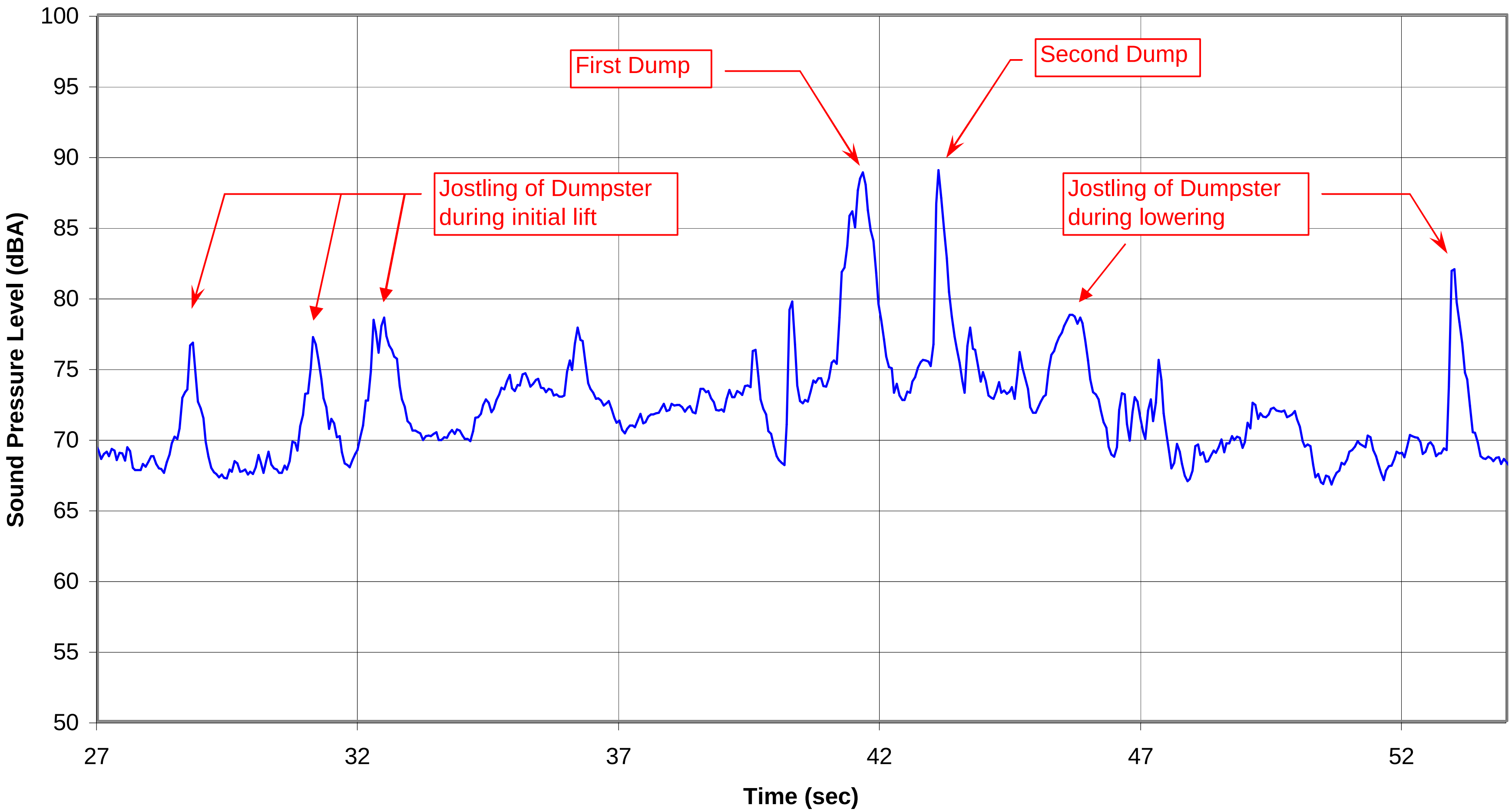

**Figure 9**
**Noise Levels Exceeded for Stated Percentages of Time**
**During Dump Cycle**

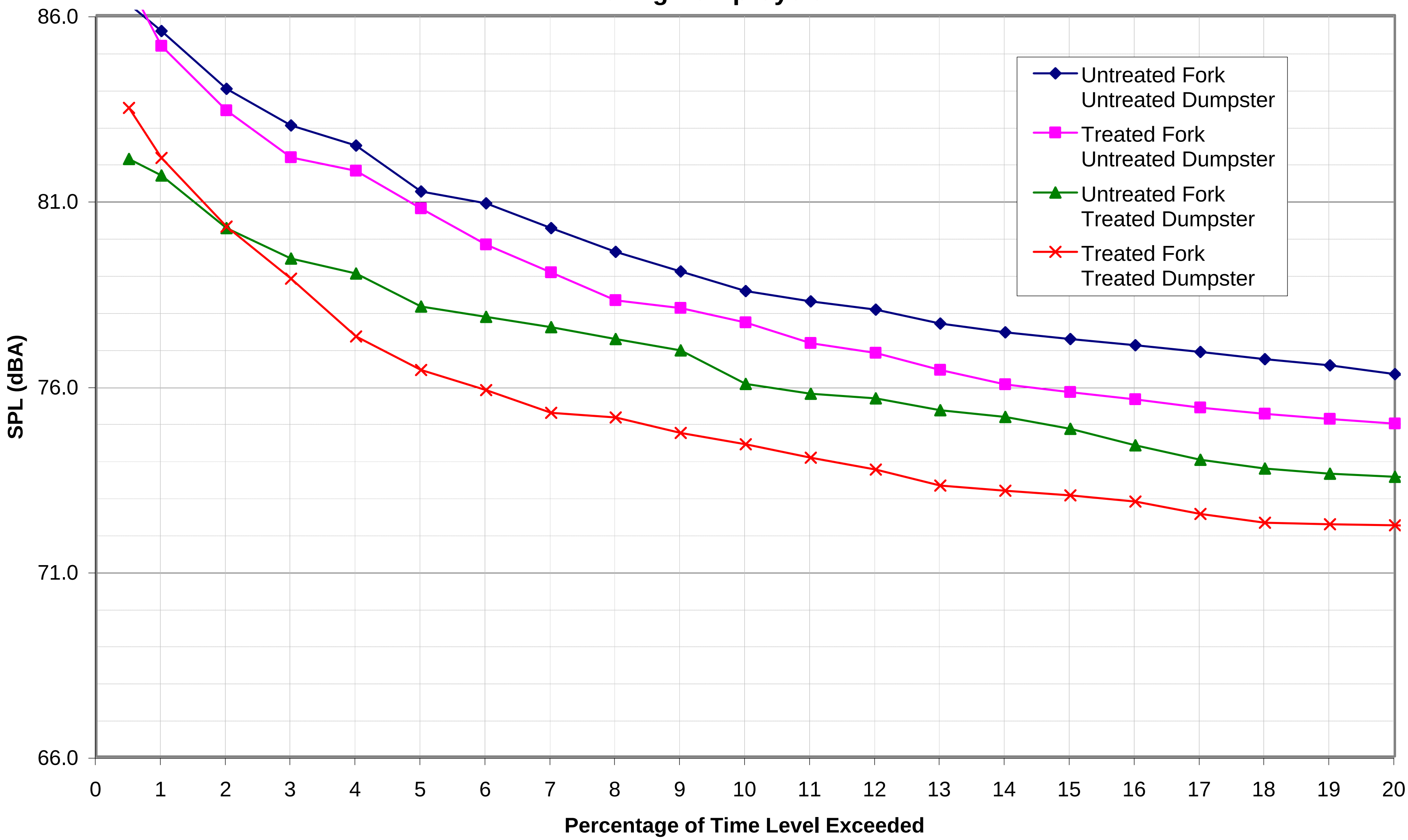

**Figure 10**
**Field Test of Fork Treatment**
**Sound Level Meter at 50 ft. during Simulation of Normal Dumpster Dump**
**Treated Fork - Treated Dumpster**