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Highways England 2016 National Dynamic Plate Test device Accreditation Trial

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Executive Summary

The 2016 UK Dynamic Plate Test device (DPT) accreditation trial was held on the Twin Straights on the MIRA proving ground, on the 4th and 6th October 2016. This was the eighteenth mandatory DPT accreditation trial to be held in the UK with the objective being to assess the performance of all DPT devices likely to be operating on the Highways England Strategic Road Network (SRN). DPT devices include Falling Weight Deflectometers (FWDs), Heavy Weight Deflectometers (HWDs) and Super Heavy Weight Deflectometers (SHWDs).

The performance of individual machines was assessed by examining and monitoring the results from the machines operating on specified test sections. Only machines that can demonstrate satisfactory performance in the accreditation trial may subsequently be approved for use on the SRN.

A total of twenty-three machines took part in the trial, consisting of:

- Eleven trailer-mounted Dynatest FWDs
- Nine Dynatest trailer-mounted HWDs
- Two Grontmij trailer-mounted FWD
- One Grontmij trailer-mounted HWD

The trials followed a similar format to that which was used successfully in previous mandatory trials carried out since 1999. The Trial is split into 3 days with machine inspections, distance calibration, and initial testing held on the first day. The main testing is then held on the second day, and the third day is used for contingency in case of bad weather or other unforeseen circumstances. The tests undertaken this time comprised the following:

- Repeatability of deflection measurement (a mandatory test)
- Reproducibility of deflection measurement (a mandatory test)
- Accuracy of measurement of elapsed distance against an independent reference (a mandatory test)
- Accuracy of temperature measurement devices (non-mandatory test)
- Accuracy of measurement of pavement temperature (at 100mm and surface temperature) against an independent reference (a non-mandatory test)
- Accuracy of 3-dimensional positional data where fitted (a non-mandatory test)

The deflection tests and associated acceptance criteria are based on but not identical to those published by the CROW standards organisation in the Netherlands. In August 2011 CROW issued an updated version of their recommendations (CROW, 2011) to include the repeatability test. The accreditation trial criteria are specified in “Accreditation and Quality Assurance of Dynamic Plate Test Survey Devices” (TRL, 2016)

Based on the results from this trial and previous trials, it is recommended that the temperature criteria are transformed into a mandatory criterion for future trials.

It is worth noting that surface and air temperature measurement equipment is only fitted to some of the devices, so it would only be mandatory for those wishing to supply surface temperature measurements. Following anticipated changes in HD29 at future trials there may be some devices being assessed for only the measurement of temperature at depth, and some devices for only the surface temperature measurement (and some for both).

At the completion of the trial it was identified that:

- All twenty-three machines met the mandatory criteria of the trial.
- 3-dimensional position data was supplied by eight of the test machines. Five of these machines achieved a high rating, six a medium rating and one a low rating.
- All twenty-three machines provided temperature measurements at depth. Sixteen achieved a high rating, six a medium rating and one a low rating.
- Nine machines provided surface temperature measurements. Two machines achieved a high rating, five a medium rating, and two a “not suitable” rating.
- Ten machines provided air temperature measurements. Five machines achieved a high rating, one a medium rating, and four a low rating.

The results from the trial are discussed in this report and are provided in the accreditation certificates issued to the trial participants. These certificates are also accessible at:

http://www.ukroadsliaisongroup.org/en/asset-condition/road-condition-information/data-collection/dynamic-plate-test-devices-dpt/index.cfm

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1 Introduction

Current advice on the use of Dynamic Plate Test devices, provided in HD29/08 (where they are referred to as FWDs) of the Design Manual for Roads and Bridges (DMRB 7.3.2), requires that all of these devices be tested and approved at an annual FWD accreditation trial before being accredited for operating on the Highways England Strategic Road Network (SRN). A similar requirement has also been in place for side force skid resistance devices and Deflectographs for many years, and forms part of a system to ensure that consistent, high quality data is obtained from condition surveys of the SRN in England. In addition, Defence Estates' Design and Maintenance Guide 27, "A Guide to Airfield Pavement Design and Evaluation" requires that FWDs be approved at an annual accreditation trial before they may be permitted to survey on MoD airfields.

As satisfactory performance at an accreditation trial is required for subsequent accreditation for use on the SRN, the trial is henceforward referred to as an accreditation trial. In addition, as the trial covers FWD, HWD and SHWD, the trial is also referred to as a DPT trial rather than an FWD trial.

The objectives of the 2016 DPT Accreditation trial were:

- To ensure that all machines are maintained in good mechanical order by conducting an inspection of each machine at the trial.
- To ensure consistent performance of individual machines and the reproducibility of all machines, including any supporting measurements (e.g. temperature).
- To monitor and seek improvements in performance over the longer term.

The eighteenth mandatory UK DPT accreditation trial was held on the 4th and 5th October 2016 on behalf of Highways England. The trial followed the basic format that was used successfully in the previous mandatory trials carried out since 1999. The 2016 trial included the following mandatory checks:

- Reproducibility
- Repeatability
- Distance measurement

And the following non-mandatory checks

- Temperature measurement devices/probes calibration check
- Temperature measurement at 100mm and at the surface
- OSGR data (obtained from 3-dimensional positional systems)

These tests and associated acceptance criteria are broadly based on those published by the CROW Standards organisation in the Netherlands. In August 2011 CROW issued an updated version of their recommendations (CROW, 2011) which has been used to guide the design of the tests incorporated in this trial. The accreditation trial criteria are specified in "Accreditation and Quality Assurance of Dynamic Plate Test Survey Devices" (TRL, 2016).

From 1999 to April 2010 the trials were conducted on the Small Roads System at TRL. The trial was then conducted at the Motor Industry Research Association (MIRA) Proving grounds in Warwickshire in November 2010 and October 2011. Due to programming issues the trial returned to the Small Roads System at TRL for the November 2012 trial. The 2013 trial and subsequent trials have all been held on the proving grounds at MIRA. This report describes the conduct and findings of the October 2016 accreditation trial and presents the details of the machines that took part in the trial.

2 Trial Format

2.1 Participants

Twenty-three machines (all trailer-mounted) took part in the 2016 Highways England DPT accreditation trial, comprising thirteen FWDs and ten HWDs. A total of thirteen owning organisations took part, with the machines brought shown in Table 2.1.

Table 2.1 DPT devices attending the trial

Company	Devices brought to trial
AECOM	3×Dynatest 8002 FWD, 2×Dynatest 8082 HWD
ALC (MoD)	Dynatest 8082 HWD
Atlas Geophysical Limited	Grontmij Primax 2100 HWD
CET Infrastructure	Dynatest 8002 FWD
Dynatest	Dynatest 8012 FWD and Dynatest 8082 HWD
Forth Bridge Constructors JV	Dynatest 8002 FWD
Milestone Pavement Technologies	Grontmij Primax 1500 FWD
PMS Ltd. (Eire)	2 × Dynatest 8002 FWD and 1 x Dynatest 8082 HWD
PTS Ltd.	1 × Dynatest 8002 FWD and 3 x Dynatest 8082 HWD
Pulse Surveying Ltd.	Dynatest 8002 FWD
Stanger Testing Services	Dynatest 8002 FWD
TestConsult Ltd.	Grontmij Primax 2500 HWD
TRL	Dynatest 8002 FWD

More details of the attending machines are provided in Appendix A and example photographs are given in Appendix B.

In this report the individual machines are referred to by the running numbers assigned to them for the trial. For ease of comparison, machines usually retain the same running number year-on-year.

2.2 Preparation of vehicles

All operators were asked to prepare their machines for testing under standard conditions prior to their arrival at the trial, as follows:

- Positions of deflection sensors: 0, 300, 600, 900, 1200, 1500 and 2100 mm. Note: this is the flexible and flexible-composite set-up described in HD29/08 and is different from the positions used for trials before 2013.
- Standard loading plate, diameter 300mm.
- Data storage in standard metric output (“.F20” or “.F25” format).

For the repeatability testing the following were also specified:

- Load 50kN (fixed height, seek may not be used).
- Configured for 12 drops at each test site.

For the reproducibility testing the following were also specified:

- Load 50kN (fixed height or seek).
- Configured for 5 drops at each test site.

Operators were also advised to have the peak smoothing function, if available, activated.

2.3 Inspection of vehicles

Operators were requested to provide details of the latest manufacturer's calibration and their own dynamic calibrations and stack/tower consistency checks prior to the start of the trial. The machines were subsequently checked by a TRL inspector before testing began to ensure that the machines were set up correctly and configured as required for the trial. The findings are summarised in Appendix A.

2.4 Location of Trial

Four test sections were used for the trial; each with different constructions and associated deflection levels, and located on the Twin Straights on the MIRA proving ground. Each section contained three test stations (12 stations in total) which were clearly marked out using road paint (see Figure 2.1 below) and swept clear of debris prior to the trial. An additional station (number 13) is located on a concrete section and this station (along with 2, 5 and 8) is used in the repeatability testing. Two additional test lengths were set up; one to allow operators to undertake distance calibrations and one for the odometer test. Nominal construction details for the four main test sections can be found in Appendix C. Crews were instructed that the loading plate should be placed completely within the marked box for testing.

Figure 2.1 Test station marked by a painted box

2.5 Temperature monitoring

The pavement temperature was measured throughout the trial using two pairs of temperature sensors connected to two data loggers located near stations 1 and 9. These devices were set to record temperature every minute at depths of 40mm and 100mm within the pavement. In addition another set of temperature sensors connected to a data logger was set up to record air and pavement surface temperatures near station 1.

2.6 Test Programme

Appendix D contains the detailed instructions provided to participants regarding the conduct of the trial. An outline of the programme is provided below.

2.6.1 Day 1 – Inspection and Repeatability

Day 1 is used to conduct machine inspections, repeatability tests and a check lap. The check lap is designed to give new operators the chance to familiarise themselves with the course, and to seek to highlight any obvious problems with machines that would otherwise delay progress during the main part of the trials on the following day.

TRL staff members are made available during testing to assist crews with positioning at test stations.

The check lap follows the same format as used for the main day (day 2) with five replicate drops at each of the standard twelve test stations. The peak values of load and deflection are recorded as well as time histories. For this testing it is recommended that the load “Seek” setting is switched on (if available).

Four stations (2, 5, 8 and 13) were selected for the repeatability testing. For this testing two laps of twelve replicate drops at each station was required, with peak values of load and deflection recorded as well as time histories. For the repeatability testing the load “Seek” setting is switched off.

During this day the crews are also asked to perform a distance calibration using a marked out length (400m).

The operators’ temperature probes were compared using a stabilised environment to provide a simple check on the calibration of these devices.

2.6.2 Day 2 – Main running trial day

Reproducibility tests are conducted on day 2. As with day 1, TRL staff members are made available during testing to assist crews with positioning at test stations.

Five replicate drops are made at the twelve test stations, with peak values of load and deflection recorded as well as time histories. Each complete set of 12 test stations is referred to as a lap.

The first lap is treated as a warm-up lap, and then followed by two test laps. After completing each lap, the data is handed over to TRL staff before beginning the next lap, and any anomalies reported by operators are recorded. Real-time data processing enables

summary results of each lap to be available to the TRL inspectors soon after each lap is completed.

During each lap the crews are asked to make temperature measurements using a pre-drilled hole near one of the temperature loggers. In addition, on returning to the start of the test site the operators are asked to measure a predefined length to provide an assessment of the odometers fitted to the equipment.

2.6.3 Day 3 – Contingency day

Day 3 is reserved for contingency for bad weather or other unforeseen circumstances.

3 Assessment criteria

The accreditation trial criteria are specified in "Accreditation and Quality Assurance of Dynamic Plate Test Survey Devices" (TRL, 2016). The specification is a live document (i.e. is subject to change) and the July 2016 version of the document was used for the trial. The relevant section of the document is reproduced verbatim below (section 3.1 and 3.2). The appendices referred to in section 3.1 and 3.2 are not included in this report.

Note in the text below, "Equipment" is a defined term and refers to the overall machine being assessed, incorporating the measuring systems and the survey vehicle. "System" refers to an individual measurement system installed on the Equipment e.g. the side-force measurement system, GPS, distance measurement system etc. "Employer" refers to the organisation that commissions the Survey Contractor to complete a survey and will generally be the final user of the data provided. "Owner" refers to the organisation or individual to which the Equipment belongs and to whom Accreditation Certificates are awarded.

3.1 Mandatory Trial criteria from the Accreditation and QA document

E4.2 Repeatability testing – Mandatory Requirement

E4.2.1 Repeatability testing will be conducted on a series of test stations identified by the Auditor. The requirements for these test stations are given in Appendix C.

E4.2.2 Repeatability testing will use a test procedure typical of general usage on the network. The test procedure will include a minimum of two seating drops and ten measurement drops at each test station. The specific details of the test procedure for Repeatability testing (including nominal peak load and number of drops) will be communicated by the Auditor prior to the trial.

E4.2.3 It is noted that some Equipment have drop height variation functionality which varies the drop height based on the load measured on the previous drops (sometime referred to as "seek" mode). This functionality may not be used for the repeatability testing.

E4.2.4 The following must be achieved with regards to the load applied on each station:

- The mean load applied shall be within 10% of the target load.
- The standard deviation of the load recorded shall be less than, or equal to two percent of the mean of the recorded values.

E4.2.5 In the event that these load requirements are not achieved the data will be disregarded and additional tests will be undertaken. If the Equipment does not meet the load requirements given above in subsequent tests then it is deemed to be unable to undertake the assessment and have failed the Repeatability criteria.

E4.2.6 The valid Repeatability data will be collected and the Equipment will pass the Repeatability test if it meets the criteria given in Table 1. A worked example of the analysis process is given in App D.1.

Table 1 – Deflection Repeatability Criteria

Parameter	Acceptability Limit
Standard deviation of load corrected deflections	95% of the data less than or equal to 2µm or the sum of 1µm and 0.75% of the mean of the recorded normalised values (whichever is greater)

E4.3 Reproducibility testing – Mandatory Requirement

E4.3.1 Reproducibility testing will be based on at least two test sets conducted on a series of test stations identified by the Auditor. The requirements for these test sets and test stations are given in Appendix C.

E4.3.2 To be classified as a valid Reproducibility test the 100mm pavement temperature must not change by more than ±3°C between tests conducted by the different Equipment on the same test station in each test set. If the temperature varies by more than this then this is likely to introduce additional variation to the Survey Data of the Equipment and should be disregarded. Additional test sets should then be undertaken in order to obtain the required amount of Survey Data within the required temperature range.

E4.3.3 Reproducibility testing will use a test procedure typical of general usage on the network. The test procedure will include a minimum of one seating drop and four measurement drops at each test station. The specific details of the test procedure (including nominal peak load and number of drops) will be communicated by the Auditor prior to the trial.

E4.3.4 The Field Calibration Factor (FCF) and the Standard Deviation of the Deviation Ratio (SDDR) are used as the basis for the assessment of Reproducibility.

E4.3.5 For each deflection sensor the reference deflection divided by the Equipment's mean deflection, averaged over all test stations, is defined as the FCF for that sensor. The overall FCF for each Equipment is calculated by averaging the FCF values for the individual sensors. The FCF therefore indicates, on average, how well the deflections recorded by each Equipment relate to the reference deflection basins.

E4.3.6 The difference between the deflection measured by each sensor at each test point and that of the reference deflection basin, expressed as a fraction of the reference deflection is defined as the Deviation Ratio. For each Equipment, the SDDR is calculated over all test stations and gives an indication of the consistency with which the Equipment tends to over-read or under-read over the set of test stations.

E4.3.7 The FCF and SDDR statistics will be calculated for each test set. The Equipment will pass the Reproducibility test if the criteria in Table 2 are met for each test set. A worked example of the analysis process is given in App D.2.

Table 2 - Deflection Reproducibility Criteria

Parameter		Maximum	Minimum
FCF	Mean for all sensors	1.05	0.95
	Individual sensor value	1.10	0.90
SDDR	Mean for all sensors	0.05	N/A
	Individual sensor value	0.07	N/A

E4.3.8 Occasionally, Equipment will produce isolated anomalous sensor readings which may result in FCF or SDDR values falling outside the acceptable limits. To compensate for this the accreditation procedure allows for the measurement from a single sensor from one test station to be removed from the analysis of each lap of the test site if required.

E4.4 Location Referencing Testing (Distance) – Mandatory Requirement

E4.4.1 Accreditation of an Equipment's ability to measure distance is carried out by comparing its measurements of a test length with the Reference Data. The test is carried out at least four times. All of the test measurements must be within the criteria given in Table 3.

Table 3 - Acceptance Criteria for Location Reference Measurement

Parameter	Acceptability Limit
Elapsed chainage versus Reference Data	± 2m or 1% (whichever is greater)

3.2 Additional test criteria from the Accreditation and QA document

E5.2 Location reference – OSGR coordinates

E5.2.1 For Equipment undertaking this test, the difference in position (as the horizontal error) between the reported OSGR coordinates from each test station and the reference OSGR coordinates will be calculated. A minimum of 18 stations will be used to undertake this test (either 18 different test stations or a lower number of test stations using multiple laps). The criteria for the assessment of OSGR coordinates are given in Table 4.

Table 4 - Acceptance Criteria for OSGR data

Performance	Criteria
High	75% of the data is within 2m of the Reference Data
Medium	75% of the data is within 5m of the Reference Data
Low	75% of the data is within 10m of the Reference Data
Not suitable	Otherwise

E5.3 Temperature measurement – temperature sensor for measurement at depth (within the pavement)

E5.3.1 If undertaking this test, the Contractor will be required to collect at least eight measurements in the pre-drilled holes (100mm depth) during the course of the test laps. The criteria for the assessment of temperature measurement at depth are given in Table 5.

Table 5 - Acceptance Criteria for temperature measurement at depth

Performance	Criteria
High	80% of the data is within 1˚C of the Reference Data
Medium	60% of the data is within 1˚C of the Reference Data
Low	25% of the data is within 1˚C of the Reference Data
Not suitable	Otherwise

E5.3.2 The Re-accreditation trial may also incorporate a check on the calibration of the temperature Systems via measurement of a static sample of known temperature (e.g. ice).

E5.4 Temperature measurement – temperature sensor for surface measurement

E5.4.1 If undertaking this test the Contractor will be required to collect at least eight measurements of the pavement surface at defined points during the course of the test laps. The criteria for the assessment of temperature measurement of the pavement surface are given in Table 6.

Table 6 - Acceptance Criteria for temperature measurement of pavement surface

Performance	Criteria
High	80% of the data is within 1˚C of the Reference Data
Medium	60% of the data is within 1˚C of the Reference Data
Low	25% of the data is within 1˚C of the Reference Data
Not suitable	Otherwise

4 Results – Day 1

4.1 Machine set-up and configuration

The machine check on the first day of the trial ran efficiently due largely to the vehicle inspection check sheets being sent to participants and completed prior to the trial, ensuring that most of the machines arrived correctly set up and configured with only minor checks required by TRL staff.

Appendix A itemises the configuration of the various machines, while Table 4.1 summarises the findings of the inspection with regards to certain key parameters that either affect operation or are requested in the trial documentation.

Table 4.1 Summary of DPT configurations on arrival

Checklist item	Number compliant (out of 23)
Completed Check list returned to TRL before trial	23
Date of last tower calibration	22
Date of last dynamic calibration	22
Date of last manufacturer's calibration	23
Calibration details correct in field program	23
All seven geophones in correct positions	10
Correct seating of frame	23

Following the 2006 accreditation trial, it had been agreed with the DPT operators that routine dynamic and tower calibration records should be made available for viewing at the 2007 and subsequent accreditation trials. The dates supplied by the contractors for their latest calibrations (regardless of whether evidence of the calibration was supplied) is shown in Appendix A.

4.2 Day 1 check lap

A check lap is conducted on Day 1 to familiarise operators with the test procedure and to provide early data to highlight any obvious problems with the survey machines to allow corrective action to be undertaken prior to the main testing. If any machines undergo any corrective action during the trial then additional testing (if required) is undertaken to make sure there is a suitable set of data for all of the assessments (i.e. reflective of the current condition and configuration of the device).

Machine 16 was involved in a road traffic incident on route to the trial and was undergoing repairs and therefore could not take part in this testing. The tow vehicle for Machine 32 became immobilised due to a seized handbrake and Machine 36 suffered from software issues and therefore these machines were also unable to take part in this testing.

The remaining 20 machines undertook the familiarisation lap and the data is shown in Figure 4.1 and Figure 4.2 below. In these figures the circle and square show the mean FCF and SDDR respectively for the machine on the lap. The error bars show the range of the FCF

and SDDR values for each geophone. In the full assessment the machines would be deemed suitable if the mean FCFs are within the mean limit (i.e. between 0.95 and 1.05), the individual FCFs within the individual limit (i.e. between 0.90 and 1.10), and the SDDR mean and individual values below their corresponding limits (0.05 and 0.07 respectively).

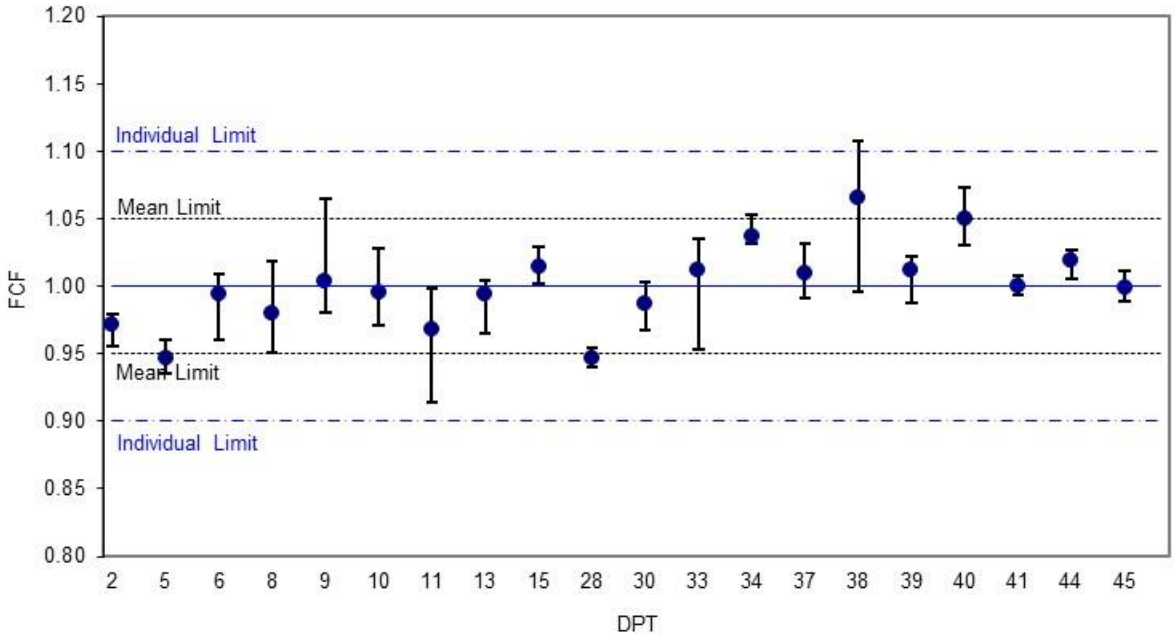

Figure 4.1 FCF (check lap – full dataset)

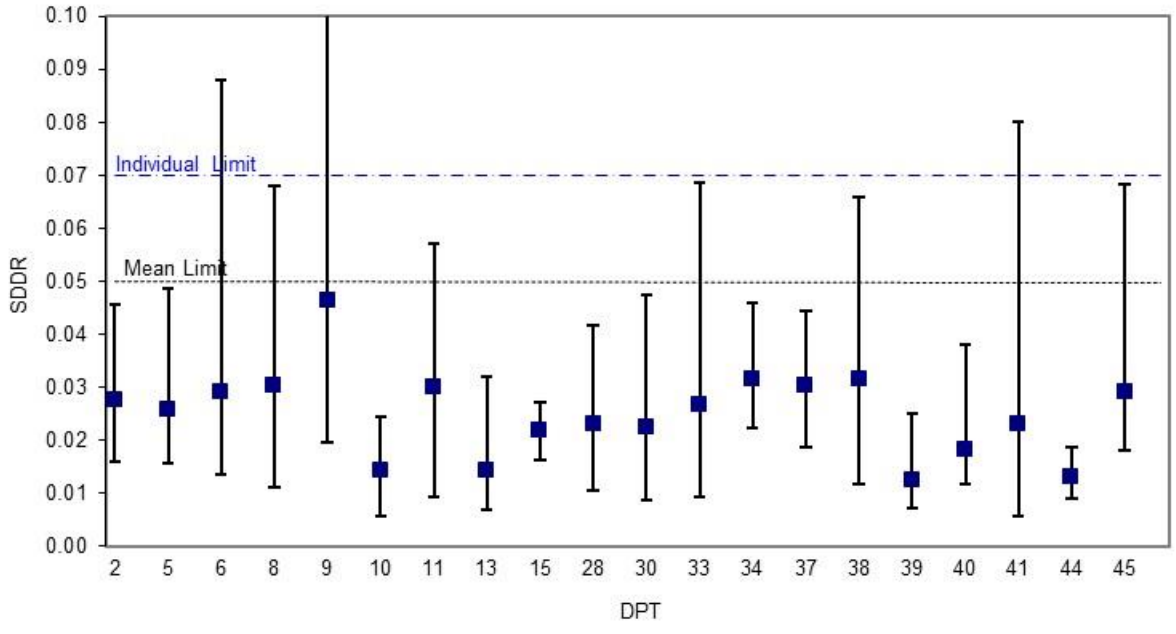

Figure 4.2 SDDR (check lap – full dataset)

On examination of the check lap data it was found that Machines 5, 28 and 38 exceeded the limits for the mean FCF (Machine 40 was on the threshold). In addition Machine 38 also exceeded the limit for the individual FCF values. All of the machines met the mean SDDR limit, but Machines 6, 9 and 41 did not meet the individual SDDR limit.

However, due to the chances of isolated anomalous sensor readings, the accreditation criteria allows for the removal of the measurement from a single sensor from one test station to be removed from the analysis if required. The results after removing these points (for machines which didn't originally meet the criteria) are shown in Figure 4.3 and Figure 4.4.

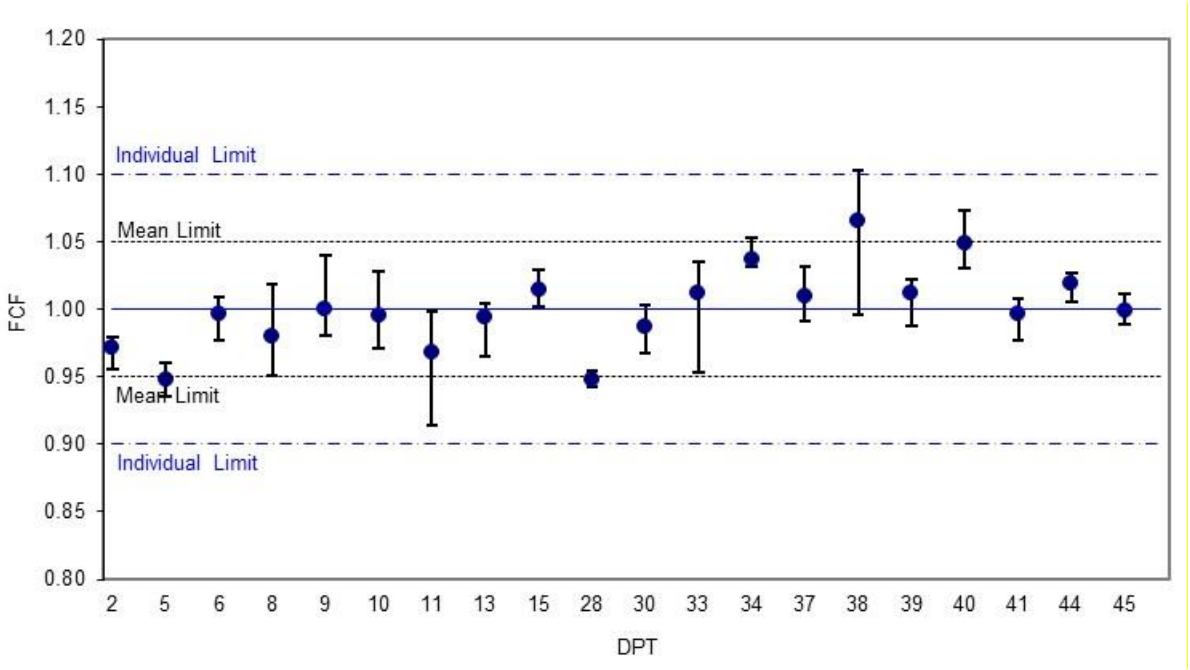

Figure 4.3 FCF (check lap- single data point removed)

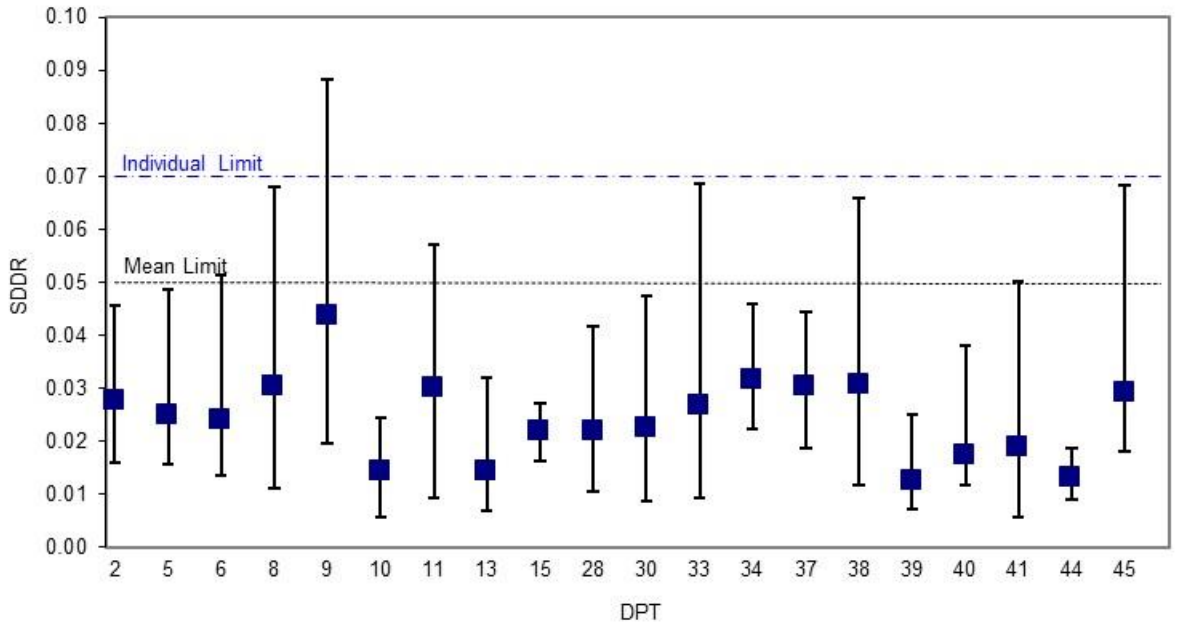

Figure 4.4 SDDR (check lap- single data point removed)

It can be seen from this data that Machines 5, 28 and 38 still did not meet the FCF criteria and Machine 9 did not meet the SDDR criteria even after the removal of a data point. The

operators of these machines were notified of these issues so that they could investigate their machines before the testing on day two.

4.3 Repeatability tests

Repeatability tests were also conducted on day 1 using stations 2, 5, 8 and 13 and the test criteria can be found in section 3.1. Two machines (Machines 6 and 33) provided data with loads outside of the required tolerance. A further two machines (Machines 28 and 30) provided data which failed to meet the criteria. Three machines (Machines 36, 41 and 44) were unable to complete both or either of the Repeatability laps due to work being undertaken on the machines. All seven of these machines completed the required Repeatability testing on day 2 or day 3 of the trial. Investigations and work done on the machines is discussed in section 5.2. Table 4.2 shows the summary of the final results for the repeatability assessment for all machines, including those which did not undertake the testing on day 1. The full details of each repeatability test (including the load values obtained) can be found in Appendix E.

Table 4.2 Repeatability assessment

ID	Count of failure to meet SD of normalised deflections criteria							Percentage met criteria	Status
	D1	D2	D3	D4	D5	D6	D7		
2	0	0	0	0	0	0	0	100%	Pass
5	1	0	0	0	0	0	0	98%	Pass
6	0	0	0	0	0	0	0	100%	Pass
8	0	0	0	0	0	0	0	100%	Pass
9	0	0	0	0	0	0	0	100%	Pass
10	0	0	0	0	0	0	0	100%	Pass
11	0	0	0	0	0	0	0	100%	Pass
13	0	0	0	0	0	0	0	100%	Pass
15	0	0	0	0	0	0	0	100%	Pass
16	0	0	0	0	0	0	0	100%	Pass
28	0	0	0	0	0	0	0	100%	Pass
30	0	0	0	0	0	0	0	100%	Pass
32	0	1	0	0	1	0	0	96%	Pass
33	0	0	0	0	0	0	0	100%	Pass
34	0	0	0	0	0	0	0	100%	Pass
36	0	0	0	1	0	0	0	98%	Pass
37	0	0	0	0	0	0	0	100%	Pass
38	0	0	0	0	0	0	0	100%	Pass
39	0	0	0	0	0	0	0	100%	Pass
40	0	0	0	0	0	0	0	100%	Pass
41	0	0	0	0	0	1	0	98%	Pass
44	0	0	0	0	0	0	0	100%	Pass
45	0	0	0	0	0	0	0	100%	Pass

On examination of the data it can be seen that all of the assessed machines meet the repeatability criteria.

4.4 Temperature Probes

During the inspection day the operators' temperature probes were compared to the data-loggers using a stabilised environment (a container of water). From this testing it was identified that no probes were providing anomalous readings.

5 Results – Day 2

5.1 Temperature variation

A maximum "asphalt layer" (at 100mm depth) temperature change of 3°C during each test lap is recommended under the CROW procedure (CROW 2011) on which the deflection assessment part of the UK trials are based. The aim of this limit is to minimise changes in deflections due to temperature changes within the pavement construction in each test lap.

On day 2, pavement temperatures were recorded at 40 and 100mm depths near stations 1 and 9. The temperatures steadily increased over the day as shown in Figure 5.1.

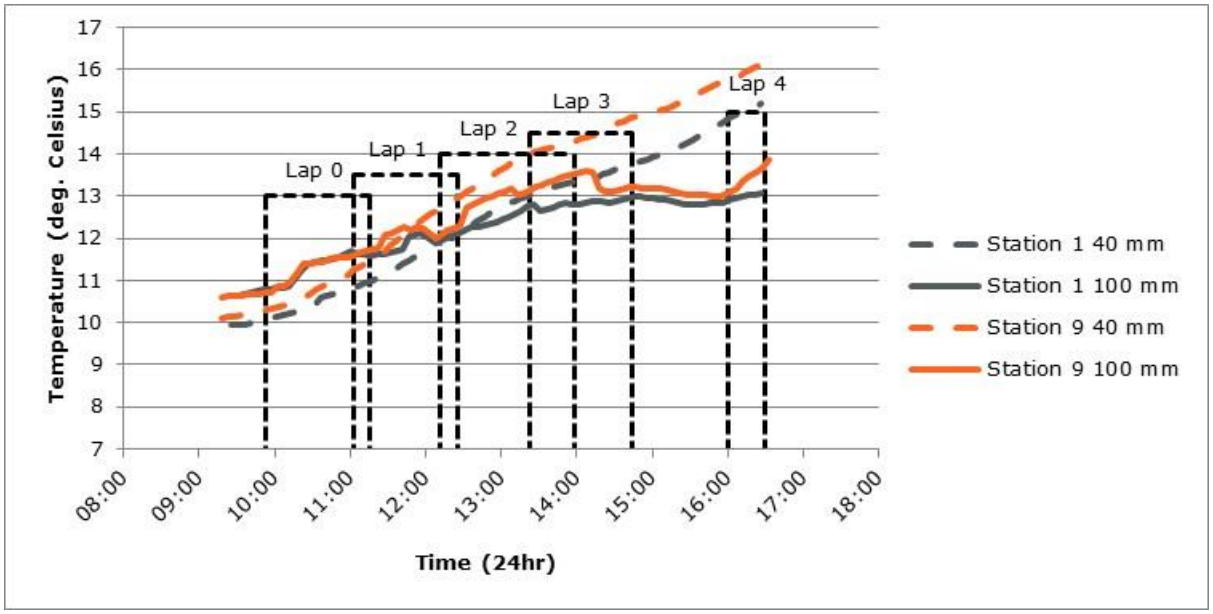

Figure 5.1 Pavement temperatures during main trial day (Day 2)

Summaries of the temperature measurements for each test lap are given in Table 5.1 and Table 5.2 for stations 1 and 9 respectively.

Table 5.1 Pavement temperatures for each lap during Day 2, near station 1

Lap	Start of Lap			End of Lap			Lap Duration (Hours:mins)	Temperature difference during lap (°C)	
	Time	Temperature		Time	Temperature				
		40mm	100mm		40mm	100mm		40mm	100mm
0	09:53	10.1	10.8	11:16	10.9	11.6	01:23	0.9	0.8
1	11:03	10.8	11.7	12:25	12.0	12.1	01:22	1.2	0.4
2	12:12	11.9	11.9	13:58	13.3	12.8	01:46	1.4	0.9
3	13:23	13.0	12.7	14:44	13.7	13.0	01:21	0.7	0.2
4	16:00	14.7	12.9	16:30	15.2	13.1	00:30	0.4	0.2

Table 5.2 Pavement temperatures for each lap during Day 2, near station 9

Lap	Start of Lap			End of Lap			Lap Duration (Hours:mins)	Temperature difference during lap (°C)	
	Time	Temperature		Time	Temperature				
		40mm	100mm		40mm	100mm		40mm	100mm
0	09:53	10.3	10.7	11:16	11.4	11.7	01:23	1.1	1.0
1	11:03	11.2	11.6	12:25	12.9	12.2	01:22	1.7	0.7
2	12:12	12.6	12.0	13:58	14.3	13.5	01:46	1.7	1.5
3	13:23	14.0	13.1	14:44	14.9	13.2	01:21	0.8	0.1
4	16:00	15.7	13.0	16:30	16.1	13.7	00:30	0.4	0.6

It can be seen that the 3°C limit was not exceeded for the 100mm temperature on any lap at either station.

5.2 Reproducibility results from test laps

In order to evaluate the performance of each machine two laps are chosen from the test set: these laps are denoted lap i and lap ii. In general, the laps chosen for i and ii are laps 1 and 2 respectively (the data from the warm up lap [lap 0] is always discarded). However, when machines do not perform as expected additional laps may be required. A summary of the points raised with the operators and the steps undertaken is discussed below.

- Machine 9 failed to meet the individual SDDR criteria (geophone 7) on laps 1 and 2. This was investigated after lap 1 and it was found that geophone 7 had excess grease on it making it unstable in the holder. This was removed and correctly seated in the holder. This did not improve the results for lap 2 so the geophone was replaced with a fresh geophone. The machine then went on to provide acceptable performance after the removal of single data points on laps 3 and 4.
- Machine 28 failed to meet the mean FCF criteria (the FCF was too low) on lap 1. After replacement of “catch parts” the machine went on to provide acceptable performance on laps 2 and 3.
- Machine 32 failed to meet the mean FCF criteria (the FCF was too high) and the individual SDDR criteria (geophone 7) on lap 1. Following inspection of the device the mean FCF fell within the criteria on lap 2. The SDDR was outside of the criteria on lap 2, inside on lap 3 and outside again on lap 4.
- Machine 36 failed to meet the mean FCF criteria (the FCF was too low) on lap 1. This was investigated and the machine then went on to provide suitable results on laps 2 and 3.

The FCF and SDDR values derived from each machine’s laps are given in Appendix F, Table F.1. The laps chosen for assessment (lap i and ii) were laps 1 and 2 for all machines apart for the exceptions discussed above and as shown in Table 5.3.

Table 5.3 Machines for which laps 1 and 2 were not used for the assessment

Machine	Lap i	Lap ii
9	Lap 3	Lap 4
28	Lap 2	Lap 3
32	Lap 3	Lap 4
36	Lap 2	Lap 3

5.2.1 Plots of FCF and SDDR (prior to geophone removal)

The results from laps i and ii (prior to the removal of individual geophone readings) are shown graphically in Figure 5.2 for FCF and Figure 5.3 for SDDR. The vertical bars in these figures indicate the range of values from individual sensors and the filled circles/squares indicate the mean value for all seven sensors.

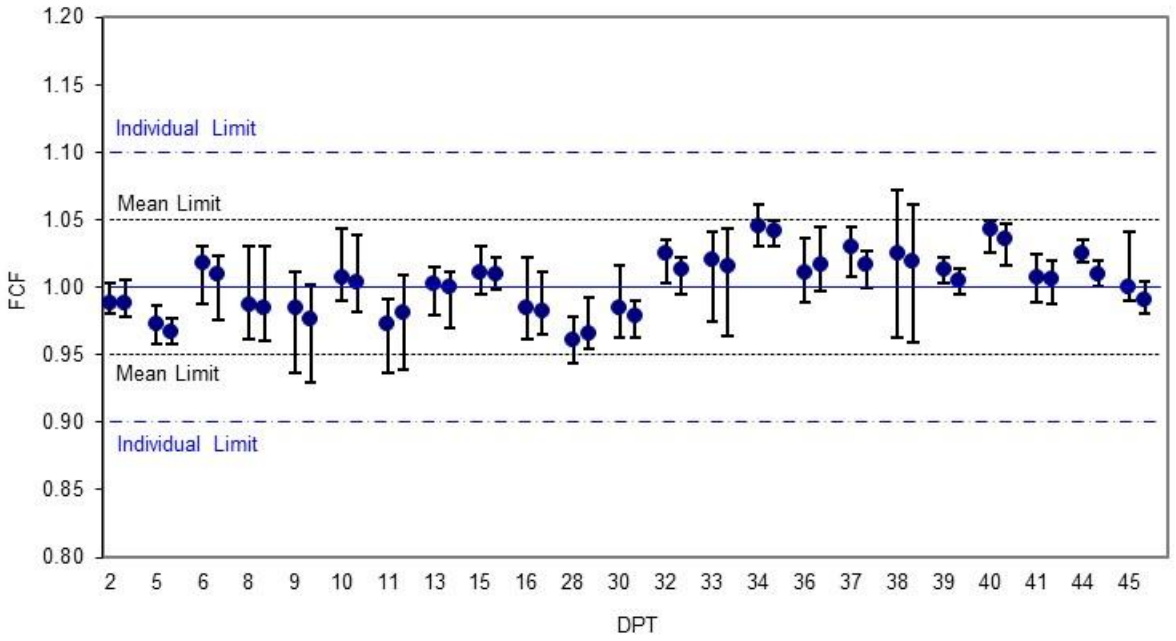

Figure 5.2 FCF for each DPT (main trial day for laps i and ii – full data set)

It can be seen from Figure 5.2 that all twenty-three machines met the trial requirements for mean Field Calibration Factor (FCF) using the full data set from the two chosen test laps. In addition all of the machines met the trial requirements for the individual geophone FCF values using the full set of data.

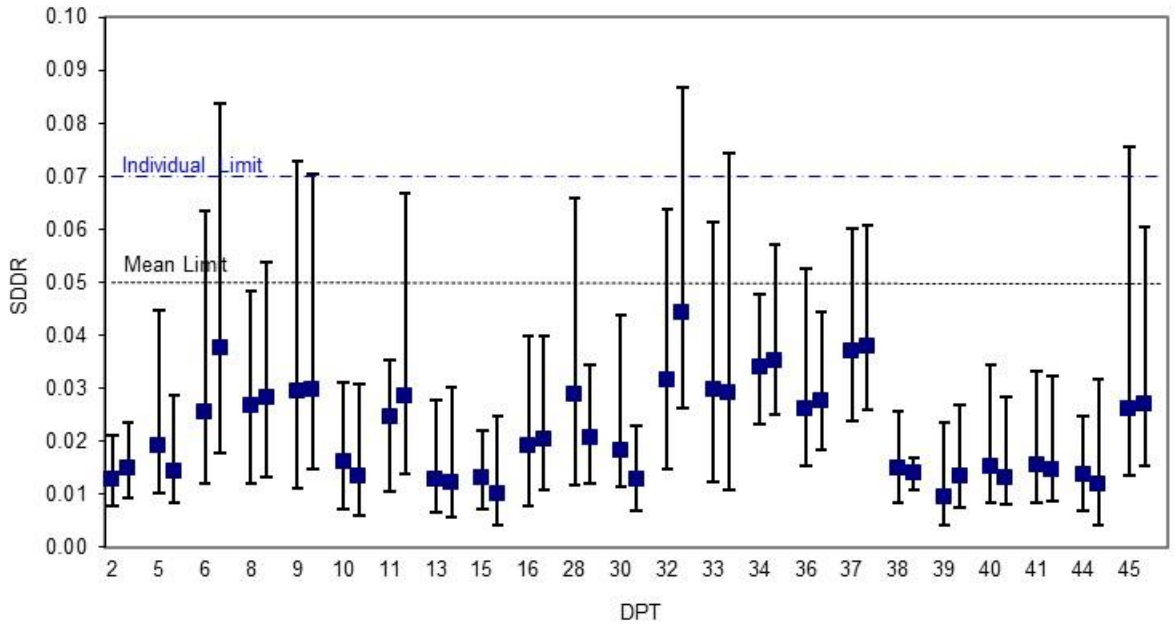

Figure 5.3 SDDR for each DPT (main trial day for laps i and ii – full dataset)

All twenty-three machines passed the criteria for the mean SDDR without the removal of any data points. Five machines (Machines 6, 9, 32, 33 and 45) did not meet the individual SDDR criteria using the full set of data.

5.2.2 Plots of FCF and SDDR (after geophone removal)

The results from laps i and ii (after geophone removal) are shown graphically in Figure 5.4 for FCF and Figure 5.5 for SDDR.

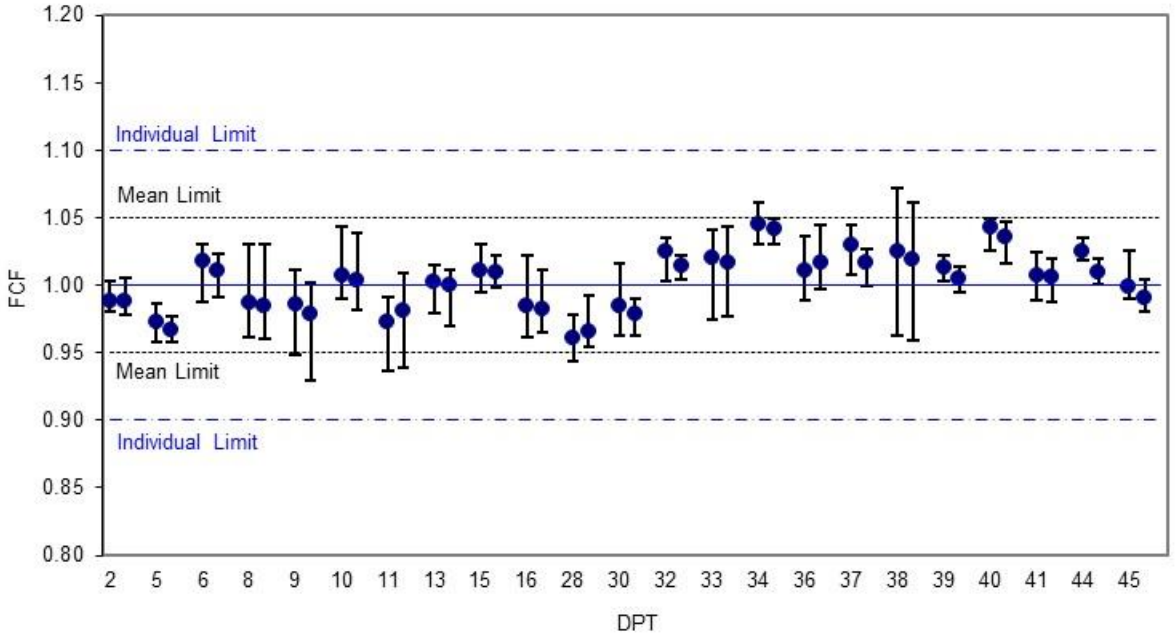

Figure 5.4 FCF for each DPT (main trial day for laps i and ii - single data point removed)

It can be seen from Figure 5.4 that there is no change in performance for the FCF values following the removal of a single geophone reading from one station on each lap.

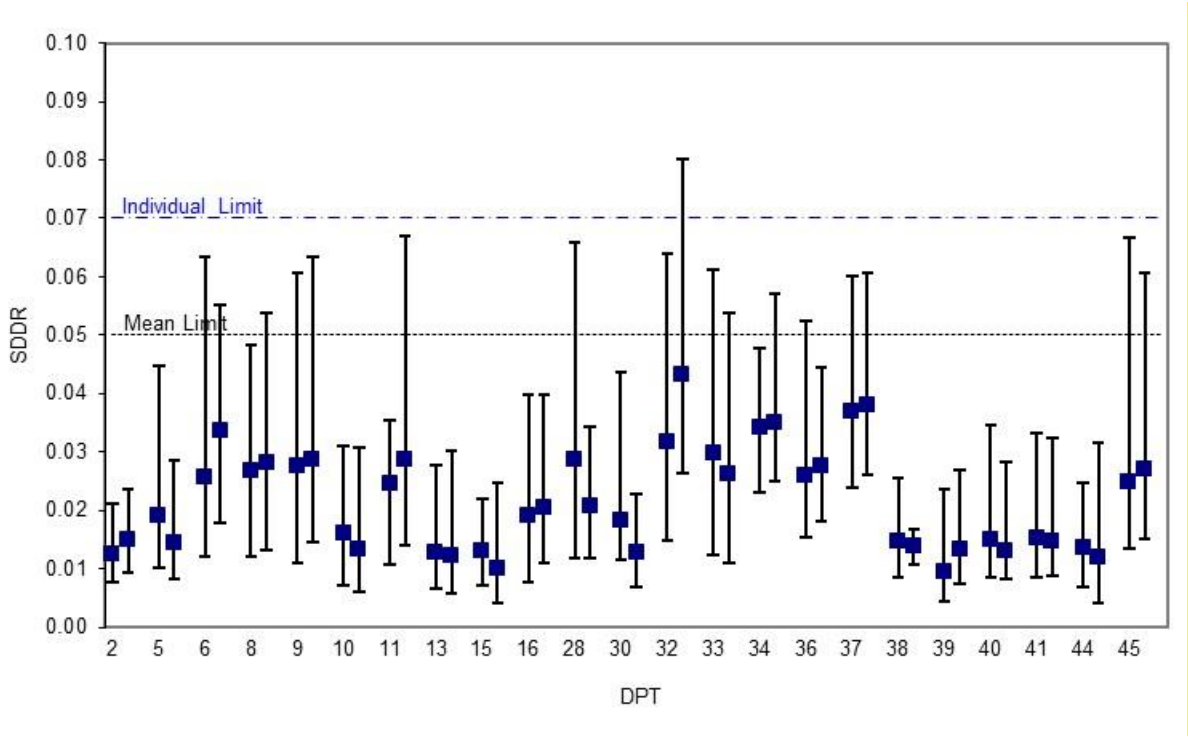

Figure 5.5 SDDR for each DPT (main trial day for laps i and ii – single data point removed)

Following the removal of a single geophone reading from one station on each lap it can be seen that the Machine 32 still does not met the trial criteria for SDDR. This was discussed with the Machine owners and the likely cause of the issue was identified by the manufacturer of the device. As Day 3 was being utilised to complete the repeatability assessment for Machine 36 (discussed in section 4.3) It was therefore decided that Machine 32 would also return on Day 3 along with some reference devices to re-do the assessment. This is further discussed in section 6.

5.3 Distance measurement tests

In order to assess the measurement of distance the measurements provided for laps 0, 1, 2 and 3 were used for each machine. The reference length was 522.82m and the criteria applied to this data are described in section 3.1. The differences between the trial data and the reference are given in Table 5.4 (negative denotes the operator recorded a shorter length). In this table the data is shown in grey if the difference measured was within or equal to 1m of the reference, and highlighted in bold and red font if the difference measured was greater than the tolerance (1% i.e. 5.23m). A machine would fail this test if it could not supply three measured lengths within the criteria.

Table 5.4 Difference between operators' measured values and reference

Machine	Difference between measured distance and reference				Performance
	Lap 0	Lap 1	Lap 2	Lap 3	
2	-0.8	0.2	-0.8	-0.8	Pass
5	0.2	0.1	0.2	0.1	Pass
6	0.2	0.3	0.2	0.2	Pass
8	-0.8	-0.8	-0.8	-0.8	Pass
9	0.2	0.2	0.2	0.2	Pass
10	0.2	0.2	0.2	0.2	Pass
11	1.2	1.4	1.3	1.3	Pass
13	0.2	0.2	0.2	0.2	Pass
15	0.2	0.2	0.2	0.2	Pass
16	1.2	1.2	1.2	1.2	Pass
28	0.2	0.2	0.2	0.2	Pass
30	0.2	0.2	0.2	0.2	Pass
32	1.2	1.2	1.2	1.2	Pass
33	1.2	0.2	0.2	0.2	Pass
34	1.2	1.2	1.2	1.2	Pass
36	1.2	1.2	1.2	1.2	Pass
37	0.0	-0.1	0.0	0.0	Pass
38	0.2	0.2	0.2	0.2	Pass
39	0.6	0.4	0.6	0.4	Pass
40	0.2	0.2	0.2	0.2	Pass
41	0.2	1.2	1.2	1.2	Pass
44	1.2	1.2	1.2	1.2	Pass
45	0.2	0.2	-0.8	0.2	Pass

It can be seen from this table that all machines met the trial criteria. In addition, 70% of the measurements were within 1m and all of the measurements were within 1.5m.

5.4 OSGR measurements (from 3-dimensional position data)

3-dimensional position data was supplied by 8 of the 23 machines at the trial. These devices all provide the data in lat/long/height format. Therefore the data has been converted to OSGR format (eastings and northings) before assessment against the criteria (given in section 3.2).

The percentage of the data within 2m, 5m and 10m for each of the machines that supplied GPS data is given in Table 5.5. This data is highlighted in bold and red text if the percentage is below 75% for any of the criteria.

Table 5.5 Assessment of positional data

Machine	Percentage of data that is within x m of the reference (horizontally)			Performance band
	2m	5m	10m	
6	69	75	79	Medium
9	100	100	100	High
30	85	94	94	High
36	9	61	98	Low
38	0	58	100	Low
39	96	100	100	High
40	98	100	100	High
44	100	100	100	High

5.5 Operator temperature measurements

The DPT operators were asked to use their own equipment to record temperatures from two pre-drilled holes so that the accuracy of temperature collection could be assessed. These holes are drilled to 100mm depth and located near stations 1 and 9. The temperatures recorded by the operators are plotted against the data recorded from the temperature data logger (located in the same hole) in Figure 5.6 and Figure 5.7.

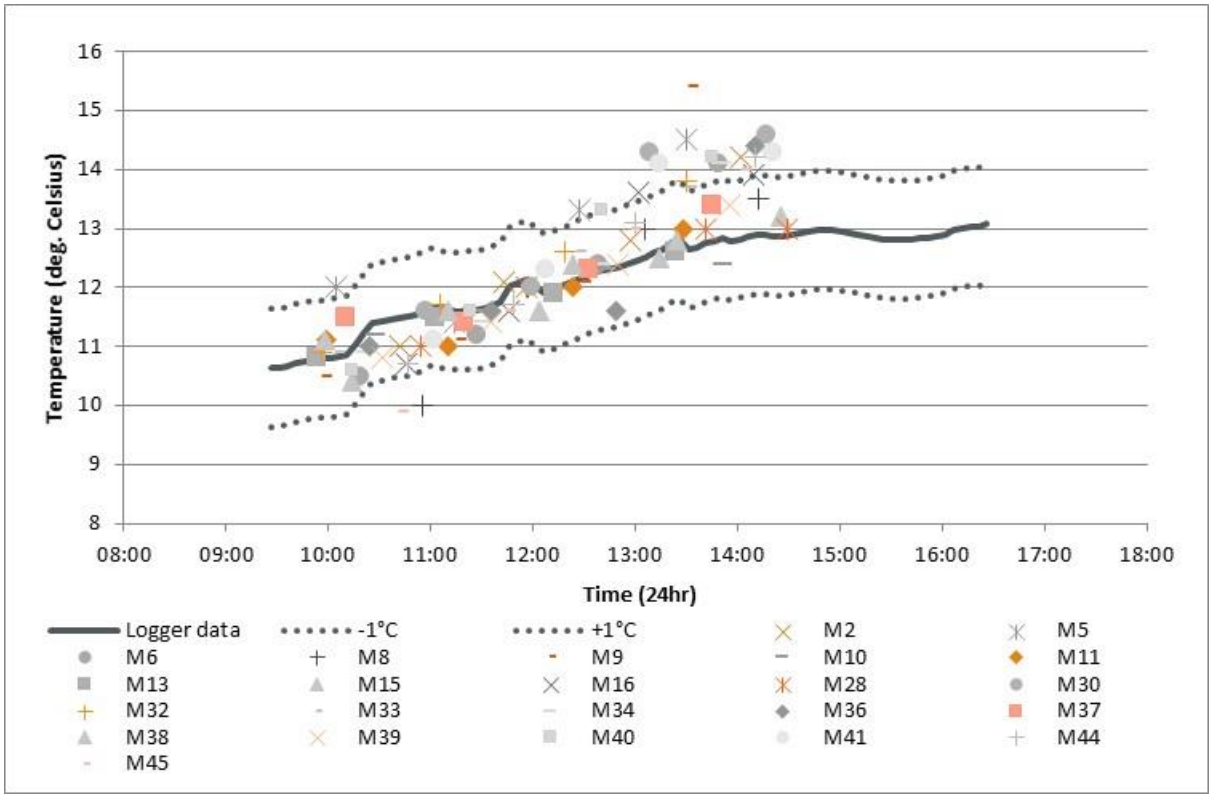

Figure 5.6 Comparison of operator's temperatures and logger temperatures (day 2 near station 1, 100mm depth)

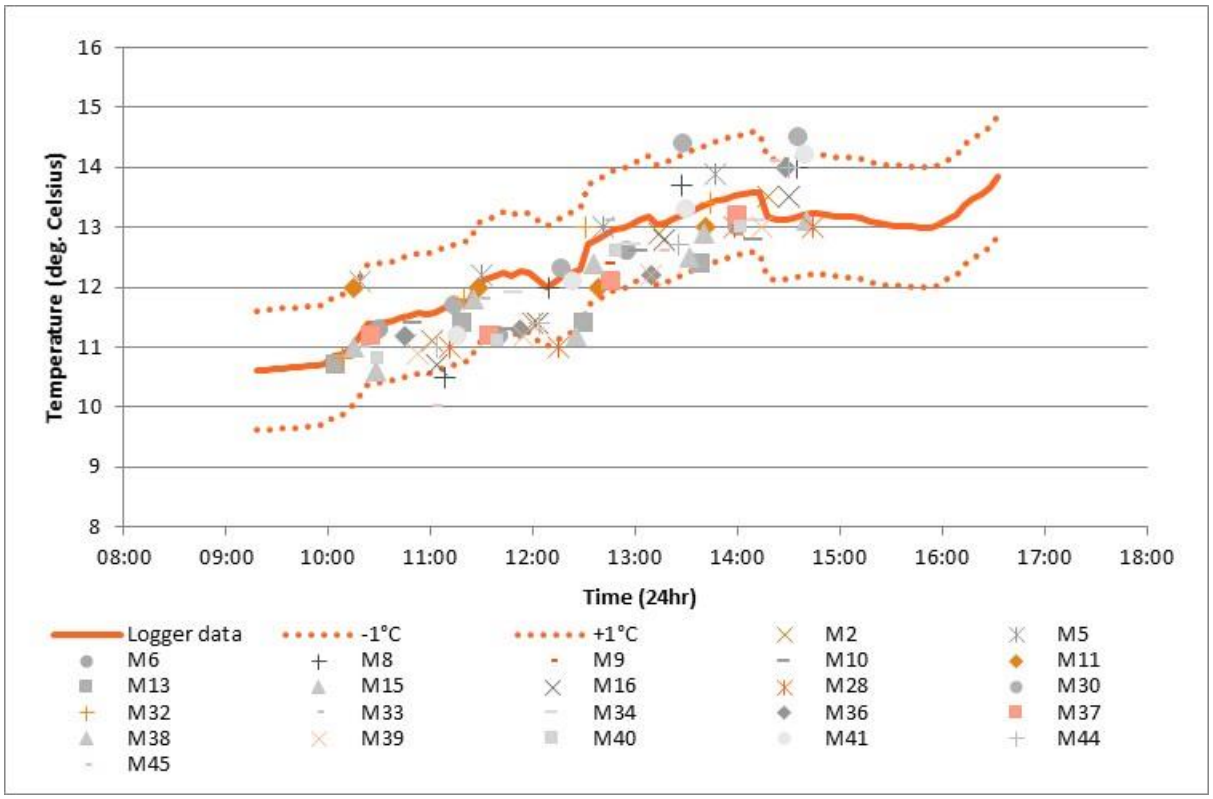

Figure 5.7 Comparison of operator's temperatures and logger temperatures (day 2 near station 9, 100mm depth)

It can be seen from these two plots that (apart from a slight upward drift at the end of the testing on station 1) the operators' measurements are generally consistent with the logger measurements. The test criteria for temperature measurement at depth are given in section 3.2, and the machines were assessed using the data from laps 0, 1, 2 and 3. The differences and ratings given are presented in Table 5.6. In the table values are highlighted in bold and red font if the value was more than 1˚C away from the reference.

Table 5.6 Assessment of operators' temperature measurement at depth (stations 1 and 9)

Machine	Difference between operators' measurement and reference data								Percentage within 1˚C	Rating
	Lap 0		Lap 1		Lap 2		Lap 3			
	1	9	1	9	1	9	1	9		
2	-0.49	-0.45	0.35	-0.84	0.40	-0.13	1.38	0.33	88%	High
5	1.20	0.92	-0.20	0.13	1.17	0.20	1.69	0.52	63%	Medium
6	-0.54	-0.10	-0.41	-0.99	0.14	-0.38	1.30	-0.52	88%	High
8	-1.54	-1.16	-0.13	-0.01	0.54	0.56	0.60	0.84	75%	Medium
9	-0.29	0.12	-0.50	-0.93	-0.03	-0.48	2.77	-0.18	88%	High
10	-0.20	-0.13	-0.01	-0.95	0.02	-0.45	-0.44	-0.79	100%	High
11	0.31	1.03	-0.63	-0.07	-0.07	-0.80	0.19	-0.33	88%	High
13	0.03	-0.14	-0.18	-0.34	-0.03	-0.90	-0.15	-0.93	100%	High
15	-0.45	-0.80	-0.43	-1.05	-0.08	-0.71	0.34	-0.10	88%	High
16	-0.79	-0.89	-0.15	-0.73	1.14	-0.23	1.04	0.38	75%	Medium
28	-0.54	-0.66	-0.08	-1.10	0.31	-0.52	0.14	-0.22	88%	High
30	-0.01	0.00	-0.13	0.20	1.79	1.19	1.70	1.34	50%	Low
32	0.13	-0.07	0.02	0.06	0.59	0.70	0.99	0.02	100%	High
33	0.10	-0.18	-0.20	-0.27	0.53	0.22	0.89	-0.18	100%	High
34	-0.33	-0.29	-0.21	-0.30	0.14	-0.35	1.30	-0.49	88%	High
36	-0.23	-0.29	-0.04	-0.90	-0.71	-0.99	1.54	0.88	88%	High
37	0.67	-0.18	-0.20	-0.93	0.10	-0.78	0.66	-0.32	100%	High
38	0.31	0.03	-0.03	0.01	0.33	-0.32	0.05	-0.43	100%	High
39	-0.63	-0.63	-0.24	-1.06	0.09	-0.99	0.56	-0.57	88%	High
40	-0.25	-0.60	-0.01	-1.09	1.04	-0.35	1.46	-0.52	63%	Medium
41	-0.58	-0.50	0.38	-0.15	1.52	0.09	1.40	1.00	75%	Medium
44	-0.81	-0.59	-0.33	-0.73	0.70	-0.44	1.34	0.88	88%	High
45	-1.59	-1.55	-0.15	-0.94	0.60	-0.43	1.18	0.93	63%	Medium

It can be seen from this table that the majority of the machines achieved the High performance rating. One machine (Machine 30) achieved a Low performance rating and a further six (Machine 5, 8, 16, 40, 41 and 45) achieved a Medium performance rating.

5.5.1 Contactless surface and air temperature measurements

There is currently in development a methodology for estimating the temperature at 100mm from measurements of the surface and air temperatures. Therefore a number of contractors have fitted sensors for the automatic measurement of air and surface temperatures to their survey devices.

Of the twenty-three machines which took part in the trial, nine machines (33, 34, 36, 37, 38, 39, 40, 44 and 45) had surface temperatures in their datasets which changed during testing (i.e. not fixed default values). The surface temperature data from station 1 for these machines is shown along with surface temperature data from the logger in Figure 5.8. The

data is repeated in Figure 5.9 with a reduced scale y axis (excluding Machine 36 which was a clear outlier).

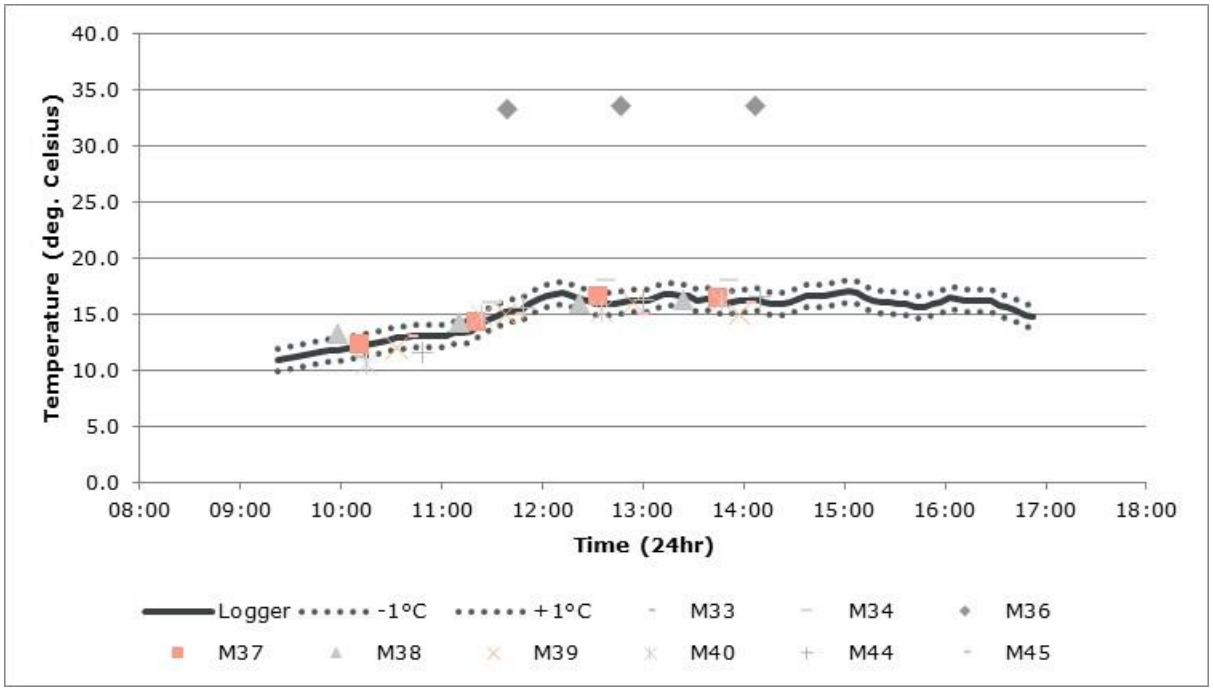

Figure 5.8 Comparison of surface temperatures recorded by DPTs and reference logger measurements

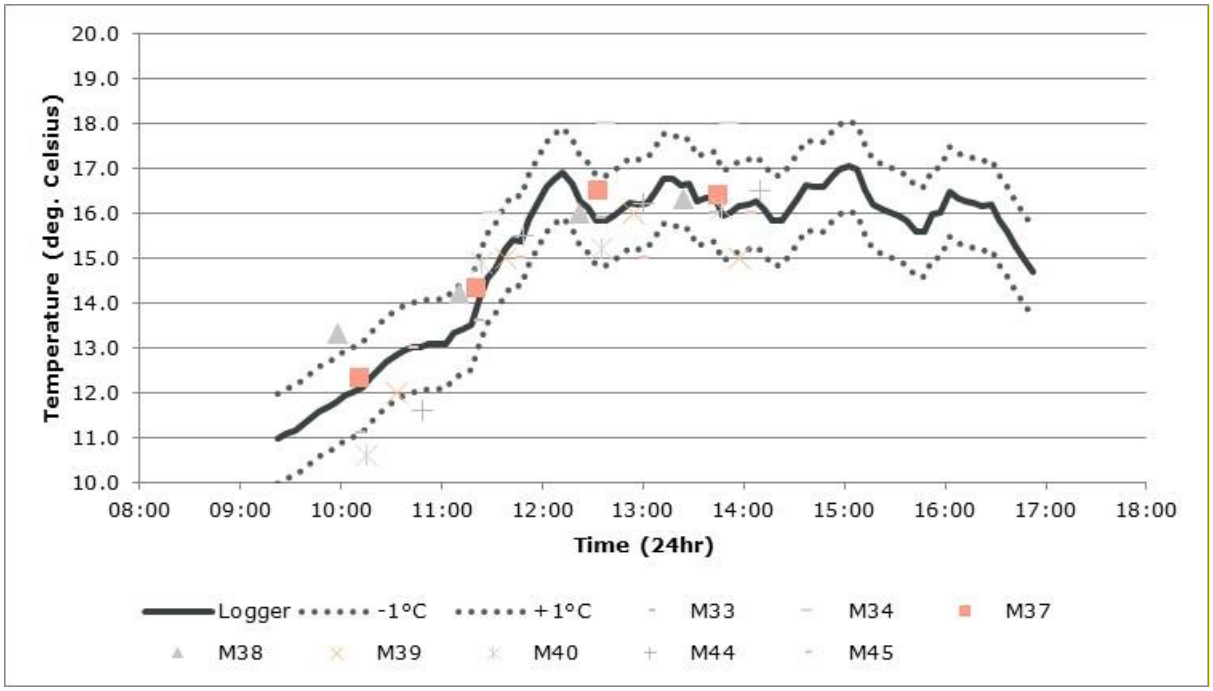

Figure 5.9 Comparison of surface temperatures recorded by DPTs and reference logger measurements

It can be seen from these graphs (Figure 5.10 and Figure 5.11) that (after excluding Machine 36) there is a good correlation between the device measurements and the reference data from the logger.

The test criteria for surface temperature measurement are given in section 3.2, and the machines were assessed using the data from laps 0, 1, 2 and 3. The differences and ratings given are presented in Table 5.7. In the table values are highlighted in bold and red font if the value was more than 1˚C away from the reference.

Table 5.7 Assessment of operators' surface temperature measurement (station 1)

Machine	Difference between operators' measurement and reference data				Percentage within 1˚C	Rating
	Lap 0	Lap 1	Lap 2	Lap 3		
33	-0.90	0.10	-0.23	-0.35	100	High
34	.	**1.45**	**2.15**	**2.08**	0	Not Suitable
36	.	**18.13**	**17.55**	**17.30**	0	Not Suitable
37	0.30	0.80	0.65	0.02	100	High
38	1.50	0.85	-0.65	-0.33	75	Medium
39	-0.85	-0.18	-0.23	-1.03	75	Medium
40	-1.53	0.83	-0.65	-0.27	75	Medium
44	-1.43	0.13	0.02	0.22	75	Medium
45	0.07	-0.40	-1.18	-0.15	75	Medium

Ten machines (6, 30, 33, 36, 37, 38, 39, 40, 44 and 45) provided air temperatures in their datasets which changed during testing. The air temperature data from station 1 for these machines is shown along with air temperature data from the logger in Figure 5.10.

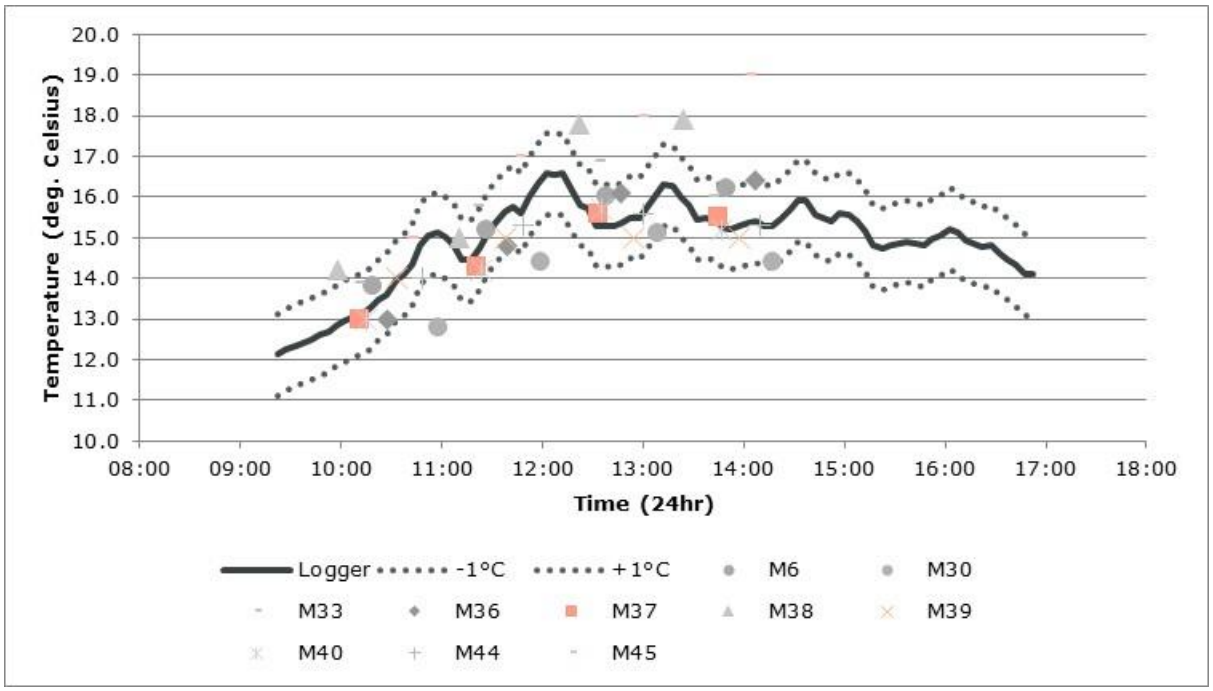

Figure 5.10 Comparison of air temperatures recorded by DPTs and reference logger measurements

Test criteria for the assessment of air temperature sensors is not included in the accreditation and QA specification. As such the data has been assessed against the surface

temperature measurement criteria (given in section 3.2), and the machines were assessed using the data from laps 0, 1, 2 and 3. The differences and ratings given are presented in Table 5.7. In the table values are highlighted in bold and red font if the value was more than 1˚C away from the reference.

Table 5.8 Assessment of operators' air temperature measurement (station 1)

Machine	Difference between operators' measurement and reference data				Percentage within 1˚C	Rating
	Lap 0	Lap 1	Lap 2	Lap 3		
6	0.52	0.47	0.70	0.95	100	High
30	-2.33	-1.95	-0.92	-0.90	50	Low
33	0.85	1.35	1.18	0.50	50	Low
36	-0.47	-0.82	0.83	1.05	75	Medium
37	-0.05	-0.15	0.30	0.05	100	High
38	1.35	0.18	1.65	1.90	25	Low
39	0.05	-0.63	-0.50	-0.23	100	High
40	-0.13	-0.53	0.40	-0.25	100	High
44	-0.83	-0.30	0.12	-0.10	100	High
45	0.90	1.23	2.53	3.73	25	Low

Currently the air and surface measurements are assessed at one point of the test track and therefore only 4 assessments are made at the trial (one on each lap). It is recommended that at future trials a second logger set of air and temperature measurements are taken allowing two assessments to be made each lap to make this test consistent with the temperature at depth test.

6 Results – Day 3

As discussed in section 5.2.2 at the end of the testing on day 2 it was identified that Machine 32 was not meeting the SDDR criteria. The cause was identified by the manufacturer of the device and because day 3 was being utilised to complete the repeatability assessment for Machine 36 (discussed in 4.3) and the manufacturer was confident that the issue would be resolved it was decided that Machine 32 would be reassessed. For this reassessment Machines 15, 28, 33, 39, 40, 41 and 44 were also present to provide the reference dataset. The results from these tests are presented in Figure 6.1 and Figure 6.2.

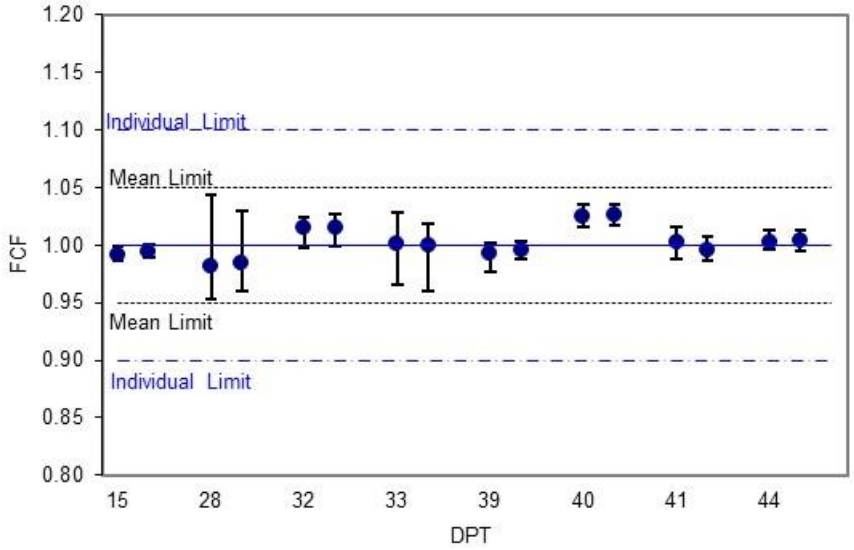

Figure 6.1 FCF for each DPT (day 3 for laps i and ii – full data set)

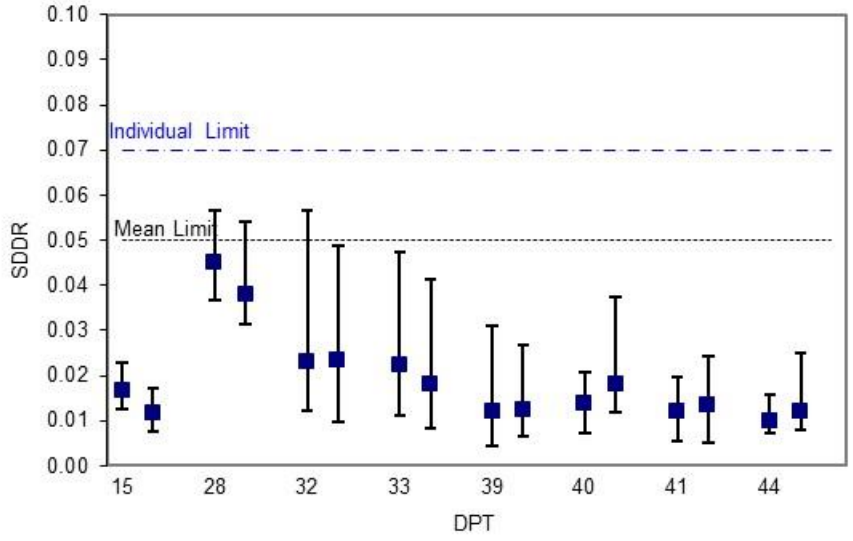

Figure 6.2 SDDR for each DPT (day 3 for laps i and ii – full dataset)

From these figures it can be seen that Machine 32 met the FCF and SDDR criteria using the full dataset on day 3.

7 Summary of trial findings

The 2016 UK DPT accreditation trial was held at MIRA on the 4th and 5th October 2016. Twenty-three machines took part in the trial. The key findings of the trial are as follows:

- All twenty-three machines met the mandatory trial requirements for the Repeatability assessment.
- All twenty-three machines met the mandatory trial requirements for the average and individual geophone Field Calibration Factors (FCF).
- All twenty-three machines met the mandatory trial requirements for the average and individual geophone Standard Deviation of the Deviation Ratio (SDDR).
- All twenty-three machines met the mandatory trial requirements for elapsed distance measurement.
- Eight machines provided GPS data. The machines were only assessed for horizontal reproducibility and five achieved a high rating, one a medium rating and two a low rating.
- All Twenty-three machines provided temperature measurements at depth. Sixteen achieved a high rating, six a medium rating and one a low rating.
- Nine machines provided surface temperature measurements. Two machines achieved a high rating, five a medium rating, and two a “not suitable” rating.
- Ten machines provided air temperature measurements. Five machines achieved a high rating, one a medium rating, and four a low rating.

In summary, all twenty-three machines that participated in the 2016 accreditation trial fully met the mandatory requirements of the trial.

The outcome of the trial for each machine, against both the mandatory and non-mandatory criteria, is summarised in Appendix G.

The air and surface temperature assessment was undertaken using one set of loggers (i.e. each machine was assessed once per lap). It is recommended that in future trials a second logger set be set-up so that the machines are assessed twice per lap to make these assessments consistent with the temperature at depth assessment.

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Acknowledgements

The author wishes to thank the operators of the DPT devices for their co-operation in the accreditation process. Particular thanks to the operators that took part on day 3 of the trial to aid the assessment of the machine which did not meet the criteria on day 2. The author is also grateful to David Gershkoff who carried out the technical review of this report, and to Nick Lindley, Christopher Torkington and Patrick Werro for their assistance with the trial.

Appendix A Machine details table

ID	Owner	Make, model and serial number	Trailer or vehicle mounted?	No of weights / buffers per side	Plate type	Date of last tower calibration	Date of last dynamic calibration	Date of last manufacturer calibration
2	AECOM Ltd.	Dynatest FWD 8002 SN 102	Trailer	6/3	Solid plate	Purchased July 2016	03/10/2016	Sept 2016
5	AECOM Ltd.	Dynatest HWD 8082 SN 050	Trailer	2/5	2-way segmented	09/02/2016	03/10/2016	Sept 2016
6	PMS Ltd.	Dynatest HWD 8082 SN 018	Trailer	1/5	Solid plate	27/04/2016	01/09/2016	Sept 2016
8	AECOM Ltd.	Dynatest FWD 8002 SN 028	Trailer	6/3	2-way segmented	11/02/2016	03/10/2016	Sept 2016
9	PMS Ltd.	Dynatest FWD 8002 SN 136	Trailer	4/2	2-way segmented	22/07/2016	22/07/2016	Sept 2016
10	AECOM Ltd.	Dynatest FWD 8002 SN 192	Trailer	6/3	2-way segmented	16/02/2016	03/10/2016	Sept 2016
11	Forth Crossing Bridge Constructors JV	Dynatest FWD 8002 SN 187	Trailer	3/1	Solid plate	25/07/2016	25/07/2016	25/07/2016
13	AECOM Ltd.	Dynatest HWD 8082 SN 029	Trailer	2/5	Solid plate	09/02/2016	03/10/2016	Sept 2016
15	CET Infrastructure	Dynatest FWD 8002 SN 203	Trailer	6/3	2-way segmented	20/06/2016	20/06/2016	20/06/2016
16	PTS	Dynatest FWD 8002 SN 214	Trailer	5/2	2-way segmented	19/09/2016	19/09/2016	19/09/2016

ID	Owner	Make, model and serial number	Trailer or vehicle mounted?	No of weights / buffers per side	Plate type	Date of last tower calibration	Date of last dynamic calibration	Date of last manufacturer calibration
28	Pulse Surveying Ltd.	Dynatest FWD 8002 SN 271	Trailer	4/2	Solid plate	21/04/2016	28/09/2016	05/08/2016
30	PMS Ltd.	Dynatest FWD 8002 SN 173	Trailer	5/2	Solid plate	31/08/2016	23/09/2016	26/05/2016
32	PTS	Dynatest HWD 8082 SN 069	Trailer	1/2	4-way segmented	28/09/2016	28/09/2016	28/09/2016
33	PTS	Dynatest HWD 8082 SN 070	Trailer	1/2	4-way segmented	20/09/2016	20/09/2016	20/09/2016
34	PTS	Dynatest HWD 8082 SN 108	Trailer	1/2	4-way segmented	22/09/2016	22/09/2016	22/09/2016
36	Testconsult Ltd.	Grontmij PRI 2500 0608-303	Trailer	3/4	4-way segmented	20/05/2016	18/12/2015	25/11/2015
37	Stanger Testing Services	Dynatest FWD 8002 SN 352	Trailer	6+1/3	4-way segmented	20/09/2016	20/09/2016	16/09/2016
38	Milestone Pavement Technologies	Grontmij PRI 1500 1111-448	Trailer	3/4	4-way segmented	22/09/2016	26/09/2016	22/09/2016
39	TRL	Dynatest FWD 8002 SN 388	Trailer	6/3	segmented	22/09/2016	19/09/2016	March 2016
40	Dynatest	Dynatest FWD 8012 SN 002	Trailer	0/4	4-way segmented	03/10/2016	03/10/2016	03/10/2016
41	ALC (MoD)	Dynatest HWD 8082 SN 108	Trailer	0/4	4-way segmented	23/09/2016	23/09/2016	23/09/2016

ID	Owner	Make, model and serial number	Trailer or vehicle mounted?	No of weights / buffers per side	Plate type	Date of last tower calibration	Date of last dynamic calibration	Date of last manufacturer calibration
44	Dynatest	Dynatest HWD 8082 SN 156	Trailer	0/4	4-way segmented	03/10/2016	03/10/2016	03/10/2016
45	Atlas Geophysical	Grontmij Carlbro PRI2100 0903-088	Trailer	5/4	Solid plate	15/06/2016	None	15/06/2016

Appendix B Example photographs

Figure B.1 Dynatest 8002 FWD

Figure B.2 Dynatest 8082 FWD

Figure B.3 Grontmij Primax 2100 HWD

Figure B.4 Grontmij Primax 1500 HWD

Appendix C Construction details for Highways England reference site at MIRA proving ground

Table C.1 Design construction of Highways England reference site

Section	Test points	Nominal construction details and material type (mm)				
		Surface course	Binder course	Base	Total asphalt thickness [mm]	Sub-base
1	1-3	30 TSC	235 EME2		270	200mm C8/10 HBM
2	4-6	35 TSC	170 DBM		200	250mm 6F1 granular capping material
3	7-9	30 TSC	170 EME2		200	200 Type 1 granular material
4	10-12	35 TSC	35 Axo	230 JRC	70	150-175 Hoggin
Notes	TSC = Cl 942 Thin Surface Course EME2 = Enrobé à Module Élevé, DBM = Dense Bitumen Macadam, Axo = Axoshield, HBM = Hydraulically Bound Material, JRC = Jointed reinforced concrete, 6F1 = Selected granular capping.					

Table C.2 Construction details of Highways England reference site from cores

Section	Test points	Post Construction Results from cores (mm)			
		Surface course	Binder/ Binder+ base courses	Total asphalt thickness [mm]	Base/Sub-base (mm)
1	1-3	42 TSC	228	270	217 (HBM sub-base)
2	4-6	37 TSC	158	192	-
3	7-9	35 TSC	191	226	-
4	10-12	30 TSC	36 Axo	66	194 (JRC base)
Notes	TSC = Cl 942 Thin Surface Course , HBM = Hydraulically Bound Material, JRC = Jointed reinforced concrete, Axo= Axoshield				

Table C.3 Construction details of Highways England reference site from GPR

Section	Test points	Post Construction layer information results from GPR (in mm)			
		Minimum	Average	Maximum	Material
1	1-3	192 166 388	242 188 431	272 215 468	Asphalt HBM Total bound thickness
2	4-6	167	192	240	Asphalt
3	7-9	167	199	240	Asphalt
4	10-12	47	65	76	These results are for the bitumen-bound surfacing. No lower GPR trace due to steel reinforcement.
Notes	HBM = Hydraulically Bound Material				

Appendix D Dynamic Plate Test device 2016 Accreditation trial – instructions to operators

The 2016 Dynamic Plate test (DPT) accreditation trial is carried out as a prerequisite to operating FWD and HWD devices under Highways England contracts. The objective of the trial is to identify machines that produce results within a specific tolerance of the fleet average. The trial has been designed to ensure that the results of the trial are scientifically robust, and impartial. This document acts as an outline to the trial and provides operators with instructions for the trial activities. All trial attendees must read and understand this document before attending the trial.

D.1 Prior to trial

D.1.1 Machine checks and Inspection sheets

Please perform your QA checks, routine inspections and any other relevant checks for your machine to reduce the chances of any issues occurring during the trial. The QA procedure for DPT devices operating on Highways England's road network is given in "Accreditation and Quality Assurance of Dynamic Plate Test Devices" available on the RCMG web site (http://www.ukroadsliaisongroup.org/en/asset-condition/road-condition-information/data-collection/dynamic-plate-test-devices-dpt.cfm).

You will also be supplied with inspection sheets which will need to be completed and returned to the Auditor prior to the trial. These sheets will form the basis of the machine inspections conducted on day 1 of the trial.

D.1.2 Geophone positions and machine set up

The operation of the DPTs will be as described in HD29/08 of the DMRB using the flexible and flexible composite set up (i.e. geophones at 0, 300, 600, 900, 1200, 1500 and 2100).

Please make sure that your geophones are in the correct positions prior to arrival. In addition please ensure that only the data from these seven geophones will be present in your F20/F25 files (and the geophones are in the correct order).

Further details on machine set-up can be seen in Appendix B.

D.1.3 Preparation for Repeatability testing

The Repeatability testing part of the trial (on day 1) requires the application of loads of 50±5kN with load targeting or "seeking" turned **off**. Therefore it may be necessary for crews to carry out some initial tests prior to the trial to identify the test procedure/test settings to achieve this result. If the average load for the drops is not 50±5kN then the machine will be deemed to have failed the repeatability criteria.

D.1.4 Trial attendee names

To make accessing the MIRA site as smooth as possible please provide the names of all persons (and registrations of all vehicles) attending the trial as soon as possible before the trial. These will be passed to MIRA security and used to produce yellow test track access permits.

D.2 Trial Outline

The trial will last for **2 days** and takes place between the **4th and 5th of October 2016**. The morning of the **6th October may also be required as a contingency for bad weather** or other unforeseen circumstances.

The trial activities have been split as follows:

- **Day 1** – Machine inspection, distance calibration, a pre-main testing Reproducibility lap and Repeatability testing (2 laps).
- **Day 2** – Reproducibility laps (at least 4 laps).
- **Day 3** – Contingency day.

D.3 General requirements during trial

D.3.1 Safety briefing

On the morning of each day a safety briefing will be given detailing the site rules. If any of these rules are broken then trial marshals will give **one** verbal warning to relevant parties. **If the behaviour persists then the relevant parties will be escorted from the site and they will not be able to take part in the remainder of the trial**.

D.3.2 Cameras

Please note MIRA **do not allow cameras on site** without prior written consent. Any cameras will have to be left at the gatehouse, camera phones have to be declared and (tamper proof) stickers will be placed over the camera lens (so as to allow the phones to be used). **Any person found to be in conflict with these rules will be immediately evicted from the site**.

D.3.3 Smoking

Smoking is not permitted anywhere on the MIRA site.

D.3.4 Escorting of vehicles and moving around the site

Escorting of vehicles around the proving ground by trial marshals is essential. It is therefore important that particular care is taken when moving around the site. In addition MIRA require vehicle headlights to be switched on whenever you are moving around the test track.

D.3.5 Speed limits on site and PPE

The nature of DPT testing means that there will often be staff walking around the test sections. Therefore a **10 mph speed restriction will be imposed for the test lengths**. The

extent of the site which will have this speed restriction in place will vary depending on the testing being conducted and will be described in the test description parts of this document. If you are unsure of the extents of the restriction please ask a trial marshal.

All staff must wear high visibility tops when walking on the twin straights or in the manoeuvres area.

D.3.6 Data format, GPS and automatic temperature measurement

Survey data should be supplied as ".F20" or ".F25" files, further details on naming conventions for the trial can be found in Appendix C.

If your device has an integrated GPS system and/or contactless sensors for measurement of air and surface temperature at each test point then please have these devices switched on and recording at each test location during the test laps. Location information should be provided in OSGR format and must correspond to the centre of the loading plate. The system must be capable of providing all results in the F20/F25 file.

D.4 Day 1 (Tuesday 4th October) - Machine inspection, distance calibration and initial testing

D.4.1 Arrival at MIRA

Please arrive at the MIRA site by 09:00, directions to MIRA are provided in Appendix A.

On arrival, MIRA security should ask you to move onto the manoeuvres area and then return (on foot) to the gatehouse to sign in, get a sticker on your camera phone and receive a pass for the week. After you have done this please see the trial marshal in the welfare van. Here you shall be asked to sign a log in sheet and will be given a USB data stick and participant pack with machine numbers and the necessary paperwork.

Please read all the paperwork. An introductory briefing will be given once all machines have arrived.

Figure 1: Access to MIRA

D.4.2 Machine inspections

Machine inspections of the devices will be carried out on a "first come first served basis" and may take place before or after the introductory briefing (depending on arrival times). The machine inspections will follow the format of the machine check list supplied prior to the trial (see section 1.1).

During this time your temperature probe will also be collected for the "water bucket" test. The "water bucket" test involves allowing the collected temperature probes to equalise to the same temperature (using a water bucket or similar). Any differences in the reported measurements will be noted and fed back to the operators and used to aid advice on any low performance in the temperature measurements on the main trial day. Note: the water bucket test is for additional information and will not have any test criteria attached to it. The temperature probes will be returned after the initial reproducibility test lap, therefore please **make sure that your temperature probe has a suitable identifying mark** so that you can identify which one is yours when collecting the device. If your temperature probe is part of the DPT and cannot be separated, please notify the Trial Marshal who will arrange for the temperature probe to be checked at the end of the inspection day.

D.4.3 Distance calibration

Once the inspections have been completed you will be escorted to the twin straights by an escort vehicle. When the escort vehicle stops on the twin straights, stop behind them (the blue area in Figure 2).

When clear to do so please conduct your distance calibration using the cones A and B which are 400m apart. After completion of the distance calibration proceed to the holding area as shown in Figure 2. If you had an issue with your distance calibration and need to repeat it, please drive round to the queue (the blue area in Figure 2) and repeat the calibration when clear to do so.

During this testing a 10mph speed limit will be in place on the outward bound side of the track (i.e. the side with the A and B cones on it).

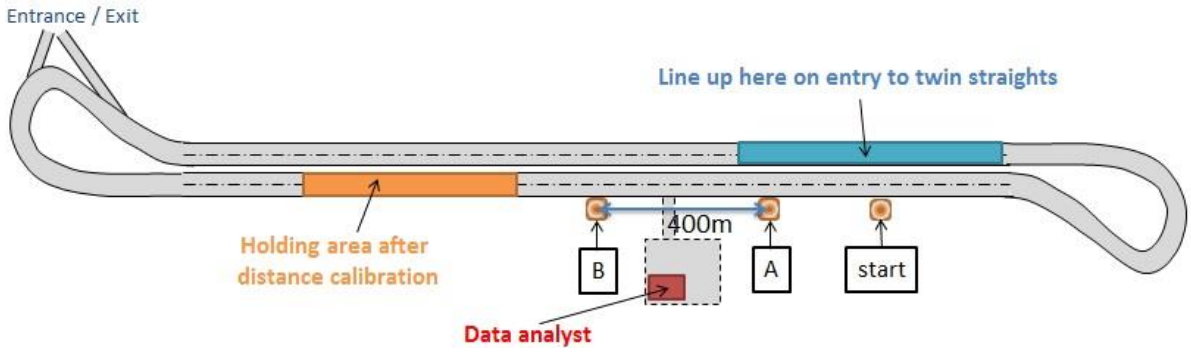

Figure 2: Distance Calibration

D.4.4 Initial Reproducibility test (stations 1-12)

Once all distance calibrations have been conducted, a Trial Marshal will clear you to undertake one Reproducibility lap of the test track.

The **reproducibility** testing is as follows:

- 5 drops at stations 1 to 12
- 50±5kN load
- Load targeting ("seeking") may be used
- Filename: MMFAM.F20 or MMFAM.F25, where: MM = Machine Trial Number (see Appendix C)

Once you have completed the lap please stop in the new holding area as shown in Figure 3 and hand in your data to the Data Analyst (located in the welfare van as shown in Figure 3). Note this data will not form part of the trial data and is instead used to help identify major issues. This data will be processed during the repeatability testing and you will be notified if any large anomalies become apparent.

During this testing a 10mph speed limit will be in place on the outward bound side of the track (i.e. the side with the cones 1-12 on it).

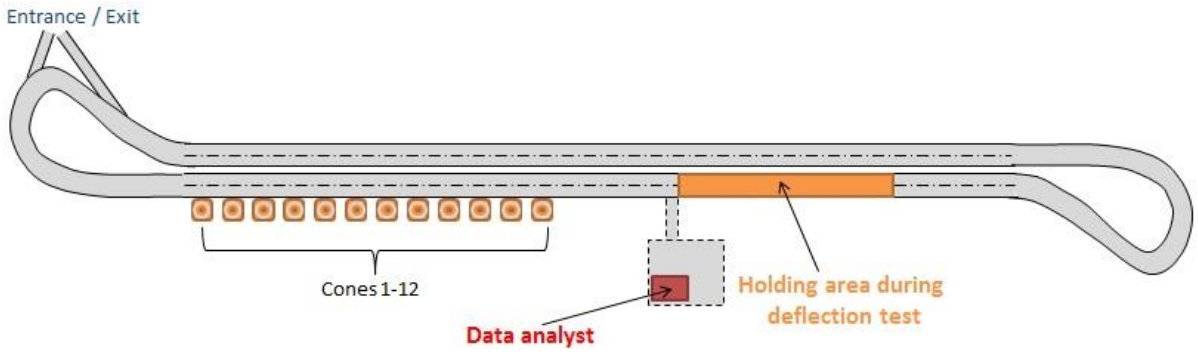

Figure 3: Initial Reproducibility lap

D.4.5 Repeatability (stations 2, 5, 8 and 13)

When you have supplied your data from the reproducibility lap please carry out two repeatability test passes when instructed to do so.

During this testing a 10mph speed limit will be in place from the start cone to cone 13 (excluding the banked bend).

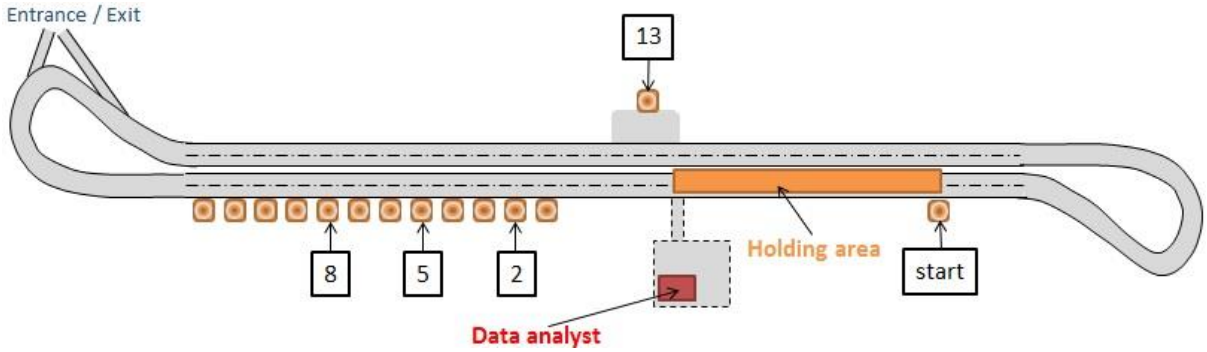

Figure 4: Repeatability lap

The **repeatability** testing is as follows:

- 12 drops at stations 2, 5, 8 and 13
- 50±5kN load

- Load targeting ("seeking") may **not** be used
- Filename: MMREPEAT.F20 or MMREPEAT.F25, where: MM = Machine Trial Number (see Appendix C)

On completion of each repeatability test stop in the holding area (orange area in Figure 4) and hand in your data to the data analyst.

Once you have completed your second repeatability lap and handed in your data, the marshal will then inform you if any issues have been identified from the reproducibility data (stations 1-12) and clear you to leave the site (unless an additional pass is required).

D.5 Day 2 (Wednesday 5th October) – Main test day

Please **arrive at the MIRA site by 08:30**. If any issues with your machine were highlighted after the first day please make sure they are fully rectified before this time.

On arrival, MIRA security should let you onto the manoeuvres area. If you have removed the sticker from your camera phone then you will need to return to the gatehouse to get a new one.

When you arrive in the manoeuvres area please see the trial marshal to sign the log in sheet.

After the morning briefing you will be escorted to the twin straights. Stop in the holding area as shown in Figure 5.

During this testing a 10mph speed limit will be in place from the start cone to cone B (excluding the banked bend).

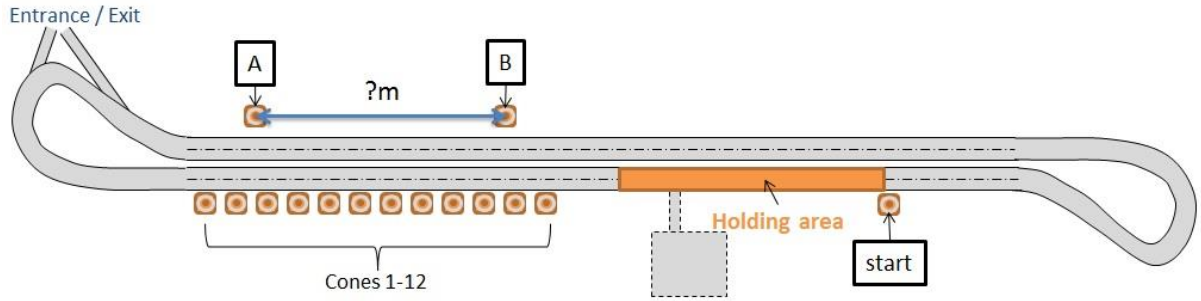

Figure 5: Main day testing

Once you have been cleared for testing, conduct a warm-up lap followed by 3 test laps. This reproducibility testing is as follows:

- Testing at stations 1 to 12
- 5 drops at each of the twelve stations
- 50±5kN load
- Load targeting ("seeking") may be used
- Filename: MMLLACC.F20 or MMLLACC.F25, where: MM = Machine Trial Number and LL = Run number (see Appendix C)
- Temperatures collected using the 100mm depth supplied holes (near cones 1 and 9)
- Distance between A and B measured

After the Deflection testing (cones 1-12) p**lease measure the distance between A and B on each lap**. This should be done by doing a test drop at cone A and then move up to cone B (recording the distance) and do a test drop at cone B. The distance measured should be written on the run log sheet and the file saved as MMLLDist.F20 or MMLLDist.F25, where: MM = Machine Trial Number and LL = Run number (see Appendix C)

Hand in all of this data to the Data Analyst after completion of each run

After completion of the laps and initial processing of the test data, you will be notified if additional laps are required.

D.6 Day 3 (Thursday 1st October) –Contingency day

The format of the contingency day will depend on what additional testing is required. It is likely to involve some combination of days 1 and 2. If the contingency day is required, then a plan will be constructed and you will be notified of what is required.

D.7 Reporting of results

The required criteria for receiving accreditation are laid out in the document “Accreditation and Quality Assurance of Dynamic Plate Test Devices”.

The reporting of trial results will be implemented as below:

- End of trial day 1 – Operators shall be informed if any machine is producing values which indicate a serious machine fault, such as a component failure.
- End of trial day 2 – Operators shall be informed of initial findings and if the contingency day is required.
- Within one week of the trial – Operators will be informed via e-mail whether their machine is an outlier with regards to reproducibility measurements.
- Within 2-3 weeks of the trial - Trial certificates will be e-mailed. These certificates will detail the pass/fail status of the machine with regards to each of the trial criteria.

D.8 Appendix A Directions to MIRA

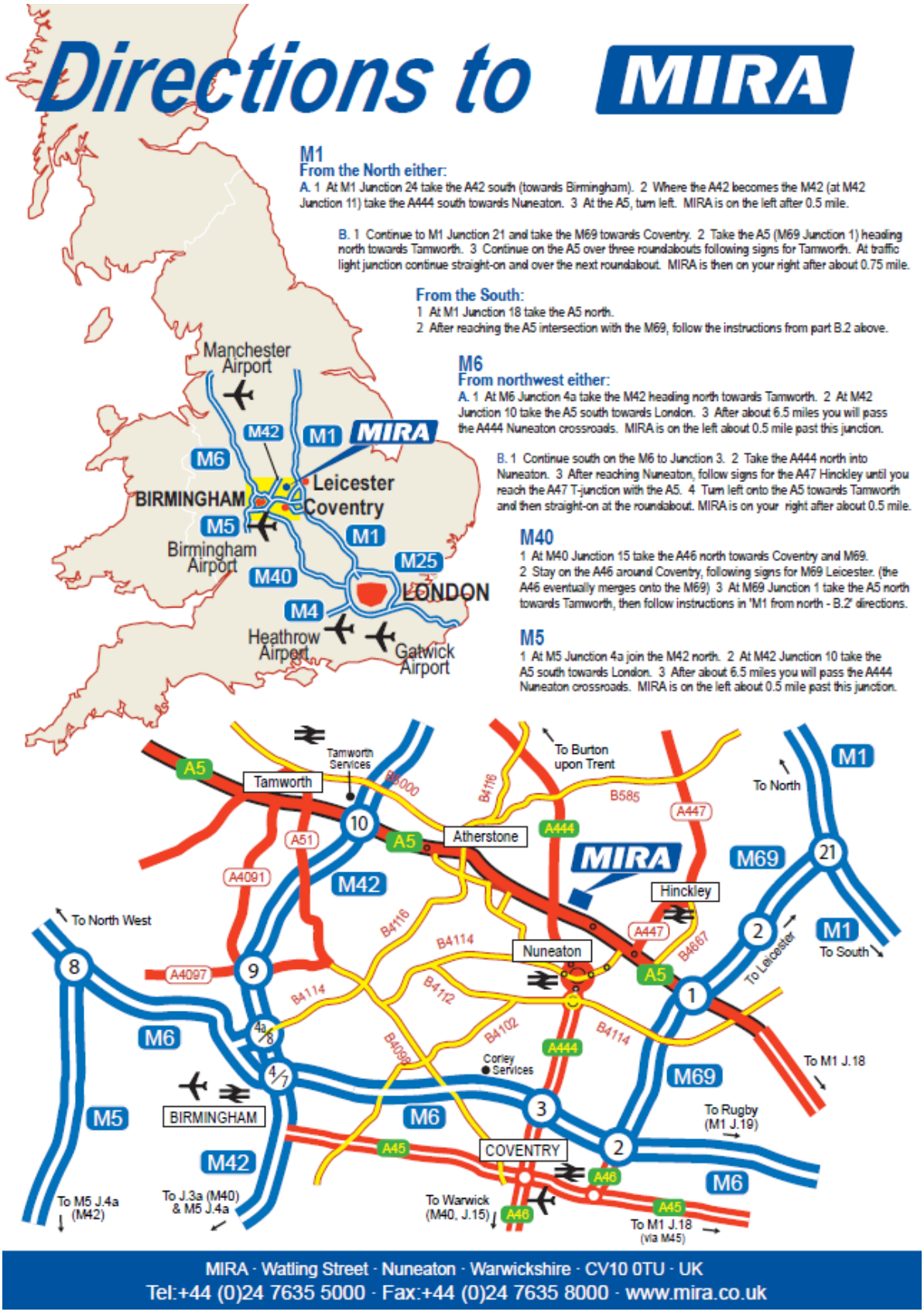

Figure 6: MIRA location

D.9 Appendix B DPT set-up

Please ensure that your machine is set up as follows:

- geophone spacings: 0, 300, 600, 900, 1200, 1500 and 2100mm **only**;
- standard 300mm diameter plate.
- it is recommended that a rear extension bar is **not** fitted

All testing will take place at the standard load of **50kN** and we strongly recommend that if you have a smoothing facility, you activate it.

Please ensure that time histories are recorded for all tests. You will be provided with a suitably-sized USB stick for delivery of data for processing.

To facilitate the analysis of the data, data should be provided in standard metric ".F20" or ".F25" format.

Please ensure you bring along a calibrated temperature probe capable of measuring to a pavement depth of 100mm.

The accuracy of the location referencing of your machine will be assessed. Please ensure the DMI or odometer (and GPS system if fitted) is working correctly.

These DPT set-up requirements are summarised as follows:

Number of geophones	7 only
Geophone spacing	300mm
Load plate	300mm diameter
Load	50kN
Smoothing (if available)	ON
Extension bar	Removed
Data output	Standard metric
Time history data	To be recorded

Repeatability Testing

The Repeatability Testing will require 12 drops at each of 4 marked test stations. Only the last 10 drops will be used in the analysis. Load targeting ("seeking") may **NOT** be used for this phase of the testing.

Please ensure that the DPT is suitably configured for this test arrangement.

Reproducibility Testing (Including Familiarisation Lap)

The Reproducibility Testing (and check lap) will require 5 drops at each of 12 marked test stations. Only the last 4 drops will be used in the analysis. Load targeting ("seeking") may be used.

Please ensure that the DPT is suitably configured for this test arrangement.

D.10 Appendix C Naming format for data files

Please note the requirements are different for different aspects of the accreditation trial

Day 1

Familiarisation Lap: *One lap, 12 stations, 5 drops per station. Seek allowed.*
Results will be saved as a separate data file defined as follows: **Filename: MM**FAM.F20 Where: ***MM*** **=** Machine Trial Number
Each test point/station within the file has a letter S (S = 1-12). Each station tested will be labelled using the numeric or chainage setting facility of the DPT software.
EXAMPLE: Machine 9, Familiarisation Lap should be saved as: **09FAM.F20**

Repeatability Test: *One lap, four stations, 12 drops per station. No seek to be used.*
Results will be saved as a separate data file defined as follows: **Filename: *MMLL***REPEAT.F20 Where: ***MM*** **=** Machine Trial Number and ***LL*** **=** Run number
Each test point/station within the file has a letter **S** (S = 2, 5, 8 or 13). Each station tested will be labelled using the numeric or chainage setting facility of the DPT software.
EXAMPLE: Machine 7, first Repeatability lap should be saved as: **0701REPEAT.F20**

Day 2

Main Accreditation Trial*: Minimum 4 laps, 12 stations, 5 drops/ station. Seek allowed.*
Deflection Results *from each lap* will be saved as a separate data file according to the following naming format: **Filename: *MMLL***ACC.F20 Where: ***MM*** **=** Machine Trial Number, and ***LL*** **=** Run number
Run Numbers Warm up lap: 00 Lap 1: 01 Lap 2: 02 Lap 3: 03 …etc
Each test point/station within the lap has a letter S (S = 1 to 12). Each station tested will be labelled using the numeric or chainage setting facility of the DPT software.
EXAMPLE: Machine 2, lap 1 should be saved as: **0201ACC.F20**

Distance assessment: *On each main trial lap until told to stop.*
Perform a drop at cone A and the move to cone B (recording the distance) and perform a drop at cone B, Results will be saved as a separate data file defined as follows: **Filename:** ***MMLL***Dist.F20 Where: **MM =** Machine Trial Number, and **LL =** Run number
EXAMPLE: Machine 29, first distance measurements should be saved as: **2901Dist.F20**

Appendix E Repeatability trial data

Data is highlighted in bold red text if it does not meet the criteria (for a valid test or for the assessment). Laps not used in the assessment are shown in itallics and grey text (apart from the data points which exceed the criteria).

E.1 Machine 2

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	718.0	0.2%	73	62	55	48	41	35	24	0.3	0.6	0.7	0.3	0.4	0.3	0.2
	5	699.6	0.2%	482	386	246	147	85	52	31	0.8	0.4	0.3	0.1	0.3	0.2	0.3
	8	704.9	0.2%	244	215	173	130	95	68	34	0.5	0.5	0.5	0.2	0.2	0.3	0.4
	13	712.2	0.2%	124	109	96	77	64	51	31	0.3	0.1	0.9	0.5	0.2	0.2	0.6
2	2	723.1	0.3%	72	62	55	48	41	35	24	0.3	0.2	0.1	0.1	0.2	0.1	0.3
	5	703.3	0.2%	460	369	243	146	85	52	32	1.4	0.6	0.5	0.2	0.1	0.2	0.3
	8	710.3	0.3%	247	216	175	131	96	68	35	0.3	0.3	0.2	0.2	0.2	0.2	0.2
	13	717.4	0.2%	123	110	95	78	64	51	33	0.2	0.3	0.6	0.6	0.3	0.2	1.2

E.2 Machine 5

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	739.4	1.3%	75	66	58	51	44	37	26	0.9	0.7	0.6	0.6	0.5	0.5	0.6
	5	715.9	1.3%	498	410	266	157	93	55	30	**4.7**	4.0	2.6	1.7	1.1	0.8	0.6
	8	701.5	1.1%	263	233	188	141	105	74	38	2.2	2.0	1.5	1.2	0.9	0.8	0.5
	13	718.9	1.1%	130	117	101	83	68	55	32	1.6	1.0	0.8	0.7	0.6	0.5	0.6
2	2	744.4	0.4%	75	65	58	50	44	37	25	0.5	0.5	0.5	0.5	0.6	0.4	0.5
	5	716.5	0.7%	505	414	267	157	94	54	33	3.4	2.9	2.1	1.3	0.8	0.5	0.7
	8	715.1	1.1%	262	232	187	140	104	73	38	2.1	1.9	1.8	1.2	0.9	1.0	0.3
	13	711.4	0.6%	130	116	99	82	67	54	33	0.7	0.7	0.5	0.4	0.3	0.4	0.4

E.3 Machine 6

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	*2*	*706.2*	*0.5%*	*62*	*54*	*48*	*42*	*36*	*31*	*21*	*0.6*	*0.2*	*0.3*	*0.2*	*0.4*	*0.1*	*0.3*
	5	*688.3*	*0.7%*	*440*	*357*	*235*	*143*	*85*	*56*	*34*	*2.6*	*1.9*	*1.5*	*1.6*	*1.6*	*0.8*	*0.8*
	8	*700.4*	*0.6%*	*215*	*188*	*153*	*116*	*86*	*61*	*31*	*0.9*	*0.9*	*0.8*	*0.6*	*0.6*	*0.3*	*0.4*
	13	**864.8**	*0.7%*	*87*	*78*	*67*	*55*	*45*	*37*	*24*	*0.7*	*0.2*	*0.4*	*0.5*	*0.2*	*0.2*	*0.6*
2	2	727.7	0.3%	60	52	47	41	35	30	20	0.2	0.3	0.2	0.2	0.2	0.3	0.2
	5	697.8	0.3%	438	354	234	142	86	53	37	1.3	1.4	0.7	0.9	0.9	0.8	1.1
	8	714.9	0.2%	214	185	151	114	85	61	31	1.1	0.4	0.5	0.5	1.2	0.7	0.5
	13	760.3	0.5%	96	86	75	61	50	40	25	0.6	0.2	0.3	0.3	0.2	0.3	0.3
3	2	731.8	0.6%	59	51	46	40	34	29	20	0.5	0.3	0.2	0.2	0.4	0.2	0.1
	5	698.2	0.5%	425	348	232	142	86	55	34	0.9	1.0	0.8	0.7	0.9	0.6	0.4
	8	718.0	0.6%	212	183	150	113	84	60	31	1.5	0.8	0.7	0.6	0.6	0.3	0.8
	13	718.3	0.4%	94	85	73	60	49	40	25	0.3	0.3	0.3	0.3	0.2	0.2	0.2

E.4 Machine 8

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	713.4	0.4%	74	64	57	50	42	35	24	0.5	0.3	0.9	1.1	0.7	0.5	0.5
	5	692.7	0.1%	498	390	244	147	82	48	27	1.1	0.6	0.5	0.4	0.4	0.3	0.0
	8	707.2	0.6%	248	220	175	133	95	66	33	1.1	1.4	0.7	0.9	0.6	0.6	0.5
	13	717.0	0.9%	123	110	96	80	64	51	31	0.8	1.0	1.0	0.8	0.5	0.6	0.5
2	2	722.2	0.6%	73	63	56	49	42	35	24	0.4	0.4	0.3	0.5	0.3	0.4	0.3
	5	698.4	0.7%	496	389	243	147	82	47	27	1.0	0.6	0.7	0.5	0.3	0.4	0.2
	8	705.8	0.3%	249	221	176	133	95	66	33	0.7	0.5	0.7	0.8	0.7	0.4	0.5
	13	713.2	1.0%	123	109	100	78	59	52	24	0.4	0.4	0.5	0.4	0.4	0.4	0.6

E.5 Machine 9

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	696.1	0.2%	71	63	57	52	39	35	24	0.2	0.7	0.5	1.0	0.2	0.3	0.3
	5	680.5	0.2%	452	364	239	145	90	48	32	1.2	0.6	0.5	0.2	0.8	0.3	0.1
	8	686.8	0.1%	242	211	172	132	91	67	29	0.3	0.6	0.4	0.5	0.2	0.2	0.5
	13	690.1	0.2%	123	112	94	83	66	53	27	0.6	0.1	0.3	0.2	0.2	0.3	0.3
2	2	695.1	0.1%	71	61	57	47	43	34	30	0.2	0.1	0.4	0.1	0.4	0.1	0.4
	5	679.7	0.2%	464	369	242	146	85	45	40	1.0	1.1	0.7	0.2	0.5	1.6	1.4
	8	687.1	0.2%	245	213	172	129	95	66	33	0.3	0.8	0.8	0.2	0.7	0.3	0.2
	13	688.1	0.3%	124	109	94	79	60	50	33	0.1	0.2	0.3	0.4	0.2	1.0	1.2

E.6 Machine 10

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	707.2	0.4%	68	58	54	48	40	33	24	0.7	0.1	0.2	0.2	0.1	0.2	0.3
	5	684.2	0.2%	489	368	243	152	85	51	34	0.9	1.6	0.4	0.9	0.6	0.7	0.5
	8	696.3	0.2%	241	202	169	129	94	65	35	1.1	0.5	0.2	0.3	0.4	0.3	0.3
	13	696.0	0.3%	129	103	92	78	62	49	30	1.2	0.2	0.1	0.1	0.2	0.2	0.2
2	2	706.1	0.3%	70	57	55	48	41	33	24	0.4	0.2	0.1	0.2	0.1	0.2	0.2
	5	683.5	0.2%	484	369	243	151	86	52	32	1.0	1.0	0.5	0.3	0.2	0.2	0.2
	8	697.5	0.3%	240	204	169	131	93	65	35	0.8	0.2	0.3	0.1	0.2	0.2	0.1
	13	697.6	0.3%	126	103	92	78	63	49	32	1.0	0.1	0.1	0.2	0.1	0.2	0.2

E.7 Machine 11

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	691.1	0.1%	79	64	57	50	43	36	25	0.5	0.1	0.1	0.2	0.2	0.1	0.3
	5	671.2	0.2%	518	390	251	148	84	48	29	1.5	0.7	0.4	0.2	0.3	0.5	0.4
	8	681.1	0.2%	254	217	176	133	96	68	34	0.4	0.2	0.2	0.2	0.3	0.1	0.3
	13	692.2	0.2%	132	111	92	78	63	50	30	0.9	1.0	1.0	0.7	0.8	1.1	1.0
2	2	686.4	0.2%	80	63	56	50	43	35	24	0.8	0.2	0.2	0.1	0.1	0.3	0.6
	5	668.3	0.2%	492	371	245	144	81	47	30	1.1	0.7	0.5	0.4	0.5	0.3	0.6
	8	678.5	0.3%	258	217	177	131	95	67	35	0.7	0.4	0.6	0.7	0.4	0.4	1.2
	13	690.0	0.3%	134	110	94	78	63	50	30	1.9	0.2	0.2	0.1	0.1	0.7	0.4

E.8 Machine 13

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	708.3	0.2%	74	62	56	49	42	35	24	0.3	0.5	0.2	1.0	0.5	0.3	0.2
	5	712.5	0.2%	476	382	244	146	85	51	30	0.9	0.5	0.3	0.3	0.3	0.3	0.2
	8	704.5	0.2%	245	214	171	129	94	67	34	1.1	0.4	0.4	0.4	0.3	0.4	0.4
	13	701.5	0.3%	125	110	95	79	64	51	29	0.3	0.1	0.1	0.3	0.5	0.3	0.6
2	2	709.3	0.2%	75	62	56	48	41	34	24	1.2	0.3	0.4	0.6	0.5	0.8	0.1
	5	707.5	0.3%	480	388	246	148	86	51	30	1.1	0.7	0.5	0.5	0.3	0.2	0.3
	8	704.1	0.4%	247	216	172	130	94	67	34	0.4	0.3	0.3	0.3	0.4	0.2	0.2
	13	701.1	0.3%	123	110	94	78	63	51	31	0.9	0.3	0.2	0.2	0.3	0.1	0.1

E.9 Machine 15

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	722.6	0.2%	71	60	53	47	41	33	23	0.2	0.1	0.2	0.1	0.1	0.1	0.1
	5	705.3	0.2%	461	371	240	144	85	51	32	0.6	0.6	0.3	0.3	0.1	0.2	0.2
	8	713.4	0.3%	239	208	167	126	93	65	33	1.2	1.2	1.2	1.0	0.8	0.7	0.3
	13	714.3	0.2%	119	107	92	76	63	50	29	0.6	0.7	0.7	0.6	0.6	0.7	0.7
2	2	719.7	0.1%	70	60	53	47	41	34	23	1.7	0.2	0.2	0.2	0.1	0.1	0.2
	5	699.0	0.3%	463	374	241	145	86	51	32	0.7	0.3	0.1	0.2	0.1	0.1	0.1
	8	708.4	0.2%	239	209	167	127	93	65	33	0.9	0.2	0.2	0.1	0.1	0.1	0.1
	13	708.7	0.2%	118	110	91	73	61	49	30	0.2	0.4	0.1	0.3	0.2	0.2	0.2

E.10 Machine 16

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	724.7	0.2%	68	65	55	49	41	35	25	0.7	0.3	0.1	0.1	0.1	0.5	0.3
	5	708.3	0.1%	479	379	243	148	83	47	33	1.0	0.7	0.5	0.5	0.2	0.5	0.0
	8	715.0	0.2%	249	220	174	133	95	66	36	0.6	0.4	1.1	0.4	0.4	0.7	0.5
	13	721.6	0.1%	122	110	93	80	65	51	33	0.3	0.5	0.7	0.6	0.5	0.5	0.4
2	2	724.0	0.1%	71	64	54	50	42	33	25	0.5	0.1	0.1	0.1	0.5	0.5	0.0
	5	707.2	0.2%	505	386	240	148	85	49	32	0.8	0.4	0.8	0.3	0.3	0.4	0.3
	8	713.8	0.2%	249	217	171	131	94	65	37	0.4	0.7	0.8	0.4	0.3	0.8	0.9
	13	721.2	0.2%	124	111	94	79	63	49	31	0.5	0.3	0.2	0.3	0.3	0.1	0.3

E.11 Machine 28

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	682.1	1.2%	74	65	58	51	44	36	25	1.3	0.8	0.7	0.7	0.6	0.5	0.4
	5	672.7	1.6%	508	398	253	152	88	52	32	**8.1**	**6.3**	**4.1**	**2.4**	1.4	0.9	0.6
	8	676.7	1.3%	256	223	180	136	99	70	35	**3.3**	**3.0**	**2.4**	1.8	1.3	1.0	0.5
	13	689.3	0.9%	124	113	97	81	66	53	31	1.4	1.0	0.9	0.8	0.7	0.5	0.3
2	2	686.6	1.4%	75	62	59	49	43	38	25	1.0	0.8	0.8	0.7	0.7	0.7	0.4
	5	668.4	1.2%	508	404	256	153	90	54	32	**6.9**	**5.5**	**3.6**	2.1	1.5	0.8	0.5
	8	676.2	1.0%	254	225	180	136	100	70	35	2.8	2.3	1.8	1.4	1.0	0.7	0.4
	13	679.2	0.9%	122	113	97	81	66	52	31	1.1	1.1	0.8	0.7	0.6	0.4	0.3
3	2	696.1	1.3%	71	61	55	49	42	35	24	0.8	0.8	0.7	0.6	0.5	0.4	0.3
	5	677.7	1.1%	437	356	239	152	94	57	32	**5.1**	**4.1**	**2.8**	1.8	1.1	0.7	0.4
	8	685.6	1.0%	238	208	171	130	97	68	36	2.4	2.5	2.0	1.4	1.3	0.8	0.5
	13	686.9	0.6%	127	113	97	80	66	52	36	0.7	0.7	0.6	0.5	0.4	0.6	0.2
4	2	690.3	1.3%	69	64	56	50	44	36	25	1.1	1.2	0.8	0.7	0.8	0.8	0.6
	5	675.7	0.7%	490	391	251	150	87	52	30	3.8	2.9	2.5	1.4	0.7	0.6	0.7
	8	682.5	1.6%	246	219	176	133	97	68	35	**3.6**	**3.5**	**2.5**	1.9	1.4	1.0	0.4
	13	694.0	1.2%	122	111	94	79	64	49	29	1.6	1.7	1.3	1.1	1.4	1.0	0.8
5	2	697.4	1.3%	71	63	58	51	43	36	25	0.8	0.9	1.0	1.0	0.5	0.6	0.5
	5	669.3	1.6%	509	396	250	150	88	52	32	**8.2**	**6.5**	**4.2**	**2.5**	1.6	1.0	0.6
	8	679.0	1.5%	252	225	182	135	98	68	35	**3.8**	**3.5**	**3.0**	**2.1**	1.6	1.1	0.7
	13	693.3	1.3%	125	111	95	79	64	51	32	1.9	1.4	1.2	1.0	0.8	0.8	0.4
6	2	690.3	1.4%	70	64	58	51	43	36	26	1.2	0.9	0.7	0.7	0.6	0.5	0.6
	5	676.7	1.1%	492	392	249	150	88	52	31	**5.3**	**4.1**	2.7	1.6	1.1	0.6	0.5
	8	682.4	1.1%	256	223	179	136	98	68	35	2.8	2.3	2.0	1.6	1.2	0.8	0.5
	13	698.4	0.8%	125	112	96	80	65	51	33	1.0	1.0	1.1	0.6	0.5	0.4	0.5
7	2	742.5	1.0%	75	67	60	53	47	40	26	0.8	0.7	0.7	0.5	0.8	1.4	0.3
	5	719.5	0.3%	460	388	266	174	110	68	37	1.9	2.1	1.4	0.9	0.6	0.4	0.2
	8	768.4	0.3%	241	217	177	137	102	72	38	0.6	0.7	0.5	0.6	0.4	0.5	0.3
	13	713.6	1.0%	151	136	117	98	81	66	52	1.6	1.4	1.3	1.1	1.0	0.9	0.7

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
8	2	705.4	0.1%	64	61	49	46	42	32	22	0.4	0.4	0.7	0.1	0.3	0.3	0.3
	5	691.6	0.1%	413	339	223	144	89	53	27	1.0	0.6	1.2	0.4	0.3	0.3	0.4
	8	695.9	0.1%	222	198	160	124	91	63	32	0.5	1.0	0.4	0.3	0.7	0.5	0.5
	13	689.2	0.5%	140	127	110	91	75	60	37	0.7	0.7	1.0	0.5	1.3	0.5	0.6

E.12 Machine 30

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	*2*	*701.8*	*0.2%*	*71*	*66*	*57*	*49*	*43*	*35*	*23*	*0.5*	**2.0**	*1.5*	*0.6*	*0.4*	*0.2*	**2.1**
	5	*692.5*	*0.3%*	*479*	*397*	*242*	*146*	*87*	*51*	*29*	*1.6*	*3.3*	*0.7*	*0.4*	*0.2*	*0.5*	*1.0*
	8	*694.2*	*0.4%*	*245*	*214*	*167*	*132*	*98*	*70*	*36*	*0.3*	*0.5*	*0.6*	*0.4*	*0.3*	*0.8*	*2.0*
	13	*700.7*	*0.4%*	*117*	*111*	*88*	*77*	*63*	*51*	*23*	*1.5*	*1.8*	*1.7*	*1.2*	*0.8*	*0.4*	*1.8*
2	*2*	*709.6*	*0.4%*	*71*	*64*	*54*	*49*	*43*	*35*	*18*	*0.3*	**2.7**	*0.5*	*0.7*	*0.4*	*0.5*	**2.7**
	5	*700.7*	*0.3%*	*489*	*391*	*241*	*147*	*88*	*51*	*29*	*1.5*	*2.8*	*2.1*	*0.4*	*0.2*	*0.4*	*0.8*
	8	*703.7*	*0.3%*	*244*	*216*	*170*	*129*	*96*	*67*	*33*	*1.0*	*0.8*	*1.6*	*0.8*	*1.2*	*0.2*	**2.3**
	13	*712.9*	*0.5%*	*120*	*107*	*85*	*75*	*62*	*50*	*20*	*1.2*	*1.0*	*1.2*	*0.6*	*0.5*	*0.4*	*1.7*
3	2	727.1	0.8%	67	59	54	46	39	34	24	0.6	1.3	1.3	0.9	1.2	0.4	0.2
	5	713.8	0.2%	427	359	234	148	94	57	31	0.6	0.5	0.7	0.2	0.2	0.2	0.4
	8	717.6	0.1%	231	204	163	124	94	67	35	0.3	0.5	0.9	0.7	0.3	0.1	0.1
	13	723.6	0.2%	120	113	93	74	62	49	32	0.7	0.8	0.9	0.9	0.9	1.0	1.3
4	2	720.8	0.5%	70	62	55	48	42	35	24	0.7	0.5	0.3	0.5	0.2	0.3	0.7
	5	707.1	0.2%	477	391	246	146	87	54	32	1.0	1.4	0.6	0.5	0.4	0.3	0.2
	8	715.4	0.5%	244	218	171	129	96	67	35	1.0	0.8	0.7	0.8	0.5	0.4	0.2
	13	719.7	0.3%	117	110	93	78	64	51	29	0.5	0.2	0.1	0.4	0.2	0.3	0.5

E.13 Machine 32

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	725.6	0.8%	69	57	51	45	50	31	22	1.5	0.8	0.5	0.5	**10.0**	0.5	0.5
	5	738.1	0.4%	486	361	231	143	85	54	36	1.9	1.0	0.6	0.6	0.4	0.3	0.3
	8	736.2	0.4%	228	198	160	122	89	63	35	0.6	0.5	0.6	0.4	0.3	0.2	0.4
	13	742.6	0.3%	113	99	84	70	57	44	28	0.8	0.5	0.4	0.3	0.3	0.3	0.3
2	2	735.3	0.3%	66	55	50	44	37	31	21	0.4	0.2	0.2	0.3	0.1	0.4	0.1
	5	726.3	0.9%	440	372	239	149	88	54	35	2.3	1.1	0.6	0.6	0.5	0.4	0.3
	8	719.6	1.1%	233	203	163	124	91	65	35	2.1	**2.6**	1.6	1.5	1.4	0.8	0.8
	13	731.1	0.7%	117	103	88	73	59	44	30	0.9	0.8	0.7	0.6	0.6	0.7	1.1

E.14 Machine 33

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	*2*	**824.7**	*0.8%*	*65*	*58*	*52*	*46*	*39*	*33*	*22*	*1.0*	*0.5*	*0.4*	*0.3*	*0.3*	*0.3*	*0.4*
	5	**819.4**	*0.2%*	*475*	*373*	*240*	*149*	*90*	*57*	*41*	*1.6*	*1.0*	*1.1*	*0.8*	*0.3*	*1.7*	*1.0*
	8	**819.2**	*0.5%*	*229*	*201*	*161*	*123*	*91*	*65*	*35*	*1.9*	*1.0*	*0.9*	*0.9*	*0.6*	*0.4*	*0.4*
	13	**822.3**	*0.6%*	*116*	*107*	*93*	*78*	*64*	*51*	*33*	*1.1*	*0.7*	*0.6*	*0.4*	*0.5*	*0.8*	*0.5*
2	2	724.4	0.4%	68	58	52	46	40	33	23	1.3	0.4	0.2	0.4	0.5	0.7	0.1
	5	718.1	0.6%	461	366	242	148	89	56	38	3.7	2.2	1.6	1.1	1.8	0.5	0.4
	8	718.3	0.5%	231	205	165	125	93	66	35	2.1	0.4	0.6	0.6	0.4	0.6	0.5
	13	725.2	0.3%	113	107	89	76	62	49	31	0.9	0.5	0.3	0.4	0.7	0.9	0.6
3	2	717.6	0.6%	66	59	52	46	40	33	23	0.6	0.4	0.3	0.6	0.4	0.3	0.3
	5	712.2	0.6%	449	367	242	149	91	55	39	2.7	2.0	1.5	0.8	0.6	0.6	0.3
	8	721.2	0.4%	231	207	166	125	93	66	35	0.8	0.7	0.5	0.3	0.7	0.3	0.4
	13	716.1	0.6%	112	105	88	74	60	48	31	1.4	0.7	0.9	0.5	0.5	0.4	0.6

E.15 Machine 34

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	724.3	0.4%	66	57	51	45	39	32	22	0.4	0.5	0.3	0.3	0.3	0.4	0.1
	5	710.3	0.4%	494	363	234	141	86	53	29	1.4	0.6	0.2	0.8	0.5	0.6	0.5
	8	719.1	0.3%	232	206	164	123	90	63	34	0.3	0.5	0.4	0.3	0.3	0.3	0.1
	13	705.7	0.8%	109	100	87	73	60	48	30	0.6	0.5	0.4	0.5	0.2	0.3	0.5
2	2	721.8	0.3%	65	57	51	45	38	32	20	0.6	0.6	0.6	0.6	0.7	0.7	0.8
	5	711.2	0.2%	462	392	244	148	89	53	32	0.4	1.2	1.9	0.3	0.3	0.2	1.6
	8	723.0	0.5%	231	205	166	125	91	64	33	0.6	0.3	0.4	0.4	0.2	0.3	0.8
	13	707.9	0.1%	112	102	87	72	58	45	27	0.4	0.1	0.2	0.2	0.2	0.1	0.2

E.16 Machine 36

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	707.7	0.9%	67	61	55	48	41	35	25	0.4	0.4	0.5	**2.4**	0.3	0.3	0.2
	5	707.0	0.8%	449	359	240	144	81	49	30	1.4	1.1	0.9	1.2	0.4	0.4	0.2
	8	706.6	0.8%	234	207	170	128	91	66	34	0.8	0.8	0.7	0.6	0.4	0.5	0.2
	13	710.2	0.9%	116	105	91	75	60	49	30	1.0	0.4	0.4	1.1	0.4	0.3	0.3
2	2	701.7	0.6%	68	61	56	49	41	36	25	0.3	1.1	0.4	0.4	0.3	0.2	0.2
	5	706.0	0.8%	438	363	240	145	81	50	30	1.7	1.2	0.9	0.7	0.4	0.6	0.4
	8	708.7	0.7%	237	210	171	129	92	66	35	0.9	0.8	0.8	0.9	0.4	0.3	0.3
	13	708.8	0.7%	122	108	94	78	63	51	33	0.8	0.3	0.3	0.3	0.2	0.2	0.4

E.17 Machine 37

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	737.3	0.2%	67	59	53	46	41	35	21	0.9	1.6	0.8	0.9	0.8	0.7	0.6
	5	708.8	0.2%	497	394	252	153	92	58	34	1.5	0.7	0.4	0.3	0.7	1.0	0.8
	8	724.4	0.2%	234	207	167	127	93	67	34	0.5	0.4	0.4	0.3	0.2	0.2	0.3
	13	730.2	0.1%	116	103	90	74	60	48	28	0.4	0.7	0.3	0.2	0.1	0.1	0.6
2	2	735.1	0.3%	67	59	53	46	39	34	21	0.6	0.4	0.2	0.2	0.3	0.8	0.3
	5	700.9	0.2%	494	390	250	152	91	58	34	0.6	0.9	0.3	0.4	0.7	0.5	1.4
	8	717.7	0.3%	237	209	169	128	93	67	34	0.8	0.3	0.6	0.5	0.5	0.6	0.2
	13	726.8	0.3%	116	104	90	74	60	48	28	0.4	0.5	0.3	0.4	0.3	0.5	0.3

E.18 Machine 38

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	731.4	1.4%	63	56	49	46	39	34	20	0.2	0.1	0.1	0.1	0.1	0.1	0.1
	5	717.4	1.1%	457	361	237	149	89	59	33	1.0	1.1	0.8	0.5	0.4	0.6	0.3
	8	715.5	0.4%	222	194	157	122	89	66	32	0.9	0.8	0.5	0.5	0.2	0.3	1.1
	13	719.7	1.2%	108	98	85	73	59	49	27	0.2	0.2	0.2	0.2	0.2	0.2	0.3
2	2	738.7	0.9%	63	55	49	45	38	34	20	0.1	0.2	0.1	0.1	0.2	0.2	0.2
	5	720.8	0.6%	452	360	238	149	89	58	33	0.7	0.5	0.4	0.3	0.2	0.2	0.3
	8	721.6	1.0%	221	194	157	122	89	66	32	0.5	0.4	0.3	0.4	0.2	0.2	0.1
	13	715.8	0.8%	109	99	85	73	59	49	27	0.2	0.2	0.1	0.1	0.2	0.1	0.1

E.19 Machine 39

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	676.8	0.2%	67	59	53	46	40	33	22	0.7	0.3	0.4	0.5	0.6	0.6	1.1
	5	651.4	0.3%	469	377	241	146	88	51	33	1.8	1.1	1.0	0.8	0.5	1.1	0.6
	8	666.3	0.4%	232	202	163	122	92	65	32	0.7	0.5	0.4	0.4	0.6	0.4	1.1
	13	690.9	0.4%	112	100	86	73	60	47	29	0.6	0.5	0.4	0.6	0.5	0.5	0.6
2	2	676.1	0.4%	70	59	52	46	40	33	24	1.3	0.4	0.5	0.4	0.5	0.5	0.7
	5	647.6	0.4%	474	378	242	147	88	52	32	2.6	0.8	1.0	0.4	0.4	0.4	0.4
	8	665.6	0.4%	234	204	164	125	92	65	35	1.3	0.6	0.5	0.6	0.3	0.3	0.6
	13	687.6	0.3%	114	102	85	70	58	47	27	0.8	0.9	0.4	0.5	0.3	0.1	1.0

E.20 Machine 40

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	710.5	0.2%	65	57	51	46	38	31	22	0.8	0.5	0.4	0.8	1.3	0.6	0.4
	5	703.8	0.1%	460	373	235	143	83	50	32	1.1	0.4	0.4	0.3	0.3	0.2	0.2
	8	705.3	0.2%	228	201	161	123	88	63	33	1.0	0.3	0.3	0.4	0.4	0.3	0.1
	13	707.7	0.3%	113	101	85	71	57	46	27	0.7	0.3	0.3	0.3	0.5	0.6	0.3
2	2	708.8	0.1%	67	57	51	45	38	32	22	1.0	0.1	0.2	0.3	0.2	0.1	0.2
	5	702.1	0.1%	464	374	235	143	83	50	32	1.6	0.5	0.4	0.3	0.3	0.4	0.4
	8	705.0	0.2%	231	203	163	124	88	61	33	1.2	0.5	0.4	0.3	0.3	0.3	0.2
	13	707.6	0.2%	112	100	86	72	58	45	28	0.7	0.3	0.3	0.4	0.2	0.4	0.2

E.21 Machine 41

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	703.2	0.5%	70	61	54	48	41	34	24	0.7	0.6	0.4	0.3	0.5	0.3	0.5
	5	697.5	0.3%	467	373	243	148	84	53	33	2.2	1.7	0.9	0.7	0.7	0.7	1.2
	8	694.0	0.7%	243	211	170	128	93	67	35	1.4	1.0	1.0	0.7	0.4	0.5	0.5
	13	700.2	0.4%	121	110	92	77	62	50	29	0.8	0.9	0.6	0.6	0.7	0.4	0.3
2	2	730.3	0.5%	65	56	51	45	39	32	22	0.3	0.3	0.3	0.5	0.2	0.6	0.1
	5	722.2	0.3%	407	333	227	146	90	57	30	1.6	0.9	0.7	0.4	0.3	0.2	0.4
	8	724.7	0.3%	222	195	158	122	90	64	33	0.5	0.5	0.4	0.3	0.3	0.4	0.1
	13	713.3	0.4%	123	110	95	80	65	53	38	0.5	0.5	0.5	0.4	0.6	**2.2**	0.4

E.22 Machine 44

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	718.3	0.1%	69	60	54	46	41	34	23	0.5	0.4	0.4	0.5	0.5	0.6	0.5
	5	710.6	0.1%	467	376	242	144	84	53	31	0.4	0.6	0.2	0.8	0.8	0.2	0.3
	8	708.5	0.2%	235	206	166	124	90	65	34	0.3	0.3	0.4	0.2	0.3	0.1	0.1
	13	712.3	0.1%	116	105	90	75	61	49	29	0.2	0.1	0.2	0.4	0.1	0.1	0.1
2	2	714.0	0.2%	70	60	54	47	40	34	23	0.2	0.2	0.2	0.1	0.1	0.1	0.1
	5	705.4	0.2%	476	371	241	144	84	54	34	1.4	0.9	0.6	0.3	0.3	0.2	0.4
	8	703.2	0.3%	237	208	165	125	91	65	34	0.4	0.3	0.3	0.3	0.2	0.1	0.1
	13	709.5	0.1%	119	106	91	76	62	49	30	0.1	0.2	0.1	0.2	0.5	0.5	0.6

E.23 Machine 45

Lap	Station	Load		Mean of the normalised deflection(µm)							Standard deviation of the normalised deflections (µm)						
		Mean	SD	D1	D2	D3	D4	D5	D6	D7	D1	D2	D3	D4	D5	D6	D7
1	2	717.0	0.2%	72	62	56	50	42	35	25	0.2	0.1	0.5	0.1	0.1	0.5	0.1
	5	715.6	0.1%	468	371	248	149	86	50	28	0.7	0.4	0.6	0.4	0.3	0.0	0.0
	8	714.1	0.2%	239	213	174	132	95	68	35	0.5	0.4	0.4	0.5	0.3	0.6	0.1
	13	725.9	0.2%	117	106	92	77	63	51	31	0.2	0.2	0.4	0.2	0.1	0.1	0.1
2	2	717.4	0.1%	72	62	56	50	42	36	25	0.1	0.1	0.5	0.1	0.1	0.3	0.0
	5	711.5	0.1%	466	376	248	151	87	50	29	1.0	0.7	0.7	0.6	0.4	0.4	0.3
	8	712.9	0.2%	243	216	176	133	95	67	35	0.4	0.5	0.3	0.4	0.2	0.6	0.3
	13	728.5	0.3%	119	107	92	77	62	52	32	0.8	0.3	0.3	0.3	0.2	0.2	0.1

Appendix F Reproducibility trial data

Note: In the tables below bold red text indicates that the value is outside of acceptable limits. Data from laps disregarded in the accreditation analysis are shown in grey italics (accept where the value is outside of acceptable limits).

Table F.1 All trial data during the main trial day (all laps - full dataset)

ID	Lap	Lap used	Field Calibration Factor (FCF)								Standard Deviation of Deviation Ratio (SDDR)							
			D1	D2	D3	D4	D5	D6	D7	Mean	D1	D2	D3	D4	D5	D6	D7	Mean
2	*0*	*N*	*0.986*	*0.987*	*0.984*	*0.996*	*0.990*	*0.979*	*0.992*	*0.988*	*0.020*	*0.011*	*0.011*	*0.014*	*0.015*	*0.020*	*0.026*	*0.017*
	1	Y	0.982	0.987	0.985	0.994	0.990	0.980	1.003	0.989	0.016	0.008	0.008	0.010	0.009	0.016	0.021	0.013
	2	Y	0.978	0.986	0.982	0.990	0.990	0.986	1.005	0.988	0.021	0.009	0.010	0.011	0.013	0.017	0.024	0.015
	3	*N*	*0.984*	*0.989*	*0.986*	*0.993*	*0.997*	*0.989*	*1.004*	*0.992*	*0.012*	*0.010*	*0.011*	*0.011*	*0.013*	*0.015*	*0.016*	*0.013*
5	*0*	*N*	*0.985*	*0.972*	*0.974*	*0.992*	*0.967*	*0.967*	*0.980*	*0.977*	*0.017*	*0.016*	*0.016*	*0.020*	*0.022*	*0.025*	*0.043*	*0.022*
	1	Y	0.987	0.970	0.973	0.985	0.961	0.958	0.980	0.973	0.023	0.015	0.012	0.013	0.010	0.016	0.045	0.019
	2	Y	0.976	0.964	0.964	0.976	0.958	0.961	0.966	0.966	0.016	0.010	0.010	0.010	0.008	0.018	0.029	0.014
	3	*N*	*0.979*	*0.966*	*0.964*	*0.975*	*0.961*	*0.962*	*0.993*	*0.971*	*0.010*	*0.008*	*0.007*	*0.006*	*0.006*	*0.009*	*0.057*	*0.015*
6	*0*	*N*	*1.010*	*1.026*	*1.022*	*1.034*	*1.023*	*1.011*	*0.984*	*1.016*	*0.025*	*0.018*	*0.021*	*0.022*	*0.026*	*0.027*	**0.074**	*0.030*
	1	Y	1.020	1.030	1.026	1.030	1.021	1.009	0.988	1.018	0.017	0.012	0.016	0.017	0.023	0.029	0.066	0.026
	2	Y	1.004	1.024	1.019	1.023	1.018	1.001	0.976	1.009	0.023	0.018	0.024	0.026	0.036	0.052	**0.085**	0.038
	3	*N*	*1.009*	*1.021*	*1.015*	*1.020*	*1.016*	*1.006*	*1.002*	*1.013*	*0.028*	*0.020*	*0.023*	*0.024*	*0.029*	*0.039*	*0.056*	*0.031*
	4	*N*	*1.002*	*1.012*	*1.006*	*1.011*	*1.008*	*0.989*	*0.978*	*1.001*	*0.022*	*0.018*	*0.024*	*0.021*	*0.030*	*0.038*	*0.064*	*0.031*
8	*0*	*N*	*0.973*	*0.964*	*0.970*	*0.981*	*0.995*	*1.003*	*1.030*	*0.988*	*0.017*	*0.013*	*0.020*	*0.018*	*0.024*	*0.029*	*0.059*	*0.026*
	1	Y	0.969	0.961	0.969	0.977	0.997	1.008	1.031	0.987	0.019	0.012	0.020	0.021	0.025	0.041	0.048	0.027
	2	Y	0.966	0.960	0.969	0.970	0.993	1.008	1.030	0.985	0.018	0.013	0.024	0.025	0.025	0.037	0.054	0.028
	3	*N*	*0.968*	*0.955*	*0.967*	*0.967*	*0.991*	*1.003*	*1.029*	*0.983*	*0.021*	*0.014*	*0.022*	*0.023*	*0.026*	*0.035*	*0.061*	*0.029*
9	*0*	*N*	*1.004*	*1.002*	*1.004*	*1.014*	*1.016*	*1.042*	*1.073*	*1.022*	*0.020*	*0.022*	*0.016*	*0.027*	*0.038*	*0.039*	**0.099**	*0.037*
	1	*N*	*0.997*	*1.009*	*0.997*	*1.019*	*1.009*	*1.038*	*0.964*	*1.005*	*0.016*	*0.014*	*0.022*	*0.023*	*0.039*	*0.037*	**0.082**	*0.033*
	2	*N*	*0.991*	*0.988*	*0.990*	*0.997*	*0.986*	*0.949*	*0.908*	*0.973*	*0.014*	*0.024*	*0.013*	*0.019*	*0.035*	*0.041*	**0.128**	*0.039*
	3	Y	0.992	0.998	0.993	1.002	1.012	0.957	0.937	0.984	0.014	0.015	0.011	0.017	0.021	0.055	**0.073**	0.029
	4	Y	0.992	0.987	0.988	0.995	1.002	0.929	0.944	0.977	0.019	0.017	0.015	0.021	0.016	0.049	**0.071**	0.030

ID	Lap	Lap used	Field Calibration Factor (FCF)								Standard Deviation of Deviation Ratio (SDDR)							
			D1	D2	D3	D4	D5	D6	D7	Mean	D1	D2	D3	D4	D5	D6	D7	Mean
10	*0*	*N*	*0.998*	*1.036*	*1.000*	*0.993*	*1.007*	*1.009*	*1.003*	*1.006*	*0.016*	*0.014*	*0.008*	*0.013*	*0.010*	*0.016*	*0.029*	*0.015*
	1	Y	0.998	1.044	1.007	0.992	1.006	1.018	0.990	1.008	0.031	0.012	0.007	0.013	0.008	0.014	0.028	0.016
	2	Y	1.002	1.039	0.999	0.982	1.001	1.016	0.989	1.004	0.031	0.008	0.007	0.010	0.006	0.012	0.020	0.013
	3	*N*	*0.996*	*1.040*	*1.001*	*0.983*	*1.005*	*1.022*	*0.972*	*1.003*	*0.028*	*0.009*	*0.009*	*0.011*	*0.006*	*0.014*	*0.038*	*0.016*
11	*0*	*N*	*0.935*	*0.982*	*0.984*	*0.984*	*0.986*	*0.994*	*0.985*	*0.979*	*0.031*	*0.016*	*0.007*	*0.015*	*0.018*	*0.022*	*0.044*	*0.022*
	1	Y	0.937	0.976	0.975	0.978	0.977	0.991	0.979	0.973	0.031	0.011	0.015	0.020	0.025	0.035	0.035	0.025
	2	Y	0.939	0.978	0.979	0.976	0.990	0.997	1.009	0.981	0.032	0.014	0.015	0.018	0.022	0.033	0.067	0.029
	3	*N*	*0.933*	*0.977*	*0.972*	*0.970*	*0.978*	*0.997*	*0.970*	*0.971*	*0.046*	*0.027*	*0.020*	*0.015*	*0.022*	*0.044*	*0.048*	*0.032*
13	*0*	*N*	*0.974*	*1.001*	*1.008*	*1.020*	*1.010*	*1.005*	*0.995*	*1.002*	*0.031*	*0.005*	*0.008*	*0.008*	*0.008*	*0.008*	*0.017*	*0.012*
	1	Y	0.979	1.003	1.009	1.015	1.006	1.004	1.002	1.003	0.028	0.010	0.009	0.007	0.007	0.008	0.022	0.013
	2	Y	0.970	0.999	1.005	1.012	1.008	1.008	1.002	1.001	0.030	0.006	0.007	0.008	0.006	0.009	0.019	0.012
	3	*N*	*0.969*	*0.998*	*1.003*	*1.010*	*1.008*	*1.009*	*0.997*	*0.999*	*0.028*	*0.006*	*0.005*	*0.005*	*0.005*	*0.010*	*0.012*	*0.010*
15	*0*		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1	Y	1.004	0.995	1.005	1.013	1.005	1.023	1.031	1.011	0.020	0.007	0.007	0.008	0.014	0.022	0.013	0.013
	2	Y	0.998	1.003	1.009	1.012	1.004	1.022	1.016	1.009	0.013	0.005	0.004	0.007	0.007	0.010	0.025	0.010
	3	*N*	*1.003*	*1.003*	*1.007*	*1.009*	*1.003*	*1.023*	*1.015*	*1.009*	*0.023*	*0.015*	*0.016*	*0.015*	*0.017*	*0.017*	*0.018*	*0.017*
	4	*N*	*1.011*	*0.998*	*1.001*	*1.000*	*0.999*	*1.003*	*1.004*	*1.002*	*0.018*	*0.004*	*0.005*	*0.004*	*0.005*	*0.009*	*0.009*	*0.008*
16	*0*	*N*	*0.995*	*0.976*	*0.993*	*0.989*	*1.006*	*1.028*	*0.967*	*0.993*	*0.033*	*0.014*	*0.012*	*0.013*	*0.017*	*0.025*	*0.026*	*0.020*
	1	Y	0.984	0.971	0.984	0.979	0.992	1.022	0.961	0.985	0.024	0.010	0.010	0.008	0.014	0.027	0.040	0.019
	2	Y	0.977	0.970	0.981	0.977	0.990	1.012	0.965	0.982	0.033	0.012	0.013	0.011	0.012	0.024	0.040	0.020
	3	*N*	*0.975*	*0.970*	*0.980*	*0.972*	*0.989*	*1.012*	*0.955*	*0.979*	*0.025*	*0.015*	*0.018*	*0.015*	*0.022*	*0.028*	*0.029*	*0.022*
28	*0*	*N*	*0.915*	*0.939*	*0.942*	*0.946*	*0.937*	*0.948*	*0.967*	**0.942**	**0.216**	*0.020*	*0.012*	*0.022*	*0.031*	*0.028*	*0.024*	**0.050**
	1	*N*	*0.943*	*0.928*	*0.935*	*0.937*	*0.934*	*0.951*	*0.973*	**0.943**	*0.036*	*0.013*	*0.015*	*0.017*	*0.025*	*0.035*	*0.040*	*0.026*
	2	Y	0.965	0.944	0.952	0.958	0.956	0.971	0.979	0.961	0.066	0.018	0.025	0.023	0.028	0.029	0.012	0.029
	3	Y	0.966	0.954	0.954	0.960	0.957	0.976	0.992	0.966	0.025	0.012	0.016	0.016	0.019	0.024	0.034	0.021
30	*0*	*N*	*0.982*	*0.967*	*0.983*	*0.995*	*0.975*	*0.982*	*0.984*	*0.981*	*0.011*	*0.014*	*0.009*	*0.008*	*0.010*	*0.012*	*0.019*	*0.012*
	1	Y	0.981	0.963	0.984	0.990	0.974	0.983	1.016	0.984	0.019	0.015	0.012	0.012	0.012	0.014	0.044	0.018
	2	Y	0.979	0.963	0.984	0.986	0.968	0.982	0.989	0.979	0.018	0.010	0.007	0.009	0.008	0.016	0.023	0.013
	3	*N*	*0.981*	*0.967*	*0.986*	*0.987*	*0.981*	*0.988*	*1.008*	*0.985*	*0.017*	*0.009*	*0.009*	*0.007*	*0.015*	*0.012*	*0.020*	*0.013*

ID	Lap	Lap used	Field Calibration Factor (FCF)								Standard Deviation of Deviation Ratio (SDDR)							
			D1	D2	D3	D4	D5	D6	D7	Mean	D1	D2	D3	D4	D5	D6	D7	Mean
32	0	N	1.062	1.073	1.071	1.073	1.066	1.056	0.994	**1.056**	0.028	0.016	0.017	0.021	0.028	0.042	**0.073**	0.032
	1	N	1.062	1.069	1.070	1.068	1.068	1.057	1.007	**1.057**	0.026	0.012	0.014	0.017	0.028	0.050	**0.084**	0.033
	2	N	1.046	1.063	1.061	1.054	1.050	1.056	0.991	1.046	0.048	0.015	0.012	0.016	0.025	0.036	**0.082**	0.033
	3	Y	1.025	1.034	1.035	1.026	1.025	1.029	1.003	1.025	0.048	0.015	0.016	0.016	0.025	0.038	0.064	0.032
	4	Y	1.012	1.018	1.018	1.013	1.022	1.012	0.994	1.013	0.037	0.026	0.027	0.030	0.040	0.060	**0.087**	0.044
33	0	N	1.052	1.044	1.046	1.047	1.034	1.025	0.986	1.033	0.021	0.016	0.017	0.018	0.024	0.034	0.065	0.028
	1	Y	1.041	1.032	1.037	1.035	1.021	1.006	0.975	1.021	0.043	0.018	0.012	0.017	0.022	0.034	0.061	0.030
	2	Y	1.044	1.025	1.025	1.023	1.014	1.011	0.964	1.015	0.028	0.011	0.013	0.017	0.023	0.038	**0.074**	0.029
	3	N	1.029	1.018	1.026	1.018	1.010	1.010	0.964	1.011	0.031	0.014	0.014	0.013	0.022	0.034	**0.075**	0.029
34	0	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1	Y	1.062	1.042	1.045	1.047	1.044	1.031	1.044	1.045	0.023	0.025	0.030	0.029	0.039	0.045	0.048	0.034
	2	Y	1.049	1.042	1.045	1.046	1.041	1.039	1.031	1.042	0.029	0.025	0.028	0.028	0.034	0.044	0.057	0.035
	3	N	1.051	1.035	1.035	1.034	1.034	1.031	1.036	1.037	0.025	0.029	0.030	0.028	0.039	0.052	0.056	0.037
36	0	N	0.968	0.941	0.923	0.931	0.946	0.939	0.917	**0.938**	0.028	0.017	0.013	0.020	0.030	0.032	0.040	0.026
	1	N	0.981	0.941	0.924	0.928	0.946	0.931	0.918	**0.938**	0.027	0.013	0.012	0.017	0.015	0.033	0.038	0.022
	2	Y	1.034	1.006	0.990	0.988	1.020	1.002	1.037	1.011	0.023	0.017	0.015	0.022	0.022	0.030	0.052	0.026
	3	Y	1.044	1.018	0.999	1.007	1.041	1.012	0.997	1.017	0.023	0.019	0.018	0.030	0.025	0.034	0.044	0.028
37	0	N	1.047	1.034	1.026	1.033	1.022	0.996	1.037	1.028	0.027	0.028	0.028	0.034	0.043	0.060	0.059	0.040
	1	Y	1.045	1.040	1.032	1.034	1.022	1.007	1.031	1.030	0.027	0.025	0.024	0.030	0.037	0.055	0.060	0.037
	2	Y	1.026	1.025	1.016	1.015	1.012	1.000	1.023	1.017	0.026	0.027	0.027	0.031	0.039	0.055	0.061	0.038
	3	N	1.031	1.025	1.014	1.013	1.013	0.999	1.020	1.017	0.023	0.024	0.025	0.030	0.030	0.048	0.060	0.034
38	0	N	1.043	1.034	1.025	0.999	1.006	0.963	1.062	1.019	0.019	0.009	0.008	0.011	0.014	0.018	0.016	0.014
	1	Y	1.050	1.040	1.037	1.003	1.007	0.963	1.072	1.025	0.026	0.012	0.008	0.013	0.013	0.019	0.013	0.015
	2	Y	1.047	1.035	1.031	0.996	1.003	0.959	1.061	1.019	0.017	0.011	0.011	0.014	0.015	0.017	0.014	0.014
	3	N	1.043	1.032	1.027	0.992	1.002	0.958	1.062	1.017	0.031	0.015	0.013	0.012	0.014	0.017	0.017	0.017

ID	Lap	Lap used	Field Calibration Factor (FCF)								Standard Deviation of Deviation Ratio (SDDR)							
			D1	D2	D3	D4	D5	D6	D7	Mean	D1	D2	D3	D4	D5	D6	D7	Mean
39	*0*	*N*	*1.009*	*1.019*	*1.019*	*1.024*	*1.005*	*1.009*	*0.999*	*1.012*	*0.010*	*0.006*	*0.009*	*0.009*	*0.010*	*0.013*	*0.029*	*0.012*
	1	Y	1.012	1.019	1.022	1.019	1.003	1.012	1.004	1.013	0.013	0.005	0.004	0.006	0.006	0.009	0.024	0.010
	2	Y	0.999	1.014	1.011	1.011	0.995	1.005	0.997	1.005	0.016	0.009	0.007	0.013	0.011	0.010	0.027	0.013
	3	*N*	*1.002*	*1.016*	*1.016*	*1.014*	*1.005*	*1.017*	*1.008*	*1.011*	*0.028*	*0.008*	*0.008*	*0.006*	*0.006*	*0.012*	*0.019*	*0.012*
	4	*N*	*1.002*	*1.009*	*1.008*	*1.001*	*1.000*	*1.005*	*0.996*	*1.003*	*0.021*	*0.008*	*0.008*	*0.009*	*0.007*	*0.006*	*0.017*	*0.011*
40	*0*	*N*	*1.044*	*1.040*	*1.046*	*1.045*	*1.052*	*1.056*	*1.048*	*1.047*	*0.010*	*0.007*	*0.012*	*0.009*	*0.012*	*0.012*	*0.044*	*0.015*
	1	Y	1.048	1.039	1.049	1.041	1.049	1.047	1.025	1.043	0.017	0.008	0.011	0.011	0.012	0.013	0.034	0.015
	2	Y	1.037	1.035	1.041	1.033	1.041	1.047	1.016	1.036	0.015	0.009	0.008	0.008	0.011	0.011	0.028	0.013
	3	*N*	*1.039*	*1.043*	*1.046*	*1.041*	*1.056*	*1.061*	*1.019*	*1.043*	*0.016*	*0.015*	*0.010*	*0.013*	*0.016*	*0.021*	*0.034*	*0.018*
41	*0*	*N*	*1.007*	*1.013*	*1.010*	*1.020*	*1.023*	*1.036*	*1.052*	*1.023*	*0.009*	*0.008*	*0.008*	*0.013*	*0.012*	*0.014*	*0.025*	*0.013*
	1	Y	0.988	0.999	0.999	1.002	1.020	1.024	1.019	1.007	0.011	0.010	0.010	0.008	0.017	0.017	0.033	0.015
	2	Y	0.988	1.001	1.000	1.003	1.011	1.019	1.020	1.006	0.014	0.013	0.009	0.011	0.010	0.014	0.032	0.015
	3	*N*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4	*N*	*0.995*	*1.002*	*0.997*	*0.997*	*1.011*	*1.007*	*1.031*	*1.006*	*0.010*	*0.005*	*0.005*	*0.010*	*0.014*	*0.019*	*0.026*	*0.013*
44	*0*	*N*	*1.026*	*1.020*	*1.024*	*1.033*	*1.034*	*1.017*	*1.008*	*1.023*	*0.016*	*0.007*	*0.007*	*0.012*	*0.009*	*0.019*	*0.038*	*0.015*
	1	Y	1.019	1.019	1.027	1.035	1.033	1.019	1.021	1.025	0.013	0.009	0.007	0.012	0.012	0.018	0.025	0.014
	2	Y	1.004	1.009	1.013	1.017	1.020	1.007	1.001	1.010	0.007	0.004	0.005	0.011	0.007	0.018	0.032	0.012
	3	*N*	*1.008*	*1.011*	*1.014*	*1.018*	*1.025*	*1.008*	*1.002*	*1.012*	*0.014*	*0.006*	*0.006*	*0.008*	*0.008*	*0.011*	*0.023*	*0.011*
45	*0*	*N*	*0.995*	*0.995*	*0.981*	*0.990*	*0.994*	*0.987*	*1.036*	*0.997*	*0.031*	*0.024*	*0.024*	*0.022*	*0.024*	*0.035*	*0.064*	*0.032*
	1	Y	0.995	0.996	0.990	0.991	0.999	0.994	1.041	1.001	0.019	0.016	0.014	0.016	0.014	0.029	**0.075**	0.026
	2	Y	0.985	0.995	0.984	0.980	0.995	0.988	1.005	0.990	0.030	0.019	0.016	0.016	0.015	0.033	0.061	0.027
	3	*N*	*0.993*	*0.994*	*0.979*	*0.976*	*0.992*	*0.990*	*1.006*	*0.990*	*0.023*	*0.021*	*0.018*	*0.017*	*0.016*	*0.033*	*0.055*	*0.026*

Table F.2 All trial data during the main trial day (analysed laps – single data point removed where appropriate)

ID	Lap	Field Calibration Factor (FCF)								Standard Deviation of Deviation Ratio (SDDR)								Excluded Geophones and test station
		D1	D2	D3	D4	D5	D6	D7	Mean	D1	D2	D3	D4	D5	D6	D7	Mean	
2	1	0.982	0.987	0.985	0.994	0.990	0.980	1.003	0.989	0.016	0.008	0.008	0.010	0.009	0.016	0.021	0.013	
	2	0.978	0.986	0.982	0.990	0.990	0.986	1.005	0.988	0.021	0.009	0.010	0.011	0.013	0.017	0.024	0.015	
5	1	0.987	0.970	0.973	0.985	0.961	0.958	0.980	0.973	0.023	0.015	0.012	0.013	0.010	0.016	0.045	0.019	
	2	0.976	0.964	0.964	0.976	0.958	0.961	0.966	0.966	0.016	0.010	0.010	0.010	0.008	0.018	0.029	0.014	
6	1	1.020	1.030	1.026	1.030	1.021	1.009	0.988	1.018	0.017	0.012	0.016	0.017	0.023	0.029	0.066	0.026	
	2	1.004	1.024	1.019	1.023	1.018	1.001	0.991	1.011	0.023	0.018	0.024	0.026	0.036	0.052	0.055	0.034	Station 5 D7
8	1	0.969	0.961	0.969	0.977	0.997	1.008	1.031	0.987	0.019	0.012	0.020	0.021	0.025	0.041	0.048	0.027	
	2	0.966	0.960	0.969	0.970	0.993	1.008	1.030	0.985	0.018	0.013	0.024	0.025	0.025	0.037	0.054	0.028	
9	3	0.992	0.998	0.993	1.002	1.012	0.957	0.949	0.984	0.014	0.015	0.011	0.017	0.021	0.055	0.061	0.029	Station 1 D7
	4	0.992	0.987	0.988	0.995	1.002	0.929	0.954	0.977	0.019	0.017	0.015	0.021	0.016	0.049	0.063	0.030	Station 9 D7
10	1	0.998	1.044	1.007	0.992	1.006	1.018	0.990	1.008	0.031	0.012	0.007	0.013	0.008	0.014	0.028	0.016	
	2	1.002	1.039	0.999	0.982	1.001	1.016	0.989	1.004	0.031	0.008	0.007	0.010	0.006	0.012	0.020	0.013	
11	1	0.937	0.976	0.975	0.978	0.977	0.991	0.979	0.973	0.031	0.011	0.015	0.020	0.025	0.035	0.035	0.025	
	2	0.939	0.978	0.979	0.976	0.990	0.997	1.009	0.981	0.032	0.014	0.015	0.018	0.022	0.033	0.067	0.029	
13	1	0.979	1.003	1.009	1.015	1.006	1.004	1.002	1.003	0.028	0.010	0.009	0.007	0.007	0.008	0.022	0.013	
	2	0.970	0.999	1.005	1.012	1.008	1.008	1.002	1.001	0.030	0.006	0.007	0.008	0.006	0.009	0.019	0.012	
15	1	1.004	0.995	1.005	1.013	1.005	1.023	1.031	1.011	0.020	0.007	0.007	0.008	0.014	0.022	0.013	0.013	
	2	0.998	1.003	1.009	1.012	1.004	1.022	1.016	1.009	0.013	0.005	0.004	0.007	0.007	0.010	0.025	0.010	
16	1	0.984	0.971	0.984	0.979	0.992	1.022	0.961	0.985	0.024	0.010	0.010	0.008	0.014	0.027	0.040	0.019	
	2	0.977	0.970	0.981	0.977	0.990	1.012	0.965	0.982	0.033	0.012	0.013	0.011	0.012	0.024	0.040	0.020	
28	2	0.965	0.944	0.952	0.958	0.956	0.971	0.979	0.961	0.066	0.018	0.025	0.023	0.028	0.029	0.012	0.029	
	3	0.966	0.954	0.954	0.960	0.957	0.976	0.992	0.966	0.025	0.012	0.016	0.016	0.019	0.024	0.034	0.021	
30	1	0.981	0.963	0.984	0.990	0.974	0.983	1.016	0.984	0.019	0.015	0.012	0.012	0.012	0.014	0.044	0.018	
	2	0.979	0.963	0.984	0.986	0.968	0.982	0.989	0.979	0.018	0.010	0.007	0.009	0.008	0.016	0.023	0.013	
32	3	1.025	1.034	1.035	1.026	1.025	1.029	1.003	1.025	0.048	0.015	0.016	0.016	0.025	0.038	0.064	0.032	
	4	1.012	1.018	1.018	1.013	1.022	1.012	1.004	1.014	0.037	0.026	0.027	0.030	0.040	0.060	**0.080**	0.043	Station 5 D7

ID	Lap	Field Calibration Factor (FCF)								Standard Deviation of Deviation Ratio (SDDR)								Excluded Geophones and test station
		D1	D2	D3	D4	D5	D6	D7	Mean	D1	D2	D3	D4	D5	D6	D7	Mean	
33	1	1.041	1.032	1.037	1.035	1.021	1.006	0.975	1.021	0.043	0.018	0.012	0.017	0.022	0.034	0.061	0.030	
	2	1.044	1.025	1.025	1.023	1.014	1.011	0.977	1.017	0.028	0.011	0.013	0.017	0.023	0.038	0.054	0.026	Station 5 D7
34	1	1.062	1.042	1.045	1.047	1.044	1.031	1.044	1.045	0.023	0.025	0.030	0.029	0.039	0.045	0.048	0.034	
	2	1.049	1.042	1.045	1.046	1.041	1.039	1.031	1.042	0.029	0.025	0.028	0.028	0.034	0.044	0.057	0.035	
36	2	1.034	1.006	0.990	0.988	1.020	1.002	1.037	1.011	0.023	0.017	0.015	0.022	0.022	0.030	0.052	0.026	
	3	1.044	1.018	0.999	1.007	1.041	1.012	0.997	1.017	0.023	0.019	0.018	0.030	0.025	0.034	0.044	0.028	
37	1	1.045	1.040	1.032	1.034	1.022	1.007	1.031	1.030	0.027	0.025	0.024	0.030	0.037	0.055	0.060	0.037	
	2	1.026	1.025	1.016	1.015	1.012	1.000	1.023	1.017	0.026	0.027	0.027	0.031	0.039	0.055	0.061	0.038	
38	1	1.050	1.040	1.037	1.003	1.007	0.963	1.072	1.025	0.026	0.012	0.008	0.013	0.013	0.019	0.013	0.015	
	2	1.047	1.035	1.031	0.996	1.003	0.959	1.061	1.019	0.017	0.011	0.011	0.014	0.015	0.017	0.014	0.014	
39	1	1.012	1.019	1.022	1.019	1.003	1.012	1.004	1.013	0.013	0.005	0.004	0.006	0.006	0.009	0.024	0.010	
	2	0.999	1.014	1.011	1.011	0.995	1.005	0.997	1.005	0.016	0.009	0.007	0.013	0.011	0.010	0.027	0.013	
40	1	1.048	1.039	1.049	1.041	1.049	1.047	1.025	1.043	0.017	0.008	0.011	0.011	0.012	0.013	0.034	0.015	
	2	1.037	1.035	1.041	1.033	1.041	1.047	1.016	1.036	0.015	0.009	0.008	0.008	0.011	0.011	0.028	0.013	
41	1	0.988	0.999	0.999	1.002	1.020	1.024	1.019	1.007	0.011	0.010	0.010	0.008	0.017	0.017	0.033	0.015	
	2	0.988	1.001	1.000	1.003	1.011	1.019	1.020	1.006	0.014	0.013	0.009	0.011	0.010	0.014	0.032	0.015	
44	1	1.019	1.019	1.027	1.035	1.033	1.019	1.021	1.025	0.013	0.009	0.007	0.012	0.012	0.018	0.025	0.014	
	2	1.004	1.009	1.013	1.017	1.020	1.007	1.001	1.010	0.007	0.004	0.005	0.011	0.007	0.018	0.032	0.012	
45	1	0.995	0.996	0.990	0.991	0.999	0.994	1.025	0.998	0.019	0.016	0.014	0.016	0.014	0.029	0.067	0.025	Station 5 D7
	2	0.985	0.995	0.984	0.980	0.995	0.988	1.005	0.990	0.030	0.019	0.016	0.016	0.015	0.033	0.061	0.027	

Table F.3 All trial data during the reserve day (all laps - full dataset)

ID	Lap	Lap used	Field Calibration Factor (FCF)								Standard Deviation of Deviation Ratio (SDDR)							
			D1	D2	D3	D4	D5	D6	D7	Mean	D1	D2	D3	D4	D5	D6	D7	Mean
15	0	N	0.990	0.990	0.994	0.991	0.985	0.995	1.002	0.992	0.016	0.010	0.011	0.012	0.013	0.015	0.014	0.013
	1	N	0.990	0.987	0.990	0.993	0.987	0.995	0.999	0.992	0.023	0.014	0.013	0.015	0.017	0.016	0.020	0.017
	2	N	0.990	0.992	0.994	0.997	0.990	0.999	1.001	0.995	0.017	0.007	0.009	0.010	0.012	0.014	0.013	0.012
28	0	N	0.978	0.961	0.951	0.953	0.953	0.989	1.014	0.971	0.050	0.044	0.052	0.045	0.053	0.050	0.059	**0.051**
	1	N	0.979	0.973	0.960	0.953	0.962	0.997	1.044	0.981	0.048	0.037	0.037	0.052	0.045	0.040	0.057	0.045
	2	N	0.991	0.961	0.968	0.968	0.971	1.001	1.030	0.984	0.031	0.033	0.032	0.038	0.038	0.040	0.054	0.038
32	0	N	1.000	1.015	1.016	1.024	1.011	1.015	1.007	1.013	0.034	0.018	0.013	0.018	0.021	0.037	0.044	0.026
	1	Y	0.998	1.020	1.018	1.022	1.014	1.025	1.005	1.014	0.057	0.018	0.012	0.014	0.014	0.020	0.027	0.023
	2	Y	1.000	1.022	1.019	1.026	1.018	1.017	0.998	1.014	0.047	0.013	0.010	0.011	0.016	0.019	0.049	0.024
33	0	N	1.013	1.000	1.004	1.000	0.994	0.995	0.980	0.998	0.034	0.011	0.011	0.014	0.016	0.024	0.042	0.022
	1	N	1.028	1.004	1.010	1.008	0.998	0.993	0.966	1.001	0.024	0.015	0.011	0.013	0.017	0.029	0.048	0.022
	2	N	1.019	1.011	1.008	1.006	0.999	0.992	0.961	0.999	0.020	0.008	0.009	0.011	0.015	0.021	0.041	0.018
39	0	N	0.992	1.002	1.002	1.002	0.987	0.996	0.986	0.995	0.011	0.007	0.008	0.009	0.009	0.011	0.012	0.010
	1	N	0.992	1.001	1.001	1.000	0.984	0.992	0.976	0.992	0.012	0.006	0.004	0.007	0.010	0.013	0.031	0.012
	2	N	0.996	1.003	1.000	0.999	0.987	0.995	0.990	0.996	0.014	0.007	0.008	0.009	0.010	0.013	0.027	0.012
40	0	N	1.030	1.027	1.025	1.021	1.031	1.033	0.996	1.023	0.017	0.009	0.005	0.007	0.008	0.009	0.018	0.010
	1	N	1.022	1.024	1.024	1.020	1.033	1.035	1.016	1.025	0.016	0.013	0.007	0.010	0.014	0.014	0.021	0.014
	2	N	1.035	1.024	1.024	1.019	1.035	1.033	1.018	1.027	0.021	0.012	0.012	0.013	0.017	0.013	0.037	0.018
41	0	N	0.996	1.003	0.997	0.998	1.006	1.004	1.018	1.003	0.014	0.008	0.005	0.007	0.009	0.012	0.027	0.012
	1	N	0.988	0.997	0.994	0.995	1.007	1.015	1.016	1.002	0.014	0.007	0.005	0.008	0.010	0.020	0.020	0.012
	2	N	0.987	0.991	0.990	0.991	1.001	1.005	1.008	0.996	0.013	0.005	0.011	0.010	0.010	0.024	0.021	0.013
44	0	N	0.996	1.002	1.004	1.005	1.009	0.994	0.998	1.001	0.012	0.006	0.007	0.010	0.009	0.006	0.021	0.010
	1	N	0.997	1.000	1.004	1.006	1.013	0.996	0.998	1.002	0.010	0.007	0.007	0.009	0.008	0.012	0.016	0.010
	2	N	1.001	1.005	1.005	1.010	1.012	0.996	0.994	1.003	0.012	0.008	0.009	0.010	0.008	0.011	0.025	0.012

Appendix G Accreditation trial – Trial results

ID	Make, model and serial number	Repeatability	Reproducibility				Elapsed distance	Temperature			OSGR (Horizontal)
			FCF		SDDR			100mm	Surface	Air	
			Mean	Individual	Mean	Individual					
2	Dynatest FWD 8002 SN 102	Pass	Pass	Pass	Pass	Pass	Pass	High	*No data*	*No data*	*No data*
5	Dynatest HWD 8082 SN 050	Pass	Pass	Pass	Pass	Pass	Pass	Medium	*No data*	*No data*	*No data*
6	Dynatest HWD 8082 SN 018	Pass	Pass	Pass	Pass	Pass	Pass	High	*No data*	High	Medium
8	Dynatest FWD 8002 SN 028	Pass	Pass	Pass	Pass	Pass	Pass	Medium	*No data*	*No data*	*No data*
9	Dynatest FWD 8002 SN 136	Pass	Pass	Pass	Pass	Pass	Pass	High	*No data*	*No data*	High
10	Dynatest FWD 8002 SN 192	Pass	Pass	Pass	Pass	Pass	Pass	High	*No data*	*No data*	*No data*
11	Dynatest FWD 8002 SN 187	Pass	Pass	Pass	Pass	Pass	Pass	High	*No data*	*No data*	*No data*
13	Dynatest HWD 8082 SN 029	Pass	Pass	Pass	Pass	Pass	Pass	High	*No data*	*No data*	*No data*
15	Dynatest FWD 8002 SN 203	Pass	Pass	Pass	Pass	Pass	Pass	High	*No data*	*No data*	*No data*
16	Dynatest FWD 8002 SN 214	Pass	Pass	Pass	Pass	Pass	Pass	Medium	*No data*	*No data*	*No data*
28	Dynatest FWD 8002 SN 271	Pass	Pass	Pass	Pass	Pass	Pass	High	*No data*	*No data*	*No data*
30	Dynatest FWD 8002 SN 173	Pass	Pass	Pass	Pass	Pass	Pass	Low	*No data*	Low	High
32	Dynatest HWD 8082 SN 069	Pass	Pass	Pass	Pass	Pass	Pass	High	*No data*	*No data*	*No data*
33	Dynatest HWD 8082 SN 070	Pass	Pass	Pass	Pass	Pass	Pass	High	High	Low	*No data*
34	Dynatest HWD 8082 SN 108	Pass	Pass	Pass	Pass	Pass	Pass	High	Not Suitable	*No data*	*No data*
36	Grontmij PRI 2500 0608-303	Pass	Pass	Pass	Pass	Pass	Pass	High	Not Suitable	Medium	Low
37	Dynatest FWD 8002 SN 352	Pass	Pass	Pass	Pass	Pass	Pass	High	High	High	*No data*
38	Grontmij PRI 1500 1111-448	Pass	Pass	Pass	Pass	Pass	Pass	High	Medium	Low	Low
39	Dynatest FWD 8002 SN 388	Pass	Pass	Pass	Pass	Pass	Pass	High	Medium	High	High
40	Dynatest FWD 8012 SN 002	Pass	Pass	Pass	Pass	Pass	Pass	Medium	Medium	High	High
41	Dynatest HWD 8082 SN 108	Pass	Pass	Pass	Pass	Pass	Pass	Medium	*No data*	*No data*	*No data*
44	Dynatest HWD 8082 SN 156	Pass	Pass	Pass	Pass	Pass	Pass	High	Medium	High	High
45	Grontmij Carlbro PRI2100 0903-088	Pass	Pass	Pass	Pass	Pass	Pass	Medium	Medium	Low	*No data*

Highways England 2016 National Dynamic Plate Test device Accreditation Trial

A key element for the successful maintenance of a road network is accurate, reliable and consistent survey data. To this aim Highways England commissions annual accreditation trials for the Dynamic Plate test devices (FWDs and HWDs) supported by ongoing QA for the devices. In order to undertake accredited surveys, the survey devices are required to meet the mandatory criteria of the trial.

This report covers the 2016 trial run by TRL and held on the Horiba-MIRA proving ground between 4th and 6th October 2016.

Other titles from this subject area

PPR 946	Highways England 2015 National Dynamic Plate Test device Accreditation Trial. S Brittain, M Militzer. 2020
PPR 947	Highways Agency 2014 National Dynamic Plate Test device Accreditation Trial. S Brittain. 2020
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