Standard Method for: **Pavement Surface Deflection Testing Using the DYNATEST® Falling Weight Deflectometer**

1.0 PURPOSE

This standard outlines the minimum requirements for pavement surface deflection testing using the Falling Weight Deflectometer (FWD) and normalization of deflection data.

2.0 SCOPE

This Standard covers the procedures for the collection of FWD deflection data using the DYNATEST® FWD equipment, including the new Fast FWD (FFWD) model, for the following pavement types:

a) Flexible: Asphalt Concrete (AC) i.e., Bituminous and Road Mixed Surface

b) Semi-Flexible: Asphalt Surface Treatment (AST)

c) Rigid: Portland Cement Concrete (PCC)

d) Composite: AC overlay of PCC

This standard also includes the normalization process of the collected FWD deflection data to standard temperature and standard load.

3.0 DATA COLLECTION AND REPORTING PROCEDURES

3.1 FWD Equipment Calibration

Reference calibration of the FWD equipment shall be performed at a US Federal Highway Administration's Long-Term Pavement Performance Program (LTPP) approved Calibration Centre within the 12 month period prior to the commencement of annual FWD deflection testing.

3.2 FWD Equipment Setup and Testing

3.2.1 General

a) The radius of the FWD load plate shall be 150 mm (300 mm in diameter), unless specified otherwise in the scope of work.

b) At least one seating drop of 40 KN shall be applied to the pavement surface. The data from any seating drop(s) shall not be stored in the FWD file.

c) All peak deflection data files shall be provided in DYNATEST® F20 file format. A complete load and deflection history shall be taken at one of the 40 KN load level drops and data provided in DYNATEST® F20 file format.

3.2.2 Flexible, Semi-Flexible and Composite Pavements

a) The offset spacing of the geophone deflection sensors shall be 0, 200, 300, 450, 600, 900, 1200, 1500 and 1800 mm for testing on flexible, semi-flexible and composite pavements using a 300 mm diameter FWD load plate. The offset spacing of the geophone deflection sensors shall be 0, 300, 450, 600, 900, 1200, 1500 and 1800 mm if a 450 mm diameter FWD load plate is used.

b) For network and project (pre-construction) data collection from flexible, semi-flexible and composite pavements, two drops of 40 and 70 KN loads (total four drops) shall be applied at each test point.

   i. The loads can be reduced to suitable levels (e.g., 25 and 40 KN or 20 and 30 KN) for testing on weak roads (e.g., weak AST roads), if the peak deflection values at the standard (40 and/or 70 KN) loads are higher than the geophone sensor range. Alternatively, a 450 mm diameter FWD load plate can be used.

c) For the research data collection from flexible, semi-flexible and composite pavements, two drops of 25, 40, 55 and 70 KN loads (total eight drops) shall be applied at each test point.

The upper two loads (55 and 70 KN) can be eliminated and the lower two loads (25 and 40 KN) can be further reduced (e.g., 20 and 30 KN) for testing on weak roads (e.g., weak AST roads), if the peak deflection values at the standard (40, 55 and/or 70 KN) loads are higher than the geophone sensor range. Alternatively, a 450 mm diameter FWD load plate can be used.

3.2.3 Rigid Pavement

a) The offset spacing of the geophone deflection sensors shall be -300, 0, 300, 450, 600, 900, 1200, 1500 and 1800 mm for network, project and research testing on rigid pavements.

b) Two drops of 25, 40, 55 and 70 KN loads (total eight drops) shall be applied at each test point.

3.3 FWD Data File Format/Specifics and Reporting

The formatting and reporting convention shall be as shown in Attachment A.

3.4 FWD Test Protocols for Flexible, Semi-flexible and Composite Pavements

3.4.1 General

a) The centre of the FWD plate shall be located at least 2.0 m away from any transverse crack for all levels of testing, unless specified otherwise in the scope of work.

b) Each test point shall represent the overall condition of the surrounding area.

3.4.2 Network Level Data Collection

a) All test points shall be located at the outer wheel path only.

b) Data shall be collected at 200 m intervals (five test points per km). The first test point shall be at 100 m from the start of the control section.

c) For a section of less than 1.0 km in length, data shall be collected from at least five (5) test points. These test points shall be reasonably spread along the length of the section.

d) On divided highways, tests shall be performed at the outer wheel path of the outermost travel lanes in both directions.

e) On composite pavement, each test point shall be located in the middle of the concrete panel (i.e., middle of adjacent cracks) at the outer wheel path.

f) All newly paved highway section(s) shall be tested in the following year after construction is complete.

3.4.3 Project Level (Pre-Construction) Data Collection

a) Project level data shall be collected for highway projects that are scheduled for rehabilitation or reconstruction within the next three (3) years.

b) All test points shall be located at the outer wheel path only, unless specified otherwise in the scope of work.

c) Data shall be collected at 100 m intervals, unless specified otherwise in the scope of work. The first test point shall be located at 50 m from the start of the project, unless specified otherwise in the scope of work.

d) For a project length of less than 500 m, data shall be collected from at least five (5) test points. These test points shall be reasonably spread along the length of the project.

e) On divided highways, tests shall be performed at the outer wheel path of the outermost travel lanes in both directions, unless specified otherwise in the scope of work.

f) On composite pavement, each test point shall be located in the middle of the concrete panel (i.e., middle of adjacent cracks) at the outer wheel path.

3.4.4 Research/Investigation Level Data Collection

a) Research/investigation level data collection will include research projects, special projects, forensic investigation, etc.

b) Testing shall be done at 10 m (typical) interval with a minimum of 15 points in each test or investigation site/area, unless specified otherwise in the scope of work.

3.5 FWD Test Protocol for Rigid (Jointed PCC) Pavements

3.5.1 General

a) Testing at a selected joint shall constitute a set of test points (J_1 to J_6), which include centres of PCC panel length at the mid lane, wheel path and lane edge of both adjoining panels, corners along lane edge of both adjoining panels, and the leave and approach sides of the joint, as shown in Attachments B and C.

b) Testing on concrete (PCC) shoulders (points J_7 and J_8) shall be done only in the case where concrete in shoulder shows higher distress than the main lane, which is generally applicable to a tied PCC shoulder (not applicable to monolithic PCC shoulder).

c) All testing shall be conducted on uncracked concrete panels, except for PCC slab crack investigation.

d) Test protocols for PCC slab crack investigation shall be developed based on each specific circumstance.

3.5.2 Network Level Data Collection

a) Each control section of a highway shall be divided into representative subsection(s), each not exceeding 2.0 km in length, based on the uniformity/variation in pavement surface roughness and other distresses.

b) FWD deflection data shall be collected from at least five randomly selected joints within a 250 m area (which should be closed to traffic) that represent the overall condition of each 2.0 km subsection.

c) All newly paved highway section(s) shall be tested in the following year after the completion of construction.

3.5.3 Project Level (Pre-Construction) Data Collection

a) Project level data shall be collected from highway projects that are scheduled for repair, rehabilitation, reconstruction within the next three (3) years.

b) The selection criteria and quantity of joints that are to be tested shall be based on the overall condition, including the observed distresses within the project area.

c) The selection criteria and quantity of joints to be tested will be specified in the scope of work.

3.5.4 Research/Investigation Level Data Collection

a) Research/investigation level data collection will include research projects, special projects, forensic investigation, etc.

b) Testing shall be conducted at a minimum of 15 randomly selected joints in each test site or investigation area, unless specified otherwise in the scope of work.

3.6 Temperature Data Collection

Each FWD shall be equipped with built-in temperature sensors to read the air and pavement surface temperatures. The FWD operator shall also have a hand-held infrared temperature gun. The air and pavement surface temperatures shall be read and recorded as follows:

a) Air and pavement surface temperatures with the built-in temperature sensors shall be recorded at every test point in the appropriate columns as specified in Dynatest Standards[(2)]. The temperature recorded by the built-in sensors shall be verified on a daily basis with a hand-held

infrared temperature gun at a minimum of three locations (near the start, middle and near the end) in a control section or project area.

b) If the FWD is not equipped with built-in temperature sensors, surface and air temperatures shall be recorded at every test location with a hand-held infrared temperature gun.

i. Surface temperatures shall be recorded by holding the infrared thermometer vertically over the test point not closer than 150 mm and not farther than 300 mm from the pavement surface.

ii. Air temperatures shall be recorded by holding the infrared thermometer at about 1.5 m above the pavement surface and directing the thermometer downwind. The thermometer shall not be directed upward, downward or toward the sun.

3.7 GPS Data Collection and Reporting

GPS readings shall be taken at each test location. GPS readings shall be reported in latitudes and longitudes.

4.0 FWD DATA ANALYSIS AND REPORTING PROCEDURE

4.1 Normalization of FWD Data and Reporting

a) For flexible and composite pavements, the pavement surface temperature shall be converted to the effective pavement temperature *(at 20 mm below the pavement surface)* using the following expression[3]:

$$T_{eff} = 0.4082 + 0.9655T_{surf} \quad (1)$$

Where,

T_{eff} = *effective pavement temperature, °C*

T_{surf} = *pavement surface temperature, °C*

b) For semi-flexible (≤40 mm thick chip seal surface) and rigid pavements, the effective temperature is the same as the pavement surface temperature.

c) For calculating the resilient moduli values of pavement layers/materials and subgrade, and for determining the effective structural numbers of pavements, the measured FWD deflection values from flexible, semi-flexible and composite pavements shall be normalized to a standard

temperature of 20 °C using applicable correction factors. The correction factors are calculated using the following equations[3]:

Geophone Position, mm	Models for Correction Factors (CF)	
D0	$CF = 10^{0.0088*(20-T_{eff})}$	(2)
D200	$CF = 10^{0.0062*(20-T_{eff})}$	(3)
D300	$CF = 10^{0.0050*(20-T_{eff})}$	(4)
D450	$CF = 10^{0.0034*(20-T_{eff})}$	(5)
D600	$CF = 10^{0.0026*(20-T_{eff})}$	(6)
D900	$CF = 10^{0.0018*(20-T_{eff})}$	(7)
D1200	$CF = 10^{0.0019*(20-T_{eff})}$	(8)
D1500	$CF = 10^{0.0021*(20-T_{eff})}$	(9)
D1800	$CF = 10^{0.0021*(20-T_{eff})}$	(10)

Where,

CF = Correction factor for temperature

T_{eff} = Effective pavement temperature, °C.

d) The CF is 1.00 for rigid pavement (i.e., no temperature correction is required for the PCC surfaced pavements).

e) The temperature corrected deflections shall be normalized to standard 566 stress (40 KN load on a 30 cm diameter plate).

f) The normalized deflection data shall be reported in MS Excel Spreadsheet (see Attachment D for a sample template).

4.2 Determination of Layer Moduli and Design Parameters

The normalized deflection data shall be used to determine pavement layer(s) and subgrade moduli through backcalculation and to determine other design parameters, if specified and as detailed in the scope of work.

5.0 REFERENCES

(1) "Manual for FWD Testing in the Long-Term Pavement Performance Program", Strategic Highway Research Program report # SHRP-P-661, National Research Council, Washington, D.C., 1993.

(2) Dynatest FWD User Manual

(3) Ahammed, M.A., Shah, Y. and Wong, M., "Manitoba's New Models for Correcting FWD Deflections to Standard Temperature for Pavement Design and Analysis." Innovations in Pavement Management, Engineering and Technologies Session of the 2022 Annual Conference of the Transportation Association of Canada, Edmonton, AB, 2022.

(4) Jackson, D.J., Murphy, M.R., and Wismatt, A., "Strategies for the Application of the Falling Weight Deflectometer to Evaluate Load Transfer Efficiencies at Joints in Jointed Concrete Pavements" Nondestructive Testing and Backcalculation of Moduli (Second Volume), ASTM 1198, Harold L. Von Quintos, Albert J. Bush III and Gilbert Y. Baladi, Eds. American Society of Testing and Materials, Philadelphia, 1994.

ATTACHMENT A
Reporting DYNATEST® Falling Weight Deflectometer Field Data (Format for .FWD and .F20 Field Data Files)

The FWD field files shall follow the DYNATEST formats for .FWD or .F20 files with the following additional requirements. The line numbers in the following are the line numbers in the DYNATEST manual [(4)].

Line 1 shall contain the following additional information:

- One (1) alphabetic character for the number of the FWD test session for the particular Control Section (i.e.: A for the first testing, B for the second testing, etc.).

Line 24 (see page 10) of the FWD file shall contain the following information:

- 2 numeric characters for the Region # (01 through 05),
- 3 numeric characters for the Route # (1 through 999),
- 3 numeric characters for the Control Section (010 through 999),
- 2 alphabetic characters for the indication of a 2 or 4 lane roadway as follows:
  - HU – designates a 2 lane roadway
  - HA – designates the two lanes of a 4 lane roadway in the ahead direction (South to north or west to east)
  - HB – designates the two lanes of a 4 lane roadway in the back direction (North to south or east to west)
- surveyed direction and lane identifiers shall be the lane number as follows:
  - HU – Lane 1 is the ahead direction (south to north or west to east)
    – Lane 2 is the back direction (north to south or east to west)
  - HA – Lane 1 is the passing lane
    – Lane 3 is the travel lane
  - HB – Lane 2 is the passing lane
    –Lane 4 is the travel lane

- The offset distance (which is the distance in kilometres (Km) from the beginning of a control section at which point the survey will commence) is to be recorded.

- The surface type is to be recorded according to the following table:

Table 1: Surface Type Code

Code Number	Surface Type
01	Earth
02	Gravel
03	AST
04	Road Mix
5a	Bituminous (AC)
5b	Bituminous over Concrete (Composite)
06	Concrete (PCC)

Line 25 shall contain the location description.

Line 26 shall contain the project objective or description.

Line 37 shall be same as line 24

Line 38 shall contain 10 characters x-coordinate and 10 characters y-coordinate

Line 39 shall contain the following:

- Two (2) alphabetic and 5 numeric characters for the kilometre distance within a control section for each drop, e.g., km1.014
- Four (4) character alphanumeric field for lane and wheel path description. The first character is numeric (1 to 4) designating lane code, and the rest three alphabetic designating wheel path (OWP, IWP and BWP)
- A three-character field for the surface temperature.
- A three-character field for the air temperature.

The first data set shall always begin on **line 40**.

```
Line #
1     R32      8097   0205222002FILENAME36F10
2     700033008002-004    03111  8
3     150 0   200 300 450 600 900 1200
4     A:\FWD\           .FWD
5     Manitoba Highways
6     S26      EB 19          7788
7     S27      EB 19          8098
8     0' 100'0' 100'1                26
9     8   15  3.5 5  2  8  2  8
10    Ld 057   1.032 87.4
11    D1 3583  1.014 .9790
12    D2 3584  1.013 1.012
13    D3 3585  1.017 .9910
14    D4 3586  1.019 1.024
15    D5 3587  1.014 .9860
16    D6 3588  1.011 1.017
17    D7 3589  1.015 1.018
18    D0 3590  1.012 1.011
19    D0 3591  1.008 1.014
20    D* 813  1.012 1.043
21    Glenn
22    00110010
23    6   .5   3   .5
24    *XXXXXXXXXX ØØØØØHWY XXXØØØØØXX
25    LOCATION DESCRIPTION
26    PROJECT OBJECTIVE
27    *
28    ……….
29    0     0Peak
30    123456789……
31    C11223344111111111111111111111
32    ……..
33    ****************************************
34    ……
```

8- character file name (Operator choice). Last Character is reserved for a suffix (A, B, C etc.) if the same section will be repeatedly tested.

Control section: (e.g.) **01059050HB** (10 characters including 0)

(e.g.) **PTHØ101** **PRØØ274** (7 characters)

Surface Type **XX** (2 characters code)

5 blank spaces (Delimiters)

As per contract documents

35 ……*……..

36 Manitoba AC Setup
37 *PTH 2-Benk. Beam Correlation
38 GPS Coordinates
39 SI NXXX 19 21 D01423
40 420 94 87 82 73 65 51 39
41 416 92 87 80 72 64 50 38
42 617 147 137 127 114 101 78 60
43 616 148 137 127 115 102 79 61
44 762 192 177 164 148 131 102 79
45 759 192 176 164 148 131 103 79
46 999 245 227 210 188 167 130 99
47 990 246 227 210 189 167 131 99
48 GPS Coordinates
49 S2 NXXX 19 21 I01429
50 406 175 131 113 94 78 56 41
51 406 173 130 111 93 77 53 39
52 611 268 204 176 147 123 86 64
53 607 266 203 174 145 121 86 62
54 746 334 255 221 186 155 109 80
55 746 334 256 222 186 155 110 80
56 978 416 321 278 234 195 139 103
57 976 417 322 279 235 196 140 102
58 GPS Coordinates
59 S3 NXXX 19 21 I01432
60 976 417 322 279 235 196 140 102

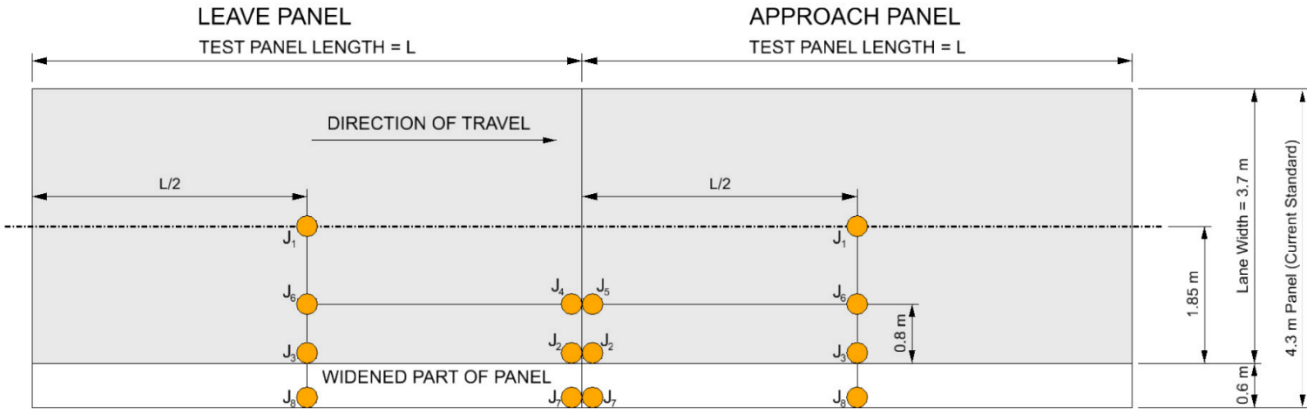
Line 38: GPS coordinates (first test point) **(Refer to Dynatest Manual)**

Line 39:
Surface Temperature at Positions 21-23.
Air Temperature at Positions 24-26.
(Refer to Dynatest Manual)

Line 39: Position 10-13 reserved for lane and wheel path designation: Position 10 – one character code (1 to 4) for Lane description. Position 11-13 for wheel path description (OWP, IWP or BWP).

Start the first deflection data set always on line 40 and every subsequent data set at regular line intervals: 6 lines for 4 load drops (Network Level), 8 lines for 6 load drops (Project Level) and 10 lines for 8 load drops (Research Level).

ATTACHMENT B
Layout for Tests on Jointed Plain Concrete Pavements (JPCP)



Point J_1 shall be located at the centre of the panel length along the mid lane.

Point J_2 shall be located such that the lane edge (paint line in the case widened panel) and the joint are tangential to the edges of the FWD load plate.

Point J_3 shall be located at the centre of panel length such that the lane edge (paint line in the case widened panel) is tangential to the edge of the FWD load plate.

Points J_4 and J_5 shall be located along the centre of wheel path such that the joint is tangential to the edge of the FWD load plate.

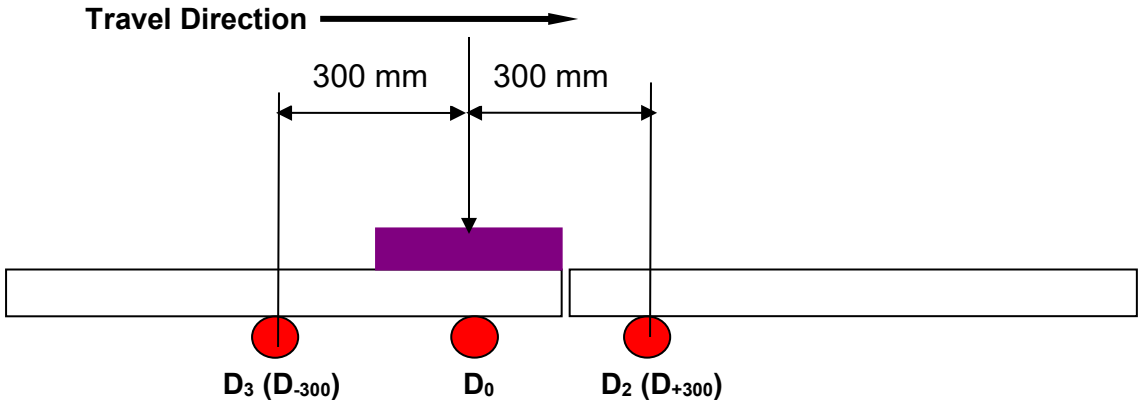
Point J_6 shall be located at the centre of the panel length along the centre of wheel path.

Point J_7 (when specified) shall be located in the widened portion of the PCC panel such that the pavement (panel) edge and the joint are tangential to the edges of the FWD load plate.

Point J_8 (when specified) shall be located at the centre of panel length such that the pavement (panel) edge is tangential to the edge of the FWD load plate.

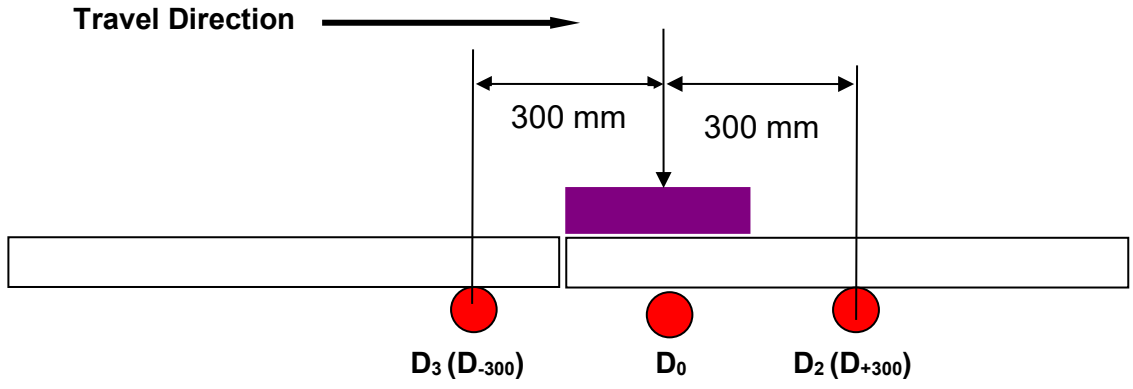
ATTACHMENT C
(Load Plate and Geophone Locations)

APPROACH SLAB LOAD TRANSFER EFFICIENCY (LTE)



$$Approach\ Slab\ LTE = D_2 / D_0$$

LEAVE SLAB LOAD TRANSFER EFFICIENCY (LTE)



$$Leave\ Slab\ LTE = D_3 / D_0$$

$$Average\ Joint\ LTE = Average\ of\ Approach\ and\ Leave\ Slabs\ LTE$$

Standard Method for: **Pavement Surface Deflection Testing Using the DYNATEST® Falling Weight Deflectometer**

ATTACHMENT D
(Reporting Normalized Deflection Data)

Point No.	Station	Stress (kPa)	Surface Temp., ºC	Air Temp. °C	Pvmt. Eff. Temp., ºC	Corr. Factor	Load Normalized and Temperature Corrected Readings, µm								
							D0	D200	D300	D450	D600	D900	D1200	D1500	D1800
1	0.3201OWP	566	20	20	19.72	0.000	123	107	98	91	81	66	54	41	34
2	0.5991OWP	566	20	20	19.72	0.000	129	110	102	92	82	65	50	39	32
3	1.0011OWP	566	20	19	19.72	0.000	111	94	87	79	70	55	44	36	31
4	1.5031OWP	566	20	19	19.72	0.000	112	96	89	80	71	56	45	35	28
5	2.1181OWP	566	21	18	20.68	0.000	124	107	99	89	79	62	50	39	32
6	2.4991OWP	566	21	18	20.68	0.000	196	157	144	127	106	78	60	44	36
7	3.0001OWP	566	21	18	20.68	0.000	132	112	106	98	87	70	57	46	38
8	3.5031OWP	566	21	18	20.68	0.000	158	133	122	110	98	77	61	48	39
9	4.0011OWP	566	22	18	21.65	0.000	246	201	182	155	130	93	69	52	42
10	4.5001OWP	566	21	18	20.68	0.000	154	130	123	113	99	77	61	46	37
11	5.0001OWP	566	21	18	20.68	0.000	140	120	113	101	88	62	50	37	29
12	5.5111OWP	566	23	18	22.61	0.000	119	101	95	86	77	60	47	36	29
13	6.0011OWP	566	22	18	21.65	0.000	153	136	126	113	98	74	56	40	31
14	6.5001OWP	566	22	18	21.65	0.000	116	101	94	86	76	60	49	36	30
15	7.0031OWP	566	22	18	21.65	0.000	155	133	121	107	93	70	54	39	30
16	7.5011OWP	566	22	18	21.65	0.000	191	161	149	133	117	88	66	50	38
17	8.0001OWP	566	22	18	21.65	0.000	146	129	122	110	97	74	58	44	35
18	8.5001OWP	566	22	18	21.65	0.000	126	110	103	92	82	64	51	39	32
19	9.0001OWP	566	22	18	21.65	0.000	95	86	84	82	78	67	46	36	32
20	9.5071OWP	566	22	19	21.65	0.000	102	91	88	83	78	67	57	47	39
21	10.0031OWP	566	21	18	20.68	0.000	122	108	102	92	84	65	51	40	32
22	10.5021OWP	566	22	18	21.65	0.000	160	143	134	119	104	79	60	46	38
23	10.9971OWP	566	22	18	21.65	0.000	220	186	171	148	125	86	61	45	34
24	11.5011OWP	566	22	18	21.65	0.000	123	111	104	95	83	64	51	38	30
25	11.9161OWP	566	22	17	21.65	0.000	193	158	150	141	129	75	56	43	34
26	12.5001OWP	566	22	17	21.65	0.000	134	117	110	101	87	67	52	41	33
27	12.9991OWP	566	22	17	21.65	0.000	102	92	87	80	73	60	49	39	31
28	13.5041OWP	566	22	17	21.65	0.000	94	83	78	73	65	52	42	32	25
29	14.0011OWP	566	23	18	22.61	0.000	85	77	75	72	66	57	49	39	33
30	14.5001OWP	566	22	18	21.65	0.000	109	102	99	94	91	70	50	37	30
31	15.0001OWP	566	23	18	22.61	0.000	117	116	95	80	72	58	48	37	31
32	15.5001OWP	566	23	18	22.61	0.000	117	109	104	100	94	78	66	54	46
33	16.0041OWP	566	23	18	22.61	0.000	105	95	90	85	80	69	58	48	39
34	16.5001OWP	566	23	18	22.61	0.000	79	75	74	73	71	60	44	36	30
35	17.0011OWP	566	23	18	22.61	0.000	76	69	67	66	64	59	43	36	29
36	17.5011OWP	566	23	18	22.61	0.000	99	88	86	82	76	61	52	43	37
37	18.0001OWP	566	23	18	22.61	0.000	93	86	83	79	73	60	52	42	35
38	18.5051OWP	566	23	18	22.61	0.000	119	110	107	105	93	79	68	55	44
39	19.0021OWP	566	22	18	21.65	0.000	85	73	71	68	60	49	41	32	26
40	19.5001OWP	566	23	18	22.61	0.000	85	76	70	66	58	47	40	30	26
41	20.0001OWP	566	23	18	22.61	0.000	172	134	122	109	96	74	58	44	34
42	20.4981OWP	566	23	18	22.61	0.000	169	139	126	110	95	71	53	40	31
43	20.9981OWP	566	23	18	22.61	0.000	275	159	117	100	85	61	48	36	30
44	21.5051OWP	566	23	18	22.61	0.000	118	108	104	96	86	69	56	43	28
45	22.0051OWP	566	23	18	22.61	0.000	138	128	121	111	99	78	60	46	35
46	22.5001OWP	566	23	18	22.61	0.000	135	123	116	105	92	69	52	38	29
47	23.0001OWP	566	23	18	22.61	0.000	171	155	144	126	108	77	58	41	32
48	23.5851OWP	566	23	18	22.61	0.000	111	97	91	85	73	56	44	33	25
49	24.0021OWP	566	22	18	21.65	0.000	135	120	111	99	86	64	49	36	27
50	24.5071OWP	566	22	18	21.65	0.000	142	129	123	112	101	81	64	49	38