SAE Aerospace
An SAE International Group

AEROSPACE RECOMMENDED PRACTICE

SAE ARP5564

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Airport Runway Brooms

RATIONALE

The rational for this SAE Aerospace Recommended Practice (ARP) is to provided the purchaser with the background knowledge and minimum specifications relating to Airport Runway Brooms commonly used in airport snow removal operations.

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http://www.sae.org/technical/standards/ARP5564

1. SCOPE

This aerospace recommended practice provides definition for Airport Runway Brooms and covers requirements for various configurations of runway brooms with and without a carrier vehicle. Runway brooms are primarily used to move and clear snow and ice down to bare pavement on airport operational areas such as runways, taxiways and ramp areas. The term carrier vehicle represents the various self-propelled prime movers that provide the forward motion of the various configurations of runway brooms.

1.1 Purpose

This aerospace recommended is intended to establish definition and minimum standards specification for Runway Brooms. It is subject to change as technology and requirements change. Other considerations such as local conditions, maintenance, commonality of fleet, product support, and advances in technology should also be used when specifying equipment.

2. REFERENCES

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of the other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

J931 Hydraulic Power Circuit Filtration

J1503 Performance Test for Air-Conditioned, Heated, and Ventilated Off-Road, Self-Propelled Work Machines

J185 Access Systems for Off-Road Machines

ARP5943 Snowplows and Hitches

ARP5539 Rotary Plow with Carrier Vehicle

R-159 Dictionary of Automotive Engineering, Don Goodsell, 1995

2.2 AGMA: American Gear Manufactures Association, 500 Montgomery Street, Suite 350, Alexandria, VA 22314-1581 USA, Phone: 703-684-0211, Fax: 703-684-0242, www.agma.org.

2.3 FAR & FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

AC 150/5200-30A Airport Winter Safety and Operations

AC 150/5200-18 Buildings for Storage and Maintenance of Airport Snow and Ice Control Equipment and Materials

AC 150/5210-5B Painting, Marking, and Lighting of Vehicles on an Airport

AC 150/5220-20 Airport Snow And Ice Control

2.4 Federal Spec 297 D, Rustproofing of Commercial (Nontactical) Vehicles

2.5 FMCSR Publications

Available from Federal Motor Carrier Safety Administration, 400 Seventh Street SW., Washington, DC, 20590; Internet address: http://www.fmcsa.dot.gov.

Title 49, Chapter III, Subchapter B-Federal Motor Carrier Safety Regulations (Title 49)

2.6 FMVSS Standards-latest edition

2.7 RTCA Publications

Available from Radio Technical Commission for Aeronautics Inc., 1828 L Street, NW, Suite 805, Washington, DC 20036, Tel: 202-833-9339, www.rtca.org.

DO-186 Minimum Performance Standards for Airborne Radio Communications Equipment Operating Within the Radio Frequency Range 117.975 - 137.000

3. DEFINITIONS

See also, Dictionary of Automotive Engineering, Don Goodsell

Airport runway Broom: A device designed to clean snow, slush and ice; and when specified, other materials such as sand, snow and ice control chemicals, debris, rubber residue, and other materials from airport runway, taxiway, and ramp areas by using a brush with bristles to clean the surfaces.

Air Blast: A device for developing and directing a continuous stream of forced air ahead or behind the brush for moving snow and debris.

Auxiliary Equipment: Any equipment, in addition to the basic chassis that is required for a piece of equipment/vehicle to perform its functions. For example, a winch would be auxiliary equipment for a tow truck.

Axle Capacity: The allowable weight load on an axle based on supportive engineering data and the best judgment of the manufacturer of the axle.

Axle Ratio: The numerical ratio of the drive shaft speed to the speed of the axle. The numerical ratio equals the torque multiplication factor of the axle.

Axle, Dead: A means of support for the wheels at each end that is non-driven.

Axle, Live: A means of support for the wheels at each end that is driven.

Broom: A complete operating unit. A broom contains a brush with bristles that sweep.

Broom Capacity Rating: The amount of snow moved per unit of time, normally in tons per hour, resulting in an acceptable surface condition.

Brush Core: The center rotating structure which supports the bristles

Brush Head: The portion of the runway broom which supports and carries the bristle and its core

Brush Hood Cover: A cover for the top half of the brush.

Brush: The rotating cylinder of many bristles

Brush Angling System: The capability of angling or rotating the brush head to allow the discharge of snow to the left or right of the carrier vehicle when moving in a forward direction. The angle is changed from the operator's position in the cab by use of a system such as hydraulic rams, hydraulic or electric motors, or other devices or mechanisms.

Brush Elevation Mechanism: A device for raising and lowering the brush. The height is changed from the operator's position in the cab by use of a system such as hydraulic rams, hydraulic or electric motors, or other devices or mechanisms.

Brush Pattern: The width, perpendicular to the brush core, of the area the rotating brush contacts with the surface in the down position.

Brush Pattern Adjusting System: A system for adjusting the pattern of the brush

Cab: An enclosed area on a vehicle designed and intended to hold and carry an operator.

Cab Conventional: A cab mounted just behind the drive engine for the chassis.

Cab Forward:A cab mounted to the most forward position on the chassis

Cab-Over Attachment: A cab mounted over the front attachment.

Cab-Over Engine: A cab mounted over the front mounted engine.

Carrier Vehicle: The prime mover for a runway broom of any configuration

Casting Distance: The distance the snow moves left or right measured perpendicular to the vehicle travel from the broom end, to the center of the area of most concentrated snow cast observed during casting.

Center Drive Brooms: Brush driven from the center position of the brush head.

Certification:

Application Approval: Confirmation by a manufacturer or qualified expert that the unit or component fulfills the requirement of the application.

Performance; Written confirmation of the ability of a unit or component to performance as specified based on calculations or testing.

Curbside: The right side of the vehicle when viewed from the rear. Opposite side from roadside.

Curb Weight: The weight of the carrier vehicle with all factory installed and auxiliary equipment, in the travel position, full fuel tank(s) and a nominal 180 pound operator.

Deflector (Brush): A device mounted on the front of the brush hood to allow the operator to direct the snow casting. The deflector position is changed from the operator's position in the cab by use of a system such as hydraulic rams, hydraulic or electric motors, or other devices or mechanisms.

Deluge System: A means of providing large amounts of fluid to windshield(s), side and rear window(s), mirror(s), and other surfaces to improve operational visibility from the cab.

Differential: The gear assembly in the drive axle that permits one wheel to turn slower or faster than the other when negotiating a turn. The gear assembly in the transfer case that allows the front drive-shaft to turn slower or faster than the other when negotiating a turn.

Differential, Automatic Locking: The gear assembly in the transfer case that allows the front drive-shaft to turn slower or faster than the rear prop-shaft when negotiating a turn while providing maximum driving torque to both the front and rear axles. The gear assembly on the drive axle that permits one wheel to turn slower or faster than the other when negotiating

a turn while providing maximum driving torque to both wheels. Automatic locking differentials provide positive drive to both driven members while not requiring operator input or control.

Differential, Manual Locking (bevel gear): The gear assembly on the drive axle that permits one wheel to turn slower or faster than the other when negotiating a turn but with provisions for the operator to fully lock and unlock the differential action from the cab. Bevel gears provide positive drive to both driven members.

Dimensions:

AE	Centerline of rear axle/tandem to the end of frame.
BA	Bumper to centerline of Front axle
BBC	Bumper to back of Cab
CA	Back of Cab to centerline of rear axle
CE	Back of cab to end of the frame (AE + CA = CE)
FH	Frame height from the ground to the top of frame
OAL	Overall Length
WB	Wheelbase
OAH	Ground to top of highest point on the unit

End Drive Brooms: Brush driven from one or both ends

FMVSS: An abbreviation for the Federal Motor Vehicle Safety Standards.

FOD: Foreign Object Debris. Anything that does not belong.

Front/Rear Axle Disconnect: A mechanism designed to engage and disengage power to the axle.

Fuel Capacity: The actual volume of fuel able to be stored in on-board tanks.

GAWR: Abbreviation for Gross Axle Weight Rating. The rating of the lowest rated member of an axle as defined by the component manufacturer(s) from the following components: Tires, suspension, hubs/wheels, rims, bearings, beam and brakes.

Gear Ratio: The ratio of the speed of the input to a gear to the speed of the output from the gear. For a pair of gears, the ratio is found by dividing the number of teeth on the driven gear by the number of teeth on the driving gear.

Geared Speed: The theoretical vehicle speed based on maximum governed engine RPM, transmission gear ratio(s), driving axle ratio, and tire size.

Gears, Single & Multiple Reduction: Single reduction gearing refers to one speed reduction through the gearing component. Multiple reduction refers to more than one step of speed reduction through the gearing component.

Grade-ability: The percent grade that a vehicle will negotiate

GVWR: Abbreviation for Gross Vehicle Weight Rating. The sum of the Gross Axle Weight Ratings (GAWR).

HID Light: Acronym for High Intensity Discharge light. Light created by electric arc, not a filament in a light bulb.

High Speed Broom: A runway broom designed to perform at its maximum Capacity Rating while operating at a forward speed of at least 25 MPH.

Hitch. A device to couple/uncouple a working head or appliance to its carrier vehicle.

Horsepower, Gross brake (or actual delivered horsepower): A measure of the rate at which work is produced. The time rate of doing work, as measured by a Prony brake or dynamometer. Brake horsepower is expressed as the torque in foot – pounds times the number of revolutions per minute divided by the constant 5252.

$$HP = \frac{\text{torque x rpm}}{5252}$$

Horsepower, Gross: The brake HP determined under conditions defined by dynamometer test of the stripped engine, that is, the brake horsepower of the engine with only those accessories and attachments necessary to the functioning of the engine during test.

Horsepower, Net: The brake horsepower delivered to the clutch, or its equivalent, with all accessories and attachments functioning (including exhaust pipe, muffler and tail pipe) which are standard or regular equipment on the engine as installed in the particular chassis. Gross horsepower less the parasitic loads.

Impeller (Air blast): The internal rotating portion of the air blast which produces the air movement.

Maximum Tire Load Rating: The load rating at the maximum permissible inflation pressure for that tire

Maximum Permissible Inflation Pressure: The maximum cold inflation pressure to which a tire may be inflated.

Maximum Speed: The speed attainable by accelerating at maximum rate from a standing start for one mile.

NHTSA: An abbreviation for the National Highway Traffic Safety Administration

New and Current Production Components: new, unused and free of all defects and imperfections that could affect the serviceability of the finished product. Component with a manufacture date no older than one (1) year prior to bid proposal.

New and of Current Production Unit (as in total unit Chassis and attachments): Unit whose manufacture (assembly of) started no earlier than the award date of the contract.

Performance Rating: Capacity Rating.

Ply Rating: A unit of measurement used in tire construction to denote strength of tires.

Power Divider: Usually a small auxiliary gear box or chain driven device to allow distribution of drive shaft power to several different mechanical devices mounted on the same truck.

Power Take-off (PTO): A mechanical device used to transmit engine power to auxiliary equipment. Power take-offs can be mounted on either a main or auxiliary transmission. Front-mounted and flywheel-mounted power take-offs are also used in various applications.

Power Train: All the components from a power source such as an engine to the powered device such as driving wheels of a chassis or the brush shaft of the broom. This includes Engines, transmissions, gearboxes, drive shafts, differentials, driving axles, hydraulic pumps, motors and hoses.

Reflectors: Glass or plastic prism lenses which reflect light.

Resisting Bending Moment (RBM): A calculation used to compare frames of different section modulus and of different material. It is the product of the section modulus times the yield strength of the frame material. The formula expression is:

$$RBM = \text{Section Modulus} \times \text{Yield Strength}$$

Road Rolling Resistance: Sum of the forces at the area of contact between a vehicle's tires and road surface acting against the direction of movement.

Roadside: The left side of the vehicle when viewed from the rear. Opposite side from curbside.

Rolling Radius: Height measured from the center of the axle to the ground

Serial Number: A unique number issued to a vehicle or to a component of a vehicle for identification purposes. Also see VIN number.

Single Engine Runway Broom: Runway broom with a single engine that provides power to both the chassis motive power and the brush head.

Snow Shield: A cover positioned over the brush hood, designed and intended to minimize cumulative weight caused by the accumulation of snow on the brush assembly, which can have a negative effect on the brush pattern.

Spring Capacity: The allowable load that can be supported by the spring(s).

Steering, All Wheel: Any system that augments the steering action of a chassis, providing for power or power assisted steering controlled by the operator in the cab, on all wheels of the vehicle.

Steering, Power: Also commonly referred to as “hydraulic steering”. A Steering system that uses hydraulic pressure to control a steering axle without a direct mechanical (controlling) link between the operator’s controls and the steering axle. A backup system must be provided to maintain steering at all times.

Steering, Power Assisted: Steering gear or mechanism with a direct mechanical (controlling) connection to a steering axle that has provisions for part of the force required for operation to be provided by air, hydraulic, or other means, not including mechanical leverage (longer handles)

Stopping Distance: The distance traveled by a vehicle from the point of application of force to the brake control to the point at which the vehicle reaches a full stop.

Structural Member: A part of a vehicle designed primarily to support the load of a vehicle in operation

Suction Line: A tubular connection between a reservoir or tank and the inlet of a pump.

Swept Surface Condition: A measurement of coefficient of friction (braking action) from a friction measuring device after being swept. Also a visual inspection of whether the surface is clean and bare with no remaining debris or chunks of snow and ice.

Third Party: A disinterested party professionally qualified to observe, understand, and/or record test data other than the manufacturer that is acceptable to the purchaser.

Tilt Cab: A cab that pivots forward to gain access to the engine or other major component.

Tire Clearance: Space between tires and the nearest part of the body or under-structure.

Tons per hour: A function of snow density x depth of snow x swept path x vehicle speed.

Tractive Effort: The maximum force developed by a vehicle power train at contact between the driven wheels and road surface with 100% available traction.

Transfer Case: Split power gear box transmitting drive to the front and rear axles.

Transmission: Selective gearbox providing various combinations of gear ratios.

Transmission, Automatic: A type of transmission designed to self select and change gear ratios based on vehicle and engine speed.

Transmission, Hydrostatic: A type of transmission that provides gear reduction between the engine and drive wheels that uses fluid under pressure to transmit power and torque rather than mechanical components.

Transmission, Manual: A type of transmission that can function only with periodic mechanical input from an operator to select the gear reduction or drive ratio used in the transmission, and a mechanism (clutch) to disengage the power from the engine to the transmission during the mechanical shift input from the operator.

Transmission, Powershift: A type of transmission that can function only with periodic input from an operator to select the gear reduction or drive ratio in use in the transmission. Powershift transmissions include a device that allows the change of drive ratios or gears by means of an internal device that does not require operator action to interrupt power from the engine while changing the gear or drive ratio.

Tread; Wheel Track: a) The distance between the centers of tires on the same axle at the points where they contact the road surface. Duals are measured from the center of dual wheels. (b) That portion of a tire that comes into contact with the road. c) The pattern of the surface of the tire that comes in contact with the road.

Trunnion: (a) The axis, pivot point, or center point between axles. (b) The axis or pivot point of power transmission in a steerable drive axle where the turning member joins the non turning member of the axle.

Turning Circle, wall to wall: The diameter of a semi-circle described by the outmost edge of the vehicle and / or attachment while the vehicle maneuvers through an 180^{O} turn and the attachment is at its worst case position.

Two-Speed Axle: A driving axle arrangement whereby the driver can select one of two ratios.

Vehicle Identification Number (VIN): A unique number issued to a vehicle for identification purposes. Format and code of a VIN is prescribed by law to identify manufacturer, configuration, and date of production.

4. RUNWAY BROOM USES

Airport runway brooms are primarily used to clean snow, slush, and ice from airport runway, taxiway, and ramp areas by using a brush with bristles to clean the surfaces. When specified other uses for runway broom are:

- Rubber removal: The brush is used to agitate and scrub the pavement with the aid of a rubber removal solution.
- Dirt cleanup: The broom is used to clean and move dirt and debris from pavement. A FOD box (large collection bin) can also be attached to the front of the broom for high speed FOD and debris pickup.
- Cutting ice: Using an all wire bristle brush, the broom is used at slow speeds to cut through hardpack and ice.

5. RUNWAY BROOM CONFIGURATIONS

There are many configurations of runway brooms with many different carrier vehicles providing the forward motion for the runway brooms. Typical configurations are described below and one is to be chosen by the user.

The front mount type clears snow before passing wheels or plow blades have a chance to compact and push the snow into the grooves and pores of the pavement.

5.1 Front Mount Dedicated

This type is a pushed broom and air blast only and configured with the broom preceding the carrier vehicle allowing the operator to observe the area being swept. Two power plant configurations possible are: a single engine that provides the power to the broom, high velocity air blast and the motive power. Or a dual engine; one engine provides power to the broom, air blast and the other engine provides motive power.

Visibility of the sweeping operation allows the operator to see the area being swept. The compact design enables maximum maneuverability in confined areas. The unit can only be used for brooming. It is not capable of sharing attachments with other similar equipment.

5.2 Front Mount Dual Purpose

This type is identical to the Front Mount Dedicated except it has the ability to accept a plow in place of the broom, making the unit capable of sweeping or plowing. An interchangeable hitch is required for the plow and broom, allowing fast changeover. The auxiliary engine is dedicated to the broom and air blast power requirements. The carrier vehicle engine is normally larger (more horsepower) than the Front Mount Dedicated broom configuration for pushing power for the plow.

5.3 Front Mount Multi Purpose

This type has the ability to accept a rotary plow in place of the broom or plow making the unit capable of sweeping, plowing or snow blowing. Not simultaneously. Again, an interchangeable hitch is required for fast changeover.

An interchangeable hitch is required minimizing changeover time, however snow removal operation time will be lost during the changeover.

5.4 Loader Mounted

This type has the broom preceding the loader. It requires an auxiliary engine dedicated for the broom and air blast. The engine assembly can be attached to the loader arms or mounted on the back of the loader chassis if the weight distribution allows this. The size of the broom must be matched to the capacity of the loader. Since the loader quick attach is used, changeover times to attached the broom are minimal. Sweeping speed may be limited due to the maximum speed of the loader.

5.5 Tractor Mounted

This type normally has the broom preceding the tractor. Power for the unit comes from the power take-off shaft (PTO) of the tractor. For efficient snow moving capacity, the PTO of the tractor must be adequate for the projected snow removal requirements. The uses, advantages and disadvantages are the same as the loader mounted. The tractor mounted broom is ideal for small area sweeping. Sweeping speed may be limited due to the maximum speed of the tractor.

5.6 Tow Behind

This type utilizes a trailer frame with and auxiliary engine for the broom and air blast, towed by a vehicle. The hitch to the towing chassis can either be a:

- Fifth-wheel type hitch with jackstand
- Direct pintle hook with jackstand
- Pintle hook on a tow pole with castering front nose wheel. This is used when the towing vehicle cannot carry the weight load of a direct pintle. This configuration is very difficult to back up since there is an additional pivot point.

The operator controls for the broom are in the towing vehicle cab and are ergonomically mounted for use by the driver. The controls can either be integrated or in a removable box with quick disconnects.

The axle(s) on the tow broom frame can either be fixed or steering type as defined by the user. The steering type shall allow the broom to follow the towing chassis and ultimately keeping the broom in the plowed path.

5.7 Multi-Tasking (MTE)

This type is defined as a minimum of Plow, Broom, and Air blast. See ARP 5548 for complete description of this configuration.

6. TECHNICAL REQUIREMENTS / GENERAL SPECIFICATIONS

The specific components and systems that make up a complete airport runway broom differ for various classifications and configurations, but in general they are similar. Because of the many different classifications and configurations, all specific components and systems cannot be specified in detail here. The intent here is to provide a basis from which the user can develop detailed specifications for procuring a runway broom. Based on local conditions and needs the user must specify the parameters required. Other considerations such as local conditions, maintenance, commonality of fleet, product support, and advances in technology should also be used when developing their detailed specification.

6.1 General Description

This airport runway broom will be primarily used in the sweeping and cleaning of snow slush and ice from airport runway, taxiway, and ramp areas. The broom must be manufactured expressly for airport pavement sweeping. All items of design and equipment not listed in these specifications, but involved in carrying out their intent, are required to be furnished the same as if these items were specifically mentioned and described in these specifications.

Components shall be new, unused, of current production to the satisfaction of the purchaser. They shall be free of all defects and imperfections that could affect the serviceability of the finished product. Components should be readily accessible for repair and replacement, with minimal removal or disturbance to adjacent parts or components. Designs must use components within their rated values. Parts which are exposed to wear shall be capable of being replaced. Regular maintenance and servicing should be readily accomplished under normal working conditions.

All broom components shall be designed to provide continuous service under difficult working conditions in -20 degrees F to +100 degrees F weather conditions or as specified without degradation of performance. The broom shall be designed to allow bristles to be easily replaced once worn or damaged. When mounted on a carrier vehicle, no components of the broom shall interfere with the servicing and maintenance of the carrier vehicle.

The broom shall have the ability to remove snow, ice, slush, sand and other debris at the rated speed, capacity, and conditions per the following (Also see Table A2 in the Appendix):

a) The broom must be able to move 3 inches of snow at 15 pounds per cubic foot at the rated vehicle speed and full swept path.

And,

b) The broom must be able to move 1 inch of snow at 40 pounds per cubic foot at the rated vehicle speed and full swept path.

At a minimum, the user must specify (See Table A2 and Table A3 in the Appendix for typical values):

- Broom configuration (Select per section 5):
- Required speed of operation (MPH):
- Brush swept path (feet):
- Snow moving capacity (tons per hour):
- Surface area swept rate (square feet per hour):
- Broom power supply horsepower (horsepower):
- Brush diameter (inches):
- Brush rotation speed (0-RPM):

- Brush available torque (foot-pounds):
- Air blast capacities (CFM @ MPH):
- Bristle type and configuration:

Care must be taken by the user when specifying the capacity in Tons per Hour. The broom must have enough “Available Horsepower” to meet the capacity (Tons per Hour) requirements of the specification. See example in section 7.5 of the appendix.

To confirm the brush rotational speed and available torque values, the manufacture must supply engineering hydraulic power calculations of the brush drive train from the engine or power supply to the brush shaft. This includes sizes and specifications of all components of the brush drive train from the engine to the brush shaft including specification sheets for the broom engine, brush and air blast hydrostatic pumps, motors, and gearbox(s) showing type, size, and manufacture. Efficiency losses must also be accounted for. The calculations must be understandable, complete, logical, and in a mathematical order per the Society of Automotive Engineers (SAE) and the Fluid Power Society standard formulas and practices. The burdened of proof is the responsibility of manufacturer. Failure to provide this information for whatever reason will result in disqualification

6.2 Broom Chassis Platform

This section must be defined by user based on configuration

6.2.1 Carrier vehicle: The term carrier vehicle represents the various self-propelled prime movers that provide forward motion for the broom, such as a truck chassis, tractor, or loader per section 7. Due to the many variations and for simplicity they are not described here. Specifications for the carrier vehicle must be developed based on the application. The design of this unit shall ensure positive tire to ground tractive effort while sweeping and doing full wall to wall turning circle of 75 feet or less or as specified. Tests for maneuverability, meeting the wall to wall turning circle requested or proposed. A sample truck chassis specification for a heavy duty front mount dedicated configuration is supplied in the Appendix.

6.2.2 Tow broom frame: The tow broom chassis frame shall be fabricated from heavy gauge tubular, channel or wide flange sections reinforced as required to minimize loading distortion. It shall have gussets front to rear at each welded joint. It shall be designed to minimize flexing and bouncing bounce.

Axles for the broom frame shall be rigid suspension (no springs) type and shall use a standard truck axle and air brakes (or electrical, user to specify) for ease of service and parts availability. The axle, wheels and tires manufacturer’s published rating shall at least be equal to the load imposed at the maximum load configuration. The equipment shall not overload the rating of the frame, axles, wheels, tires, or steering.

The suspension shall be rigid (no springs). All tires and wheels on the unit shall be interchangeable. User shall specify air or electric brakes. Air brake units shall have ABS brakes, FMVSS 121 compliant for trailers. When electrical brakes are used they shall be controlled utilizing an electric brake controller in the tow vehicle and shall be equipped with ABS brakes if available. The electric brake controller and connector shall be supplied and installed in the towing chassis by the user.

The hitch to the towing chassis shall be: (The user must define what best suits their requirements based on towing vehicle configuration)

- A single pintle lunette eye with height adjustment for chassis frame leveling and hydraulic jack stand for ease of hooking up and detaching. A single pintle hook shall be supplied and installed by the user at the rear of the towing chassis.
- A front dolly wheel with tow pole, 360 degree swiveling. A single pintle hook shall be supplied and installed by the user the rear of the towing chassis.

- Fifth wheel type with SAE 2” diameter kingpin with height adjustment for chassis frame leveling and hydraulic jack stand for ease of hooking up and detaching. The fifth wheel receptacle on the tow chassis shall be supplied and installed by the user.

- Dual pintle hooks with draw bar with height adjustment for chassis frame leveling and hydraulic jack stand for ease of hooking up and detaching. Two pintle hooks shall be supplied and installed by the user at the rear of the towing chassis.

When trailer steering is specified, the brush must follow in the plowed path at all times There shall be provisions for centering and disengaging the axle steering system from both the main (cab) and service control consoles. There shall also be a provision for constantly and automatically recentering the steering system during operation to accommodate any drift in the system.

The lighting system, including reflectors, markers identification and clearance lights, shall conform to FMVSS 108 as though the vehicle were an on-highway vehicle. Customers may specify an all LED sealed wiring lighting system for reduced maintenance costs and improved lighting system reliability. In addition, task-oriented lights, and other lighting shall be furnished to help the operator identify the overall width, and when practical to project a beam or light pattern on the ground in front of the broom to assist the operator in determining those areas to be cleared and to provide adequate illumination for the operator and service personal when the unit is on darkened aeronautical areas.

In addition at a minimum one high mounted stop light and a back-up alarm shall be provided.

6.2.3 Backup Lights: There shall be at least two backup lights installed at the rear of and at either side of the vehicle that will automatically be activated when the vehicle is shifted into reverse gear.

6.2.4 Vehicle Safety Identification Lights: The vehicle shall have a minimum of one revolving yellow beacon or flashing strobe mounted on its uppermost part (see FAA AC 150/5210-5B, Painting, Marking and Lighting of Vehicles on an Airport). The light emitted from the beacon should not reflect off rearview mirrors and into the operator's eyes.

An SAE 7 pin or 7-wire flat prong (type must be specified) trailer connector shall be supplied and installed by customer at rear bumper of the towing chassis by the user.

The wiring for broom controls, which shall be a harness with weatherproof and structurally sound connectors at both the cab and rear bumper, shall be supplied and installed by the manufacture. Trailer lights connector and the broom controls connector cannot be interchangeable.

6.3 Broom Engine Assembly (or Power Supply)

The broom engine manufacturer and broom manufacturer shall provide an application approval, at the time of sweeper delivery, which states the engine is suitable for use in the broom as configured and that the installation is approved by the engine manufacturer. The engine shall develop sufficient torque and horsepower to meet the operational requirements of the broom. It shall be of internal combustion type. It shall meet current (at time of build) federal emissions standards and local requirements as defined by the user. It shall be equipped with electronic controls for fuel injection and engine management including an automatic shutdown system with manual override and an electrical connector for diagnostic system. The diesel engine shall be designed and tuned for operation using ASTM D975-93 Standard Specifications for Diesel Fuel Oils, unless otherwise specified by the user, at the performance characteristics specified herein. Engine noise and vibration shall be minimized for the operator by use of best engineering practices and machine layout. The brush and air blast must be designed to efficiently utilize the rated engine horsepower.

The engine shall be provided with a full-flow replaceable oil filter and bypass filter and an air intake with a three-stage air cleaner. A filter restrictor indicator with tattletale features shall be supplied.

- External turbine type pre-cleaner or other means to prevent snow ingestion into the air cleaner

- Internal fixed vane centrifugal pre-cleaner

- Primary dry element and safety element

The engine shall be equipped with an efficient and safe exhaust system including mufflers. Its location shall minimize noise and exhaust gases entering the vehicle cab under all operating conditions. Noise reduction by noise suppression materials, such as muffler insulation, is encouraged. Horizontal portions of exhaust systems shall be protected, whenever possible, from corrosive agents and fuel spills. Mufflers and exhaust components positioned in or near normal operator work areas shall include appropriate guards to minimize the burn risk to airport personnel. Exhaust systems shall be positioned on the vehicle in a manner to minimize contact with slush and snow. Muffler(s) are to be made of aluminum, aluminized steel, stainless steel, or materials coated with ceramics. Devices shall be installed to prevent snow and slush from entering vertical exhaust stacks. Purchaser may specify the location and direction of exhaust system discharge when appropriate for storage building ventilation systems or other operational needs.

The engine cooling system shall be based on either a liquid or forced air design. Internal temperatures of liquid cooled engines shall be controlled by a by-pass thermostat that regulates the flow of engine coolant. Drain cocks shall be installed at the lowest point of the cooling system and at other points necessary to completely drain the system. A sight glass or other device is required in all liquid cooling systems to allow the operator to determine that there is sufficient fluid for normal and safe operation without the need to open the system. Coolant shall be per engine manufacture recommendation and approval. A tag or label shall be supplied at the fluid servicing point indication proper coolant.

The design and installation of the system shall assure that coolant temperatures shall remain within the engine manufacturer's operational specification (both high and low) when properly maintained and operated in ambient temperatures during snow removal operations. In areas which frequently experience temperatures below 0 degrees F and/or units stored outside, cooling system heaters, oil pan heaters, lubricating oil heaters, battery heaters, and cold start aides are required unless otherwise specified.

Engine speed shall be regulated by a governor set to provide the maximum operating speed recommended by the engine manufacturer.

An engine's lubricating system shall be equipped with standard production fittings and accessories. Engine oil filter(s) shall be engine manufacturers approved design and able to accept commercial replacement elements. All engine(s) shall receive lubrication prior to delivery with lubricants designated for use under rated temperature conditions. The unit(s) shall be tagged to identify the proper lubricants and their temperature ranges.

An automatic engine protection system to prevent engine damage due to low engine pressure, high coolant temperature, or low coolant level is required. A provision for the emergency movement of the unit from a runway or taxiway must be provided.

6.4 Fuel System

The fuel system shall comply with Title 49 and include all components necessary for a complete operational system.

Fuel Tank(s) and Lines: Useable fuel capacity should be no less than an 8-hour supply unless the user requires a longer period. Engine literature shall be provided in the bid package that includes certified fuel usage rates. For estimating purposes, useable fuel capacity may be calculated using the value of: (total maximum brake horsepower for all engines) x (0.055 gals/hr/bhp) x (desired operating hours) x (0.5 for a 50% load factor). If dual tanks are used, the supply system shall be designed to ensure an uninterrupted flow of fuel to the engine(s) without input by the operator, and to allow shutoff of each tank should the crossover lines (or either tank) be damaged. Dual tanks shall also have adequately sized crossover lines to allow refilling both tanks from one location. Fuel lines shall be securely fastened in place, installed to prevent chafing or strain and protected by grommets where lines project through metal apertures. Each fuel tank is to be equipped with an accessible bronze or brass drain plug or a quick drain. A properly rated fuel water separator with integral heater shall be installed in an accessible location in the engine compartment or near the tank. If the engine requires a boost pump to assure adequate fuel flow to the engine, a pressure-operated switch with in-cab warning light shall be furnished to warn the operator of low boost pump pressure. The boost pump should be installed to shut off when the engine is turned off, or to have an emergency shutoff switch or circuit breaker located near the light to allow the operator to shut off the boost pump in the event of fuel leakage downstream of the boost pump.

Fuel Filler Pipe: The fuel filler pipe(s) shall be located outside of the vehicle cab preferably accessible from the ground. A light chain shall be attached near its opening and to the filler cap to prevent loss of the cap. The filler neck shall include a screen to prevent the entry of foreign objects into the tank. The fuel filler cap shall be painted a color appropriate for the type of fuel, and a permanent label shall be affixed as close as practical to the fill neck(s), in an area visible to the person refueling the vehicle, stating the appropriate fuel and capacity of the tank(s). If fuel fillers are not installed on both sides of the vehicle, a label shall be installed in the cab near the fuel gauge indicating which side of the vehicle must be positioned towards the fuel pumps (e.g., Fuel Fill).

6.5 Electrical System

The electrical system shall be negatively grounded and installed in accordance with current state-of-the-art practices and appropriate Federal requirements. All vehicle wiring shall be in accordance with J1292. All broom electrical equipment, components, and wiring shall meet the requirements set forth in ARP1247, latest revision. All parts of the electrical system shall be waterproof, easily accessible, securely mounted, and protected against extreme temperatures, physical damage, snow, oil, and corrosion. All electrical circuit wiring shall be made of stranded conductors with a capacity exceeding the anticipated maximum circuit loading by 10%. Insulation of electrical wiring shall be equal to the recommended standards established for insulation materials by the Society of Automotive Engineers (SAE). All wiring shall be either harness, cable, split loomed, or shrink-wrapped. All wiring shall be color-coded or wire numbered matching drawing schematics and terminal strip, and labeled every 3 inches as to what it is used for. The gauge wire and processes shall be in accordance with common wiring practices, SXL insulation type. The wiring codes shall match information to be provided in the supporting service manuals.

All vehicle components and systems shall operate without being affected by interference damage or disruption including detrimental effects or interference to on-board computer modules from either vehicle generated noise, or stray EMF or RMF fields encountered from any airport operations. EMF and RMF noise sources that may be generated by the vehicle, especially if such noise is detrimental to aircraft, Air Traffic Control or air navigation equipment, shall be shielded.

When required, the broom shall be equipped with self regulating electric alternators having an output capacity that exceeds the anticipated electrical load by 20% at idle. An electrical load analysis worksheet shall be provided to the purchaser prior to construction showing the electrical loads during the above described conditions.

When required, the batteries shall be securely mounted and adequately protected against physical injury, water, chemicals and exhaust heat. They shall be properly sized based on vehicle manufacturer recommendations and be readily accessible for change out and for other purposes. Enclosed battery compartments shall have adequate ventilation. Battery capacity (cranking amps, voltage, reserve power, continuous/deep cycle demand) shall be compatible with the size of the engine and the anticipated electrical load expected under normal operating conditions. An on-board self-regulating battery charger may be specified by the purchaser. A battery master disconnect switch shall be provided with a means to secure it in the off position for servicing.

The vehicle shall have an electrical starter that shall not introduce a voltage drop sufficient to adversely affect the ignition system. It shall be equipped with an overload protection device if such device is available from the manufacturer of the starter. The purchaser shall specify the type(s) of electrical systems that are acceptable such as.

- 12 volt electrical and starting.
- 12 volt electrical/24 volt starting.
- 24 volt electrical and starting

6.6 Sheet Metal Components and Accessibility

The engine and other components shall be positioned to allow easy access for inspection and maintenance purposes. Components that historically require frequent maintenance or those that have the potential to cause operational problems should particularly be located in unobstructed areas. Fluid capacities that must be checked during a pre-trip inspection, such as engine oil, engine coolant, hydraulic oil level(s), windshield washer fluid level, and diesel fuel level shall be visually observable or otherwise capable of being checked without the need for tools, and without requiring work stands, portable ladders, or other equipment to check the service levels. Lighting in these areas shall be adequate to perform the checks without the need for flashlights or other portable lighting. Cover plates shall be equipped with either quick-disconnect latches or hinges. Locks, controls and latches shall be designed to prevent over-torquing.

6.6.1 Engine Enclosure: The broom engine, as well as all attached hydraulic, electrical, and mechanical components, shall be protected wherever practical from snow, rain, chemicals, and other winter elements. Enclosures may be fabricated from aluminum, fiberglass, steel and/or other durable material commonly used for this application. Self tapping bolts are unacceptable in the construction of these enclosures. The enclosure shall be designed with openings which allow adequate cooling air flow to prevent overheating of the engine and other components. Adequate switched lighting shall be included. Drain lines shall be provided for engine oil, radiator coolant and hydraulic oil.

6.6.2 Steps: Steps, stairways, ladders, walkways, handholds, and handrails used to access the cab, maintenance areas, operation areas, or other areas of the equipment shall conform to the most recent additions of J185 – Access Systems for Off-Road Machines, using the “preferred” dimensions offered in this standard. When required, four-way ‘safety tread’ design steps shall be supplied to ascend and descend certain high profile area. These steps, together with assist handles, shall be of ample size to ensure safe and easy access for persons wearing bulky winter clothing.

6.6.3 Walkways: A four-way safety tread design walkway shall be provided, as necessary, for access.

6.6.4 Handrails: Handrails shall be provided as required at all steps, walkways, and work stations. They shall be made of corrosion-resistant materials or otherwise treated to prevent corrosion.

6.6.5 Doors: Door openings of adequate size to facilitate equipment servicing shall be provided. Doors shall be equipped with a positive closing mechanism and, where appropriate, a locking mechanism. Top hinged compartment doors shall be held in the open position by a support arm(s).

6.6.6 Drains: Plugged or free flowing drains shall be provided at all body and compartment locations where standing water can collect. Free flowing drains shall not drain onto sensitive mechanical or electrical components or on areas anticipated to be occupied by personnel during normal operations.

6.7 Broom Hitch

The broom hitch shall be capable of sustaining all loads imposed during operation. It shall provide low friction and free flotation for the brush head for bounce and skip free operation. It shall allow the brush head to be independent so the broom chassis does not induce bounce into the brush. The broom hitch shall have the necessary degrees of freedom to follow normal contours in the pavement and to accommodate surface irregularities, while sweeping at the rated speed, bouncing skipping, binding or sustaining damage. The broom oscillation shall provide true flotation left to right for the brush head. It shall have at least 8 degrees (+4, -4) of free floating oscillation from left to right.

For some configurations, an interchangeable hitch and hydraulic connections is required allowing fast changeover. There are various types of hitch and hydraulic connections which the user must specify.

6.8 Brush Angle

The brush angling mechanism shall be power actuated and controlled by the operator. The brush shall be capable of swinging at least 30 degrees left and 30 degrees right from the straight ahead position. Angling from full right to full left shall not take more then 10 seconds and shall not change the brush pattern. In between full left and full right, the pattern shall not change more then 50%. For resultant swept path based on angle and brush length, see Table A1 in the Appendix.

6.9 Brush Elevation and Brush Pattern Adjustment

The brush elevation mechanism shall be power actuated and controlled by the operator, typically a joystick, which shall raise the brush off the surface and lower it for sweeping. The elevation mechanism shall have adequate stroke to achieve 4 inches of ground clearance with a new brush. The lift cylinders shall be equipped with a counterbalance valve, which prevents the brush head from creeping down.

An easily adjustable and accessible height adjustment that sets the brush pattern shall be provided. The adjustment, when preset, shall act as a stop for the elevation mechanism allowing repeatable pattern adjustment. A toggle switch near the adjustment for remote brush elevation control and pattern confirmation shall also be provided.

6.10 Brush Head

The brush head frame must sustain the loads imposed by the snow removal capacity of the unit. The brush head and air blast shall be hydrostatic drive with infinitely variable speed hydraulic pump(s) and fixed displacement motor(s) or as specified by the user. If gearboxes are used they shall be made with precision gears, AGMA 10 rating minimum, and a method for checking oil level without the use of tools. Hydrostatic motor(s) shall be tightly coupled to the brush core shaft with no looseness in any connection. The connection must be capable of handling the loads imposed by the hydrostatics.

The brush shall be vibration analyzed at final inspection with report on vibration provided upon request.

The brush head shall allow an easy access for core and / or bristle replacement allowing repeatable location of brush centerline alignment during brush core remove and replace operations.

6.11 Brush Hood

The brush hood shall be fabricated from heavy gauge sheet steel or other durable material and securely fastened to the brush frame. It shall shield the top half of the brush completely and shall be nonclog design to prevent snow and ice buildup underneath the hood. It shall provide the necessary quick access to the brush for replacement of bristles and for inspection.

There shall be a device on the front of the hood to strip the snow from the brush, preventing snow carryover from the front of the brush to the back of the brush. It shall be the full length of the brush. The device must be easily adjustable to the brush diameter as the bristles wear.

The broom must have the capability to control the snow and ice once it is airborne. The snow must be put where and only where the operator desires and the operator must have visibility. The snow control device must be automatic or adjusted by the operator from the operator control station.

6.12 Broom Casters

The weight of the brush head shall be supported by swivel caster tire assemblies. They shall be mounted along the rear of the brush frame. The quantity of tires shall be commensurate with the loading from the brush head. The mounting position must be spaced for uniform weight distribution and shall track within the swept path of the brush. The caster tire assembly shall be capable of revolving a full 360 degrees or 270 degrees if the brush head raises automatically when reversing the vehicle. The caster assembly shall not bind or come into contact with the brush or any other surface of the broom throughout their full rotational arc. Loading and operating speed of the broom shall not overload the caster assembly manufactures rating of the entire caster assembly including the tires, wheels, hubs, bearings and shafts. To keep the caster assembly from shimming, a shimmy damper device is required for each assembly. The mounting of the tire, wheel, hub, shaft and bearings must be quick change type for easy change while on the airfield.

6.13 Brush Bristles

The bristles for the brush shall be designed for runway operation and shall withstand the normal operation of the broom. They shall be made with adequate retention to keep the bristle from falling out, fatigue strength to keep them from breaking, and wear resistance for acceptable life. The bristles shall withstand storage temperatures ranging from -60 °F to + 160 °F and operating temperatures ranging from -40 °F to +125 °F, without functional degradation due to the environment.

6.13.1 Wafers, Flat: The bristles shall be fastened in a radial wafer fashion and shall consist of a steel support ring filled with steel wire bristles or polypropylene (poly) bristles. The wafers may be separated by a steel spacer.

Typical wafer bristles dimensions are:

Outside diameter: 36 inch, Inside diameter = 10.75 +0.13 -0.00 inches

Outside diameter: 46 inch, Inside diameter = 19.50 +0.13 -0.00 inches

The support ring for the wafer shall be made of coil steel, minimum thickness 0.048 inch with edge protection to protect bristle from premature wear and breakage. All joints shall be welded to insure structural integrity. Each ring shall have steel drive pins to engage the sweeper core. These pins shall have a minimum diameter of 0.250 inch and 0.63 inches long with 0.50 inches of protrusion from the inside of support ring. One of the drive pins shall be installed at the center of overlap of support ring. The 46 inch wafer shall have not less than 4 drive pins spaced at 90 degrees around the inside circumference. The 36 inch shall have 1 or more drive pins. Each wafer shall be marked on the ring to indicate the point of maximum static unbalance. The maximum static unbalance for any wafer shall be 50 oz-in.

The wire bristles shall be crimped and made of zinc galvanized drawn steel wire. The bristles shall have a minimum diameter of 0.0165 to 0.0180 inch nominal with minimum tensile strength of 325 000 pounds per square inch (psi). The bristles crimp shall be not less than 3 crimps per inch at amplitude of 1/16 inch minimum. The total weight of the 46 inch wafer shall be 10 pounds minimum. The total weight of the 36 inch wafer shall be 5.5 pounds minimum.

The poly bristles shall be made from extruded and pulled strands. The material shall be virgin polypropylene with UV inhibitor. Typically the bristles shall have an oval cross section not less than .060 x .090 inch with minimum tensile strength of 4800 pounds per square inch (psi). The total weight of the 46 inch wafer shall be 8 pounds minimum. The total weight of the 36 inch wafer shall be 5 pounds minimum.

The spacer ring which separates the wafer shall be made of coil steel with a minimum thickness of 0.048 inch. Forming the spacer shall create a flat bottom cross section with a welded overlap end seam to create adequate stiffness and strength to withstand the load imposed.

6.13.2 Wafers, Convoluted: The bristles shall be fastened in a radial wafer fashion and shall consist of a steel support ring filled with steel wire bristle or a polypropylene (poly) bristles. After bristle assembly the support ring shall be formed creating a depth for the ring, eliminating the need for a spacer. The height of this convolute shall be 2.0”

Typical convoluted wafer bristles dimensions are:

Outside diameter: 36 inch, Inside diameter = 10.75 +0.13 -0.00 inches

Outside diameter: 46 inch, Not available

The support ring for the wafer shall be made of coil steel, minimum thickness 0.048 inch with edge protection to protect bristle from premature wear and breakage. All joints shall be welded to insure structural integrity. Each ring shall have two steel drive pins to engage the sweeper core. These pins shall have a minimum diameter of 0.250 inch and 0.63 inches long with 0.50 inches of protrusion from the inside of support ring. One of the drive pins shall be installed at the center of overlap of support ring. The other shall be 1.50 inches nominal from the first. Each wafer shall be marked on the ring to indicate the point of maximum static unbalance. The maximum static unbalance for any wafer shall be 50 oz-in.

6.13.3 Cassettes: The bristles shall be fastened in a lengthwise fashion and shall consist of a plastic support bar filled with steel wire bristle or a polypropylene (poly) bristles. Typical bar cross section dimensions are 0.55 inches wide by 1.72 inches wide made to industry standard to fit into the industry standard “T” slot track. The maximum length of each bar shall be 33 inches. All bars installed into a particular core shall be of the same length. Each tuft must be securely fastened to the bar and provision made for adequate fatigue stress relief at the base of the tuft.

The circumference of bristles (i.e. number of rows) must be such that the vehicle speed does not overrun the brush, allowing the bristle to strike the surface at least once, and keeping the brush from leaving gaps of unswept surface. Thus, the number of rows must be such that the outer circumference of a new brush is full with no gaps.

The weight of each cassette bar must be with 1% of its nominal weight for balance reasons.

The wire bristles shall be crimped and made of zinc galvanized drawn steel wire. The bristles shall a minimum diameter of 0.0165 to 0.0180 inch nominal with minimum tensile strength of 325,000 pounds per square inch (psi). The bristles crimp shall be not less than 3 crimps per inch at amplitude of 1/16 inch minimum. On each bar there shall be 1750 wires per foot minimum.

The poly bristles shall be made from virgin polypropylene with UV inhibitor extruded and pulled strands. Typically bristles shall have an oval cross section not less than .060 x .090 inch with minimum tensile strength of 4,800 pounds per square inch (psi). On each bar there shall be 220 strands per foot minimum.

6.14 Brush Cores

The core shall be bearing supported and may be driven from either end, center, or from both ends. Each core shall be individually dynamically balanced by the manufacture at rated RPM. The bristles on the cores shall be full width to the rated length and replaceable. All steel on steel couplings of the drive and core must be replaceable hardened steel.

6.14.1 Wafers: The cores shall be made of tubular steel construction with four hardened steel (163 Brinell hardness minimum) drive bars, equally spaced to center each wafer bristle. The diameter which the four drive bars create must be such that the wafer bristle is easily installed and removed but not to allow movement of the wafer bristle on the core. The diameter of the core must also be industry standard for compatibility of various bristle manufacturers.

6.14.2 Cassettes: The cores shall be made of aluminum extrusion “T” slot track rails with a wear resistant feature, bolted together to form a one piece cylinder. The slot of the rail must be such that the cassette bristle bar is easily installed and removed but not to allow movement in the T slot allowing wear. The size of the slot must also be industry standard for compatibility of various cassette bristle manufacturers.

6.15 Forced Air Blast

The system shall feature either a single or double inlet centrifugal blower. Unless otherwise specified, the centrifugal impeller(s) shall be hydrostatically driven including a variable displacement pump and fixed displacement motor(s). It shall be capable of varying its speed allowing blower speed from the operator station.

Air duct(s) shall be installed at the outlet of the impeller(s). Nozzles(s) shall be attached to these air duct(s). Nozzle ends shall direct the flow to one side or the other. When the brush is angled, the airblower direction shall be capable of automatically following, directing air perpendicular to the direction of travel and toward the direction of broom discharge. The nozzles direction control shall be interlocked with the brush head angle to blow in the direction of broom casting thus controlled by the operator’s joystick. A separate control shall allow the nozzle direction opposite of the brush angle by choice. The controls shall permit blowing without broom operation. All controls for the air blast shall be operated from the operator station.

The air ducts shall retract within the width of the vehicle for transport and storage unless otherwise specified. There shall be 8 inches of ground clearance minimum when raised unless otherwise specified.

The impeller / shaft assembly(s) shall be dynamically balanced at the rated RPM. The velocity and CFM at each nozzle shall be certified by an independent test facility and supplied with the bid.

6.16 Hydraulic System

The hydraulic system shall consist of appropriate rams, pumps, piping, fittings, valves, controls, fluid reservoirs, filters, coolers, and other parts essential to its full operation. The system shall be capable of hydraulically positioning equipment through the entire range of its design limits. It shall be capable of operating all controls simultaneously without a detrimental reduction in power response.

All controls shall be located in the vehicle cab. All hydraulic functions of the broom shall be electric over hydraulic valving. Connectors to the solenoids shall be interlocking type to provide a secure connection, which can withstand normal pressure washing procedures. All positioning functions (for example but not limited to: brush head lift, brush head swing, deflector, and air nozzle lift) shall be equipped with a position locking system as necessary to prevent unwanted movement. There shall be no hydraulic lines within the operator station

The system shall be ruggedly constructed and able to withstand all imposed loads. It shall maintain operating temperatures suitable to all system components throughout normal operating conditions. The hydraulic system shall meet the same low temperature requirements as the engine coolant system.

Filters within the hydraulic system shall conform to the Society of Automotive Engineers (SAE) Information Report, SAE J 931- Hydraulic Power Circuit Filtration. Proper filtering shall be done on both the high pressure and low pressure circuits. There shall be a 5-micron absolute rating on the hydrostatic pumps' filters and placed in the charge pressure lines. There shall be a clogged filter indicator light at the operator's station indicating filter replacement. Shut off valves for all filters below tank fluid level shall be installed to allow filter changes with minimal loss of oil.

All hoses for all systems shall be properly sized and strength to work with the pressure and volume of oil required and have the appropriate temperature ratings for the climate conditions in which they will be used. Only commercial quality hydraulic lines, hoses, and fittings that are capable of withstanding system working pressures under load are acceptable. Hydraulic hoses shall have a bursting pressure of three times their rated working pressure. The use of fittings, joints, and connections shall be kept to a minimum. Where required, hoses should be equipped with quick couplers as necessary to facilitate rapid removal and attachment.

The hydraulic fluid tank shall have; a filler neck with a strainer, a drain plug, a shutoff valve, an air vent and baffles. Its capacity shall exceed the volume of oil required for the operation of any combination of attachments by 50 percent. A sight glass shall be provided to allow the operator to verify that fluid level is sufficient for safe operation without the necessity of opening the system. A low oil level warning and engine shutdown device shall be provided in the cab. A high hydraulic oil temperature warning and engine shutdown device shall be provided in the cab. A low hydraulic oil temperature or high back pressure warning shall also be provided in the cab.

6.17 Controls and Instrumentation

All controls shall be electric over hydraulic type. All instruments and controls shall be labeled in a manner to remain legible for the life of the unit and shall be illuminated. The operator station shall be conveniently mounted in-cab, user friendly and easily accessed by operators wearing heavy winter clothing. Frequently used instruments shall be located in direct line-of-sight and within forearm reach of a medium-sized person sitting in the operator's position. The controls shall allow the operator to direct all functions required to fully operate the equipment. Gauges showing fluid pressures, temperature, and warning readings shall also be furnished. Instruments should display urgency-of-action lights, i.e., green for normal operation, amber for warning, and red for emergency. Instruments shall be illuminated by background lighting regulated by dimmer switches capable of providing infinitely variable lighting intensities. Circuit breakers shall be grouped for easy access and convenience.

The operator's control shall have diagnostic capabilities for the broom, broom engine, and air blast. It must incorporate automatic diagnostics which displays what is wrong with a particular system. All systems for the broom and broom engine must be part of the diagnostics

The operator's control in the chassis cab shall have all the necessary functions to operate the broom and air blast and shall have the following:

- System On / off (keyed)
- Joystick for lift/lower and left/ right swing. The brush swing, lift and blower nozzle shall have automatic one touch for cycle control. This allows the operator to have hands free operation during cycle movement. Moving the joystick in the opposite direction can reverse the cycle. An additional switch shall allow the operator to use the automatic control or disengage the system.
- Engine oil pressure with visual and audible warning alarms

- Engine coolant temperature with visual and audible warning alarms
- Hydraulic oil temperature with visual and audible warning alarms
- Fuel level with low fuel visual and audible warning alarm
- Low coolant level alarm
- Engine tachometer
- Voltmeter and warning indicators
- Alarms for engine diagnostics and visual warning indicators and displayed faults.
- Lights On / Off
- Deflector Up / Down
- Mode Auto / Manual
- Brush On / Off and speed adjustment
- Blower On / Off and speed adjustment
- Engine hour meter
- Brush down and operating hour meter for determining brush life
- Single circuit breaker with Master Battery disconnect
- Rear vision camera monitor if specified

An additional “service” control station shall be supplied unless otherwise specified, at the broom engine assembly when the broom engine is not installed on the carrier vehicle such as a tow broom. This service control station shall have all of the same features as the main operator’s control in the chassis cab. In additions it shall have a selector switch for main or service controls station. The service control station shall have engine speed control priority over main control station.

6.18 Finish and Paint

The broom shall be painted Chrome-Yellow in accordance with FAA AC 150/5210-5B: Painting, Marking, and Lighting of Vehicles on an Airport or as specified. The rear of the broom head on a front mounted broom shall have a non-glare finish to reduce glare for the operator or as specified. Other configuration brush heads can have a non-glare finish.

All equipment shall be cleaned first, then treated as necessary per coating manufacturer’s recommendations with; corrosion inhibitor, primer, putty, sanding, and finally, the finish coating process. The coating of customer specified color shall be applied per the coating manufacturers approved process and shall consist of polyurethane enamel, acrylic enamel, acrylic urethane, or similar high durability, long life coating having a combined thickness per the manufacturer’s recommendations.

The finished paint shall be free of “fisheye,” “orange peel,” chips, runs, or other imperfections that detract from the equipment’s corrosion resistance and appearance.

6.19 Technical Publications

The manufacturer shall furnish two complete sets of manuals. One in hardcopy form and one in electronic format. The set of manuals shall consist of:

- Operation, Maintenance, and Troubleshooting manual
- Supplied equipment manual
- Parts manual identifying every part on the unit both in parts list form and exploded view or schematic form in the case of electrical and hydraulic

6.20 Delivery, Start-up and Training

The unit must be fully assembled and tested prior to delivery. The manufacturer is responsible for the safe and timely delivery of the broom and its accessories, spare parts, and tools to the place of delivery.

The manufacturer shall, at no additional cost, furnish the services of trained personnel to the purchaser at a time and place agreed to by all parties. A qualified factory representative must fully install, start-up, and test the unit prior to training. Training shall be performed by a factory trained and authorized technician. The training shall be performed at the customer's site and shall be 4 hours for operators training and an additional 4 hours for mechanics training (mechanics shall attend the operating training first). The purpose of this training is to review safe and effective procedures for use and maintenance of the machine, review and test all systems, assure the full function of the machine.

6.21 Warranty

The equipment provided shall be warranted against defective materials and workmanship for a period of 12 months after the machine is delivered. Warranty includes replacement or repair of defective parts or material and the associated labor to perform the repairs

6.22 Additional Equipment which may be specified by the user.

- Specialized Tools: Specialized tools shall be supplied as required for routine servicing of the broom assembly and related equipment.
- Cold weather package
    - Plug in (weatherproof) engine block heater
    - Plug in (weatherproof) broom engine oil heater
    - Plug in (weatherproof) hydraulic oil tank heater
    - Ether starting system – Engine ECM controlled
    - 60/40 coolant mixture to -50 degrees Fahrenheit
- Central drain lines for all fluids for broom portion
- Spare brush core assemblies in order that the cores can be preloaded with new wafers for quick change during snow operations

- Optional brush wafers and cassettes
    - 100% poly wafers in place of 50/50 poly/wire
    - 100% wire wafers in place of 50/50 poly/wire
    - 13 lbs heavy duty wire wafers
- Complete spare set of boxed refill bristle wafers with spacers.
- Set of 4 brush carts for easy brush core loading
- Brush speed tachometer with digital readout in the cab
- Brush hydrostatic pressure gage with digital readout in the cab.
- A complete set of replacement caster wheels, tires, bearings and axle assemblies.
- LED marker lights located at each end of the brush head using amber LED's on the front of the light assembly with red LED's facing the rear
- Black and white or color rear view camera and monitor system consisting of a monitor (minimum 6 inch) in the cab and a camera at the rear of the unit facing the rear. It shall be operator selectable on / off. It shall automatically turn on when chassis is shifted into reverse. A flood light at rear shall also be supplied which automatically turns on with the camera. Shielding shall also be supplied to prevent snow build-up on the camera.
- An automatic lubrication system for all possible grease points. The system shall automatically deposit the correct amount and type of grease to the application per manufactures specifications.
- 20 pound fire extinguisher
- To include an automatic dry chemical ABC fire suppression system in the broom engine compartment area. This system shall be connected to the engine shutdown system so in case of fire the engine will shutdown.
- An auxiliary electric motor / pump shall be provided to operate all the broom control functions and other auxiliary functions such as tilting engine enclosures without running an engine.
- Snow shed hood or snow shield hood to keep snow off the top of the brush hood
- Brush head vibrator: Attached to the brush head shall be a dump truck body vibrator to shake snow and ice accumulation off the brush head. 3000 pounds thrust impact force minimum. The vibrator shall be cab controlled with on / off rocker style switch.
- Automatic brush pattern control: In addition to the manual system brush pattern adjustment, there shall be automatic brush pattern control with adjustment from the cab. There shall be a three-position momentary toggle switch in the cab. Toggle forward increases the pattern in predetermined increments. Toggle back and the pattern is decreased in predetermined increments. (These brush pattern adjustments can be achieved in the cab while moving and without raising the brush head). The center position is the run position. There shall be an additional three-position pattern control switch at the brush head for control from outside. When the switch is in the run position, a time based system shall be used to readjust the brush pattern by counting the time in the brush down position. When the preset time is reached, the brush head will index down a preset amount. At that time the timer is reset and restarts counting. Time running in the up mode is not counted. Manually adjusting the pattern from the cab or brush head will reset the timer.

- Brush speed controlled by ground speed: Automatically adjusts the brush rotational speed depending on the vehicle speed. An increase in vehicle speed shall increase the brush rotational speed. There shall be a minimum of six ranges for the operator to choose from to match the conditions.

  For example:

  Idle: 60 RPM

  Range 1: 225 to full RPM

  Range 2: 250 to full RPM

  Range 3: 275 to full RPM

  Range 4: 310 to full RPM

  Range 5: 350 to full RPM

  The brush rotational speed shall also compensate for bristle wear to maintain a constant bristle tip speed relative to vehicle speed no matter what the brush diameter. The result is that the brush rotational speed must increase as the vehicle goes faster and as the brush wears. Manual override capabilities shall also be supplied. Option requires the automatic pattern adjustment feature and brush rational speed tachometer option.

- FOD / debris pick-up box with cab controls. Self supporting “dust pan” in front of the brush for sweeping sand, FOD, and debris at speeds up to 40 MPH. Self supporting with four standard broom caster wheels (same as brush head) with no additional weight on the brush head affecting brush pattern. The controls must be simple and electric over hydraulic. It must be easily attached and detached to the brush head with quick disconnects for the hydraulics. There must be three positions: Transport, Pick-up, Dump (90 degrees) all powered by a pair of hydraulic cylinders. The actuation from the transport to the pick up position must be coordinated with the brush head through the broom joystick. There shall be separate rocker switch for the dump.

APPENDIX A – ADDITIONAL INFORMATION CONCERNING AIRPORT RUNWAY BROOMS

A.1.1 Runway Broom General Information

TABLE A1 - BRUSH SWEPT PATH COMPARISON

	Brush Angle (Degrees)			
Brush Head Width (Feet)	30	35	40	45
12	10.4	9.8	9.2	8.5
14	12.1	11.5	10.7	9.9
16	13.9	13.1	12.3	11.3
18	15.6	14.7	13.8	12.7
20	17.3	16.4	15.3	14.1
22	19.1	18.0	16.9	15.6

TABLE A2 - THEORETICAL TONS PER HOUR AND SURFACE AREA SWEPT RATE

Snow Depth (in)	**Snow Density** (lbs/cubic foot)	**Vehicle Speed** (MPH)	**Swept Path** (ft)	**Tons per hour** (TPH)	**Surface Area Swept Rate** (sq ft/hr)
3	15	10	13.0	1287	549,120
3	15	10	14.5	1436	612,480
3	15	10	16.0	1584	675,840
3	15	10	18.0	1782	760,320
3	15	20	13.0	2574	1,098,240
3	15	20	14.5	2871	1,224,960
3	15	20	16.0	3168	1,351,680
3	15	20	18.0	3564	1,520,640
3	15	30	13.0	3861	1,647,360
3	15	30	14.5	4307	1,837,440
3	15	30	16.0	4752	2,027,520
3	15	30	18.0	5346	2,280,960
1	40	10	13.0	1144	549,120
1	40	10	14.5	1276	612,480
1	40	10	16.0	1408	675,840
1	40	10	18.0	1584	760,320
1	40	20	13.0	2288	1,098,240
1	40	20	14.5	2552	1,224,960
1	40	20	16.0	2816	1,351,680
1	40	20	18.0	3168	1,520,640
1	40	30	13.0	3432	1,647,360
1	40	30	14.5	3828	1,837,440
1	40	30	16.0	4224	2,027,520
1	40	30	18.0	4752	2,280,960

TPH = Snow depth * Snow Density * Vehicle Speed * Swept Path * 5280 / (12 * 2000)
Surface Area Swept Rate = Vehicle Speed * Swept Path * 5280 * 0.80
Note: Surface Area Swept Rate was determined at an 80% efficiency to allow for overlap and turnaround.

TABLE A3 - TYPICAL USER SPECIFIED CRITERIA FOR RUNWAY BROOMS

Configuration	Required Speed of Operation (MPH)	Brush Swept Path (Feet)	Broom Power Supply Horsepower	Brush Diameter (Inches)	Brush Rotation Speed (RPM)	Brush Available Torque (Foot - Pounds)	Air Blast Capacities (CFM @ MPH)	Brush Available Horsepower
	(User to select width)							Calculated
Front Mount Dedicated	25	8.0, 9.5, 11.5, 13.0	170	36	475	1800	8,600 CFM @ 260 MPH	163
	25	9.5, 11.5, 13.0, 14.5	300	36	525	1800	20,000 CFM at 320 MPH	180
	25	11.5, 13.0, 14.5, 16.0	300	46	475	2600	17,000 CFM @ 300 MPH	235
	25	13.0, 14.5, 16.0	385	46	475	2600	22,000 CFM @ 400 MPH	235
	30	13.0, 14.5, 16.0, 18.0	475	46	525	3100	22,000 CFM @ 400 MPH	310
	40	13.0, 14.5, 16.0, 18.0	475	46	525	4750	22,000 CFM @ 400 MPH	475
Front Mount Dual Purpose	Same as Front Mount Dedicated							
Front Mount Multi Purpose	25	13.0, 14.5, 16.0	Uses snow blower engine	46	400	2400	23,000 CFM @ 400 MPH	183
	30	13.0, 14.5, 16.0, 18.0		46	400	3300	23,000 CFM @ 400 MPH	251
Loader mounted	10	8.0, 9.5, 11.5, 13.0	170	36	475	1800	10,000 CFM @ 270 MPH	163
	10	8.0, 9.5, 11.5, 13.0	300	46	475	2600	12,000 CFM @ 300 MPH	235
Tractor mounted	10	8.0, 9.5, 11.5, 13.0	100 PTO	36	325	1600	7,400 CFM @ 220 MPH	99
	10	11.5, 13.0, 14.5	250 PTO	46	430	2600	11,500 CFM @ 300 MPH	213
Tow behind	25	8.0, 9.5, 11.5, 13.0	170	36	475	1800	8,600 CFM @ 260 MPH	163
	25	9.5, 11.5, 13.0, 14.5	300	36	500	1800	20,000 CFM at 320 MPH	171
	25	13.0, 14.5, 16.0, 18.0	385	36	600	2200	22,000 CFM @ 400 MPH	251
	30	13.0, 14.5, 16.0, 18.0	475	36	750	2200	22,000 CFM @ 400 MPH	314
	40	13.0, 14.5, 16.0, 18.0	475	36	800	3100	22,000 CFM @ 400 MPH	472
	25	11.5, 13.0, 14.5, 16.0	300	46	475	2600	17,000 CFM @ 300 MPH	235
	25	13.0, 14.5, 16.0	385	46	475	2600	22,000 CFM @ 400 MPH	235
	30	13.0, 14.5, 16.0, 18.0	475	46	525	3100	22,000 CFM @ 400 MPH	310
	40	13.0, 14.5, 16.0, 18.0	475	46	620	4000	22,000 CFM @ 400 MPH	472
Multi-Tasking (MTE)	Same as Tow Behind							

A.1.2 Why use a Runway Broom

Aircraft winter operational safety, time restraints, and advances in aircraft technology warrants maximum runway surface friction which promotes better braking conditions and safer aircraft landings. Clean and bare surfaces obtain maximum surface friction. Current methods used to remove snow and ice on airfield surfaces and / or increase the surface friction include:

Snow plows…leaves residuals, not clean and bare

Sand dispersion…messy and abrasive to aircrafts and other vehicles

Chemical dispersion…costly and environmental issues

Heated surfaces…costly for energy

Jet airblast systems…costly, safety issues and not always effective

Warm weather and sun…time and unreliable

Runway Brooms…most effective and efficient

Plows can move more snow (tons per hour) than brooms. But a broom can clean the surface to bare pavement where a plow leaves a residual layer of snow behind which is normally unacceptable. For acceptable braking action after plowing, the pavement must be swept with a broom, sanded, chemically melted, or wait for the sun or temperature to melt the snow and ice. Runway brooms are normally the most effective and efficient method to remove snow for maximum friction.

Also, during the plowing operation, the plow forces snow and ice into the pores and grooves of the pavement, making it even more difficult to achieve good braking action even after being swept with the broom. In addition the tires of the plowing vehicle compact the residual snow from the plow, again making it difficult to have completely bare pavement. Thus, maximum friction and braking action is obtained with a front mounted broom only (virgin snow, no plow).

As technology advances, the performance level of runway brooms increases specifically being able to move more snow faster (tons per hour) and still clean to bare pavement. With these advances, the snow moving capability gap between a broom and plow will reduce.

A.1.3 Runway Broom Performance Criteria

Performance of a runway broom is based on the amount of snow moving capacity, specifically tons per hour moved and the resultant surface condition. Tons per hour = snow density x depth of snow x swept path x vehicle speed. Resultant surface condition is a function of coefficient of friction (braking action) determined from a friction measuring device and whether the surface is clean and bare.

A.1.3.1 Snow moving capacity: There are many factors which determine how many tons per hour of snow, slush, and ice a runway broom can move. Each of the listed factors is valid for all configurations of runway brooms.

A.1.3.1.1 Swept path: The brush swept path depends on the width and angle of the broom. From trigonometry, the swept path for typical runway broom widths and angles can be calculated and is shown in Table A1 in the Appendix. The larger length brush and smaller angle produces a larger swept path or more tons per hour of snow moved per pass with a give snow density, depth and vehicle speed. Thus, when determining and specifying a broom it must be based on swept path not brush length. Also, Airport broom brush lengths typically range from 10 feet, and increase in 2 foot increments, to 24 feet. Typically the user maximizes the width of the broom based on the width of the doors in the maintenance facility of the storage facility. When designing these facilities, the user should maximize the door widths.

A.1.3.1.2 Brush diameter: Currently, runway broom brush diameters range from 36 inches to 46 inches. Since the circumference is larger, large diameter brushes have more bristles ends (proportional to the circumference of the ring). The aggressiveness of a brush is directly proportional to the amount of bristle ends. Thus, for a given RPM, the larger the brush diameter, the more bristles contact or “strike” the pavement. Thus larger diameter brushes allow higher capacity (Tons per hour) and faster sweeping speeds (MPH). Also since there are more bristles, life between brush change is increased. Bristle length is longer with larger diameter brushes. This also increases time between brush changes.

A.1.3.1.3 Bristles: Currently there are two bristle materials to make up a bristle assembly: plastic (poly) and wire. Poly bristles create a flicking action giving the broom snow cast distance. Wire bristles have cutting action which cut through snow hard pack and ice but are more expensive than poly. Since the wire bristles gives better cutting action, wire is the more aggressive bristle material. A combination of both poly and wire gives both cast distance and cutting action at an effective cost. Again, the overall performance of the broom is directly proportional to the amount of bristle ends on the brush but cost increases with the amount of bristle ends.

The stiffer the bristle, the more aggressive it will be. But fatigue strength is sacrificed with a stiffer bristle since the bending load at the bristle base increases with stiffness. It is a tradeoff of bristle stiffness and aggressiveness versus bristle life in hours.

There are many different stack patterns for the bristles assemblies. There are also different weights (bristle end counts) for the bristle assemblies. What to use is a balance of cost to performance and aggressiveness (Bristle material: wire vs. poly, Bristle end count: quantity and weight of bristle assemblies) depending on the snow condition for an airport.

Currently there are basically two configurations of bristle assemblies: wafers and cassettes. There is no apparent performance difference between cassettes and wafers.

An advantage of cassettes is that cassettes are easier to replace than wafers since the brush core is not removed from the broom. In comparison, a set of spare wafer cores packed with wafers beforehand can be as fast to install on the broom during a snow event than changing a set a cassette bristle assemblies.

Due to the segmented or spoked wheel nature of the bristle ends at the circumference of a cassette brush, care must be taken in determining the number of rows of cassettes per brush. Given a brush diameter with a brush shaft speed (RPM), the faster the required sweeping speed (MPH), the more rows are required. The circumference of bristles (i.e. number of rows) must be such that the vehicle speed does not overrun the brush, allowing the bristle to strike the surface at least once, and keeping the brush from leaving gaps of unswept surface. For examples:

Brush diameter: 46 inch

Brush shaft speed: 500 RPM

Desired sweeping speed: 40 MPH

Resultant minimum number of rows = 28 rows minimum

Brush diameter: 36 inch

Brush shaft speed: 700 RPM

Desired sweeping speed: 40 MPH

Resultant minimum number of rows = 20 rows minimum

A.1.3.1.4 Brush shaft torque: Available brush shaft torque is a key property for determining the performance (snow moving capacity) of a broom. Just like a cable crane where the lifting capacity of the crane is the amount of available torque on the cable drum. Likewise for a broom and its brush shaft. Given a brush geometry (length, diameter, and bristle type), the more torque that is on the brush shaft, the more snow (tons per hour) the broom can move. True performance of a broom is its capability of moving snow from the swept path with clean and bare surface left behind.

The calculation of horsepower is Torque x RPM / 5252. Thus, given a specified horsepower, one can trade off torque with RPM. Increasing RPM decreases the amount of torque capacity. Again, available torque on the brush shaft is a key mechanical property for determining the snow moving capacity of a runway broom. Thus, when classifying and specifying a broom it must be based, in part, on torque on the brush shaft. And since the available torque of each individual bristle is dependent upon the swept path, the classification and/or specification for a runway broom must be based on “available torque on the brush shaft per foot of swept path”.

A.1.3.1.5 Brush shaft speed (RPM): Brush shaft speed (RPM) and the amount of bristle ends on the circumference of the brush determines the amount of strikes the bristles impose on the pavement at a given vehicle speed. The more bristle ends, the more strikes, which make the brush more aggressive as stated in the previous section. Increasing the brush shaft speed produces more strikes but there is a point of diminishing returns since there is a point where the surface is already clean and more strikes does not improve performance. Also, increasing brush shaft speed tends to:

- Wears out bristles faster
- Churn and toss the snow creating unwanted snow clouds.
- Decrease the torque available since there is a limit on horsepower.
- Increase the torque requirement to rotate the brush

Bristle tip speed (MPH) is a function of brush shaft speed (RPM) and brush diameter. The minimum designed brush RPM must be such that the tip speed at the smallest brush diameter (worn bristles) must be at least 1.25 times faster than the rated vehicle speed (MPH) of the broom using a continuous brush. For example:

46 inch diameter brush (new)

28 inch diameter brush (worn)

35 MPH desired sweeping speed

$$RPM = 1.25* (35*5280*12) / (60*PI*28) = 525 RPM$$

or simplified: RPM = 1.25*Desired Speed*336/worn brush diameter = Brush RPM

Thus the resultant minimum designed brush RPM is 525 RPM

Due to the segmented or spoked wheel nature of the bristle ends at the circumference of a cassette brush, this factor may require to go up to as much as 2.5 times faster than the rated vehicle speed (MPH) of the broom when using cassettes.

A.1.3.1.6 Snow control: The broom must have the capability to control the snow and ice once it is airborne. The snow must be put where and only where the operator desires and the operator must have visibility.

A.1.3.1.7 Chassis handling and axle loading: For all runway broom configurations the chassis on which the broom is mounted on must be positively and most efficiently controlled. Traction, steering, braking, and cornering cannot be sacrificed and must be maximized. Designs to distribute weight, lower the center of gravity, and add traction are required. Axle ratings and actual loading must be taken into account and the loading dispersed among the axles in accordance with best engineering practices. The center of gravity shall be kept as low as possible under maximum load conditions.

When writing specifications for a runway broom, it should always be a concern that the equipment does not overload the GAWR of the axles, wheels, tires, springs or steering of the vehicle to which it is to be installed.

A.1.3.1.8 Turning circle: For maneuverability, the turning circle of the broom must be minimized. Due to runway lights, the correct definition here is the wall to wall turning diameter, 75 feet maximum or as specified. The broom must be able to make a 180 degree turn in a 75 feet taxiway or as specified without the broom protruding past the edge

A.1.3.2 Resultant surface condition: The resultant surface condition after the broom has passed is a measurement of coefficient of friction (braking action) determined from a friction measuring device and whether the surface is clean and bare. Items which comprise a dirty surface are:

- Snow residuals left from the brush
- Fall off from snow buildup on anything behind the brush
- Compressed snow and ice from a snow plow
- Compressed snow and ice from aircraft and vehicle tire tracks

There are a few factors which influence whether the broom can manage these items. Each of the following factors is valid for all configurations of runway brooms.

A.1.3.2.1 Bristle presentation to surface being swept / pattern control: Brooms are most effective when the brush contact with the pavement (brush pattern) is 4 inches, producing a flicking action that casts the snow rather than a plowing action. The requirement is to maintain this 4 inch pattern at all times, under all conditions. Whether swung to the left or the right, the brush must maintain this 4 inch pattern and must be consistent across the full length of the brush. Thus the broom hitch and swing system must be designed to accommodate this requirement. If the 4 inch pattern is compromised the potential exists for the broom to leave snow residuals. Large brush patterns will not produce adequate flicking action. The bristles tend to bend over the snow and act like a plow. Large brush patterns also wear out bristles much faster.

A.1.3.2.2 Insufficient brush shaft speed (RPM) is another major cause of snow residuals being left from the broom. The brush acts like a plow, pushing the snow rather than flicking it. In operation, the brush shaft speed is adjusted from this rated RPM to what is required to do the job based on current snow conditions. Thus brush speed is a tradeoff between what is required to do the job based on snow conditions (minimum) but not too fast to keep wearing out bristles and keep from churning and tossing the snow creating unwanted snow clouds.

A.1.3.2.3 Insufficient brush torque allowing the brush to stall resulting in insufficient brush RPM is another major cause of snow residuals being left from the broom. When the brush stalls due to snow load, the hydrostatic pump for the brush drive reached its maximum pressure (normally 5000 psi) and the pump saves it self, destrokes, and reduces flow. The result is a reduction in brush shaft speed (RPM) and the brush acts like a plow, pushing the snow rather than flicking it.

A.1.3.2.4 Snow carryover from the front of the brush to the back of the brush is anther cause of snow residuals being left from the broom. Care must be taken in the design of the stripping device and brush hood to keep this from occurring. The hood must be kept as close to the bristles for non-clog design.

A.1.3.2.5 An air blast is an effective device to try and blow some of the snow residuals left from the broom. There are many configurations, sizes, and classifications. The air blast can also be used to blow snow away from lights and to blow down snow berms.

A.1.3.2.6 In order to maintain a 4 inch brush pattern the brush head cannot bounce at any speeds up to the rated speed (MPH) of the broom on normal surfaces. If the 4 inch pattern is compromised, snow will be left behind the brush. Physics and experience show that the faster the broom vehicle travels, the more susceptible the brush is to bounce and / or skip. For rated speeds above 20 MPH it is more critical that the broom hitch be designed to keep the brush head steady and to keep the chassis from inducing a bounce into the brush. Additional devices should be employed, such as shocks absorbers on the broom hitch, to aid in keeping the brush head steady and to keep the chassis from inducing a bounce into the brush.

A.1.3.2.7 Excessive brush vibration can also cause brush bounce. In the raised position, the brush must not vibrate through its speed range. The rotation must be smooth for all speeds. To accomplish this, the brush core must be dynamically balanced and the bristles such that they do not put the brush out of balance. The drive components for the brush core must be tight with no looseness in any connection and must stay that way for the life of the broom. The brush core connection points must also be inline with no misalignment.

A.2 CARRIER VEHICLE

A.2.1 Carrier Vehicle Description:

The term carrier vehicle represents the various self-propelled prime movers that provide the power necessary to move snow and ice control equipment during winter operations. The design of the vehicle chassis shall be based on an all-wheel drive concept for optimized performance and safety. Vehicle selection is determined by the purchaser for the mission to be performed and the capacity of the selected equipment. Although these units may not be designed as over-the-road highway vehicles, the following Federal Motor Vehicle Safety Standards shall apply as though they were an on-highway vehicle:

FMVSS 101 Controls & Displays

FMVSS 102 Transmission Shift Lever Sequence, Starter Interlock & Transmission Braking Effect

FMVSS 103 Windshield Defrosting & Defogging Systems

FMVSS 104 Windshield Wiping & Washing Systems

FMVSS 105 Hydraulic & Electric Brake Systems

FMVSS 106 Brake Hoses

FMVSS 108 Lamps, Reflective Devices, & Associated Equipment

FMVSS 111 Rearview Mirrors

FMVSS 113 Hood Latch Systems

FMVSS 116 Motor Vehicle Brake Fluids

FMVSS 119 New Pneumatic Tires

FMVSS 120 Tire Selection & Rims for Vehicles Other Than Passenger Cars

FMVSS 121 Air Brake Systems

FMVSS 124 Accelerator Control Systems

FMVSS 201 Occupant Protection in Interior Impacts

FMVSS 205 Glazing Materials

FMVSS 206 Door Locks & Door Retention Components

FMVSS 207 Seating Systems

FMVSS 208 Occupant Crash Protection

FMVSS 209 Seat Belt Assemblies

FMVSS 210 Seat Belt Assembly Anchorages

FMVSS 302 Flammability of Interior Materials

a. Truck Type Vehicles: Truck type vehicles are standard production models designed primarily to meet an airport's snow and ice control needs but can also have the ability to perform secondary functions. They may be self-contained, designed specifically for a singular purpose, or they may be multi-tasking, or they may be multi-purpose. They should conform to the manufacturer's recommendations and be suitable for mounting all specified accessories.

b. Special Purpose Vehicles: Special purpose vehicles are customized specifically to meet special airport operator needs such as high-volume and/or extra wide swath clearing operations.

c. Wheel Loader Vehicles: Wheel loaders are standard production four-wheel drive articulated and non-articulated vehicles, normally equipped with a front-mounted bucket, that operate at low speeds of 5 to 20 mph (8 to 30 km/h). They are very efficient for short haul operations and are used to clear compacted snow and ice from heavily used ramp and terminal areas and around pavement lights. Other applications include snow loading and stockpiling and loading of solid chemicals and abrasives.

d. Industrial 4x4 Tractor Vehicles: Industrial 4x4 tractors are standard production models adapted for snow and ice control work in confined areas. While similar to wheel loaders, most are built to operate at higher speeds.

A.2.1.1 Materials: Materials used on a carrier vehicle shall conform to the specifications listed in the appropriate sections of Title 49, Chapter III, Federal Motor Carrier Safety Regulations. When not specifically listed, materials shall be of the best quality available for their intended commercial use. Component parts shall be new, unused, of current production to the satisfaction of the purchaser. They shall be free of all defects and imperfections that could affect the serviceability of the finished product.

A.2.1.2 Design: Equipment shall be developed in accordance with the best engineering practices available. This includes the incorporation of ergonomic designs specifically directed at the vehicle’s cab environment. Vehicle design shall include current state-of-the-art procedures that consider improved cab visibility, communications systems, interior lighting and the mitigation of noise and vibration. Design and installation of equipment shall permit easy accessibility for maintenance and service. All vehicle stress points shall be designed to distribute and dissipate shock forces. When writing specifications for a runway broom, it should always be a concern that the equipment does not overload the GAWR of the axles, wheels, tires, springs or steering of the vehicle to which it is to be installed.

A.2.1.3 Construction: Vehicle construction shall provide maximum protection against structural member failures. Equipment shall withstand the cold, moisture, strains, jars, vibration, and other conditions that are likely to be encountered during operation. All components and assemblies shall be free of hazardous protrusions, sharp edges, cracks, or other elements that might cause injury to personnel or damage to equipment. Location of all oil, hydraulic, and air lines and electrical wiring shall be in protected positions properly attached to the frame or body structure. Wherever these lines pass through apertures they shall be protected with looms or grommets except where a through-frame connector is necessary.

A.2.2 Chassis:

The design of the vehicle chassis shall be based on an all-wheel drive concept for optimized performance and safety. It shall have power assisted steering and a transmission with suitable load and speed ranges to accommodate normal operating conditions. Vehicles shall have heavy duty tow hooks, tow eyes, or other suitable tow connections attached to the rear of the vehicle. The tow hooks, eyes, or other suitable tow connections shall be attached to the frame or structure of the vehicle, and provide adequate strength to allow lifting and/or pulling the vehicle for emergency recovery situations. A pintle hook, rated at not less than the GVWR shall be permanently attached to the rear frame structure capable of towing a vehicle. All installed parts and accessories necessary for the safe operation of the vehicle shall conform to applicable provisions of Title 49.

A.2.2.1 Structural Members: The frame shall be made of either pressed or structural steel shape and reinforced as required to prevent distortion under maximum load conditions. All frames and stiffeners shall be treated with a corrosion inhibitor and shall be primed and painted before assembly.

A.2.2.2 Dimensions and Clearances: Carrier vehicles with snow removal attachments shall have the following overall dimensions:

a. Minimum Ground Clearance: The minimum ground clearance of a vehicle chassis shall be 8 inches (20 cm).

b. Maximum Overall Height: Change Maximum Overall Height to read: The maximum overall height of a vehicle including discharge chutes, lights, and exhaust stacks (with rain cap up if so equipped) shall not exceed 13 feet (4.0 m) unless otherwise specified by the customer. A placard shall be installed in the vehicle cab stating the maximum overall height. If practical, the placard should be located at the top of the windshield as nearly over the steering wheel as possible to be immediately visible to the operator when looking upwards.

c. Maximum Overall Width: The overall width of a vehicle including rotary brush head shall be specified by the purchaser who shall take into consideration gates and doors to equipment shops at the airport.

d. Maximum Overall Length: Maximum vehicular length may be specified by the purchaser who shall take into consideration shop areas and maneuverability expected of the vehicle during operation.

A.2.2.3 Weight Distribution: The gross vehicle weight of the vehicle shall be distributed over its axles in accordance with best engineering practices. The center of gravity shall be kept as low as possible under maximum load conditions. While it is loaded the vehicle shall be capable of resting on a 20% transverse grade without danger of overturning. A copy of the calculated weight distribution shall be provided to the customer prior to construction, and the produced vehicle shall not deviate from the calculated weight distribution by more than 5% on any axle, or for the gross weight as determined by weighing the unit at a public certified scale.

A.2.3 Engine

Engine and vehicle manufacturers shall provide an application approval, at the time of vehicle delivery that states the engine is suitable for use in the vehicle as configured and that the installation is approved by the engine manufacturer. The vehicle engine shall be of internal combustion type. Unless specified, the diesel engine shall be designed and tuned for operation using ASTM D 2 diesel fuel. Anti-freeze, crankcase and gear oils, greases, automatic transmission fluid, and hydraulic oils shall be as per current SAE, API, or ASTM specifications and not proprietary products. It shall be able to meet the performance characteristics specified herein on commercial grade fuel. Dual engine vehicles shall use a common fuel. The engine shall develop sufficient torque and horsepower to meet its normal operational requirements without exceeding the no-load speed at the peak of its certified gross brake horsepower curve. Engine noise and vibration shall be reduced in the vehicle cab by use of best engineering practices and machine layout. Idle time limiters or other automatic shut down devices designed to limit emissions, conserve fuel, or enhance operating costs must be permanently disabled if such devices could leave a unit disabled on a taxiway or runway. Permanently disabled means the disabling must be done in such a manner so as not to be easily or accidentally re-activated.

A.2.3.1 Cooling System: The engine cooling system shall be based on either a liquid or forced air design. Internal temperatures of liquid cooled engines shall be controlled by a by-pass thermostat that regulates the flow of engine coolant. Drain cocks shall be installed at the lowest point of the cooling system and at other points necessary to completely drain the system. A sight glass or other device is required in all liquid cooling systems to allow the operator to determine that there is sufficient fluid for normal and safe operation without the need to open the system.

A.2.3.2 Coolant Temperatures: The design and installation of the system shall assure that coolant temperatures shall remain within the engine manufacturer's operational specification (both high and low) when properly maintained and operated in ambient temperatures during snow removal operations. In areas which frequently experience temperatures below 20°, cooling system heaters, oil pan heaters, lubricating oil heaters, battery and block heaters, and cold start aides required unless otherwise specified.

A.2.3.3 Fuel System: The fuel system shall comply with Title 49 and include all components necessary for a complete operational system.

A.2.3.4 Fuel Tank(s) and Lines: Useable fuel capacity should be not less than a calculated value of: (total maximum brake horsepower for all engines) x (0.55 gals/hr/bhp) x (desired operating hours) x (0.5 for a 50% load factor). Normal operating hours should be eight unless a higher number is desired by the customer. If dual tanks are used, the supply system shall be designed to ensure an uninterrupted flow of fuel to the engine(s) without input by the operator, and to allow shutoff of each tank should the crossover lines of either tank be damaged. Dual tanks shall also have adequately sized crossover lines to allow refilling both tanks from one location. Fuel lines shall be securely fastened in place, installed to prevent chafing or strain and protected by grommets where lines project through metal apertures. Each fuel tank is to be equipped with an accessible bronze or brass drain plug or a quick drain. A properly rated fuel water separator with integral heater shall be installed in an accessible location near the tank. If the engine requires a boost pump to assure adequate fuel flow to the engine, a pressure operated switch with in-cab warning light shall be furnished to warn the operator of low boost pump pressure. The boost pump should be installed to shut off when the engine is turned off, or to have an emergency shutoff switch or circuit breaker located near the light to allow the operator to shut off the boost pump in the event of fuel leakage downstream of the boost pump.

A.2.3.5 Fuel Filler Pipe: The fuel filler pipe(s) shall be located outside of the vehicle cab in an area accessible for refueling from the ground where possible. A light chain shall be attached near its opening and to the filler cap to prevent loss of the cap. The filler neck shall include a screen to prevent the entry of foreign objects into the tank. The fuel filler cap shall be painted a color appropriate for the type of fuel, and a permanent label shall be affixed as close as practical to the fill neck(s), in an area visible to the person refueling the vehicle, stating the appropriate fuel and capacity of the tank(s). A label shall also be installed in the cab near the fuel gauge indicating which side of the vehicle must be positioned towards the fuel pumps (e.g., Fuel Fill →).

A.2.3.6 Air Cleaner: The air cleaner shall be of a two-stage design. The first stage incorporates a pre-cleaner while the second consists of a dry type replaceable paper filter. A restriction indicator is required in the cab for each engine air intake system. The connection between the air cleaner outlet(s) and the engine intake(s) shall be waterproof and dust tight. The air cleaner intake shall be positioned in a manner to discourage the ingestion of snow and other contaminants, e.g. within the hood cavity.

A.2.3.7 Exhaust System and Muffler: The engine shall be equipped with an efficient and safe exhaust system including mufflers. Its location shall minimize noise and exhaust gases entering the vehicle cab under all operating conditions. Further noise reduction by noise suppression materials, such as muffler insulation, is encouraged. Horizontal portions of exhaust systems shall be protected, whenever possible, from corrosive agents and fuel spills. Mufflers and exhaust components positioned in or near normal operator work areas shall include appropriate guards to minimize the burn risk to airport personnel. Exhaust systems shall be positioned on the vehicle in a manner to minimize contact with slush and snow. Muffler(s) are to be made of aluminum, aluminized steel, stainless steel, or materials coated with ceramics. Devices shall be installed to prevent snow and slush from entering vertical exhaust stacks. Customers may specify the location and direction of exhaust system discharge when appropriate for storage building ventilation systems or other operational needs.