

Washington Metropolitan Area Transit Authority

**Project Title:** 

**Rail Grinding Services** 

#### 1.0 Scope

- 1.1 The Contractor shall provide pre-grind profile measurement services and production rail grinding services. The pre-grind profile measurement services shall be performed annually as requested for all 234 miles (± 10%) of revenue track in the WMATA rail system. The services shall be used to develop and identify surface defects and profile conditions. Based on the pre-grind, the Contactor shall provide an outlined preliminary grinding schedule indicating the location, anticipated number of passes and the preliminary patterns.
- 1.2 The Contractor shall provide production rail grinding using a rail bound vehicle, equipped with angle profile grinding techniques for both right and left rails. The Contractor will supply all equipment, tools, materials and labor required to complete the rail grinding project.
- 1.3 The equipment must have sixteen (16) stone grinding capability, or greater. Services will be performed at various locations throughout the WMATA rail system and the work hours will vary as determined by WMATA personnel.

### 2.0 Applicable Documents

- Appendix 11.1 Standard Clearance Packages
- Appendix 11.2 Grinding Log Recording Sample
- Appendix 11.3 Rail Profile Grinding Tolerance Tables
- Appendix 11.4 Rail Profile Templates

## 3.0 Technical Specifications

- 3.1 Pre-grind Profile Measurements Equipment:
  - 3.1.1 Must be capable of data collection and traversing track at a minimum 255 foot radius.
  - 3.1.2 Must be capable of operating within WMATA's dynamic clearance envelope including the ability to work on third rail territories. (See 11.1 Appendices)
  - 3.1.3 Must be equipped with Rail Profile Measuring System (RPMS) to acquire undistorted digitized images of the rail cross section (including the rail's base) for both rails simultaneously in an electronic format. The RPMS must provide a full rail head cross section as well as base data for the gauge and field side of the rail. The system must have accuracy of 0.005" across the railhead with a maximum measurement frequency of up to 10 Hz.
  - 3.1.4 Must be equipped with a computer controlled Rail Monitoring System (RSMS) that will allow the equipment operator the ability to view railhead surface images. The RSMS is required to take blur-free images of the railhead at set intervals (time or distance based) at speeds up to 30 mph. The images must be displayed on a monitor screen, inside the vehicle, for viewing and interpretation by the equipment operator for input into the rail grinding planning software.

RSMS images must have sufficient resolution to detail the top of rail surface condition for rolling contact fatigue.

- 3.1.5 Must be equipped with a Differential Global Positioning System (DGPS) based location updating system that provides on-track location in real time to the data collection system. In all areas, whether or not GPS is available, the Contractor is required to utilize an encoder with reliance on the operator for accurate mapping information. The automatic location updates include accurate DGPS coordinates, automatic updates for subdivision/line-segments information and automatic updates for the mile post/ chain marker positions.
- 3.2 Note: WMATA will provide the Contractor with the following information which will include:

Division, line and track details;

Milepost/ chain marker information;

Curve information including location, direction, and degrees. The curve location should detail the spiral transition points.

3.3 The Contractor must include a vehicle inspection (FRA Inspection certificate for Hi- Rail vehicles), and vehicle maintenance and operation's records from the last two (2) years for Rail Bound and Hi-Rail vehicles. In addition, the Contractor's grinding equipment must be equipped with a spark arrester system (grinding process), spare rail wheels, and a fire suppression system.

## 4.0 Required Submittals

The Contractor's grinding machine shall take real- time rail profile measurements and compare them to pre-grind profiles and the templates provided in Appendix 11.4 for attainment of the specific rail profile. Continuous rail profile data shall be provided to WMATA daily in the form of JPEG or PNG files for upload into WMATA's linear asset management system. Data should also be submitted in .csv and .ban formats. Data should be available in foot by foot frequencies and include pre and post grind profiles in the same image. Specifications for rail profile threshold data are provided in the Appendix 11.3 – Table 1 & 2.

- 4.1 Pre-Grind Profile Measurement Reporting Requirements: The contractor shall provide the following within two weeks of the rail profile assessment inspection completion:
  - 4.1.1 A report that clearly identifies the metal removal and rail grinding requirements for the current rail condition (profile and surface) including prioritized recommendations. WMATA will provide the Contractor a CAD profile of the desired templates including tangents, mild curves, sharp curves and the XY coordinates in Excel format (a minimum of 108 points or more) to support the rail measurement program.
  - 4.1.2 A report that determines the optimum number of grind passes, grinding patterns and grind speeds per pass for any section of track to create a grind plan for the rail grinder.

- 4.1.3 Detailed rail wear analysis report, including percentage of head loss over time to indicate inspection results and wear exceptions. WMATA will provide the Contractor with the defined parameters for this report from the WMATA 1000 Track Maintenance and Inspection Manual.
- 4.1.4 Charts showing rail profile quality/grinding quality index, rail wear and rail geometry information over single or multiple cycles. WMATA must also be provided with full access to the optical rail measurement data allowing the ability to drill down to any point of the track to view the detailed profile and analyze grinding requirements.
- 4.1.5 A rail quality index performance summary report(s) showing rail condition by subdivision or line.
- 4.1.6 A report that displays cant and other rail geometry measurements.
- 4.1.7 Provide one four-hour training session for a class of four WMATA employees once per contract year as requested on profile image software database programs. Training should include how to interpret prioritized recommendations based on collected data, and how to interpret rail profile images.

### 5.0 Rail Grinding Services

- 5.1 The equipment must have sixteen (16) stone grinding capability or greater. Production rail grinding services can be expected on the entire WMATA rail system to include revenue tracks, pocket tracks, interlocking, connector tracks, yard lead tracks and yard loop tracks with restraining rail. Rail is constructed of 115 lbs. head hardened (HH), heat treated (HT), vacuumed treated (VT) and control cooled (CC) running rail. The approximate length of track scheduled for grinding any given night will vary upon type of grinding required and non-revenue allotted time.
- 5.2 The Contractor shall provide a copy of the grinding data collected and distribute it electronically in .csv spread sheet format (provided in Appendix 11.2),and through a written electronic report at the end of each shift which includes completed or partially completed grinding work.
- 5.3 The Contractor shall identify surface defects that cannot be removed after the grinding process has been completed.
- 5.4 The Contractor must be escorted at all times while on WMATA property. If maintenance work on the vehicle is required during non-grinding hours a request for an escort shall be required prior to the time of the activity.
- 5.5 The Contractor shall be responsible for cleanup of environmental hazards (ex. hydraulic line, diesel or oil spills etc.) that are created while on the WMATA rail system.
- 5.6 Disbursements of wet chemicals to running rails must be approved prior to usage on the WMATA system.

- 5.7 Fire suppression systems shall have a minimum capacity of 1,200 gallons of water with freeze resistance solution (as applicable), or approved equivalent suppression material with recommended volume.
- 5.8 Grinding stones shall be approved by WMATA.
- 5.9 Rail grinding will be performed at various locations throughout the WMATA rail system and the work hours will vary and will be determined by WMATA personnel.
- 5.10 The Contractor will NOT be permitted to use gasoline powered equipment; NO GASOLINE POWERED EQUIPMENT IS ALLOWED ON THE WMATA RAIL SYSTEM.
- 5.11 Real time deliverables during grinding operations:
  - 5.11.1 Contractor must document the following information on an Excel spreadsheet (xlsx or similar spreadsheet type format) for each section of track at the end of each shift:
  - 5.11.1.1 Date of grinding, beginning and end of nearest station location, alphabet letter of rail line, beginning and ending chain markers, track number, tangent or curve, which rails were ground, type of rail grinding performed, and Grind Quality Index of post grinding rail template.
    - NOTE: Sample of such data entry on the spreadsheet are shown on Appendix 11.2.

## 6.0 Contractor Training

Prior to working at WMATA property, <u>ALL</u> Contractor personnel shall be required to have background checks completed by the Contractor. Contractor personnel must also attend a Contractor Roadway Worker Protection training class, to be held at a WMATA facility. All contractor personnel shall wear Personal Protective Equipment (PPE) provided by the contractor including hard hats, eye protection, Orange ANSI Class 3 safety vests or approved ANSI Class 3 safety shirts, and safety toe boots. The Contractor's personnel must have their WMATA access pass in their possession at <u>ALL</u> time while on WMATA property.

## 7.0 Delivery Schedule

- 7.1 A grinding schedule will be set by WMATA. The Contractor will be notified daily of the reporting location for the work. The transportation of the inspection and grinding vehicles to and from the work location will be the sole responsibility of the Contractor, with navigational assistance on the rail system provided by WMATA. The reporting locations are as follows: Alexandria Rail Yard, Branch Ave Rail Yard, Brentwood Rail Yard, Glenmont Rail Yard, New Carrollton Rail Yard, Shady Grove Rail Yard, West Falls Church Rail Yard, and the anticipated Dulles Rail Yard.
- 7.2 Upon mobilization of the Rail Inspection Vehicle to the WMATA project location, the contractor shall perform a pre-grind rail profile assessment throughout the entire WMATA

system consisting of 234 miles ( $\pm$  10%) of revenue track within 20 days as scheduled by WMATA. These assessments shall be performed, once per year, during the base and option years.

- 7.3 Production grinding WMATA track system includes revenue tracks, pocket tracks, interlockings, connector tracks, yard lead tracks and yard loop tracks with restraining rail. Upon mobilization of the rail-bound grinding unit to the WMATA project location, the time allotted will be for 2,080 hours, annually. Project hours are defined as hours the contractors work from the arrival to the departure at the respective WMATA locations. If the contractor starts a shift at one yard and completes an 8 hour work shift at another yard, 8 hours will be applied against the 2,080 project hours.
- 7.4 All revenue pre-grind profile and production grinding shall be performed at night during non-revenue hours generally between 0030 hours to 0430 hours, when Maintenance-Of-Way (MOW) service equipment has access to the revenue lines. The weekends may vary based on track availability.
- 7.5 Daily logs/timesheets shall be kept and signed by both the Contractor and WMATA for specific description of work performed and hours worked for all Contractor personnel.
- 7.6 Contractor personnel reporting to work will be paid for a minimum of four hours if track access is not available due to actions of WMATA. If track access is available, Contractor personnel reporting to work will be paid for the actual number of hours worked.
- 7.7 Regardless of the time services are required or the quantity of services required, no overtime will be paid.

#### **11.1 Standard Clearance Packages**

#### 11.1.1 Crane Car Design Loading



#### 11.1.2

Rapid Transit Vehicle Design Loading



11.1.3 - Design Vehicle Dynamic Outline Diagram – Tangent Track







METRO Rapid Transit Car – Dynamic Outline, Under Floor Car Clearance



### 11.1.5 METRO Rapid Transit Car – Dynamic Outline, Under Floor Car Clearance

# 11.2 Grinding Log Recording Sample

Date	Location	To Location	Start CM	Start Offset	End CM	End Offset	Line	Trk	Passes Made	Profile	Tangent	Curve	Rail Need	Label	Grinding Type	Comments
7/7/2016	К04	K05	329	0	343	0	к	1	5	Pattern 4	Yes	No	Reprofile	RPF	Profile	Both Rails
7/8/2016	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Mechanical Problems
7/9/2016	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Mechanical Problems
7/12/2016	K98	N01	495	0	511	0	к	2	5	Pattern 4	Yes	No	Reprofile	RPF	Profile	Both Rails
7/12/2016	К98	N01	511	0	531	0	к	2	5	Pattern 6	No	Yes	Reprofile	RPF	Profile	Left Rail
7/12/2016	К98	N01	511	0	531	0	к	2	5	Pattern 5	No	Yes	Reprofile	RPF	Profile	Right Rail
7/12/2016	К98	N01	531	0	535	0	к	2	5	Pattern 4	Yes	No	Reprofile	RPF	Profile	Both Rails
7/13/2016	N01	N02	650	0	664	0	N	2	5	Pattern 4	Yes	No	Reprofile	RPF	Profile	Both Rails
7/13/2016	N01	N02	664	0	673	0	Ν	2	5	Pattern 4	No	Yes	Reprofile	RPF	Profile	Left Rail
7/13/2016	N01	N02	664	0	673	0	N	2	5	Pattern 6	No	Yes	Reprofile	RPF	Profile	Left Rail
7/13/2016	N01	N02	664	0	673	0	N	2	5	Pattern 5	No	Yes	Reprofile	RPF	Profile	Right Rail
7/13/2016	N01	N02	664	0	673	0	N	2	5	Pattern 4	No	Yes	Reprofile	RPF	Profile	Right Rail
7/13/2016	N01	N02	673	0	682	0	N	2	5	Pattern 4	Yes	No	Reprofile	RPF	Profile	Both Rails
7/13/2016	N01	N02	682	0	689	0	N	2	5	Pattern 6	No	Yes	Reprofile	RPF	Profile	Left Rail
7/13/2016	N01	N02	682	0	689	0	N	2	5	Pattern 5	No	Yes	Reprofile	RPF	Profile	Right Rail
7/13/2016	N01	N02	689	0	705	0	N	2	5	Pattern 4	Yes	No	Reprofile	RPF	Profile	Both Rails
7/14/2016	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Track Rights Cancelled by ROCC
7/15/2016	N04	N05	815	0	870	0	Ν	2	5	Pattern 4	Yes	No	Reprofile	RPF	Profile	Both Rails
7/16/2016	N04	N05	870	0	935	0	N	2	5	Pattern 4	Yes	No	Reprofile	RPF	Profile	Both Rails
7/17/2016	N04	N05	965	0	1020	0	Ν	2	5	Pattern 4	Yes	No	Reprofile	RPF	Profile	Both Rails
7/19/2016	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Track Rights Cancelled by ROCC

# 11.3 Rail Profile Grinding Tolerance Tables

Table-1 cross sectional rail profile guidelines for all subdivisions

Rail	Target Profile	Re-Profiling Zone (Minimum)	Tolerance to Template (Inches)
High Rails in curves < 800' radius	High Sharp ZT5	+33° to -5°	
		+33° to 0°	+0.012" / -0.012"
		0° to -5°	+0.012" / -NA
High Rails in curves < 2800', > 800'	High Moderate ZT4	+33° to -5°	
		+33° to 0°	+0.012" / -0.012"
		0° to -5°	+0.012" / -NA
Low Rail in curves < 800'	Low Sharp ZT3	+33° to -5°	
		+33° to 0°	+0.012" / -0.012"
		0° to -5°	+0.012" / -0.012"
Low Rails in curves < 2800', > 800'	Low Moderate ZT2	+33° to -5°	
		+33° to 0°	+0.012" / -0.012"
		0° to -5°	+0.012" / -0.012"
Tangent Rail and curves > 2800'	Tangent ZT1	+33° to -5°	
		+33° to -5°	+0.012" / -0.012"

## Table-2 maximum facet width

Angle Range	Maximum Facet Width
+45° to +15°	0.25″
+15° to +6°	0.30"
+6° to -5°	0.50″
<-5°	0.63"

## 11.4 Rail Profile Templates

Templates for Tangent up to 2 degrees ((2800 foot radius or greater).<sup>1</sup>



## In x/y coordinates

1	-1.2533	0.748888
2	-1.2333	0.761203
3	-1.2133	0.773001

<sup>&</sup>lt;sup>1</sup> In all cases, gauge is to the left on each diagram

4	-1.1933	0.784297
5	-1.1733	0.795108
6	-1.1533	0.805451
7	-1.1333	0.815341
8	-1.1133	0.824794
9	-1.0933	0.833825
10	-1.0733	0.842448
11	-1.0533	0.850678
12	-1.0333	0.85853
13	-1.0133	0.866017
14	-0.9933	0.873152
15	-0.9733	0.879949
16	-0.9533	0.88642
17	-0.9333	0.892579
18	-0.9133	0.898437
19	-0.8933	0.904006
20	-0.8733	0.909299
21	-0.8533	0.914325
22	-0.8333	0.919096
23	-0.8133	0.923624

24	-0.7933	0.927918
25	-0.7733	0.931988
26	-0.7533	0.935845
27	-0.7333	0.939498
28	-0.7133	0.942956
29	-0.6933	0.946228
30	-0.6733	0.949323
31	-0.6533	0.95225
32	-0.6333	0.955016
33	-0.6133	0.957629
34	-0.5933	0.960098
35	-0.5733	0.96243
36	-0.5533	0.964631
37	-0.5333	0.966709
38	-0.5133	0.96867
39	-0.4933	0.970521
40	-0.4733	0.972267
41	-0.4533	0.973915
42	-0.4333	0.97547
43	-0.4133	0.976938

44	-0.3933	0.978324
45	-0.3733	0.979632
46	-0.3533	0.980868
47	-0.3333	0.982036
48	-0.3133	0.98314
49	-0.2933	0.984184
50	-0.2733	0.985172
51	-0.2533	0.986108
52	-0.2333	0.986994
53	-0.2133	0.987835
54	-0.1933	0.988633
55	-0.1733	0.989391
56	-0.1533	0.990111
57	-0.1333	0.990796
58	-0.1133	0.991448
59	-0.0933	0.992069
60	-0.0733	0.99266
61	-0.0533	0.993224
62	-0.0333	0.993761
63	-0.0133	0.994273
	1	1

64	0.0067	0.994761
65	0.0267	0.995225
66	0.0467	0.995668
67	0.0667	0.996088
68	0.0867	0.996486
69	0.1067	0.996863
70	0.1267	0.997218
71	0.1467	0.997551
72	0.1667	0.997863
73	0.1867	0.998152
74	0.2067	0.998419
75	0.2267	0.998661
76	0.2467	0.998879
77	0.2667	0.999071
78	0.2867	0.999236
79	0.3067	0.999373
80	0.3267	0.999481
81	0.3467	0.999557
82	0.3667	0.9996
83	0.3867	0.999609

84	0.4067	0.999581
85	0.4267	0.999514
86	0.4467	0.999406
87	0.4667	0.999254
88	0.4867	0.999057
89	0.5067	0.998812
90	0.5267	0.998516
91	0.5467	0.998167
92	0.5667	0.997761
93	0.5867	0.997295
94	0.6067	0.996767
95	0.6267	0.996174
96	0.6467	0.995512
97	0.6667	0.994778
98	0.6867	0.993969
99	0.7067	0.993081
100	0.7267	0.99211
101	0.7467	0.991053
102	0.7667	0.989907
103	0.7867	0.988668
	1	

104	0.8067	0.987331
105	0.8267	0.985893
106	0.8467	0.98435
107	0.8667	0.982698
108	0.8867	0.980933
109	0.9067	0.979051
110	0.9267	0.977048
111	0.9467	0.974919
112	0.9667	0.97266
113	0.9867	0.970267
114	1.0067	0.967736



Moderate Curvature greater than 2 degrees up to 7 degrees (2800 foot radius to 800 foot radius)

## In x/y coordinates

1	-1.3523	0.748162
2	-1.3223	0.766823
3	-1.2923	0.784253
4	-1.2623	0.800517
5	-1.2323	0.81568
6	-1.2023	0.829801
7	-1.1723	0.842941

8	-1.1423	0.855155
9	-1.1123	0.866499
10	-1.0823	0.877025
11	-1.0523	0.886783
12	-1.0223	0.895821
13	-0.9923	0.904185
14	-0.9623	0.911919
15	-0.9323	0.919065
16	-0.9023	0.925664
17	-0.8723	0.931753
18	-0.8423	0.937368
19	-0.8123	0.942545
20	-0.7823	0.947315
21	-0.7523	0.951709
22	-0.7223	0.955757
23	-0.6923	0.959486
24	-0.6623	0.962922
25	-0.6323	0.966088
26	-0.6023	0.969007
27	-0.5723	0.971701

28	-0.5423	0.974188
29	-0.5123	0.976486
30	-0.4823	0.978613
31	-0.4523	0.980582
32	-0.4223	0.982409
33	-0.3923	0.984104
34	-0.3623	0.98568
35	-0.3323	0.987145
36	-0.3023	0.98851
37	-0.2723	0.98978
38	-0.2423	0.990963
39	-0.2123	0.992062
40	-0.1823	0.993084
41	-0.1523	0.994029
42	-0.1223	0.994901
43	-0.0923	0.9957
44	-0.0623	0.996427
45	-0.0323	0.997081
46	-0.0023	0.997659
47	0.0177	0.998001
	l	1

48	0.0377	0.998309
49	0.0507	0.998489
50	0.0637	0.998653
51	0.0767	0.998801
52	0.0897	0.998933
53	0.1027	0.999048
54	0.1157	0.999146
55	0.1287	0.999225
56	0.1417	0.999287
57	0.1547	0.99933
58	0.1677	0.999353
59	0.1807	0.999357
60	0.1937	0.99934
61	0.2067	0.999302
62	0.2197	0.999242
63	0.2327	0.999161
64	0.2457	0.999056
65	0.2587	0.998928
66	0.2717	0.998776
67	0.2847	0.998599

68	0.2977	0.998396
69	0.3107	0.998167
70	0.3237	0.997911
71	0.3367	0.997627
72	0.3497	0.997315
73	0.3627	0.996973
74	0.3757	0.996601
75	0.3887	0.996198
76	0.4017	0.995763
77	0.4147	0.995296
78	0.4277	0.994795
79	0.4407	0.99426
80	0.4537	0.993689
81	0.4667	0.993083
82	0.4797	0.99244
83	0.4927	0.991759
84	0.5057	0.991039
85	0.5187	0.99028
86	0.5317	0.98948
87	0.5447	0.988639

88	0.5577	0.987755
89	0.5707	0.986829
90	0.5837	0.985858
91	0.5967	0.984842
92	0.6097	0.98378
93	0.6227	0.982671
94	0.6357	0.981515
95	0.6487	0.980309
96	0.6617	0.979054
97	0.6747	0.977748
98	0.6877	0.97639
99	0.7007	0.97498
100	0.7137	0.973517
101	0.7267	0.971999
102	0.7397	0.970426
103	0.7527	0.968796
104	0.7657	0.96711
105	0.7787	0.965365
106	0.7917	0.963561
107	0.8047	0.961698

108	0.8177	0.959773



## In x/y coordinates

1	-1.269	0.722303
2	-1.246	0.736777
3	-1.223	0.750485
4	-1.2	0.763462
5	-1.177	0.775743
6	-1.154	0.787362
7	-1.131	0.798352

8	-1.108	0.808742
9	-1.085	0.818564
10	-1.062	0.827847
11	-1.039	0.836619
12	-1.016	0.844906
13	-0.993	0.852736
14	-0.97	0.860132
15	-0.947	0.86712
16	-0.924	0.873722
17	-0.901	0.87996
18	-0.878	0.885856
19	-0.855	0.89143
20	-0.832	0.896701
21	-0.809	0.901688
22	-0.786	0.90641
23	-0.763	0.910882
24	-0.74	0.915121
25	-0.717	0.919142
26	-0.694	0.92296
27	-0.671	0.926588
	l	

28	-0.648	0.93004
29	-0.625	0.933328
30	-0.602	0.936464
31	-0.579	0.939458
32	-0.556	0.942321
33	-0.533	0.945062
34	-0.51	0.94769
35	-0.487	0.950214
36	-0.464	0.952642
37	-0.441	0.95498
38	-0.418	0.957235
39	-0.395	0.959414
40	-0.372	0.961522
41	-0.349	0.963563
42	-0.326	0.965543
43	-0.303	0.967466
44	-0.28	0.969335
45	-0.257	0.971154
46	-0.234	0.972925
47	-0.211	0.97465
	l	

48	-0.188	0.976333
49	-0.165	0.977974
50	-0.142	0.979574
51	-0.119	0.981135
52	-0.096	0.982658
53	-0.073	0.984142
54	-0.05	0.985588
55	-0.027	0.986996
56	-0.004	0.988366
57	0.019	0.989696
58	0.042	0.990987
59	0.065	0.992236
60	0.088	0.993444
61	0.111	0.994608
62	0.134	0.995727
63	0.157	0.996801
64	0.18	0.997827
65	0.203	0.998803
66	0.226	0.999728
67	0.249	1.000601
	l	

68	0.272	1.001418
69	0.295	1.00218
70	0.318	1.002883
71	0.341	1.003526
72	0.364	1.004108
73	0.387	1.004627
74	0.41	1.005081
75	0.433	1.005469
76	0.456	1.00579
77	0.479	1.006042
78	0.502	1.006226
79	0.525	1.006339
80	0.548	1.006381
81	0.571	1.006353
82	0.594	1.006253
83	0.617	1.006082
84	0.64	1.005841
85	0.663	1.00553
86	0.686	1.00515
87	0.709	1.004702
	1	1

88	0.732	1.004189
89	0.755	1.003612
90	0.778	1.002973
91	0.801	1.002275
92	0.824	1.001522
93	0.847	1.000718
94	0.87	0.999865
95	0.893	0.99897
96	0.916	0.998037
97	0.939	0.997071
98	0.962	0.996079
99	0.985	0.995067
100	1.008	0.994043
101	1.031	0.993014
102	1.054	0.991989
103	1.077	0.990976
104	1.1	0.989986
105	1.123	0.989028
106	1.146	0.988114
107	1.169	0.987255

108	1.192	0.986464
109	1.215	0.985753
110	1.238	0.985136

Sharp curves greater than 7 degrees (less than 800 foot radius)



# In x/y Coordinates

1	-1.2533	0.74828
2	-1.2303	0.762726
3	-1.2073	0.776424
4	-1.1843	0.789407
5	-1.1613	0.801706

6	-1.1383	0.813352
7	-1.1153	0.824374
8	-1.0923	0.8348
9	-1.0693	0.844659
10	-1.0463	0.853978
11	-1.0233	0.862781
12	-1.0003	0.871095
13	-0.9773	0.878943
14	-0.9543	0.886348
15	-0.9313	0.893333
16	-0.9083	0.899919
17	-0.8853	0.906128
18	-0.8623	0.911979
19	-0.8393	0.917491
20	-0.8163	0.922682
21	-0.7933	0.927571
22	-0.7703	0.932174
23	-0.7473	0.936507
24	-0.7243	0.940586
25	-0.7013	0.944425

26	-0.6783	0.948039
27	-0.6553	0.951441
28	-0.6323	0.954643
29	-0.6093	0.957658
30	-0.5863	0.960497
31	-0.5633	0.963171
32	-0.5403	0.96569
33	-0.5173	0.968064
34	-0.4943	0.970302
35	-0.4713	0.972412
36	-0.4483	0.974403
37	-0.4253	0.976282
38	-0.4023	0.978056
39	-0.3793	0.979731
40	-0.3563	0.981314
41	-0.3333	0.98281
42	-0.3103	0.984223
43	-0.2873	0.985559
44	-0.2643	0.986822
45	-0.2413	0.988016

46	-0.2183	0.989143
47	-0.1953	0.990208
48	-0.1723	0.991212
49	-0.1493	0.992159
50	-0.1263	0.993049
51	-0.1033	0.993885
52	-0.0803	0.994668
53	-0.0573	0.9954
54	-0.0343	0.99608
55	-0.0113	0.996709
56	0.0117	0.997288
57	0.0347	0.997817
58	0.0577	0.998296
59	0.0807	0.998723
60	0.1037	0.999099
61	0.1267	0.999424
62	0.1497	0.999695
63	0.1727	0.999911
64	0.1957	1.000073
65	0.2187	1.000178
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66	0.2337	1.000216
67	0.2487	1.000228
68	0.2637	1.000215
69	0.2787	1.000176
70	0.2937	1.00011
71	0.3087	1.000018
72	0.3237	0.999899
73	0.3387	0.999752
74	0.3537	0.999576
75	0.3687	0.999372
76	0.3837	0.999139
77	0.3987	0.998876
78	0.4137	0.998583
79	0.4287	0.99826
80	0.4437	0.997905
81	0.4587	0.997519
82	0.4737	0.997101
83	0.4887	0.996651
84	0.5037	0.996168
85	0.5187	0.995653
	1	1

86	0.5337	0.995103
87	0.5487	0.99452
88	0.5637	0.993902
89	0.5787	0.99325
90	0.5937	0.992564
91	0.6087	0.991842
92	0.6237	0.991085
93	0.6387	0.990292
94	0.6537	0.989464
95	0.6687	0.988599
96	0.6837	0.987699
97	0.6987	0.986763
98	0.7137	0.98579
99	0.7287	0.984782
100	0.7437	0.983738
101	0.7587	0.982657
102	0.7737	0.981541
103	0.7887	0.980389
104	0.8037	0.979202
105	0.8187	0.977979

106	0.8337	0.976722
107	0.8487	0.97543
108	0.8637	0.974104
109	0.8787	0.972745
110	0.8937	0.971352



In x/y Coordinates

1	-1.236	0.720849
2	-1.215	0.734616
3	-1.194	0.747661
4	-1.173	0.760018
5	-1.152	0.771721
6	-1.131	0.782801
7	-1.11	0.793289
8	-1.089	0.803216

9	-1.068	0.81261
10	-1.047	0.821499
11	-1.026	0.82991
12	-1.005	0.837869
13	-0.984	0.8454
14	-0.963	0.852527
15	-0.942	0.859274
16	-0.921	0.865661
17	-0.9	0.87171
18	-0.879	0.877441
19	-0.858	0.882872
20	-0.837	0.888024
21	-0.816	0.892911
22	-0.795	0.897553
23	-0.774	0.901963
24	-0.753	0.906158
25	-0.732	0.91015
26	-0.711	0.913955
27	-0.69	0.917585
28	-0.669	0.921051

29	-0.648	0.924366
30	-0.627	0.927539
31	-0.606	0.930581
32	-0.585	0.933501
33	-0.564	0.936308
34	-0.543	0.93901
35	-0.522	0.941615
36	-0.501	0.944129
37	-0.48	0.94656
38	-0.459	0.948913
39	-0.438	0.951193
40	-0.417	0.953407
41	-0.396	0.955557
42	-0.375	0.957648
43	-0.354	0.959684
44	-0.333	0.961669
45	-0.312	0.963604
46	-0.291	0.965492
47	-0.27	0.967336
48	-0.249	0.969137

49	-0.228	0.970896
50	-0.207	0.972616
51	-0.186	0.974296
52	-0.165	0.975938
53	-0.144	0.977541
54	-0.123	0.979106
55	-0.102	0.980634
56	-0.081	0.982123
57	-0.06	0.983573
58	-0.039	0.984985
59	-0.018	0.986356
60	0.003	0.987688
61	0.024	0.988978
62	0.045	0.990226
63	0.066	0.991431
64	0.087	0.992592
65	0.108	0.993474
66	0.128	0.9944
67	0.148	0.995268
68	0.168	0.996076
	1	1

69	0.188	0.996825
70	0.208	0.997513
71	0.228	0.99814
72	0.248	0.998706
73	0.268	0.99921
74	0.288	0.999652
75	0.308	1.000032
76	0.328	1.00035
77	0.348	1.000606
78	0.368	1.000802
79	0.388	1.000936
80	0.408	1.001012
81	0.428	1.001028
82	0.448	1.000988
83	0.468	1.000892
84	0.488	1.000743
85	0.508	1.000542
86	0.528	1.000292
87	0.548	0.999997
88	0.568	0.999658
	1	1

89	0.588	0.999281
90	0.608	0.998868
91	0.628	0.998423
92	0.648	0.997953
93	0.668	0.997461
94	0.688	0.996953
95	0.708	0.996436
96	0.728	0.995915
97	0.748	0.995397
98	0.768	0.994891
99	0.788	0.994403
100	0.808	0.993942
101	0.828	0.993518
102	0.848	0.993138
103	0.868	0.992815
104	0.888	0.992558
105	0.908	0.992301
106	0.928	0.992044
107	0.948	0.991787
108	0.968	0.99153
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109	0.988	0.991273
110	1.008	0.991016