Magnet Speed Testing

Purpose

For each tow behind/hanging magnet testing will be performed to determine the maximum speed at which metal debris can be picked up and to what level performance will be degraded at set speeds.

By performing these tests our goal is to collect clear performance information to present to customers. Data will be presented in the form of video clips, tables, and charts.

Data obtained will be used for more efficient magnet designs (longer vs stronger magnet). Comparing the magnet effectiveness at various speeds with the field strength will allow for better performance estimates when working on future designs.

Equipment

- Towing vehicle (UTV or truck)
- Magnetic sweeper (1 spare tire for sweepers wheelbase that are inside wheelbase of the trucks)
- Tarp with painted grid
- Plain tarp
- Hi vis paint for debris
- White paint for grid (or tape)
- Magnet camera, high framerate (GoPro or similar)
- Debris camera (GoPro Hero 7 White)
- 3 x 128Gb micro SD card
- Sweeper camera mount
- Tall tripod
- Digital scale
- Laptop
- Debris storing containers
- Tape measure
- Weights
- Markers
- Small whiteboard
- Walkie talkies
- Masking tape
- Plane radio
- Gauss meter
- GPS speedometer
- Bora 25 sweeper

Location (see Appendix E)

- Delhi Aerodrome (taxiway)

Roles

- Driver
  - Drive test vehicle
- Magnet spotter
  - Passenger in towing vehicle
  - Monitor magnet during tests
  - Watch for aircraft
- Debris spotter
  - Monitor debris tarp
  - Remove debris tarp if necessary
  - Watch for aircraft

Test Variables

- Field strength
- Length of magnet in direction of travel
- Sweeping height
- Sweeping speed
- Debris (shape/weight)
    - Nails (2 ½")
    - Wire scraps (~8" long)
    - Metal strips (~8" long)
    - Nuts (1/2-13)
    - Bolts (1/2-13 x 3" hex bolts)
    - Ball Bearings (3/16" – ¾")

Test Preparation

- Define random but repeatable debris layout (see Appendix B)
- Paint grid pattern on test mat
- Paint debris with hi vis paint
- Determine optimal camera mounting positions
- Mount camera to magnet

Test Procedure

Conduct test three times for each speed, sweeping height, magnet, and debris type combination. Test speeds from 1km/h to 50km/h in 1km/h increments. Test sweeping heights from 1" to 6" in 1" increments. Record mass of debris on tarp before each test and mass of debris collected after each test.

1. Travel to test site with test equipment
2. Lay out tarp and metallic debris
3. Photograph debris layout
4. Set sweeping height to the sweepers highest setting (Max Height)
5. Sweep debris field at 25km/h
6. Remove and weigh collected debris
7. Verify sweeping height (At the end of the test)
8. Reset debris
9. Photograph debris layout
10. Repeat steps 5-9 decreasing speed in 5km/h increments to find the 5km/h range at which 100% and 90% of debris is collected, repeat again in 1km/h increments to find the exact speed at which 100% and 90% of debris is collected
11. Repeat steps 4-10 at 0.5" increments (or lowest incremental height change of the sweeper)
12. Repeat steps 2-11 with different debris types and classes
13. Once all speed tests are completed gather a random assortment of debris (weight and size) and arrange them by approximate size perpendicular to the sweepers travel across the tarp
14. Arrange some debris outside the wheelbase of the truck and set up recording to be taken to see magnet behavior of field at edges of sweeping width

15. At one speed (chosen at experimenter discretion) test and record the way in which the metal debris is picked up by each sweeper

Safety Considerations

- Store test debris in defined containers when not in use, ensure that no debris is left at the test site by weighing debris before starting and after finishing tests
- Debris spotter will be clear of test path while towing vehicle is approaching
- Debris spotter and magnet spotter will monitor sky for incoming aircraft. Debris mat will be removed from the path if aircraft are approaching
- Magnet will be monitored while the test vehicle is in motion
- Tarp will be held down with weights to prevent blowing and scattering of debris

Post Testing Data Analysis

1. Review footage gathered to confirm sweeping speed
2. Analyze motion of debris in magnetic field
    a. Measure speed of each debris moving towards magnet
3. Take gauss measurements every 1” along the surface of the magnet and every 1” from the surface of the magnet to create gauss map and compare to simulated gauss map
4. Measure magnets pull strength measurements every 1” along the surface of the magnet and every 1” from the surface with different debris types
5. Use gauss measurements to correlate sweeping speed with sweeper effectiveness and compare to simulation data

Additional Information to Gather

The performance of ceramic magnets degrades 0.18%/°C [1] and neodymium magnets degrade 0.11%/°C [2]. It may be beneficial to conduct tests before and after allowing the magnets to warm in the sun. This test could be aided with a thermal camera.

Some footage from the testing can be reused for marketing purposes. While tests are being performed some time can be taken to gather additional footage if necessary.

If possible, tests should be performed using competitor magnets for comparison.

References

[1] First4Magnets, "How Does Temperature Affect Ferrite Magnets?," [Online]. Available: https://www.first4magnets.com/tech-centre-i61/information-and-articles-i70/ferrite-magnet-information-i83/how-does-temperature-affect-ferrite-magnets-i105.

[2] First4Magnets, "How Does Temperature Affect Neodymium Magnets?," [Online]. Available: https://www.first4magnets.com/tech-centre-i61/information-and-articles-i70/neodymium-magnet-information-i82/how-does-temperature-affect-neodymium-magnets-i91.

Appendix A – Data Recording

Data Recording Template

Sweeper Model:		Debris Type:		Debris Mass:		Collected Mass:	

		Sweeping Height (inches)									
		1	1.5	2	2.5	3	4	4.5	5	5.5	6
Sweeping Speed (km/h)	1			O	O	O	O	O	X		
	2			O	O	O	O	X	----		
	3			O	O	O	X	----	----		
	4			O	O	O	X	----			
	5			O	O	O	X	----			
	6			O	O	O	----	----			
	7			O	O	O	----	----			
	8			O	O	X	----				
	9			O	O	X	----				
	10			O	O	X	----				
	11			O	O	X	----				
	12			O	X	----	----				
	13			O	X	----					
	14			X	X	----					
	15			X	----	----					
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	40										
	45										
	50										

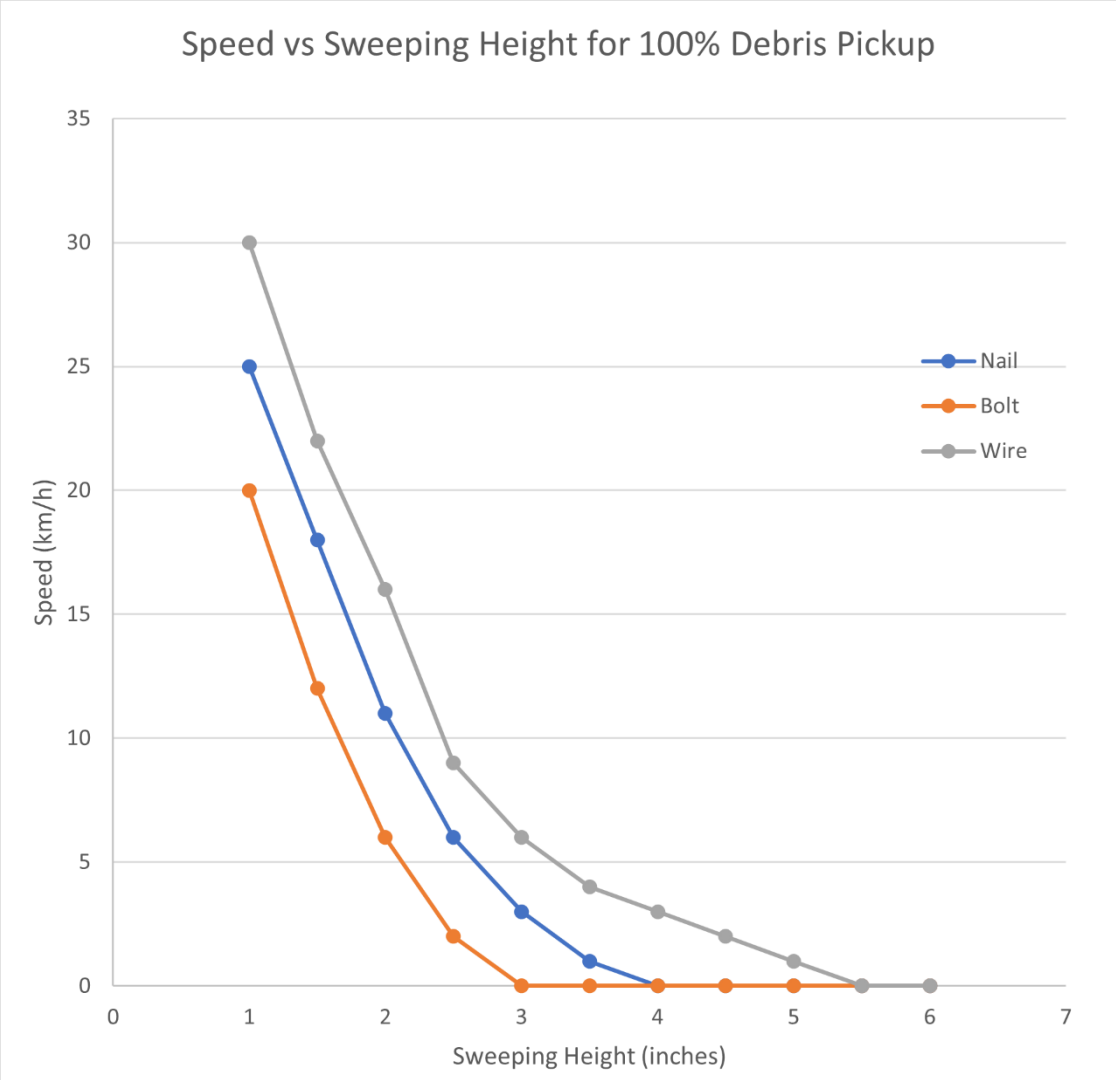
Legend: Circle inside grids denote 100% pickup by weight. “X” grids denote 90% pickup by weight. Above sheet layout gives example of how the form is to be used during testing.

*See Speed Testing Data Recording Form

Filename Format

[yyyy-mm-dd]-[sweeper]-[debris type]-[sweeping height]-[speed]-[test number]

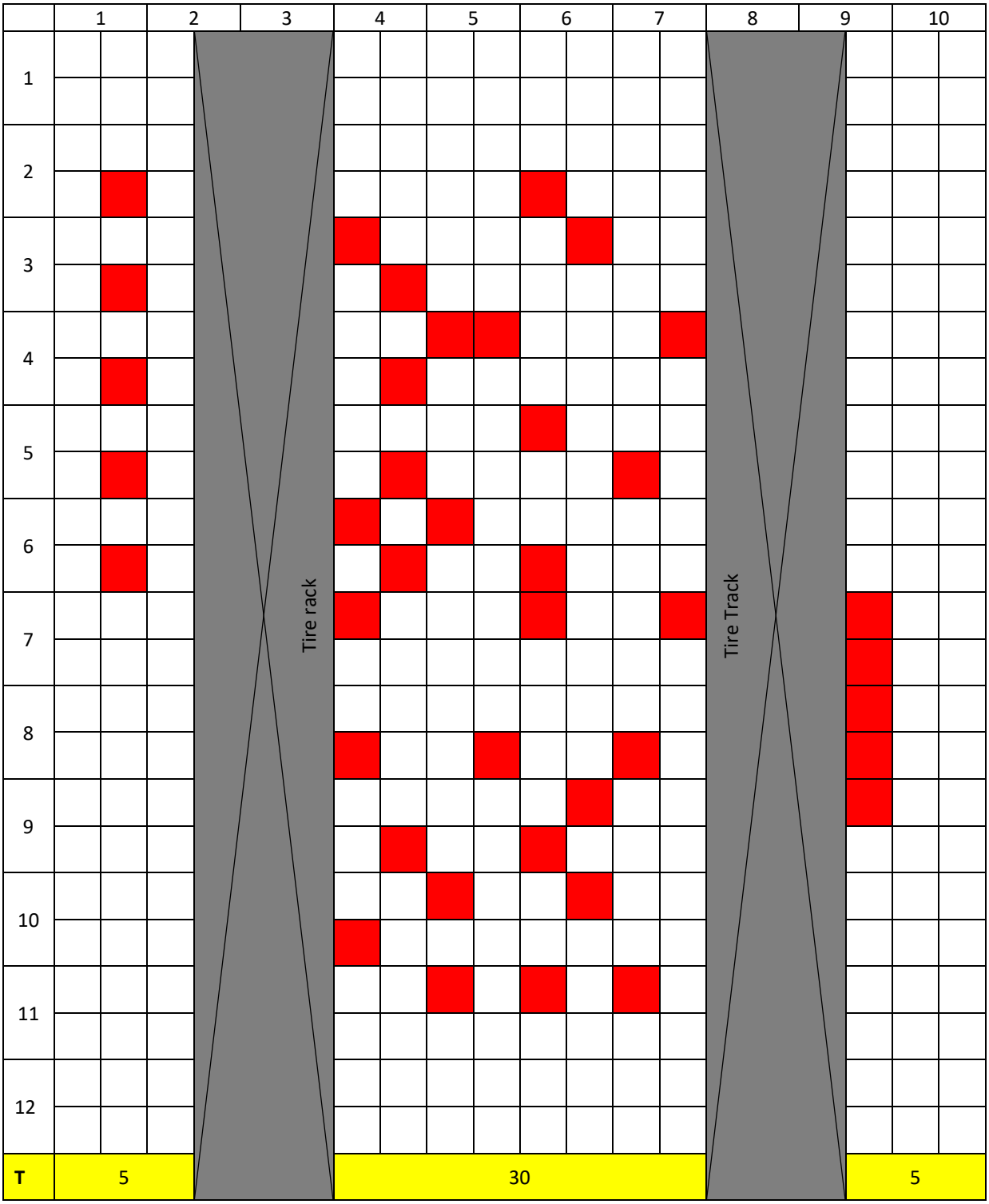
Data Display



Appendix B – Test Debris Layout

Paint 6” x 6” grid on a 10’ x 12’ mat

Sample Grid



*red shading represents one unit of debris

Debris Weight Classifications

This section defines the weight and amount of each type of debris that will be placed in the 6” x 12” grid

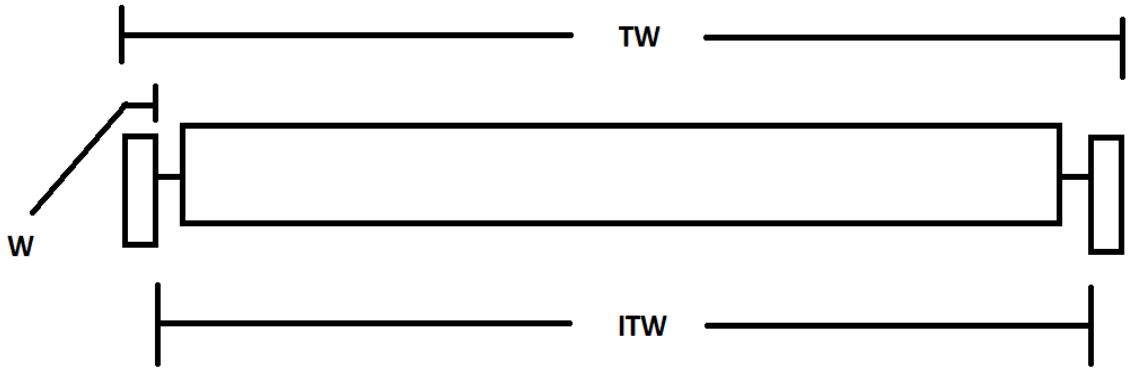
Debris Type	Weight [g]			Number of Each
Nails (2 ½”)	22.78			5
Wire Scraps*	15.1	6.9	1.25	2 (Various sizes)
Nuts (1/2-13)	81.20			5
Bolts (1/2-13 x 3” hex bolts)	85.74			1
Ball Bearings (3/16-3/4)*	42			2 (Various Diameters)

*Note: There are four types of wire scrap which will be dispersed in matching pairs

**Note: Ball bearings are going to be dispersed in groups of two (various diameters) so approximate weight of each grid will vary across the test surface) but total weight of the ball bearing debris will remain constant

Tow Behind Sweeper Wheel Spacing

Helpful dimensions [all in inches] for each sweeper being tested:



Sweeper	Total Width [TW]	Tire Width [W]	Inside Tire-to-Tire Width [ITW]
Piranha 96	97	7.875	81.25
Yacare	75.125	5.25	44.472
Caiman	87.5	6.5	48.385
Aardvark	Same as Caiman		
Mammoth	100	9	82
Pyr 86 [4.5 x 4.5]	92	1.7*	87.51*
Wrasse	86		
Defiant	42.5-48.5		
Vigilant	42.5-48.5		

*Note: The Pyr 86 will not feature the wheel assembly for testing making its overall width 86”

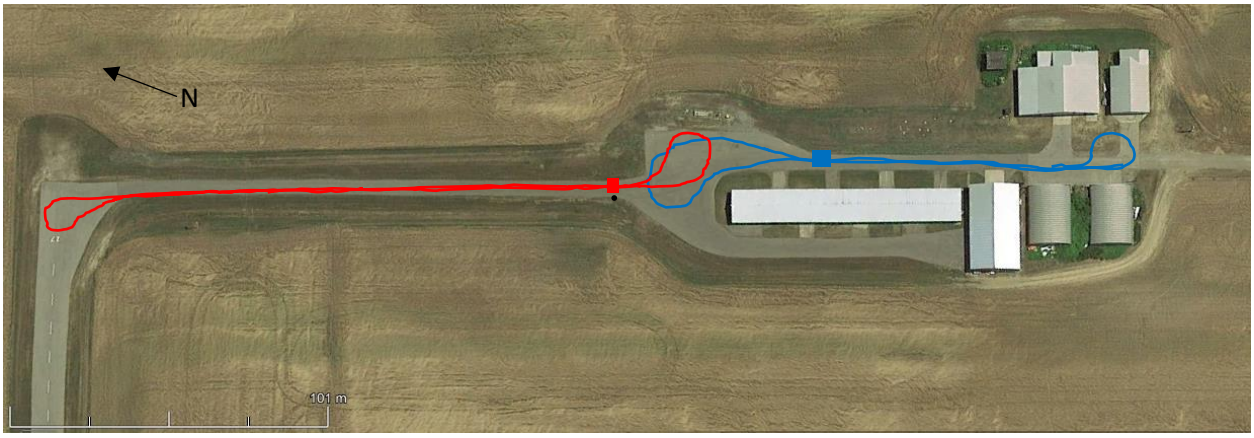
Appendix C – Speed Reference

Time over 10’ mat at various speeds

Speed (km/h)	Speed (m/s)	Speed (in/s)	Speed (ft/s)	Time over Tarp (s)
1.00	0.28	10.94	0.91	10.97
2.00	0.56	21.87	1.82	5.49
3.00	0.83	32.81	2.73	3.66
4.00	1.11	43.74	3.65	2.74
5.00	1.39	54.68	4.56	2.19
6.00	1.67	65.62	5.47	1.83
7.00	1.94	76.55	6.38	1.57
8.00	2.22	87.49	7.29	1.37
9.00	2.50	98.43	8.20	1.22
10.00	2.78	109.36	9.11	1.10
11.00	3.06	120.30	10.02	1.00
12.00	3.33	131.23	10.94	0.91
13.00	3.61	142.17	11.85	0.84
14.00	3.89	153.11	12.76	0.78
15.00	4.17	164.04	13.67	0.73
16.00	4.44	174.98	14.58	0.69
17.00	4.72	185.91	15.49	0.65
18.00	5.00	196.85	16.40	0.61
19.00	5.28	207.79	17.32	0.58
20.00	5.56	218.72	18.23	0.55
21.00	5.83	229.66	19.14	0.52
22.00	6.11	240.59	20.05	0.50
23.00	6.39	251.53	20.96	0.48
24.00	6.67	262.47	21.87	0.46
25.00	6.94	273.40	22.78	0.44
30.00	8.33	328.08	27.34	0.37
35.00	9.72	382.76	31.90	0.31
40.00	11.11	437.45	36.45	0.27
45.00	12.50	492.13	41.01	0.24
50.00	13.89	546.81	45.57	0.22

Appendix D – Testing Location

Proposed Testing Route – Delhi Aerodrome



Route A – 340m

Route B – 480m – use for magnets with long tongue (I.e., Mammoth)

Test Site Photos