Subsidiary of Federal Signal Corporation

Reducing Storm-Water Pollution Through Effective Street Sweeping:

Street Sweeper Pickup Performance Test Results for Elgin Sweeper

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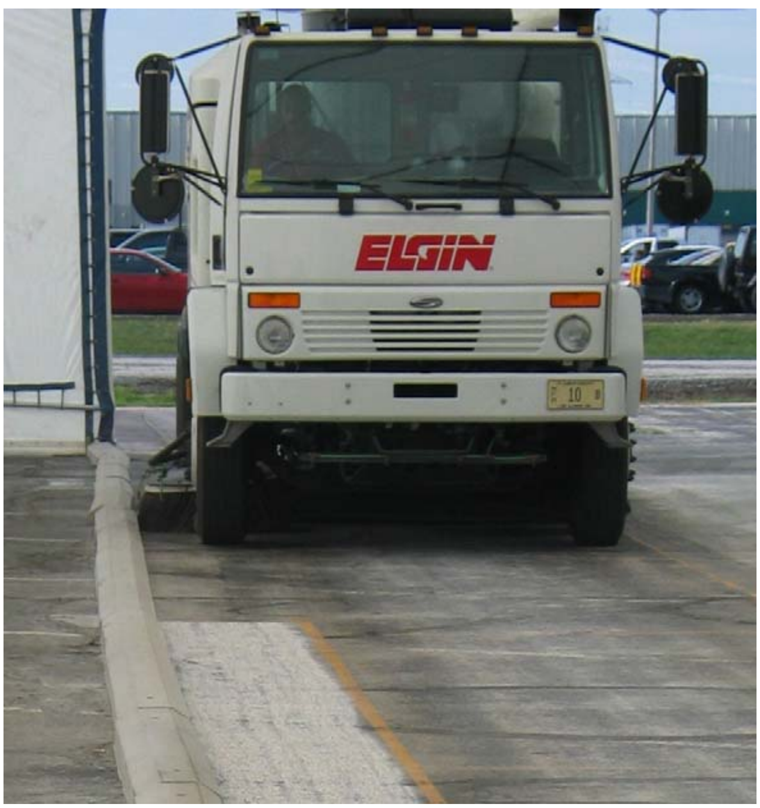

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Elgin Sweeper, a leading manufacturer of street sweepers, recently made a significant investment in conducting an independent, credible, repeatable test to measure the sweeping efficiency of its sweepers. The company sought out Pacific Water Resources, Inc. (PWR), one of the most recognized independent experts on storm-water control in the United States, to conduct the tests.

Five controlled pickup performance tests on four different Elgin Sweeper street sweepers (a prototype Crosswind NX high-performance filter regeneration sweeper with dust control, a standard Crosswind® sweeper, a vacuum Whirlwind® MV sweeper and a mechanical Waterless Eagle® FW sweeper) were conducted over a three-day period at a curbed test track under a tent that was erected on a parking lot.

The overall pickup efficiencies for the six tests ranged from 97.5 percent to 81.0 percent, with the prototype Crosswind NX high-performance filter regeneration sweeper with dust control performing the best. The next best performer was the standard Crosswind sweeper, followed by the Whirlwind MV sweeper and then the Waterless Eagle FW sweeper. The Waterless Eagle sweeper was also tested with water spray for fugitive dust control and had the lowest overall pick-up of the sweepers tested.

INTRODUCTION

In 1977, Congress passed the Clean Water Act to preserve the environmental health of the waterways of the United Sates. Originally, the law called for the Environmental Protection Agency (EPA) to regulate water pollution at the source. Later amendments to the law regulated pollution from storm-water runoff so that nothing but rainwater enters the rivers, lakes and estuaries.

The EPA has issued two sets of storm water regulations since 1977. Phase I set standards for municipal storm water systems (MS4s) serving populations of more than 100,000, construction sites larger than five acres, and 10 major industries. Phase II runoff rules, issued in 2000, simplified compliance and extended coverage to MS4s in small towns and suburbs and building sites that disturb between one and five acres of land. Phase II rules also give municipalities the flexibility to select a variety of best management practices (BMPs) to control storm-water runoff pollution.

In today's economy, everybody is challenged with doing more with fewer resources. Many municipalities in the United States are using structural treatment devices such as underground vaults and drain catch basin inserts as part of their BMPs. These options are expensive to install and maintain. However municipalities are spending their money, it is essential that they receive a measurable return.

The sweeping industry has long been looking for a way to quantify repeatable effectiveness of sweepers on picking up street debris. During the last 20 years, several tests have been conducted to try to determine if street sweepers reduce storm-water pollution. A number of sweeper manufacturers have been making claims about what their machines can do to reduce storm-water pollution, without any supporting data.

Elgin Sweeper recently made a significant investment in conducting an independent, credible, repeatable test to measure the sweeping efficiency of its sweepers. The company wanted quantifiable results of what storm-water experts say about the performance of its street sweepers. The company sought out Pacific Water Resources, Inc. (PWR), one of the most recognized independent experts on storm-water control in the United States.

PWR has developed a state-of-the art load estimation procedure called SIMPTM (simplified particulate transport model) that can quantify urban pollution loadings and accurately estimate optimum cleaning practices for streets and catch basins. Developed and refined over a period of approximately 20 years, SIMPTM has been used on numerous occasions to predict pollutant loading and wash-off processes and is considered by many industry experts to be the most credible storm-water quality modeling package in the United States.

Roger Sutherland, the president of PWR and a leading storm-water control expert in his own right, was directly involved in the test conducted on the Elgin Sweeper units. Sutherland is a senior water resources engineer with 30 years of professional engineering experience in drainage master planning, water quality management planning, riverine hydraulics, flood management and water-quality facility design.

From the standpoint of dollars per pound of pollutant removed from the storm water, these test results confirm what Elgin Sweeper already knew – that nothing comes close to matching the effectiveness of Elgin Sweeper street sweepers in removing storm-water pollutants.

Now Elgin Sweeper can provide its municipal customers – and the overall industry – with solid, factual data on the efficiency of its sweepers in picking up street debris and removing storm-water pollutants.

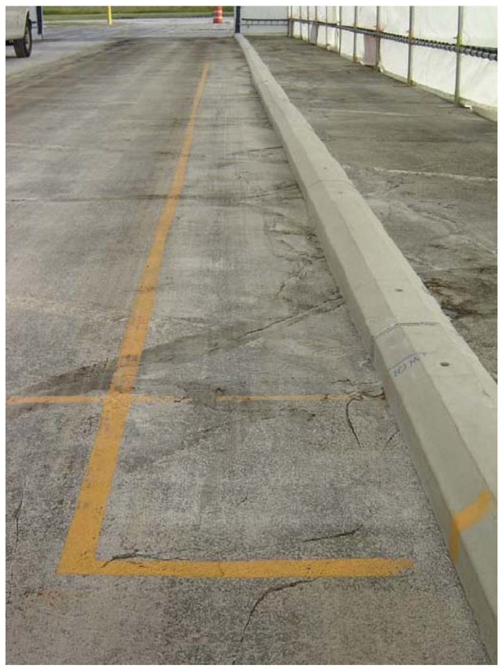
This paper describes the details of the testing performed and documents many details regarding the importance of street sweeping as part of a municipality's efforts to comply with the EPA's Storm Water Phase II regulations.

METHODOLOGY

Test Site Selection

Since the testing was expected to occur over a number of days, it was important that PWR design a test that could be repeated under dry weather and low wind conditions at the same location on any given day. Dry weather conditions were needed since the test involved the use of a street dirt simulant – remaining amounts of which had to be removed after the sweeping operation, using an industrial vacuum cleaner (i.e., shop vac) powered by an electric generator. It was also important to select a site that essentially had no traffic or could at least be closed to traffic. And most importantly, the test site needed to be a curbed street with at least fair pavement conditions similar to the conditions generally encountered by street sweepers on their routes.

Given these requirements, it was decided to conduct the tests at a parking lot under a large tent. The following photographs show the tent and the 50-foot long curbed test track that was used.



Testing Protocol

The test procedure was quite simple. A known quantity of the street dirt simulant was spread evenly along the test track curb line using a fertilizer spreader whose spreading width is approximately two feet.

A street sweeper then performed a single pass at a specified forward speed. However, the actual time that the machine spent cleaning the test length was recorded using a stopwatch so the average sweeping speed could be computed. Several digital photographs were taken before and during the sweeping operation. Before the test material was actually applied, the street sweeper operator was given the opportunity to practice several timed sweeping passes. This was to ensure that the operator would successfully execute the desired sweeping speed when the actual test was performed. For example, a street sweeper traveling at exactly five miles per hour would be on the test track for only 6.8 seconds. These practice runs also ensured the track was very clean before the simulant was applied.

Following the sweeping, an industrial vacuum cleaner with a smooth stainless steel canister was used to vacuum up by hand all of the simulant that remained on the test track, including any simulant moved further away from the original application area by the gutter broom action. After the hand cleaning, the vacuum hose was elevated and shaken several times to ensure that all of the pebbles had traveled to the canister. The vacuum was then turned off and the canister carefully opened in a working area protected from any wind. The Dacron filter cloth covering the canister to separate the machine's built-in air filter from the captured material was tapped several times by a brand-new, clean paintbrush before it was very carefully removed and brushed to dislodge material trapped on the canister side of the filter cloth. The cloth was then carefully transferred to the canister. A new Dacron filter was used after each test, and a new paper filter was used for each day of testing.

The captured material was then slowly transferred from the vacuum canister to a plastic zip-lock bag using the paintbrush and a wire holder needed to keep the bag open. This delicate operation required two people to ensure that none of the captured material was spilled. Some loss of dust was expected despite these precautions, but its mass weight would be generally very small and not significant enough to meaningfully influence the results. Each zip-lock bag was sealed and labeled. The material was weighed in the field using a kitchen scale (after zeroing out the weight of an empty zip-lock bag), and that weight was recorded along with other test information on a sampling log. The material was then taken to a soils lab where it was weighed, dried, weighed again and sieved into eight pre-selected particle size groups. A single representative sample of the simulant was also sieved so the particle size distribution of the initial material was recorded.

As noted earlier, before the application of the test material for the first test, the test track and its approach section was swept several times by the sweeper waiting to be tested, and then hand vacuumed. However, this sample was not retained but discarded instead. Between tests, the test track and approach section were swept several times, but not hand cleaned again. If water was used in these pre-test sweepings, ample time would have been needed for the track to completely dry before the next test material could be applied. On cloudy or cool days, there was no water spray between testing. On those occasions when water was used during a test, ample time was needed for the track to completely dry before the sample collection using the vacuum started.

Spreading the dust simulant on the test track

Street sweeper performing single pass on test track

Hand vacuuming remaining simulant on track after sweeping

Transferring captured material from hand vacuum to zip-lock bag

Safety

When conducting a street cleaning performance test, safety is perhaps the most important consideration. It took a considerable amount of time to initially clean the test track, place the material on the track, sweep the track and hand vacuum the remaining material for each machine and initial mass tested. Working at a location open to traffic would have been dangerous and highly undesirable. This is why the test track used in this test was closed to traffic.

Length of track

The length of the test track was also very important. The longer the length of the test track, the longer it would take to prepare the test and hand vacuum the remaining amount. If the test track was too short, the mass of the remaining material may have been too little to effectively measure its particle size distribution. The 50-foot test track length used in this test provided the length needed to balance these competing considerations.

Forward speed

The forward speed of a street sweeper will also affect its ability to pick up particulate material. The pickup effectiveness increases as the forward speed decreases. The machine operators were instructed to clean at approximately 5 miles per hour, which is generally considered the optimum operating speed, given the tradeoff between pickup performance effectiveness and the need to sweep a certain number of miles a day. Operating at 5 miles per hour, it took only about 7 seconds to sweep the 50-foot long test track. Since the testing protocol called for measuring the actual time it took the cleaner to sweep the test track, it was clear exactly how fast each machine was going during each test.

Street dirt simulant

One of the most important aspects of the street cleaner pickup performance test was the amount and particle size distribution of the street dirt that was used. The magnitude and particle size distribution of accumulated street dirt was first investigated in the United States in 1969 when the historic APWA Chicago study of urban runoff pollution sources was conducted. PWR is unaware of any other significant street dirt accumulation or particle size data set for the Chicago metropolitan area.

The test for each Elgin Sweeper machine used 7.5 pounds (3405 grams) of simulant applied along the 50-foot test track, which was equivalent to 792 pounds per curb mile (225 grams per curb meter).

The materials needed to create the simulant mixture had to be available in relatively small quantities; have a known particle size distribution so the proper recipe could be designed; and have the same specific gravity of real street dirt. The actual total particle size distribution of the simulant was chosen on the basis of years of research of street dirt in testing at numerous cities in the US.

PWR had previously developed a spreadsheet tool that allowed them to enter the manufacturer's specified particle size distribution (PSD) of up to ten different simultant ingredients. The output from the tool was the optimal quantity of material for each ingredient needed to most closely match a targeted PSD. The targeted PSD was the overall average measured in the Bellevue National Urban Runoff Project (NURP) during dry season conditions. Previous analyses had concluded that this PSD – which was the average of hundreds of street dirt samples collected on four different catchments over the course of several dry seasons – closely matched the overall average PSD observed in the extensive monitoring of street dirt conducted by PWR staff over a period of nearly 20 years.

RESULTS

Sweeper models tested

Five controlled pickup performance tests on four different Elgin Sweeper street sweeper models were conducted over a three-day period at a curbed test track under a tent that was erected on a parking lot:

- The standard Crosswind sweeper
- A prototype Crosswind NX high-performance filter regeneration sweeper with dust control

- The waterless Eagle FW designed with shrouded gutter brooms and vacuum assist that transports dust to the hopper (this model was tested both without and with water). The Eagle is a mechanical machine with main broom action and a conveyor used to entrap and transport sweepings to its hopper.
- A truck-mounted vacuum-based Whirlwind MV.

Overall Pickup performance

The overall pickup performance results from the five tests conducted are presented in Table 2.

Table 2 – Overall Pick-Up Performance Test Results

Sweeper Model	Type	Remaining Mass (gms)	Initial Mass (gms)	Pick-up Mass (gms)	Pick-Up %	Forward Sweeping Speed (mph)
Crosswind (NX)	Regenerative	85.6	3405	3319.4	97.5	4.7
Crosswind	Regenerative	121.1	3405	3283.9	96.4	4.9
Waterless Eagle (FW)	Mechanical	288.3	3405	3116.7	91.5	4.9
Waterless Eagle (FW) with water	Mechanical	646.0	3405	2759.0	81.0	4.7
Whirlwind (MV)	Vacuum	221.1	3405	3183.9	93.5	5.1

Remaining Material by Particle Size (PS) Range

The remaining material in each particle size (PS) range that was measured through the use of sieve analyses is presented in Table 3.

Table 3 – Remaining Material by Particle Size Range (grams)

PS No.	Size Range (microns)	Crosswind NX	Crosswind Std.	Eagle FW	Eagle FW with water	Whirlwind MV
7	2000-6370	3.8	3.5	23.6	24.6	4.4
6	1000-2000	5.6	4.6	24.6	32.3	6.8
5	600-1000	5.2	4.7	16.7	28.4	8.9
4	250-600	13.6	15.9	43.5	104.7	43.1
3	125-250	23.4	44.3	91.4	287.3	106.1
2	63-125	7.2	17.0	24.5	75.6	32.7
1	<63	26.8	31.1	64.0	93.1	19.1

Fugitive dust losses will only affect the remaining material measured in the two smallest PS ranges (i.e., less than 125 microns). Qualitative analysis of the photographs taken during sweeping indicated that no visible fugitive dust losses occurred during the testing on the prototype Crosswind NX high-performance filter regeneration sweeper with dust control. The fugitive dust losses observed when the Eagle was being tested (both with and without the use of the water spray) were very low. In the case of the test without water, this was due to the shrouded gutter broom design with the vacuum assist that transports fugitive dust generated by the gutter brooms directly to the hopper.

Some fugitive dust losses occurred in the process of transferring collected material from the stainless steel vacuum canister to the plastic container bags. However, it was largely believed that these losses were small in comparison to those from the sweeping process itself, and the losses through material transfer were essentially the same for each sample obtained.

Pickup performance results by PS range

The pickup efficiencies computed for each of the particle size ranges is presented in Table 4.

Table 4 – Pick-Up Performance Efficiencies by Particle Size Range (Percent of Initial Mass)

PS No.	Size Range (microns)	Crosswind NX	Crosswind Std.	Eagle FW	Eagle FW with water	Whirlwind MV
7	2000-6370	99.4	99.4	95.9	95.8	99.3
6	1000-2000	98.5	98.7	93.3	91.2	98.2
5	600-1000	97.8	98.1	93.1	88.3	96.3
4	250-600	97.9	97.6	93.4	84.2	93.5
3	125-250	97.7	95.7	91.1	72.0	89.6
2	63-125	97.0	93.0	89.9	68.7	86.5
1	<63	90.8	89.4	78.1	68.2	93.5

DISCUSSION OF THE RESULTS

Overall pickup performance

The pickup performance results were very good. The prototype Crosswind NX high-performance filter regeneration sweeper with dust control performed the best, with an impressive overall efficiency of 97.5 percent. The second-best performer was the standard regenerative air Crosswind at 96.4 percent overall. Regenerative air machines are generally considered the best overall performers in particulate pickup. The Whirlwind MV vacuum machine had an overall pickup efficiency of 93.5 percent. The mechanical Waterless Eagle FW finished in fourth place overall with a still-impressive pick-up efficiency for a machine of its type measured at 91.5 percent. The Waterless Eagle FW operating with a water spray had an overall pickup efficiency measured at 81.0 percent. This result was also expected, since it has been known for some time by sweeper manufacturers that water spray used to suppress fugitive dust reduces a machine's ability to pick up particulate material. In fact, the pickup performance of the Waterless Eagle that used water spray was approximately 10.5 percent lower than the measured pickup of the Waterless Eagle without water.

Remaining material by particle size (PS) range

When we examined the remaining material by particle size (PS) range data, it became clear that the use of water to suppress fugitive dust resulted in a significant amount of additional material remaining on the street surface for particles less than 1000 microns. The use of water with the Eagle sweeper resulted in a 121 percent increase in the remaining mass for particles 250 to 1000 microns in size and a 153 percent increase in remaining material for particles less than 250 microns, when compared to using the same machine with no water spray for fugitive dust control.

Pickup performance by particle size range

In addition to the overall pickup performance discussed previously, there is a heightened amount of concern for pickup performance relative to the finest particles (i.e., less than 63 microns). As expected, all of the regenerative air and vacuum machines outperformed the mechanical one in this regard. It is interesting to note that the Whirlwind MV vacuum machine actually outperformed the prototype Crosswind NX model and the Crosswind in terms of finest particle pickup. However, the pickup percentages were very close, and this factor alone would not preclude the potential selection of a regenerative air machine (like the prototype model with dust control) over a vacuum one.

CONCLUSION

The results of this rigorous sweeper test clearly demonstrate the efficiency of Elgin Sweeper street sweepers – and specifically, the prototype Crosswind NX high-performance filter regeneration sweeper with dust control, the regenerative air Crosswind, the vacuum Whirlwind MV and the mechanical Waterless Eagle FW – in removing storm-water pollutants.

Elgin Sweeper encourages other sweeper manufacturers to take this independent test and see what results their sweepers achieve. In the near future, perhaps this test will become a standard test in the industry to measure the efficiency of all sweepers on the market.

Elgin Sweeper is committed to providing municipalities with environmental solutions that reduce storm water and air pollution. From its alternative fuel-powered sweepers and waterless dust control sweepers, to its regenerative filtration systems, Elgin Sweeper is a technology leader in developing innovative products that result in cleaner streets, water and air.

ABOUT ELGIN SWEEPER

Sold and serviced through a network of more than 100 dealer locations worldwide, Elgin products are the sweepers of choice for a variety of general street maintenance, special industrial and airport applications. With more than 90 years of experience, Elgin Sweeper offers municipalities, contractors and industries the most sweeper options in the country, using the latest sweeping technologies—mechanical, pure vacuum, regenerative air, alternative fuel and waterless dust control. Elgin Sweeper is a subsidiary of Federal Signal Corporation's Environmental Solutions Group.

Federal Signal Corporation (NYSE: FSS) is a leader in advancing security and wellbeing for communities and workplaces around the world. The company designs and manufactures a suite of products and integrated solutions for municipal, governmental, industrial and airport customers. Federal Signal's portfolio of trusted, high-priority products include Bronto aerial devices, Elgin and Ravo street sweepers, Federal Signal safety and security systems, Guzzler industrial vacuums, Jetstream waterblasters and Vactor sewer cleaners and vacuum excavators. Federal Signal was founded in 1901 and is based in Oak Brook, Illinois.

ABOUT PACIFIC WATER RESOURCES, INC.

Located in Beaverton, Oregon, Pacific Water Resources, Inc., is an engineering consulting firm specializing in the fields of hydraulics, hydrology, water quality modeling and evaluation, fluvial geomorphology, sediment transport, and computer-aided mapping. Recognized as a leader in watershed management planning and design, PWR's technical expertise has been at the forefront of every major regulatory and technical advancement for assessing, enhancing and protecting water resources since 1978.

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FOR MORE INFORMATION

To learn more about Elgin Sweeper's role in reducing air and storm-water pollution or to find out how to make Elgin Sweeper's proven waterless sweeping technology part of your community's best management practices, please visit www.elginsweeper.com/airandwater. For additional information on Elgin Sweeper's line of sweepers or to schedule a demonstration, please visit www.elginsweeper.com or see your local Elgin Sweeper dealer.

For more information on Pacific Water Resources, Inc., or to learn more about the SIMPTM test procedure used for this test, please visit www.pacificwr.com.

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