

Operational On-Street Test Protocol

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Operational On-Street Test Protocol

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The Protocol may be modified, revised or further developed under the authority of the City of Toronto as additional information or test data becomes available.

While this protocol attempts to provide an extensive level of specific details and guidance, it is impractical to provide every last detail. So as with most standards, it is up to the user to strive to achieve the intent that is written into this protocol. If the user is unsure and needs clarification on any item, those listed as contacts will attempt to provide that information. Any disputes on interpretation of this standard may be referred to the above group of contacts.

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The City of Toronto wishes to acknowledge and thank those who contributed to developing, initiating and undertaking the first Toronto Operational On-Street testing of street sweepers in 2007. The work was carried out as a replicable, quantifiable supplement to other subjective and objective evaluation undertaking by both fleet and transportation staff.

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1.0 INTRODUCTION

The main objectives of private and public organizations, when providing street sweeping services, are to:

- operate environmentally sustainable technologies that improve human health, air and stormwater quality;
- operate efficiently year round under various sweeping conditions;
- reduce maintenance costs and downtimes;
- evaluate the different types of street sweeper technologies in a manner that produces objective and quantifiable results; and
- require the vendors to have their equipment tested as a requirement of the procurement process.

The Canadian Environment Technology Verification (Canadian ETV) under the licence of Environment Canada and Climate Change provides a mechanism to evaluate and third party verify the environmental and operational performance of various street sweeper technology.

Third-party testing is a method that can be used to evaluate Particulate Matter (PM) removal and entrainment efficiencies (air quality performance) and operational efficiency of various street sweeper technologies using a quantifiable rather than a qualitative method. Canadian ETV can provide a Verification Certificate of operational performance using the Operational On-Street Test Protocol described here.

A Canadian ETV Certificate will indicate the specific make and model of a street sweeper and the efficiency values obtained in respect to each of the established criteria. The user community, through their purchasing process, may compare the efficiency values from multiple street sweepers by using a weighting method to determine the final score for all of the criteria.

A street sweeper can be tested under various operational settings. A change in a street sweeper's operational settings will result in a change in either air quality and/or operational performance. For example, the street sweeper can be tested using either shrouds or no shrouds on the gutter brooms.

Four consecutive tests (weather permitting) must be completed with specific operational settings determined at the start of the testing sequence and a full Test Run must be performed with the same specific operational settings. It is beneficial for the street sweepers to be tested in as many operational settings as are deemed appropriate when taking into consideration the specific operational requirements of the user community.

This document provides the detailed methodology of the Operational On-Street Test Protocol and all supporting documentation, such as: data log sheets, spreadsheets used to perform calculations and key components of the protocol.

The document is intended to be used together with the PM₁₀ and PM_{2.5} Street Sweeper Efficiency Test Protocol. In order to ascertain the overall comprehensive performance of a street sweeper an evaluation of both the air quality and operational performance of the street sweeper should be undertaken.

2.0 BACKGROUND

In 2003, the Clean Roads to Clean Air program (CRCA) was initiated by the City of Toronto and through a number of air quality studies and tests, a standard process, along with efficiency criteria, was developed and used to evaluate various street sweeper technologies. Specifically, the sweeper technologies were evaluated on their efficiency in cleaning streets including: removing “invisible” fine particulate matter (PM₁₀ and PM_{2.5})¹ from roads; reducing the concentration levels of fine particulate matter entrained into the air while sweeping; and operating year-round effectively, including during winter periods, under various sweeping conditions typically encountered in Toronto.

In order to meet the above objectives, City of Toronto staff developed two testing protocols: a PM₁₀ and PM_{2.5} Street Sweeper Efficiency Test Protocol and an Operational On-Street Test Protocol. The PM₁₀ and PM_{2.5} Street Sweeper Efficiency Test Protocol is intended to provide an objective and quantitative method for assessing the ability of the sweeper to capture and remove PM₁₀ and PM_{2.5} from typical urban street surfaces and to limit the amount of PM₁₀ and PM_{2.5} that is disturbed (entrained) into the air and subsequently deposited during the sweeping process.

The Operational On-Street Test Protocol provides an objective and quantitative method of evaluating the operational performance of street sweeper technologies operating under various sweeping conditions. Operational criteria evaluate and determine the operational performance levels of the various street sweepers. A high level of performance against these criteria indicates in a year round efficient and effective delivery of street sweeping service.

The City of Toronto developed **testing protocols**, along with **efficiency criteria**, that can be used to evaluate the operational performance and removal and entrainment efficiencies for Particulate Matter (PM) between **various street sweeper technologies**.

City of Toronto does not have mandates or resources to test such equipment on a continual basis, and to that end, Canadian ETV and the Prairie Agricultural Machinery Institute (PAMI) were contracted by Toronto to review the Testing Protocols with a view to potentially undertake such testing in the future.

Canadian ETV is delivered by GLOBE Performance Solutions under a license agreement with Environment Canada and Climate Change to provide a mechanism for third-party verification of environmental technology performance claims and to facilitate successful technology commercialization. Canadian ETV builds vendor confidence and provides the marketplace with the assurance that environmental performance claims are valid, credible and supported by high quality, independent test data and information. Vendors of equipment **apply to Canadian ETV for verification of their environmental performance claims**.

PAMI is an **independent government testing agency with experience and credentials in street sweeping testing**.

¹Fine Particulate matter (PM₁₀) is particulate matter less than 10 microns aerodynamic diameter which includes particulates less than 2.5 microns aerodynamic diameter (PM_{2.5}).

3.0 SCOPE

This protocol establishes an objective method by which to evaluate the on-street operational performance of street sweepers. Seven key operational criteria of street sweepers are evaluated and collectively used to determine the operational performance of street sweepers. The protocol is intended to provide an objective and quantitative method for assessing the pick-up efficiency performance of street sweepers in picking-up simulated street sweepings. Testing is undertaken to establish a comparative assessment rather than to establish a 'pass/fail' approach.

The operational on-street test includes six separate operational tests (Individual Tests), based on the operational criteria. The testing method evaluates the ability of street sweepers to perform the following tasks:

- sweep a wet paved surface and remove typical street sweepings;
- maneuver around parked cars and remove typical street sweepings;
- remove leaf and typical street sweepings combined;
- pick-up of large debris and typical street sweepings combined;
- pick-up of heavy street sweepings; and
- sweep typical street sweepings effectively in a dustless mode, without the use of gutter brooms.

The street sweeper will sweep at 5-10 km/h, or at a manufacturers recommended speed, throughout each Individual Test, applying all required operational settings, including: the main and side brooms, vacuums and filtration system. The street sweeper should use normal flow output of water inside the hopper and on the street sweeper's gutter brooms and main broom while sweeping, as required for dust suppression. Once the operational settings are determined and documented they must be retained and maintained throughout the Test Run for each test, except during the testing of the "dustless mode" where modifications to the operational settings can be made.

Four consecutive tests (weather permitting) must be completed for each specific operational setting. Only the three best overall performance results will be used to establish the performance level for each of the operational criteria.

4.0 TERMINOLOGY

The following terms are used throughout this document.

Street Sweeper:

A street sweeper is a self-propelled machine that is primarily designed to remove a wide range of material sizes from road surfaces using mechanical rotating brooms, or mechanical brooms with vacuum assistance or regenerative-air vacuum with gutter brooms.

Test Site:

A curb lane of a four lane paved road that has the following characteristics: a posted speed of 50 km/hr or less; a classification of local or collector road; less than 2% grade and approximately seven hundred metres of uncut curb (without driveway cuts). Included in the seven hundred metres requirement is approximately two hundred metres or as required for traffic to merge safely to the adjacent lane. One curb lane will be closed for approximately 8-10 hours on each test day, depending on how many test will be implemented in one day. The lane closure should not impact the safe operation and/or impede traffic to any adjacent driveways, unsignalized or signalized intersections. The Test Site must include a Test Track and Traffic Merge Area(s). The entire Test Site may be defined using pylons.

Conditioning Road:

A Conditioning Road is a two kilometre section of roadway that the Test Sweeper sweeps at normal operating speeds and with specific operational settings, three times prior to performing the Test Run (i.e. for a total of 6 kilometres).

Test Track (see Figure 1):

An area of the Test Site, a minimum of four hundred metres over which the subject Test Sweeper sweeps at normal operating speeds and with specific operational settings. Test Track includes Test Section(s), Set-Up Area(s), Track-Out Area(s), Start-Up Area(s) and Warm-Up Track Area.

Test Section(s) (see Figure 1):

A defined area of the Test Track, there are two Test Sections 40 metres long by 2 metres wide and four Test Sections 30 metres by 2 metres where a specific Individual Test is performed.

Test Strip(s) (see Figure 1):

A defined area of the Test Section, 0.3 metre wide adjacent to the curb, where the Standard Test Material and/or Leaf Material and/or Large Debris Material and/or Heavy Debris Material is applied.

Set-Up Area(s) (see Figure 1):

A defined area of the Test Track, 30 metre in length, where no Standard Test Material is applied, and is located between two the Track-Out Area and the Start-Up Area and where the

Test Sweeper can be stored all necessary operational configurations can be performed in preparation for the next Individual Test.

Track-Out Area(s) (see Figure 1):

A defined area of the Test Track, 10 metres in length, where no Standard Test Material is applied and is located between the end of each Test Section and the beginning of each Set-Up Area.

Start-Up Area(s) (see Figure 1)

A defined area of the Test Track, 10 metres in length, where no Standard Test Material is applied and is located between the end of each Set-Up Area and the beginning of each Test Section.

Warm Up Track Area (see Figure 1):

A defined area of the Test Track located at the beginning of the Test Track, where the Test Sweeper can be stored and all the necessary operational settings can be made prior to the Test Run.

Traffic Merge Area(s) (see Figure 1):

Defined areas of the Test Track located at the beginning and the end of the Test Track in order to facilitate the merging of the traffic from the travelled portion of the curb lane to the adjacent inside lane.

Test Sweeper: A Street Sweeper that undertakes a Test Run.

Wet Paved Surface Test Section:

The first Test Section of the Test Track, forty metres in length, used to evaluate the Test Sweeper's operational efficiency to sweep a wet paved road surface that is covered with Standard Test Material.

Manoeuvrability Around Parked Cars Test Section:

The second Test Section of the Test Track, forty metres in length, used to evaluate the Test Sweeper's operational efficiency to sweep around parked cars on a paved road surface covered with Standard Test Material.

Test Run:

A Test Run is the completion of six Individual Tests performed in a sequence in one day.

Leaf Test Section:

The third Test Section of the Test Track, thirty metres in length, used to evaluate the Test Sweeper's operational efficiency to sweep on a paved road surface covered with Standard Test Material and Leaf Test Material.

Large Debris Test Section:

The fourth Test Section of the Test Track, thirty metres in length, used to evaluate the Test Sweeper's operational efficiency to sweep on a paved road surface covered with Standard Test Material and Large Debris Test Material.

Heavy Debris Test Section:

The fifth section of the Test Track, thirty metres in length, used to evaluate the Test Sweeper's operational efficiency to sweep a paved road surface with Standard Test Material and Heavy Debris Test Material.

Dustless Mode Test Section:

The sixth section of the Test Track, thirty metres in length, used to evaluate the Test Sweeper's operational efficiency to sweep a paved road surface in a "dustless mode" applying no gutter brooms and with Standard Test Material.

Standard Test Material:

A surrogate of typical street sweepings material applied to all the Test Sections. The Standard Test Material consists of 50/50 mixture of limestone screenings and construction sand.

Large Debris Test Material:

Large debris such as: empty crushed pop cans, full pop can, small tree branches, glass bottle, crushed plastic water bottles, full water bottle, empty plastic bottle, one plastic bag, plastic strips, crushed coffee cup, cigarette box, chunks of coal patch and gravel are added to the Standard Test Material.

Leaf Test Material:

A mixture of various deciduous broad and moist leaves.

Heavy Debris Test Material:

A 50/50 mixture of salt and coal patch.

Residue Material:

Residue Material is the test material left behind by the Test Sweeper after completing the Individual Test on each of the Test Sections.

Individual Test:

An individual, replicable, test of a Test Sweeper, whereby the Test Sweeper is tested for its ability to remove the test material from a Test Section and deposits the test material into its hopper.

Operating Speed:

The Test Sweeper will sweep at a constant operating speed between 5 to 10 km per hour (or at manufacturer's recommended sweeping speed).

Operational Settings:

The Test Sweepers will sweep at the operating speed applying all required operational settings, including but not limited to: the main and side brooms, vacuum, vacuum and filtration systems and should use normal output of water inside and outside the street sweeper as required for dust suppression. The use of shrouds on gutter brooms constitutes a modification to the operational settings and requires the undertaking of a complete new test.

Operational Configuration:

The Test Sweepers will sweep applying the pick-up head/main broom in a normal operating position. The projection, angle and tilt of gutter brooms can be re-configured within the normal range of operating parameters.

Street Sweepings:

Street Sweepings are here specified as materials consisting primarily of sand, soil and dust generated during the routine cleaning of roadways but may also contain some leaves and other miscellaneous solid waste collected during street sweeping. Material generated during the clean up of a spill or material from other structures associated with a roadway such as catch basins are not included as street sweepings.

Paved Road Surface:

A curbed lane that has a concrete barrier curb with a standard gutter design or a concrete barrier curb with a narrow gutter or concrete barrier curb and wide gutter design or concrete barrier curb and no gutter and an asphalt surface. Appendix F shows the Ontario Provincial Standard Drawing OPSD 600.040 of the concrete barrier curb with a standard gutter design, OPSD 600.080 of the concrete barrier with a narrow gutter design, OPSD 600.110 of the concrete barrier curb with no gutter design and OPSD 600.020 concrete barrier with a wide gutter design.

5.0 PROTOCOL FEATURES

The Test Sweeper can be tested under various operational settings. A change in a sweeper's operational settings could result in a change in either air quality performance and/or operational performance. For example, the Test Sweeper can be tested using either shrouds or no shrouds on the gutter brooms. Four consecutive tests (weather permitting) must be completed with specific operational settings determined at start of the testing sequence and a full Test Run or multiple Test Runs on the same day performed with the same specific operational settings. Once the operational settings are determined and documented they must be retained and maintained throughout the Test Run for each Individual Test, except during the testing of the "dustless mode" where modifications to the operational settings can be made.

Only the three best overall performing days test results will be used to establish the performance levels for each of the operational criteria. Four days of testing are required such that if there is an operator error and/or a sweeping system failure and the Test Run is deemed null and void there are still three additional opportunities to obtain three valid tests as required to calculate the achieved performance levels. It is deemed beneficial that sweepers be tested in as many operational settings as are deemed appropriate taking into consideration the specific operational requirements by the user community.

The test is to be implemented over several consecutive days (weather permitting), if there are prevailing environmental conditions that prevent four consecutive days of testing, then testing will be postponed and will proceed on the next consecutive day when the environmental conditions are acceptable. Postponement of the testing due to weather is not considered to create a null and void test.

The City of Toronto's specific operational requirements are that sweepers must provide levels of performance without using shrouds/skirts on the sweeper's gutter brooms and/or main brooms.

- The protocol requires an objective test of a sweeper's road sweeping abilities using a reproducible and quantifiable method at a selected Test Site with specific characteristics, under specified conditions, where a Test Sweeper sweeps using specific operational settings and various operational configurations, using an applied Standard Test Material.
- Prior to the Test Run, the Test Track will be pre-swept three times by a test agency's in-house street sweeper or by the local municipality's street sweeper. The Test Section Area's Test Strips will be covered with a known amount of the Standard Test Material, Leaf Test Material, Large Debris Test Material and Heavy Debris Test Material as appropriated for each Test Section.
- The Standard Test Material is used as a base material for all Test Sections and a sufficient amount of Test Material must be applied to permit adequate confidence in the measurements performed. Standard Test Material consists of a mixture of limestone screening and construction sand that represent typical street sweepings found on urban roads.
- Prior to each Test Run, a Conditioning Track, which exhibits a typically heavy load of street sweepings condition on a daily basis, will be pre-swept three times, and on both

sides of the road, by a test agency's in-house street sweeper or by the local municipality's street sweeper. The Test Sweeper will be "conditioned" by sweeping one side only of the pre-swept road for six kilometres immediately prior to undertaking the controlled Test Run.

- During the Test Run, the pre-weighed Test Sweeper will sweep over each Test Section starting at Test Section A and proceeding to Test Section F. The Test Sweeper, having swept through each Test Section, will continue to sweep into the adjacent Track-Out Area. The Test Sweeper must stop and cease all sweeping systems (i.e. vacuum, gutter brooms, main broom, etc.) before exiting the Track-Out Area. The Test Sweeper will then proceed and travel in a non-sweeping mode and exit the Track-Out Area and enter the Set-Up Area, where the Test Sweeper can stop and adjust any operational configurations (if required) before proceeding to the next Test Section. Once the Test Sweeper operational configurations have been adjusted the Test Sweeper will proceed into the Start-Up Area without sweeping, where the Test Sweeper must activate all operating settings and align the Test Sweeper to the curb and begin sweeping through the Start-Up Area and through the adjacent Test Section without stopping.
- The Test Sweeper will be weighed both prior to and after completion of the Test Run. The weighing of a Test Sweeper is used only as a quick assessment that illustrates the rough efficiency (or lack of) for any Test Run, if a significant amount of Residue Material is left behind as a result of operator error and/or sweeper malfunction such that the vacuuming procedures should not be initiated, then the Test Run will be aborted and deemed null and void.
- The Test Site will ideally contain one long Test Track or, acceptably, two short Test Tracks. The Test Track(s) will be adjacent to a curb, and will be swept as part of one day's Test Run. Following each Test Run, the surface of the Test Sections and the Track-Out Area will be cleaned by using a canister-type vacuum, such as a commercial "Shop-Vac" or equivalent. The Residue Material, captured in HEPA filter and cartridge equipped canisters, will be weighed and identified separately by Test Section area.
- Seven operational aspects are identified as criteria that are evaluated to determine the operational performance levels of the Test Sweeper. The Test Sweeper must use all its operating systems, including gutter brooms, main broom, pick-up head, vacuum and filtration system during the Test Run. The seven test criteria are as follows:
 - A. Wet Paved Surface Condition Pick up Efficiency (%) - Assesses the ability of the Test Sweeper to sweep up Standard Test Material when the roadway is wet. The road surface will be wet and will include areas with puddles;
 - B. Maneuverability Around Parked Cars Pick-up Efficiency (%) - Assess the Test Sweeper's ability to safely and expeditiously pick-up the Standard Test Material around parked cars and stationary objects;
 - C. Pick up of Typical Street Sweepings Plus Leaves Efficiency (%) - Assess the Test Sweeper's ability to effectively pick-up Standard Test Material and a heavy deposit of leaves on the roadway;
 - D. Typical Street Sweepings plus Larger Debris Pick-up Efficiency (%) - Assess the Test Sweeper's ability to effectively pick-up Standard Test Material and Large Debris

- Test Material. Place the Larger Debris Test Material on top of the Standard Test Material using a consistent method of application;
- E. Heavy Street Sweepings Pick-up Efficiency (%) - Assesses the ability of the Test Sweeper to remove Standard Test Material and additional salt and coal patch typically found during spring clean-up and on roads adjacent to construction sites. Place the Heavy Debris Test Material on top of the Standard Test Material using a consistent method of application;
 - F. Typical Street Sweepings and Operate Sweeper without Gutter Brooms Pick-up Efficiency (%) - Assesses the ability of the Test Sweeper to sweep adjacent to the curb without the use of gutter brooms, using only the main vacuum pick-up head and/or main broom; and
 - G. Operational Settings and Configuration Adjustments - Time Score – Assess the total time that the Test Sweeper operator/technical staff require to change all the operational settings and configurations between each of the Individual Tests, measured in minutes.
- A known weight of Standard Test Material is consistently applied on the Paved Road Surface with a greater depth close to the curb.
 - The Test Track will be divided into six Test Sections with one test per section. Each Individual Test represent an operational aspect to be evaluated:
 - Test A - Sweeping during wet (inclement) weather;
 - Test B - Maneuverability around parked cars;
 - Test C - Leaf removal from the road surface;
 - Test D - Pick up of large debris from the road surface;
 - Test E - Heavy street sweepings removal from the road surface; and
 - Test F - Dustless sweeping, sweeping without gutter brooms.
 - Test Sweepers will not be permitted to leave and securely housed on the Test Site until all testing is completed.
 - Measurements and calculations must be undertaken to clearly determine the amount of test material applied, captured and removed by the Test Sweeper as well as the residual material left behind by the Test Sweeper on each of the Test Sections in order to permit objective comparison and reporting of the performance levels of each operational aspect for a Test Sweeper.
 - The methodology specified in Section 6.15 should be employed to measure all applied and residual materials. Weighing the various Test Materials to be applied on each Test Section prior to the Test Run and collecting and weighing the amount of material applied, remaining or disturbed to the adjacent Track-Out Area following the completion of the Test Run is central to the methodology. The collection of the Residue Material should be accomplished by using HEPA filter and HEPA cartridge equipped vacuum cleaners. The use of HEPA filter equipped vacuum cleaners permits for accurate and objective assessment but does require cleaning of large areas of the exposed surfaces on a Test Track.

Section 8 includes a detailed step by step summary of the Test Run procedure. Appendix C contains the key components of the Test Protocol, including site set-up; testing of sweeper, equipment, personal protection and weather requirements; and testing procedures.

6.0 PROTOCOL COMPONENT DETAILS

6.1 Submission of Detailed Specifications

Street sweeper manufacturers and/or distributors must provide detailed specifications to the testing agency in advance of the testing. The detailed specifications must include all components/parts that will be present during the Operational On-Street testing of the street sweeper. The detailed specifications will then be included as part of PAMI's "Testing Report" that includes the performance results. The "Testing Report" will be submitted to Canadian ETV for third party verification and ultimately ETV certification.

6.2 Preparation of Test Site

- The Test Site must be established on a four lane road that has the following characteristics: a posted speed of less than 50 km/hr; a local or collector road classification; and approximately 700 metres of uncut curb (without driveway cuts). One curb lane will be closed for approximately 8-10 hours on each test day, depending on how many test will be implemented in one day. The lane closure should not impact the safe operation of and/or impede traffic access to any adjacent driveways, unsignalized or signalized intersections.
- The necessary lane closure permit(s) must be obtained from the local municipal and/or regional permitting body.
- The Test Site will be exposed to prevailing environmental conditions and to extraneous disturbances (e.g. as from wind or precipitation) of the applied test material and therefore excessive precipitation and wind conditions will warrant the postponement of the testing. Adequate lighting for safe visual operations and to facilitate the use of video/camera for recording and monitoring is required and therefore testing can only be implemented during daylight hours.
- The Test Site must have sufficient space adjacent to the roadway for safe manoeuvrability of test agency staff and observers, for storage of equipment and supplies, document and videotape the testing as well as store and operate the monitors, test materials and equipment required for the spreading and collection of the test materials.
- The Test Site (see Figure 1) must contain a Test Track of sufficient length (ideally 500 metres or greater) and a curb lane width (ideally 3 metres) to accommodate sweeper movement at a constant speed (5 to 10 km per hour) along a straight path and two Traffic Merge Areas that facilitate the merging of the traffic from the travelled portion of the curb lane to the adjacent inside lane.
- The length of the Traffic Merge Areas will be determined by the responsible municipal and/or regional body that has the jurisdiction over road closures where the testing is being implemented. Book 7, Ontario Traffic Manual, March 2001 was used to determine the Traffic Merge Areas in Ontario.

- The Test Site must be available, on a prolonged basis, to permit adequate time for set-up and preferably four consecutive tests and, ideally, to permit the future replication of the testing of same or other sweepers.
- A nearby source of electrical power must be available to operate test related equipment (i.e., 110-volt line/receptacle and/or portable generator).
- Depending on location it may be necessary to provide relevant information (e.g. Test Run dates, times and lane closure information) to nearby landowners and post detour signs for local traffic control and any other pertinent warning signs.
- There must be no water on the surface of the Warm-Up Track or Test Sections or Test Set-up Areas, Start-Up Areas or Track-Out Areas except for Test Section A.

6.3 Test Track

The Test Track includes Test Section(s), Warm-Up Area, Start-Up Area(s), Set-Up Area(s), Track-Out Area(s) and Test Strip(s) areas. These areas must have the following features:

- Similar Test Track, Test Section Areas, Warm-Up Area, Start-Up Area(s), Set-Up Area(s), Track-Out Area(s) and Test Strip(s) areas must be available and used for all comparative testing wherever possible;
- The Test Track should be as level as reasonably possible;
- The Test Site must have curbs extending the full length of the Test Track;
- Any catch basins, road gratings or inspection covers must be temporarily covered and sealed for the duration of the Test Run with insulation foam;
- A Warm-up Track Area (ideally forty metres or greater), is located immediately upstream to Test Section A, and must be of adequate size to allow a Test Sweeper to be stored and Test Sweeper staff can prepare and implement all the necessary operational settings prior to each Test Run;
- The Track-Out Areas (ideally 10 metres or greater), located downstream from the Test Sections. The Set-Up Areas (ideally 30 metres or greater), located downstream from the Track-Out Areas. The Start-Up Areas (ideally 10 metres or greater), located upstream from the Test Sections. See Figure 2 for the location of the above areas;
- Sections A (Test A- Sweeping during wet weather) and Sections B (Test B- Manoeuvrability around parked cars) are ideally 40 metres or greater, by 2 metres. Section C (Test C-Leaf removal from the road surface), Section D (Test D-Pick-up of large debris from the road surface), Section E (Test E-Heavy street sweepings removal from the road surface) and Section F (Test F-Dustless sweeping, sweeping without gutter brooms) are ideally 30 metres or greater, by 2 metres, as shown in Figure 1; and

- Figure 2 illustrates the Test Track markings for each of the areas: the mid point (solid blue line) of the Set-Up Areas, and the beginning and end of each Test Sections (dashed pink line), the end of the Start-Up Areas (solid pink line), mid point (solid white line) of each Test Sections and the end of the Track-Out Areas (solid green line).
- The pavement condition of the Test Course is determined by two types of distresses: surface defects and cracking. Surface defect distress includes raveling. Cracking distresses include longitudinal and meandering, alligator and transverse cracking.
- The pavement distress requirements only apply to the Test Strip Area (30 metres by 7 metres) of the Test Track.
- The area of the Test Strip should contain greater than 20% and less than 40% of total raveling and use the following formula to determine the percentage of severe versus moderate raveling: $\text{Total Raveling} = \text{Severe Raveling \%} \times 2 + \text{Moderate Raveling \%}$.
All other raveling must only be slight (no more than loss of fines) or better.
- The area of the Test Strip should contain cracks that are greater than 12 mm to less than 30 mm wide and are greater than 10 metres to less than 25 metres in total length. All other cracks must be less than 12 mm wide.
- Other areas of the Test Course should be paved and in reasonable condition such that the Test Sweeper will not loosen pavement particles.
- The following other types of distress must all be at or below the values given, or at a condition better than the descriptions stated:
 - Bleeding – none;
 - Patching - good condition;
 - Potholes – none;
 - Wheel Track Rutting: less than 12 mm;
 - Distortion – less than 50 mm deviation;
 - Rippling/Shoving - if any, does not create a rough ride; and
 - Excess Crown – less than 3% cross fall.
- Any distress that exceeds the allowable range must be corrected with patching or other repair.
- If total raveling and/or cracks is below the allowable range, those conditions need to be created. Deviations from the above may only occur if they will not affect results and are approved by the protocol development group.
- Note: As more testing occurs, the allowable range of pavement distress may be modified by the protocol development group if it is determined that a wider acceptable range of conditions does not affect sweeper protocol results.
- Appendix F, Description of Key Flexible Pavement Distresses provides detailed description of the key pavement distresses that are being used to determine the

pavement condition of the Test Track. Also, included is the City of Toronto's, Pavement Distress Manifestations Summary Table for Composite and Flexible Pavements summarizing the pavement distress types, the severity and extent criteria.

Figure 1: Operational On-Street Test Track



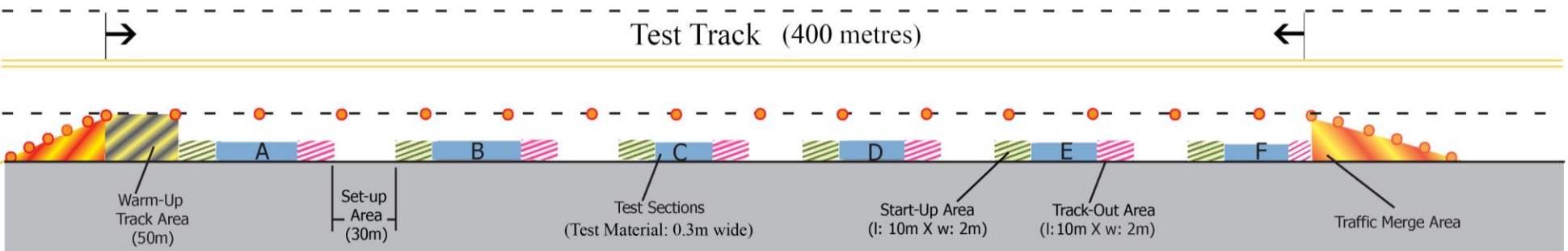
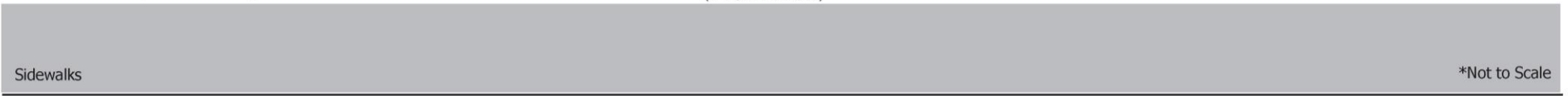
Section A - Sweeping During Wet Weather
(l: 40m X w: 2m)



Section B - Maneuverability Around Parked Cars
(l: 40m X w: 2m)



Section C - Leaf Removal
(l: 30m X w: 2m)



Section D - Pick-up of Large Debris
(l: 30m X w: 2m)

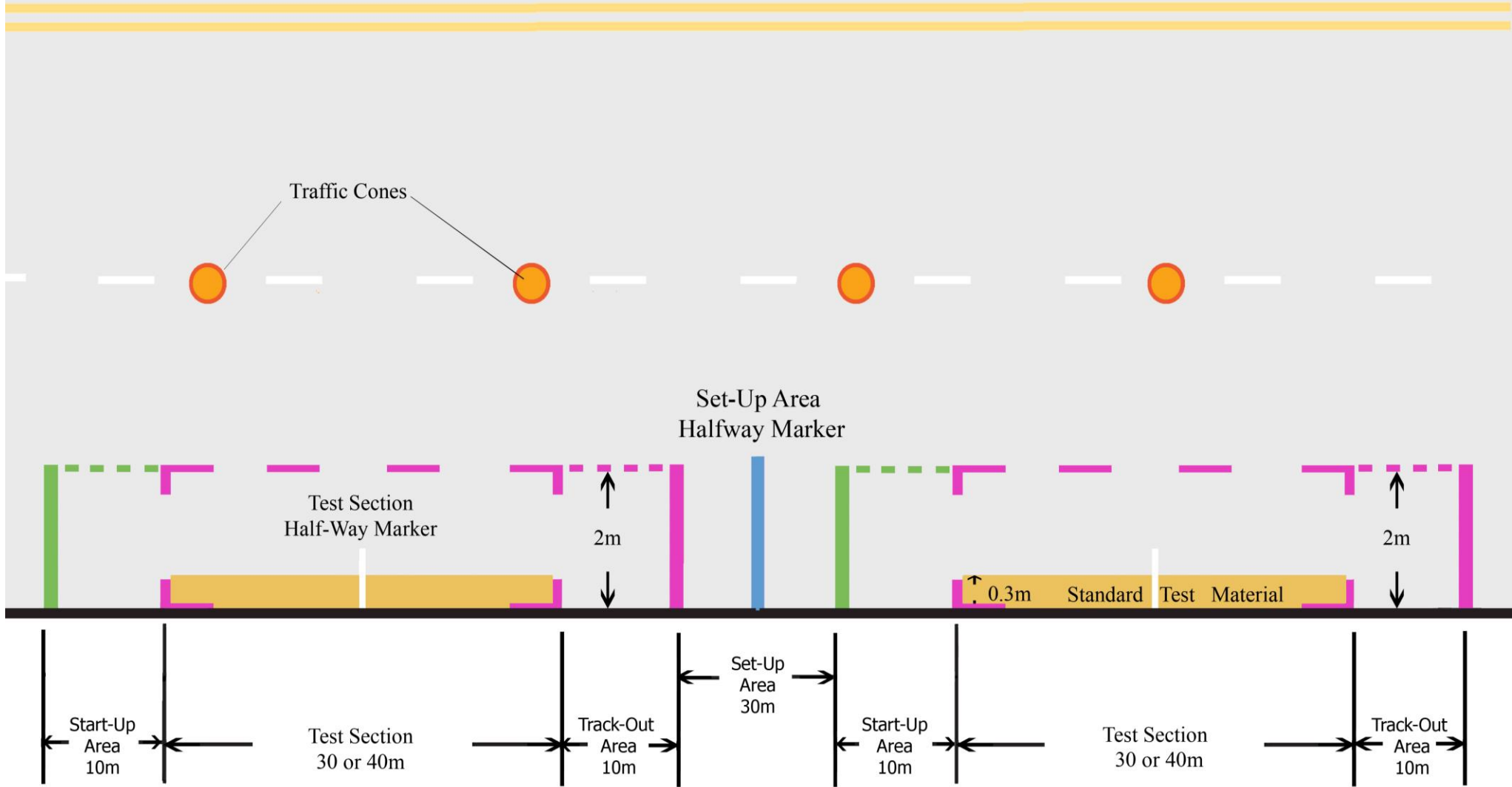


Section E - Heavy Silt Loading Removal
(l: 30m X w: 2m)



Section F - Dustless Sweeping
(l: 30m X w: 2m)

Figure 2: Detailed Marking of Test Track



* Not To Scale

6.4 Pre-Cleaning of Test Track Surface

The Test Track (i.e. Test Section(s), Test Strip(s), Start-Up Area(s), Set-Up Area(s), Track-Out Area(s), Warm-Up Track and Traffic Merge Area(s)) should be dry and free of oils and paints or any other materials that would interact with the test materials or their subsequent removal. Prior to testing, the Test Site will require a very thorough cleaning of all appropriate surfaces. The Test Track Surface should be pre-swept three times by a test agency's in-house street sweeper or by the local municipality's street sweeper each day prior to initiating the Test Run.

6.5 Standard Test Material Preparation

The Standard Test Material must be used as a base material for all Test Sections which simulates street sweepings found on a typical roadway. The following steps should be taken for the preparation, measurement and documentation of the Standard Test Material:

- mix 50% of construction sand and 50% of limestone screenings using concrete mixer (see Figure 3) to create the Standard Test Material;
- place Standard Test Material in each 23 litre container, 4 containers with approximately 30 kg (+/- 1kg) of Standard Test Material mixture and 8 containers with approximately 22.5 kg (+/- 1kg) of Standard Test Material mixture for each test day;
- number the containers required for each test day and for each Test Section;
- Appendix E contains MSDS sheets for the construction sand and limestone screening; and
- weigh and label each of the containers and fill out all appropriate documentation.

Figure 3 Concrete Mixer and Containers



6.6 Leaf Test Material

The following steps should be taken for the preparation, measurement and documentation of the Leaf Test Material:

- Collect approximately 30 kg (+/- 1 kg) of Leaf Test Material;

- Weigh and place leaves in containers for each test day; and
- Label all containers and document all measurements.

6.7 Large Debris Test Material

The following steps should be taken for the preparation, measurement and documentation of the Large Debris Test Material:

- Collect a specific number of large debris items (2 crushed 335 ml pop cans, 1 full 335 ml pop can, 8 small tree branches (max length = 1.0 metre) , 1 glass bottle, 2-500 ml crushed plastic water bottles, 1-500 ml full water bottle, 1-1 L empty plastic bottle, one plastic bag, 2 plastic strips, 1 crushed coffee cup, 1 cigarette box, 3 pieces of coal patch (various sizes));
- Place, weigh, label and document, approximately 3 kg of gravel in a separate container for each test day;
- Weigh, count and measure the size of the large debris; and
- Separate the rest of the large debris and place the specific items of large debris in containers for each test day.

6.8 Heavy Debris Test Material

Place, weigh, label and document, approximately 5 kg (+/- 0.25 kg) of salt and 10kg (+/- 0.5 kg) of coal patch in a separate container for each test day.

6.9 Test Material Application

The six Test Sections each require a different set-up procedure and a specific application of test material. The following documents the procedures used to apply the test material to each Test Section. All Test Sections contain the Standard Test Material and the same method of applying the material is to be used in all sections, see Figure 4 for an illustration of the Standard Test Material application.

In order to simulate typical Street Sweepings found on Paved Road Surface the amounts of approximately 60kg and 45 kg must be used. For each Test Run the exact amount weight of all test material must be measured and documented.

A known weight and volume of the Standard Test Material must be consistently applied in the Test Strip area to a width of 30 cm for the full length of all Test Sections. The Standard Test Material must be placed along the curb with a greater depth of material adjacent to the curb. The width of the Test Sections is 2 metres and is less than the maximum swept path. Standard Test Material is solely applied on Test Sections A, B and F and other Test Sections contain Standard Test Material and other test materials.

Figure 4: Standard Test Material Application



(i) Spreader



(ii) Applying Test Material Along The Curb



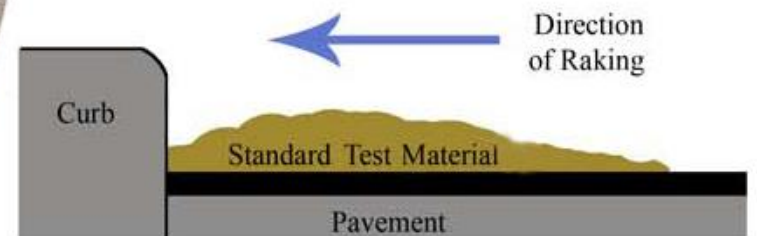
(iii) Raking the Standard Test Material Towards the Curb



(iv) Sample of Operational On-Street Test Section



(v) Standard Test Material



(vi) Cross Section of Standard Test Material

A professional grade, manually operated and powered, large fertilizer spreader (see Figure 5) modified to release Standard Test Material evenly along a width of 30 cm only should be used. Also, a garden rake (see Figure 6) should be used to move the Standard Test Material completely into the curb.

Figure 5: Fertilizer Spreader



Figure 6: Garden Rake



6.9.1 Wet Paved Surface - Test Section A

- A mass of approximately 60 kg (+/-1kg) of Standard Test Material should be applied to the Test Strip (length of 40 metres by a width of 30 cm) in Test Section A;
- Catchbasins and/or inspection covers should not be present within Test Section A;
- Build a dam to ensure that the water from the Wet Paved Surface Test Section does not contaminate other Test Sections. It should be located at the end of the Track-Out Area that is adjacent to the Wet Paved Surface Test Section;
- Use a flusher truck (see Figure 7) and flush the curbed lane the full 40 metre length of the Test Section with water, the flusher truck engine set at 1100 RPM and flusher truck traveling approximately 5 km/hr; and
- 20 minutes after the flusher truck has flushed the road surface, then apply the Standard Test Material.

Figure 7: Flusher Truck

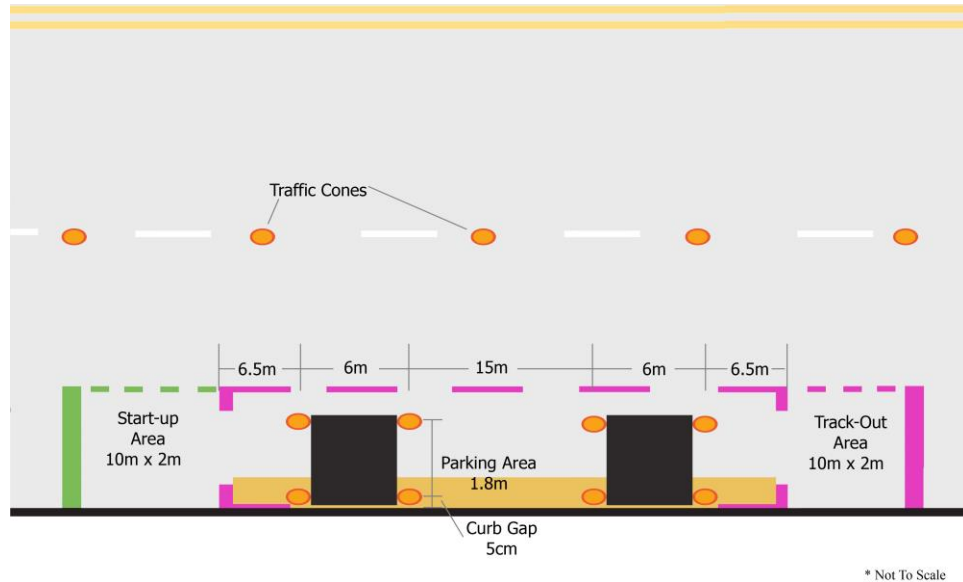


6.9.2 Maneuverability Around Parked Cars - Test Section B

- A mass of approximately 60 kg (+/-1kg) of Standard Test Material should be applied to the Test Strips (length of 40 metres by a width of 30 cm) in Test Section B;
- Apply the Standard Test Material prior to parking the vehicles;
- Park one car and one pick-up truck along the curb with a gap of 15 metres between the car and pick-up truck;
- The car and pick-up truck should be parked between 10 to 15 cm from the curb; and

- Refer to Figure 8 for the placement of traffic cones in the Test Section B that delineate the parking space for the car and pick-up truck.

Figure 8: Schematic of Parking Spaces in Test Section B



6.9.3 Leaf Removal – Test Section C

- A mass of approximately 45 kg (+/-1kg) of Standard Test Material should be applied to the Test Strips (length of 30 metres by a width of 30 cm) in Test Section C; and
- Apply the Standard Test Material prior to randomly applying a mass of approximately 30 kg (+/- 1kg) of Leaf Test Material on top the Standard Test Material.

6.9.4 Large Debris Removal – Test Section D

- A mass of approximately 45 kg (+/-1kg) of Standard Test Material should be applied to the Test Strip (length of 30 metres by a width of 30 cm) in Test Section D;
- Apply the Standard Test Material prior to randomly placing the Large Debris Test Material on top of the Standard Test Material; and
- The larger debris will be placed on the surface using as uniform a longitudinal distribution as possible when applying.

6.9.5 Heavy Debris Removal – Test Section E

- A mass of approximately 45 kg (+/-1kg) of Standard Test Material should be applied to the Test Strips (length of 30 metres by a width of 30 cm) in Test Section E;
- Apply the Standard Test Material prior to placing the Heavy Debris Test Material on top; and

- Apply a mass of approximately 16 kg (+/-1kg) of Heavy Debris Test Material in the central 15 metres of the Test Strip (length of 15 metres by a width of 30 cm).

6.9.6 *Dustless Mode – Test Section F*

- A mass of approximately 40 kg (+/-1kg) of Standard Test Material should be applied to the Test Strips (length of 30 metres by a width of 30 cm) in Test Section F.

6.10 **Sweeper Test**

During a Test Run, the pre-weighed Test Sweeper will sweep through each Test Section starting at Test Section A and proceeding to Test Section F. The Test Sweeper will start at the Warm-Up Track Area where the Test Sweeper can be stored and all the necessary operational settings can be made prior to the initiation of the Test Run. Once all sweeper operational settings and configurations for the Test Section A have been adjusted, the Test Sweeper will enter the Start-Up Area without sweeping. Once inside the Set-Up Area, the Test Sweeper must activate all sweeping systems and when ready sweep through the Sweeping Set-Up Area into the adjacent Test Section without stopping.

The Test Sweeper, having swept each Test Section, will continue to sweep into the adjacent Track-Out Area. The Test Sweeper must stop before the front bumper passes the end of the Track-Out Area and close down all sweeping systems (i.e. vacuum, water, filters and lift pick-up head, gutter broom, main broom, etc.) prior to exiting the adjacent Track- Area.

The Test Sweeper will then proceed and travel in a non-sweeping mode past the end of the Track-Out Area and enter the adjacent Set-Up Area, where the Test Sweeper can stop and adjust any operational configurations (if required) before proceeding with the next Individual Test with the above process being repeated for each Individual Test.

The test agency staff will document all the changes made to the Test Sweeper's settings as implemented by the manufacturer's representatives and also document the time, to the nearest minute, that it takes for the manufacturer's representatives to adjust the Test Sweeper settings.

6.11 **Equipment Used to Vacuum the Residue Material**

The Test Track must be cleaned following each Test Run with a canister type HEPA vacuum (see Figure 9). It is advisable to use at least four Shop-Vac (e.g. Contractors Model) vacuums throughout the testing. The Shop-Vac vacuum must be equipped with a combination of High-Performance HEPA Cartridge Filters and High-Efficiency Disposable HEPA Filter Bags. Any similar commercially available unit of equivalent performance and accessories or better can be used. The vacuums must be fitted with stainless steel accessories and metal brushes.

Figure 9: Shop-Vac HEPA Vacuums



6.12 Test Track Cleaning Methodology

The purpose of the rigorous Test Track cleaning methodology is to determine the amount of Residue Material remaining on each of the Test Sections including that which has been removed from the Test Strips but deposited in Track-Out Areas after the completion of all tests, by vacuuming and subsequently weighing the Residue Material. Systematic cleaning of the Test Sections must be undertaken with the HEPA vacuum equipment after the completion of the Test Run.

The HEPA vacuum equipment must be pre-conditioned once with the Standard Test Material prior to the first Test Run. Pre-conditioning of HEPA vacuum equipment can be done as part of a (strongly recommended) operator training process that fully duplicates a Test Run including material spreading and residue vacuuming prior to the first Test Run.

One fresh cartridge filter should be used for each Individual Test. Each cartridge filter must also be weighed prior to and post each Individual Test. The Wet Paved Test Section Shop-Vac vacuums set-up may differ from the set-up of all other Test Sections in that if the Test Section may still be wet after the Test Sweeper has completed the Test Run, the Shop-Vac vacuums will contain a laundry bag, cheese cloth and foam filters (see Figure 10) when vacuuming the Residual Material in Test Section A.

Sufficient filter bags must be available to capture Residue Material following each Test Run. The average weight of the unused HEPA filter bag, heavy-duty plastic bag, plastic container, container lid, laundry bag, cheese cloth and foam filter must be established and the weights recorded.

Figure 10 Shop-Vac cartridge, HEPA filter bag, and cheese cloth



Filter bags should be removed and transferred into a leak-proof heavy-duty plastic bag and placed in a sealable holding container of known weight. Each filter bag and contents must be weighed and labelled with the date; time, model and make of Test Sweeper, test number and weight recorded less weight of (average) filter bag, plastic bag and holding container.

At the beginning of each Test Section a fresh disposable HEPA filter bag and HEPA cartridge filter should be installed. The HEPA filter bags should be checked periodically during the vacuuming and should be replaced once the HEPA filter bags are approximately 50% full in order to prevent the bags from breaking either inside the HEPA vacuum and/or when removing an over filled bag. Once the HEPA filter bag is removed from the vacuum equipment the HEPA filter bag should be placed in a plastic container with a sealable lid that is lined with a heavy-duty plastic bag for storage.

At the completion of each Individual Test the vacuum canisters and metal accessories must be thoroughly cleaned of all residue and/or moisture.

6.13 Weighing the Test Sweeper

Test Sweepers must be weighed immediately prior to, and following, the completion of a Test Run. A portable four pad Axle Weigh Scale (Canadian Scale Company Ltd), capacity of 20,000 lbs at a graduation of 10 lbs, or equivalent should be used to weigh the Test Sweeper. The Axle Weigh Scale should be setup adjacent to the Test Facility, see Figure 16. The weigh scale that is used to weigh the Test Sweeper, should be verified (ability to incrementally weigh the differential weight), ideally this should be verified shortly before any testing commences and preferably checked for consistency with a known truck weight on a daily basis.

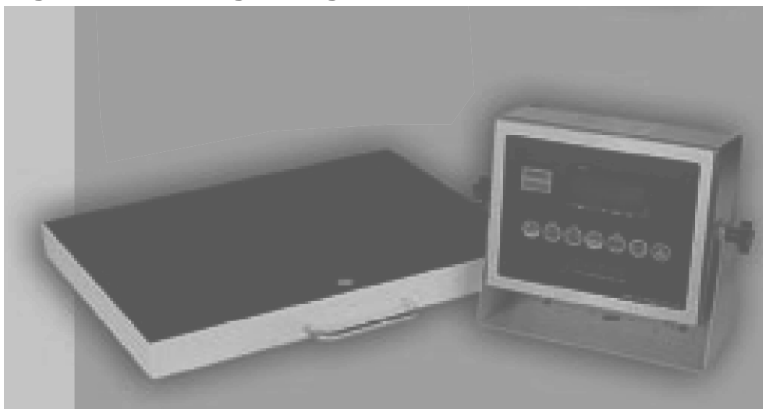
Figure 11 Portable Axle Weigh Scale



6.14 Weighing of Test Material and Residue Material

A lightweight portable scale (e.g. Cardinal Scale Manufacturing Company, GP Series Digital Low-Profile Scales, GP-400-205 Model) with a capacity of approximately 180 kg at a graduation of 0.1kg, or equivalent equipment should be used to weigh the Standard Test Material, all other test material and Residue Material stored in the plastic containers. The portable scale (see Figure 12) should be setup in the Weighing Area, where the Test Material is stored. The weigh scale should be calibrated at the beginning and at the end of the weighing of Test Material and Residue Material and/or after every 3rd weighing.

Figure 12 Lightweight Portable Scale for Test Material



6.15 Weighing of Sample Material

A lightweight portable scale (see Figure 13) (e.g. Fresco Digital Low-Profile Scales, FSC-100, Model), capacity of 3 kg at graduation of 1 g, or equivalent equipment should be used to weigh the samples of all applied test materials and residual materials. The portable scale should be setup in a dedicated area, such

as where the test material is stored. The weigh scale that weighs the sample materials should be verified at the beginning and end of the weighing and after every 3rd weighing.

Figure 13 Lightweight Portable Scale for Sample Material



6.16 Method Used to Analyze Data

After the initial weighing of all the materials contained in each of the containers, a sample of all the test material applied (except from Large Debris Material) and Residue Material must be collected and placed in a mason jar to be baked to obtain dry weight. Weigh all test material and Residue Material prior to baking the samples. Bake the samples in an oven at a range of 105°C to 110°C for 24 hours. Weigh all the test material and Residue Material samples after baking the samples. Document all the weights obtained and perform the statistical analysis to determine the operational performance efficiency of the Test Sweeper for each Test Section. Section 9 contains the basic calculations for each of the criteria.

Appendix A contains the sweeper information forms that should be used to document all data observed and measured during the Test Run for each day of testing. Appendix B contains the spreadsheets and the calculations that must be performed in order obtain the efficiency levels for each operational criteria.

An average of the three best values calculated for each of the operational criteria must be used to determine the performance level.

7.0 OTHER TEST RUN REQUIREMENTS

7.1 Conditioning Run for Test Sweepers

The Test Sweepers must be preconditioned under dry street conditions and without the use of water, either outside or inside the Test Sweeper. The conditioning should take place on a asphalt paved two-lane road with a typically heavy fine road dust for a minimum of 6 kilometres (sweeping the 2 km Conditioning Road three times) prior to the weighing of the Test Sweeper and subsequent Test Run. The pre-conditioning must be repeated for all the subsequent Test Runs in the Test Sequence. A dry dump of the sweepings could be made prior to weighing, should the hopper become filled to capacity - but it should not be necessary. The roadway used to precondition the street sweepers should be of similar road classification and must be external to the Test Facility.

A “sweeper-experienced” test agency representative must accompany the Test Sweeper by riding in the cab.

Monitor and record on video or photographs from another vehicle, the performance of each Test Sweeper as the Test Sweeper undertakes its Conditioning Run.

The Conditioning Run will be exposed to prevailing environmental conditions and to extraneous disturbances (e.g. as from wind or precipitation) and therefore excessive precipitation will warrant the postponement of the testing.

Figure 14: Conditioning Run



7.2 Weather Conditions

Air temperature, relative humidity, wind strength and direction must be recorded using on-site meteorological equipment and accessing meteorological data from Environment Canada or USA NOAA. Meteorological data (temperature and relative humidity plus wind strength) should be obtained from the on-site meteorological equipment, see Figure 14 and 15. For example, TSI Incorporated Q-Track IAQ Model 8550/8551 equipment can be used to measure Humidity and Temperature. Forecast information (used to predict and avoid initiating a test

during unacceptable weather conditions) should be obtained on-line from Environment Canada-Meteorological Service Canada (MSC) or US NOAA. Also, hourly recorded data must be obtained from the nearest weather station for the duration of the testing plus one day prior.

The following activities must be undertaken during the testing:

- Prevailing weather conditions must be recorded before, during and after each Test Run;
- There must be no standing water remaining from precipitation or post precipitation seepage into the Test Track and no damp surface on the Test Track – i.e. the Test Track must remain dry, except for Test Section A; and
- Meteorological instrumentation must either exist or be installed near the Test Track to measure temperature, relative humidity, and permit absolute humidity to be calculated.

The excessive presence of water vapour (moisture) in the air is very likely to have an influence in increasing the moisture content of the test materials which may lead to material “clumping”. Essentially, the material becomes both more inherently self-cohesive than if the material were perfectly dry and free-running. (This may be envisaged as being similar to the common clumping of salt grains in the presence of moisture.)

How critical this is to on-street test results obtained is uncertain. The moisture itself will add only marginal mass to samples – but this is corrected for by drying and weighing samples. Particle bonding caused by moisture is likely to be present but may well be insignificant.

However, based on prudent avoidance it is recommended that test materials not be laid down or swept up in conditions with a relative humidity (air) greater than 90%. Further, if the moisture content of materials to be spread exceeds 15% (i.e. is approaching saturation), such materials should be spread out to air-dry until the soil moisture content percentage by weight is less than 20%. These two values may be modified if after specific testing for clumping and moisture content of material, it is deemed appropriate to do so at higher relative humidity levels or higher material moisture content levels.

These following values are provided to identify conditions above or below which weather will adversely impact the test material or the measurements or its removal. Consideration is also given to ensure combinations of weather factors do not combine to create unacceptable conditions. The following conditions must be present:

- Air temperature needs to be above freezing, (otherwise loose material might be bound by ice forming in interstices);
- Air temperature should be below levels at which any Test Material is baked into cohesive or partially cohesive wholes. This value will vary with relative humidity;

- The suggested test operating temperature range is from 5°C to 30°C with additional restrictions depending on Relative Humidity and Precipitation to ensure material is consistently and reproducibly dry and loose;
- Test material should not be laid down or swept up in conditions with a relative humidity (air) greater than 90%, if the moisture content of materials to be spread exceeds 15% (i.e. is approaching saturation) and the material should not be laid down;
- During the test, wind speeds on site must be below 25 km/hr so as not to disturb and remove the test material from the Test Sections and/or deposit material on the Test Section from adjacent areas, if the test agency observes wind speeds of less than 25 km/hr disturbing the test material the testing should be delayed and/or postponed;
- Precipitation should be almost non-existent, when light rain falls it can act to clump dry material into different effective size fractions and when heavy rain falls it can also lead to washing test material out of the Test Sections;
- A very light mist like rain may be tolerated if of very short duration. A longer period of very light rain or mist should be followed by a substantial drying period “if” the Test Material has already been laid down, otherwise sufficient time should be allowed for all pavement surfaces to dry completely;

The presence of significant amount of rainfall , temperature below 5°C or above 30°C, relative humidity greater than 90%, and wind in excess of 25 km/hr at the test site on the test day will lead to the Test Run being postponed until the next day and/or a subsequent days when suitable environmental conditions exist.

Figure 15: Meteorological Equipment (Q-Track)



Figure 16: Anemometer



7.3 Recording of Individual Tests

It is advisable to maintain a good visual record of all test procedures throughout the test day. Agency staff should set-up video recorders (at least two). An additional digital camera should be used to record all key components of the test, including the demonstration of Test Sweeper, conditioning of Test Sweeper, weighing of Test Sweeper, weighing of all test materials, application of all test materials, Individual Tests, vacuuming of Residual Material, weighing of Residual Material, post test weighing of Test Sweeper and its clean-up.

7.4 Safety Requirements

All necessary safety equipment and requirements as specified by the Occupational Health and Safety regulatory agency responsible for the jurisdiction where the test is being implemented must be employed, including all requirements in respect to the handling, storage and disposal of the Test Material, plus lane closure and working in the road right-of-way. All personnel should wear the appropriate safety equipment as required when working at the Test Site, such as: hard hats, safety vests, safety boots, goggles/sun glasses, gloves, sunscreen and mosquito repellent.

8.0 TEST RUN PROCEDURE SUMMARY

8.1 Procedure Prior to the Test

Performed Days Prior to the Test	Prepare Standard Test Material, place in sealed containers and weigh all the containers separately;
	Review all tasks, roles and responsibility with agency staff;
	Obtain lane closure permits from local municipality (if required);
	Perform a dry run of the key tasks, such as spreading of Standard Test Material, vacuuming of Residue Material and documentation procedures;
Performed One Day Prior to the Test	The night (6-18 hours) before the test, a best available sweeper sweeps the Conditioning Road and the Test Track three times on each side of the street;
Morning of the First Test Run	Implement lane closure using appropriate and safe traffic operation procedures and mark-out the road surface of the Test Track identifying all the Traffic Merge Areas, the Warm-up Track Area, and all Test Sections, Start-Up Areas, Set-Up Areas and Track-Out Areas;
	Identify the mid point (solid blue line) of the Set-up Areas, and the beginning and end of the Test Sections (dashed pink line) and the end of the Track-Out Areas (solid green line);
	Prepare road surface by covering the specific catch basins, as related to Test Section A and any other catch basin that may have the test material spread over it;
	Set-up all necessary equipment and materials on one side of the Test Track, including: generator, power cords, material spreader, vacuums, cameras, masks, weather monitor, tables, all pre-prepared test material, garbage containers, water cooler, water, shovels/brooms, two rakes, PC's and other miscellaneous supplies and equipment;
	Ensure all staff comply with all safety equipment requirements : safety boots, vest, hard hats, gloves, sun screen, mosquito repellent and bottled water;

8.2 Test Run Procedure

- The test procedure should be implemented over four consecutive days (weather permitting). If there are prevailing environmental conditions that prevent the implementation of four consecutive days of testing, then testing will be postponed and will proceed on the next consecutive day when the environmental conditions are acceptable;
- Postponement of the testing due to weather is not considered to void the test;
- The test must be completed in consecutive test days for all operational settings by completing the full Test Run on each day. Only the three best overall performances will be used to establish the performance levels for each of the operational criteria; and
- If shrouds (or skirts) are not permitted on the Test Sweeper’s gutter brooms during the test, the flexible portion of the shrouds need to be removed and no portion of the shrouds (flexible or non-flexible) are to be in contact with the curb during the Test Run.

	Key Steps
Immediately Prior to Test Run	Meet and greet the manufacturers and review safety equipment requirements with the Vendor’s representative(s)
	Vendor’s representative(s) demonstrate the Test Sweeper at an appropriate location;
	A Test Agency representative will accompany the Test Sweeper at all times;
	Start the videotaping and taking of still shots to record necessary information;
	Test Agency staff and vendor representative(s) inspect the Test Track and review the Individual Test;
	Perform the Conditioning Test Run;
	Collect a sample in a mason jar from each container of the Standard Test Material, Large Debris Material, Heavy Debris Material and Leaf Material used on the first Test Run of the first day of testing;
Test Run	Each replicated Individual Test will include one pass by the Test Sweeper through one Test Section. A Test Run includes the completion of all six Individual Tests;
	Obtain the pre-test weight of Test Sweeper;
	Apply all the prepared Test Materials along the curb for a width of 30 cm on each of the six Test Sections;
	Test Sweeper must meet the following requirements: <ul style="list-style-type: none"> • operate with steel-bristled gutter brooms; • main brooms can be either poly-bristled or steel-bristled;

	<ul style="list-style-type: none"> • use standard gutter broom operating procedures regarding the proximity to curb, rotation speed, angle of attack, when deploying their gutter brooms; • operated in accordance with manufacturer/supplier recommended maintenance schedules, safety checks, and daily operational checks; • apply water on the gutter brooms should conform to the sweeper model standard specification (number, size and pressure of water nozzle); and • application of water on the gutter brooms is not permitted during the dustless sweeping test, i.e. sweeping without gutter brooms.
Test Run continued	<ul style="list-style-type: none"> • The Wet Paved Surface Test Section (sweeping during wet conditions) has to be flushed using a flusher truck, the flusher truck engine set at 1100 RPM and flusher truck traveling approximately 5 km/hr prior to the application of the Standard Test Material. • 20 minutes after the truck has flushed the road surface, 60 kg (+/- 1kg) of the Standard Test Material is applied on the full 40 metre length by 30 cm wide by approximately 0.6 cm in depth;
	<p>Apply the Standard Test Material on each of the five Test Sections:</p> <ul style="list-style-type: none"> • use a fertilizer spreader to spread 2 containers of Standard Test Material on each of the Test Sections; • 60 kg (+/- 1kg) of Standard Test Material covering an area of 30 cm by 40 metres of approximately 0.6 cm in depth; • 45kg (+/- 1kg) of Standard Test Material covering an area of 30 cm by 30 metres of approximately 0.6 cm in depth; • spread salt and coal patch material, of approximately 15 kg (+/- 0.5 kg) weight over an area of 30 cm by 15 metres (middle of the 30 metres) on the Heavy Debris Test Section; • spread leaves, approximately 30 kg (+/- 1 kg) weight over an area of 30 cm by 30 metres on the Leaf Test Section; and • spread gravel and large debris material, of approximately 2.5 kg (+/- 0.25 kg) weight over an area of 30 cm by 30 metres on the Large Debris Test Section
	Rakes are to be used to move the Standard Test Material closer to and abutting the curb;
	Test Sweeper operational settings must be recorded and confirmed to be in compliance for each Test Section. All operating settings and configurations will be recorded by a “sweeper experienced” test agency representative riding in the cab with the Test Sweeper operator;
Test Run continued	<p>Individual Test of Test Sweeper</p> <ul style="list-style-type: none"> • Test Sweeper will be positioned in the Warm Up Track Area and ensure all operational settings are set and functioning;

	<ul style="list-style-type: none"> • Once ready the Test Sweeper will move into the Start-Up Area without sweeping; • In the Start-Up Area, the Test Sweeper will activate all operational settings and configurations and be in full street sweeping mode, before the pink line (beginning of each Test Section) and continue to sweep along the Test Section in full sweeping mode; • The Test Sweeper will continue to sweep through the Test Section and enter the Track-Out Area, where the sweeper will stop all sweeping systems before exiting the Track-Out Area (solid green line); • Test Sweepers are to operate at speeds within the manufacturers' officially specified range, as identified in the manufacturer's "official" specifications are available – a sweeper will operate at an operating speed within the range of 5–10 km per hour along the Test Track applying all operational setting, including but not limited to: the main and side brooms, vacuum and filtration system and in keeping with Test Section requirements; • Test Sweeper should apply water inside and outside the sweeper as required for dust suppression; • Test Sweeper's operating speed must be consistently maintained throughout the Test Run and independently recorded; • Test Sweeper can stop at the mid-point of each of the Set-Up Areas located between each Track-Out Areas and Start-Up Areas and make all the necessary operational configuration adjustments for the next Individual Test; and • Test Sweeper will continue along the Test Track until all Individual Tests are completed;
	Video record all Test Sections so as to show general performance of Test Sweeper in each Test Section and also specifically record action of gutter broom sweeping Test Material in each Test Section;
	Obtain the post Test Run weight of the Test Sweeper;
	Test agency staff and vendor representatives inspect the Test Track for Residue Material;
	Dump the street sweepings from the hopper of the Test Sweeper in an enclosed street sweepings pit. A light mist of water should be sprayed from a flusher truck onto the material as the hopper is being emptied;
	Clean the Test Sweeper, park and lock the Test Sweeper inside a secure building;
Test Run continued	Vendor's representatives cannot remove the Test Sweeper from the test agency's premises for the duration of the testing;
	Vacuum to collect the Residue Material inside the Test Track using two or more Shop-Vac vacuums or equivalent. The Test Agency staff will vacuum the 30 metres by 2 metres of paved road surface area (plus 10 metres of Track-Out Area(s) beyond the end of each of the Test Sections C-F) or 40 metres by 2 metres of paved road surface area (plus 10 metres of Track-Out Area beyond the end of each of the Test

	Sections A and B);
	Use Shop-Vac vacuums with HEPA filter bags and HEPA filter cartridges to collect the Residue Material from the surface of the road;
	After vacuuming each Test Section, remove HEPA filter bags from the Shop-Vac vacuums and wipe the vacuum canisters and inlet with Swifter dust wipes or equivalent and store in sealed plastic containers;
	Replace the HEPA filter bags for every Individual Test, replace the HEPA filter cartridges after completing vacuuming of all the Test Sections on the Test Track for one Test Run;
	Note: The Wet Paved Test Section Shop-Vac vacuums set-up may differ from the set-up of all other Test Sections in that if the Test Section is still wet after the Test Sweeper has completed the Test Run, the Shop-Vac vacuums will contain a laundry bag, cheese cloth and foam filters when vacuuming the Residual Material in Test Section A;
	Residue Material containers will be weighed, labeled and documented at the weigh station;
Immediately After the Test	Collect a sample of the Residue Material from each Test Section in a mason jar or equivalent;
	Remove all equipment and materials from the road;
	Reopen the road;
	Clean and store all equipment;
	The disposal of Residual Material from a Test Sweeper's hopper must follow all applicable regulations and is to be removed from the Test Sweeper's hopper after the completion of the Test Run.

8.3 Procedure After the Test

Analysis Performed	Edit and condense all the video footage and photo shots;
	Weigh the Standard Test Material and Residue Material samples prior to baking the samples;
	Bake the samples in an oven at a range of 105°C to 110°C for 24 hours;
	Weigh the Standard Test Material and Residue Material samples after baking the samples; and
	Document all the weights obtained and perform the calculations to obtain the operational performance efficiency for each Test Section as well as the time required to change the operational configuration and/or setting between each Individual Test.

9.0 BASIC CALCULATIONS

The following calculations are completed for each Test Run. The performance levels for each of the seven operational efficiency criteria are calculated by averaging the results of the overall three best Test Runs.

9.1 Wet Paved Surface Condition Pick-up Efficiency (%)

Assesses the Test Sweeper's ability to sweep Standard Test Material, when the roadway is wet.

$$PE_{\text{Test A}} = [(W_{\text{standard}} - W_{\text{residue}})/W_{\text{standard}}] \times 100 \text{ where,}$$

where,

$$PE_{\text{Test A}} = \text{pick-up efficiency of sweeper sweeping during wet conditions (\%)} \\ W_{\text{standard}} = \text{total net weight of Standard Test Material applied over Test Section before the Individual Test (kg)} \\ W_{\text{residue}} = \text{total net weight of Residue Material vacuumed from Test Section after Individual Test (kg)}$$

9.2 Maneuverability Around Parked Cars Pick-up Efficiency (%)

Assess the Test Sweeper's ability to safely and expeditiously pick-up the Standard Test Material around parked cars and stationary objects.

$$PE_{\text{Test B}} = [(W_{\text{standard}} - W_{\text{residue}})/W_{\text{standard}}] \times 100 \text{ where,}$$

where,

$$PE_{\text{Test B}} = \text{pick-up efficiency of sweeper sweeping while manoeuvring around parked cars (\%)} \\ W_{\text{standard}} = \text{total net weight of Standard Test Material applied over Test Section before the Individual Test (kg)} \\ W_{\text{residue}} = \text{total net weight of Residue Material vacuumed from Test Section after the Individual Test (kg)}$$

9.3 Pick-up of Typical Street Sweepings Plus Leaves Efficiency (%)

Assess the Test sweeper's ability to effectively pick-up Standard Test Material and heavy deposit of leaves on the paved road surface.

$$PE_{\text{Test C}} = [((W_{\text{standard}} + W_{\text{leaves}}) - W_{\text{residue}})/(W_{\text{standard}} + W_{\text{leaves}})] \times 100 \text{ where,}$$

$$PE_{\text{Test C}} = \text{pick-up efficiency of sweeper sweeping combination of standard sweepings and leaves (\%)} \\ W_{\text{standard}} = \text{total net weight of Standard Test Material applied over Test Section before the Individual Test (kg)} \\ W_{\text{leaves}} = \text{total net weight of Leaf Test Material applied over Test Section before the Individual Test (kg)}$$

W_{residue} = total net weight of Residue Material vacuumed from Test Track after the Individual Test (kg)

9.4 Typical Street Sweepings plus Larger Debris Pick-up Efficiency (%)

Assess the sweeper's ability to pick-up Standard Test Material and Large Debris Test Material.

$$PE_{\text{Test D}} = \frac{[(W_{\text{standard}} + W_{\text{large debris}}) - W_{\text{residue}}]}{(W_{\text{standard}} + W_{\text{large debris}})} \times 100$$

where,

$PE_{\text{Test D}}$ = pick-up efficiency of sweeper sweeping a combination of standard sweepings and large debris (%)

W_{standard} = weight of Standard Test Material applied over Test Section before the Individual Test (kg)

$W_{\text{large debris}}$ = weight of Large Debris Test Material applied over Test Section before the Individual Test (kg)

W_{residue} = weight of Residue Material vacuumed from Test Track after the Individual Test (kg)

9.5 Heavy Street Sweepings Pick-up Efficiency (%)

Assess the ability of the Test Sweeper to remove a Standard Test Material and additional salt and coal patch typically found during spring clean-up and on roads adjacent to construction sites.

$$PE_{\text{Test E}} = \frac{[(W_{\text{standard}} + W_{\text{heavy debris}}) - W_{\text{residue}}]}{(W_{\text{standard}} + W_{\text{heavy debris}})} \times 100$$

where,

$PE_{\text{Test E}}$ = pick-up efficiency of sweeper sweeping a combination of standard sweepings and heavy debris (%)

W_{standard} = weight of Standard Test Material applied over Test Section before the Individual Test (kg)

$W_{\text{heavy debris}}$ = weight of Heavy Debris Test Material applied over Test Section before the Individual Test (kg)

W_{residue} = weight of Residue Material vacuumed from Test Track after the Individual Test (kg)

9.6 Typical Street Sweepings and Operate Sweeper without Gutter Brooms Pick-up Efficiency (%)

Assess the ability of the Test Sweeper to sweep adjacent to the curb without the use of gutter brooms, using only the main vacuum pick-up head.

$$PE_{\text{Test F}} = \frac{(W_{\text{standard}} - W_{\text{residue}})}{W_{\text{standard}}} \times 100$$

where,

- $PE_{\text{Test F}}$ = pick-up efficiency of sweeper sweeping large without the use of gutter brooms (%)
- W_{standard} = weight of Standard Test Material applied over Test Section before the Individual Test (kg)
- W_{residue} = weight of Residue Material vacuumed from Test Track after the Individual Test (kg)

9.7 Change in Operating System - Time Score

$$T_{\text{Total}} = \text{Test A-B}_{\text{time}} + \text{Test B-C}_{\text{time}} + \text{Test C-D}_{\text{time}} + \text{Test D-E}_{\text{time}} + \text{Test E-F}_{\text{time}}$$

where,

$\text{Test A-B}_{\text{time}}$ = the time (rounded to nearest minute) it takes for the manufacturer's representatives to adjust any operational configurations between Individual Test A and Individual Test B.

$\text{Test B-C}_{\text{time}}$ = the time (rounded to nearest minute) it takes for the manufacturer's representatives to adjust any operational configurations between Individual Test B and Individual Test C.

$\text{Test C-D}_{\text{time}}$ = the time (rounded to nearest minute) it takes for the manufacturer's representatives to adjust any operational configurations between Individual Test C and Individual Test D.

$\text{Test D-E}_{\text{time}}$ = the time (rounded to nearest minute) it takes for the manufacturer's representatives to adjust any operational configurations between Individual Test D and Individual Test E.

$\text{Test E-F}_{\text{time}}$ = the time (rounded to nearest minute) it takes for the manufacturer's representatives to adjust any operational settings and/or configurations between Individual Test E and Individual Test F.

10.0 REPORTING

The following will be included in the Operational On-Street Test Report prepared by the independent test agency that implemented the testing of the Test Sweeper:

- All Test Dates and times;
- Temperature, Wind Speed, Precipitation, Relative Humidity;
- Manufacturer, Type, Model, Serial Number of the Test Sweeper;
- Detailed Specifications including all components/parts present during the testing of the Test Sweeper;
- Manufacturer's Operator and Representative(s) Names;
- Document all the security measures for the Test Sweeper storage outside the testing times;
- Provide full calibration records of all the weighing balances;
- All Operational Adjustments made to the Test Sweeper during each of the Individual Tests and the Resulting Time Taken for Adjustments;
- Copy of all Calculations Performed;
- Copy of All Field Notes;
- Comments on any and all Environmental and Operational Conditions;
- Results for each Operational Criteria and Operating System Time Score; and
- Description of Pavement Distresses

11.0 PROCUREMENT METHOD

This section provides information and shows how a Request for Proposal (RFP) can be successfully used to evaluate sweeper's performance and cost in a comparative manner.

The RFP process consists of three stages. In the first stage, each Proponent is required to submit, as part of their proposal, all the requested information. Once the proposals have been received by the user community staff will check to see that all mandatory requirements, specifically: Operational On-Street Canadian ETV certificate and PM₁₀ and PM_{2.5} Street Sweeper Efficiency Canadian ETV certificate as well as street sweeper specifications. If the mandatory requirements are met, the Proponent will qualify for stage two of the process.

The second stage involves the evaluation of the sweeper's performance values provided in the following:

- Operational On-Street Canadian ETV certificate; and
- PM₁₀ and PM_{2.5} Street Sweeper Efficiency Canadian ETV certificate.

The sweeper can be verified under the Environmental Technology Verification Canadian ETV. Canadian ETV performs credible and independent technology verification of performance claims based on the following two protocols:

- PM₁₀ and PM_{2.5} Street Sweeper Efficiency Test; and
- Operational On-Street Test.

In the last stage, the Proponent must provide the sweeper model and make that received the above ETV certificates to the user community for a further one week of Hands-on Operation and Maintenance evaluation testing. The Hands-on Operation and Maintenance will include the Proponent's providing of an in-depth one day demonstration, training and presentation of the equipment capabilities on the first day of the testing week. The same sweeper will be made available by the Proponent for a further four days, during which time the user community will operate and perform an on-the-job evaluation of the sweeper.

Following the final testing and the results achieved will be evaluated and scored by members of an evaluation committee. The Total Cost of Ownership will be evaluated including maintenance. Therefore a full overall performance and value of the street sweeper to the city will be evaluated. Finally, the Proponent achieving the highest overall score for their proposal, will be selected as the successful Proponent, and will be recommended for the award of the purchase contract for the supply of street sweepers.

12.0 MODIFICATION OF THE PROTOCOL

The Protocol contained herein was prepared by the City of Toronto with input from PAMI and Canadian ETV. This **Operational On-Street Test Protocol** is the property of the City of Toronto and cannot be copied and modified without the expressed permission of the City of Toronto. This is the 3rd revision of the Operational On - Street Test Protocol, dated May, 2016.

APPENDIX A

Sweeper Information Sheet



Sweeper Information Sheet

Date:

Test No.:

Sweeper Make and Model:

Serial No.:

License Plate No.:

Testing Agency Operator's Name:

Sweeper Operator's Name:

Manufacturer's Representatives

Name:

Title:

Name:

Title:

Name:

Title

Distributor's Representatives

Name:

Title:

Name:

Title:

Name:

Title

Demonstration of the Sweeper by Distributor

Time Started

Time Completed

Inspection of Test Site and Review of Test Run

Time Started

Time Completed

Conditioning of Test Sweeper

Time Started

Time Completed

Operational On-Street Test

Time Started

Time Completed

Testing Agency Recorder's Name:

Signature:

Verification Witness' Name:

Signature:

Date:

Test No.:

Sweeper Make and Model:

Serial No.:

License Plate No.:

Weight of Test Material Applied

	Test Section	Gross Container Weight (g)	Net Sample Weight (g)	Container + Lid Weight (g)	Total Net Weight (g)
Container 1					
Container 2					
Container 3					
Container 4					
Container 5					
Container 6					
Container 7					
Container 8					
Container 9					
Container 10					
Container 11					
Container 12					
Leaves					
Salt and Coal Patch					
Gravel					
Large Debris					
# and type of Large Debris	2 crushed 335 ml pop cans, 1 full 335 ml pop can, 8 small tree branches, 1 glass bottle, 2-500 ml crushed plastic water bottles, 1-500 ml full water bottle, 1-1 L empty plastic bottle, one plastic bag, 2 plastic strips, 1 crushed coffee cup, 1 cigarette box, 3 chunks of coal patch and 3 kg of gravel				

	Average Weight
Container + Lid	
Jar + Lid	

Testing Agency Recorder's Name:

Verification Witness' Name:

Signature:

Signature:

Date:

Test No.:

Sweeper Make and Model:

Serial No.:

License Plate No.:

Sample Weight of Applied Test Material

Test Section	Jar #	Container #	Gross Jar Sample Weight (g)	Jar and Lid Weight (g)	Net Sample Weight (g)
Sample of Applied Material - A					
Sample of Applied Material – B					
Sample of Applied Material – C					
Sample of Applied Material – D					
Sample of Applied Material – E					
Sample of Applied Material – F					
Sample of Applied Material – leaves					
Sample of Applied Material – salt					

Testing Agency Recorder's Name:
Verification Witness' Name:

Signature:
Signature:



Date:

Test No.:

Sweeper Make and Model:

Serial No.:

License Plate No.:

Operating Condition of Sweeper

	Test Section A	Test Section B	Test Section C	Test Section D	Test Section E	Test Section F
Time Started						
Time Completed						
Speed (km/hr)						
RPM						
Water Use On Gutter Broom (y/n)						
Water Inside Hopper (y/n)						
Breaking during sweeping/vacuuming (y/n)						
Pick-up Head On/Off						
Pick-up Head Up/Down/Out						
Set-up Mode of Pick-up Head						
Main Broom On/Off						
Main Broom Up/Down						
Left Gutter Broom On/Off						
Left Gutter Broom Up/Down						
Right Gutter Broom On/Off						
Right Gutter Broom Up/Down						
Dustless System On/Off						
Other Comments:						

Test Section A: Wet Paved Surface Test Section

Test Section B: Manoeuvrability Around Parked Cars Test Section

Test Section C: Leaves Test Section

Test Section D: Large Debris Test Section

Test Section E: Heavy Debris Test

Test Section F: Dustless Mode Test

Testing Agency Recorder's Name:

Verification Witness' Name:

Signature:

Signature:



Date:

Test No.:

Sweeper Make and Model:

Serial No.:

License Plate No.:

Weight of Residue Material

	Test Section	Weight	Sample	Container, Lid, Cartridge, Filter, Laundry Bag, Cheese Cloth, Foam Filter, Plastic Bag Weight	Total Net Weight
Container 1					
Container 2					
Container 3					
Container 4					
Container 5					
Container 6					
Container 7					
Container 8					
Container 9					
Container 10					
Container 11					
Container 12					
Leaves					
Salt and Coal Patch					
Gravel					
Large Debris					
# and type of Large Debris					

Testing Agency Recorder's Name:
Verification Witness' Name:

Signature:
Signature:



Date:

Test No.:

Sweeper Make and Model:

Serial No.:

License Plate No.:

	Average Weight
Container + Lid	
Jar + Lid	
Container + Filter + Lid + Plastic Bag (Dry Material)	
Container + Filter + Lid + Cartridge + Plastic Bag (Dry Material)	
Container + Laundry Bag + Cheese Cloth + Lid + Foam + Plastic Bag (Wet Material)	

Sample Weight of Residue Material

Test Section	Jar #	Container #	Gross Jar Sample Weight (g)	Jar and Lid Weight (g)	Net Sample Weight (g)
Sample of Residue Material – A					
Sample of Residue Material – A					
Sample of Residue Material – B					
Sample of Residue Material – B					
Sample of Residue Material – B					
Sample of Residue Material – B					
Sample of Residue Material – C					
Sample of Residue Material – C					
Sample of Residue Material – D					
Sample of Residue Material – D					
Sample of Residue Material – E					
Sample of Residue Material – E					
Sample of Residue Material – F					
Sample of Residue Material – F					

Testing Agency Recorder's Name:

Verification Witness' Name:

Signature:

Signature:



Date:

Test No.:

Sweeper Make and Model:

Serial No.:

License Plate No.:

	Time	Humidity	Temperature
During Vacuuming			
Test Section A			
Test Section B			
Test Section C			
Test Section D			
Test Section E			
Test Section F			
Post Vacuuming			

Test Speed

Test Section	Test Time (seconds)	Section Length (meters)	Calculated Sweeper Test Speed (km/hr)
A			
B			
C			
D			
E			
F			

Approximate Weight of Test Material Inside the Test Sweeper Hopper

	Rear Axle (kg)	Front Axle (kg)
Pre Test Weight		
Post Test Weight		
Net Weight of Test Material Collected		

Testing Agency Recorder's Name:

Verification Witness' Name:

Signature:

Signature:



Date:

Test No.:

Sweeper Make and Model:

Serial No.:

License Plate No.:

Operating and Sweeping System Adjustments

Area	Adjustment Time (minutes)	Type of Adjustments
Start-up A		
Track-Out A		
Set-Up A-B		
Start-up B		
Track-Out B		
Set-Up B-C		
Start-up C		
Track-Out C		
Set-Up C-D		
Start-up D		
Track-Out D		
Set-Up D-E		
Start-up D		
Track-Out D		
Set-Up D-E		
Start-up E		
Track-Out E		
Set-Up E-F		
Start-up F		
Track-Out F		
Total		

Testing Agency Recorder's Name:

Verification Witness' Name:

Signature:

Signature:

APPENDIX B

Calculations Performed

Table B-1: Applied Material Calculations

Test No.: Test Date: Manufacturer: Distributor: Model: Serial No:		Test Sections A Wet Paved Surface Test Section B Maneuverability Around Parked Cars Test Section C Leaf Test Section D Large Debris Test Section E Heavy Debris Test Section F Dustless Mode Test Section									
											Conversion: 1000g = 1kg
Type of Applied Material	Row No.	A	B	C	D	E	F	G	H	I	J
		Jar #	Container #	Test Section	Pre-Dry Jar Weight (g)	Post-Dry Jar Weight (g)	Jar +Lid Weight (g)	Final Pre-Dry Weight D-F (g)	Final Post-Dry Weight E-F (g)	Net Change In Weight H-G (g)	% Change (I/G)*100%
SC-CS	1			A				=D1-F1	=E1-F1	=ABS(H1-G1)	=(I1/G1)*100
SC-CS	2			A				=D2-F2	=E2-F2	=ABS(H2-G2)	=(I2/G2)*100
SC-CS	3			B				=D3-F3	=E3-F3	=ABS(H3-G3)	=(I3/G3)*100
SC-CS	4			B				=D4-F4	=E4-F4	=ABS(H4-G4)	=(I4/G4)*100
SC-CS	5			C				=D5-F5	=E5-F5	=ABS(H5-G5)	=(I5/G5)*100
SC-CS	6			C				=D6-F6	=E6-F6	=ABS(H6-G6)	=(I6/G6)*100
leaves	7			C				=D7-F7	=E7-F7	=ABS(H7-G7)	=(I7/G7)*100
SC-CS	8			D				=D8-F8	=E8-F8	=ABS(H8-G8)	=(I8/G8)*100
SC-CS	9			D				=D9-F9	=E9-F9	=ABS(H9-G9)	=(I9/G9)*100
gravel and large debris	10			D				=D10-F10	=E10-F10	=ABS(H10-G10)	=(I10/G10)*100
SC-CS	11			E				=D11-F11	=E11-F11	=ABS(H11-G11)	=(I11/G11)*100
SC-CS	12			E				=D12-F12	=E12-F12	=ABS(H12-G12)	=(I12/G12)*100
salt and coal	13			E				=D13-F13	=E13-F13	=ABS(H13-G13)	=(I13/G13)*100
SC-CS	14			F				=D14-F14	=E14-F14	=ABS(H14-G14)	=(I14/G14)*100
SC-CS	15			F				=D15-F15	=E15-F15	=ABS(H15-G15)	=(I15/G15)*100

SC-CS limestone screenings and construction sand

Table B-2: Applied Material Calculations

Test No.:
Test Date:
Manufacturer:
Distributor:
Model:
Serial No.:

Test Sections

A Wet Paved Surface Test Section
 B Maneuverability Around Parked Cars Test Section
 C Leaf Test Section
 D Large Debris Test Section
 E Heavy Debris Test Section
 F Dustless Mode Test Section

Conversion:
1000g=1kg

Type of Applied Material	Row No.	A Jar #	B Container #	C Test Section	K Container Weight (g)	L Post Sample Container Weight K-H (g)	M Container, Lid or Bag, etc Weight (g)	N Applied Material Weight L-M (g)	O Net Applied Material Weight N-(N*(J/100)) (g)	P Total Net Applied Material Weight Sum(Test Section) (g)
SC-CS	1			A		=SUM(K1-H15)		=L1-M1	=N1-(N1*(K1/100))	
SC-CS	2			A		=SUM(K2-H2)		=L2-M2	=N2-(N2*(K2/100))	=SUM(O1:O2)
SC-CS	3			B		=SUM(K3-H3)		=L3-M3	=N3-(N3*(K3/100))	
SC-CS	4			B		=SUM(K4-H4)		=L4-M4	=N4-(N4*(K4/100))	=SUM(O3:O4)
SC-CS	5			C		=SUM(K5-H5)		=L5-M5	=N5-(N5*(K5/100))	
SC-CS	6			C		=SUM(K6-H6)		=L6-M6	=N6-(N6*(K6/100))	
leaves	7			C		=SUM(K7-H7)		=L7-M7	=N7-(N7*(K7/100))	=SUM(O5:O7)
SC-CS	8			D		=SUM(K8-H8)		=L8-M8	=N8-(N8*(K8/100))	
SC-CS	9			D		=SUM(K9-H9)		=L9-M9	=N9-(N9*(K9/100))	
gravel and large debris	10			D		=SUM(K10-H10)		=L10-M10	=N10-(N10*(K10/100))	=SUM(O8:O10)
SC-CS	11			E		=SUM(K11-H11)		=L11-M11	=N11-(N11*(K11/100))	
SC-CS	12			E		=SUM(K12-H12)		=L12-M12	=N12-(N12*(K12/100))	
salt and coal	13			E		=SUM(K13-H13)		=L13-M13	=N13-(N13*(K13/100))	=SUM(O11:O13)
SC-CS	14			F		=SUM(K14-H14)		=L14-M14	=N14-(N14*(K14/100))	
SC-CS	15			F		=SUM(K15-H15)		=L15-M15	=N15-(N15*(K15/100))	=SUM(O14:O15)

Average Weight (g)

Average Weight (g)

Container+Lid	Container+Lid+Filter+Cartridge+Plastic Bag
Container+Lid+Filter+Plastic Bag	Container+Lid+Laundry Bag+Cheese Cloth+Foam Filter+Plastic Bag

Table B-3: Residue Material Calculations

Test No.:	
Test Date:	
Manufacturer:	
Distributor:	
Model:	
Serial No.:	

Test Sections

- A** Wet Paved Surface Test Section
- B** Maneuverability Around Parked Cars Test Section
- C** Leaf Test Section
- D** Large Debris Test Section
- E** Heavy Debris Test Section

F Dustless Mode Test Section Conversion: 1000g = 1kg

Type of Residue Material	Row No.	A	B	C	D	E	F	G	H	I	J
		Jar #	Container #	Test Section	Pre-Dry Jar Weight (g)	Post-Dry Jar Weight (g)	Jar +Lid Weight (g)	Final Pre-Dry Weight D-F (g)	Final Post-Dry Weight E-F (g)	Net Change In Weight H-G (g)	% Change (I/G)*100%
SC-CS	1			A				=D1-F1	=E1-F1	=ABS(H1-G1)	=(I1/G1)*100
SC-CS	2			A				=D2-F2	=E2-F2	=ABS(H2-G2)	=(I2/G2)*100
SC-CS	3			B				=D3-F3	=E3-F3	=ABS(H3-G3)	=(I3/G3)*100
SC-CS	4			B				=D4-F4	=E4-F4	=ABS(H4-G4)	=(I4/G4)*100
SC-CS, leaves	5			C				=D5-F5	=E5-F5	=ABS(H5-G5)	=(I5/G5)*100
SC-CS, leaves	6			C				=D6-F6	=E6-F6	=ABS(H6-G6)	=(I6/G6)*100
SC-CS, gravel, large debris	7			D				=D7-F7	=E7-F7	=ABS(H7-G7)	=(I7/G7)*100
SC-CS, gravel, large debris	8			D				=D8-F8	=E8-F8	=ABS(H8-G8)	=(I8/G8)*100
SC-CS, salt, coal	9			E				=D9-F9	=E9-F9	=ABS(H9-G9)	=(I9/G9)*100
SC-CS, salt, coal	10			E				=D10-F10	=E10-F10	=ABS(H10-G10)	=(I10/G10)*100
SC-CS	11			F				=D11-F11	=E11-F11	=ABS(H11-G11)	=(I11/G11)*100
SC-CS	12			F				=D12-F12	=E12-F12	=ABS(H12-G12)	=(I12/G12)*100

SC-CS limestone screenings and construction sand

Table B-4: Residue Material Calculations

Test No.:
Test Date:
Manufacturer:
Distributor:
Model:
Serial No.:

Test Sections	
A	Wet Paved Surface Test Section
B	Maneuverability Around Parked Cars Test Section
C	Leaf Test Section
D	Large Debris Test Section
E	Heavy Debris Test Section
F	Dustless Mode Test Section

Conversion:
1000g=1kg

Type of Residue Material	Row No.	A Jar #	B Container #	C Test Section	K Container Weight (g)	L Post Sample Container Weight K-H (g)	M Container, Lid or Bag, etc Weight (g)	N Residue Material Weight L-M (g)	O Net Residue Material Weight N-(N*(J/100)) (g)	P Total Net Residue Material Weight Sum(Test Section) (g)
SC-CS	1			A		=SUM(K1-H1)		=L1-M1	=N1-(N1*(K1/100))	
SC-CS	2			A		=SUM(K2-H2)		=L2-M2	=N2-(N2*(K2/100))	=SUM(O1:O2)
SC-CS	3			B		=SUM(K3-H3)		=L3-M3	=N3-(N3*(K3/100))	
SC-CS	4			B		=SUM(K4-H4)		=L4-M4	=N4-(N4*(K4/100))	=SUM(O3:O4)
SC-CS, leaves	5			C		=SUM(K5-H5)		=L5-M5	=N5-(N5*(K5/100))	
SC-CS, leaves	6			C		=SUM(K6-H6)		=L20-M20	=N6-(N6*(K6/100))	=SUM(O5:O6)
SC-CS, gravel, large debris	7			D		=SUM(K7-H7)		=L21-M21	=N7-(N7*(K7/100))	
SC-CS, gravel, large debris	8			D		=SUM(K8-H8)		=L22-M22	=N8-(N8*(K8/100))	=SUM(O7:O8)
SC-CS, salt, coal	9			E		=SUM(K9-H9)		=L23-M23	=N9-(N9*(K9/100))	
SC-CS, salt, coal	10			E		=SUM(K10-H10)		=L24-M24	=N10-(N10*(K10/100))	=SUM(O9:O10)
SC-CS	11			F		=SUM(K11-H11)		=L25-M25	=N11-(N11*(K11/100))	
SC-CS	12			F		=SUM(K12-H12)		=L26-M26	=N12-(N12*(K12/100))	=SUM(O11:O12)

Average Weight (g)

Average Weight (g)

Container+Lid	Container+Lid+Filter+Cartridge+Plastic Bag
Container+Lid+Filter+Plastic Bag	Container+Lid+Laundry Bag+Cheese Cloth+Foam Filter+Plastic Bag

Table B-5: Operational Evaluation Summary

Test No.:	Test Sections
Test Date:	A Wet Paved Surface Test Section
Manufacturer:	B Maneuverability Around Parked Cars Test Section
Distributor:	C Leaf Test Section
Model:	D Large Debris Test Section
Serial No:	E Heavy Debris Test Section
	F Dustless Mode Test Section

	Test Sections	Total Applied Test Material (g) - 'W _{applied} '	Total Test Material Vacuumed (g) - 'W _{residue} '	Pick-up Efficiency (%) - 'PE'
Wet Paved Surface	A	Applied P2	Residue P2	$=1-(\text{Residue A}/\text{Applied A}) \times 100$
Maneuverability Around Parked Cars	B	Applied P4	Residue P4	$=1-(\text{Residue B}/\text{Applied B}) \times 100$
Leaves	C	Applied P7	Residue P6	$=1-(\text{Residue C}/\text{Applied C}) \times 100$
Large Debris	D	Applied P10	Residue P8	$=1-(\text{Residue D}/\text{Applied D}) \times 100$
Heavy Debris	E	Applied P13	Residue P10	$=1-(\text{Residue E}/\text{Applied E}) \times 100$
Dustless Mode	F	Applied P15	Residue P12	$=1-(\text{Residue F}/\text{Applied F}) \times 100$
Operating System Time Score (min)	A-F			

APPENDIX C

Key Components of the Test Protocol

Key Components of Test Protocol

Test Site	Material and Equipment
<p>Design</p> <ul style="list-style-type: none"> 1.1 Four lane roadway; 1.2 Operating speed <50km/hr; 1.3 700 metres of uncut curbs (without driveways); 1.4 Curb Lane width (3-3.65 metres); 1.5 Electrical power must be available (110-volt line/receptacle and/or portable generator); 1.6 Test Track – curbs extending the full length, one long section (preferable) or two short sections; 1.7 Test Track – level as reasonable; 1.8 Test Track must be covered with an aged asphalt surface representative of an aged city street (include cracking, potholes and/or crevices are desirable); 1.9 Test Track area must be covered with a typical aged asphalt surface representative of an urban street; 1.10 Catch basins or inspection covers must be temporarily covered and sealed for the duration of the Test Run; 1.11 Test Sections – Section A and B – 40 metres or greater by 2 metres; Section C, D, E and F – 30 metres or greater by 2 metres; 1.12 Test Strips – 30 cm wide strip adjacent to the curb; 1.13 Test Gap – 30 metres or greater – located between each Test Section; 1.14 Track-Out Area – 10 metres, beginning at the end of each Test Section and covers the first 10 metres of the Test Gap; 1.15 Warm-up Track Area - 50 metres or greater; 1.16 Traffic Merge Area- a defined area of the Test course located at the beginning and the end of the Test Course in order to facilitate the merging of the traffic from the traveled portion of the curb lane to adjacent inside lane; 	<p>Equipment</p> <ul style="list-style-type: none"> 4.1 Use two Canister-type vacuum equipment – Shop-Vac (Contractors Model), or equivalent; 4.2 Use HEPA high efficiency disposable filter bags and HEPA high performance cartridge filters; 4.3 Use stainless steel accessories and metal brushes to be used for the Shop-Vacs; 4.4 Sweeper Weigh Scale (portable four pad scale) capacity of 20,000 lbs at graduation of 10 lbs; 4.5 Sweeper weigh scale to weigh the Test Sweeper should be calibrated, daily; 4.6 The material weigh scale that weighs the Standard Test and Residue Material and sample materials should be calibrated at the beginning and end of the weighing and after every 3rd weighing; 4.7 23 litre plastic containers and lids are to be used to store the heavy-duty plastic bags, cartridges, filter bags, laundry bags, cheese cloth and foam cartridges containing Residue Material; 4.8 A professional grade manually powered and operated large fertilizer spreader redesigned to apply Standard Test Material for a width of 30 cm adjacent to the curb - see Figure 5 Fertilizer Spreader; 4.9 A designated operator should use a garden rake to move the Standard Test Material into the curb – see Figure 4: Standard Test Material Application;

Test Site	Material and Equipment
<p>Environmental Conditions</p> <p>2.1 Test Site must be exposed to environmental conditions and extraneous disturbance of the applied test material;</p> <p>2.2 Precipitation and wind in excess of 10km/hr during the day of the test warrants the postponement of the testing;</p> <p>2.3 Adequate lighting for safe visual operations and the use of video/camera for recording and monitoring;</p> <p>Test Sweeper</p> <p>3.1 Test Sweeper must operate with steel-bristled gutter brooms. Main brooms may be either poly-bristled or steel-bristled;</p> <p>3.2 It is beneficial that the manufacturers test their sweepers in as many operating configuration as deemed appropriate taking into consideration the specific operational requirements by the user community;</p> <p>City of Toronto's specific operational requirements are that sweepers must operate without using shrouds/skirts on the gutter brooms and/or main brooms;</p>	<p>Test Material</p> <p>5.1 Standard Test Material includes a 50/50 mixture of limestone screenings and construction sand;</p> <p>5.2 Test materials are applied only on Test Strips;</p> <p>5.3 Test Section A – 60 kg of Standard Test Material;</p> <p>5.4 Test Section B – 60 kg of Standard Test Material;</p> <p>5.5 Test Section C – 45 kg of Standard Test Material and 30 kg of Leaf Test Material;</p> <p>5.6 Test Section D – 45 kg of Standard Test Material and a known weight and quantity of Large Debris Test Material;</p> <p>5.7 Test Section E – 45 kg of Standard Test Material and an additional 15 kg of salt and coal patch applied to only the centre 15 metres of the 30 metre Large Debris Test Section;</p> <p>5.8 Test Section F – 45 kg of Standard Test Material;</p>
Procedures	Procedures
<p>Test Site</p> <p>6.1 8-10 hours of curb lane closure;</p> <p>6.2 Pre-sweep the Test Track by a mechanical sweeper three times the day of the testing;</p> <p>Test Material</p> <p>7.1 All test material must be weighed and documented prior to the application of the material;</p> <p>7.2 All test material must be applied consistently with a greater depth close to the curb;</p> <p>7.3 Samples of all test material applied and samples of residual material must be taken from all material containers;</p> <p>7.4 Measure the pre and post drying (accomplished by baking the samples for 24 hours to eliminate the moisture and than cooling the samples prior to weighing the samples again) weight of the samples and determine the total net weight of dry applied test material and collected residual material;</p>	<p>Other Equipment</p> <p>8.1 The HEPA vacuum equipment must be pre-conditioned at least once with the Standard Test Material prior to the first Test Run;</p> <p>8.2 One fresh cartridge filter to be used for each Test Section except if a foam cartridge needs to be used to vacuum the Wet Paved Surface Test Section;</p> <p>8.3 At the completion of each Test Run the vacuum canisters and metal accessories should be thoroughly cleaned;</p> <p>8.4 Each 23 litre container containing the heavy duty plastic bag, filter and/or cartridge and/or foam cartridge and/or cheese cloth must be weighed, recorded and labelled with the date; time and test number and the weight recorded less the weight of the average weight of the filter bag, plastic bag, cartridge, foam cartridge, cheese cloth and container/lid;</p>

Procedures	Procedures
<p>Sweeper</p> <p>9.1 Test Sweeper Operating Speed to be between 5 to 10 km/hr, unless otherwise “officially” recommended by manufacturer;</p> <p>9.2 Test Sweeper is not permitted to leave the Test Site;</p> <p>9.3 Operating Conditions – to sweep using all operating systems, including but not limited to: the main and side brooms, vacuum, regenerative-air vacuum and filtration system and should apply water inside and outside for dust suppression;</p> <p>9.4 Application of water on the gutter brooms should conform to the sweeper model’s standard specifications (number, size and pressure of water nozzle);</p> <p>9.5 Application of water on the gutter brooms or the pick-up head is not permitted during the dustless sweeping test, sweeping without gutter brooms;</p> <p>9.6 The weight of the Test Sweeper before and after the Test Run is used only as a quick and approximate assessment that illustrates the efficiency (or lack of) for any Test Run, if a significant amount of Residue Material is left behind as a result of operator error and/or sweeper malfunction such that vacuuming procedures may not be initiated, then the Test Run must be aborted and deemed null and void;</p> <p>9.7 Test Run is an individual replicable test of a Test Sweeper at a Testing Track whereby the Test Sweeper is tested for its ability to remove various types of test materials from Test Sections and deposit into its hopper;</p> <p>9.8 Test Run – a completion of six Individual Tests consecutively in one day;</p> <p>9.9 Test Sweeper setting can be adjusted after each Test Section;</p> <p>9.10 Test Track swept as part of one day’s Test Run. Once Test Sweeper initiates sweeping in a Test Section, no stopping is permitted. All Test Sweeper’s operating systems must be recorded and confirmed to be in compliance by an “experienced sweeper operator” riding inside the cab;</p>	<p>Environmental Conditions</p> <p>10.1 Air temperature, humidity (relative and absolute) and wind direction should be recorded using on site equipment and by accessing standard meteorological data;</p> <p>10.2 Test materials should not be laid down or swept up in conditions with a relative humidity (air) greater than 90%. And further, that if the soil moisture content of materials to be spread exceeds 15% (i.e. is approaching saturation);</p> <p>10.3 Wind speed should be below 10km/hr;</p> <p>10.4 Dry Test Track, Warm Up Track and Test Gaps with no standing water remaining from precipitation or post precipitation seepage into the Test Track or no damp test track surface, except for Test Section A;</p> <p>10.5 All personnel should wear the appropriate safety equipment;</p> <p>Documentation</p> <p>11.1 See diagrams of the Operational On-Street Test Track (Figure 1); Standard Test Material Application (Figure 3); and Detailed Marking of Test Track (Figure 2);</p> <p>11.2 Test Run Summary of procedures during one day of testing can be found in Section 8.0 of the Operational On-Street Test Protocol;</p> <p>11.3 Appendix A contains the Operational On-Street Test – Sweeper Information Sheet that can be used to collect all the records and measurements during the testing;</p> <p>11.4 Appendix B contains the calculations performed on applied and vacuumed test material;</p> <p>11.5 Appendix C contains the key components of the test protocol;</p> <p>11.6 Appendix D contains the description of key flexible pavement distresses;</p> <p>11.7 Appendix E contains the MSDS Sheets for the Test Material;</p> <p>11.8 Appendix F contains the Concrete Barrier Curb and Gutter Designs; and</p> <p>11.9 Appendix G contains the sample of scoring for each criteria in the proposed evaluation form</p>

APPENDIX D

Description of Key Flexible Pavement Distresses

Description of Key Flexible Pavement Distresses

The following provides detailed description of the key pavement distresses that are being used to determine the pavement condition of the Test Track. The two types of distresses are surface defects and cracking. Surface defect distress includes raveling. Cracking distresses include longitudinal and meandering, alligator and transverse cracking.

Also, included is the City of Toronto's, Pavement Distress Manifestations Summary Table for Composite and Flexible Pavements summarizing the pavement distress types, the severity and extent criteria.

1. Raveling and Weathering:

a. Definition:

Weathering and raveling occur when the pavement surface is worn away due to loss of fine asphalt particles or asphalt cement and dislodged aggregate particles. These types of distress indicate that the asphalt binder has hardened or that a poor-quality mixture was used.

b. Causes:

Raveling may be caused by traffic loading from tracked vehicles as well as a lack of bond between aggregate particles and mortar. Frost action on concrete that is not fully cured may also cause raveling. Dislodging of the aggregates and softening of the surface due to spillage are also included under raveling. This type of distress is often worse in the wheel tracks of the riding surface.

c. Measurement:

Weathering and raveling are measured in square metres of surface.

d. Classification:

Raveling Severity Levels

Severity Level	Description
Slight	Barely noticeable, with some loss of pavement material. Minor loss of fines.
Moderate	Pavement has a pockmarked appearance with marks well spaced. There is a shallow disintegration of the pavement surface. Minor loss of coarse aggregate.
Severe	Pavement has a pockmarked appearance with large, shallow marks closely spaced, progressing to potholes. Severe loss of coarse aggregate.

Raveling Extent Levels

Extent Level	Description- % of Total Area
1	0-10%
2	10-20%
3	20-40%
4	40-60%
5	60-100%

e. **Physical Appearance:**



Figure 1a Slight Raveling



Figure 1b Moderate Raveling



Figure 1c Severe Raveling

2. Longitudinal and Meandering Cracking

a. Definition:

The relatively straight pavement longitudinal cracking occurs in a direction parallel to the pavement centreline. Meandering cracking tends to weave its way across the pavement but in a general direction parallel to the centre line. The

location of either crack within the lane (e.g. wheel path, non-wheel path) is significant because it is created by different causes.

Longitudinal cracks associated with the beginning of alligator cracking are generally discontinuous, broken, and occur in the wheel path. Any longitudinal crack that is clearly within the wheel path should be rated.

b. Causes:

Wheel path cracking is generally caused by shear forces created by heavy loading from heavy trucks and tractor trailers. Non-wheel path cracking is generally related to a paving cold construction joint.

c. Measurement:

Cracking is generally measured in metres of length.

d. Classification:

Longitudinal Cracking Severity Levels

Severity Level	Description
Slight	A crack with a mean width < 12 mm, or a sealed crack with a sealant material in good condition and with a width that cannot be determined.
Moderate	Any crack with a mean width between 12 mm and 25 mm Or any crack with a mean width < 25 mm and adjacent low severity random cracking.
Severe	Any crack with a mean width > 25 mm, Or any crack with a mean width < 25 mm and adjacent to high severity random cracking.

Longitudinal Cracking Extent Levels

Extent Level	Description- Length per 2 lanes
1	<1 full length crack
2	1 to 2 full length cracks
3	2 to 3 full length cracks
4	3 to 4 full length cracks
5	> 4 full length cracks

e. Physical Appearance:

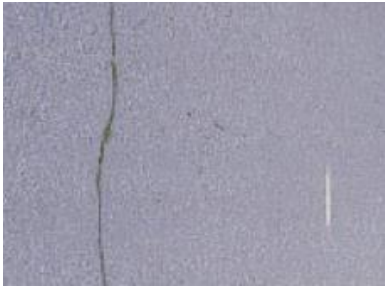


Figure 2a Slight Longitudinal Cracking



Figure 2.b Moderate Longitudinal Cracking



Figure 2.c Severe Longitudinal Cracking

Non-wheel path cracking should be recorded separately, for each severity level. The length in metres with sealant in good condition should also be recorded, at each severity level.

3. Transverse Cracking

a. Definition:

This type of distress refers to cracks that are predominantly perpendicular to the pavement centerline and, in composite pavements, are not located over the joints of the Portland cement concrete base underneath. (Distress of the latter type is known as reflection cracking). They may extend partially or fully across the roadway.

b. Causes:

They may be caused by surface shrinkage due to low temperatures, hardening of the asphalt, or cracks in underlying pavement layers such as cracked asphalt layer or PCCP slabs, in the case of composite pavements.

c. Measurement:

Cracking is generally measured in meters of length.

The number and length in meters of transverse cracks at each severity level should be recorded. The entire crack should be rated at the highest severity level present for at least 10% of the total length of the crack.

The length of cracks with sealant in good condition at each severity level should also be recorded. Only record this quantity when the sealant is in good condition for at least 90% of the length of the crack.

d. Classification:

Transverse Cracking Severity

Severity Level	Description
Slight	An unsealed crack with a mean width < 12 mm, or a sealed crack with a sealant material in good condition and with a width that cannot be determined.
Moderate	Any crack with a mean width between 12 mm and 25 mm Or any crack with a mean width < 25mm and adjacent low severity random cracking.
Severe	Any crack with a mean width > 25 mm, Or any crack with a mean width < 25 mm and adjacent to high severity random cracking.

Transverse Cracking Extent Levels

Extent Level	Description- Space between cracks
1	> 25m
2	15-25m
3	10-15m
4	5-10m
5	0-5m

f. Physical Appearance:



Figure 3a Slight Transverse Cracking



Figure 3b Moderate Transverse Cracking



Figure 3c Severe Transverse Cracking

4. Alligator Cracking

a. Definition:

This type of distress (also known as fatigue cracking) consists of interconnecting cracks caused by fatigue failure of the asphalt concrete surface under repeated traffic loading. Cracking begins at the bottom of the asphalt surface where the tensile stress and strain are the highest under load. The cracks then propagate to the surface as a series of parallel longitudinal cracks, which eventually connect to form sharp-angled pieces, which resemble the skin of an alligator.

b. Causes:

This type of cracking is normally associated with poor drainage, where the moisture softens the supporting base thus allowing high deflections in the pavement. The greater the deflection, the greater the strain and tensile stress experienced by the pavement.

Alligator cracking occurs only in areas that are subjected to repeated traffic heavy loads, such as in wheel paths and edge of pavements where parking is allowed.

c. Measurement:

Alligator cracking is measured in square metres of surface area.

A major difficulty in measuring this type of distress is that several levels of severity can exist within the same distressed area. If the different severity levels can easily be distinguished, they should be measured and recorded separately. If not, the entire area should be rated at the highest severity level present.

If alligator cracking and rutting occur in the same area, each is recorded separately.

d. Classification:

Alligator Cracking Severity Levels

Severity Level	Description
Slight	Cracks with a mean width between < 12mm. Fine, longitudinal hairline cracks running parallel to each other with no or few interconnecting cracks. The cracks are not spalled. Pumping is not evident.
Moderate	Cracks with a mean width between 12mm to 25mm. Light alligator cracks into a pattern or network of cracks, which may be lightly spalled. Cracks may be sealed. Pumping is not evident.
Severe	Cracks with a mean width between > 25mm. A network or pattern of cracks that has progressed to the point that the pieces are well defined and spalled at the edges. Some of the pieces may rock under traffic. Pumping may be evident.

Alligator Cracking Extent Levels

Extent Level	Description- % of Total Area
1	0-4%
2	4-10%
3	10-30%
4	30-60%
5	60-100%

e. *Physical Appearance:*



Figure 4a Slight Alligator Cracking



Figure 4b Moderate Alligator Cracking



Figure 4c Severe Alligator Cracking

PAVEMENT DISTRESS MANIFESTATIONS SUMMARY TABLE FOR COMPOSITE AND FLEXIBLE PAVEMENTS
Transportation Infrastructure Asset Management, Transportation Services, City of Toronto

DISTRESS TYPE	EVALUATION CRITERIA								MEASURE
	SEVERITY			EXTENT					
	Slight (0)	Moderate (1)	Severe (2)	1	2	3	4	5	
Surface Defects									
Raveling	Minor Loss of Fines	Minor loss of CA	Severe Loss of CA	0-10%	10-20%	20-40%	40-60%	60-100%	% of Total Area
Bleeding	Interconnected Veining	Free Asphalt	Wet looking	0-10%	10-20%	20-40%	40-60%	60-100%	% of Total Area
Patching	Good Condition	Fair Condition	Failure	0-10%	10-20%	20-40%	40-60%	60-100%	% of Total Area
Potholes	<75mm	<300mm no base mat'l	>300mm w base mat'l	1PHs <0.1%	2PHs 0.1-0.5%	3PHs 0.5-1%	4PHs 1-5%	>5 PHs >5%	Count per 30m Length % of Total Area
Surface Deformations									
Wheel Track Rutting	<12mm	12mm to 25mm	>25mm	<10% <¼ of WTs	10-25% ¼ of WTs	25-50% ½ of WTs	50-75% ¾ of WTs	75-100% All WTs	% of Affected Wheel Path Area
Distortion	<50 mm Dev	50mm to 100mm Dev	>100mm Dev	0-10%	10-20%	20-40%	40-60%	60-100%	% of Total Area
Rippling/Shoving	Decrease in Rideability	Rough Ride	Very Rough Ride	0-10%	10-20%	20-40%	40-60%	60-100%	% of Total Area
Excessive Crown	2-3% CF	3-4% CF	>4% CF	0-10%	10-20%	20-40%	40-60%	60-100%	% of Total Area
Cracking									
Alligator	Cracks are <12mm	Cracks 12mm to 25mm	Cracks are ≥ 25mm	0-4%	4-10%	10-30%	30-60% 3 to 4 FLC	60-100%	% of Total Area
Longitudinal	Cracks are <12mm	Cracks 12mm to 25mm	Cracks are ≥ 25mm	<1 FLC	1 to 2 FLC	2 to 3 FLC	FLC	>4 FLC	Length per 2 Lanes
Transverse	Cracks are <12mm	Cracks 12mm to 25mm	Cracks are ≥ 25mm	>25m	15-25m	10-15m	5-10m	0-5m	Space Between Cracks
Block	Cracks are <12mm	Cracks 12mm to 25mm	Cracks are ≥ 25mm	0-4%	4-10%	10-30%	30-60%	60-100%	% of Total Area
Edge	< 0.3m to EP	0.3m to 0.5 to EP	> 0.5m to EP	0-4%	4-10%	10-30%	30-60%*	100%**	Edge Length
Joint Reflection Cracks	Cracks are <12mm	Cracks 12mm to 25mm	Cracks are ≥ 25mm	>25m	15-25m	10-15m	5-10m	0-5m	Space Between Cracks

Note: WT = Wheel Track
 PH = Pothole
 CF = Cross Fall

CA = Coarse Aggregate
 EP = Edge of Pavement

Dev = Deviation
 FLC = Full Length Crack

* = Continuous one side
 ** = Continuous on both sides

APPENDIX E

MSDS Sheets for the Test Material

Material Safety Data Sheet



Sand and Stone Mixes

1. Product and company identification

Product name	: Sand and Stone Mixes
Supplier	: King Packaged Materials Company 3385 Harvester Road Burlington, ON L7R 3Y5
Synonym	: Not available.
Trade name	: All Purpose Sand Play Sand Jointing Sand Construction Sand Screenings Gravel - Various Grades Silica Sand Permasand
Material uses	: Consumer product.
Manufacturer	: King Packaged Materials Company 3385 Harvester Road Burlington, ON L7R 3Y5
Code	: Not available.
MSDS #	: Not available.
Validation date	: 4/9/2007.
Print date	: 4/9/2007.
Responsible name	: Company
In case of emergency	: 1-800-461-0566
Product type	: Solid.

2. Hazards identification

Physical state	: Solid. [Granular solid.]
Odor	: Odorless.
Emergency overview	: Handle with care. Keep out of reach of children. CONTAINS MATERIAL THAT CAN CAUSE TARGET ORGAN DAMAGE. CANCER HAZARD - CONTAINS MATERIAL WHICH CAN CAUSE CANCER. Avoid exposure - obtain special instructions before use. Contains material that can cause target organ damage. Contains material which can cause cancer. Risk of cancer depends on duration and level of exposure.
Routes of entry	: Not available.
Potential acute health effects	
Inhalation	: No known significant effects or critical hazards.
Ingestion	: No known significant effects or critical hazards.
Skin	: No known significant effects or critical hazards.
Eyes	: No known significant effects or critical hazards.
Potential chronic health effects	
Chronic effects	: Contains material that can cause target organ damage.
Carcinogenicity	: Contains material which can cause cancer. Risk of cancer depends on duration and level of exposure.
Mutagenicity	: No known significant effects or critical hazards.

Sand and Stone Mixes

2. Hazards identification

- Teratogenicity** : No known significant effects or critical hazards.
- Developmental effects** : No known significant effects or critical hazards.
- Fertility effects** : No known significant effects or critical hazards.
- Target organs** : Contains material which causes damage to the following organs: upper respiratory tract. Contains material which may cause damage to the following organs: kidneys, mucous membranes, lymphatic system, cardiovascular system, immune system, eye, lens or cornea, nose/sinuses, trachea.

Over-exposure signs/symptoms

- Inhalation** : No specific data.
- Ingestion** : No specific data.
- Skin** : No specific data.
- Eyes** : No specific data.
- Medical conditions aggravated by over-exposure** : Pre-existing disorders involving any target organs mentioned in this MSDS as being at risk may be aggravated by over-exposure to this product.

See toxicological information (section 11)

3. Composition/information on ingredients

<u>Name</u>	<u>CAS number</u>	<u>%</u>
Quartz, Crystalline Silica, Silicon Dioxide.	14808-60-7	5 - 10

There are no ingredients or additional ingredients present which, within the current knowledge of the supplier and in the concentrations applicable, are classified as hazardous to health or the environment and hence require reporting in this section.

4. First aid measures

- Eye contact** : In case of contact, immediately flush eyes with plenty of water for at least 15 minutes.
- Skin contact** : Flush contaminated skin with plenty of water. Remove contaminated clothing and shoes. Wash contaminated clothing thoroughly with water before removing or wear gloves. Continue to rinse for at least 10 minutes. Wash clothing before reuse. Clean shoes thoroughly before reuse.
- Inhalation** : If inhaled, remove to fresh air.
- Ingestion** : If swallowed, call a poison control centre or doctor immediately. DO NOT induce vomiting.
- Protection of first-aiders** : No action shall be taken involving any personal risk or without suitable training. If it is suspected that fumes are still present, the rescuer should wear an appropriate mask or self-contained breathing apparatus. It may be dangerous to the person providing aid to give mouth-to-mouth resuscitation. Wash contaminated clothing thoroughly with water before removing or wear gloves.

Antidote information

<u>Product/ingredient name</u>	<u>Antidote information</u>
No antidote information known	

- Notes to physician** : No specific treatment. Treat symptomatically. Contact poison treatment specialist immediately if large quantities have been ingested or inhaled.

Sand and Stone Mixes

5 . Fire-fighting measures

- Flammability of the product** : No specific fire or explosion hazard.
- Extinguishing media**
 - Suitable** : Use an extinguishing agent suitable for the surrounding fire.
 - Not suitable** : None known.
- Special exposure hazards** : Promptly isolate the scene by removing all persons from the vicinity of the incident if there is a fire. No action shall be taken involving any personal risk or without suitable training.
- Hazardous combustion products** : No specific data.
- Special protective equipment for fire-fighters** : Fire-fighters should wear appropriate protective equipment and self-contained breathing apparatus (SCBA) with a full face-piece operated in positive pressure mode.
- Special remarks on fire hazards** : Not available.
- Special remarks on explosion hazards** : Not available.

6 . Accidental release measures

- Personal precautions** : No action shall be taken involving any personal risk or without suitable training. Evacuate surrounding areas. Keep unnecessary and unprotected personnel from entering. Do not touch or walk through spilled material. Provide adequate ventilation. Wear appropriate respirator when ventilation is inadequate. Put on appropriate personal protective equipment (see section 8).
- Environmental precautions** : Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers. Inform the relevant authorities if the product has caused environmental pollution (sewers, waterways, soil or air).
- Large spill** : Move containers from spill area. Approach release from upwind. Prevent entry into sewers, water courses, basements or confined areas. Vacuum or sweep up material and place in a designated, labeled waste container. Note: see section 1 for emergency contact information and section 13 for waste disposal.
- Small spill** : Move containers from spill area. Vacuum or sweep up material and place in a designated, labeled waste container.

7 . Handling and storage

- Handling** : Put on appropriate personal protective equipment (see section 8). Eating, drinking and smoking should be prohibited in areas where this material is handled, stored and processed. Workers should wash hands and face before eating, drinking and smoking. Do not get in eyes or on skin or clothing. Do not ingest. If during normal use the material presents a respiratory hazard, use only with adequate ventilation or wear appropriate respirator. Keep in the original container or an approved alternative made from a compatible material, kept tightly closed when not in use. Empty containers retain product residue and can be hazardous. Do not reuse container.
- Storage** : Store in accordance with local regulations. Store in original container protected from direct sunlight in a dry, cool and well-ventilated area, away from incompatible materials (see section 10) and food and drink. Keep container tightly closed and sealed until ready for use. Containers that have been opened must be carefully resealed and kept upright to prevent leakage. Do not store in unlabeled containers. Use appropriate containment to avoid environmental contamination.

Sand and Stone Mixes

8 . Exposure controls/personal protection

Product name

Quartz, Crystalline Silica, Silicon Dioxide.

Exposure limits

ACGIH TLV (Canada).

TWA: 0.05 mg/m³ 8 hour(s). Form: Respirable fraction

Consult local authorities for acceptable exposure limits.

Recommended monitoring procedures : If this product contains ingredients with exposure limits, personal, workplace atmosphere or biological monitoring may be required to determine the effectiveness of the ventilation or other control measures and/or the necessity to use respiratory protective equipment.

Engineering measures : If user operations generate dust, fumes, gas, vapor or mist, use process enclosures, local exhaust ventilation or other engineering controls to keep worker exposure to airborne contaminants below any recommended or statutory limits.

Hygiene measures : Wash hands, forearms and face thoroughly after handling chemical products, before eating, smoking and using the lavatory and at the end of the working period. Appropriate techniques should be used to remove potentially contaminated clothing. Wash contaminated clothing before reusing. Ensure that eyewash stations and safety showers are close to the workstation location.

Personal protection

Respiratory

: Use a properly fitted, air-purifying or air-fed respirator complying with an approved standard if a risk assessment indicates this is necessary. Respirator selection must be based on known or anticipated exposure levels, the hazards of the product and the safe working limits of the selected respirator.

Hands

: Chemical-resistant, impervious gloves complying with an approved standard should be worn at all times when handling chemical products if a risk assessment indicates this is necessary.

Eyes

: Safety eyewear complying with an approved standard should be used when a risk assessment indicates this is necessary to avoid exposure to liquid splashes, mists, gases or dusts.

Skin

: Personal protective equipment for the body should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling this product.

Environmental exposure controls

: Emissions from ventilation or work process equipment should be checked to ensure they comply with the requirements of environmental protection legislation. In some cases, fume scrubbers, filters or engineering modifications to the process equipment will be necessary to reduce emissions to acceptable levels.

Other protection

: Not available.

Personal protective equipment (Pictograms)

: Not available.

9 . Physical and chemical properties

Physical state : Solid. [Granular solid.]

Flash point : Not available.

Auto-ignition temperature : Not available.

Flammable limits : Not available.

Color : Not available.

Odor : Odorless.

Taste : Not available.

Molecular weight : Not applicable.

Molecular formula : Not applicable.

pH : Not available.

Boiling/condensation point : Not available.

Sand and Stone Mixes

9 . Physical and chemical properties

- Melting/freezing point** : Not available.
- Critical temperature** : Not available.
- Relative density** : Not available.
- Vapor pressure** : Not available.
- Vapor density** : Not available.
- Volatility** : Not available.
- Odor threshold** : Not available.
- Evaporation rate** : Not available.
- VOC** : Not available.
- Viscosity** : Not available.
- Ionicity (in water)** : Not available.
- Dispersibility properties** : Not available.
- Solubility** : Not available.
- Physical/chemical properties comments** : Not available.

10 . Stability and reactivity

- Stability** : The product is stable. Under normal conditions of storage and use, hazardous polymerization will not occur.
- Conditions to avoid** : Avoid exposure - obtain special instructions before use.
- Materials to avoid** : No specific data.
- Hazardous decomposition products** : Under normal conditions of storage and use, hazardous decomposition products should not be produced.
- Hazardous polymerization** : Not available.
- Conditions of reactivity** : Not available.
Not available.

11 . Toxicological information

Acute toxicity

Product/ingredient name	Result	Species	Dose	Exposure
Not available.				

Conclusion/Summary : Not available.

Chronic toxicity

Product/ingredient name	Result	Species	Dose	Exposure
Not available.				

Conclusion/Summary : Not available.

Carcinogenicity

Product/ingredient name	Result	Species	Dose	Exposure
Not available.				

Conclusion/Summary : Not available.

Classification

Product/ingredient name	ACGIH	IARC	EPA	NIOSH	NTP	OSHA
Crystalline Silica Quartz	A2	1	-	+	Proven.	-

Mutagenicity

Sand and Stone Mixes

11 . Toxicological information

Product/ingredient name	Test	Experiment	Result			
Not available.						
Conclusion/Summary : Not available.						
Teratogenicity						
Product/ingredient name	Result	Species	Dose	Exposure		
Not available.						
Conclusion/Summary : Not available.						
Reproductive toxicity						
Product/ingredient name	Maternal toxicity	Fertility	Development toxin	Species	Dose	Exposure
Not available.						
Conclusion/Summary : Not available.						
Synergistic products : Not available.						

12 . Ecological information

Environmental effects	: No known significant effects or critical hazards.			
Aquatic ecotoxicity				
Product/ingredient name	Test	Result	Species	Exposure
Not available.				
Conclusion/Summary : Not available.				
Biodegradability				
Product/ingredient name	Test	Result	Dose	Inoculum
Not available.				
Conclusion/Summary : Not available.				
Octanol/water partition coefficient	: Not available.			
Bioconcentration factor	: Not available.			
Mobility	: Not available.			
Toxicity of the products of biodegradation	: Not available.			
Other adverse effects	: No known significant effects or critical hazards.			

13 . Disposal considerations

Waste disposal	: The generation of waste should be avoided or minimized wherever possible. Dispose of surplus and non-recyclable products via a licensed waste disposal contractor. Disposal of this product, solutions and any by-products should at all times comply with the requirements of environmental protection and waste disposal legislation and any regional local authority requirements. Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers.
Waste stream	: Not available.
RCRA classification	: Not available.
Disposal should be in accordance with applicable regional, national and local laws and regulations.	
Refer to Section 7: HANDLING AND STORAGE and Section 8: EXPOSURE CONTROLS/PERSONAL PROTECTION for additional handling information and protection of employees.	

Sand and Stone Mixes

14 . Transport information

Regulatory information	UN number	Proper shipping name	Classes	PG*	Label	Additional information
DOT Classification	Not available.	Not available.	Not available.	-		-
TDG Classification	Not regulated.	-	-	-		-
Mexico Classification	Not available.	Not available.	Not available.	-		-
ADR/RID Class	Not available.	Not available.	Not available.	-		-
IMDG Class	Not available.	Not available.	Not available.	-		-
IATA-DGR Class	Not available.	Not available.	Not available.	-		-

PG* : Packing group

15 . Regulatory information

- WHMIS (Canada)** : Not controlled under WHMIS (Canada).
 - Canadian lists** :
 - CEPA Toxic substances:** None of the components are listed.
 - Canadian ARET:** None of the components are listed.
 - Canadian NPRI:** None of the components are listed.
 - Alberta Designated Substances:** None of the components are listed.
 - Ontario Designated Substances:** None of the components are listed.
 - Quebec Designated Substances:** None of the components are listed.
 - Canada inventory** : **Canada inventory:** Not determined.
- This product has been classified according to the hazard criteria of the CPR and the MSDS contains all the information required by the CPR.**
- EU regulations**
 - Hazard symbol or symbols** : Not available.
 - Risk phrases** : This product is not classified according to EU legislation.
 - Safety phrases** : Not applicable.
 - International regulations**
 - International lists** :
 - Australia inventory (AICS):** All components are listed or exempted.
 - China inventory (IECSC):** Not determined.
 - Korea inventory (KECI):** Not determined.
 - Philippines inventory (PICCS):** Not determined.
 - Japan inventory (ENCS):** Not determined.

16 . Other information

Label requirements : CONTAINS MATERIAL THAT CAN CAUSE TARGET ORGAN DAMAGE. CANCER HAZARD - CONTAINS MATERIAL WHICH CAN CAUSE CANCER.

Hazardous Material Information System (U.S.A.) :

Health	0
Flammability	0
Physical hazards	0

Caution: HMIS® ratings are based on a 0-4 rating scale, with 0 representing minimal hazards or risks, and 4 representing significant hazards or risks. Although HMIS® ratings are not required on MSDSs under 29 CFR 1910.1200, the preparer may choose to provide them. HMIS® ratings are to be used with a fully implemented HMIS® program. HMIS® is a registered mark of the National Paint & Coatings Association (NPCA). HMIS® materials may be purchased exclusively from J. J. Keller (800) 327-6868.

The customer is responsible for determining the PPE code for this material.

- References** : Not available.
- Other special considerations** : These products may/may not contain non hazardous proprietary ingredients. As these products are not WHIMS Controlled, their disclosure is not required.
- Date of printing** : 4/9/2007.
- Date of issue** : 4/9/2007.
- Date of previous issue** : No previous validation.
- Version** : 1

Indicates information that has changed from previously issued version.

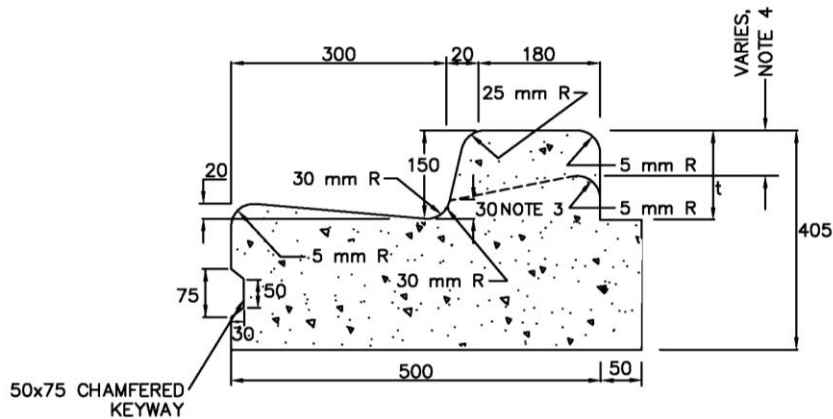
Notice to reader

To the best of our knowledge, the information contained herein is accurate. However, neither the above-named supplier, nor any of its subsidiaries, assumes any liability whatsoever for the accuracy or completeness of the information contained herein.

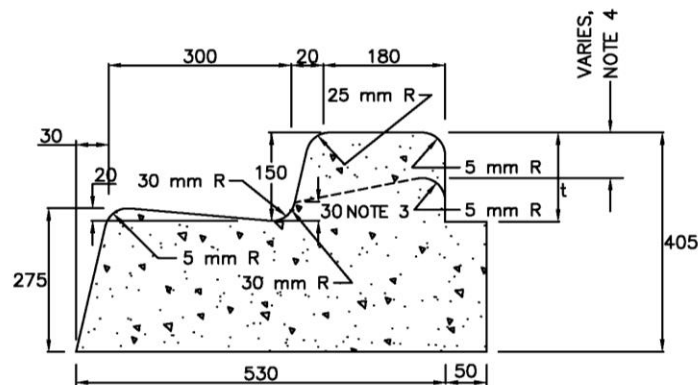
Final determination of suitability of any material is the sole responsibility of the user. All materials may present unknown hazards and should be used with caution. Although certain hazards are described herein, we cannot guarantee that these are the only hazards that exist.

APPENDIX F

Concrete Curb and Gutter Design



FOR USE WITH RIGID PAVEMENT



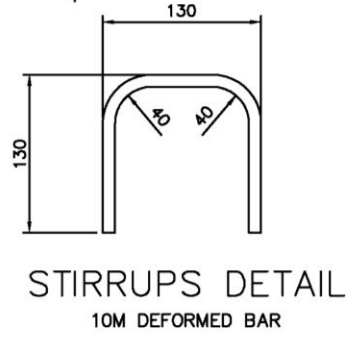
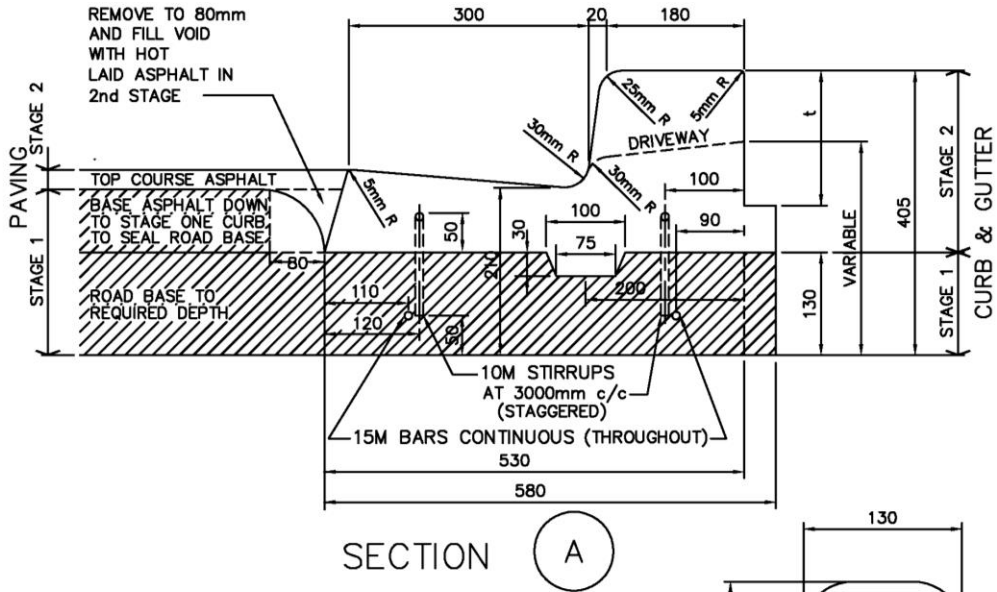
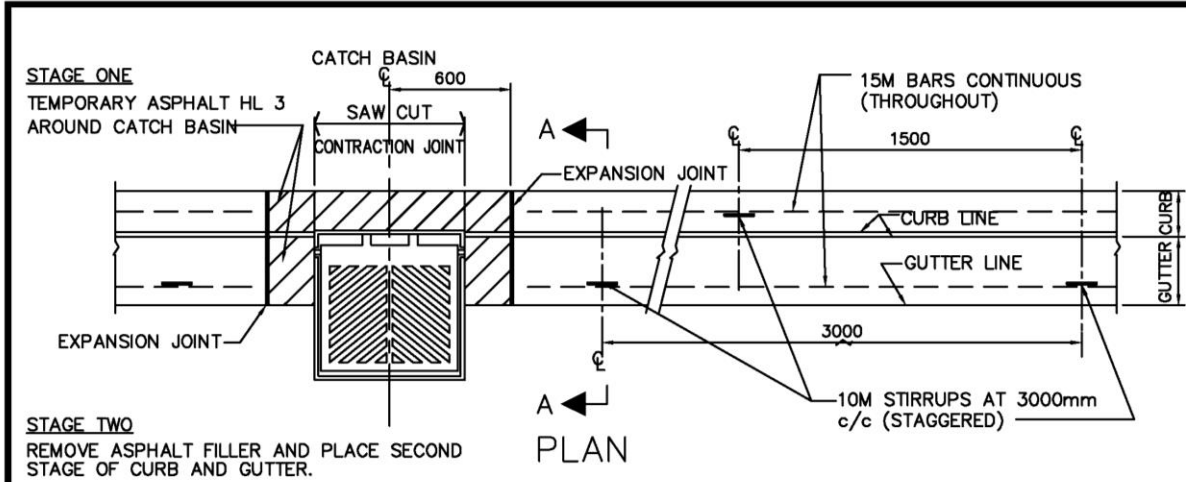
FOR USE WITH FLEXIBLE PAVEMENT

NOTES:

1. EXPANSION/CONTRACTION JOINTS SHALL BE SPACED 6 METERS APART OR COINCIDE WITH JOINTS IN ADJACENT SIDEWALK AND CONCRETE ROAD BASE.
2. $t=130\text{mm}$, 150mm or 180mm TO SUIT CONCRETE SIDEWALK, CONCRETE BOULEVARD OR CONCRETE DRIVEWAY MEASURED FROM THE TOP OF CURB DEPRESSION.
3. 10mm FOR SIDEWALK RAMPS AND DISABILITY ACCESSSES.
4. ENTRANCE TERMINATION AS PER DRAWING T-350.01. DROP CURB AT ENTRANCE, TYP. $70-100\text{mm}$, DEPENDS ON SITE CONDITION AS SPECIFIED.
5. $2-15\text{mm}$ REINFORCING BARS FOR INDUSTRIAL DRIVEWAYS, 50mm CONCRETE COVER, TO BE EXTENDED 600mm BEYOND WIDTH OF DRIVEWAY ON EACH END.

METRIC
ALL DIMENSIONS SHOWN HERE ARE IN MILLIMETRES UNLESS OTHERWISE NOTED

		TECHNICAL SERVICES Engineering Services - Works Facilities & Structures CADD Services	
SCALE:	N.T.S.	CONCRETE CURB AND GUTTER	DRAWING NUMBER:
DATE:	NOVEMBER 2009		T-600.05-1
DRAFTING:	V. DIDIANO		GENERAL



- NOTES:
1. $t=130\text{mm}$, 150mm or 180mm TO SUIT CONCRETE SIDEWALK, CONCRETE BOULEVARD OR CONCRETE DRIVEWAY MEASURED FROM THE TOP OF CURB DEPRESSION.
 2. CURB CUT TAPERED ENDS AT 4:1
 3. STAGE ONE TO BE THOROUGHLY CLEANED TO THE SATISFACTION OF THE CITY PRIOR TO STAGE TWO INSTALLATION.

METRIC
ALL DIMENSIONS SHOWN HERE ARE IN MILLIMETRES UNLESS OTHERWISE NOTED

		TECHNICAL SERVICES Engineering Services - Works Facilities & Structures CADD Services	
SCALE:	N.T.S.	TWO - STAGE CONCRETE CURB AND GUTTER	DRAWING NUMBER:
DATE:	NOVEMBER 2009		T-600.07-1
DRAFTING:	V. DIDIANO		GENERAL