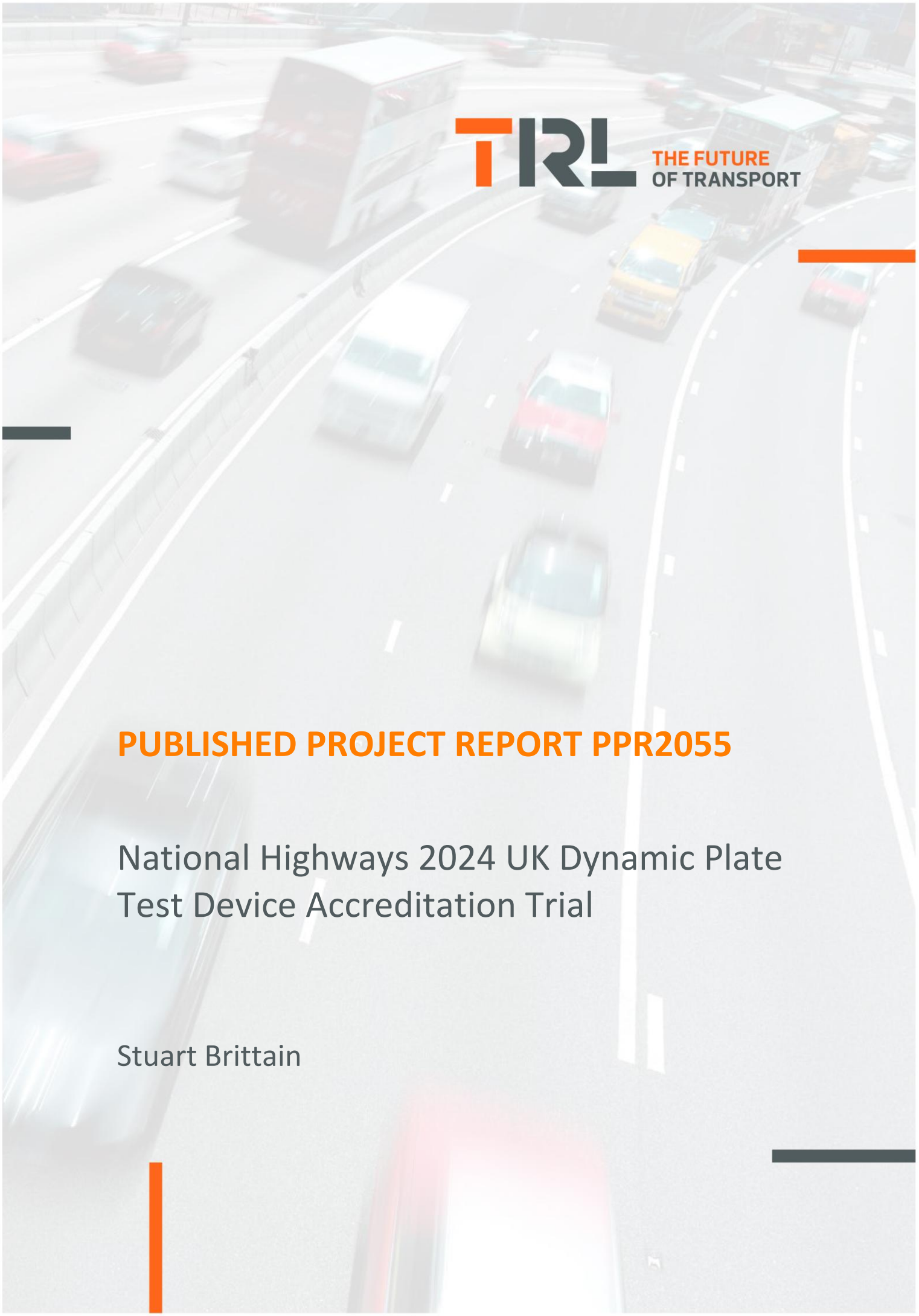

THE FUTURE OF TRANSPORT

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National Highways 2024 UK Dynamic Plate Test Device Accreditation Trial

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Executive Summary

The 2024 UK Dynamic Plate Test (DPT) device accreditation trial was held on the Twin Straights on the Horiba-MIRA proving ground in the week beginning the 23rd September 2024. This was the twenty-sixth mandatory DPT accreditation trial to be held in the UK with the objective being to assess the performance of all DPT machines likely to be operating on the National Highways Strategic Road Network (SRN). DPT machines 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 reviewing 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-two machines took part in the trial, consisting of:

- Thirteen trailer-mounted Dynatest FWDs;
- Six trailer-mounted Dynatest HWDs;
- One trailer-mounted Sweco FWD;
- One trailer-mounted Sweco HWD; and
- One trailer-mounted Rincent HWD.

The 2024 trial followed a format similar to the approaches that have been used successfully in previous trials carried out since 1999. Three days are set aside for the trial and for the 2024 trial all three days were used. The first day included machine inspections and initial testing of the machines. The second day was used to reassess machines (following some alterations). The third day was used to complete the testing.

The assessments undertaken 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 measurement of pavement temperature (at 100mm and surface temperature) and air temperature against an independent reference (a non-mandatory test); and
- Accuracy of 3-dimensional positional data where fitted (a non-mandatory test).

At the completion of the trial, it was identified that:

- All twenty-two machines met the repeatability of deflection criteria.
- Twenty-one machines met the reproducibility of deflection criteria.
- All twenty-two machines met the measurement of elapsed distance criteria.

- 3-dimensional positional data was supplied by nineteen of the test machines. This data was provided in latitude/longitude/height format during the trial and participants were asked to provide the data converted into Ordnance Survey Grid Reference (OSGR) format after the trial. Using the OSGR converted data, fourteen machines achieved a high performance level and five a medium performance level.
- All twenty-two operators of the machines provided 100mm pavement temperature measurements using hand-held probes. Fifteen achieved a high performance rating, five achieved a medium, and two a low.
- Nine machines provided surface temperature measurements using infra-red thermometers (IRTs) fixed to their machines that were suitable for assessment. Five machines achieved a high performance rating, one a medium performance and three were identified as low performance.
- Nine machines provided air temperature measurements from apparatus fixed to their machines that were suitable for assessment. This data was assessed using the surface temperature criteria. Five machines achieved a high performance rating, three a low performance, and one was identified as not suitable.

The results of all of the machines are summarised in a single table in Appendix G.

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1 Introduction

Current advice on the use of Dynamic Plate Test devices, (where they are referred to as Falling Weight Deflectometers [FWDs]), provided in CS 229 of the Design Manual for Roads and Bridges (DMRB CS 229, 2020), requires that all of these machines shall be operated in accordance with the Accreditation and Quality Assurance of Dynamic Plate Test Survey Devices document (TRL, 2020). This Accreditation and QA specification document outlines the Accreditation trial procedure that needs to be undertaken. This process forms part of a system to ensure that consistent, high-quality data is obtained from condition surveys. 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.

The objectives of the 2024 Dynamic Plate Test (DPT) Accreditation trial were:

- To ensure that all measuring systems are in good mechanical order.
- To ensure consistent performance of individual machines and the reproducibility of all machines, including any supporting measurements (i.e. temperature and location).
- To monitor and seek improvements in performance over the longer term.

The twenty-sixth mandatory UK DPT accreditation trial was held in the week beginning the 23rd September 2024, organised on behalf of National Highways. The trial followed a similar format to the approaches that were used in previous trials carried out since 1999. The 2024 trial included the following mandatory checks:

- Reproducibility;
- Repeatability; and
- Distance measurement;

and the following non-mandatory checks:

- Temperature measurement at 100mm, air and surface; and
- 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.

From 1999 to April 2010, the trials were conducted on the Small Roads System at TRL in Berkshire. The trials were then moved to the Horiba-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 in November 2012. The 2013 trial, and all subsequent trials, have been held on the proving grounds at Horiba-MIRA.

This report describes the conduct and findings of the September 2024 accreditation trial and presents the details of the machines that took part.

2 Trial details

2.1 Participants

Twenty-two machines (all trailer-mounted) took part in the 2024 National Highways DPT accreditation trial, comprising fourteen Falling Weight Deflectometers (FWD) and eight Heavy Weight Deflectometers (HWD). The machines in attendance were owned by eleven separate organisations as shown in Table 2.1 (note "FFWD" is a newer FWD type, the Fast FWD and uses an electric motor instead of hydraulics to increase the speed of testing).

Table 2.1: DPT machines attending the trial

Company	Machines brought to trial
AECOM	2 × Dynatest 8002 FWD, 2 × Dynatest 8082 HWD
Alptest	Dynatest 8002 FWD
Atlas Geophysical Limited	Sweco Primax 2100 HWD
Construction Testing Solutions Ltd	Dynatest 8002 FWD
Dynatest	2 x Dynatest 8002 FWD
Milestone	Sweco PRI1500 FWD
PMS Ltd.	2 x Dynatest 8002 FWD, 1 x Dynatest 8082 HWD
XAIS-PTS	1 × Dynatest 8002 FWD, 3 x Dynatest 8082 HWD 1 x Dynatest 8012 FFWD
Pulse Surveying Ltd.	2 x Dynatest 8002 FWD
SOCOTEC	RINCENT HeavyDyn
TRL Ltd.	Dynatest 8002 FWD

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

Throughout 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 provided with detailed instructions for the trial and 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 recommended setup described in CS 229 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 station.

For the reproducibility testing the following were also specified:

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

Operators were also advised to have the peak smoothing function, if available, activated and asked to record and provide time histories.

2.3 Inspection of vehicles

Operators were asked 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 geophones were in the correct positions. The configurations are summarised in Appendix A.

2.4 Location of trial

Four test sections were used for the trial; each with different construction and associated deflection levels and are located on the Twin Straights on the Horiba-MIRA proving ground. Each section contained three test stations (12 stations in total), located between the wheelpaths, 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 is used (along with stations 2, 5 and 8) 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. Construction details for the four deflection 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

Pavement temperatures were measured by TRL throughout the trial using five sets of temperature sensors and were also recorded using data loggers.

Three of the five sets contained thermocouples to measure the 40mm and 100mm pavement temperatures (or the water bucket at station 13) and also the air and pavement surface temperatures. The loggers connected to the sensors were set to record the temperature measurement once every minute. These sets were set-up to provide measurements near station 2, station 10 and station 13.

The remaining two sets, which use platinum resistance probes, were set up on different stations at different parts of the trial. The loggers connect to the sensors were set to record the temperature every second.

The results from these sensors and the position of the platinum resistance probes are further discussed in sections 5.1 and 6.1.

2.6 Planned test programme

Details about the trial, including the test programme and instructions, were provided to all participants in advance of the trial. An outline of the planned trial programme provided to participants, including details on the contingency planning, is reproduced below. The testing conducted and any changes to the process are discussed in the rest of the report.

2.6.1 Day 1 – inspection, repeatability and reproducibility testing

All machines are due to arrive on site for 8:30. After arrival on site, participants will be briefed on the test plan and site rules. This will be followed by machine inspections and the repeatability testing. TRL staff members will be available during testing to assist crews with positioning at test stations.

Four stations (2, 5, 8 and 13) have been selected for the repeatability testing. For this testing, two laps of twelve replicate drops at each station are 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.

The data from the repeatability laps will be processed by TRL during the test day and feedback provided to operators so that they can investigate their machine, if required, before they take part in the reproducibility laps.

Once the repeatability laps are completed (and processed), the machines will undertake the reproducibility testing.

For the reproducibility testing five replicate drops are made at each of 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.

Operators will be asked to undertake three reproducibility laps. If time permits, crews will be asked to make temperature measurements using pre-drilled holes (the same ones used for the temperature loggers to measure the 100mm depth). In addition, on returning to the start of the test site, the operators will be asked to measure a predefined length to provide

an assessment of the odometers fitted to the equipment. If there is insufficient time available then these measurements (temperature and distance) will be carried out on a later day in the trial.

Data collected will be processed on site. Where appropriate, i.e. if there is an issue with the machine, feedback from this processing will be provided to the operators as soon as possible.

At the completion of the testing on this day, operators will be informed of the selected test plan for day 2.

2.6.2 Day 2 –Investigation of machines and continued testing

The test plan for day 2 will be dependent on the outcomes of the testing on day 1. The two main options for this day are:

- If machines are identified as requiring alterations following testing on day 1 then the morning of day 2 will be set aside to allow these to be undertaken. The remaining machines will return to site for 10:00 to conduct at least 3 reproducibility laps.
- If no machines are identified as requiring alterations then all machines will return to site for 8:30 to complete and outstanding testing.

If significant number of machines require alteration or significant alterations are needed, then consideration will be given to using all of day 2 for alterations and continuing the testing on day 3.

2.6.3 Day 3 – Completion of testing

Day 3 will be used to complete any testing that could not be completed on days 1 and 2 e.g. due to bad weather, a stop testing call from HORIBA-MIRA or other unforeseen events.

3 Machine set-up and configuration

The machine checks 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. Most of the machines arrived correctly set up and configured with only minor changes required following inspection by TRL staff.

Appendix A itemises the configuration of the various machines, while Table 3.1 summarises the findings with regards to availability of key information requested in the trial documentation.

Table 3.1: Summary of key information for DPTs provided on arrival

Checklist item	Number compliant (out of 22)
Completed Check list returned to TRL before trial	20
Geophones in correct position on arrival at trial	20
Date of last tower calibration	21
Date of last dynamic calibration	20[1]
Date of last manufacturer's calibration	22

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

[1] One of the two machines that did not provide the date of the last dynamic calibration is a new machine and as such has not started the QA procedure yet.

4 Repeatability testing

Since the repeatability test assesses the ability of the machine to produce repeatable results, this testing can be carried out at different times for each machine (i.e. the results are not temperature dependent and therefore they do not need to test the site in convoy). This testing is conducted using stations 2, 5, 8 and 13 and the results were assessed using the test criteria in Appendix D, D.1.

The first step of the repeatability testing is to produce a valid test dataset. This requires the data to have the load applied within a specified range, and the standard deviation of the load applied also needs to be within a specified range. The requirements for a valid test are also given in Appendix D, D.1.

Some machines had issues providing valid results during the repeatability testing on Day 1. In addition, during the reproducibility testing (discussed in sections 5 and 6) some machines were identified as requiring investigation and subsequently underwent alterations. Therefore, additional repeatability testing for these machines was carried out on Day 2.

Table 4.1 shows a summary of the final results for the repeatability assessment for all machines for geophones D1 to D7. For this testing there are 56 data points per machine (7 geophones x 4 stations x 2 laps). The full details of each repeatability test (identifying the failures and details on load applied) can be found in Appendix E.

Table 4.1: Repeatability assessment

ID	Failures for D1	Failures for D2	Failures for D3	Failures for D4	Failures for D5	Failures for D6	Failures for D7	Percentage met criteria	Status
2	0	0	0	0	0	0	0	100.0%	Pass
5	0	0	0	0	0	0	0	100.0%	Pass
6	0	0	0	0	0	1	0	98.2%	Pass
10	0	0	0	0	0	0	0	100.0%	Pass
11	0	0	0	0	0	0	0	100.0%	Pass
13	2	0	0	0	0	0	0	96.4%	Pass
15	0	0	0	0	0	0	0	100.0%	Pass
16	0	0	0	0	0	1	0	98.2%	Pass
28	0	1	0	0	0	0	0	98.2%	Pass
30	0	0	0	0	0	0	0	100.0%	Pass
32	0	0	0	0	0	0	0	100.0%	Pass
33	0	0	0	0	0	0	0	100.0%	Pass
34	0	0	0	0	0	0	0	100.0%	Pass
39	0	0	0	0	0	0	0	100.0%	Pass
45	0	0	0	0	0	0	0	100.0%	Pass
47	0	0	0	0	1	0	0	98.2%	Pass
48	0	0	0	0	0	0	0	100.0%	Pass
50	2	0	0	0	0	0	0	96.4%	Pass
52	0	0	0	0	0	0	0	100.0%	Pass
53	0	0	0	0	0	0	0	100.0%	Pass
54	0	0	0	0	0	0	0	100.0%	Pass
56	0	0	0	0	0	0	0	100.0%	Pass

From Table 4.1, it can be seen that all Machines met the repeatability criteria.

5 Reproducibility testing - Day 1

5.1 Temperature variation – Day 1

The maximum permitted change in the 100mm depth pavement temperature during a test lap is 3°C. The aim of this limit is to minimise changes in deflections due to temperature changes within the pavement construction in each test lap.

During the test days of the trial, pavement temperatures were recorded at 40 and 100mm depths near stations 2 and 10 by TRL. In addition, air and surface temperatures were also collected near these stations. Issues were encountered with some of the sensors during the trial, resulting in some gaps in the data. The temperature at depth data collected for Day 1 are shown in Figure 5.1. The air and surface temperatures collected for Day 1 are shown in Figure 5.2. There were some issues with the logger at station 2 on Day 1 as such no suitable data was available for the temperature at 40mm for this station.

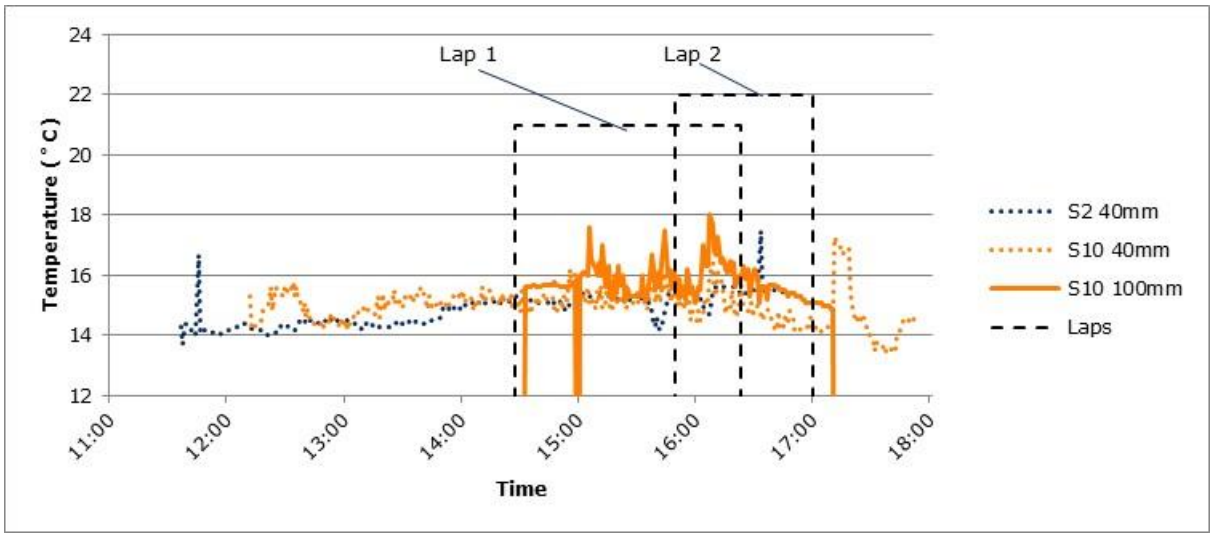

Figure 5.1: Pavement temperatures during Day 1

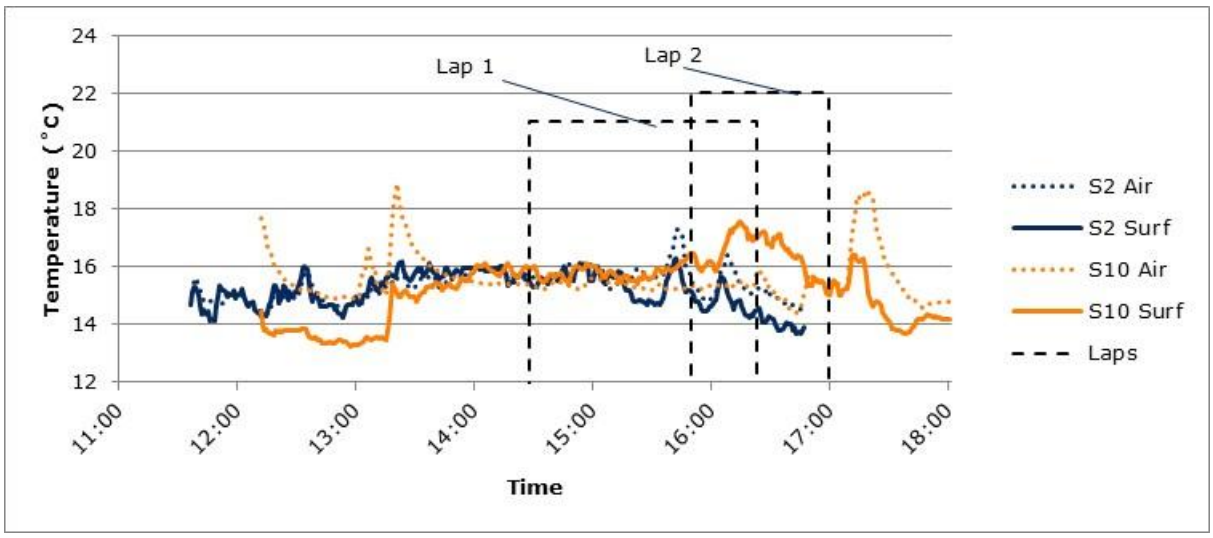

Figure 5.2: Air and surface temperatures during Day 1

Summaries of the pavement temperature measurements for each test lap on Day 1 are given in Table 5.1 and Table 5.2 for stations 2 and 10 respectively.

Table 5.1: Pavement temperatures (˚C) for each lap during Day 1, near station 2

Lap	Start time	Start temp 40mm	Start temp 100mm	End time	End temp 40mm	End temp 100mm	Duration (hh:mm)	Temp diff during lap 40mm	Temp diff during lap 100mm
01	14:28	15.3	-	16:23	15.5	-	01:55	0.2	-
02	15:50	15.6	-	17:00	15.4	-	01:10	-0.2	-

Table 5.2: Pavement temperatures (˚C) for each lap during Day 1, near station 10

Lap	Start time	Start temp 40mm	Start temp 100mm	End time	End temp 40mm	End temp 100mm	Duration (hh:mm)	Temp diff during lap 40mm	Temp diff during lap 100mm
01	14:28	15.2	15.6	16:23	15.6	16.0	01:55	0.4	0.4
02	15:50	15.2	16.1	17:00	14.2	15.1	01:10	-1.0	-1.0

Although there are gaps in the data, the range of values seen (and the 40mm depth temperatures) suggests that the 100mm depth temperatures were well within the 3°C limit on all laps on Day 1.

5.2 Reproducibility testing – Day 1

In order to evaluate the performance of each machine with regards to reproducibility, two laps are required (see Appendix D for further details). Due to the chances of isolated anomalous geophone readings, the accreditation rules permit the measurement from a single geophone from one test station to be removed from each reproducibility lap.

During Day 1, two reproducibility laps were undertaken. It was decided that if all machines met the deflection criteria at this stage of the testing then Day 2 would be used to collect the remaining temperature and distance measurements, as required. However, a number of machines did not meet all the criteria on Day 1. Therefore, the operators were given the opportunity to investigate their machines and all machines were retested on Day 2 followed by some additional testing on Day 3. The results of the Day 2 testing are discussed in section 6 and Day 3 in section 7.

The Field Calibration Factor (FCF) and Standard Deviation of the Deviation Ratio (SDDR) values derived from each machine's lap are given in Appendix F, F.1 (including the laps done on Days 2 and 3). To clearly distinguish between the test days, the first lap on Day 2 was labelled as 21 and the first lap on Day 3 was labelled as 31. Further details on the FCF and SDDR and how they are calculated are given in Appendix D.

During this testing there were computer issues for Machine 53, and therefore this machine was excluded from the analysis. Also, Machine 6 only undertook one reproducibility lap due to the machine being investigated for performance in the repeatability testing.

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

Plots of the FCF and SDDR values (before removal of a single data point) for laps 1 and 2 on day 1 are shown in Figure 5.3 and Figure 5.4 (FCF and SDDR, respectively. 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. 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 are below their corresponding limits (0.05 and 0.07 respectively).

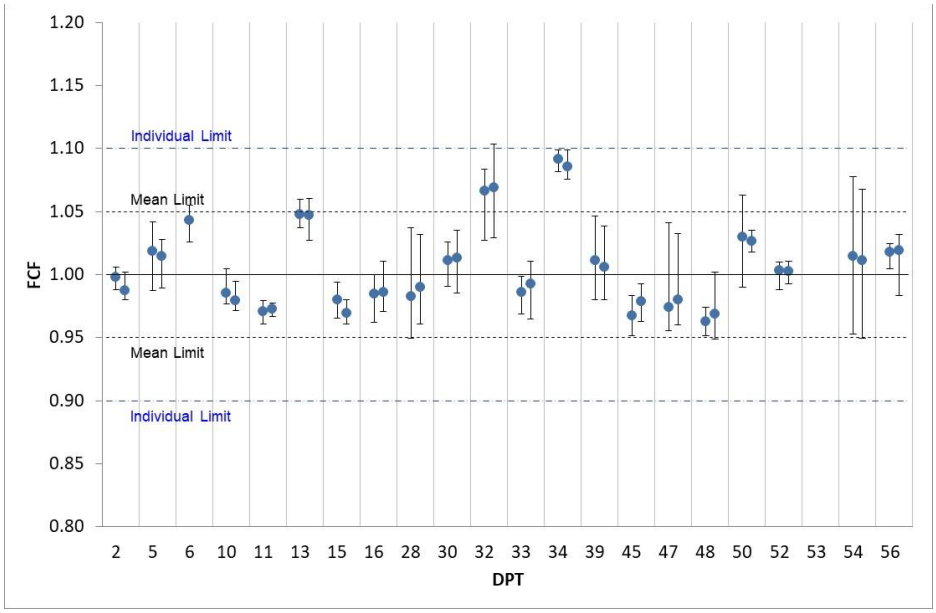

Figure 5.3: FCFs, day 1 last two laps– full data set

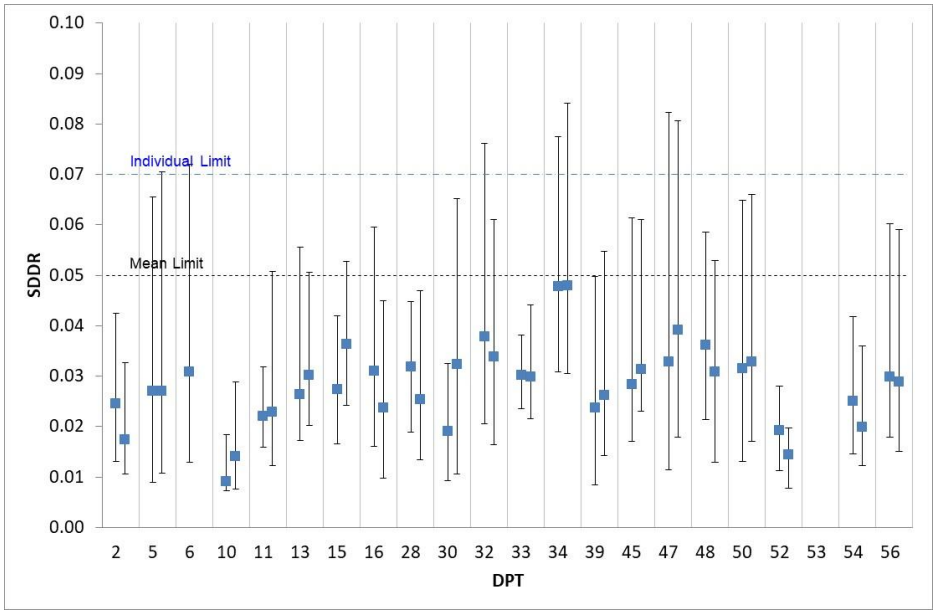

Figure 5.4: SDDRs, day 1 last two laps – full dataset

From Figure 5.3 it can be seen that (prior to removal of single geophone points) Machine 32 and Machine 34 are producing Mean FCF values too high. In addition, Machine 32 is

producing individual FCF values too high. Figure 5.5 shows that the individual SDDR limit is exceeded for machines 5, 6, 32, 34 and 47.

5.2.2 Plots of FCF and SDDR (after geophone removal)

As previously noted, due to chances of isolated anomalous geophone readings, the process permits the measurement from a single geophone from one test station to be removed from each reproducibility lap. The data from the last two laps from Day 1 after removal of a single data point (where required) are shown in Figure 5.5 and Figure 5.6.

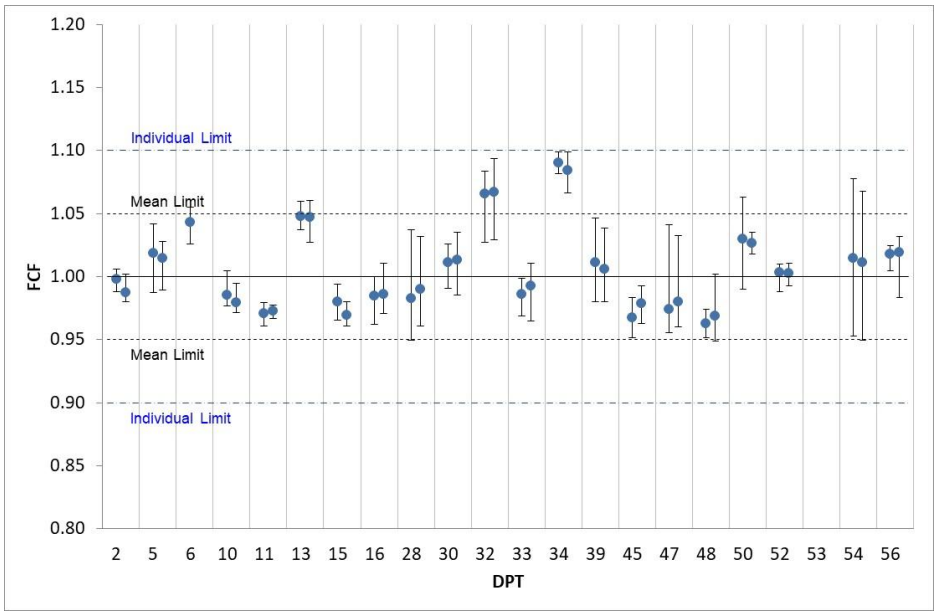

Figure 5.5: FCFs, day 1 last two laps – single data point removed where required

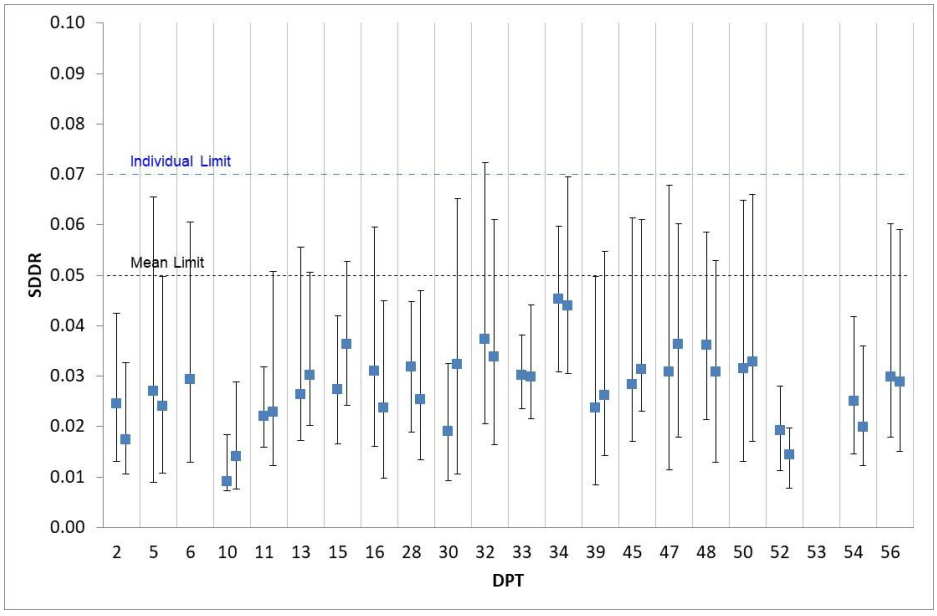

Figure 5.6: SDDRs, day 1 last two laps – single data point removed where required

From this data it can be seen that some machines are still not meeting the FCF, SDDR or either criteria. This information was fed back to operators and is discussed below.

5.2.3 Feedback provided following testing on Day 1

Following the processing of data from Day 1, the following feedback was provided to the operators:

- **Machine 13**. Although this machine was within the FCF requirements it was noted that it was close to the upper threshold for the mean FCF. Due to the feedback provided to other machines it is expected that the fleet mean will shift in the later testing in the trial likely resulting in this machine falling outside of the criteria.
- **Machine 32**. The Mean FCF for this machine was too high. In addition, the individual SDDR was too high on one of the two laps.
- **Machine 34**. The Mean FCF for this machine was too high.

6 Reproducibility testing – Day 2

6.1 Temperature variation – Day 2

The temperatures recorded for the 40 and 100mm depths near stations 2 and 10 for Day 2 by TRL are shown in Figure 6.1. The data for air and surface temperatures for these stations on Day 2 are shown in Figure 6.2. There were some issues with the logger at station 2 on Day 2 as such no suitable data was available for the temperature at 40mm or the air temperature for this station. Note: to clearly differentiate between the testing from day 1, the first lap on Day 2 was called lap 21.

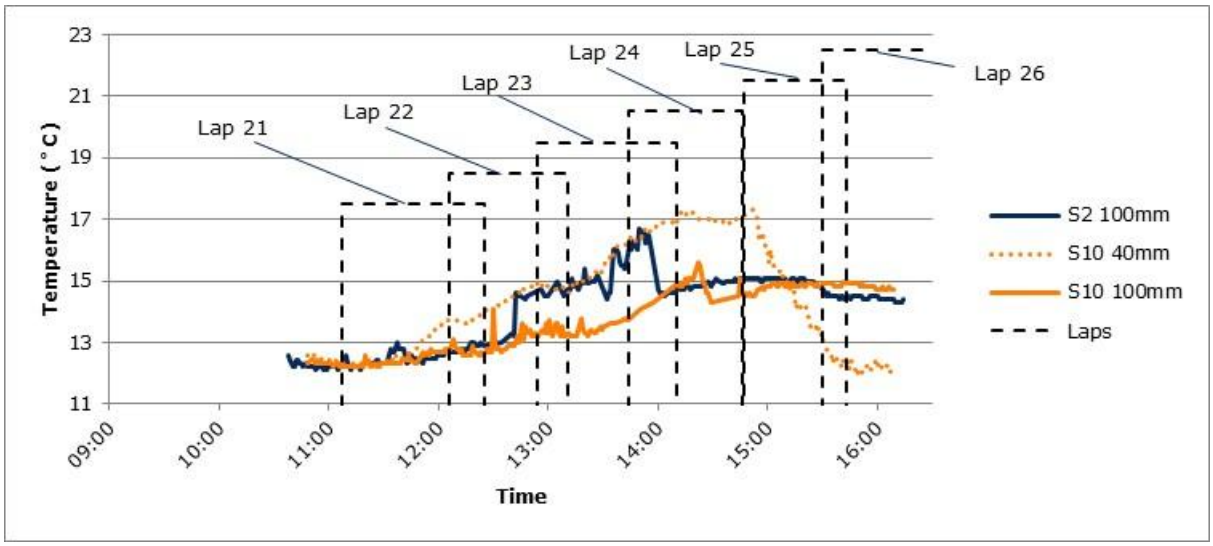

Figure 6.1: Pavement temperatures during Day 2

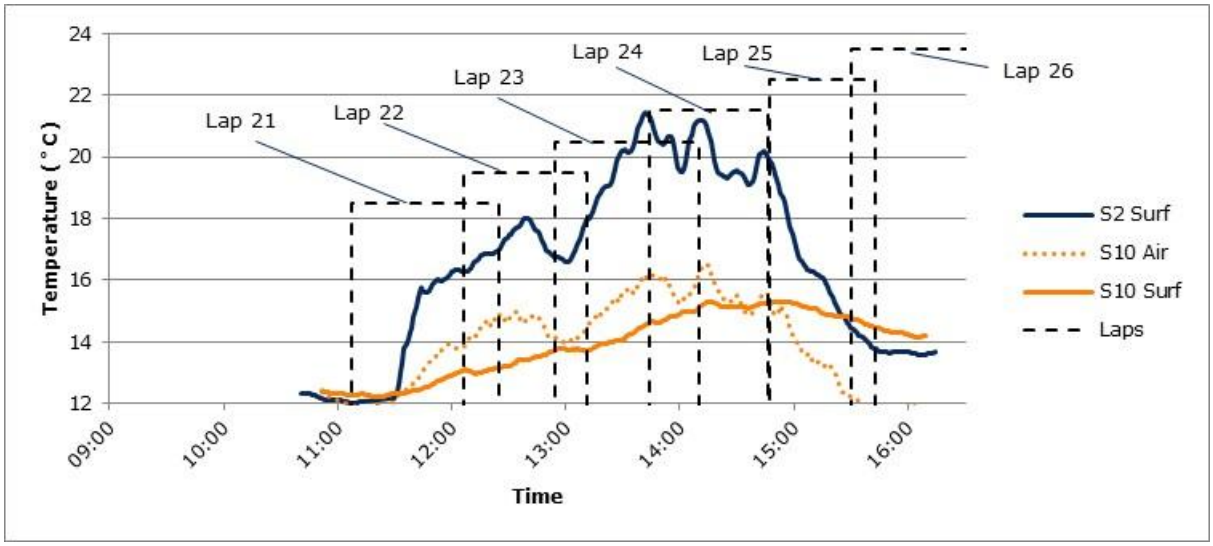

Figure 6.2: Air and surface temperatures during Day 2

Summaries of the pavement temperature measurements for each test lap on Day 2 are given in Table 6.1 and Table 6.2 for stations 2 and 10 respectively.

Table 6.1: Pavement temperatures (˚C) for each lap during Day 2, near station 2

Lap	Start time	Start temp 40mm	Start temp 100mm	End time	End temp 40mm	End temp 100mm	Duration (hh:mm)	Temp diff during lap 40mm	Temp diff during lap 100mm
21	11:07	-	12.2	12:25	-	13.0	01:18	-	0.8
22	12:06	-	12.7	13:11	-	14.7	01:05	-	2.0
23	12:54	-	14.5	14:10	-	14.6	01:16	-	0.1
24	13:44	-	15.6	14:46	-	15.1	01:02	-	-0.5
25	14:47	-	15.1	15:43	-	14.4	00:56	-	-0.7
26	15:30	-	14.8	16:40	-	14.4	01:10	-	-0.4

Table 6.2: Pavement temperatures (˚C) for each lap during Day 2, near station 10

Lap	Start time	Start temp 40mm	Start temp 100mm	End time	End temp 40mm	End temp 100mm	Duration (hh:mm)	Temp diff during lap 40mm	Temp diff during lap 100mm
21	11:07	12.3	12.3	12:25	13.9	12.6	01:18	1.6	0.3
22	12:06	13.7	12.8	13:11	14.6	13.3	01:05	0.9	0.5
23	12:54	15.0	13.2	14:10	16.8	14.3	01:16	1.8	1.1
24	13:44	16.3	13.7	14:46	17.0	14.6	01:02	0.7	0.9
25	14:47	17.0	14.5	15:43	12.3	14.9	00:56	-4.7	0.4
26	15:30	13.3	14.8	16:40	12.1	14.7	01:10	-1.2	-0.1

It can be seen that the differences in 100mm depth temperatures were well within the limit (3°C) for all laps on Day 2.

6.2 Reproducibility testing – Day 2

To evaluate the performance of each machine with regards to reproducibility, two laps are chosen from the test set. To distinguish these chosen laps, they are denoted as lap i and lap ii. For all machines, the laps chosen for i and ii were laps 25 and 26 (the last two laps of day 2).

The FCF and SDDR values derived from each machine's lap are given in Appendix F, F.1 (including the laps from Day 1 and Day 3).

In the initial testing on this day, issues were found with the following machines:

- **Machine 32**. In laps 21 and 23 the SDDR values produced for this machine were too high. The geophone in position D7 was swapped prior to lap 24.
- **Machine 47**. In laps 23 and 24 the SDDR values produced for this machine were too high. The geophone in position D7 was swapped prior to lap 24.

6.2.1 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 6.3 for FCF and Figure 6.4 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.

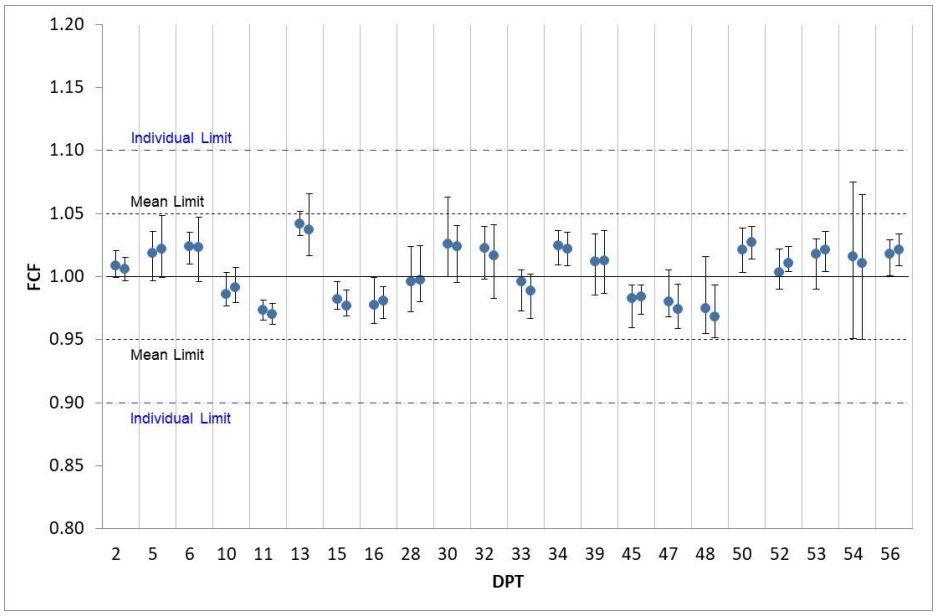

Figure 6.3: FCF for each DPT (Day 2 for laps i and ii – full data set)

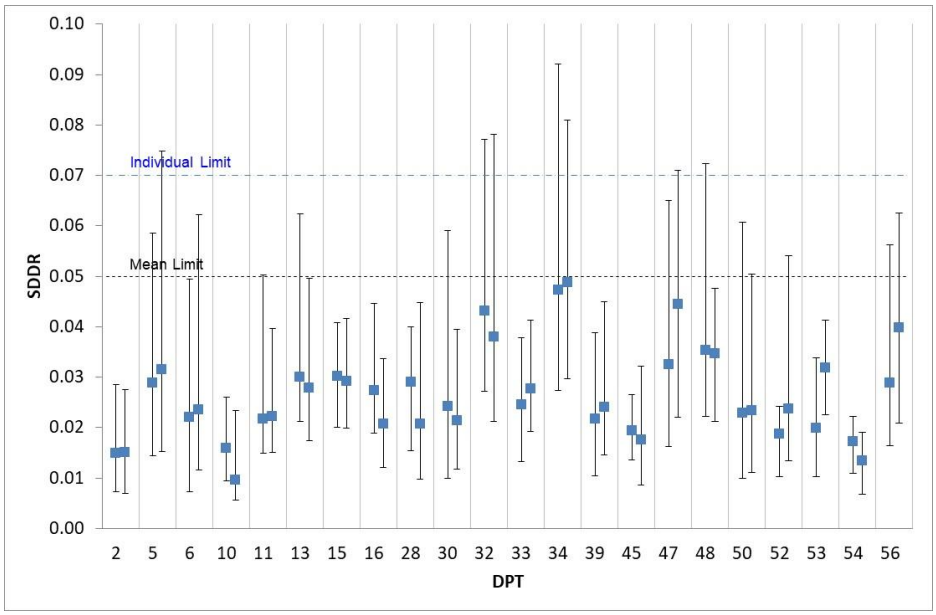

Figure 6.4: SDDR for each DPT (Day 3 for laps i and ii – full dataset)

It can be seen from Figure 6.3 that all machines meet the FCF criteria using the full data set from the two chosen test laps.

From Figure 6.4, it can be seen that five machines (Machine 5, Machine 32, Machine 34, Machine 47 and Machine 48) failed to meet the individual SDDR criterion using the full set of data.

6.2.2 Plot of SDDR (after geophone removal)

The results from laps i and ii (after geophone removal for identified machines) are shown graphically in Figure 6.5 for SDDR.

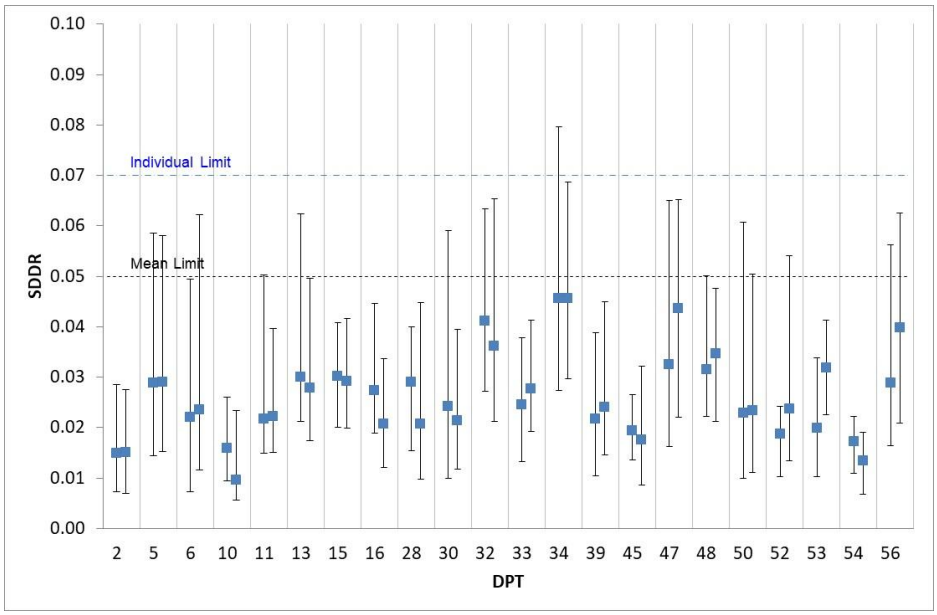

Figure 6.5: SDDR for each DPT (laps i and ii – single data point removed where required)

Following the removal of a single geophone reading from one station on each lap (where required) it can be seen that one machine (Machine 34) fails to meet the SDDR criteria for laps i and ii.

Due to the variable performance of Machine 34, and the retesting required for distance measurement (discussed in section 8.1) it was decided that further testing would be carried out on Day 3 using a sub-set of machines.

7 Testing on Day 3

The accreditation trial is planned as a three day trial, with the third day used to complete any testing that could not be completed on days 1 and 2 e.g. due to bad weather, a stop testing call from HORIBA-MIRA or other unforeseen events.

For the 2024 trial, day 3 was used to carry out additional testing.

7.1 Temperature variation – Day 3

The temperatures recorded for the 40 and 100mm depths near stations 2 and 10 for Day 3 by TRL are shown in Figure 7.1. The data for air and surface temperatures for these stations on Day 3 are shown in Figure 7.2. Note: to clearly differentiate between the testing on the previous days, the first lap on Day 3 was called lap 31.

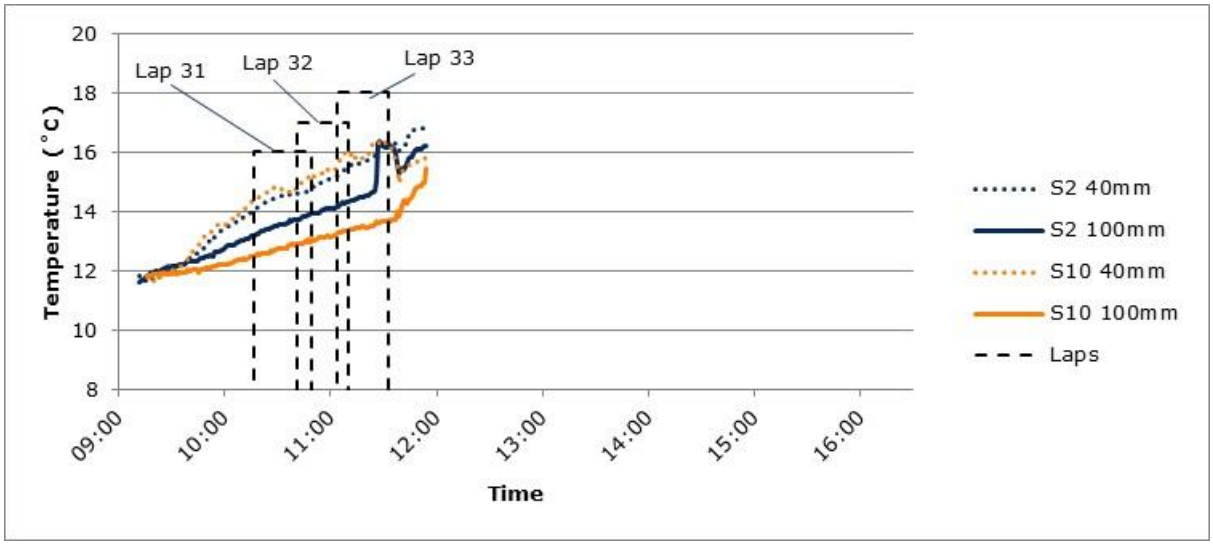

Figure 7.1: Pavement temperatures during Day 3

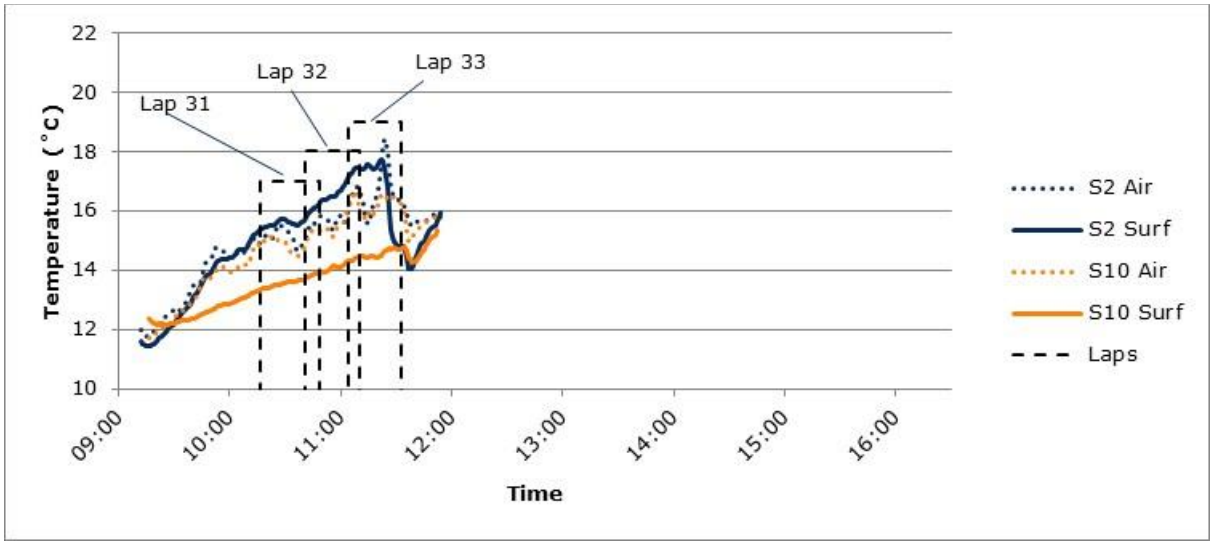

Figure 7.2: Air and surface temperatures during Day 3

Summaries of the pavement temperature measurements for each test lap on Day 3 are given in Table 7.1 and Table 7.2 for stations 2 and 10 respectively.

Table 7.1: Pavement temperatures (˚C) for each lap during Day 3, near station 2

Lap	Start time	Start temp 40mm	Start temp 100mm	End time	End temp 40mm	End temp 100mm	Duration (hh:mm)	Temp diff during lap 40mm	Temp diff during lap 100mm
31	10:17	14.1	13.2	10:49	14.8	13.9	00:32	0.8	0.7
32	10:41	14.6	13.7	11:10	15.5	14.3	00:29	1.0	0.6
33	11:04	15.2	14.2	11:33	16.3	16.2	00:29	1.1	2.0

Table 7.2: Pavement temperatures (˚C) for each lap during Day 3, near station 10

Lap	Start time	Start temp 40mm	Start temp 100mm	End time	End temp 40mm	End temp 100mm	Duration (hh:mm)	Temp diff during lap 40mm	Temp diff during lap 100mm
31	10:17	14.4	12.5	10:49	15.1	13.0	00:32	0.6	0.5
32	10:41	14.8	12.9	11:10	16.0	13.4	00:29	1.3	0.5
33	11:04	15.6	13.3	11:33	16.3	13.7	00:29	0.7	0.5

It can be seen that the differences in 100mm depth temperatures were well within the limit (3°C) for all laps on Day 3.

7.2 Reproducibility testing – Day 3

To evaluate the performance of each machine with regards to reproducibility, two laps are chosen from the test set. For Day 3 only three reproducibility laps were undertaken. To assess the performance of Machine 34, laps 32 and 33 were used.

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

The results from laps 32 and 33 (prior to the removal of individual geophone readings) are shown graphically in Figure 7.3 and Figure 7.4.

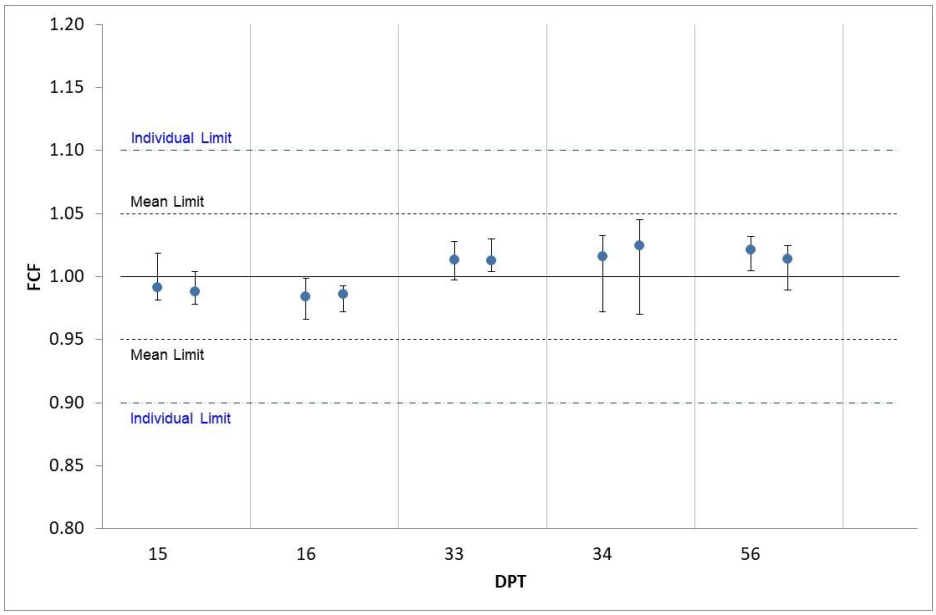

Figure 7.3: FCF for each DPT (Day 3 for laps 32 and 33 – full data set)

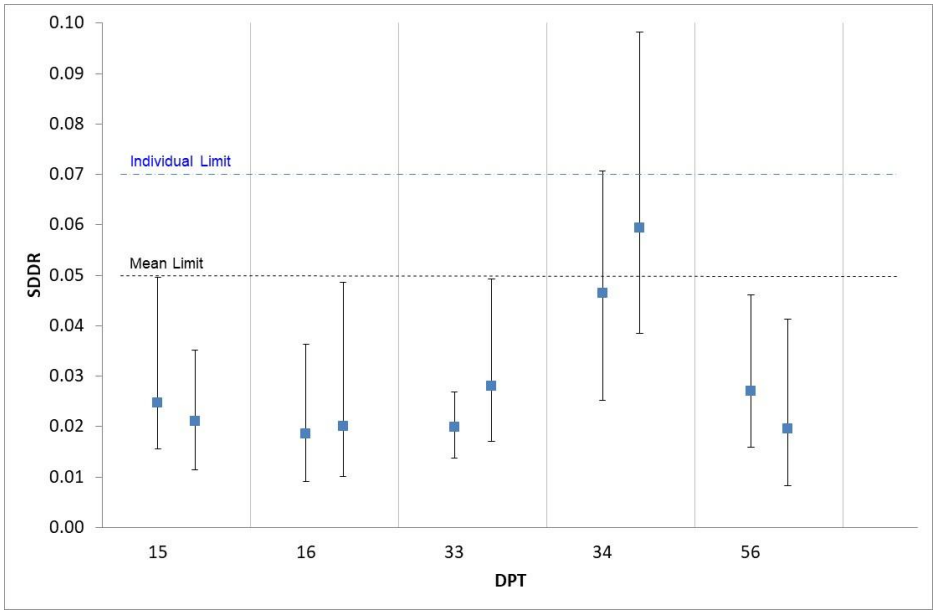

Figure 7.4: SDDR for each DPT (Day 3 for laps 32 and 33 – full data set)

It can be seen from Figure 7.3 that Machine 34 continues to meet the FCF criteria. From Figure 7.4 it can be seen that Machine 34 fails to meet the individual SDDR criterion on both laps, and the mean SDDR criterion on the last lap when using the full set of data.

7.2.2 Plot of SDDR (after geophone removal)

The results from laps 32 and 33 (after geophone removal where required) are shown graphically in Figure 7.5 for SDDR.

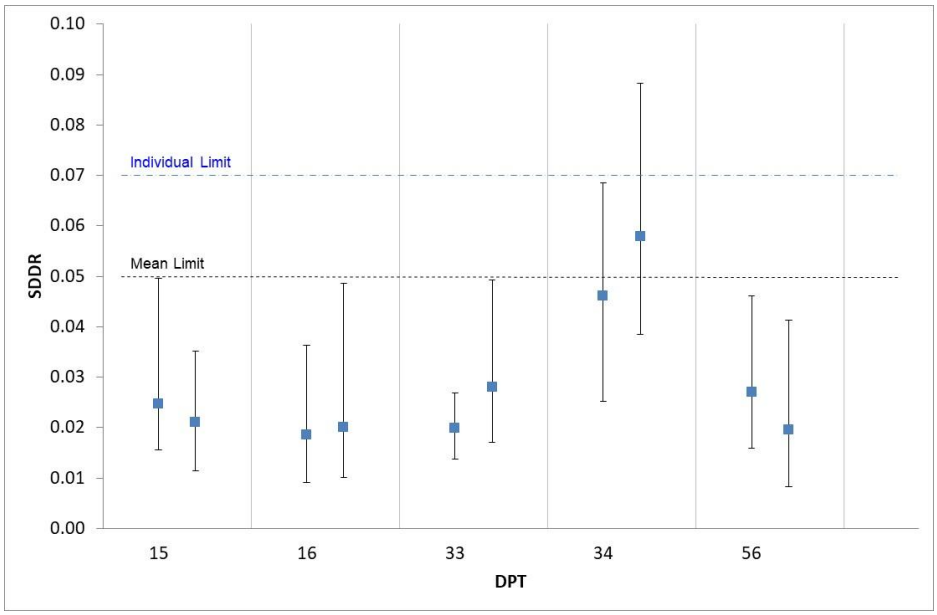

Figure 7.5: SDDR for each DPT (Day 3 for laps 32 and 33 – single data point removed where required)

Following the removal of a single geophone reading from one station on each lap for Machine 34, it can be seen that it meets the SDDR criteria on lap 32 but fails both the individual and mean SDDR criteria on lap 33.

8 Distance and OSGR

8.1 Distance measurement tests

In order to assess the measurement of distance, the operators were asked to measure the distance between two marker cones. The distance between them, 537m, was not provided to the operators.

The criteria applied to this data in previous years are described in Appendix D, D.1. However, it has been identified that the criteria were too easy to meet and did not assess the performance that these devices can achieve. Therefore, following discussions with the FWD user group an amended set of criteria were agreed and have been used in this trial. The criteria will be updated in a future version of the Accreditation and QA specification. As before, the test is carried out at least four times, and a pass is awarded if 80% of the measurements are within ±2m or 0.1% of the measurement length (whichever is greater).

During the initial testing, three machines (15, 33 and 56) were found to be outside of the tolerance. It was found that the operators of these devices were confused about the start and end points for the calibration and measurement lengths. Therefore, these devices were re-assessed for measurement of distance on day 3.

The differences between the final operator measurements and the reference length are given in Table 8.1 (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 (i.e. 2m).

Table 8.1: Difference (m) between operators' measured values and reference

Machine	Difference Lap a	Difference Lap b	Difference Lap c	Difference Lap d	Performance
2	0.0	0.0	0.0	0.0	Pass
5	-1.0	-1.0	-0.8	-0.6	Pass
6	-1.0	-0.9	-0.9	-0.9	Pass
10	-0.6	-1.0	-0.8	-0.8	Pass
11	-1.0	-1.0	-1.0	-1.0	Pass
13	-1.0	-1.0	-1.0	-1.0	Pass
15	0.0	0.0	0.0	0.0	Pass
16	-2.0	-2.0	-2.0	-2.0	Pass
28	0.0	0.0	0.0	0.0	Pass
30	-0.6	-0.6	-0.7	-0.7	Pass
32	-2.0	-2.0	-2.0	-2.0	Pass
33	0.0	0.0	0.0	0.0	Pass
34	-2.0	-2.0	-2.0	-2.0	Pass
39	-0.9	-0.9	-0.9	-0.9	Pass
45	-1.0	-1.0	-1.0	-1.0	Pass
47	-0.2	-0.3	-0.4	-0.4	Pass
48	-0.5	-0.7	-0.5	-0.6	Pass
50	-0.8	-0.8	-0.8	-0.8	Pass
52	-2.0	-2.0	-2.0	-2.0	Pass
53	-1.0	-1.0	-1.0	-1.0	Pass
54	-2.0	-2.0	-2.0	-2.0	Pass
56	-1.0	-1.0	-1.0	-1.0	Pass

It can be seen from this table that all machines met the trial criteria. In addition, 77% of the measurements were within 1m of the reference distance.

8.2 OSGR measurements (from 3-dimensional positional data)

3-dimensional positional data were supplied by 19 of the 22 machines at the trial. These machines all provide the data in lat/long/height format. However, the accreditation specification states that the data should be in OSGR format (eastings and northings). Therefore, the operators were asked to convert this data to OSGR format and provide both datasets for review. The horizontal offset from the reference point estimated from the lat/long data was compared against the horizontal offset from the reference point for the supplied OSGR data. This was done to check for anomalies in the conversion; no issues were identified.

The performance of each machine was then assessed using the provided OSGR data. The percentage of the data within 2m, 5m and 10m for each of the machines that supplied positional data is given in Table 8.2. This data is highlighted in bold and red text if the percentage is below 75% for any of the criteria.

Table 8.2: Assessment of positional data

Machine	Percentage within 2m of reference	Percentage within 5m of reference	Percentage within 10m of reference	Performance band
2	97.9%	99.0%	100.0%	High
5	98.6%	100.0%	100.0%	High
6	95.2%	100.0%	100.0%	High
10	100.0%	100.0%	100.0%	High
11	92.7%	100.0%	100.0%	High
13	88.5%	100.0%	100.0%	High
15	92.5%	98.5%	98.5%	High
16	**41.7%**	100.0%	100.0%	Medium
28	92.7%	100.0%	100.0%	High
30	97.9%	100.0%	100.0%	High
32	96.9%	100.0%	100.0%	High
33	97.5%	100.0%	100.0%	High
34	100.0%	100.0%	100.0%	High
39	**71.9%**	100.0%	100.0%	Medium
48	92.7%	100.0%	100.0%	High
50	**44.8%**	99.0%	100.0%	Medium
52	90.6%	100.0%	100.0%	High
53	**26.0%**	100.0%	100.0%	Medium
54	**35.4%**	100.0%	100.0%	Medium

It can be seen from Table 8.2 that fourteen machines achieved the high performance rating, and five machines achieved medium.

9 Operator temperature measurements

9.1 Temperature at depth (100mm)

The DPT operators were asked to use their own equipment to record temperatures from two pre-drilled holes during Days 1 and 2 so that their accuracy of temperature collection could be assessed. These holes are drilled to 100mm depth and located near stations 2 and 10. In addition, the operators were asked to measure the temperature of water in a bucket located near to station 13 during Day 2.

This data is typically assessed by comparing the values against the data collected by temperature data loggers located in the same holes (the data from Days 1 and 2 for stations 2 and 10 are discussed in sections 5.1 and 6.1). However, during the review of data, it was identified that the logger measurements were not always suitable for use in the assessment and therefore in some cases the fleet average was used as the reference. Details of the reference used is given in Table 9.1.

Table 9.1 Reference used for temperature at depth assessment

Trial Day	Location	Reference
Day 1	Station 2	Fleet Average
Day 1	Station 10	Fleet Average
Day 2	Station 2	Fleet Average
Day 2	Station 10	Logger
Day 2	Station 13 (water bucket)	Logger

The temperatures recorded by the operators using temperature probes are plotted against the reference in Figure 9.1 to Figure 9.5.

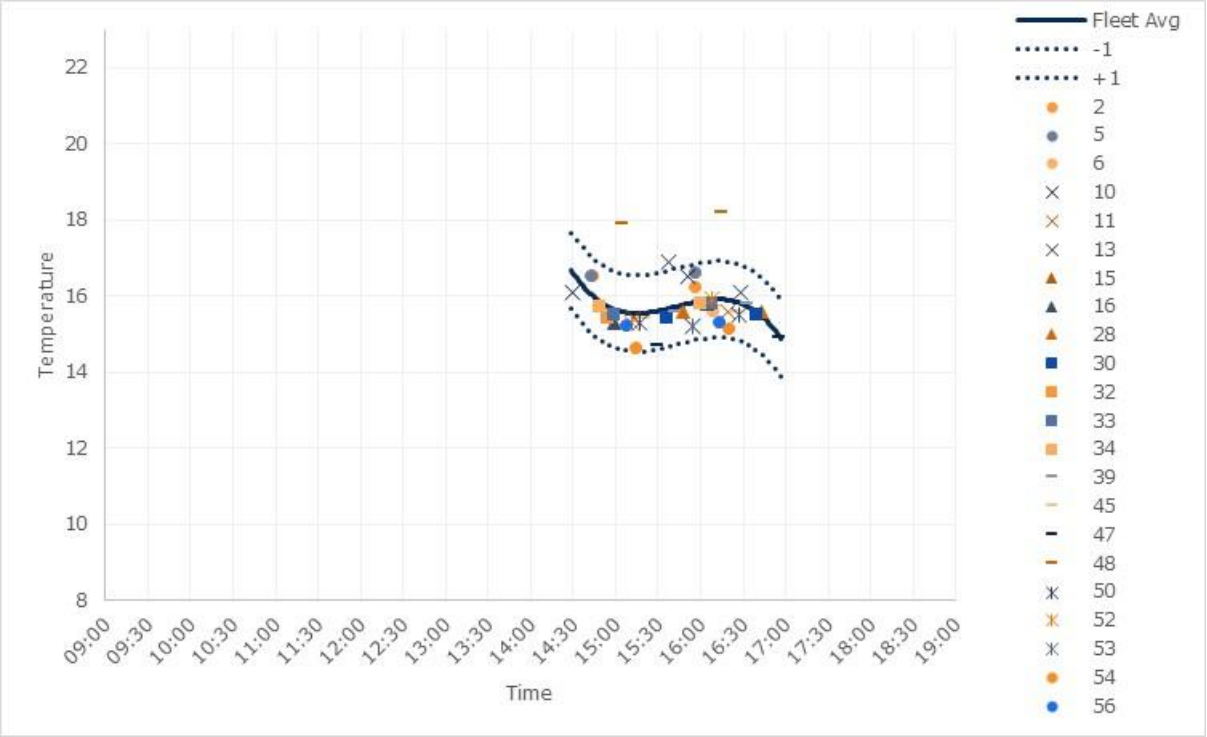

Figure 9.1: Operators' and reference temperatures (Day 1 near station 2, 100mm depth)

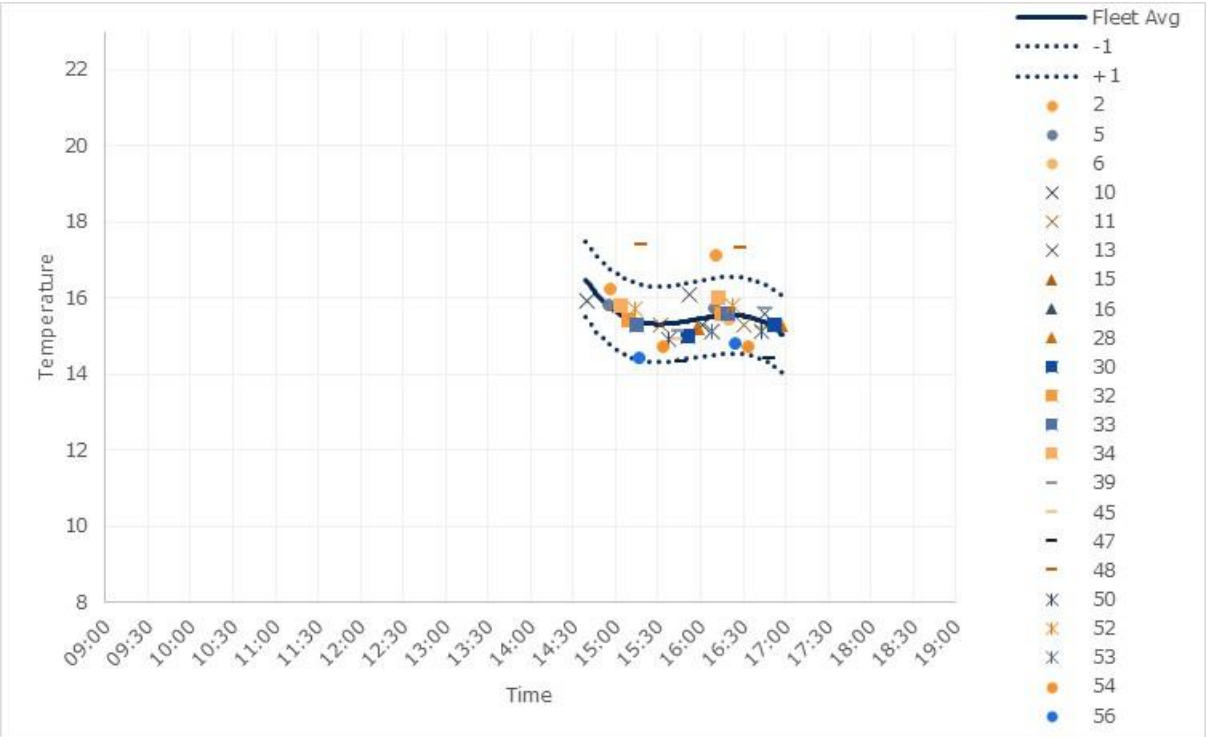

Figure 9.2: Operators' and reference temperatures (Day 1 near station 10, 100mm depth)

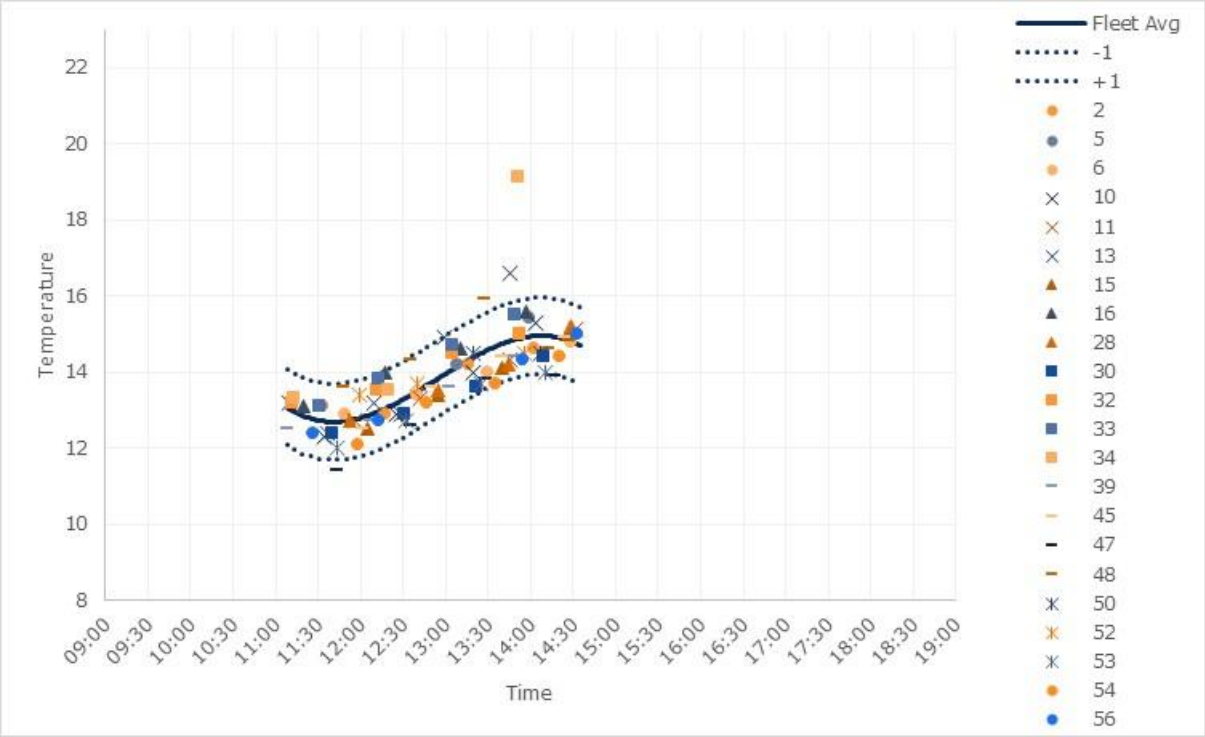

Figure 9.3: Operators' and reference temperatures (Day 2 near station 2, 100mm depth)

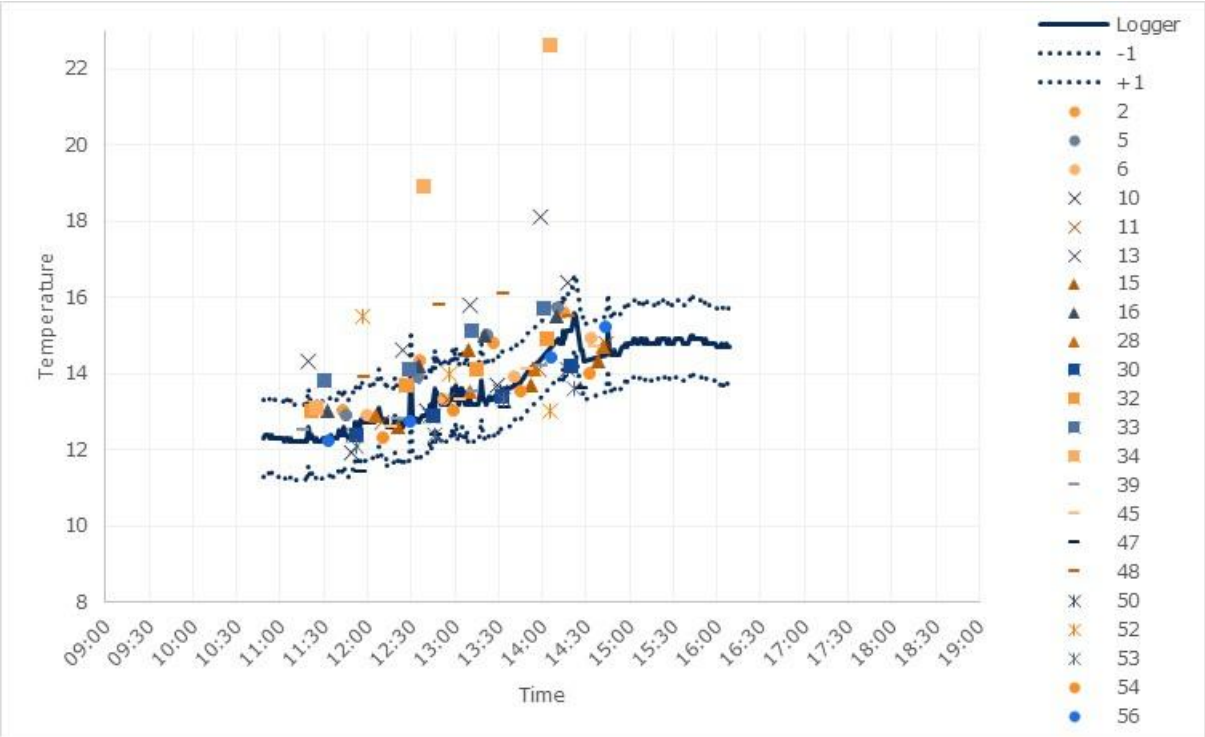

Figure 9.4: Operators' and reference temperatures (Day 2 near station 10, 100mm depth)

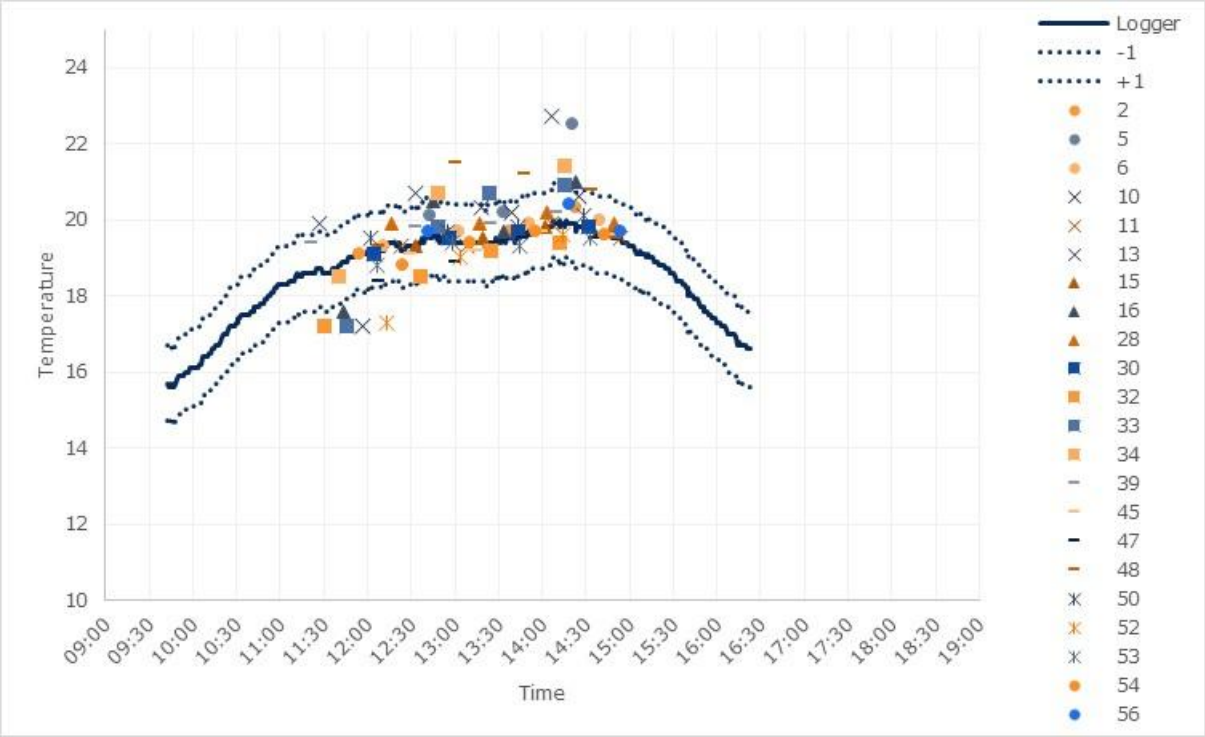

Figure 9.5: Operators' and reference temperatures (Day 2 water bucket)

It can be seen from these plots that most of the operators' measurements are close to the reference datasets although there are some noticeable outliers.

The test criteria for temperature measurement at depth are given in Appendix D, D.1. The differences are presented in Table 9.2, Table 9.3 and Table 9.4. In the tables, values are highlighted in bold and red font if the value was more than 1˚C away from the reference. The overall performance and ratings assigned are presented in Table 9.5.

Table 9.2: Assessment of operators' temperature measurement at depth - station 2

ID	Lap 1 diff	Lap 2 diff	Lap 21 diff	Lap 22 diff	Lap 23 diff	Lap 24 diff
2	0.5	0.4	0.4	-0.1	-0.1	-0.3
5	0.5	0.8	0.4	0.7	0.1	0.5
6	-0.3	.	0.2	-0.1	-0.6	0.0
10	-0.5	0.7	-0.4	-0.3	-0.4	0.4
11	-0.1	-0.3	-0.1	-0.2	-0.5	0.4
13	**1.2**	0.3	0.1	0.3	1.0	**1.8**
15	.	.	-0.3	-0.4	-0.6	0.2
16	-0.3	-0.1	0.3	1.0	0.4	0.7
28	-0.2	0.1	0.0	-0.3	-0.6	0.4
30	-0.2	-0.1	-0.3	-0.4	-0.8	-0.5
32	-0.3	-0.1	0.2	0.6	0.5	0.1
33	-0.1	-0.1	0.4	0.9	0.7	0.7
34	-0.1	-0.1	0.3	0.4	.	**4.2**
39	-0.1	0.1	-0.6	-0.2	-0.4	-0.4

ID	Lap 1 diff	Lap 2 diff	Lap 21 diff	Lap 22 diff	Lap 23 diff	Lap 24 diff
45	-0.1	-0.2	-0.3	-0.1	-0.3	0.0
47	-0.9	-0.1	**-1.3**	-0.8	-0.8	**-1.0**
48	**2.3**	**2.3**	0.9	0.9	**1.4**	-0.3
50	-0.2	-0.3	-0.3	-0.3	0.1	-0.4
52	-0.2	0.0	0.6	0.2	.	-0.4
53	-0.6	-0.6	-0.7	-0.6	-0.8	-0.9
54	-0.9	-0.8	-0.7	-0.4	-1.0	-0.5
56	-0.4	-0.6	-0.4	-0.2	-0.6	0.3

Table 9.3: Assessment of operators' temperature measurement at depth - station 10

ID	Lap 1 diff	Lap 2 diff	Lap 21 diff	Lap 22 diff	Lap 23 diff	Lap 24 diff
2	0.5	**1.6**	0.6	**1.5**	**1.4**	0.5
5	0.0	0.2	0.5	**1.2**	**1.8**	0.8
6	-0.1	.	0.2	0.0	0.2	0.6
10	-0.5	-0.2	-0.5	0.1	0.2	**1.3**
11	0.0	-0.2	-0.1	0.1	-0.2	0.3
13	0.7	0.2	**2.1**	**2.0**	**2.6**	**3.8**
15	.	.	-0.1	**1.4**	-0.4	0.0
16	0.0	0.1	0.7	**1.5**	**1.7**	**1.2**
28	-0.2	0.2	0.2	0.3	0.0	0.4
30	-0.4	0.1	-0.3	-0.4	-0.1	-0.9
32	-0.1	0.1	0.7	1.0	0.9	0.6
33	-0.1	0.1	**1.5**	**1.4**	**1.9**	**1.4**
34	0.2	0.5	0.8	**6.0**	.	**8.3**
39	-0.2	0.4	0.3	0.1	0.3	-0.1
45	-0.4	-0.2	0.0	-0.3	0.4	0.4
47	**-1.1**	-0.9	**-1.4**	-0.7	-0.5	-1.0
48	**2.0**	**1.8**	**1.2**	**2.5**	**2.6**	0.4
50	-0.4	-0.3	-0.1	-0.3	0.0	-1.0
52	0.3	0.3	**2.8**	0.7	.	**-1.3**
53	-0.4	-0.4	-0.6	**-1.2**	-0.2	**-2.0**
54	-0.6	-0.8	-0.5	-0.6	-0.2	-0.3
56	-1.0	-0.7	-0.1	**-1.4**	0.1	0.7

Table 9.4: Assessment of operators' temperature measurement at depth - water bucket

ID	Lap 1 diff	Lap 2 diff	Lap 11 diff	Lap 12 diff	Lap 13 diff	Lap 14 diff
2	.	.	0.0	0.4	0.2	0.4
5	.	.	.	0.6	0.7	**2.6**
6	.	.	0.1	0.3	0.3	0.4
10	.	.	**-1.9**	0.1	0.7	0.8
11	.	.	0.0	-0.1	0.1	0.0
13	.	.	**1.2**	**1.3**	0.9	**2.9**
15	.	.	-0.1	0.1	0.1	0.1
16	.	.	**-1.3**	0.9	0.2	**1.1**

ID	Lap 1 diff	Lap 2 diff	Lap 11 diff	Lap 12 diff	Lap 13 diff	Lap 14 diff
28	.	.	0.5	0.5	0.4	0.4
30	.	.	-0.1	0.1	0.2	0.1
32	.	.	**-1.4**	-0.9	-0.2	-0.6
33	.	.	**-1.7**	0.3	**1.3**	1.0
34	.	.	-0.2	**1.2**	.	**1.5**
39	.	.	0.8	0.4	0.5	0.3
45	.	.	-0.2	-0.2	0.0	0.0
47	.	.	-0.8	-0.5	-0.1	-0.2
48	.	.	0.1	**2.1**	**1.6**	**1.1**
50	.	.	0.4	0.2	0.3	0.3
52	.	.	**-2.0**	-0.4	.	-0.3
53	.	.	-0.4	0.0	-0.2	-0.2
54	.	.	-0.4	0.0	0.0	0.0
56	.	.	.	0.1	0.5	0.2

Table 9.5: Overall assessment of operators' temperature measurement at depth

ID	Percentage within 1˚C for S2	Percentage within 1˚C for S10	Percentage within 1˚C for W/B	Overall Percentage within 1˚C	Rating
2	100%	50%	100%	81%	High
5	100%	67%	67%	80%	High
6	100%	100%	100%	100%	High
10	100%	83%	75%	88%	High
11	100%	100%	100%	100%	High
13	67%	33%	25%	44%	Low
15	100%	75%	100%	92%	High
16	100%	50%	50%	69%	Medium
28	100%	100%	100%	100%	High
30	100%	100%	100%	100%	High
32	100%	100%	75%	94%	High
33	100%	33%	50%	63%	Medium
34	80%	60%	33%	62%	Medium
39	100%	100%	100%	100%	High
45	100%	100%	100%	100%	High
47	67%	67%	100%	75%	Medium
48	50%	17%	25%	31%	Low
50	100%	100%	100%	100%	High
52	100%	60%	67%	77%	Medium
53	100%	67%	100%	88%	High
54	100%	100%	100%	100%	High
56	100%	83%	100%	93%	High

It can be seen from Table 9.5 that fifteen machines achieved the high performance rating, five machines achieved a medium and two a low rating.

9.2 Contactless surface and air temperature measurements

A methodology for estimating the temperature at 100mm is given in the Design Manual for Roads and Bridges (DMRB CS 229, 2020). This method uses the surface temperature at the time of the survey (collected using on-board IRT sensors on the DPT) and the average air temperature for the previous day (acquired from a weather station). A number of contractors have fitted sensors for the automatic measurement of air and surface temperatures to their survey machines. Although air temperature measurements from the survey device are not used in this calculation, the air temperature measurements provided have also been assessed using the same criteria as the surface temperature measurements.

The data from the surface measurements are discussed in 9.2.1 and air measurements in 9.2.2.

9.2.1 Surface temperature measurements

Of the twenty-two machines which took part in the trial, eighteen machines included data for surface temperature in their survey files. However, a number of these datasets did not vary over the course of the trial or were otherwise unsuitable. These devices have been identified as “not suitable” on the accreditation certificates along with supporting text. Some devices produced realistic values, but were not identified as fitted (i.e. not calibrated), therefore these devices have been identified as “not assessed” on the accreditation certificates along with supporting text. After excluding these devices, nine machines were identified as being valid for assessment of their performance. These were machines 6, 30, 39, 47, 48, 50, 53, 54 and 56. The surface temperature data from stations 2 and 10 for these devices are shown along with the reference dataset in Figure 9.6 and Figure 9.7 respectively for Day 1, and in Figure 9.8 and Figure 9.9 for Day 2. For this assessment it was identified that the logger measurements (using a thermocouple attached to the road surface) were not suitable. Instead, a cubic line of best fit calculated from the fleet average was used.

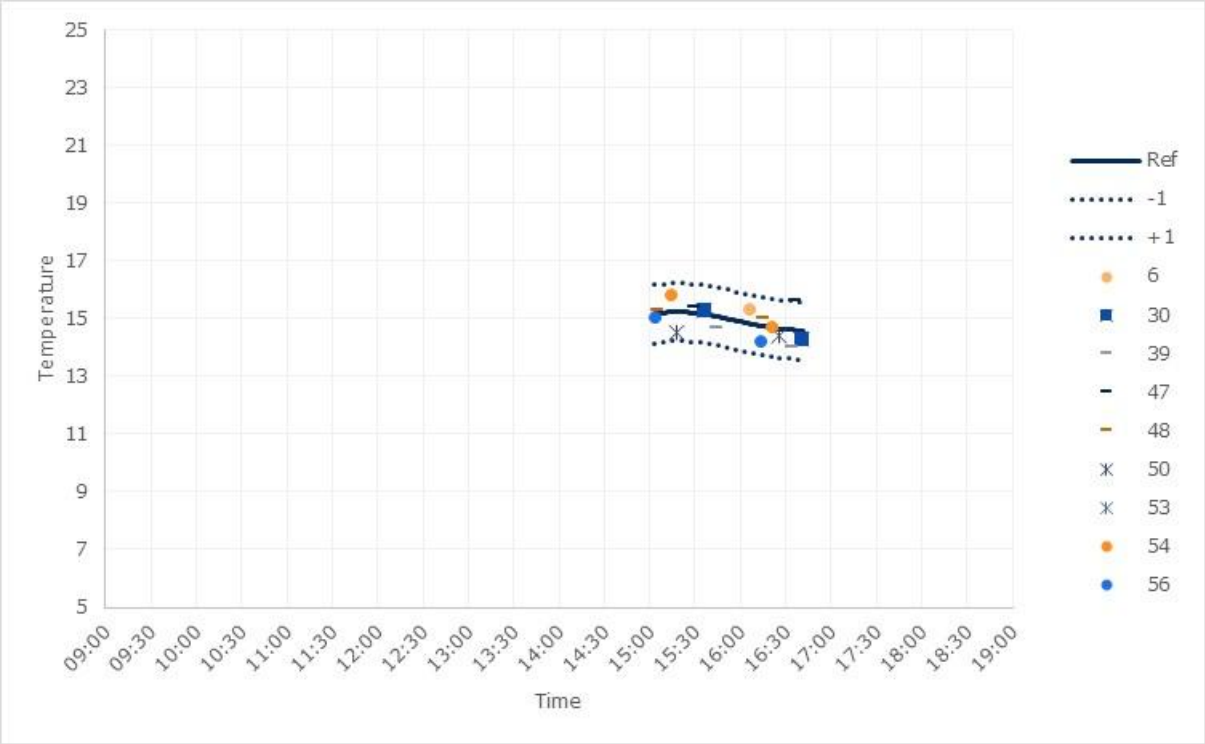

Figure 9.6: Operators' and reference surface temperatures (Day 1 near station 2)

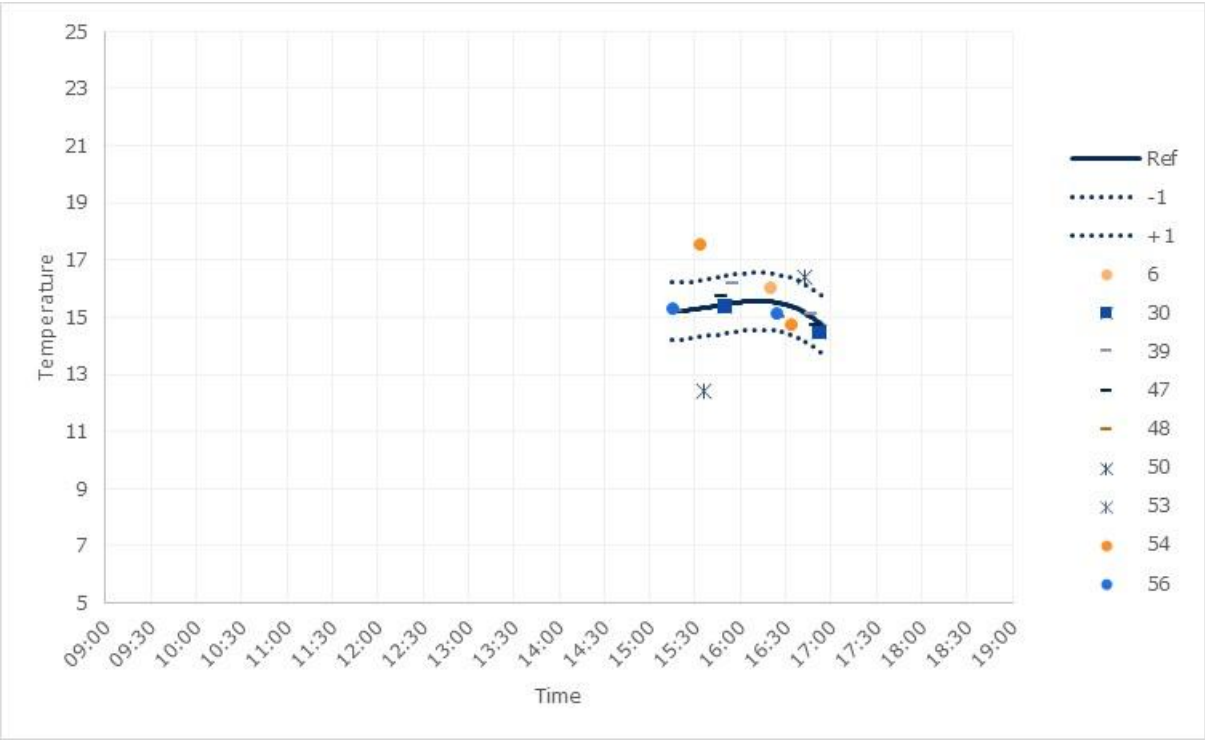

Figure 9.7: Operators' and reference surface temperatures (Day 1 near station 10)

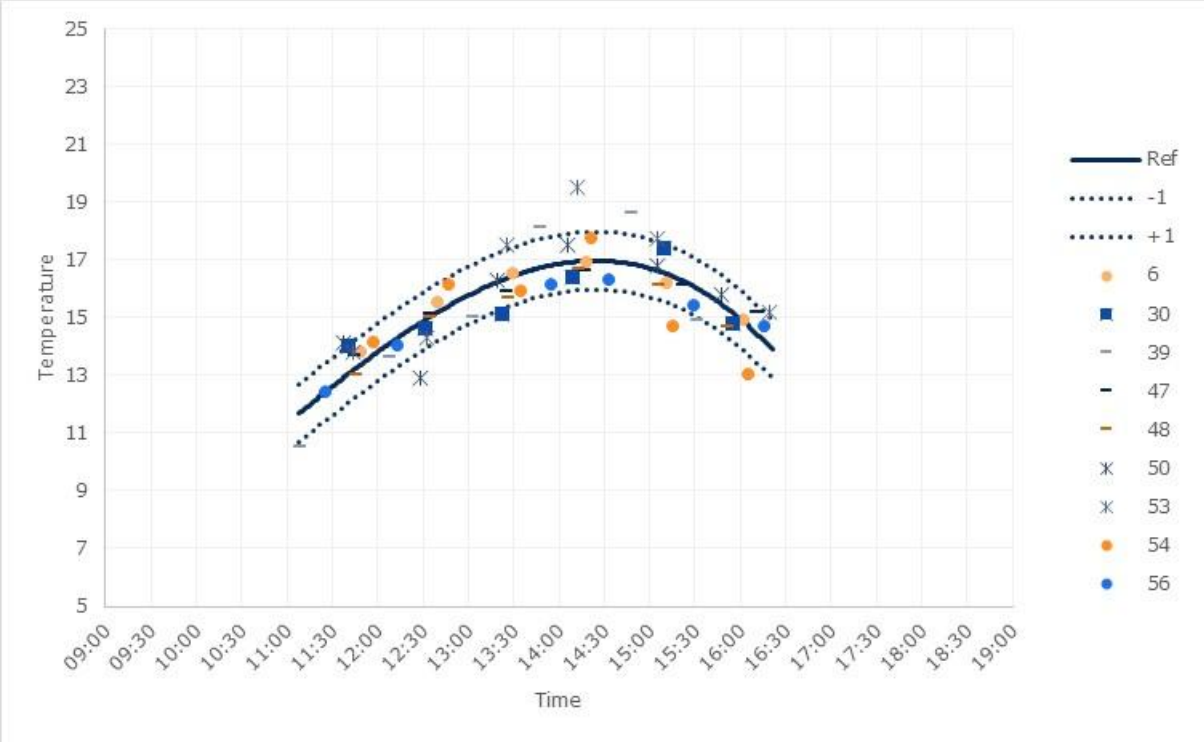

Figure 9.8: Operators' and reference surface temperatures (Day 2 near station 2)

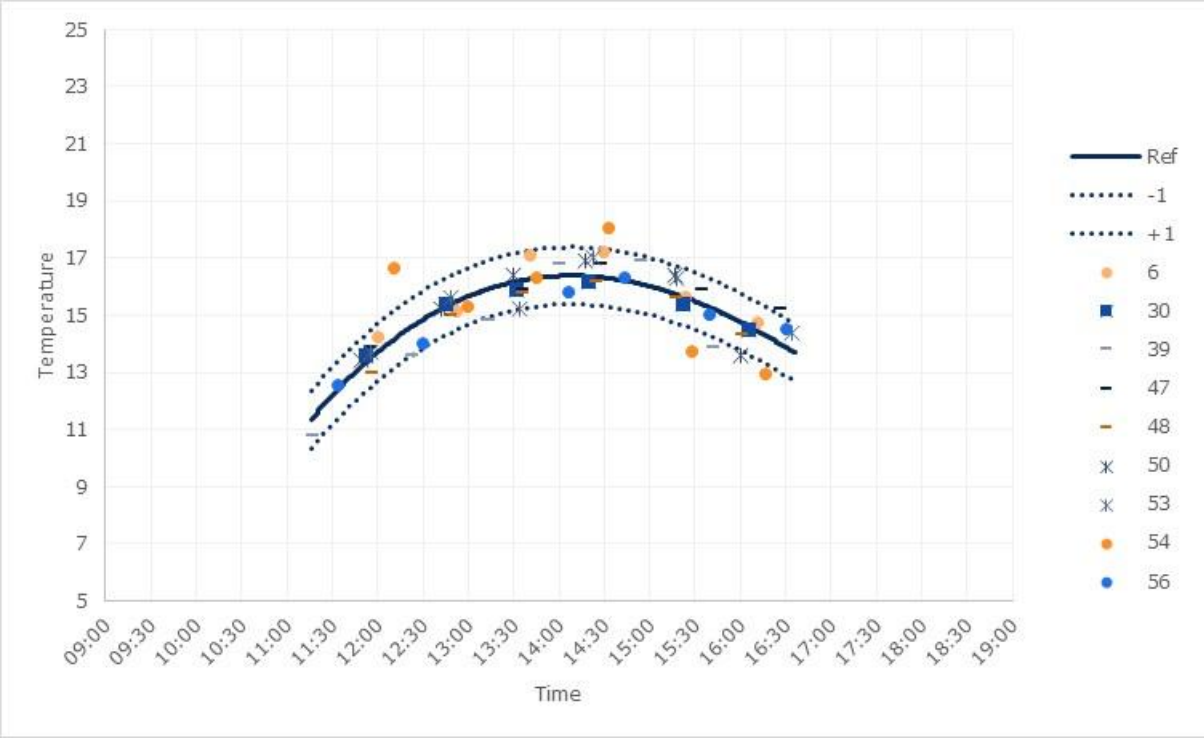

Figure 9.9: Operators' and reference surface temperatures (Day 2 near station 10)

The test criteria for surface temperature measurement are given in Appendix D, D.2. The differences are presented in Table 9.6 and Table 9.7. In the tables, values are highlighted in bold and red font if the value was more than 1˚C away from the reference. The overall performance and ratings assigned are presented in Table 9.8.

Table 9.6: Assessment of operators' surface temperature measurement - station 2

ID	Lap 1 diff	Lap 2 diff	Lap 21 diff	Lap 22 diff	Lap 23 diff	Lap 24 diff	Lap 25 diff	Lap 26 diff
6	0.5	.	0.4	0.3	0.1	-0.1	-0.3	0.0
30	0.2	-0.3	0.9	-0.3	**-1.2**	-0.5	0.9	-0.4
39	-0.4	-0.6	**-1.2**	-0.5	-0.8	**1.4**	**1.8**	**-1.1**
47	0.2	**1.0**	0.5	0.1	-0.5	-0.3	-0.2	0.8
48	0.1	0.3	-0.2	0.0	-0.7	-0.2	-0.5	-0.6
50	-0.7	-0.2	**1.2**	**-1.9**	0.1	0.6	0.2	0.4
53	.	.	0.7	-0.7	**1.2**	**2.6**	**1.1**	**1.2**
54	0.6	0.0	0.4	0.7	-0.6	0.7	**-1.7**	**-1.7**
56	-0.2	-0.5	0.0	-0.2	-0.7	-0.6	-0.7	0.5

Table 9.7: Assessment of operators' surface temperature measurement - station 10

ID	Lap 1 diff	Lap 2 diff	Lap 21 diff	Lap 22 diff	Lap 23 diff	Lap 24 diff	Lap 25 diff	Lap 26 diff
6	0.5	.	0.5	-0.4	0.8	0.9	0.0	0.3
30	0.0	-0.3	0.3	0.1	-0.3	-0.2	-0.2	-0.1
39	0.7	0.1	-0.6	**-1.0**	**-1.1**	0.4	0.8	**-1.3**
47	0.3	-0.2	0.4	-0.4	-0.3	0.5	0.5	1.2
48	0.0	-0.5	-0.6	-0.4	-0.4	-0.1	-0.1	-0.4
50	**-2.9**	**1.3**	0.2	0.0	0.2	0.5	0.7	**-1.2**
53	.	.	0.3	0.2	-1.0	0.6	0.6	0.7
54	**2.2**	-0.7	**2.5**	-0.4	0.0	**1.7**	**-1.8**	**-1.4**
56	0.1	-0.4	0.1	-0.9	-0.6	0.1	-0.3	0.7

Table 9.8: Overall assessment of operators' surface temperature measurement

ID	Percentage within 1˚C for S2	Percentage within 1˚C for S10	Overall Percentage within 1˚C	Rating
6	100%	100%	100%	High
30	88%	100%	94%	High
39	50%	63%	56%	Low
47	88%	88%	88%	High
48	100%	100%	100%	High
50	75%	63%	69%	Medium
53	33%	83%	58%	Low
54	75%	38%	56%	Low
56	100%	100%	100%	High

It can be seen from Table 9.8 that five machines achieved a high performance, one a medium and three were identified as low.

9.2.2 Air temperature measurements

Of the twenty-two machines which took part in the trial, seventeen machines included data for air temperature in their survey files. However, a number of these datasets did not vary over the course of the trial or were otherwise unsuitable. These devices have been identified as “not suitable” on the accreditation certificates along with supporting text. Some devices produced realistic values, but were not identified as fitted (i.e. not calibrated), therefore these devices have been identified as “not assessed” on the accreditation certificates along with supporting text. After excluding these devices, nine machines were identified as suitable for being valid for assessment of their performance. These were machines 30, 39, 45, 47, 48, 50, 53, 54 and 56. The air temperature data from stations 2 and 10 for these devices are shown along with the reference dataset in Figure 9.10 and Figure 9.11 respectively for Day 1, and in Figure 9.12 and Figure 9.13 for Day 2. For this assessment it was identified that the logger measurements were not suitable. Instead, a cubic line of best fit calculated from the fleet average, after removal of Machine 50 which was identified as an outlier, were used.

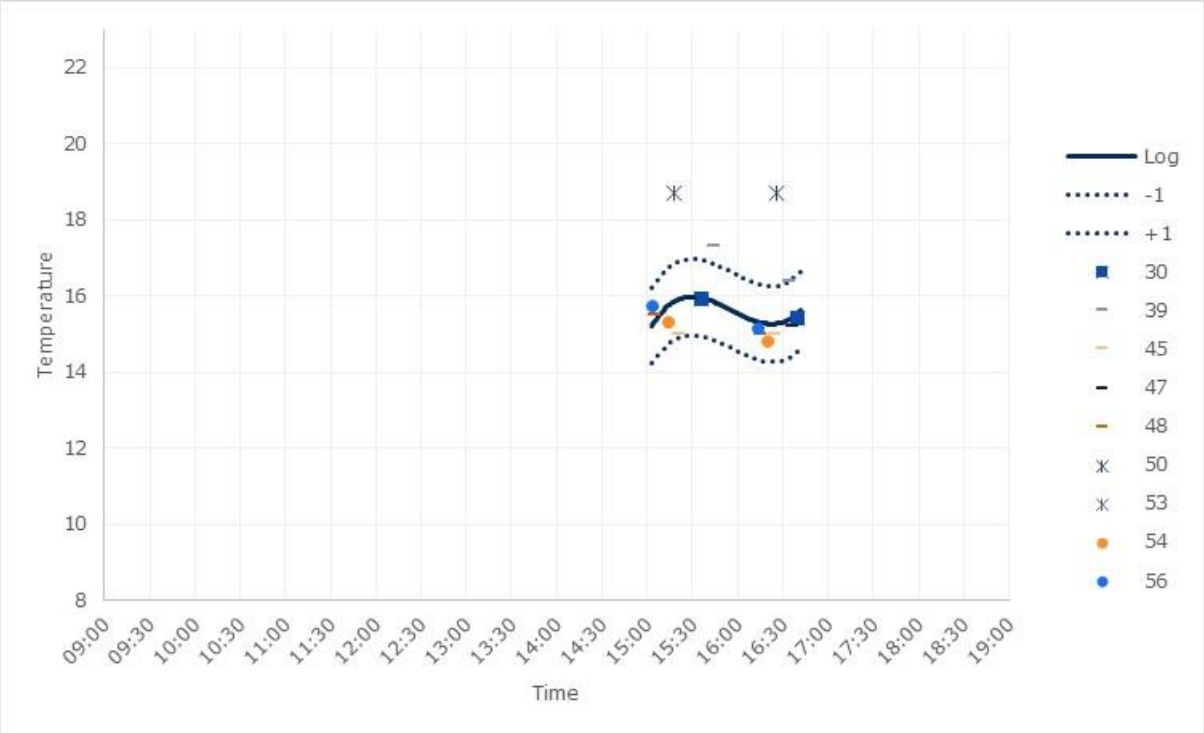

Figure 9.10: Operators’ and reference Air temperatures (Day 1 near station 2)

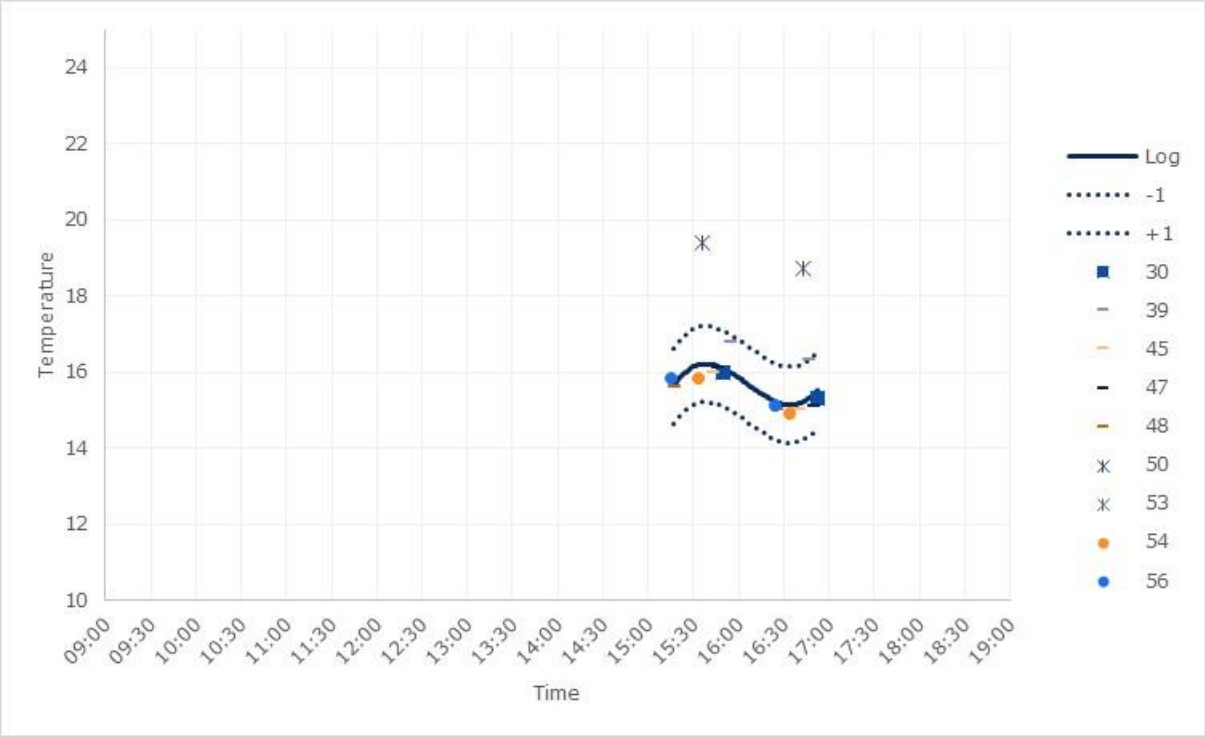

Figure 9.11: Operators' and reference Air temperatures (Day 1 near station 10)

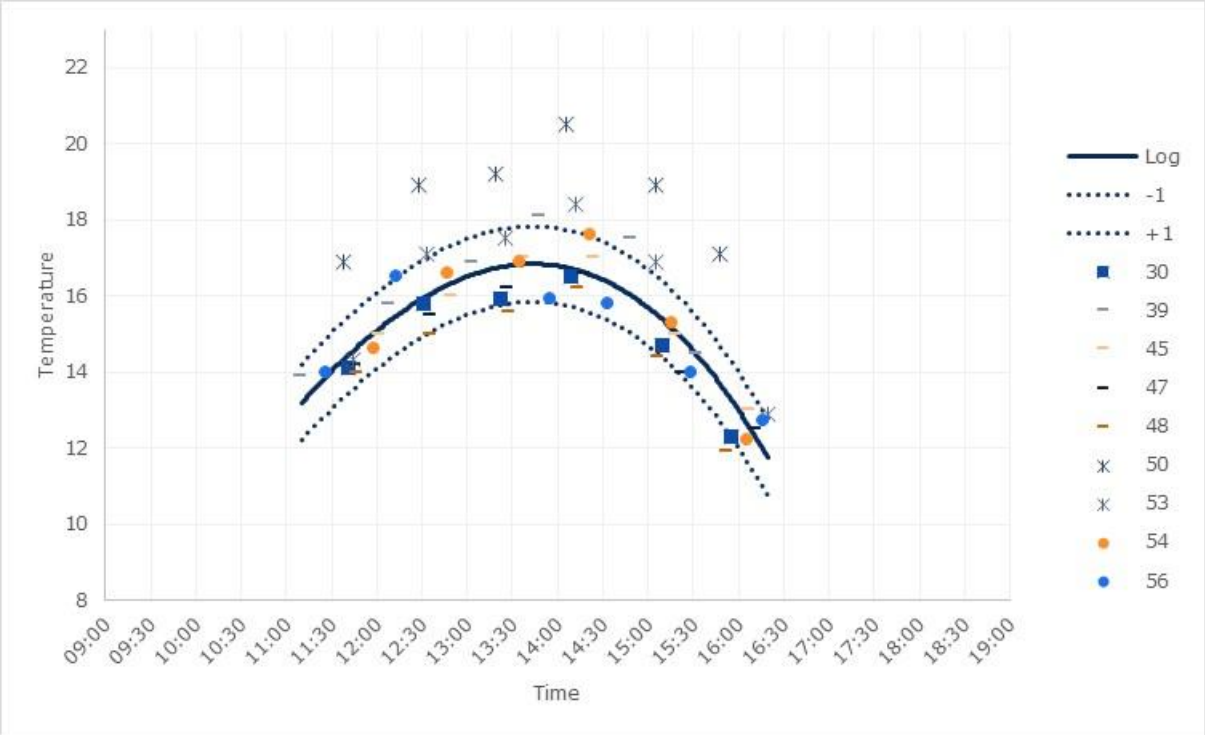

Figure 9.12: Operators' and reference Air temperatures (Day 2 near station 2)

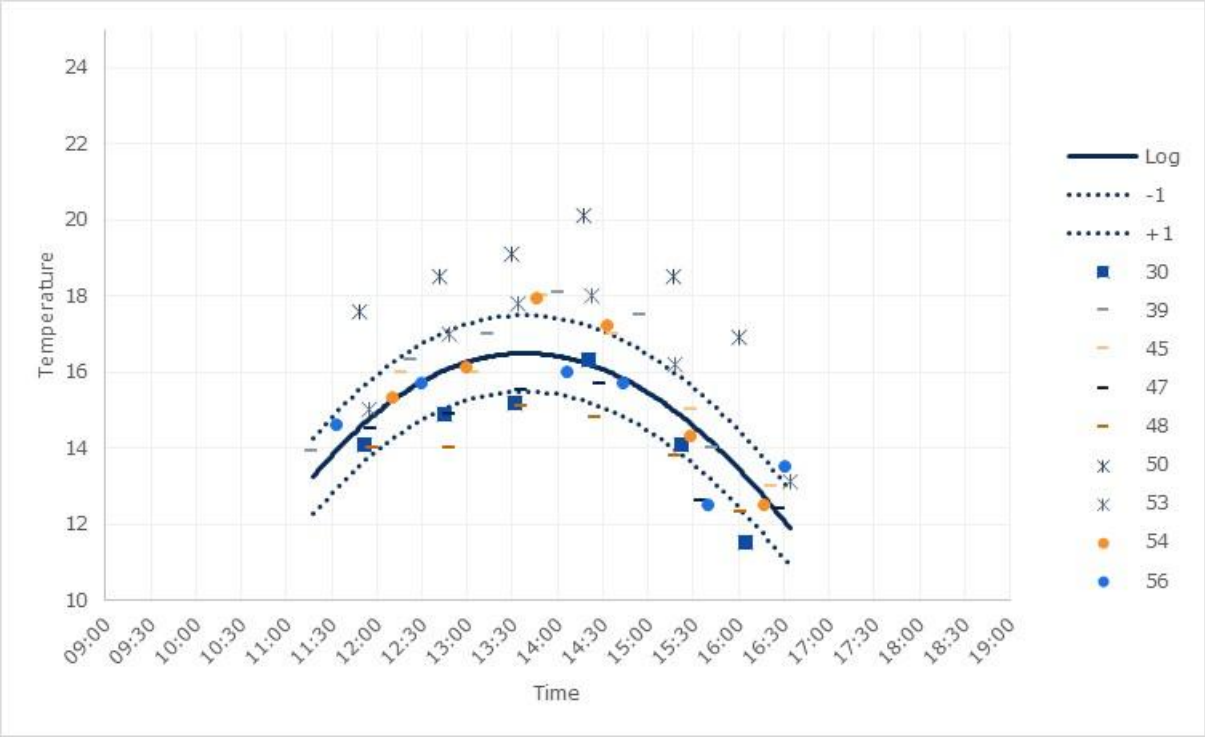

Figure 9.13: Operators' and reference Air temperatures (Day 2 near station 10)

Air temperature measurements from DPTs at the time of testing are not used for the contactless 100mm temperature calculation method and as such there are no formal criteria set for this measurement. However, it seemed prudent to assess the data supplied by the machines, therefore the criteria for the surface measurements were applied. The differences are presented in Table 9.9 and Table 9.10. In these tables, values are highlighted in bold and red font if the value was more than 1˚C away from the reference. The overall performance and ratings assigned are presented in Table 9.11.

Table 9.9: Assessment of operators' air temperature measurement - station 2

ID	Lap 1 diff	Lap 2 diff	Lap 21 diff	Lap 22 diff	Lap 23 diff	Lap 24 diff	Lap 25 diff	Lap 26 diff
30	0.0	-0.1	-0.3	-0.1	-0.9	-0.2	-0.7	-1.0
39	**1.5**	**1.0**	.	0.5	0.4	**1.3**	**1.5**	0.0
45	-0.9	-0.3	-0.1	-0.3	0.2	0.5	-0.1	0.4
47	-0.1	-0.2	-0.4	-0.5	-0.6	0.0	-0.9	0.2
48	0.2	-0.3	-0.6	**-1.0**	**-1.2**	-0.5	**-1.1**	**-1.5**
50	**2.9**	**3.4**	**2.6**	**3.0**	**2.5**	**3.8**	**3.4**	**3.4**
53	.	.	-0.2	**1.1**	0.7	**1.7**	**1.4**	**1.1**
54	-0.5	-0.5	-0.4	0.3	0.1	**1.0**	0.2	-0.4
56	0.4	-0.2	0.2	**1.1**	-0.9	-0.6	-0.6	0.7

Table 9.10: Assessment of operators' air temperature measurement - station 10

ID	Lap 1 diff	Lap 2 diff	Lap 21 diff	Lap 22 diff	Lap 23 diff	Lap 24 diff	Lap 25 diff	Lap 26 diff
30	-0.1	-0.2	-0.6	**-1.1**	**-1.3**	0.1	-0.7	**-1.7**
39	0.8	1.0	.	0.7	0.6	**1.7**	**1.9**	-0.2
45	-0.2	-0.2	0.6	-0.3	**1.5**	**1.0**	0.4	0.5
47	0.0	-0.3	-0.3	**-1.2**	-1.0	-0.4	**-1.8**	0.2
48	-0.1	-0.2	-0.8	**-2.1**	**-1.4**	**-1.3**	**-1.2**	**-1.1**
50	**3.2**	**3.5**	**3.1**	**2.5**	**2.6**	**3.9**	**3.5**	**3.4**
53	.	.	0.3	0.9	**1.3**	**1.8**	**1.2**	**1.2**
54	-0.4	-0.2	0.1	-0.2	**1.4**	**1.2**	-0.3	-0.2
56	.	-0.1	0.6	0.0	-0.4	-0.1	**-1.7**	**1.5**

Table 9.11: Overall assessment of operators' air temperature measurement

ID	Percentage within 1˚C for S2	Percentage within 1˚C for S10	Overall Percentage within 1˚C	Rating
30	100%	63%	81%	High
39	43%	71%	57%	Low
45	100%	75%	88%	High
47	100%	75%	88%	High
48	50%	38%	44%	Low
50	0%	0%	0%	Not Suitable
53	33%	33%	33%	Low
54	88%	75%	81%	High
56	88%	71%	80%	High

Table 9.11 shows that for the air temperature measurements, five achieved a high performance, three a low and one was identified as not suitable.

10 Summary of trial findings

The 2024 UK DPT accreditation trial was held at Horiba-MIRA in the week beginning the 23rd September 2024. Twenty-two machines took part in the trial.

The following conclusions were drawn in relation to the various mandatory tests and assessments:

(i) Repeatability of Deflections

- All twenty-two machines met the trial requirements for the repeatability assessment.

(ii) Reproducibility of Deflections

- All twenty-two machines met the trial requirements for the mean Field Calibration Factor (FCF).
- All twenty-two machines met the trial requirements for the individual geophone Field Calibration Factors (FCF).
- Twenty-one machines met the trial requirements for the mean Standard Deviation of the Deviation Ratio (SDDR).
- Twenty-one machines met the trial requirements for the individual Standard Deviation of the Deviation Ratio (SDDR).

(iii) Distance measurement

- All twenty-two machines met the trial requirements for distance assessment.

The following conclusions were drawn in relation to the various additional tests and assessments:

(iv) OSGR Co-ordinates

- Nineteen machines were capable of producing 3-dimensional positional data. This data is reported in lat/long format in the survey files, and the contractors were asked to convert this data into OSGR format. The performance of the machines was assessed on this converted data. Fourteen machines were identified as having achieved a high performance level and five a medium performance level.

(v) Temperature measurement at depth (100mm)

- All twenty-two operators of the machines provided 100mm pavement temperature measurements using hand-held probes. Fifteen achieved a high performance rating, five achieved a medium, and two a low rating.

(vi) Surface temperature measurement

- Nine machines provided surface temperature measurements using IRTs fixed to their machines that were suitable for assessment. Five machines achieved a high performance, one a medium performance and three were identified as low.

(vii) Air temperature measurement

- Nine machines provided air temperature measurements from apparatus fixed to their machines that were suitable for assessment. This data was assessed using the surface temperature criteria. Five machines achieved a high performance, three a low performance and one was identified as not suitable.

In summary, twenty-one of the twenty-two machines that participated in the 2024 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.

References

CROW. (2011). *Falling Weight Deflectometer Calibration Guide Report D11-07. Protocol 10. FWD correlation trial.* Ede, The Netherlands: Crow.

DMRB CS 229. (2020). *Design Manual for Roads and Bridges CS 229 Data for Pavement assessment [online]. [Accessed 3rd April 2020]*. https://www.standardsforhighways.co.uk/dmrb/: The Stationery Office.

TRL. (2020). *Accreditation and Quality Assurance of Dynamic Plate Test Survey Devices [online]. [Accessed 30th March 2021].* Available from World Wide Web: https://ukrlg.ciht.org.uk/ukrlg-home/guidance/road-condition-information/data-collection/dynamic-plate-test-devices-dpt/.

Acknowledgements

The author wishes to thank the operators of the DPT machines for their co-operation in the accreditation process. The author is also grateful to Darius Singfield and Dave Gershkoff who carried out the technical review of this report. The author also wishes to thank Darius Singfield for running the trial and to Jenessa Norman, Pawel Zwierzchowski and Roy Jaques for supporting the running of 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	4/2	2-way Segmented	06/07/2024	20/09/2024	19/08/2024
5	AECOM Ltd.	Dynatest HWD 8082 SN 050	Trailer	0/5	2-way Segmented	03/07/2024	20/09/2024	03/09/2024
6	PMS	Dynatest HWD 8082 SN 018	Trailer	0/5	Solid	28/06/2024	28/06/2024	19/09/2024
10	AECOM Ltd.	Dynatest FWD 8002 SN 192	Trailer	4/2	2-way Segmented	06/07/2024	20/09/2024	06/08/2024
11	Pulse Surveying Ltd.	Dynatest FWD 8002 SN 187	Trailer	4/2	Solid	05/03/2024	23/08/2024	11/07/2024
13	AECOM Ltd.	Dynatest HWD 8082 SN 029	Trailer	0/5	Solid	04/07/2024	20/09/2024	30/08/2024
15	Construction Testing Solutions	Dynatest FWD 8002 SN 203	Trailer	5/2	2-way Segmented	Not provided	Not provided	11/06/2024
16	XAIS-PTS	Dynatest FWD 8002 SN 214	Trailer	4/2	2-way Segmented	10/07/2024	10/07/2024	10/07/2024
28	Pulse Surveying Ltd.	Dynatest FWD 8002 SN 271	Trailer	4/2	Solid	04/03/2024	23/08/2024	03/07/2024
30	PMS	Dynatest FWD 8002 SN 173	Trailer	4/2	Solid	26/06/2024	06/09/2024	05/04/2024
32	XAIS-PTS	Dynatest HWD 8082 SN 069	Trailer	0/0	Solid	31/05/2024	31/05/2024	31/05/2024

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
33	XAIS-PTS	Dynatest HWD 8082 SN 070	Trailer	0/0	Solid	25/07/2024	25/07/2024	25/07/2024
34	XAIS-PTS	Dynatest HWD 8082 SN 108	Trailer	0/0	4-way Segmented	12/08/2024	12/08/2024	12/08/2024
39	TRL	Dynatest FWD 8002 SN 388	Trailer	6/3	2-way Segmented	May 2024	20/09/2024	17/05/2024
45	Atlas Geophysical	Sweco PRI2100 0903-088	Trailer	2/4	Single	04/09/2024	18/09/2024	04/09/2024
47	PMS	Dynatest FWD 8002 SN 452	Trailer	4/2	4-way Segmented	15/07/2024	22/08/2024	17/09/2024
48	Alptest Ltd	Dynatest FWD 8002 SN 424	Trailer	4/2	4-way Segmented	12/07/2024	13/09/2024	20/08/2024
50	SOCOTEC	RINCENT HeavyDyn HVY-101A	Trailer	10/4	Solid	17/09/2024	17/09/2024	05/06/2024
52	XAIS-PTS	Dynatest FFWD 8012 SN 057	Trailer	4/2	4-way Segmented	02/07/2024	02/07/2024	02/07/2024
53	Dynatest	Dynatest FWD 8002 SN 098	Trailer	4/2	4-way Segmented	05/09/2024	Feb 2024	12/10/2023
54	Milestone Pavement Technologies	Sweco PRI1500 0822/664	Trailer	3/7	4-way Segmented	17/09/2024	18/09/2024	11/03/2024
56	Dynatest	Dynatest FWD 8002 SN 033	Trailer	4/2	2-way Segmented	20/06/2024	New machine	20/06/2024

Appendix B Photographs of machine types (taken at previous trials)



Figure B.1: Dynatest 8002 FWD



Figure B.2: Dynatest 8082 HWD



Figure B.3: SWECO Primax 2100 HWD



Figure B.4: SWECO Primax 1500 HWD

Appendix C Construction details for the National Highways reference site at Horiba-MIRA proving ground

Table C.1: Design thicknesses and material types for the National Highways reference site

Section	Test points	Surface course	Binder course	Base	Total asphalt thickness (mm)	Sub-base
1	1-3	30mm TSC	235mm EME2	-	270	200mm C8/10 HBM
2	4-6	35mm TSC	170mm DBM	-	200	250mm 6F1 granular capping material
3	7-9	30mm TSC	170mm EME2	-	200	200mm Type 1 granular material
4	10-12	35mm TSC	35mm Axo	230mm JRC	70	150-175mm 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: Thicknesses and materials for the National Highways reference site from cores

Section	Test points	Surface course	Binder/ Binder + base courses (mm)	Total asphalt thickness (mm)	Base/Sub-base (mm)
1	1-3	42mm TSC	228	270	217 (HBM sub-base)
2	4-6	37mm TSC	158	192	-
3	7-9	35mm TSC	191	226	-
4	10-12	30mm 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: Thicknesses and materials for the National Highways reference site from GPR

Section	Test points	Material	Minimum (mm)	Average (mm)	Maximum (mm)
1	1-3	Asphalt layer	192	242	272
1	1-3	HBM layer	166	188	215
1	1-3	Total bound	388	431	468
2	4-6	Total bound (Asphalt)	167	192	240
3	7-9	Total bound (Asphalt)	167	199	240
4	10-12	Asphalt surfacing only[2]	47	65	76

Notes: HBM = Hydraulically Bound Material

[2] These results are for the bitumen-bound surfacing. No lower GPR trace due to steel reinforcement.

Appendix D Assessment criteria

The accreditation trial criteria are specified in "Accreditation and Quality Assurance of Dynamic Plate Test Survey Devices" (TRL, 2020). The accreditation specification document is a live document (i.e. is subject to change) and the September 2020 version of the document was used for the trial. The relevant sections of the document are reproduced verbatim below in blue text (section D.1 and D.2 of this report). Note that the numbering of the headings in the text within these sections have been kept as the numbering as given in the accreditation specification. In addition, the reproduced text refers to appendices that are not included in this report.

The reproduced text has some defined terms. This includes "Equipment" which 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 load measurement system, 3-dimensional positional system, 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.

D.1 Mandatory Trial criteria from the Accreditation and QA document

E4.2 Repeatability testing – Mandatory Requirement

E4.2.1 Repeatability testing shall 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 shall use a test procedure typical of general usage on the network. The test procedure shall 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) shall 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 (sometimes referred to as "seek" mode). This functionality shall not be used for the repeatability testing.

E4.2.4 The following shall 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 shall 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 to have failed the Repeatability criteria.

E4.2.6 The valid Repeatability data shall be collected and the Equipment shall 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 shall 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 For the Reproducibility test the 100mm pavement temperature should 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. Additional test sets may then need to be undertaken in order to obtain the required amount of Survey Data within the required temperature range.

E4.3.3 Reproducibility testing shall use a test procedure typical of general usage on the network. The test procedure shall 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) shall 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 shall be calculated by the Auditor for each test set. The Equipment shall 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
FCF: Individual sensor value	1.10	0.90
SDDR: Mean for all sensors	0.05	N/A
SDDR: 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 shall 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)

D.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 – direct measurement method

E5.3.1 If undertaking this test, the Contractor will be required to collect at least eight measurements at 100mm depth during the course of the test laps. These probes are required to provide results with a resolution equal to or better than 0.1˚C. Therefore if the probe does not then it will be identified as "Not suitable" regardless of the performance seen for the measurements (with a note identifying the reason for the performance given). The criteria for the direct measurement method are given in Table 5.

Table 5 - Acceptance Criteria for direct measurement method

Performance	Criteria
High	≥80% of the data is within 1.0°C of the Reference Data
Medium	≥60% of the data is within 1.0°C of the Reference Data
Low	≥25% of the data is within 1.0°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 – Contactless measurement

E5.4.1 If undertaking this test the Contractor shall be required to collect at least eight measurements of the pavement surface at defined points (specified by the Auditor) during the course of the test laps. These sensors are required to provide results with a resolution equal to or better than 0.1˚C. Therefore if the sensor does not then it will be identified as "Not suitable" regardless of the performance seen for the measurements (with a note identifying the reason for the performance given). 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 1.0°C of the Reference Data
Medium	≥60% of the data is within 1.0°C of the Reference Data
Low	≥25% of the data is within 1.0°C of the Reference Data
Not suitable	Otherwise

E5.4.2 In addition to providing the surface temperatures, the Contractor shall provide the predicted temperature at 100mm depth using this data. The Auditor may allow Contractors to provide these predicted temperatures after the trial to allow for processing time. To aid this calculation the Auditor should provide, or identify a suitable location for air temperature data for the previous day for the site. The Auditor shall confirm on the Accreditation Certificate whether the calculations have been accurately calculated.

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 italics and grey text (apart from the data points which exceed the criteria).

E.1 Machine 2

Lap	Station	Mean Load	SD of Load (%)	Mean D1	Mean D2	Mean D3	Mean D4	Mean D5	Mean D6	Mean D7	SD D1	SD D2	SD D3	SD D4	SD D5	SD D6	SD D7
1	2	724.8	0.2%	71	62	55	48	41	35	24	0.1	0.1	0.1	0.1	0.1	0.1	0.2
1	5	706.5	0.2%	534	429	266	159	91	56	34	1.2	1.0	0.4	0.2	0.7	0.5	0.4
1	8	723.8	0.2%	242	211	167	127	91	64	33	0.3	0.2	0.2	0.3	0.1	0.2	0.1
1	13	725.6	0.2%	127	116	99	82	65	53	31	0.1	0.3	0.2	0.2	0.3	0.3	0.1
2	2	727.3	0.7%	69	62	55	48	42	35	24	0.4	0.2	0.1	0.1	0.2	0.2	0.2
2	5	711.5	0.3%	565	426	259	159	91	58	34	1.2	0.4	0.2	0.4	0.2	0.2	0.1
2	8	728.4	0.2%	241	213	169	128	91	65	33	0.7	0.3	0.3	0.2	0.2	0.1	0.2
2	13	735.2	0.2%	124	113	96	79	63	49	30	0.2	0.1	0.2	0.1	0.3	0.4	0.1

E.2 Machine 5

Lap	Station	Mean Load	SD of Load (%)	Mean D1	Mean D2	Mean D3	Mean D4	Mean D5	Mean D6	Mean D7	SD D1	SD D2	SD D3	SD D4	SD D5	SD D6	SD D7
1	2	729.2	0.2%	68	59	52	46	40	33	22	0.2	0.2	0.1	0.1	0.1	0.3	0.4
1	5	705.6	0.1%	527	411	257	155	93	60	40	1.0	0.5	0.1	0.3	0.3	0.3	0.1
1	8	708.3	0.1%	233	205	163	124	90	64	34	0.3	0.2	0.2	0.2	0.3	0.1	1.1
1	13	705.9	0.3%	117	107	91	78	61	47	28	0.4	0.4	0.1	0.6	0.2	0.2	0.3
2	2	727.2	0.3%	69	61	52	46	40	33	22	0.6	0.7	0.2	0.3	0.3	0.2	0.3
2	5	699.5	0.2%	541	424	259	156	95	62	40	1.1	0.5	0.3	0.4	0.6	0.5	0.3
2	8	711.9	0.2%	236	207	164	124	90	64	33	0.6	0.2	0.2	0.1	0.1	0.2	0.5
2	13	707.0	0.4%	121	109	93	77	62	48	29	0.4	0.3	0.1	0.4	0.5	0.4	1.4

E.3 Machine 6

Lap	Station	Mean Load	SD of Load (%)	Mean D1	Mean D2	Mean D3	Mean D4	Mean D5	Mean D6	Mean D7	SD D1	SD D2	SD D3	SD D4	SD D5	SD D6	SD D7
1	*2*	*726.6*	*0.5%*	*67*	*58*	*52*	*46*	*38*	*31*	*21*	*0.2*	*1.0*	*0.4*	*0.8*	*1.3*	*0.3*	***2.1***
1	*5*	*711.8*	*0.6%*	*537*	*409*	*257*	*150*	*89*	*57*	*39*	*0.9*	*0.5*	*0.9*	*0.4*	*1.2*	*0.9*	*1.2*
1	*8*	*716.8*	*0.4%*	*230*	*201*	*161*	*120*	*86*	*60*	*33*	*0.8*	*0.5*	*0.3*	*1.3*	*1.6*	***2.1***	*0.6*
1	*13*	*694.6*	*0.3%*	*117*	*107*	*92*	*76*	*61*	*49*	*30*	*0.8*	*0.3*	*0.3*	*0.5*	*0.2*	*0.5*	*0.6*
2	*2*	*739.9*	*0.7%*	*67*	*57*	*51*	*44*	*38*	*32*	*21*	*0.4*	*0.6*	*0.5*	*0.5*	*2.0*	***3.5***	*1.1*
2	*5*	*705.5*	*0.5%*	*545*	*410*	*254*	*147*	*87*	*58*	*38*	*1.1*	*1.2*	*0.9*	*0.7*	*1.3*	*1.6*	***2.6***
2	*8*	*674.2*	*0.3%*	*234*	*204*	*163*	*120*	*85*	*59*	*29*	*0.9*	*0.4*	*0.6*	*0.5*	*0.5*	*1.5*	*0.9*
2	*13*	*641.8*	*1.1%*	*119*	*107*	*92*	*76*	*60*	*48*	*29*	*1.9*	*0.4*	*0.3*	*0.3*	*0.4*	*0.7*	*0.3*
3	2	718.9	0.2%	68	57	52	45	39	32	21	0.5	0.5	0.8	1.2	1.5	**2.3**	1.0
3	5	702.0	0.3%	523	404	256	154	93	60	36	0.9	0.7	0.5	0.8	1.2	0.5	1.6
3	8	694.3	1.3%	228	200	160	120	86	60	33	0.6	0.6	0.6	0.8	0.9	0.9	1.0
3	13	650.8	0.4%	122	111	95	78	62	49	31	0.4	0.2	0.9	0.5	0.4	0.9	1.6
4	2	707.3	0.2%	68	58	52	46	38	32	22	0.2	0.3	0.2	0.2	0.3	0.2	0.3
4	5	683.1	0.8%	521	405	261	155	94	58	38	0.4	0.7	0.8	0.9	0.5	0.6	0.4
4	8	684.6	0.4%	230	203	163	122	88	63	31	0.5	0.7	0.5	1.0	0.4	0.8	0.6
4	13	644.1	0.6%	124	112	96	79	64	51	32	0.3	0.3	0.2	0.2	0.4	0.3	0.6

E.4 Machine 10

Lap	Station	Mean Load	SD of Load (%)	Mean D1	Mean D2	Mean D3	Mean D4	Mean D5	Mean D6	Mean D7	SD D1	SD D2	SD D3	SD D4	SD D5	SD D6	SD D7
1	2	703.2	0.2%	75	62	56	50	43	35	24	0.3	0.1	0.1	0.2	0.2	0.1	0.2
1	5	699.8	0.2%	536	401	262	155	92	58	37	0.5	0.2	0.1	0.1	0.1	0.2	0.1
1	8	704.4	0.2%	238	206	167	127	92	64	34	0.3	0.1	0.1	0.1	0.2	0.1	0.1
1	13	710.7	0.2%	122	108	95	80	66	51	30	0.3	0.7	0.5	0.2	0.4	0.1	0.2
2	2	702.2	0.2%	73	61	55	49	43	35	24	0.6	0.1	0.1	0.2	0.1	0.1	0.2
2	5	687.3	0.2%	562	418	270	159	93	59	37	1.5	0.7	0.4	0.1	0.3	0.1	0.1
2	8	704.0	0.1%	242	209	170	129	93	65	34	0.2	0.2	0.3	0.2	0.2	0.1	0.1
2	13	709.6	0.2%	124	110	96	80	65	50	31	0.2	0.2	0.3	0.3	0.3	0.1	0.1

E.5 Machine 11

Lap	Station	Mean Load	SD of Load (%)	Mean D1	Mean D2	Mean D3	Mean D4	Mean D5	Mean D6	Mean D7	SD D1	SD D2	SD D3	SD D4	SD D5	SD D6	SD D7
1	2	705.9	0.1%	71	63	56	50	43	39	28	0.5	0.4	0.2	0.4	0.5	0.7	0.8
1	5	691.7	0.2%	566	423	267	157	90	56	33	1.1	0.7	0.3	0.2	0.3	0.4	0.2
1	8	705.7	0.2%	247	214	171	130	94	66	35	0.4	0.2	0.3	0.2	0.2	0.3	0.1
1	13	710.1	0.1%	131	115	100	83	68	55	35	0.2	0.6	0.9	0.4	0.4	0.9	0.6
2	2	705.5	0.2%	74	64	57	51	44	36	25	0.3	1.0	0.6	1.5	0.9	0.2	0.3
2	5	689.6	0.2%	554	423	262	157	94	57	39	1.3	0.8	1.6	0.5	0.5	0.3	1.0
2	8	704.5	0.2%	247	216	172	129	94	66	35	0.3	0.3	0.1	0.2	0.2	0.5	0.3
2	13	709.8	0.1%	130	114	95	82	67	54	33	0.2	0.5	0.2	0.3	0.3	0.5	0.4

E.6 Machine 13

Lap	Station	Mean Load	SD of Load (%)	Mean D1	Mean D2	Mean D3	Mean D4	Mean D5	Mean D6	Mean D7	SD D1	SD D2	SD D3	SD D4	SD D5	SD D6	SD D7
1	2	722.9	0.4%	62	57	51	44	38	32	22	0.7	0.3	0.3	0.5	0.3	0.9	1.3
1	5	707.4	0.6%	544	396	249	147	89	58	36	2.2	1.0	0.6	1.5	0.4	0.6	0.3
1	8	703.4	0.4%	224	198	159	119	87	62	32	1.0	0.7	0.4	0.3	0.2	0.2	0.3
1	13	675.0	0.3%	119	107	93	77	63	50	31	**3.1**	0.3	0.2	0.2	0.2	0.3	1.4
2	2	723.7	0.5%	69	56	51	44	38	32	22	1.2	0.3	0.2	0.3	0.2	0.2	0.3
2	5	707.0	0.4%	525	403	252	148	90	58	38	2.6	0.9	0.7	0.3	0.3	0.2	1.0
2	8	701.2	0.3%	229	200	160	120	88	62	31	1.9	0.2	0.2	0.2	0.2	0.2	1.5
2	13	682.1	0.3%	113	109	94	77	63	50	31	**2.6**	0.3	0.4	0.3	0.3	0.3	0.4

E.7 Machine 15

Lap	Station	Mean Load	SD of Load (%)	Mean D1	Mean D2	Mean D3	Mean D4	Mean D5	Mean D6	Mean D7	SD D1	SD D2	SD D3	SD D4	SD D5	SD D6	SD D7
1	2	699.0	0.3%	131	118	102	84	68	54	32	0.4	0.5	0.2	0.3	0.5	0.4	0.3
1	5	692.9	0.2%	72	64	57	50	43	36	25	0.3	0.1	0.2	0.1	0.2	0.1	0.3
1	8	674.5	0.2%	481	375	246	149	86	53	35	1.3	0.9	0.6	0.2	0.3	0.1	0.2
1	13	692.2	0.1%	241	208	166	125	91	64	33	0.2	0.3	0.3	0.3	0.1	0.2	0.3
2	2	693.3	0.2%	73	64	58	50	43	36	25	0.3	0.1	0.2	0.2	0.3	0.2	0.1
2	5	676.9	0.2%	546	420	265	155	89	55	36	1.1	0.9	0.6	0.5	0.3	0.3	0.9
2	8	690.5	0.2%	247	215	172	130	94	65	34	0.3	0.3	0.3	0.2	0.2	0.2	0.2
2	13	694.6	0.2%	130	116	99	82	67	51	30	0.2	0.2	0.2	0.4	0.3	0.3	0.3

E.8 Machine 16

Lap	Station	Mean Load	SD of Load (%)	Mean D1	Mean D2	Mean D3	Mean D4	Mean D5	Mean D6	Mean D7	SD D1	SD D2	SD D3	SD D4	SD D5	SD D6	SD D7
1	2	695.7	0.4%	72	63	55	45	41	33	24	0.7	0.3	0.5	0.9	0.4	1.4	0.4
1	5	682.1	0.2%	568	407	255	151	87	56	38	0.6	0.4	0.8	0.4	0.5	0.6	0.4
1	8	691.8	0.2%	241	212	168	127	89	65	33	0.5	0.7	1.0	0.5	1.0	0.5	0.5
1	13	702.8	0.2%	132	117	104	84	66	50	31	0.4	0.4	0.7	1.1	0.7	1.3	0.9
2	2	686.9	0.2%	76	63	64	46	39	29	24	0.6	1.1	1.5	1.0	1.0	1.8	0.5
2	5	672.5	0.2%	539	427	268	160	90	56	36	1.6	2.3	0.5	1.2	0.7	0.7	0.7
2	8	683.4	0.2%	251	217	174	130	93	66	33	1.1	0.6	0.5	0.7	1.7	**2.0**	0.8
2	13	691.9	0.1%	130	119	100	83	69	53	33	0.9	0.6	0.3	0.3	0.8	0.9	0.5

E.9 Machine 28

Lap	Station	Mean Load	SD of Load (%)	Mean D1	Mean D2	Mean D3	Mean D4	Mean D5	Mean D6	Mean D7	SD D1	SD D2	SD D3	SD D4	SD D5	SD D6	SD D7
1	2	730.3	0.3%	67	64	54	49	40	32	25	0.6	0.3	0.4	0.7	0.9	1.3	1.0
1	5	714.6	0.1%	554	422	264	153	89	55	35	0.9	0.8	1.0	0.4	0.2	1.7	0.4
1	8	724.8	0.1%	241	218	170	127	92	62	33	0.5	0.5	0.5	0.2	0.2	0.6	0.1
1	13	734.0	0.2%	123	114	98	78	62	46	31	0.6	**2.2**	0.7	0.7	0.3	0.6	0.3
2	2	731.9	0.2%	72	63	56	49	41	34	23	1.1	0.3	1.3	0.7	0.7	0.4	0.2
2	5	715.4	0.1%	553	423	268	155	89	54	36	1.0	0.7	2.1	0.8	0.1	1.5	0.8
2	8	726.5	0.1%	241	218	173	128	93	63	34	0.3	0.7	0.9	0.4	0.5	0.8	0.9
2	13	732.7	0.1%	121	116	100	79	65	48	36	1.5	0.9	0.3	0.4	0.5	0.4	1.2

E.10 Machine 30

Lap	Station	Mean Load	SD of Load (%)	Mean D1	Mean D2	Mean D3	Mean D4	Mean D5	Mean D6	Mean D7	SD D1	SD D2	SD D3	SD D4	SD D5	SD D6	SD D7
1	2	653.4	0.3%	70	62	55	48	41	35	24	0.2	0.5	0.3	0.2	0.2	0.2	0.2
1	5	639.7	0.4%	556	417	257	150	86	53	31	0.9	0.8	0.6	0.3	0.3	0.3	0.5
1	8	652.5	0.5%	239	205	164	122	89	61	33	0.3	0.1	0.4	0.2	0.5	0.1	0.3
1	13	662.4	0.2%	124	108	93	77	62	49	26	0.3	0.3	0.5	0.5	0.2	0.2	1.0
2	*2*	*645.7*	*0.1%*	*71*	*59*	*57*	*49*	*41*	*36*	*25*	*0.1*	*0.4*	*0.8*	*0.5*	*0.1*	*0.5*	*0.4*
2	*5*	***633.2***	*0.2%*	*566*	*417*	*261*	*150*	*87*	*55*	*32*	*1.2*	*1.0*	*1.7*	*0.2*	*0.2*	*0.3*	*0.7*
2	*8*	*646.5*	*0.4%*	*239*	*206*	*165*	*123*	*87*	*64*	*36*	*0.4*	*0.4*	*0.8*	*0.2*	*0.4*	*1.3*	*1.1*
2	*13*	*655.3*	*0.2%*	*121*	*107*	*92*	*77*	*61*	*49*	*31*	*0.2*	*0.6*	*0.3*	*0.5*	*0.3*	*0.6*	*1.0*
3	2	718.2	0.2%	72	61	55	48	41	34	24	0.2	0.2	0.3	0.1	0.1	0.2	0.4
3	5	702.7	0.2%	575	418	258	149	85	54	32	1.4	0.7	0.5	0.2	0.6	0.3	0.3
3	8	718.0	0.2%	243	211	168	125	90	63	33	0.5	0.3	0.4	0.3	0.4	0.3	0.2
3	13	724.1	0.2%	119	107	91	76	61	48	29	0.4	0.2	0.7	0.3	0.1	0.2	0.3

E.11 Machine 32

Lap	Station	Mean Load	SD of Load (%)	Mean D1	Mean D2	Mean D3	Mean D4	Mean D5	Mean D6	Mean D7	SD D1	SD D2	SD D3	SD D4	SD D5	SD D6	SD D7
1	*2*	*.*	*.*	*.*	*.*	*.*	*.*	*.*	*.*	*.*	*.*	*.*	*.*	*.*	*.*	*.*	*.*
1	*5*	*757.8*	*0.2%*	*484*	*373*	*240*	*144*	*90*	*56*	*40*	*1.1*	*0.5*	*0.3*	*0.3*	*0.3*	*0.2*	*0.4*
1	*8*	*739.7*	*0.2%*	*218*	*189*	*152*	*114*	*84*	*59*	*32*	*0.3*	*0.7*	*0.3*	*0.3*	*0.1*	*0.3*	*0.4*
1	*13*	*742.8*	*0.6%*	*110*	*100*	*86*	*72*	*58*	*45*	*27*	*0.2*	*0.4*	*0.1*	*0.4*	*0.3*	*0.5*	*0.3*
2	2	756.0	0.5%	65	56	50	44	37	31	21	1.4	0.3	0.3	0.3	0.3	0.2	0.3
2	5	741.4	0.2%	537	395	248	148	92	62	40	1.1	0.3	0.2	0.3	0.2	0.2	0.7
2	8	743.7	0.3%	221	193	155	117	84	60	33	0.4	0.4	0.3	0.2	0.3	0.3	0.4
2	13	710.0	0.1%	111	101	86	72	57	45	28	0.3	0.2	0.3	0.1	0.1	0.1	0.1
3	2	770.8	0.4%	64	54	49	43	37	30	20	0.1	0.3	0.2	0.2	0.1	0.3	0.4
3	5	739.5	0.7%	525	395	249	148	90	59	40	0.8	0.9	0.7	0.5	0.3	0.3	0.5
3	8	742.9	0.3%	223	195	155	117	84	61	32	0.4	0.4	0.4	0.2	0.3	0.1	0.2
3	13	718.6	0.9%	114	103	88	73	59	46	31	0.4	0.2	0.2	0.1	0.1	0.3	0.8

E.12 Machine 33

Lap	Station	Mean Load	SD of Load (%)	Mean D1	Mean D2	Mean D3	Mean D4	Mean D5	Mean D6	Mean D7	SD D1	SD D2	SD D3	SD D4	SD D5	SD D6	SD D7
1	2	741.4	0.6%	71	60	54	46	40	34	24	0.5	0.7	0.3	0.3	0.3	0.3	0.3
1	5	726.4	0.2%	565	397	252	153	90	57	37	1.0	0.6	0.5	0.9	0.5	0.5	1.7
1	8	717.7	0.7%	240	206	167	127	92	65	34	0.7	0.2	0.5	0.7	0.5	0.1	0.7
1	13	700.9	0.4%	124	113	95	79	66	50	30	0.5	0.7	0.4	0.4	0.5	0.3	0.8
2	2	724.1	0.3%	71	60	54	48	41	34	23	0.3	0.2	0.2	0.1	0.2	0.3	0.4
2	5	686.3	1.3%	552	413	268	161	95	59	40	2.1	0.8	0.7	0.5	0.7	0.3	1.3
2	8	685.0	0.2%	245	210	168	128	93	64	35	0.4	0.3	0.3	0.3	0.4	0.3	0.4
2	13	691.1	0.2%	124	109	94	77	63	49	29	0.3	1.1	0.6	0.4	0.2	0.4	1.0

E.13 Machine 34

Lap	Station	Mean Load	SD of Load (%)	Mean D1	Mean D2	Mean D3	Mean D4	Mean D5	Mean D6	Mean D7	SD D1	SD D2	SD D3	SD D4	SD D5	SD D6	SD D7
1	2	744.9	0.3%	66	54	50	43	35	29	20	0.4	0.8	0.4	0.4	0.4	0.8	0.5
1	5	721.6	0.3%	534	404	251	150	91	57	35	0.8	1.0	0.2	0.3	0.3	0.4	1.0
1	8	714.9	0.4%	225	196	156	118	85	60	32	0.2	0.2	0.3	0.2	0.2	0.3	0.2
1	13	707.5	0.3%	114	101	88	73	58	44	28	0.3	0.5	0.1	0.4	0.3	0.5	0.5
2	2	743.4	0.5%	65	56	50	43	36	31	20	0.4	0.2	0.2	0.2	0.3	0.1	0.2
2	5	718.8	0.3%	545	403	250	149	90	59	37	0.6	0.4	0.4	0.9	0.5	0.6	0.3
2	8	715.0	0.4%	227	193	156	118	85	62	32	0.6	0.2	0.6	1.2	1.0	0.4	0.2
2	13	699.1	0.4%	114	101	87	73	57	43	28	0.5	0.5	0.4	0.6	0.3	0.7	0.8

E.14 Machine 39

Lap	Station	Mean Load	SD of Load (%)	Mean D1	Mean D2	Mean D3	Mean D4	Mean D5	Mean D6	Mean D7	SD D1	SD D2	SD D3	SD D4	SD D5	SD D6	SD D7
1	2	727.4	0.2%	75	62	55	49	42	35	24	0.5	0.2	0.1	0.1	0.1	0.1	0.3
1	5	707.4	0.2%	559	413	251	152	86	52	31	1.2	0.6	0.4	0.2	0.4	0.2	0.1
1	8	725.6	0.1%	241	209	165	126	90	63	33	0.2	0.4	0.3	0.2	0.3	0.2	0.2
1	13	731.2	0.1%	125	109	93	78	62	49	28	0.4	0.1	0.3	0.7	0.1	0.1	0.2
2	2	724.7	0.3%	70	60	54	47	41	34	23	0.7	0.2	0.2	0.3	0.3	0.3	0.2
2	5	707.2	0.2%	525	403	252	154	89	56	33	0.9	0.6	0.3	0.3	0.3	0.5	0.7
2	8	725.6	0.3%	238	205	164	126	90	64	33	0.3	0.3	0.4	0.3	0.4	0.2	0.2
2	13	732.0	0.2%	128	115	98	82	66	52	32	0.8	0.2	0.2	1.3	0.3	1.7	0.7

E.15 Machine 45

Lap	Station	Mean Load	SD of Load (%)	Mean D1	Mean D2	Mean D3	Mean D4	Mean D5	Mean D6	Mean D7	SD D1	SD D2	SD D3	SD D4	SD D5	SD D6	SD D7
1	2	707.2	0.6%	74	62	55	48	42	35	24	0.4	0.4	0.4	0.3	0.3	0.2	0.2
1	5	706.9	0.3%	518	418	264	161	94	59	38	2.5	1.9	1.2	1.0	0.6	0.6	0.6
1	8	707.6	0.4%	244	211	168	129	92	65	34	0.8	0.9	0.8	0.6	0.7	0.6	0.6
1	13	709.9	0.6%	119	106	90	75	60	48	29	0.6	0.6	0.7	0.4	0.6	0.6	0.2
2	2	706.0	0.5%	76	62	55	49	42	35	25	0.3	0.4	0.3	0.4	0.3	0.2	0.4
2	5	707.5	0.2%	542	404	269	162	96	60	37	1.6	2.8	0.9	0.8	0.7	0.3	0.5
2	8	707.5	0.5%	246	213	170	129	93	66	34	0.8	0.7	0.6	0.4	0.5	0.3	0.3
2	13	708.4	0.3%	120	107	91	75	61	49	30	0.5	0.4	0.4	0.4	0.4	0.4	0.3

E.16 Machine 47

Lap	Station	Mean Load	SD of Load (%)	Mean D1	Mean D2	Mean D3	Mean D4	Mean D5	Mean D6	Mean D7	SD D1	SD D2	SD D3	SD D4	SD D5	SD D6	SD D7
1	*2*	***779.7***	*0.2%*	*75*	*67*	*58*	*51*	*44*	*36*	*26*	*0.2*	*0.3*	*0.6*	*0.4*	*0.3*	*0.5*	*0.4*
1	*5*	*763.9*	*0.2%*	*569*	*505*	*272*	*157*	*92*	*54*	*32*	*0.9*	*1.4*	*1.3*	*1.3*	*1.8*	*1.1*	*0.4*
1	*8*	*777.2*	*0.2%*	*247*	*228*	*171*	*130*	*93*	*65*	*33*	*0.4*	*0.7*	*0.7*	*0.3*	*0.2*	*0.5*	*0.5*
1	*13*	***783.4***	*0.2%*	*126*	*121*	*99*	*83*	*67*	*53*	*32*	*0.3*	*0.4*	*0.2*	*0.2*	*0.3*	*0.7*	*0.2*
2	*2*	***778.3***	*0.2%*	*74*	*67*	*60*	*52*	*42*	*36*	*25*	*0.4*	*0.1*	*0.8*	*0.4*	*0.8*	*0.5*	*0.6*
2	*5*	*759.7*	*0.2%*	*565*	*499*	*259*	*152*	*85*	*55*	*30*	*0.5*	*0.8*	*0.5*	*0.4*	*0.3*	*1.4*	*1.1*
2	*8*	*774.1*	*0.1%*	*250*	*232*	*174*	*133*	*93*	*66*	*33*	*0.5*	*0.5*	*0.6*	*0.4*	*0.9*	*0.3*	*0.4*
2	*13*	***780.7***	*0.2%*	*129*	*122*	*99*	*84*	*68*	*54*	*32*	*0.4*	*0.2*	*0.4*	*0.3*	*0.8*	*0.2*	*0.3*
3	2	719.0	0.2%	76	68	59	52	44	37	25	0.6	0.5	0.4	0.4	1.3	0.4	0.4
3	5	705.9	0.2%	586	506	270	155	87	53	32	2.6	1.0	1.0	0.7	1.1	0.7	0.4
3	8	718.7	0.2%	254	234	176	132	96	65	33	0.4	0.4	0.3	0.2	0.4	0.3	0.1
3	13	723.6	0.2%	131	124	99	85	68	55	31	0.4	0.4	0.7	0.2	0.4	0.6	0.8
4	2	736.6	0.3%	73	63	57	50	43	36	25	0.5	0.3	0.1	0.3	0.6	0.4	0.8
4	5	722.3	0.2%	552	404	256	153	87	54	32	1.1	1.0	0.4	1.1	**2.1**	1.1	0.6
4	8	733.8	0.3%	241	212	171	129	94	66	33	0.3	0.5	0.5	0.4	0.4	0.3	0.6
4	13	738.9	0.3%	129	115	99	83	66	52	31	0.2	0.3	0.4	0.3	0.5	0.3	0.4

E.17 Machine 48

Lap	Station	Mean Load	SD of Load (%)	Mean D1	Mean D2	Mean D3	Mean D4	Mean D5	Mean D6	Mean D7	SD D1	SD D2	SD D3	SD D4	SD D5	SD D6	SD D7
1	2	697.6	0.2%	76	65	58	51	44	36	25	1.1	0.2	0.2	0.2	0.2	0.2	0.2
1	5	677.3	0.2%	540	431	265	158	89	56	35	1.2	1.3	0.4	0.2	0.2	0.2	0.6
1	8	690.2	0.2%	250	218	173	131	94	65	33	1.0	0.2	0.3	0.6	0.1	0.1	0.1
1	13	690.9	0.2%	137	123	105	88	71	56	33	0.5	0.2	0.2	0.2	0.1	0.2	0.2
2	2	691.1	0.2%	74	65	58	51	43	36	24	0.8	0.5	0.2	0.6	0.3	0.3	0.2
2	5	675.8	0.2%	548	426	262	158	87	53	34	1.2	0.7	0.4	0.3	0.2	0.2	0.3
2	8	688.5	0.2%	251	219	174	131	94	65	33	1.0	0.2	0.2	0.2	0.1	0.2	0.1
2	13	689.9	0.2%	141	126	107	89	72	57	34	0.5	0.1	0.1	0.3	0.2	0.1	0.1

E.18 Machine 50

Lap	Station	Mean Load	SD of Load (%)	Mean D1	Mean D2	Mean D3	Mean D4	Mean D5	Mean D6	Mean D7	SD D1	SD D2	SD D3	SD D4	SD D5	SD D6	SD D7
1	2	658.2	0.7%	70	58	52	46	40	34	23	**2.9**	1.1	0.6	0.8	0.5	0.7	0.3
1	5	651.1	0.5%	525	402	253	148	87	54	33	2.8	0.7	1.5	0.4	0.6	1.0	0.8
1	8	663.5	0.4%	231	201	162	122	86	62	28	**4.9**	0.8	1.0	0.5	0.8	0.7	0.9
1	13	665.5	0.6%	116	106	92	76	60	48	28	1.3	0.3	0.3	0.3	0.4	0.6	0.4
2	2	662.7	0.3%	70	59	53	46	40	33	22	1.2	0.3	0.4	0.4	0.3	0.6	0.2
2	5	650.1	0.6%	547	404	253	149	87	55	33	3.3	0.9	1.0	0.4	0.5	0.8	0.8
2	8	649.5	0.5%	240	208	164	123	89	62	32	1.4	0.6	0.8	0.5	0.7	1.4	0.9
2	13	640.3	0.7%	123	110	94	78	62	48	29	1.2	0.4	0.6	0.4	0.6	0.5	0.3

E.19 Machine 52

Lap	Station	Mean Load	SD of Load (%)	Mean D1	Mean D2	Mean D3	Mean D4	Mean D5	Mean D6	Mean D7	SD D1	SD D2	SD D3	SD D4	SD D5	SD D6	SD D7
1	2	717.1	0.2%	71	61	55	48	41	35	22	0.3	0.2	0.3	0.2	0.3	0.3	0.2
1	5	707.1	0.1%	567	406	257	149	88	54	38	1.1	0.9	0.7	0.5	0.5	0.4	0.4
1	8	713.3	0.2%	237	205	165	122	90	63	32	0.6	0.5	0.5	0.6	0.5	0.3	0.3
1	13	716.3	0.1%	121	108	94	78	63	50	29	0.3	0.2	0.2	0.2	0.4	0.1	0.1
2	2	714.7	0.1%	72	61	55	49	41	34	23	0.3	0.2	0.4	0.4	0.2	0.2	0.2
2	5	708.1	0.1%	577	409	255	149	87	54	36	1.1	0.7	0.6	0.7	0.7	0.3	0.2
2	8	712.6	0.2%	241	208	167	125	90	63	33	0.3	0.3	0.3	0.2	0.3	0.3	0.5
2	13	715.6	0.2%	123	109	95	78	63	50	30	0.4	0.3	0.1	0.2	0.2	0.2	0.2

E.20 Machine 53

Lap	Station	Mean Load	SD of Load (%)	Mean D1	Mean D2	Mean D3	Mean D4	Mean D5	Mean D6	Mean D7	SD D1	SD D2	SD D3	SD D4	SD D5	SD D6	SD D7
1	2	730.8	1.2%	71	61	54	48	42	35	24	0.7	0.3	0.4	0.3	0.2	0.2	0.1
1	5	716.1	1.1%	534	408	252	149	87	54	34	0.6	0.6	0.4	0.4	0.2	0.3	0.2
1	8	730.0	0.4%	237	205	163	123	89	63	33	0.6	0.4	0.3	0.3	0.2	0.2	0.2
1	13	729.5	0.1%	118	105	90	76	62	48	28	0.4	1.3	0.5	0.6	0.9	0.8	0.3
2	2	732.3	0.2%	75	61	54	48	41	34	24	0.2	0.2	0.3	0.2	0.3	0.2	0.2
2	5	713.3	1.1%	548	407	254	148	87	54	35	1.4	0.9	0.7	0.5	0.4	0.7	0.4
2	8	721.6	1.0%	238	208	166	124	90	63	33	0.4	0.3	0.3	0.4	0.3	0.2	0.2
2	13	731.6	0.2%	128	108	92	77	62	49	28	0.9	0.6	0.3	0.3	0.2	0.6	0.7

E.21 Machine 54

Lap	Station	Mean Load	SD of Load (%)	Mean D1	Mean D2	Mean D3	Mean D4	Mean D5	Mean D6	Mean D7	SD D1	SD D2	SD D3	SD D4	SD D5	SD D6	SD D7
1	2	748.4	1.1%	69	59	52	47	39	35	24	0.5	0.3	0.4	0.3	0.4	0.2	0.2
1	5	737.8	1.6%	530	403	249	155	88	60	35	1.7	1.3	0.8	0.7	0.8	0.6	1.0
1	8	736.0	1.4%	230	203	161	126	88	67	34	0.6	0.7	0.5	0.3	0.9	0.2	0.2
1	13	698.5	0.7%	128	116	98	84	65	55	32	0.5	0.4	0.3	0.3	0.4	0.2	0.4
2	2	745.8	1.2%	68	60	53	47	40	36	24	0.2	0.8	0.3	0.1	0.1	0.2	0.2
2	5	732.8	0.5%	535	401	248	155	89	60	36	0.8	0.5	0.3	0.6	0.5	0.3	0.8
2	8	728.3	1.4%	230	203	162	127	89	67	34	0.4	0.8	0.3	0.2	0.7	0.7	0.2
2	13	712.2	1.2%	127	114	95	81	62	52	30	0.2	0.4	0.1	0.2	0.6	0.1	0.3

E.22 Machine 56

Lap	Station	Mean Load	SD of Load (%)	Mean D1	Mean D2	Mean D3	Mean D4	Mean D5	Mean D6	Mean D7	SD D1	SD D2	SD D3	SD D4	SD D5	SD D6	SD D7
1	2	756.6	0.4%	70	60	54	46	41	33	23	0.6	0.5	0.5	0.7	0.8	0.3	0.4
1	5	739.3	0.3%	540	430	268	155	93	59	40	2.1	2.0	1.6	1.3	0.8	0.6	0.6
1	8	753.3	0.3%	236	204	163	122	89	62	33	1.4	1.3	1.2	1.1	0.9	0.7	0.6
1	13	761.0	0.3%	123	109	93	77	62	49	28	0.5	0.7	0.6	0.6	0.5	0.5	0.5
2	2	758.6	0.2%	69	60	54	47	40	33	23	0.6	0.3	0.3	0.4	0.3	0.3	0.3
2	5	741.7	0.4%	530	414	261	155	91	59	39	1.6	1.8	1.4	1.1	0.7	0.6	0.5
2	8	757.0	0.4%	238	207	166	124	89	63	34	1.6	1.6	1.5	1.4	1.2	1.1	0.6
2	13	763.0	0.2%	126	109	94	77	62	48	28	1.0	0.9	0.8	0.9	0.6	0.6	0.6

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 (except where the value is outside of acceptable limits). To clearly distinguish between the test days, the first lap on Day 2 was labelled as 21 and the first lap on Day 3 was labelled as 31.

F.1 All reproducibility trial data

Table F.1: Machine 02 - All reproducibility trial data (no data point removed)

Lap	Lap Used	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean
1	*N*	*1.006*	*0.988*	*0.993*	*0.996*	*1.006*	*0.990*	*1.005*	*0.998*	*0.042*	*0.013*	*0.014*	*0.016*	*0.019*	*0.029*	*0.038*	*0.025*
2	*N*	*0.983*	*0.986*	*0.992*	*0.986*	*1.002*	*0.992*	*0.995*	*0.991*	*0.020*	*0.011*	*0.010*	*0.015*	*0.014*	*0.014*	*0.030*	*0.016*
21	*N*	*0.993*	*0.983*	*0.991*	*0.987*	*1.003*	*0.991*	*1.017*	*0.995*	*0.023*	*0.013*	*0.011*	*0.011*	*0.015*	*0.019*	*0.046*	*0.020*
22	*N*	*0.988*	*0.985*	*0.993*	*0.987*	*0.999*	*0.998*	*0.996*	*0.992*	*0.023*	*0.007*	*0.008*	*0.008*	*0.006*	*0.010*	*0.030*	*0.013*
23	*N*	*1.005*	*0.989*	*0.997*	*0.994*	*1.004*	*1.004*	*0.989*	*0.997*	*0.019*	*0.006*	*0.007*	*0.008*	*0.007*	*0.015*	*0.035*	*0.014*
24	*N*	*0.999*	*0.991*	*0.995*	*0.993*	*1.007*	*0.998*	*1.015*	*1.000*	*0.020*	*0.013*	*0.010*	*0.014*	*0.010*	*0.011*	*0.031*	*0.016*
25	Y	1.012	0.999	1.006	1.001	1.020	1.003	1.021	1.009	0.022	0.007	0.009	0.010	0.008	0.019	0.029	0.015
26	Y	1.001	0.997	1.007	1.004	1.015	1.010	1.011	1.006	0.022	0.009	0.007	0.011	0.010	0.019	0.027	0.015

Table F.2: Machine 05 - All reproducibility trial data (no data point removed)

Lap	Lap Used	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean
1	*N*	*1.042*	*1.017*	*1.026*	*1.031*	*1.018*	*1.007*	*0.988*	*1.018*	*0.033*	*0.009*	*0.014*	*0.018*	*0.018*	*0.033*	*0.066*	*0.027*
2	*N*	*1.028*	*1.021*	*1.029*	*1.031*	*1.015*	*1.011*	*0.992*	*1.018*	*0.014*	*0.012*	*0.015*	*0.022*	*0.026*	*0.037*	***0.075***	*0.029*
21	*N*	*1.047*	*1.025*	*1.035*	*1.037*	*1.029*	*1.015*	*0.988*	*1.025*	*0.018*	*0.009*	*0.015*	*0.017*	*0.020*	*0.036*	***0.070***	*0.027*
22	*N*	*1.042*	*1.025*	*1.033*	*1.033*	*1.023*	*1.016*	*1.006*	*1.025*	*0.015*	*0.013*	*0.015*	*0.018*	*0.024*	*0.044*	*0.065*	*0.028*
23	*N*	*1.044*	*1.017*	*1.029*	*1.032*	*1.013*	*1.014*	*0.991*	*1.020*	*0.014*	*0.010*	*0.013*	*0.019*	*0.029*	*0.046*	*0.057*	*0.027*
24	*N*	*1.047*	*1.025*	*1.031*	*1.038*	*1.024*	*1.026*	*1.007*	*1.028*	*0.020*	*0.015*	*0.015*	*0.019*	*0.023*	*0.035*	*0.055*	*0.026*
25	Y	1.036	1.014	1.026	1.027	1.020	1.011	0.997	1.019	0.022	0.014	0.018	0.020	0.029	0.041	0.059	0.029
26	Y	1.049	1.015	1.027	1.031	1.018	1.013	1.000	1.022	0.021	0.015	0.019	0.022	0.025	0.043	**0.075**	0.031

Table F.3: Machine 06 - All reproducibility trial data (no data point removed)

Lap	Lap Used	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean
1	*N*	*1.055*	*1.032*	*1.026*	*1.050*	*1.054*	*1.053*	*1.034*	*1.043*	*0.027*	*0.013*	*0.019*	*0.017*	*0.024*	*0.044*	***0.073***	*0.031*
2	*N*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	*N*	*1.031*	*1.019*	*1.015*	*1.037*	*1.040*	*1.042*	*1.012*	*1.028*	*0.021*	*0.015*	*0.017*	*0.015*	*0.017*	*0.019*	*0.052*	*0.022*
22	*N*	*1.019*	*1.007*	*1.007*	*1.022*	*1.024*	*1.031*	*1.016*	*1.018*	*0.026*	*0.019*	*0.020*	*0.022*	*0.030*	*0.034*	***0.079***	*0.033*
23	*N*	*1.030*	*1.017*	*1.014*	*1.037*	*1.037*	*1.039*	*1.011*	*1.026*	*0.029*	*0.021*	*0.020*	*0.022*	*0.026*	*0.029*	*0.053*	*0.028*
24	*N*	*1.030*	*1.016*	*1.009*	*1.033*	*1.025*	*1.042*	*1.014*	*1.024*	*0.026*	*0.015*	*0.012*	*0.017*	*0.020*	*0.028*	*0.039*	*0.022*
25	Y	1.031	1.017	1.011	1.029	1.033	1.035	1.010	1.024	0.030	0.013	0.014	0.007	0.018	0.024	0.049	0.022
26	Y	1.031	1.014	1.009	1.025	1.040	1.047	0.996	1.023	0.028	0.015	0.013	0.012	0.016	0.019	0.065	0.024

Table F.4: Machine 10 - All reproducibility trial data (no data point removed)

Lap	Lap Used	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean
1	*N*	*0.987*	*1.005*	*0.989*	*0.982*	*0.977*	*0.983*	*0.977*	*0.986*	*0.018*	*0.007*	*0.007*	*0.008*	*0.008*	*0.007*	*0.008*	*0.009*
2	*N*	*0.976*	*0.999*	*0.988*	*0.980*	*0.973*	*0.988*	*0.974*	*0.982*	*0.019*	*0.008*	*0.009*	*0.009*	*0.011*	*0.015*	*0.031*	*0.015*
21	*N*	*0.984*	*1.002*	*0.986*	*0.981*	*0.977*	*0.988*	*0.976*	*0.985*	*0.021*	*0.008*	*0.008*	*0.009*	*0.011*	*0.013*	*0.014*	*0.012*
22	*N*	*0.987*	*1.001*	*0.986*	*0.978*	*0.976*	*0.989*	*0.977*	*0.985*	*0.008*	*0.005*	*0.008*	*0.008*	*0.006*	*0.008*	*0.015*	*0.008*
23	*N*	*0.992*	*1.002*	*0.987*	*0.985*	*0.975*	*0.991*	*0.969*	*0.986*	*0.017*	*0.011*	*0.012*	*0.010*	*0.013*	*0.014*	*0.023*	*0.014*
24	*N*	*0.984*	*1.001*	*0.982*	*0.984*	*0.973*	*0.986*	*0.968*	*0.983*	*0.020*	*0.006*	*0.008*	*0.007*	*0.008*	*0.010*	*0.016*	*0.010*
25	Y	0.980	1.004	0.989	0.981	0.981	0.991	0.977	0.986	0.026	0.009	0.013	0.014	0.012	0.013	0.024	0.016
26	Y	0.994	1.007	0.993	0.987	0.985	0.997	0.980	0.992	0.010	0.006	0.006	0.006	0.006	0.010	0.023	0.010

Table F.5: Machine 11 - All reproducibility trial data (no data point removed)

Lap	Lap Used	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean
1	*N*	*0.971*	*0.979*	*0.972*	*0.969*	*0.966*	*0.961*	*0.976*	*0.971*	*0.020*	*0.017*	*0.016*	*0.020*	*0.024*	*0.026*	*0.032*	*0.022*
2	*N*	*0.972*	*0.981*	*0.982*	*0.980*	*0.968*	*0.981*	*0.969*	*0.976*	*0.029*	*0.012*	*0.016*	*0.013*	*0.013*	*0.020*	*0.047*	*0.022*
21	*N*	*0.963*	*0.971*	*0.982*	*0.965*	*0.956*	*0.961*	*0.954*	*0.965*	*0.017*	*0.015*	*0.023*	*0.035*	*0.036*	*0.038*	***0.071***	*0.034*
22	*N*	*0.977*	*0.977*	*0.982*	*0.971*	*0.966*	*0.953*	*0.976*	*0.972*	*0.022*	*0.011*	*0.014*	*0.016*	*0.020*	*0.039*	*0.058*	*0.026*
23	*N*	*0.979*	*0.970*	*0.973*	*0.967*	*0.959*	*0.963*	*0.972*	*0.969*	*0.039*	*0.012*	*0.014*	*0.020*	*0.017*	*0.025*	*0.039*	*0.024*
24	*N*	*0.977*	*0.977*	*0.975*	*0.973*	*0.961*	*0.970*	*0.976*	*0.973*	*0.021*	*0.012*	*0.012*	*0.023*	*0.029*	*0.024*	*0.042*	*0.023*
25	Y	0.979	0.980	0.981	0.972	0.969	0.966	0.966	0.973	0.016	0.015	0.018	0.016	0.018	0.019	0.050	0.022
26	Y	0.973	0.979	0.977	0.967	0.962	0.964	0.968	0.970	0.018	0.019	0.015	0.019	0.021	0.024	0.040	0.022

Table F.6: Machine 13 - All reproducibility trial data (no data point removed)

Lap	Lap Used	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean
1	*N*	*1.037*	*1.055*	*1.050*	*1.060*	*1.043*	*1.042*	*1.050*	*1.048*	*0.056*	*0.017*	*0.018*	*0.020*	*0.020*	*0.027*	*0.028*	*0.026*
2	*N*	*1.030*	*1.059*	*1.056*	*1.063*	*1.044*	*1.049*	*1.050*	***1.050***	*0.037*	*0.021*	*0.023*	*0.022*	*0.027*	*0.035*	*0.055*	*0.031*
21	*N*	*1.011*	*1.044*	*1.037*	*1.048*	*1.028*	*1.027*	*1.028*	*1.032*	*0.041*	*0.017*	*0.016*	*0.018*	*0.023*	*0.033*	*0.039*	*0.027*
22	*N*	*1.029*	*1.043*	*1.039*	*1.044*	*1.024*	*1.026*	*1.033*	*1.034*	*0.038*	*0.020*	*0.022*	*0.024*	*0.024*	*0.036*	*0.029*	*0.028*
23	*N*	*1.011*	*1.045*	*1.042*	*1.050*	*1.026*	*1.028*	*1.035*	*1.034*	*0.051*	*0.017*	*0.018*	*0.022*	*0.024*	*0.038*	*0.037*	*0.030*
24	*N*	*1.040*	*1.050*	*1.044*	*1.058*	*1.032*	*1.037*	*1.028*	*1.041*	*0.042*	*0.023*	*0.025*	*0.028*	*0.033*	*0.042*	*0.052*	*0.035*
25	Y	1.034	1.046	1.042	1.052	1.035	1.033	1.052	1.042	0.062	0.021	0.022	0.023	0.025	0.036	0.021	0.030
26	Y	1.016	1.036	1.036	1.046	1.029	1.031	1.066	1.037	0.030	0.017	0.023	0.022	0.024	0.029	0.050	0.028

Table F.7: Machine 15 - All reproducibility trial data (no data point removed)

Lap	Lap Used	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean
1	*N*	*0.966*	*0.977*	*0.975*	*0.981*	*0.982*	*0.985*	*0.994*	*0.980*	*0.029*	*0.017*	*0.018*	*0.022*	*0.027*	*0.037*	*0.042*	*0.027*
2	*N*	*0.973*	*0.968*	*0.967*	*0.971*	*0.968*	*0.980*	*0.982*	*0.973*	*0.048*	*0.024*	*0.026*	*0.027*	*0.034*	*0.038*	*0.050*	*0.035*
21	*N*	*0.978*	*0.972*	*0.970*	*0.980*	*0.981*	*0.992*	*1.006*	*0.983*	*0.023*	*0.015*	*0.015*	*0.017*	*0.026*	*0.037*	*0.045*	*0.026*
22	*N*	*0.967*	*0.962*	*0.961*	*0.968*	*0.970*	*0.977*	*0.977*	*0.969*	*0.045*	*0.024*	*0.028*	*0.034*	*0.036*	*0.045*	*0.042*	*0.037*
23	*N*	*0.966*	*0.967*	*0.966*	*0.976*	*0.976*	*0.985*	*0.990*	*0.975*	*0.030*	*0.016*	*0.017*	*0.017*	*0.021*	*0.034*	*0.034*	*0.024*
24	*N*	*0.971*	*0.978*	*0.968*	*0.981*	*0.977*	*0.988*	*0.983*	*0.978*	*0.044*	*0.021*	*0.020*	*0.019*	*0.026*	*0.033*	*0.030*	*0.027*
25	Y	0.974	0.978	0.975	0.978	0.981	0.991	0.996	0.982	0.041	0.023	0.020	0.022	0.033	0.034	0.038	0.030
26	Y	0.977	0.972	0.969	0.974	0.976	0.982	0.989	0.977	0.039	0.020	0.022	0.023	0.026	0.033	0.042	0.029
31	*N*	*0.983*	*0.979*	*0.981*	*0.975*	*0.982*	*0.980*	*0.983*	*0.980*	*0.027*	*0.017*	*0.021*	*0.026*	*0.022*	*0.042*	*0.051*	*0.029*
32	*N*	*0.989*	*0.982*	*0.987*	*0.989*	*0.989*	*0.986*	*1.018*	*0.991*	*0.018*	*0.016*	*0.016*	*0.019*	*0.024*	*0.030*	*0.050*	*0.025*
33	*N*	*0.979*	*0.985*	*0.988*	*0.987*	*0.985*	*0.989*	*1.004*	*0.988*	*0.024*	*0.011*	*0.012*	*0.021*	*0.020*	*0.025*	*0.035*	*0.021*

Table F.8: Machine 16 - All reproducibility trial data (no data point removed)

Lap	Lap Used	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean
1	*N*	*0.972*	*0.962*	*0.981*	*0.985*	*0.995*	*0.999*	*1.000*	*0.985*	*0.036*	*0.025*	*0.029*	*0.019*	*0.016*	*0.032*	*0.060*	*0.031*
2	*N*	*0.978*	*0.975*	*0.977*	*0.993*	*0.996*	*0.994*	*1.013*	*0.989*	*0.033*	*0.018*	*0.014*	*0.010*	*0.018*	*0.024*	*0.044*	*0.023*
21	*N*	*0.977*	*0.975*	*0.972*	*0.976*	*0.985*	*0.988*	*0.993*	*0.981*	*0.015*	*0.022*	*0.018*	*0.018*	*0.020*	*0.018*	*0.024*	*0.019*
22	*N*	*0.989*	*0.971*	*0.981*	*0.979*	*0.986*	*0.999*	*0.992*	*0.986*	*0.024*	*0.019*	*0.013*	*0.021*	*0.038*	*0.021*	*0.033*	*0.024*
23	*N*	*0.988*	*0.977*	*0.982*	*0.989*	*0.989*	*0.997*	*1.000*	*0.989*	*0.017*	*0.020*	*0.019*	*0.018*	*0.026*	*0.028*	*0.032*	*0.023*
24	*N*	*0.980*	*0.976*	*0.968*	*0.988*	*0.990*	*0.997*	*1.003*	*0.986*	*0.016*	*0.020*	*0.021*	*0.010*	*0.021*	*0.021*	*0.033*	*0.020*
25	Y	0.983	0.963	0.964	0.974	0.978	0.980	0.999	0.977	0.045	0.023	0.022	0.019	0.025	0.026	0.033	0.027
26	Y	0.979	0.970	0.967	0.981	0.992	0.988	0.988	0.981	0.027	0.026	0.014	0.012	0.013	0.019	0.034	0.021
31	*N*	*0.984*	*0.984*	*0.989*	*0.997*	*0.997*	*1.000*	*1.001*	*0.993*	*0.016*	*0.006*	*0.011*	*0.013*	*0.014*	*0.012*	*0.024*	*0.014*
32	*N*	*0.978*	*0.966*	*0.978*	*0.985*	*0.988*	*0.999*	*0.996*	*0.984*	*0.024*	*0.009*	*0.012*	*0.017*	*0.015*	*0.017*	*0.036*	*0.019*
33	*N*	*0.993*	*0.972*	*0.980*	*0.982*	*0.989*	*0.993*	*0.993*	*0.986*	*0.030*	*0.010*	*0.010*	*0.011*	*0.016*	*0.014*	*0.049*	*0.020*

Table F.9: Machine 28 - All reproducibility trial data (no data point removed)

Lap	Lap Used	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean
1	*N*	*1.006*	*0.951*	*0.949*	*0.979*	*0.993*	*1.037*	*0.966*	*0.983*	*0.043*	*0.029*	*0.036*	*0.019*	*0.019*	*0.032*	*0.045*	*0.032*
2	*N*	*1.013*	*0.969*	*0.967*	*0.983*	*0.996*	*1.036*	*0.987*	*0.993*	*0.034*	*0.014*	*0.029*	*0.012*	*0.015*	*0.023*	*0.043*	*0.024*
21	*N*	*0.989*	*0.973*	*0.971*	*0.970*	*0.990*	*1.017*	*0.983*	*0.985*	*0.019*	*0.031*	*0.012*	*0.022*	*0.021*	*0.029*	***0.084***	*0.031*
22	*N*	*0.983*	*0.976*	*0.964*	*0.971*	*0.995*	*1.014*	*1.003*	*0.986*	*0.019*	*0.027*	*0.026*	*0.025*	*0.028*	*0.041*	*0.061*	*0.032*
23	*N*	*0.996*	*0.971*	*0.965*	*0.980*	*0.992*	*1.027*	*0.988*	*0.989*	*0.037*	*0.019*	*0.016*	*0.018*	*0.029*	*0.032*	*0.039*	*0.027*
24	*N*	*1.005*	*0.975*	*0.967*	*0.980*	*0.999*	*1.018*	*1.005*	*0.993*	*0.048*	*0.026*	*0.020*	*0.019*	*0.019*	*0.029*	*0.051*	*0.030*
25	Y	1.005	0.975	0.972	0.983	0.998	1.024	1.015	0.996	0.040	0.015	0.027	0.022	0.026	0.037	0.034	0.029
26	Y	0.999	0.980	0.987	0.984	1.006	1.025	1.003	0.998	0.014	0.013	0.010	0.023	0.017	0.024	0.045	0.021

Table F.10: Machine 30 - All reproducibility trial data (no data point removed)

Lap	Lap Used	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean
1	*N*	*0.991*	*1.008*	*1.004*	*1.017*	*1.021*	*1.014*	*1.026*	*1.012*	*0.023*	*0.009*	*0.013*	*0.014*	*0.014*	*0.028*	*0.033*	*0.019*
2	*N*	*0.988*	*1.018*	*1.014*	*1.031*	*1.035*	*1.024*	*1.006*	*1.017*	*0.064*	*0.011*	*0.016*	*0.018*	*0.015*	*0.052*	*0.046*	*0.032*
21	*N*	*1.005*	*1.016*	*1.015*	*1.025*	*1.033*	*1.023*	*1.046*	*1.023*	*0.034*	*0.005*	*0.007*	*0.011*	*0.023*	*0.021*	*0.055*	*0.022*
22	*N*	*0.988*	*1.010*	*1.007*	*1.013*	*1.027*	*1.035*	*1.022*	*1.015*	*0.049*	*0.014*	*0.019*	*0.014*	*0.019*	*0.020*	*0.051*	*0.027*
23	*N*	*1.003*	*1.007*	*1.007*	*1.016*	*1.020*	*1.027*	*1.017*	*1.014*	*0.010*	*0.008*	*0.010*	*0.018*	*0.017*	*0.028*	*0.042*	*0.019*
24	*N*	*0.989*	*1.014*	*1.008*	*1.021*	*1.021*	*1.033*	*1.019*	*1.015*	*0.052*	*0.018*	*0.017*	*0.024*	*0.016*	*0.021*	*0.039*	*0.027*
25	Y	1.000	1.015	1.021	1.025	1.039	1.020	1.063	1.026	0.022	0.013	0.010	0.014	0.014	0.037	0.059	0.024
26	Y	0.995	1.017	1.016	1.033	1.040	1.041	1.028	1.024	0.039	0.012	0.012	0.013	0.018	0.018	0.038	0.021

Table F.11: Machine 32 - All reproducibility trial data (no data point removed)

Lap	Lap Used	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean
1	*N*	*1.078*	*1.084*	*1.076*	*1.077*	*1.064*	*1.060*	*1.028*	***1.067***	*0.031*	*0.021*	*0.022*	*0.027*	*0.035*	*0.052*	***0.076***	*0.038*
2	*N*	***1.107***	*1.085*	*1.078*	*1.079*	*1.062*	*1.064*	*1.031*	***1.072***	*0.046*	*0.018*	*0.017*	*0.021*	*0.032*	*0.049*	*0.063*	*0.035*
21	*N*	*1.032*	*1.028*	*1.022*	*1.027*	*1.007*	*1.010*	*0.976*	*1.015*	*0.027*	*0.015*	*0.020*	*0.026*	*0.041*	*0.047*	***0.090***	*0.038*
22	*N*	*1.053*	*1.037*	*1.032*	*1.032*	*1.015*	*1.023*	*0.977*	*1.024*	*0.026*	*0.015*	*0.023*	*0.024*	*0.033*	*0.039*	***0.072***	*0.033*
23	*N*	*1.037*	*1.030*	*1.022*	*1.031*	*1.005*	*1.000*	*0.982*	*1.015*	*0.033*	*0.021*	*0.021*	*0.028*	*0.045*	*0.063*	***0.096***	*0.044*
24	*N*	*1.040*	*1.035*	*1.023*	*1.038*	*1.015*	*1.023*	*0.967*	*1.020*	*0.019*	*0.019*	*0.021*	*0.024*	*0.043*	*0.054*	***0.090***	*0.039*
25	Y	1.040	1.034	1.029	1.030	1.015	1.011	0.998	1.023	0.028	0.027	0.029	0.030	0.049	0.061	**0.077**	0.043
26	Y	1.041	1.030	1.020	1.023	1.012	1.008	0.983	1.017	0.026	0.021	0.024	0.027	0.038	0.051	**0.078**	0.038

Table F.12: Machine 33 - All reproducibility trial data (no data point removed)

Lap	Lap Used	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean
1	N	0.999	0.997	0.986	0.987	0.982	0.983	0.969	0.986	0.038	0.023	0.024	0.028	0.034	0.032	0.033	0.030
2	N	0.991	1.015	1.002	1.002	1.000	0.995	0.967	0.996	0.040	0.023	0.024	0.027	0.031	0.023	0.046	0.030
21	N	1.011	1.025	1.015	1.014	1.014	1.013	1.001	1.014	0.039	0.016	0.017	0.019	0.021	0.029	0.032	0.025
22	N	1.001	1.016	1.010	1.009	0.994	0.999	0.989	1.003	0.052	0.016	0.018	0.030	0.036	0.037	0.037	0.032
23	N	1.014	1.022	1.017	1.013	1.008	1.005	0.987	1.009	0.039	0.019	0.020	0.023	0.034	0.034	0.045	0.030
24	N	1.014	1.029	1.014	1.015	1.006	1.024	0.991	1.013	0.031	0.018	0.016	0.020	0.020	0.017	0.030	0.022
25	Y	1.001	1.006	0.998	1.002	0.998	0.997	0.973	0.996	0.022	0.013	0.019	0.021	0.027	0.032	0.038	0.025
26	Y	1.002	1.002	0.989	0.988	0.989	0.987	0.967	0.989	0.041	0.025	0.021	0.019	0.023	0.029	0.034	0.028
31	N	1.020	1.020	1.013	1.011	1.005	1.002	0.997	1.010	0.018	0.014	0.016	0.019	0.019	0.030	0.022	0.020
32	N	1.028	1.028	1.019	1.013	1.012	0.998	0.997	1.014	0.020	0.017	0.014	0.017	0.027	0.021	0.024	0.020
33	N	1.004	1.030	1.020	1.010	1.012	1.008	1.004	1.013	0.049	0.023	0.017	0.022	0.031	0.032	0.023	0.028

Table F.13: Machine 34 - All reproducibility trial data (no data point removed)

Lap	Lap Used	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean
1	N	1.092	1.092	1.093	1.093	1.099	1.082	1.093	**1.092**	0.048	0.032	0.031	0.036	0.051	0.060	**0.077**	0.048
2	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	N	1.026	1.016	1.025	1.032	1.027	1.015	0.995	1.019	0.041	0.022	0.032	0.039	0.053	0.061	**0.112**	**0.051**
22	N	1.020	1.016	1.019	1.021	1.015	1.013	1.010	1.016	0.033	0.027	0.027	0.036	0.039	0.059	**0.072**	0.042
23	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24	N	1.018	1.021	1.020	1.023	1.025	1.016	1.011	1.019	0.033	0.027	0.029	0.032	0.040	0.062	0.047	0.038
25	N	1.009	1.020	1.028	1.035	1.037	1.023	1.022	1.025	0.046	0.027	0.030	0.035	0.039	0.062	**0.092**	0.047
26	N	1.009	1.025	1.023	1.027	1.035	1.021	1.016	1.022	0.047	0.042	0.030	0.033	0.041	**0.081**	0.069	0.049
31	N	1.035	1.037	1.038	1.037	1.025	1.012	0.973	1.023	0.046	0.040	0.033	0.040	0.041	0.052	**0.071**	0.046
32	Y	1.018	1.028	1.026	1.032	1.026	1.008	0.972	1.016	0.032	0.039	0.025	0.036	0.058	0.064	**0.071**	0.046
33	Y	1.027	1.045	1.041	1.041	1.037	1.010	0.970	1.025	0.045	0.050	0.039	0.051	0.052	**0.081**	**0.098**	**0.059**

Table F.14: Machine 39 - All reproducibility trial data (no data point removed)

Lap	Lap Used	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean
1	*N*	*0.980*	*1.001*	*1.011*	*1.001*	*1.015*	*1.024*	*1.047*	*1.011*	*0.025*	*0.008*	*0.015*	*0.015*	*0.020*	*0.033*	*0.050*	*0.024*
2	*N*	*0.983*	*0.998*	*1.010*	*0.999*	*1.009*	*1.025*	*1.041*	*1.009*	*0.021*	*0.014*	*0.017*	*0.018*	*0.021*	*0.032*	*0.052*	*0.025*
21	*N*	*0.997*	*1.008*	*1.014*	*1.003*	*1.011*	*1.022*	*1.028*	*1.012*	*0.029*	*0.026*	*0.027*	*0.020*	*0.025*	*0.040*	*0.051*	*0.031*
22	*N*	*0.995*	*1.014*	*1.025*	*1.011*	*1.024*	*1.039*	*1.048*	*1.022*	*0.047*	*0.016*	*0.018*	*0.018*	*0.023*	*0.038*	*0.049*	*0.030*
23	*N*	*1.000*	*1.005*	*1.014*	*1.004*	*1.010*	*1.024*	*1.033*	*1.013*	*0.029*	*0.010*	*0.014*	*0.012*	*0.017*	*0.027*	*0.040*	*0.021*
24	*N*	*0.994*	*1.006*	*1.012*	*1.004*	*1.011*	*1.025*	*1.057*	*1.015*	*0.021*	*0.014*	*0.019*	*0.016*	*0.021*	*0.032*	***0.078***	*0.029*
25	Y	0.986	1.003	1.013	1.002	1.017	1.029	1.034	1.012	0.020	0.010	0.015	0.012	0.023	0.039	0.033	0.022
26	Y	0.987	1.005	1.015	1.002	1.018	1.025	1.037	1.013	0.019	0.015	0.020	0.017	0.023	0.030	0.045	0.024

Table F.15: Machine 45 - All reproducibility trial data (no data point removed)

Lap	Lap Used	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean
1	*N*	*0.952*	*0.983*	*0.983*	*0.975*	*0.971*	*0.955*	*0.955*	*0.968*	*0.061*	*0.017*	*0.019*	*0.022*	*0.023*	*0.026*	*0.030*	*0.028*
2	*N*	*0.976*	*0.996*	*0.996*	*0.985*	*0.978*	*0.978*	*0.965*	*0.982*	*0.060*	*0.023*	*0.024*	*0.025*	*0.029*	*0.027*	*0.033*	*0.032*
21	*N*	*0.970*	*0.979*	*0.975*	*0.963*	*0.971*	*0.968*	*0.964*	*0.970*	*0.031*	*0.017*	*0.025*	*0.031*	*0.046*	*0.068*	***0.134***	***0.051***
22	*N*	*0.972*	*0.988*	*0.989*	*0.977*	*0.981*	*0.973*	*0.979*	*0.980*	*0.044*	*0.011*	*0.011*	*0.017*	*0.017*	*0.017*	*0.018*	*0.019*
23	*N*	*0.993*	*0.996*	*0.994*	*0.989*	*0.983*	*0.982*	*0.969*	*0.987*	*0.031*	*0.017*	*0.020*	*0.025*	*0.025*	*0.023*	*0.023*	*0.023*
24	*N*	*0.969*	*0.985*	*0.983*	*0.980*	*0.968*	*0.965*	*0.951*	*0.972*	*0.043*	*0.014*	*0.015*	*0.018*	*0.022*	*0.019*	*0.026*	*0.022*
25	Y	0.990	0.992	0.994	0.989	0.985	0.969	0.960	0.983	0.027	0.014	0.014	0.018	0.023	0.018	0.023	0.019
26	Y	0.987	0.993	0.993	0.987	0.986	0.971	0.972	0.984	0.032	0.009	0.012	0.016	0.018	0.020	0.016	0.018

Table F.16: Machine 47 - All reproducibility trial data (no data point removed)

Lap	Lap Used	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean
1	*N*	*0.962*	*0.958*	*0.956*	*0.955*	*0.970*	*0.980*	*1.041*	*0.975*	*0.013*	*0.011*	*0.016*	*0.026*	*0.031*	*0.051*	***0.082***	*0.033*
2	*N*	*0.971*	*0.968*	*0.966*	*0.971*	*0.982*	*0.987*	*1.035*	*0.983*	*0.046*	*0.018*	*0.017*	*0.027*	*0.033*	*0.046*	***0.077***	*0.038*
21	*N*	*0.963*	*0.960*	*0.960*	*0.965*	*0.966*	*0.978*	*1.028*	*0.974*	*0.028*	*0.019*	*0.027*	*0.033*	*0.040*	*0.043*	***0.079***	*0.039*
22	*N*	*0.970*	*0.954*	*0.953*	*0.953*	*0.962*	*0.976*	*1.024*	*0.970*	*0.038*	*0.025*	*0.030*	*0.035*	*0.049*	*0.060*	***0.080***	*0.045*
23	*N*	*0.956*	*0.957*	*0.953*	*0.961*	*0.972*	*0.977*	*1.014*	*0.970*	*0.025*	*0.023*	*0.032*	*0.045*	*0.062*	*0.062*	***0.081***	*0.047*
24	*N*	*0.960*	*0.960*	*0.955*	*0.963*	*0.973*	*0.982*	*1.039*	*0.976*	*0.010*	*0.011*	*0.019*	*0.030*	*0.039*	*0.048*	***0.092***	*0.036*
25	Y	0.971	0.969	0.968	0.971	0.989	0.987	1.006	0.980	0.021	0.016	0.018	0.028	0.035	0.044	0.065	0.032
26	Y	0.964	0.970	0.965	0.959	0.984	0.981	0.994	0.974	0.030	0.022	0.032	0.045	0.047	0.064	**0.071**	0.044

Table F.17: Machine 48 - All reproducibility trial data (no data point removed)

Lap	Lap Used	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean
1	*N*	*0.968*	*0.952*	*0.959*	*0.954*	*0.961*	*0.972*	*0.974*	*0.963*	*0.048*	*0.021*	*0.024*	*0.022*	*0.027*	*0.053*	*0.058*	*0.036*
2	*N*	*0.974*	*0.953*	*0.965*	*0.962*	*0.966*	*0.979*	*1.004*	*0.972*	*0.044*	*0.012*	*0.018*	*0.020*	*0.023*	*0.038*	*0.049*	*0.029*
21	*N*	*0.969*	*0.955*	*0.961*	*0.963*	*0.968*	*0.970*	*0.989*	*0.968*	*0.020*	*0.020*	*0.026*	*0.023*	*0.033*	*0.041*	*0.051*	*0.031*
22	*N*	*0.963*	*0.955*	*0.965*	*0.963*	*0.970*	*0.982*	*0.989*	*0.970*	*0.029*	*0.016*	*0.023*	*0.021*	*0.028*	*0.043*	*0.032*	*0.027*
23	*N*	*0.978*	*0.956*	*0.966*	*0.966*	*0.967*	*0.988*	*0.987*	*0.973*	*0.022*	*0.013*	*0.020*	*0.021*	*0.027*	*0.046*	*0.048*	*0.028*
24	*N*	*0.963*	*0.946*	*0.955*	*0.958*	*0.960*	*0.970*	*0.993*	*0.964*	*0.031*	*0.019*	*0.026*	*0.027*	*0.033*	*0.038*	*0.052*	*0.032*
25	Y	0.971	0.955	0.965	0.960	0.971	0.985	1.016	0.975	0.023	0.022	0.029	0.024	0.027	0.050	**0.072**	0.035
26	Y	0.969	0.952	0.961	0.958	0.970	0.974	0.994	0.968	0.031	0.021	0.026	0.029	0.040	0.047	0.048	0.035

Table F.18: Machine 50 - All reproducibility trial data (no data point removed)

Lap	Lap Used	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean
1	*N*	*0.990*	*1.024*	*1.026*	*1.037*	*1.023*	*1.044*	*1.063*	*1.030*	*0.063*	*0.013*	*0.014*	*0.018*	*0.025*	*0.024*	*0.065*	*0.032*
2	*N*	*1.029*	*1.026*	*1.024*	*1.034*	*1.025*	*1.040*	*1.029*	*1.030*	*0.066*	*0.021*	*0.025*	*0.020*	*0.017*	*0.025*	*0.057*	*0.033*
21	*N*	*1.032*	*1.040*	*1.043*	*1.049*	*1.045*	*1.054*	*1.046*	*1.044*	*0.037*	*0.008*	*0.012*	*0.012*	*0.012*	*0.025*	*0.037*	*0.020*
22	*N*	*1.028*	*1.036*	*1.039*	*1.042*	*1.055*	*1.050*	*1.059*	*1.044*	*0.015*	*0.010*	*0.010*	*0.007*	*0.016*	*0.020*	*0.042*	*0.017*
23	*N*	*1.013*	*1.028*	*1.033*	*1.041*	*1.035*	*1.039*	*1.048*	*1.034*	*0.020*	*0.014*	*0.013*	*0.010*	*0.017*	*0.028*	*0.055*	*0.022*
24	*N*	*1.010*	*1.022*	*1.030*	*1.035*	*1.034*	*1.040*	*1.029*	*1.028*	*0.017*	*0.013*	*0.013*	*0.016*	*0.019*	*0.024*	*0.041*	*0.021*
25	Y	1.003	1.017	1.019	1.026	1.027	1.021	1.038	1.022	0.020	0.010	0.016	0.011	0.012	0.029	0.061	0.023
26	Y	1.014	1.026	1.027	1.031	1.026	1.040	1.028	1.027	0.019	0.017	0.011	0.018	0.018	0.031	0.051	0.023

Table F.19: Machine 52 - All reproducibility trial data (no data point removed)

Lap	Lap Used	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean
1	*N*	*0.988*	*1.005*	*0.998*	*1.010*	*1.007*	*1.010*	*1.007*	*1.004*	*0.028*	*0.011*	*0.015*	*0.018*	*0.016*	*0.025*	*0.022*	*0.019*
2	*N*	*0.995*	*1.008*	*1.006*	*1.013*	*1.003*	*1.014*	*1.003*	*1.006*	*0.018*	*0.010*	*0.008*	*0.012*	*0.015*	*0.015*	*0.023*	*0.014*
21	*N*	*0.991*	*1.005*	*0.997*	*1.012*	*1.009*	*1.013*	*0.996*	*1.003*	*0.016*	*0.013*	*0.014*	*0.018*	*0.018*	*0.025*	*0.026*	*0.019*
22	*N*	*0.996*	*1.006*	*1.002*	*1.009*	*1.006*	*1.011*	*1.013*	*1.006*	*0.018*	*0.009*	*0.007*	*0.013*	*0.019*	*0.018*	*0.026*	*0.016*
23	*N*	*1.002*	*1.011*	*1.004*	*1.020*	*1.011*	*1.023*	*1.014*	*1.012*	*0.019*	*0.012*	*0.014*	*0.022*	*0.021*	*0.022*	*0.037*	*0.021*
24	*N*	*0.986*	*1.002*	*0.998*	*1.017*	*1.003*	*1.010*	*1.009*	*1.004*	*0.024*	*0.011*	*0.010*	*0.015*	*0.014*	*0.015*	*0.019*	*0.016*
25	Y	0.990	1.004	0.996	1.004	0.998	1.011	1.022	1.004	0.018	0.015	0.010	0.019	0.022	0.022	0.024	0.019
26	Y	1.004	1.013	1.004	1.012	1.006	1.014	1.024	1.011	0.022	0.013	0.015	0.014	0.025	0.022	0.054	0.024

Table F.20: Machine 53 - All reproducibility trial data (no data point removed)

Lap	Lap Used	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean
1	*N*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*
2	*N*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*
21	*N*	*1.011*	*1.019*	*1.027*	*1.034*	*1.023*	*1.029*	*1.033*	*1.025*	*0.023*	*0.023*	*0.025*	*0.025*	*0.034*	*0.035*	*0.041*	*0.029*
22	*N*	*0.997*	*1.012*	*1.025*	*1.027*	*1.013*	*1.030*	*1.020*	*1.018*	*0.019*	*0.016*	*0.024*	*0.027*	*0.025*	*0.044*	*0.032*	*0.027*
23	*N*	*1.009*	*1.016*	*1.028*	*1.027*	*1.013*	*1.021*	*1.009*	*1.018*	*0.012*	*0.017*	*0.023*	*0.020*	*0.029*	*0.027*	*0.023*	*0.022*
24	*N*	*0.999*	*1.015*	*1.019*	*1.029*	*1.013*	*1.021*	*1.007*	*1.015*	*0.029*	*0.027*	*0.032*	*0.032*	*0.041*	*0.043*	*0.044*	*0.035*
25	Y	0.990	1.010	1.023	1.030	1.020	1.024	1.030	1.018	0.025	0.010	0.012	0.019	0.019	0.020	0.034	0.020
26	Y	1.004	1.014	1.025	1.036	1.028	1.028	1.015	1.021	0.038	0.038	0.023	0.027	0.030	0.041	0.027	0.032

Table F.21: Machine 54 - All reproducibility trial data (no data point removed)

Lap	Lap Used	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean
1	*N*	*1.077*	*1.029*	*1.033*	*0.999*	*1.036*	*0.953*	*0.975*	*1.015*	*0.042*	*0.017*	*0.015*	*0.025*	*0.031*	*0.021*	*0.025*	*0.025*
2	*N*	*1.071*	*1.032*	*1.042*	*1.000*	*1.030*	*0.954*	*0.974*	*1.015*	*0.036*	*0.014*	*0.013*	*0.022*	*0.024*	*0.018*	*0.022*	*0.021*
21	*N*	*1.068*	*1.031*	*1.033*	*1.006*	*1.045*	*0.984*	*1.002*	*1.024*	*0.031*	*0.019*	*0.014*	*0.023*	*0.029*	*0.023*	*0.028*	*0.024*
22	*N*	*1.071*	*1.035*	*1.040*	*1.003*	*1.048*	*0.972*	*0.986*	*1.022*	*0.022*	*0.014*	*0.012*	*0.018*	*0.024*	*0.017*	*0.016*	*0.018*
23	*N*	*1.072*	*1.038*	*1.044*	*1.010*	*1.048*	*0.969*	*0.992*	*1.025*	*0.026*	*0.018*	*0.013*	*0.021*	*0.021*	*0.020*	*0.040*	*0.023*
24	*N*	*1.078*	*1.041*	*1.042*	*1.010*	*1.042*	*0.961*	*0.977*	*1.022*	*0.018*	*0.016*	*0.015*	*0.023*	*0.024*	*0.022*	*0.027*	*0.021*
25	Y	1.075	1.038	1.039	1.000	1.039	0.951	0.971	1.016	0.020	0.011	0.011	0.018	0.020	0.022	0.019	0.017
26	Y	1.065	1.027	1.032	0.996	1.035	0.950	0.971	1.011	0.019	0.009	0.007	0.010	0.019	0.014	0.018	0.013

Table F.22: Machine 56 - All reproducibility trial data (no data point removed)

Lap	Lap Used	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean
1	*N*	*1.023*	*1.024*	*1.014*	*1.024*	*1.019*	*1.019*	*1.005*	*1.018*	*0.029*	*0.019*	*0.018*	*0.018*	*0.026*	*0.038*	*0.060*	*0.030*
2	*N*	*1.034*	*1.020*	*1.020*	*1.034*	*1.026*	*1.036*	*0.986*	*1.022*	*0.036*	*0.017*	*0.015*	*0.029*	*0.019*	*0.029*	*0.062*	*0.030*
21	*N*	*1.038*	*1.032*	*1.032*	*1.041*	*1.032*	*1.035*	*0.999*	*1.030*	*0.022*	*0.017*	*0.020*	*0.023*	*0.025*	*0.032*	*0.060*	*0.028*
22	*N*	*1.031*	*1.024*	*1.023*	*1.025*	*1.024*	*1.022*	*0.997*	*1.021*	*0.028*	*0.022*	*0.017*	*0.018*	*0.025*	*0.042*	***0.095***	*0.035*
23	*N*	*1.014*	*1.010*	*1.014*	*1.026*	*1.017*	*1.023*	*0.993*	*1.014*	*0.024*	*0.024*	*0.021*	*0.023*	*0.021*	*0.032*	*0.070*	*0.031*
24	*N*	*1.005*	*1.017*	*1.014*	*1.027*	*1.019*	*1.030*	*0.996*	*1.015*	*0.036*	*0.019*	*0.022*	*0.023*	*0.029*	*0.032*	*0.056*	*0.031*
25	Y	1.018	1.021	1.013	1.029	1.023	1.019	1.001	1.018	0.027	0.016	0.022	0.025	0.023	0.032	0.056	0.029
26	Y	1.009	1.019	1.018	1.034	1.024	1.027	1.021	1.022	0.021	0.030	0.027	0.048	0.041	0.050	0.062	0.040
31	*N*	*1.011*	*1.025*	*1.021*	*1.025*	*1.014*	*1.008*	*1.006*	*1.016*	*0.021*	*0.018*	*0.018*	*0.018*	*0.019*	*0.030*	*0.046*	*0.024*
32	*N*	*1.016*	*1.022*	*1.028*	*1.026*	*1.022*	*1.032*	*1.005*	*1.022*	*0.023*	*0.019*	*0.018*	*0.016*	*0.029*	*0.038*	*0.046*	*0.027*
33	*N*	*1.013*	*1.017*	*1.020*	*1.018*	*1.025*	*1.017*	*0.989*	*1.014*	*0.017*	*0.008*	*0.011*	*0.010*	*0.025*	*0.023*	*0.041*	*0.020*

F.2 Final reproducibility trial data for selected laps

Table F.23: Final trial data for reproducibility (analysed laps – single data point removed where appropriate)

ID	Lap	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean	Excluded Geophone and test station
2	25	1.012	0.999	1.006	1.001	1.020	1.003	1.021	1.009	0.022	0.007	0.009	0.010	0.008	0.019	0.029	0.015	
2	26	1.001	0.997	1.007	1.004	1.015	1.010	1.011	1.006	0.022	0.009	0.007	0.011	0.010	0.019	0.027	0.015	
5	25	1.036	1.014	1.026	1.027	1.020	1.011	0.997	1.019	0.022	0.014	0.018	0.020	0.029	0.041	0.059	0.029	
5	26	1.049	1.015	1.027	1.031	1.018	1.013	1.000	1.022	0.021	0.015	0.019	0.022	0.025	0.043	0.058	0.029	Station 5 D7
6	25	1.031	1.017	1.011	1.029	1.033	1.035	1.010	1.024	0.030	0.013	0.014	0.007	0.018	0.024	0.049	0.022	
6	26	1.031	1.014	1.009	1.025	1.040	1.047	0.996	1.023	0.028	0.015	0.013	0.012	0.016	0.019	0.062	0.024	
10	25	0.980	1.004	0.989	0.981	0.981	0.991	0.977	0.986	0.026	0.009	0.013	0.014	0.012	0.013	0.024	0.016	
10	26	0.994	1.007	0.993	0.987	0.985	0.997	0.980	0.992	0.010	0.006	0.006	0.006	0.006	0.010	0.023	0.010	

ID	Lap	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean	Excluded Geophone and test station
11	25	0.979	0.980	0.981	0.972	0.969	0.966	0.966	0.973	0.016	0.015	0.018	0.016	0.018	0.019	0.050	0.022	
11	26	0.973	0.979	0.977	0.967	0.962	0.964	0.968	0.970	0.018	0.019	0.015	0.019	0.021	0.024	0.040	0.022	
13	25	1.034	1.046	1.042	1.052	1.035	1.033	1.052	1.042	0.062	0.021	0.022	0.023	0.025	0.036	0.021	0.030	
13	26	1.016	1.036	1.036	1.046	1.029	1.031	1.066	1.037	0.030	0.017	0.023	0.022	0.024	0.029	0.050	0.028	
15	25	0.974	0.978	0.975	0.978	0.981	0.991	0.996	0.982	0.041	0.023	0.020	0.022	0.033	0.034	0.038	0.030	
15	26	0.977	0.972	0.969	0.974	0.976	0.982	0.989	0.977	0.039	0.020	0.022	0.023	0.026	0.033	0.042	0.029	
16	25	0.983	0.963	0.964	0.974	0.978	0.980	0.999	0.977	0.045	0.023	0.022	0.019	0.025	0.026	0.033	0.027	
16	26	0.979	0.970	0.967	0.981	0.992	0.988	0.988	0.981	0.027	0.026	0.014	0.012	0.013	0.019	0.034	0.021	
28	25	1.005	0.975	0.972	0.983	0.998	1.024	1.015	0.996	0.040	0.015	0.027	0.022	0.026	0.037	0.034	0.029	
28	26	0.999	0.980	0.987	0.984	1.006	1.025	1.003	0.998	0.014	0.013	0.010	0.023	0.017	0.024	0.045	0.021	
30	25	1.000	1.015	1.021	1.025	1.039	1.020	1.063	1.026	0.022	0.013	0.010	0.014	0.014	0.037	0.059	0.024	
30	26	0.995	1.017	1.016	1.033	1.040	1.041	1.028	1.024	0.039	0.012	0.012	0.013	0.018	0.018	0.038	0.021	
32	25	1.040	1.034	1.029	1.030	1.015	1.011	0.998	1.023	0.028	0.027	0.029	0.030	0.049	0.061	0.063	0.041	Station 5 D7
32	26	1.041	1.030	1.020	1.023	1.012	1.008	0.983	1.017	0.026	0.021	0.024	0.027	0.038	0.051	0.065	0.036	Station 5 D7
33	25	1.001	1.006	0.998	1.002	0.998	0.997	0.973	0.996	0.022	0.013	0.019	0.021	0.027	0.032	0.038	0.025	
33	26	1.002	1.002	0.989	0.988	0.989	0.987	0.967	0.989	0.041	0.025	0.021	0.019	0.023	0.029	0.034	0.028	
34	**32**	1.018	1.028	1.026	1.032	1.026	1.008	0.972	1.016	0.032	0.039	0.025	0.036	0.058	0.064	0.069	0.046	Station 8 D7
34	**33**	1.027	1.045	1.041	1.041	1.037	1.010	0.970	1.025	0.045	0.050	0.039	0.051	0.052	**0.081**	**0.088**	**0.058**	Station 6 D7
39	25	0.986	1.003	1.013	1.002	1.017	1.029	1.034	1.012	0.020	0.010	0.015	0.012	0.023	0.039	0.033	0.022	
39	26	0.987	1.005	1.015	1.002	1.018	1.025	1.037	1.013	0.019	0.015	0.020	0.017	0.023	0.030	0.045	0.024	
45	25	0.990	0.992	0.994	0.989	0.985	0.969	0.960	0.983	0.027	0.014	0.014	0.018	0.023	0.018	0.023	0.019	
45	26	0.987	0.993	0.993	0.987	0.986	0.971	0.972	0.984	0.032	0.009	0.012	0.016	0.018	0.020	0.016	0.018	
47	25	0.971	0.969	0.968	0.971	0.989	0.987	1.006	0.980	0.021	0.016	0.018	0.028	0.035	0.044	0.065	0.032	
47	26	0.964	0.970	0.965	0.959	0.984	0.981	0.994	0.974	0.030	0.022	0.032	0.045	0.047	0.064	0.065	0.044	Station 6 D7
48	25	0.971	0.955	0.965	0.960	0.971	0.985	1.016	0.975	0.023	0.022	0.029	0.024	0.027	0.050	0.046	0.032	Station 5 D7
48	26	0.969	0.952	0.961	0.958	0.970	0.974	0.994	0.968	0.031	0.021	0.026	0.029	0.040	0.047	0.048	0.035	
50	25	1.003	1.017	1.019	1.026	1.027	1.021	1.038	1.022	0.020	0.010	0.016	0.011	0.012	0.029	0.061	0.023	
50	26	1.014	1.026	1.027	1.031	1.026	1.040	1.028	1.027	0.019	0.017	0.011	0.018	0.018	0.031	0.051	0.023	

ID	Lap	FCF D1	FCF D2	FCF D3	FCF D4	FCF D5	FCF D6	FCF D7	FCF Mean	SDDR D1	SDDR D2	SDDR D3	SDDR D4	SDDR D5	SDDR D6	SDDR D7	SDDR Mean	Excluded Geophone and test station
52	25	0.990	1.004	0.996	1.004	0.998	1.011	1.022	1.004	0.018	0.015	0.010	0.019	0.022	0.022	0.024	0.019	
52	26	1.004	1.013	1.004	1.012	1.006	1.014	1.024	1.011	0.022	0.013	0.015	0.014	0.025	0.022	0.054	0.024	
53	25	0.990	1.010	1.023	1.030	1.020	1.024	1.030	1.018	0.025	0.010	0.012	0.019	0.019	0.020	0.034	0.020	
53	26	1.004	1.014	1.025	1.036	1.028	1.028	1.015	1.021	0.038	0.038	0.023	0.027	0.030	0.041	0.027	0.032	
54	25	1.075	1.038	1.039	1.000	1.039	0.951	0.971	1.016	0.020	0.011	0.011	0.018	0.020	0.022	0.019	0.017	
54	26	1.065	1.027	1.032	0.996	1.035	0.950	0.971	1.011	0.019	0.009	0.007	0.010	0.019	0.014	0.018	0.013	
56	25	1.018	1.021	1.013	1.029	1.023	1.019	1.001	1.018	0.027	0.016	0.022	0.025	0.023	0.032	0.056	0.029	
56	26	1.009	1.019	1.018	1.034	1.024	1.027	1.021	1.022	0.021	0.030	0.027	0.048	0.041	0.050	0.062	0.040	

Appendix G Accreditation trial – Trial results

ID	Make, model and serial number	Repeatability	FCF Mean	FCF Individual	SDDR Mean	SDDR Individual	Elapsed distance	Temperature at depth	Surface temperature	Air Temperature	OSGR
2	Dynatest FWD 8002 SN 102	Pass	Pass	Pass	Pass	Pass	Pass	High	No data	No data	High
5	Dynatest HWD 8082 SN 050	Pass	Pass	Pass	Pass	Pass	Pass	High	No data	No data	High
6	Dynatest HWD 8082 SN 018	Pass	Pass	Pass	Pass	Pass	Pass	High	High	Not suitable	High
10	Dynatest FWD 8002 SN 192	Pass	Pass	Pass	Pass	Pass	Pass	High	No data	No data	High
11	Dynatest FWD 8002 SN 187	Pass	Pass	Pass	Pass	Pass	Pass	High	Not suitable	Not suitable	High
13	Dynatest HWD 8082 SN 029	Pass	Pass	Pass	Pass	Pass	Pass	Low	No data	No data	High
15	Dynatest FWD 8002 SN 203	Pass	Pass	Pass	Pass	Pass	Pass	High	Not assessed	Not assessed	High
16	Dynatest FWD 8002 SN 214	Pass	Pass	Pass	Pass	Pass	Pass	Medium	Not suitable	No data	Medium
28	Dynatest FWD 8002 SN 271	Pass	Pass	Pass	Pass	Pass	Pass	High	Not suitable	Not suitable	High
30	Dynatest FWD 8002 SN173	Pass	Pass	Pass	Pass	Pass	Pass	High	High	High	High
32	Dynatest HWD 8082 SN 069	Pass	Pass	Pass	Pass	Pass	Pass	High	Not suitable	Not assessed	High
33	Dynatest HWD 8082 SN 070	Pass	Pass	Pass	Pass	Pass	Pass	Medium	Not assessed	Not assessed	High
34	Dynatest HWD 8082 SN 108	Pass	Pass	Pass	Fail	Fail	Pass	Medium	Not suitable	Not assessed	High

ID	Make, model and serial number	Repeatability	FCF Mean	FCF Individual	SDDR Mean	SDDR Individual	Elapsed distance	Temperature at depth	Surface temperature	Air Temperature	OSGR
39	Dynatest FWD 8002 SN 388	Pass	Pass	Pass	Pass	Pass	Pass	High	Low	Low	Medium
45	Sweco FWD PRI2100 SN 0903-088	Pass	Pass	Pass	Pass	Pass	Pass	High	Not suitable	High	No data
47	Dynatest FWD 8002 SN 452	Pass	Pass	Pass	Pass	Pass	Pass	Medium	High	High	No data
48	Dynatest FWD 8002 SN 424	Pass	Pass	Pass	Pass	Pass	Pass	Low	High	Low	High
50	Rincent HeavyDyn HVY-101A	Pass	Pass	Pass	Pass	Pass	Pass	High	Medium	Not suitable	Medium
52	Dynatest FFWD 8012 SN 057	Pass	Pass	Pass	Pass	Pass	Pass	Medium	Not assessed	Not assessed	High
53	Dynatest FWD 8002 SN 098	Pass	Pass	Pass	Pass	Pass	Pass	High	Low	Low	Medium
54	Sweco PRI1500 0822-664	Pass	Pass	Pass	Pass	Pass	Pass	High	Low	High	Medium
56	Dynatest FWD 8002 SN 033	Pass	Pass	Pass	Pass	Pass	Pass	High	High	High	No data

National Highways 2024 UK 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 National Highways commissions annual accreditation trials for the Dynamic Plate test devices (FWDs and HWDs) supported by ongoing QA. In order to undertake accredited surveys, the survey devices are required to meet the mandatory criteria of the trial.

This report covers the 2024 trial run by TRL held on the Horiba-MIRA proving ground in the week beginning the 23rd September 2024.

Other titles from this subject area

PPR2054	National Highways 2023 Dynamic Plate Test device Accreditation Trial. S Brittain. 2026
PPR2053	National Highways 2022 Dynamic Plate Test device Accreditation Trial. S Brittain. 2026
PPR2052	National Highways 2021 Dynamic Plate Test device Accreditation Trial. S Brittain. 2026
PPR974	Highways England 2020 National Dynamic Plate Test device Accreditation Trial. S Brittain, 2022

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