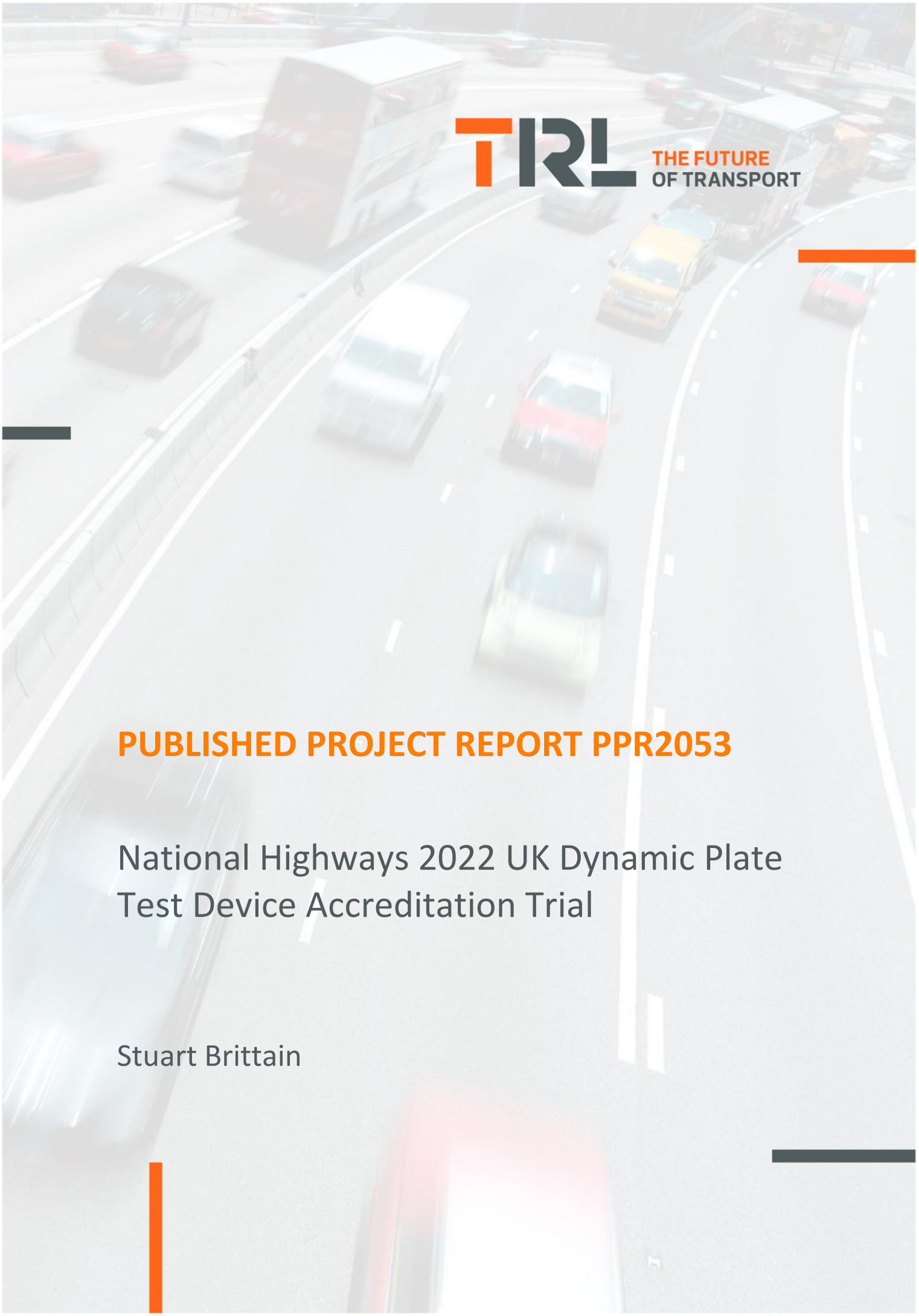

THE FUTURE OF TRANSPORT

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National Highways 2022 UK Dynamic Plate Test Device Accreditation Trial

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Executive Summary

The 2022 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 26th September 2022. This was the twenty-fourth 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 nineteen machines took part in the trial, consisting of:

- Eleven trailer-mounted Dynatest FWDs;
- Five trailer-mounted Dynatest HWDs;
- One trailer-mounted Sweco FWD;
- One trailer-mounted Sweco HWD; and
- One trailer-mounted Rincent HWD.

The 2022 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 2022 trial the third day was not required. The first day included machine inspections and initial testing of the machines. The second day was used to reassess machines (following some alterations at the end of day 1) and 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 nineteen machines met the mandatory criteria of the trial.
- 3-dimensional positional data was supplied by twelve 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, eight machines achieved a high performance level, three a medium performance level and one a low.

- All nineteen operators of the machines provided 100mm pavement temperature measurements using hand-held probes. Eight achieved a high performance rating, ten achieved a medium, and one a low.
- Six machines provided surface temperature measurements using infra-red thermometers (IRTs) fixed to their machines. Four machines achieved a low performance and two were identified as not suitable.
- Six machines provided air temperature measurements from apparatus fixed to their machines. This data was assessed using the surface temperature criteria. Two machines achieved a medium performance, three a low performance and one was identified as not suitable.

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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 2022 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-fourth mandatory UK DPT accreditation trial was held in the week beginning the 26th September 2022, organised on behalf of National Highways. The trial followed a similar format used in previous trials carried out since 1999. The 2022 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 2022 accreditation trial and presents the details of the machines that took part.

2 Trial details

2.1 Participants

Nineteen machines (all trailer-mounted) took part in the 2022 National Highways DPT accreditation trial, comprising twelve Falling Weight Deflectometers (FWD) and seven 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	Dynatest 8002 FWD
Milestone	Sweco PRI1500 FWD
PMS Ltd.	Dynatest 8002 FWD
PTS Ltd.	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 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 machines were set up correctly and configured as required for the trial. 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 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 (along with stations 2, 5 and 8) are used in the repeatability testing. Two additional test lengths were set up; one to allow operators to undertake distance calibrations and one for the odometer test. 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

Temperatures were measured by TRL throughout the trial using two sets of temperature sensors and were also recorded using data loggers. Each set contained thermocouples to measure the 40mm and 100mm pavement temperatures and also the air and pavement surface temperatures. One set was located near station 2 and the other near station 11 – one each end of the test site. The loggers connected to the sensors were set to record the temperature measurement once every minute.

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 including details on the contingency planning is presented 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 four reproducibility laps. If time permits, then 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 12:00 to conduct 4 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 19)
Completed Check list returned to TRL before trial	16
Geophones in correct position on arrival at trial	12
Date of last tower calibration	18
Date of last dynamic calibration	18
Date of last manufacturer's calibration	19

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.

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). The initial test laps for this were conducted on Day 1 of the trial using stations 2, 5, 8 and 13 and the results were assessed using the test criteria in Appendix D, D.1.

During the reproducibility testing (discussed in sections 5 and 6) some machines were identified as requiring investigation and subsequently underwent alterations. Undertaking alterations invalidates the results of previous tests, so additional repeatability testing for these machines was carried out.

The additional repeatability laps were undertaken on Day 2. Details of the additional repeatability laps are as follows (further details on the alterations are discussed in the reproducibility testing sections of this report):

- Machine 05 undertook an alteration due to the performance on Day 1. Two repeatability laps were undertaken on day 2.
- Machine 33 undertook an alteration due to the performance on Day 1. Two repeatability laps were undertaken on day 2.
- Machine 34 undertook an alteration due to the performance on Day 1. Two repeatability laps were undertaken on day 2.
- Machine 45 was unable to complete all of the testing on day 1 due to an equipment fault. It took part in one lap which identified an issue with the performance. It then undertook an alteration due to the performance on Day 1. Two repeatability laps were undertaken on day 2.

Table 4.1 shows the summary of the final results for the repeatability assessment for all machines. 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 (including 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
10	0	0	0	0	0	0	0	100.0%	Pass
11	0	0	0	0	0	0	0	100.0%	Pass
13	0	0	0	0	0	0	0	100.0%	Pass
15	0	0	0	0	0	0	0	100.0%	Pass
16	0	0	0	0	0	0	0	100.0%	Pass
28	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	1	98.2%	Pass
38	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	0	0	0	100.0%	Pass
48	0	0	0	0	0	0	0	100.0%	Pass
50	0	0	0	0	0	0	0	100.0%	Pass
52	0	0	0	0	0	0	0	100.0%	Pass
53	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 11. The pavement temperatures for Day 1 are shown in Figure 5.1. The air and surface temperatures were also collected at stations 2 and 11 and the data for Day 1 is shown in Figure 5.2.

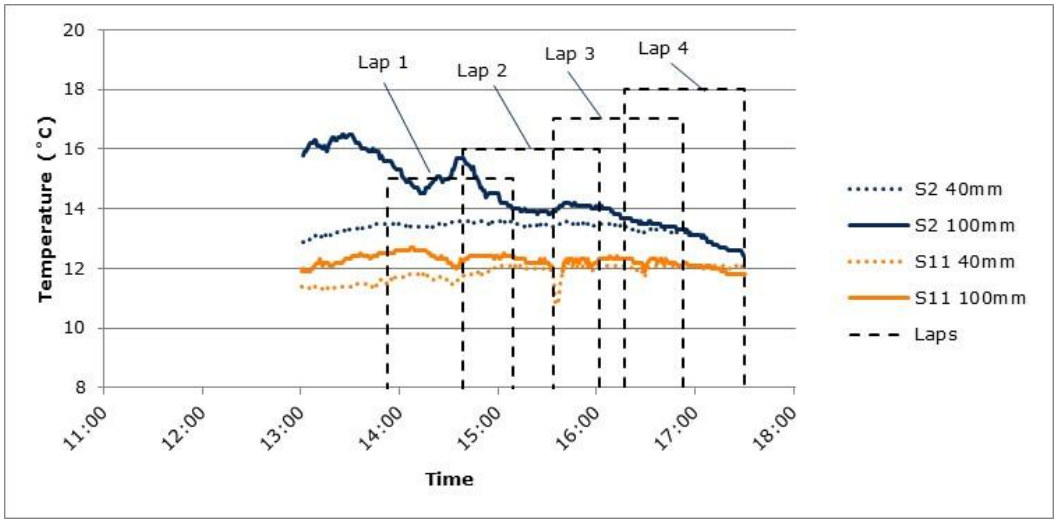

Figure 5.1: Pavement temperatures during Day 1

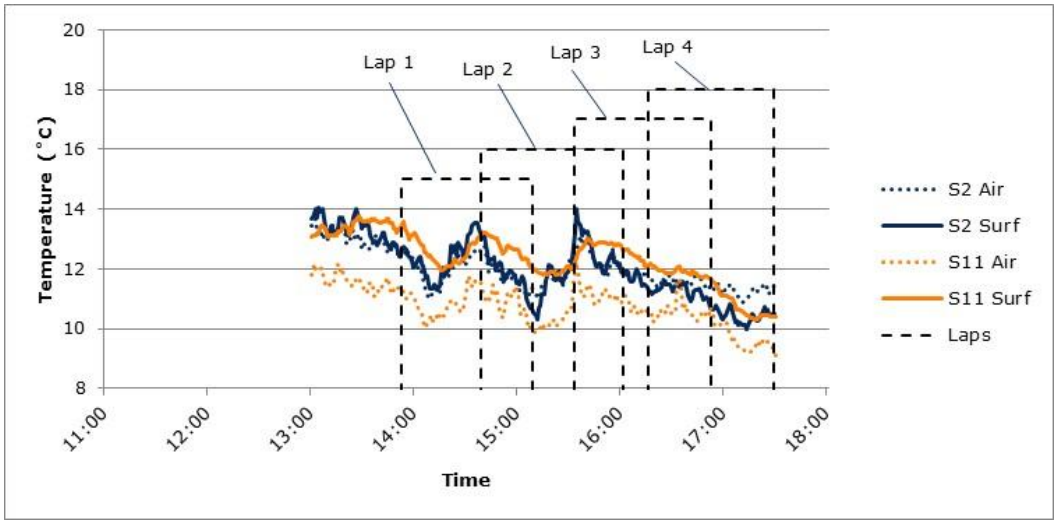

Figure 5.2: Air and surface temperatures during Day 1

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 11 respectively.

Table 5.1: Pavement temperatures 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
1	13:53	13.5	15.6	15:09	13.5	14.0	01:16	0.0	-1.6
2	14:39	13.6	15.7	16:02	13.5	14.0	01:23	-0.1	-1.7
3	15:34	13.4	13.9	16:53	13.2	13.3	01:19	-0.2	-0.6
4	16:17	13.4	13.7	17:30	13.2	12.4	01:13	-0.2	-1.3

Table 5.2: Pavement temperatures for each lap during Day 1, near station 11

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
1	13:53	11.5	12.5	15:09	12.1	12.4	01:16	0.6	-0.1
2	14:39	11.7	12.2	16:02	12.1	12.3	01:23	0.4	0.1
3	15:34	11.9	12.0	16:53	12.1	12.1	01:19	0.2	0.1
4	16:17	12.1	12.3	17:30	12.1	11.8	01:13	0.0	-0.5

It can be seen that the differences in 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, four 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. The results of the Day 2 testing are discussed in section 6.

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 Day 2 which are labelled lap 11 onwards). Further details on the FCF and SDDR and how they are calculated are given in Appendix D.

Machine 45 stopped working during testing on day 1 and was unable to take part in Laps 1, 2 or 3 (nor did it complete all of the repeatability testing on this day).

The generator on Machine 32 stopped working and as such it did not take part in lap 4.

The tow vehicle for Machine 52 was leaking oil and was asked to leave the site before the reproducibility testing was started. This machine was included in lap 4 by using the tow vehicle from another machine which tested earlier in the lap.

During the testing on this day, it was noticed that some machines were outside of the trial criteria and some alterations were undertaken on the day. These were:

- Machine 05 this machine was found to have a mean FCF that was too high. The operator investigated this machine and made alterations after lap 4. This included raising the tow hitch and adjusting the load cell relative gain.
- Machine 33 this machine was also found to have a mean FCF that was too high. The operator investigated the machine and made alterations after lap 3. This included altering the load cell value.
- Machine 34 this machine had a high mean FCF. The operator investigated the machine and made alterations after lap 4. This included altering the load cell value.

To help assess if the changes to Machines 05 and 34 improved the performance of the machines they undertook an additional lap directly after lap 4 and this data was compared to the data for lap 4 from the other machines (data referred to as lap 4.5 in Appendix F).

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 last two laps for each machine on day 1 are shown in Figure 5.3 and Figure 5.4 (FCF and SDDR, respectively). Note: Machines 45 and 52 only conducted one lap on this day as discussed above. 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).

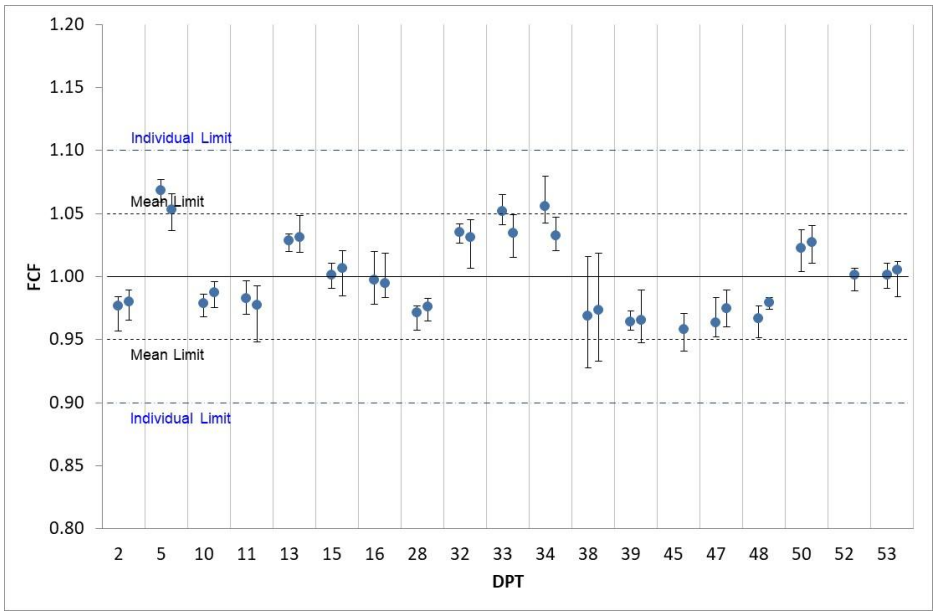

Figure 5.3: FCF for each DPT (Day 1 last two laps– full data set)

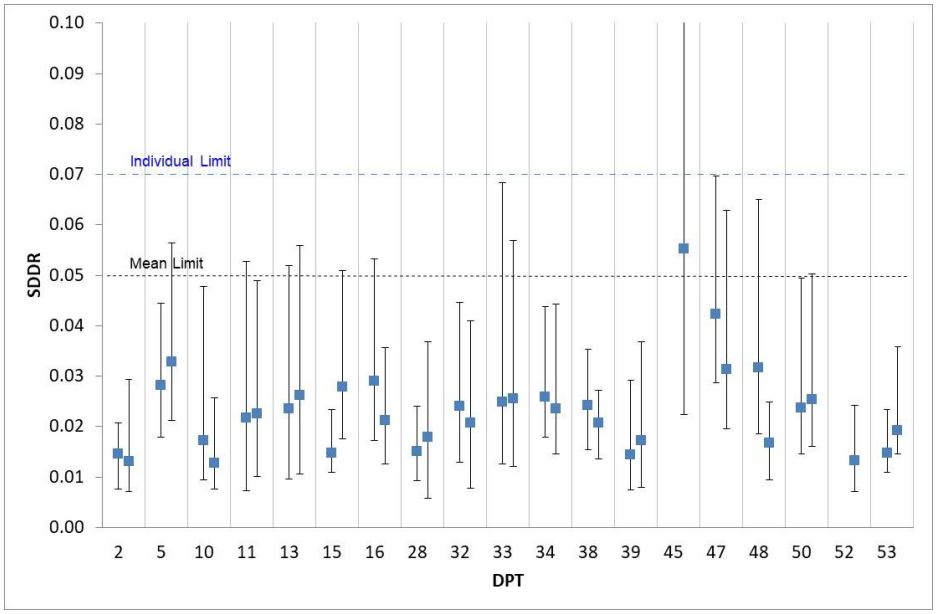

Figure 5.4: SDDR for each DPT (Day 1 last two laps – full dataset)

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 laps 3 and 4 (2 and 3 for Machine 32) from Day 1 after removal of a single data point (where required) are shown in Figure 5.5 and Figure 5.6.

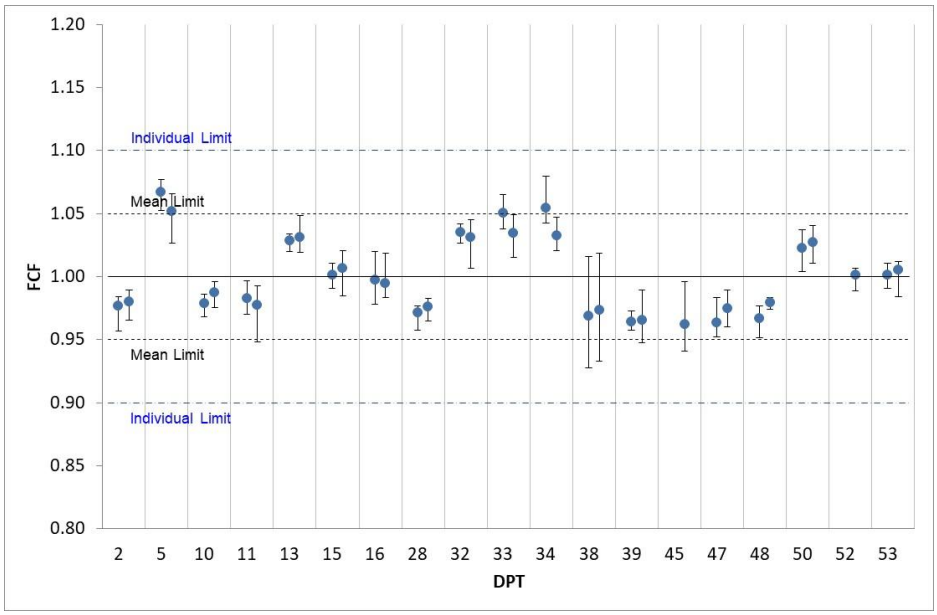

Figure 5.5: FCF for each DPT (Day 1 laps 3 and 4 – single data point removed where required)

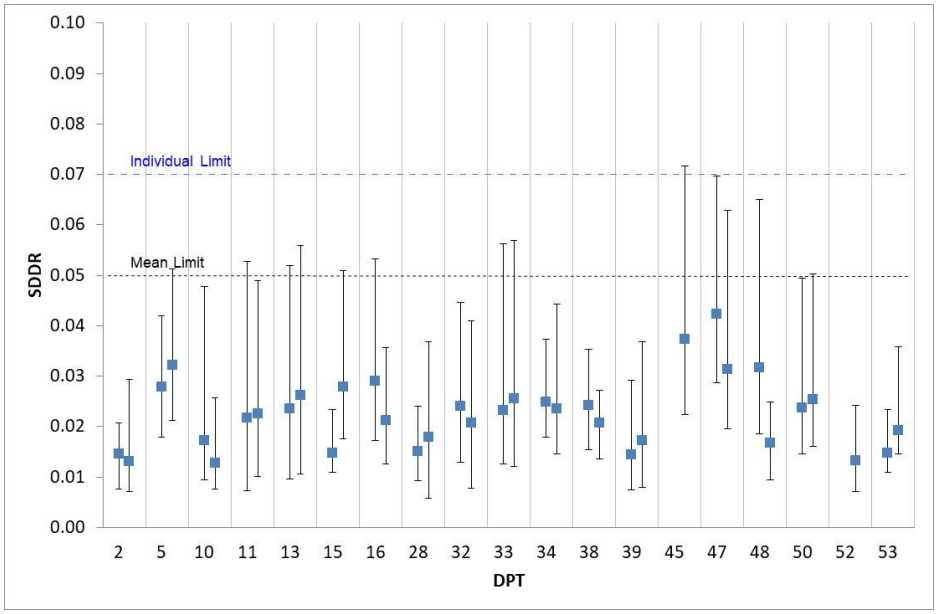

Figure 5.6: SDDR for each DPT (Day 1 laps 3 and 4 – single data point removed where required)

From this data it could be seen that the machines that underwent alterations before their last laps (Machine 05, 33 and 34) all showed an improvement in their performance with regards to mean FCF. However, although it had improved, Machine 05 remained outside of the Mean FCF tolerance. It was also noted, that for the one lap Machine 45 was able to carry out, it failed to meet the individual SDDR criteria.

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 5**. The Mean FCF for this machine was too high even after the alterations undertaken and should be further investigated before the remaining testing in the trial.
- **Machine 33**. The alterations to this machine appear to have brought the machine within the criteria.
- **Machine 34**. The alterations to this machine appear to have brought the machine within the criteria.
- **Machine 45**. This machine was outside of the criterion for individual SDDR and as such they should investigate their machine before the remaining testing in the trial.

The operators for Machine 5 and 45 further investigated their machines after the testing on day 1 and all four of these machines returned on the morning of day 2 to carry out two repeatability laps (as discussed in section 4) before conducting further reproducibility laps with the rest of the fleet (discussed in section 6).

6 Reproducibility testing – Day 2

6.1 Temperature variation – Day 2

The temperatures recorded for the 40 and 100mm depths near stations 2 and 11 for Day 2 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. Note: to clearly differentiate between the testing on the two days, the first lap on Day 2 was called lap 11.

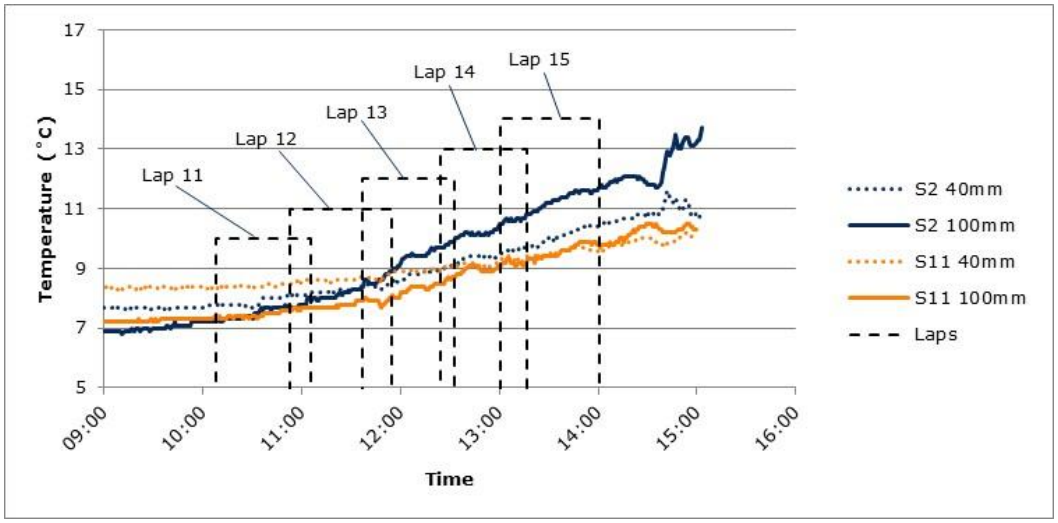

Figure 6.1: Pavement temperatures during Day 2

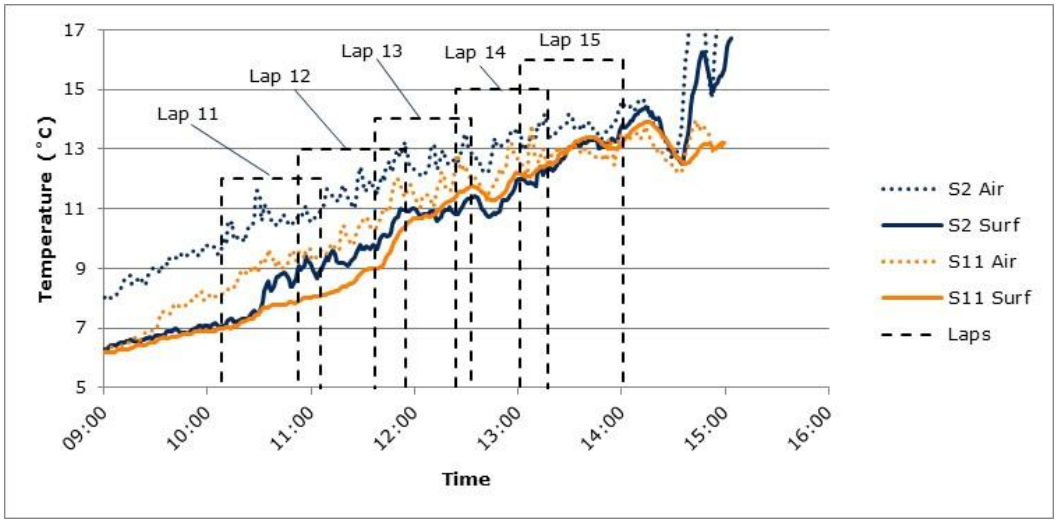

Figure 6.2: Air and surface temperatures during Day 2

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 11 respectively.

Table 6.1: Pavement temperatures 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
11	10:08	7.8	7.2	11:06	8.2	8.0	00:58	0.4	0.8
12	10:53	8.1	7.8	11:55	8.5	8.9	01:02	0.4	1.1
13	11:37	8.4	8.4	12:33	9.1	9.9	00:56	0.7	1.5
14	12:24	9.0	9.7	13:17	9.7	10.8	00:53	0.7	1.1

Table 6.2: Pavement temperatures for each lap during Day 2, near station 11

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
11	10:08	8.3	7.4	11:06	8.5	7.7	00:58	0.2	0.3
12	10:53	8.5	7.6	11:55	8.9	8.0	01:02	0.4	0.4
13	11:37	8.7	7.9	12:33	9.0	8.7	00:56	0.3	0.8
14	12:24	9.0	8.5	13:17	9.4	9.2	00:53	0.4	0.7
15	13:01	9.3	9.1	14:01	9.5	9.8	01:00	0.2	0.7

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

As discussed in section 5.2.3, Machine 05 and Machine 45 underwent alterations after their testing on day 1 and before testing on day 2. The operator for Machine 05 altered their load cell value. The operator for Machine 45 reconnected geophones 6 and 7 and also corrected the geophone fittings.

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 most machines, the laps chosen for i and ii were laps 14 and 15 (the last two laps of the trial). Machine 52 was unable to participate in lap 14, as such the laps chosen for i and ii were laps 13 and 14 for this machine.

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

The laps chosen for assessment (lap i and ii) were laps 14 and 15 for most machines apart from the exceptions discussed above, as shown in Table 6.3.

Table 6.3: Machines for which laps 14 and 15 were not used for the assessment

Machine	Lap i	Lap ii
52	13	15

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.

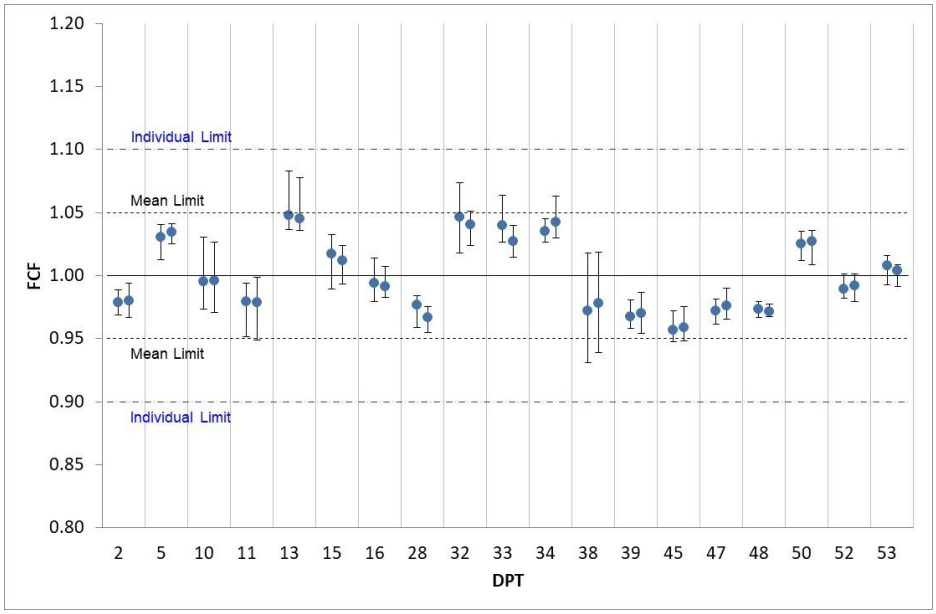

Figure 6.3: FCF for each DPT (Day 2 for laps i and ii – full data set)

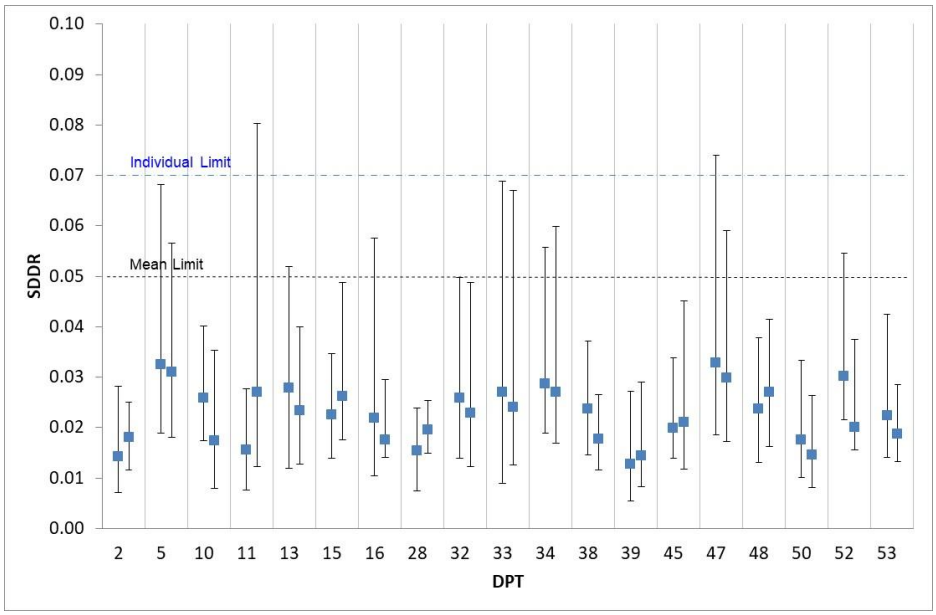

Figure 6.4: SDDR for each DPT (Day 2 for laps i and ii – full dataset)

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 two machines (Machine 11 and Machine 47) failed to meet the individual SDDR criterion using the full set of data.

6.2.2 Plots of FCF and 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 FCF and Figure 6.6 for SDDR.

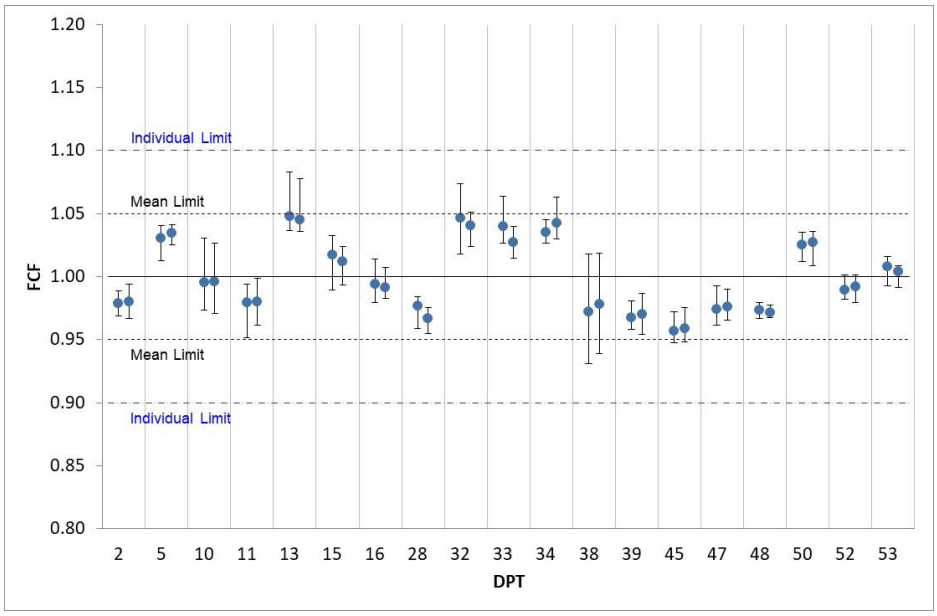

Figure 6.5: FCF for each DPT (laps i and ii – single data point removed where required)

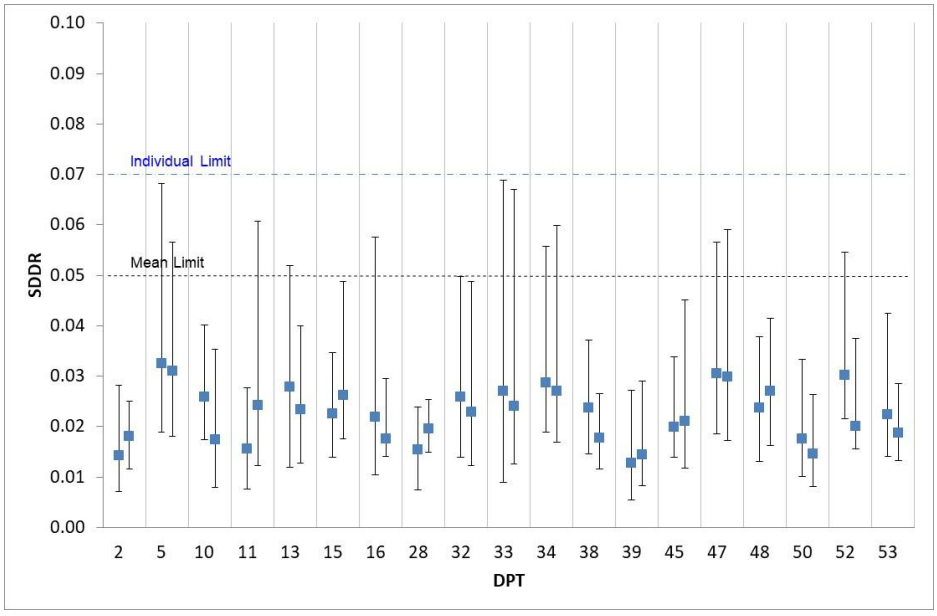

Figure 6.6: SDDR for each DPT (laps i and ii – single data point removed where required)

Following the removal of a single geophone reading from one station on each lap (where required) it can be seen that all machines meet the FCF and SDDR criteria on the laps selected for laps i and ii.

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 2022 trial, day 3 was not required.

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, 526.5m, was not provided to the operators. The criteria applied to this data are described in Appendix D, D.1. The differences between the 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 (1% i.e. 5.27m). A machine would fail this test if it could not supply all four measured lengths within the criteria.

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	1.5	1.5	1.5	1.5	Pass
5	-0.5	-0.4	-0.6	-0.7	Pass
10	-1.5	-1.5	-1.5	-1.5	Pass
11	-0.5	-0.5	-1.5	-0.5	Pass
13	-1.5	-1.5	-0.5	-0.5	Pass
15	0.5	-0.5	-0.5	0.5	Pass
16	3.5	3.5	3.5	3.5	Pass
28	-0.5	-0.5	-0.5	-0.5	Pass
32	-0.5	-0.5	-0.5	-0.5	Pass
33	-2.5	-2.5	-2.5	-2.5	Pass
34	-0.5	-1.5	-1.5	-1.5	Pass
38	-0.5	-0.5	-0.5	-0.5	Pass
39	0.5	-0.5	-0.5	-0.5	Pass
45	-0.5	-0.5	-0.5	-0.5	Pass
47	-0.5	-0.5	-0.5	-0.5	Pass
48	-0.5	-0.5	-0.5	-0.5	Pass
50	-2.5	-2.5	-2.8	-2.8	Pass
52	-0.5	-0.5	-0.5	-0.5	Pass
53	-0.5	-0.5	-0.5	-0.5	Pass

It can be seen from this table that all machines met the trial criteria. In addition, 66% 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 12 of the 19 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 and identified that a number of survey contractors used a simplified version of the mapping from Lat/Long to OSGR resulting in a poorer performance. These contractors were directed to the official conversion between these datasets given by Ordnance Survey, and they provided updated OSGR data.

The performance of the machines were 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
11	99.1%	100.0%	100.0%	High
15	99.1%	100.0%	100.0%	High
16	**62.5%**	100.0%	100.0%	Medium
28	90.7%	100.0%	100.0%	High
32	99.0%	99.0%	99.0%	High
33	100.0%	100.0%	100.0%	High
34	100.0%	100.0%	100.0%	High
38	**5.6%**	**61.1%**	100.0%	Low
39	94.8%	100.0%	100.0%	High
48	**62.0%**	100.0%	100.0%	Medium
50	**16.7%**	97.2%	100.0%	Medium
52	81.7%	100.0%	100.0%	High

It can be seen from Table 8.2 that eight machines achieved the high performance rating, three machines a medium and one a low.

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 so that their accuracy of temperature collection could be assessed. These holes are drilled to 100mm depth and located near stations 2 and 11. The operators were asked to take measurements on each of the reproducibility laps for both test days. This data is typically assessed by comparing the values against the data collected by temperature data loggers located in the same holes (the data discussed in sections 5.1 and 6.1). However, during the trial it was identified that the glycerol (conductive medium to allow the temperature probes to quickly equalise to the temperature in the hole) poured into the holes near station 11 was draining away too quickly. This meant that although the temperature loggers should have been accurately measuring the temperature at the corresponding depths, the operators measurements near station 11 would not be as they would not equalise to the temperature of the hole. Therefore, to assess this data the average of fleet data was used as the reference.

The temperatures recorded by the operators are plotted against the data recorded from the temperature data logger (located in the same hole) in Figure 9.1 and Figure 9.2 for the testing on Day 1, and in Figure 9.3 and Figure 9.4 for Day 2 testing.

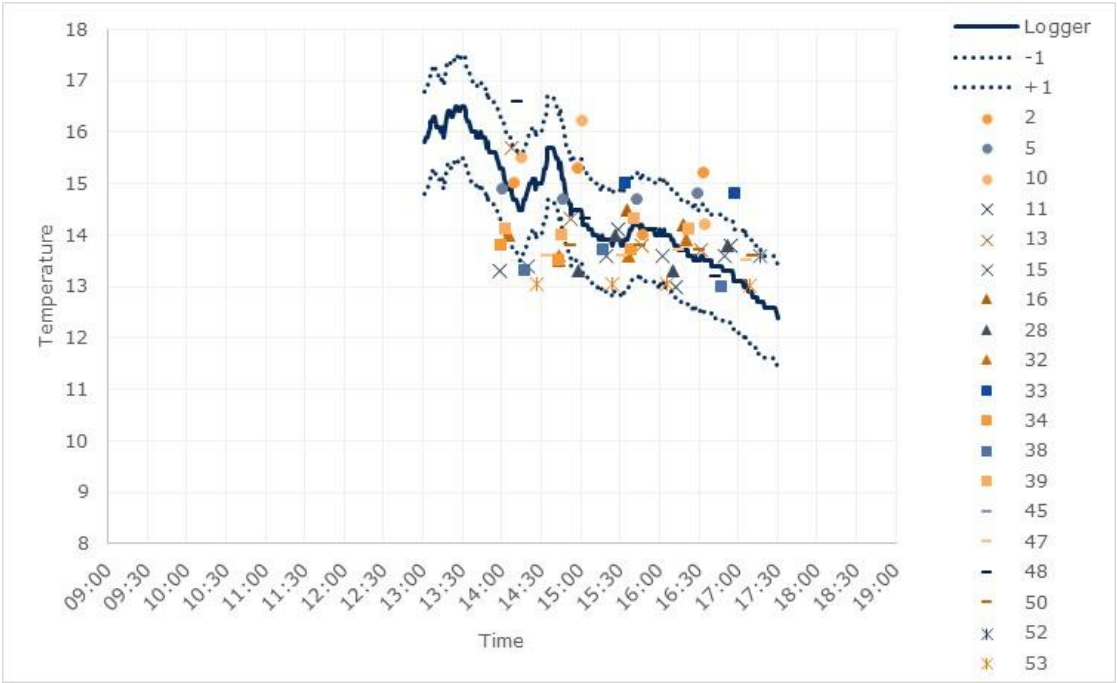

Figure 9.1: Operator's and reference temperatures (Day 1 near station 2, 100mm depth)

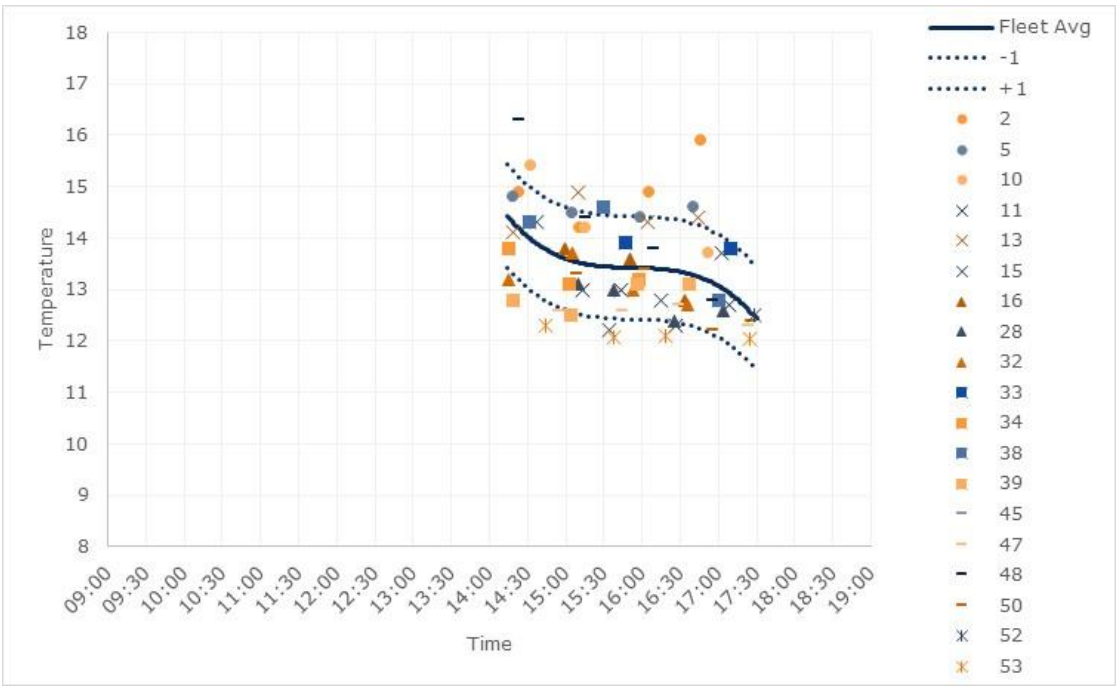

Figure 9.2: Operator's and reference temperatures (Day 1 near station 11, 100mm depth)

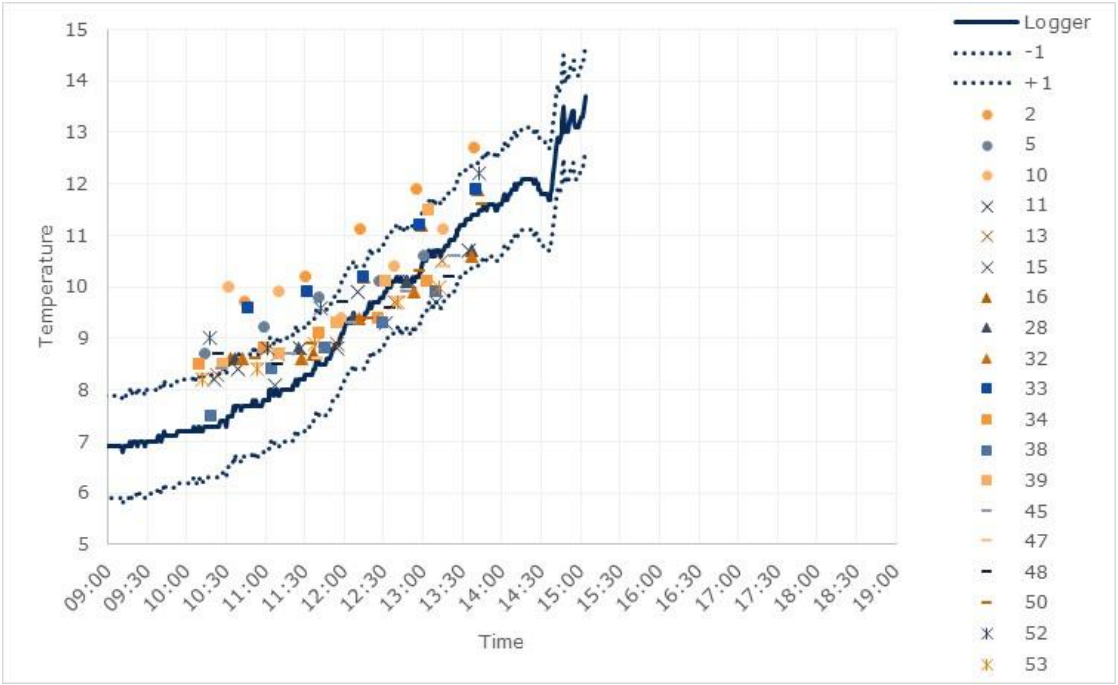

Figure 9.3: Operator's and reference temperatures (Day 2 near station 2, 100mm depth)

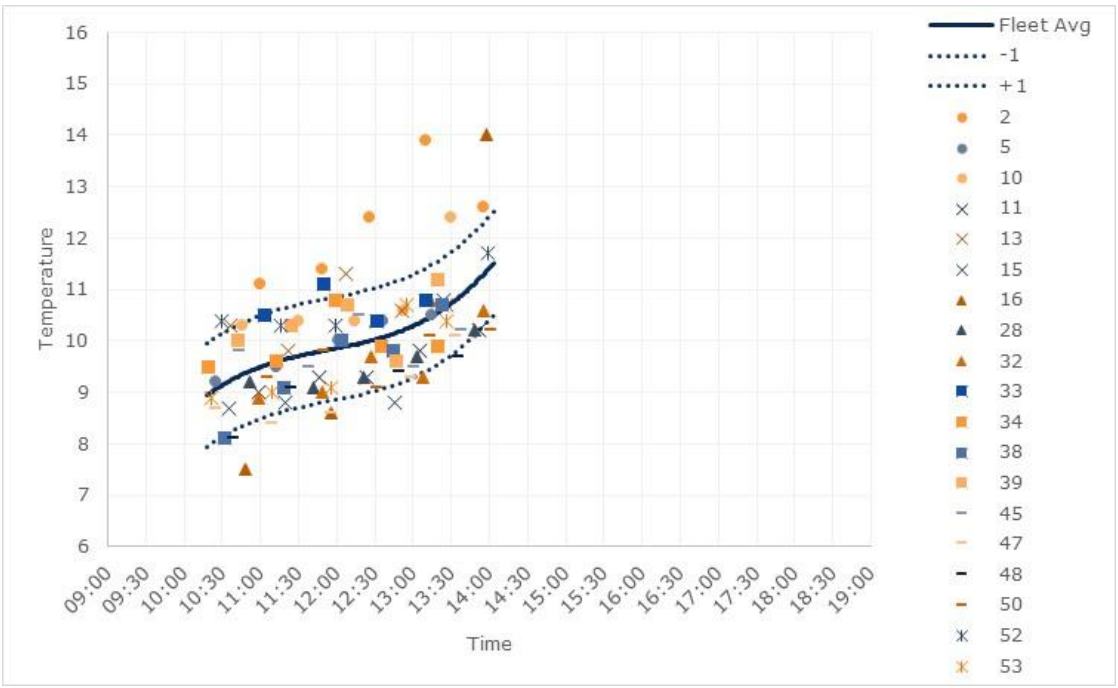

Figure 9.4: Operator's and reference temperatures (Day 2 near station 11, 100mm depth)

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

The test criteria for temperature measurement at depth are given in Appendix D, D.1. The differences and ratings given are presented in

Table 9.1. In the table, values are highlighted in bold and red font if the value was more than 1˚C away from the reference.

Table 9.1: Assessment of operators' temperature measurement at depth (stations 2 & 11)

ID	Lap 1 S2 diff	Lap 1 S11 diff	Lap 2 S2 diff	Lap 2 S11 diff	Lap 3 S2 diff	Lap 3 S11 diff	Lap 4 S2 diff	Lap 4 S11 diff	Lap 11 S2 diff	Lap 11 S11 diff	Lap 12 S2 diff	Lap 12 S11 diff	Lap 13 S2 diff	Lap 13 S11 diff	Lap 14 S2 diff	Lap 14 S11 diff	Lap 15 S2 diff	Lap 15 S11 diff	Percentage within 1˚C	Rating
2	0.3	0.7	0.8	0.7	-0.1	1.5	1.7	2.7	2.0	1.6	1.9	1.6	1.7	2.4	1.7	3.5	1.3	1.3	28%	Low
5	-0.4	0.5	-0.4	0.9	0.5	1.0	1.3	1.3	1.4	0.1	1.4	-0.1	1.2	0.1	0.4	0.3	0.1	0.0	72%	Medium
10	1.0	1.4	2.0	0.7	.	.	0.7	0.5	2.5	0.9	2.0	0.7	0.4	0.5	0.3	0.4	0.4	1.7	69%	Medium
11	-2.0	-0.5	0.2	-0.4	-0.8	-1.1	0.5	-0.2	0.7	-0.5	0.6	-0.5	0.5	-0.7	0.0	-0.6	-0.6	-1.0	83%	High
13	0.9	-0.2	-0.1	1.4	-0.4	0.9	0.1	1.1	1.0	1.1	0.7	0.1	0.0	1.4	-0.4	0.4	-0.1	0.0	78%	Medium
15	-1.5	0.4	-0.3	-1.2	-0.4	-0.6	0.3	0.7	0.9	-0.5	0.2	-0.8	-0.1	.	-0.6	-1.4	-0.9	0.2	82%	High
16	.	.	-1.9	0.2	0.6	0.2	0.5	-0.5	1.1	-1.9	0.4	-1.2	0.8	0.4	0.9	0.3	0.5	2.6	69%	Medium
28	-1.2	-0.4	0.1	-0.4	-0.6	-1.0	0.5	-0.4	1.0	-0.2	0.7	-0.7	0.0	-0.7	-0.1	-0.6	-0.6	-0.9	94%	High
32	-0.9	-1.2	-1.8	0.1	-0.4	-0.4	0.2	-0.6	0.9	-0.6	0.4	-0.8	0.0	-0.3	-0.3	-1.1	-0.7	-0.7	83%	High
33	.	.	1.1	0.5	.	.	1.7	0.9	1.9	1.0	1.6	1.3	0.8	0.4	0.9	0.4	0.5	.	62%	Medium
34	-1.5	-0.6	-1.8	-0.5	-0.4	-0.2	.	.	1.2	0.5	1.0	0.0	0.5	0.9	-0.3	-0.2	-0.4	-0.6	81%	High
38	-1.4	0.3	-0.2	1.2	.	.	-0.4	-0.3	0.2	-1.1	0.4	-0.5	0.3	0.1	-0.5	-0.3	-0.7	0.1	81%	High
39	-0.9	-1.5	-1.1	-1.1	0.1	-0.3	0.5	-0.2	1.1	0.7	0.8	0.6	0.4	0.8	0.2	-0.6	0.9	0.7	78%	Medium
45	.	.	.	.	.	.	.	.	1.0	0.5	0.7	-0.3	-0.1	0.5	-0.2	-0.8	-0.4	-0.7	100%	High
47	-2.1	-1.0	-0.2	-0.8	0.0	-0.7	0.5	-0.3	1.1	-0.4	0.8	-1.2	0.0	-1.2	-0.3	-1.0	-0.4	-0.7	72%	Medium
48	2.0	2.1	0.1	0.9	0.0	0.4	-0.2	-0.3	1.4	-1.2	0.5	-0.6	0.6	0.0	-0.4	-0.8	-0.6	-1.1	72%	Medium
50	-0.8	-0.2	-0.3	0.0	0.2	-0.9	0.8	-0.1	0.8	-0.2	0.6	0.0	-0.1	-0.9	0.0	-0.4	0.1	-1.3	94%	High
52	.	.	.	.	.	.	0.9	0.0	1.7	1.3	1.0	0.7	1.1	0.4	.	.	0.7	0.3	70%	Medium
53	-2.0	-1.5	-0.8	-1.4	-0.9	-1.3	0.1	-0.5	1.0	-0.1	0.7	-0.6	0.5	-0.7	-0.5	0.5	-0.7	-0.3	78%	Medium

It can be seen from

Table 9.1 that eight machines achieved the high performance rating, ten machines achieved a medium and one a low rating.

9.2 Contactless surface and air temperature measurements

A methodology for estimating the temperature at 100mm has been developed and 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). Due to this new methodology, a number of contractors have fitted sensors for the automatic measurement of air and surface temperatures to their survey machines.

The data from the surface measurements are shown in 9.2.1 and air measurements are shown in 9.2.2. The results are compared against the criteria and discussed in 9.2.3.

9.2.1 Surface temperature measurements

Of the nineteen machines which took part in the trial, six machines (38, 39, 45, 47, 48 and 50) had calibrated surface temperature sensors fitted. Some machines reported values in the survey data output but were identified as not having the sensor fitted or, if fitted, it was not calibrated. These details have been noted on the Accreditation Certificate for the corresponding machines. The surface temperature data from stations 2 and 11 for the machines which were identified as having calibrated sensors fitted are shown along with surface temperature data from the logger in Figure 9.5 and Figure 9.6 respectively for Day 1, and in Figure 9.7 and Figure 9.8 for Day 2. Note: as discussed in section 5.2 Machine 45 only carried out one lap on day 1.

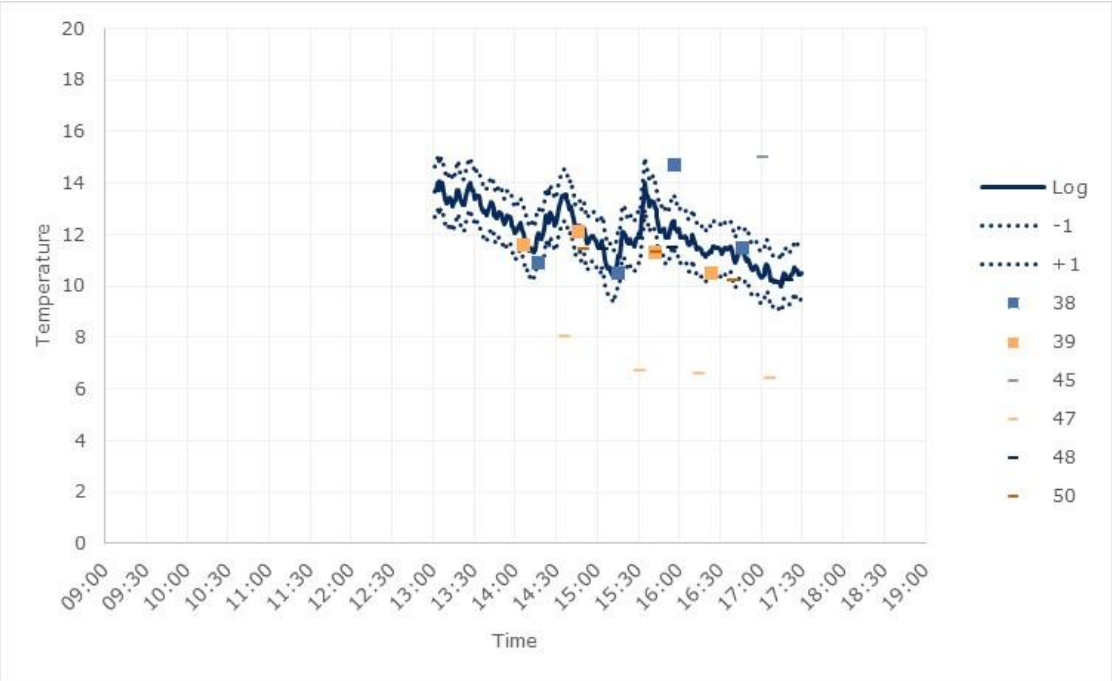

Figure 9.5: Operators' and logger Surface temperatures (Day 1 near station 2)

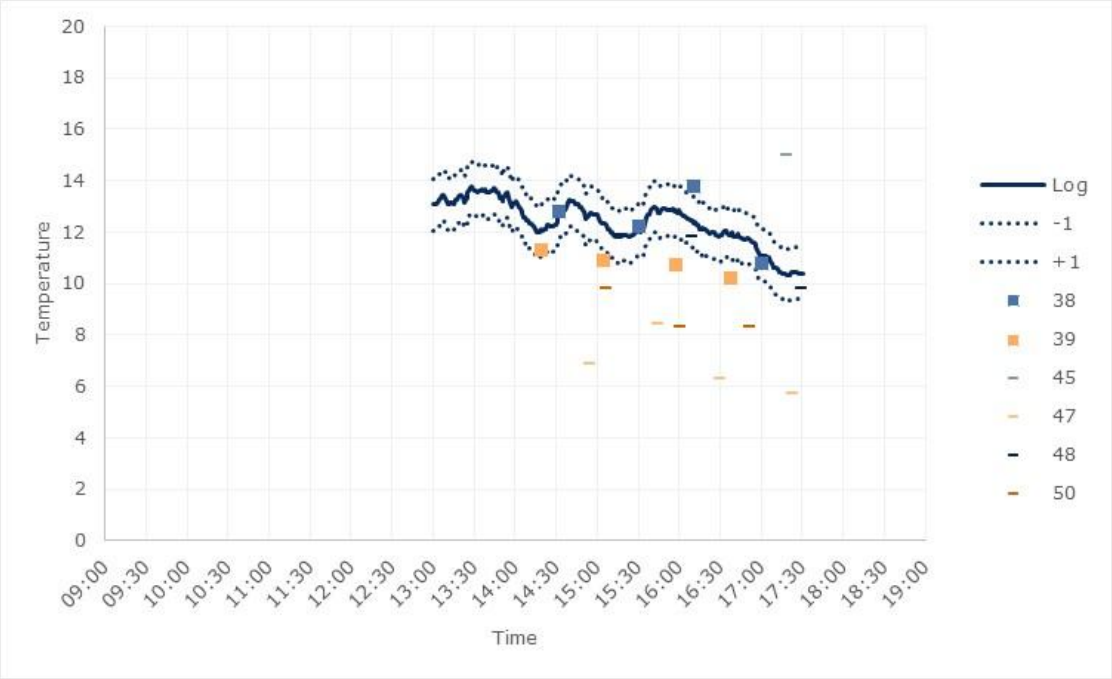

Figure 9.6: Operators' and logger Surface temperatures (Day 1 near station 11)

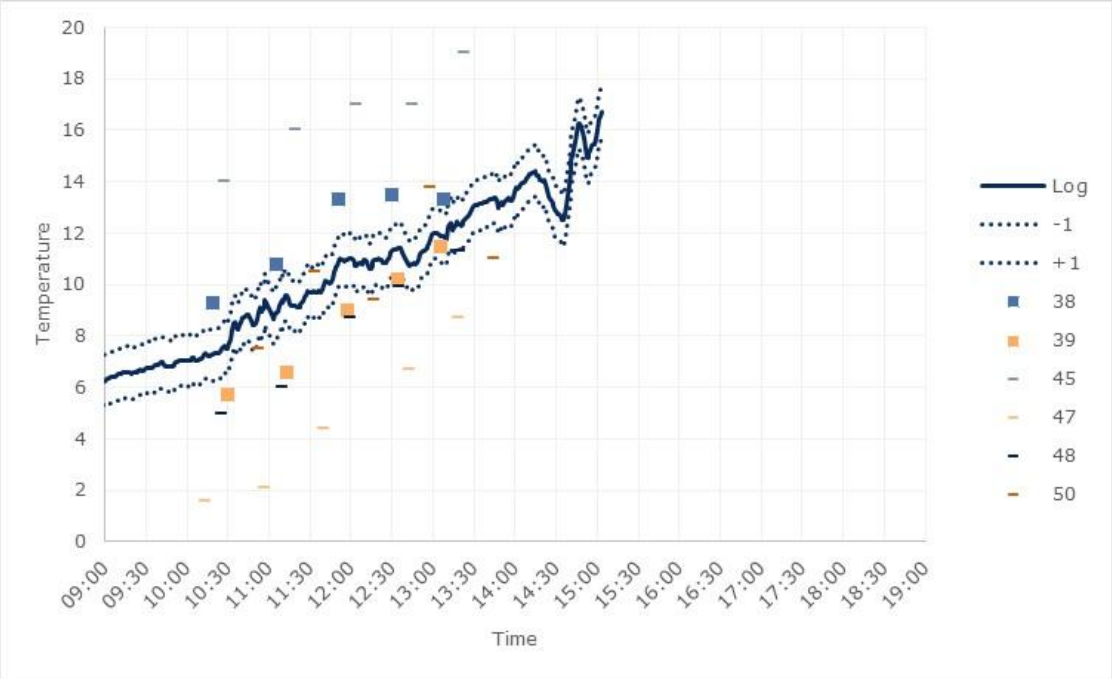

Figure 9.7: Operators' and logger Surface temperatures (Day 2 near station 2)

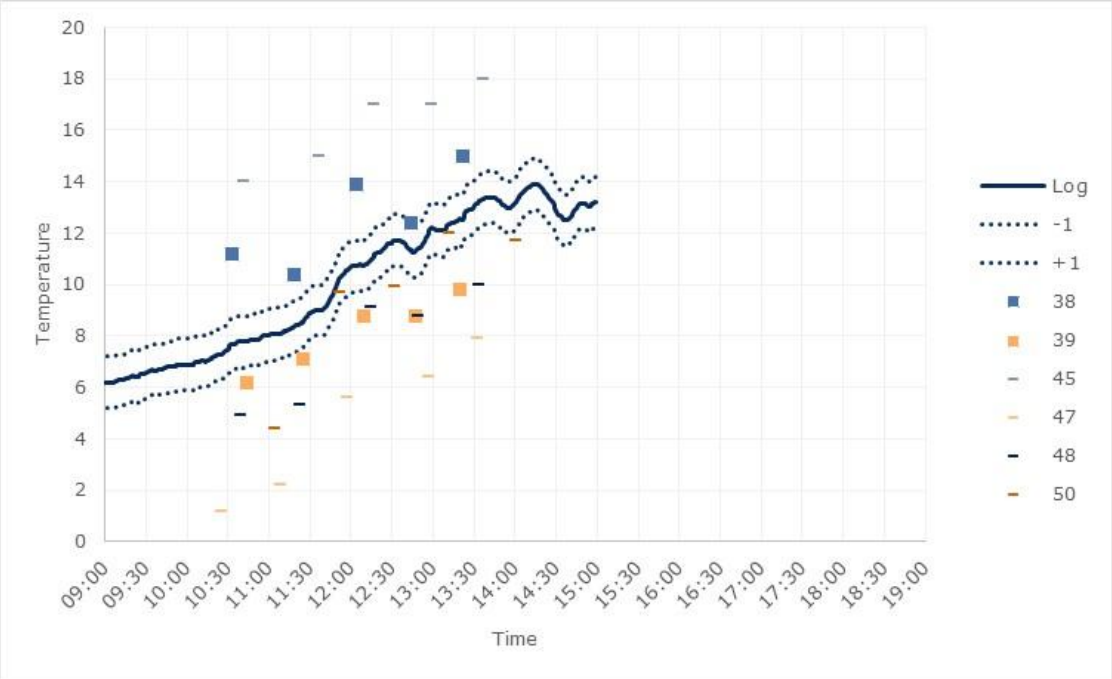

Figure 9.8: Operators' and logger Surface temperatures (Day 2 near station 11)

It can be seen from these plots that the there is a substantial spread (approximately 12 degrees) in the operators' measurements with some below the logger values and some above.

9.2.2 Air temperature measurements

Of the nineteen machines which took part in the trial, six machines (38, 39, 45, 47, 48 and 50) had calibrated air temperature sensors fitted. As with the surface temperature measurements, some machines had data reported in the survey data output but were identified as not having the sensor fitted or, if fitted, it was not calibrated. These details have been noted on the Accreditation Certificate for the corresponding machines. The air temperature data from stations 2 and 11 for the machines which were identified as having calibrated sensors fitted are shown along with air temperature data from the logger in Figure 9.9 and Figure 9.10 respectively for Day 1, and in Figure 9.11 and Figure 9.12 for Day 2. Note the data from Machine 45 was reported as approximately 30 degrees below the reference and is not shown on the graphs.

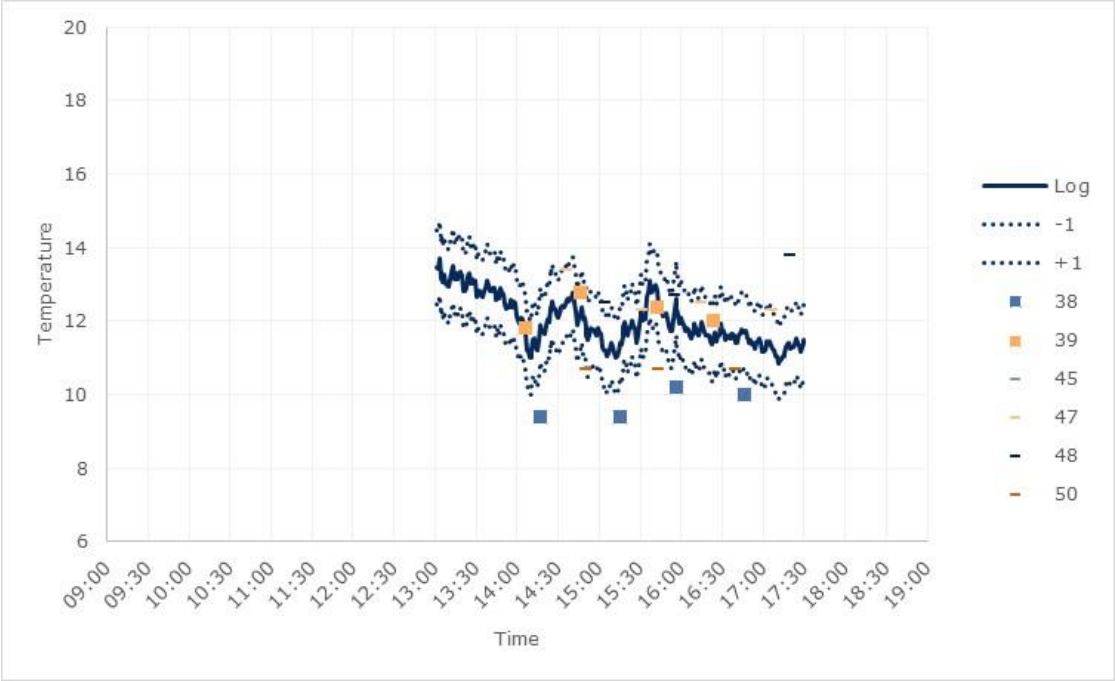

Figure 9.9: Operators' and logger Air temperatures (Day 1 near station 2)

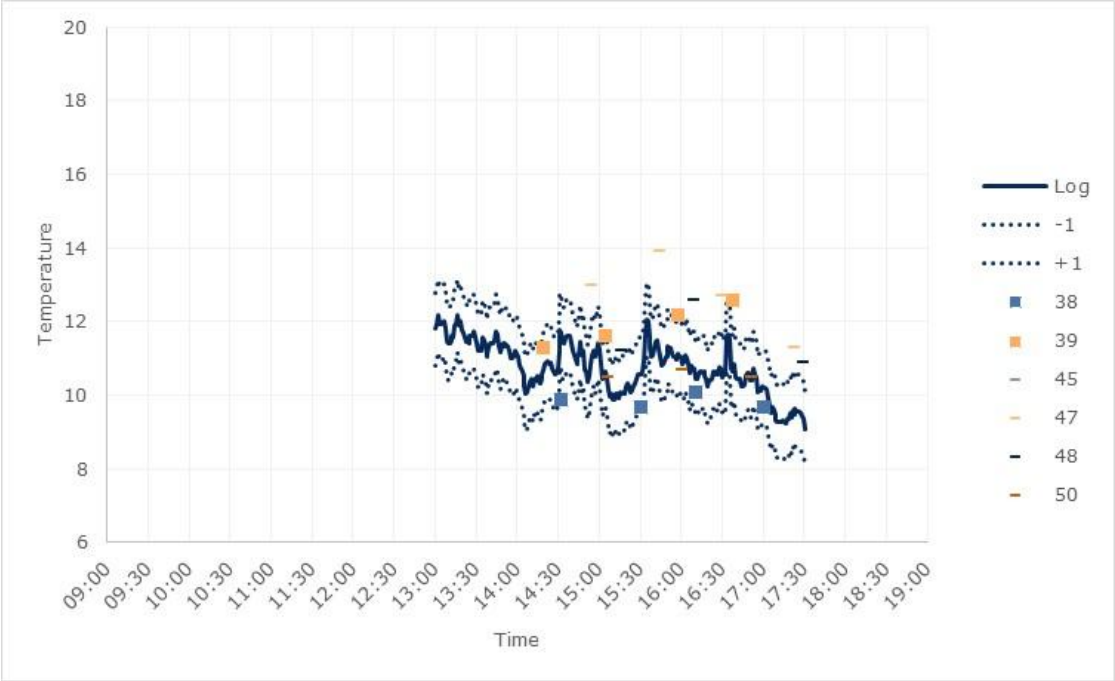

Figure 9.10: Operators' and logger Air temperatures (Day 1 near station 11)

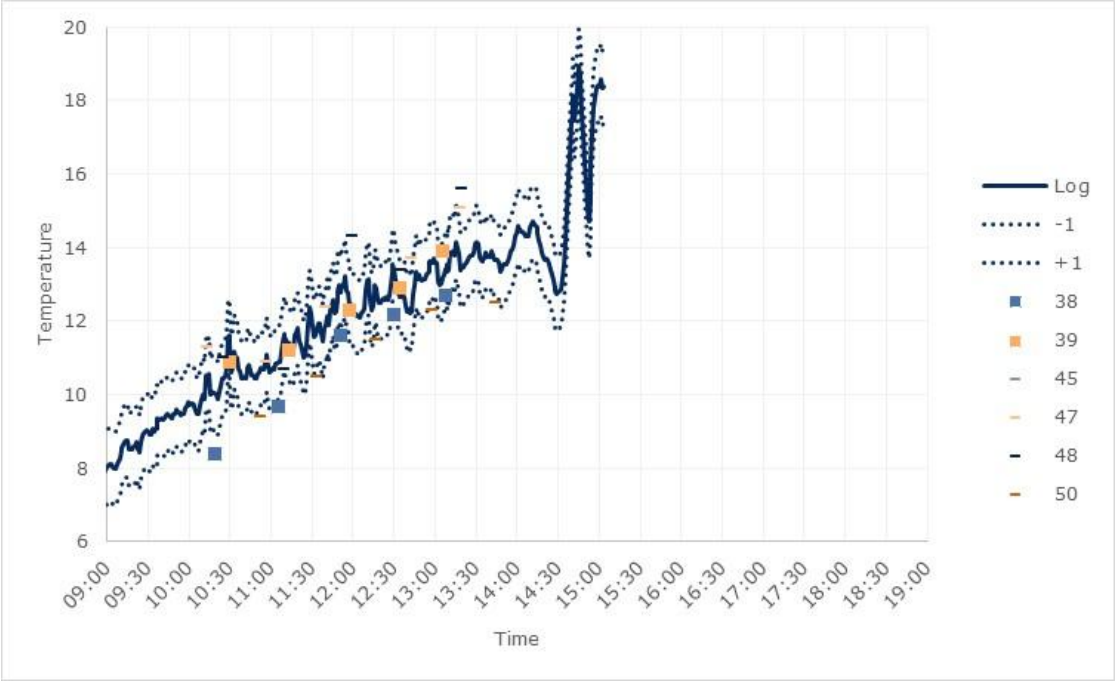

Figure 9.11: Operators' and logger Air temperatures (Day 2 near station 2)

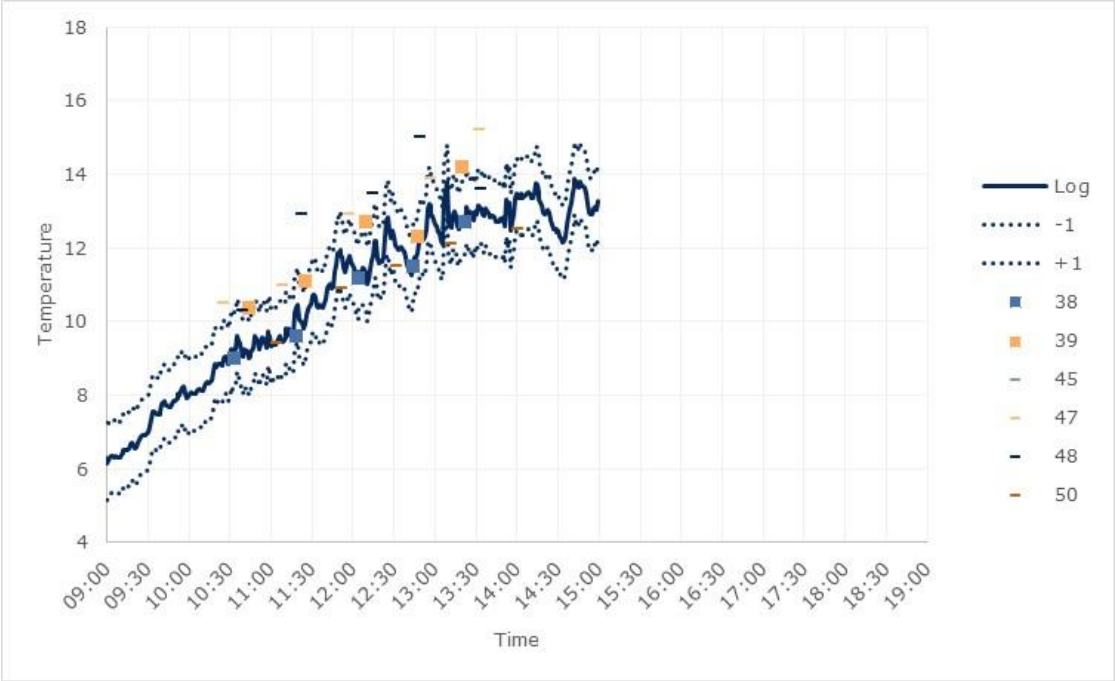

Figure 9.12: Operators' and logger Air temperatures (Day 2 near station 11)

It can be seen from these plots that the there is a spread in the operators' measurements with some below the logger and some above.

9.2.3 Assessment of air and surface temperature measurements

The test criteria for surface temperature measurement are given in Appendix D, D.2, and the machines were assessed on all supplied data. The differences and ratings given are presented in Table 9.2. In the table, values are highlighted in bold and red font if the value was more than 1˚C away from the reference.

Air temperature measurements from DPTs at the time of testing are not used for the contactless 100mm temperature calculation method and 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 and ratings are presented in Table 9.3.

Table 9.2: Assessment of operators' surface temperature measurement (stations 2 and 11)

ID	Lap 1 S2 diff	Lap 1 S11 diff	Lap 2 S2 diff	Lap 2 S11 diff	Lap 3 S2 diff	Lap 3 S11 diff	Lap 4 S2 diff	Lap 4 S11 diff	Lap 11 S2 diff	Lap 11 S11 diff	Lap 12 S2 diff	Lap 12 S11 diff	Lap 13 S2 diff	Lap 13 S11 diff	Lap 14 S2 diff	Lap 14 S11 diff	Lap 15 S2 diff	Lap 15 S11 diff	Percentage within 1˚C	Rating
38	-1.1	0.2	-0.7	0.1	2.5	1.4	0.2	-0.3	2.0	3.5	1.9	2.1	2.6	3.2	2.3	1.1	1.4	2.5	28%	Low
39	-0.5	-0.7	-0.2	-1.5	-1.7	-2.1	-0.9	-1.7	-1.8	-1.6	-3.0	-1.4	-1.9	-1.9	-1.2	-2.5	-0.4	-2.8	28%	Low
45	.	.	.	.	.	.	4.6	4.7	6.4	6.2	6.8	6.0	6.3	5.9	6.2	4.8	6.6	4.7	0%	Not Suitable
47	-5.5	-5.8	-5.3	-4.4	-4.9	-5.6	-3.8	-4.7	-5.7	-6.1	-7.0	-5.9	-5.4	-4.9	-4.1	-5.6	-3.7	-5.3	0%	Not Suitable
48	.	.	-0.3	0.1	-1.0	-0.7	-0.1	-0.6	-2.4	-2.9	-3.4	-3.2	-2.3	-1.9	-1.5	-2.6	-1.1	-3.2	38%	Low
50	-0.8	-2.5	-1.4	-4.5	-0.9	-3.4	-0.9	-3.4	-1.2	-3.7	0.8	-0.5	-1.5	-1.8	2.2	-0.3	-2.3	-1.5	33%	Low

Table 9.3: Assessment of operators' air temperature measurement (stations 2 and 11)

ID	Lap 1 S2 diff	Lap 1 S11 diff	Lap 2 S2 diff	Lap 2 S11 diff	Lap 3 S2 diff	Lap 3 S11 diff	Lap 4 S2 diff	Lap 4 S11 diff	Lap 11 S2 diff	Lap 11 S11 diff	Lap 12 S2 diff	Lap 12 S11 diff	Lap 13 S2 diff	Lap 13 S11 diff	Lap 14 S2 diff	Lap 14 S11 diff	Lap 15 S2 diff	Lap 15 S11 diff	Percentage within 1˚C	Rating
38	-2.5	-1.9	-2.0	-0.9	-2.1	-0.3	-1.7	-0.5	-1.6	-0.2	-1.1	-0.7	-1.4	0.1	-1.3	0.0	-0.7	-0.1	50%	Low
39	0.1	0.7	0.6	0.9	-0.4	1.1	0.5	2.0	-0.7	1.4	-0.2	1.3	-0.5	1.3	0.1	0.6	0.7	1.4	67%	Medium
45	.	.	.	.	.	.	-32.2	-34.4	-35.7	-35.2	-38.8	-38.4	-40.1	-41.2	-42.7	-41.9	-42.5	-42.9	0%	Not Suitable
47	0.8	1.9	0.3	2.9	0.5	2.1	1.0	1.8	0.9	1.7	-0.1	1.5	0.6	1.2	1.5	0.7	1.3	2.1	39%	Low
48	.	.	1.3	1.1	0.4	1.9	2.5	1.5	0.6	1.2	-1.0	2.9	1.9	1.7	0.7	2.8	2.1	0.5	31%	Low
50	-0.9	0.3	-1.7	-0.2	-0.7	0.1	-0.7	0.1	-1.2	0.0	-1.3	-0.9	-1.5	-0.6	-1.3	-0.5	-1.2	-0.9	67%	Medium

From Table 9.2 it can be seen that for the surface temperature measurements, four machines achieved a low performance and two were identified as not suitable. This will obviously result in low confidence or not suitable results for the estimation of temperature at depth using the Bells relationship in CS 229.

Table 9.3 shows that for the air temperature measurements, two achieved a medium performance, three a low performance and one was identified as not suitable.

10 Summary of trial findings

The 2022 UK DPT accreditation trial was held at Horiba-MIRA in the week beginning the 26th September 2022. Nineteen 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 nineteen machines met the trial requirements for the repeatability assessment.

(ii) Reproducibility of Deflections

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

(iii) Distance measurement

- All nineteen 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

- Twelve machines were capable of producing 3-dimensional positional data. This data is reported in lat/long format in the survey files, and the contractor's were asked to convert this data into OSGR format. The performance of the machines was assessed on this converted data. Eight machines were identified as having achieved a high performance level, three a medium performance level and one a low.

(v) Temperature measurement at depth (100mm)

- All nineteen operators of the machines provided 100mm pavement temperature measurements using hand-held probes. Eight achieved a high performance rating, ten achieved a medium, and one a low rating.

(vi) Surface temperature measurement

- Six machines provided surface temperature measurements using IRTs fixed to their machines. Four machines achieved a low performance and two were identified as not suitable. This will obviously result in low confidence or not suitable results for the estimation of temperature at depth using the Bells relationship.

(vii) Air temperature measurement

- Six machines provided air temperature measurements from apparatus fixed to their machines. This data was assessed using the surface temperature criteria. Two machines achieved a medium performance, three a low performance and one was identified as not suitable.

In summary, all nineteen machines that participated in the 2022 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.

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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	12/04/2022	26/09/2022	15/08/2022
5	AECOM Ltd.	Dynatest HWD 8082 SN 050	Trailer	0/5	2-way Segmented	13/04/2022	26/09/2022	19/08/2022
10	AECOM Ltd.	Dynatest FWD 8002 SN 192	Trailer	6/3	2-way Segmented	12/04/2022	26/09/2022	19/09/2022
11	Pulse Surveying Ltd.	Dynatest FWD 8002 SN 187	Trailer	4/2	Solid	02/07/2022	22/09/2022	02/08/2022
13	AECOM Ltd.	Dynatest HWD 8082 SN 029	Trailer	0/5	Solid	13/04/2022	26/09/2022	19/08/2022
15	Construction Testing Solutions	Dynatest FWD 8002 SN 203	Trailer	5/2	2-way Segmented	04/04/2022	26/09/2022	02/08/2022
16	PTS	Dynatest FWD 8002 SN 214	Trailer	4/2	2-way Segmented	23/09/2022	23/09/2022	August
28	Pulse Surveying Ltd.	Dynatest FWD 8002 SN 271	Trailer	4/2	Solid	03/07/2022	22/09/2022	21/07/2022
32	PTS	Dynatest HWD 8082 SN 069	Trailer	2/2	Solid	23/09/2022	23/09/2022	August
33	PTS	Dynatest HWD 8082 SN 070	Trailer	2/2	Solid	23/09/2022	23/09/2022	August

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
34	PTS	Dynatest HWD 8082 SN 108	Trailer	2/2	4-way Segmented	18/10/2021	18/10/2021	September
38	Milestone Pavement Technologies	Sweco PRI1500 1111/448	Trailer	3/4	4-way Segmented	September 2022	September 2022	September 2022
39	TRL	Dynatest FWD 8002 SN 388	Trailer	6/3	2-way Segmented	05/09/2022	06/09/2022	10/05/2022
45	Atlas Geophysical	Sweco PRI2100 0903-088	Trailer	5/4	Solid	Not provided	Not provided	30/08/2022
47	PMS	Dynatest FWD 8002 SN 452	Trailer	4/2	4-way Segmented	20/09/2022	20/09/2022	20/09/2022
48	Alptest Ltd	Dynatest FWD 8002 SN 424	Trailer	4/2	4-way Segmented	08/07/2022	08/07/2022	08/07/2022
50	SOCOTEC	RINCENT HeavyDyn HVY-101A	Trailer	10/4	Solid	16/09/2021	21/09/2022	22/06/2022
52	PTS	Dynatest FFWD 8012 SN 057	Trailer	0/3	4-way Segmented	18/10/2021	18/10/2021	September
53	Dynatest	Dynatest FWD 8002 SN 098	Trailer	4/2	4-way Segmented	22/09/2022	22/09/2022	22/09/2022

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



Figure B.1: Dynatest 8002 FWD



Figure B.2: Dynatest 8082 FWD



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 construction of 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: Construction details of 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: Construction details of 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[1]	47	65	76

Notes: HBM = Hydraulically Bound Material

[1] 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 no 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 as %	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	715.5	0.4%	64	60	53	46	40	34	24	1.0	0.7	0.3	0.3	0.4	0.4	0.3
1	5	693.2	0.2%	520	407	260	160	97	61	37	1.6	2.3	0.4	1.0	0.4	0.6	0.5
1	8	701.8	0.4%	234	206	165	127	93	69	36	0.4	0.4	0.5	0.9	0.8	0.4	0.3
1	13	706.7	0.2%	125	112	94	79	63	51	37	0.6	0.9	0.7	0.1	0.4	0.5	0.5
2	2	711.2	0.3%	67	62	54	46	39	35	22	0.6	0.5	0.3	0.5	0.5	0.4	0.7
2	5	686.7	0.2%	514	403	257	156	93	60	34	1.4	0.5	0.9	1.2	1.2	0.4	0.7
2	8	697.0	0.2%	234	207	167	129	94	69	37	0.6	0.2	0.3	0.3	0.3	0.4	0.4
2	13	698.4	0.3%	127	113	97	81	66	54	38	0.6	0.6	0.4	0.2	0.2	0.3	0.8

E.2 Machine 5

Lap	Station	Mean Load	SD of Load as %	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*	*718.3*	*0.3%*	*63*	*54*	*48*	*42*	*36*	*30*	*21*	*0.3*	*0.2*	*0.4*	*0.3*	*0.4*	*0.3*	*0.2*
1	*5*	*709.9*	*0.3%*	*459*	*369*	*244*	*151*	*94*	*60*	*34*	*0.9*	*0.6*	*0.4*	*0.7*	*0.7*	*0.5*	*1.2*
1	*8*	*708.1*	*0.4%*	*215*	*188*	*152*	*118*	*87*	*63*	*33*	*0.3*	*0.4*	*0.4*	*0.4*	*0.3*	*0.4*	*0.6*
1	*13*	*676.8*	*0.2%*	*114*	*101*	*87*	*71*	*58*	*44*	*29*	*0.4*	*0.3*	*0.6*	*0.7*	*0.2*	*0.2*	*0.4*
2	*2*	*713.3*	*0.5%*	*63*	*54*	*48*	*42*	*37*	*30*	*21*	*0.3*	*0.2*	*0.3*	*0.3*	*0.3*	*0.4*	*0.3*
2	*5*	*708.8*	*0.2%*	*477*	*379*	*248*	*152*	*94*	*62*	*37*	*1.3*	*0.8*	*0.4*	*0.3*	*0.5*	*0.4*	*0.9*
2	*8*	*700.9*	*0.3%*	*217*	*191*	*155*	*119*	*89*	*64*	*33*	*0.4*	*0.4*	*0.6*	*0.7*	*0.5*	*0.5*	*0.9*
2	*13*	*685.2*	*0.2%*	*116*	*103*	*88*	*72*	*58*	*44*	*30*	*0.2*	*0.3*	*0.1*	*0.4*	*0.2*	*0.3*	*0.5*
3	2	700.4	0.4%	62	54	49	42	37	31	21	0.2	0.3	0.2	0.4	0.5	0.3	1.3
3	5	690.1	0.5%	440	363	245	156	100	66	37	1.3	1.2	0.8	0.4	0.4	0.3	0.9
3	8	687.6	0.4%	211	187	153	119	90	64	34	0.5	0.4	0.5	0.5	0.5	0.3	0.4
3	13	671.2	0.2%	117	107	91	75	61	47	36	0.3	0.1	0.2	0.1	0.1	0.2	0.4
4	2	694.9	0.3%	63	55	49	43	38	31	22	0.2	0.2	0.3	0.3	0.3	0.3	0.3
4	5	689.1	0.2%	463	365	242	154	99	65	37	1.5	1.1	0.5	0.5	0.6	0.4	0.6
4	8	681.2	0.3%	213	188	154	120	91	66	34	0.1	0.3	0.4	1.1	0.3	0.6	0.6
4	13	666.0	0.2%	117	105	90	74	60	46	31	0.2	0.4	0.3	0.9	0.4	0.4	1.0

E.3 Machine 10

Lap	Station	Mean Load	SD of Load as %	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	710.4	0.1%	71	59	53	46	40	33	24	0.2	0.4	0.4	0.5	0.2	0.3	0.3
1	5	690.5	0.1%	524	402	256	157	94	61	39	0.8	0.7	1.6	0.6	0.6	0.2	0.5
1	8	702.4	0.1%	236	202	164	127	93	67	36	0.6	1.4	0.6	0.2	0.5	0.2	0.7
1	13	709.7	0.1%	127	111	95	80	65	52	38	0.3	0.1	0.1	0.1	0.1	0.1	0.2
2	2	708.1	0.1%	71	59	53	47	40	33	23	0.4	0.1	0.1	0.2	0.1	0.1	0.1
2	5	688.4	0.2%	543	404	261	159	95	61	36	0.9	0.5	0.4	0.3	0.2	0.2	0.3
2	8	700.4	0.1%	238	206	166	128	95	68	36	0.5	0.2	0.1	0.1	0.1	0.1	0.1
2	13	709.1	0.2%	125	110	94	79	64	51	37	0.3	0.2	0.1	0.0	0.1	0.2	0.1

E.4 Machine 11

Lap	Station	Mean Load	SD of Load as %	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	738.5	0.2%	71	61	56	46	40	34	24	0.2	0.7	1.0	0.7	0.2	0.3	0.2
1	5	716.0	0.1%	518	405	267	153	97	61	38	1.1	0.7	0.4	0.6	0.2	0.2	0.9
1	8	728.4	0.1%	235	206	167	127	95	68	36	0.3	0.2	0.2	0.2	0.3	0.2	0.4
1	13	727.6	0.2%	124	110	94	78	62	50	37	0.2	0.2	0.2	0.2	0.3	0.3	0.9
2	2	736.2	0.1%	72	60	55	47	40	34	25	0.2	0.6	0.2	0.2	0.5	0.7	0.9
2	5	713.6	0.1%	517	404	267	152	95	58	34	1.0	0.6	0.3	0.4	0.3	0.1	0.2
2	8	725.2	0.1%	236	209	170	130	96	69	36	0.2	0.2	0.2	0.3	0.3	0.2	0.5
2	13	730.6	0.1%	126	113	97	80	65	52	37	0.2	0.2	0.3	0.1	0.1	0.2	0.3

E.5 Machine 13

Lap	Station	Mean Load	SD of Load as %	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	722.4	0.4%	66	56	50	44	38	31	23	0.3	0.3	0.1	0.3	0.2	0.2	0.2
1	5	720.6	0.2%	481	380	252	153	93	59	32	0.9	0.6	0.4	0.3	0.2	0.1	0.3
1	8	706.9	0.3%	223	196	158	122	92	61	33	0.3	0.2	0.8	0.2	0.8	1.0	0.7
1	13	693.0	0.3%	119	107	91	75	60	48	30	1.9	0.1	0.1	0.2	0.2	0.2	0.6
2	2	713.8	0.4%	67	57	51	43	39	33	20	0.4	0.4	0.4	0.4	1.5	0.4	0.9
2	5	714.7	0.3%	484	384	252	153	92	59	36	0.8	0.4	0.5	0.4	0.5	0.5	0.4
2	8	697.8	0.4%	222	198	160	123	90	65	38	1.3	0.5	0.4	0.2	0.5	0.5	0.8
2	13	683.8	0.4%	122	108	93	75	60	51	35	0.5	0.3	0.2	0.4	0.6	0.4	0.6

E.6 Machine 15

Lap	Station	Mean Load	SD of Load as %	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	679.5	0.1%	72	60	54	47	41	34	24	0.5	0.4	0.5	0.4	0.4	0.3	0.5
1	5	657.5	0.2%	494	385	255	149	92	55	32	0.6	0.5	0.3	0.2	0.3	0.4	0.5
1	8	672.7	0.3%	233	202	164	123	91	66	34	0.4	0.3	0.4	0.4	0.2	0.3	0.6
1	13	673.5	0.2%	126	115	92	77	66	54	37	0.1	0.3	0.3	0.3	0.2	0.2	0.3
2	2	677.8	0.1%	72	60	54	47	41	34	24	0.6	0.5	0.6	0.6	0.4	0.4	0.5
2	5	660.2	0.3%	500	387	255	148	89	57	33	1.0	0.5	0.3	0.3	0.2	0.3	0.8
2	8	670.9	0.3%	233	203	164	123	92	66	34	0.9	0.4	0.3	0.4	0.4	0.3	0.4
2	13	669.4	0.3%	125	115	95	77	63	47	34	0.8	0.5	0.3	0.2	0.4	0.7	0.3

E.7 Machine 16

Lap	Station	Mean Load	SD of Load as %	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	700.9	0.2%	69	59	52	46	39	32	23	0.8	0.5	0.9	0.9	0.8	0.5	0.6
1	5	679.3	0.2%	520	393	255	157	94	56	31	1.9	0.9	1.1	1.0	0.8	0.6	1.1
1	8	692.2	0.3%	234	205	166	127	93	66	35	0.7	0.6	0.6	0.8	0.7	0.6	0.5
1	13	702.1	0.4%	126	112	96	78	62	49	33	0.5	0.5	0.7	0.9	1.3	0.7	0.8
2	2	694.7	0.2%	69	60	55	44	38	33	23	0.6	0.5	0.4	0.9	0.7	0.5	0.6
2	5	670.4	0.3%	499	397	259	156	97	62	35	1.0	0.6	0.9	1.6	0.5	1.0	0.6
2	8	686.4	0.2%	235	206	166	128	93	66	35	0.5	0.3	0.8	1.1	1.0	0.5	0.7
2	13	687.8	0.3%	121	108	93	78	64	50	37	0.6	0.5	0.5	0.9	0.6	0.6	0.6

E.8 Machine 28

Lap	Station	Mean Load	SD of Load as %	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	747.7	0.2%	71	59	55	47	41	35	24	0.3	0.2	0.2	0.2	0.4	0.2	0.3
1	5	729.3	0.1%	522	407	262	160	96	61	36	0.6	0.4	0.3	0.2	0.1	0.1	0.2
1	8	739.8	0.1%	235	206	167	129	95	69	36	0.2	0.4	0.2	0.3	0.2	0.2	0.1
1	13	741.5	0.1%	122	111	95	79	64	51	35	0.3	0.1	0.3	0.2	0.3	0.6	1.2
2	2	744.3	0.2%	71	59	53	48	42	35	23	0.1	0.2	0.3	0.2	0.1	0.2	0.6
2	5	727.6	0.1%	541	407	261	159	95	59	36	1.1	0.9	0.3	0.4	0.2	0.2	0.1
2	8	736.4	0.1%	236	206	167	130	95	69	36	0.2	0.3	0.3	0.2	0.1	0.1	0.1
2	13	739.3	0.2%	123	111	95	79	64	51	36	0.3	0.1	0.1	0.2	0.1	0.1	0.1

E.9 Machine 32

Lap	Station	Mean Load	SD of Load as %	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	726.9	0.5%	69	57	52	42	36	32	21	0.2	0.2	0.3	0.2	0.2	0.2	0.2
1	5	712.6	0.3%	488	372	244	152	93	58	35	0.8	0.4	0.3	0.4	0.3	0.3	0.7
1	8	713.4	0.3%	223	193	156	119	88	65	34	0.3	0.6	0.4	0.5	0.3	0.4	0.4
1	13	707.5	0.6%	121	103	89	75	62	50	39	0.7	0.5	0.3	0.2	0.2	0.2	1.0
2	2	709.1	0.4%	68	55	49	43	37	32	20	0.8	0.3	0.3	0.2	0.2	0.4	0.6
2	5	682.9	0.5%	488	383	247	150	91	59	33	1.4	0.8	0.4	0.9	0.7	0.7	1.1
2	8	697.6	0.2%	225	193	158	121	89	64	33	0.9	0.6	0.6	0.8	0.7	0.4	0.6
2	13	675.6	0.3%	126	111	95	78	63	50	35	0.3	1.5	0.4	0.2	0.2	0.2	0.6

E.10 Machine 33

Lap	Station	Mean Load	SD of Load as %	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*	*711.8*	*0.5%*	*66*	*56*	*48*	*44*	*37*	*32*	*22*	*0.7*	*0.3*	*0.8*	*0.2*	*0.1*	*0.3*	*0.5*
1	*5*	*677.4*	*0.6%*	*457*	*378*	*244*	*152*	*90*	*57*	*30*	*0.8*	*0.4*	*0.2*	*0.9*	*0.7*	*0.4*	*1.9*
1	*8*	*692.4*	*0.3%*	*214*	*191*	*154*	*119*	*88*	*64*	*32*	*0.4*	*0.3*	*0.3*	*0.3*	*0.4*	*0.4*	*0.4*
1	*13*	*707.8*	*0.5%*	*115*	*103*	*88*	*74*	*61*	*48*	*37*	*0.4*	*0.2*	*0.2*	*0.2*	*0.1*	*0.3*	*0.4*
2	*2*	*707.3*	*0.6%*	*65*	*56*	*50*	*44*	*39*	*30*	*23*	*0.4*	*0.3*	*0.2*	*0.2*	*0.2*	*0.6*	*0.5*
2	*5*	*686.0*	*0.3%*	*467*	*377*	*247*	*153*	*92*	*58*	*39*	*1.2*	*0.7*	*0.2*	*0.2*	*0.3*	*0.3*	*0.7*
2	*8*	*674.5*	*0.3%*	*216*	*192*	*155*	*120*	*88*	*62*	*32*	*0.2*	*0.2*	*0.2*	*0.5*	*0.2*	*0.8*	*1.1*
2	*13*	*699.5*	*0.2%*	*115*	*104*	*88*	*74*	*60*	*46*	*33*	*0.2*	*0.1*	*0.2*	*0.1*	*0.2*	*0.3*	*0.4*
3	2	726.7	0.3%	65	55	50	45	38	32	22	0.2	0.1	0.2	0.2	0.3	0.2	0.1
3	5	718.8	0.2%	407	335	233	150	94	60	40	0.5	0.2	0.2	0.1	0.4	0.8	1.2
3	8	702.3	0.2%	213	189	155	122	90	65	34	0.2	0.2	0.2	0.4	0.2	0.3	0.3
3	13	726.1	0.5%	118	108	91	79	64	50	45	0.4	0.1	0.2	0.2	0.1	0.2	0.3
4	2	722.5	0.6%	63	55	50	43	37	31	22	0.1	0.2	0.1	0.2	0.2	0.4	0.5
4	5	714.2	0.3%	426	351	236	153	94	59	31	1.5	0.9	0.6	0.4	0.3	0.7	1.3
4	8	678.2	0.5%	212	189	155	121	89	65	33	0.2	0.1	0.2	0.2	0.1	0.3	0.7
4	13	709.4	0.3%	125	110	96	81	68	56	47	0.8	0.1	0.1	0.1	0.1	0.2	0.2

E.11 Machine 34

Lap	Station	Mean Load	SD of Load as %	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*	*738.2*	*0.5%*	*65*	*55*	*49*	*43*	*37*	*31*	*21*	*0.6*	*0.2*	*0.1*	*0.2*	*0.1*	*0.1*	*0.2*
1	*5*	*735.1*	*0.3%*	*482*	*380*	*246*	*155*	*93*	*56*	*31*	*0.9*	*0.7*	*0.8*	*0.7*	*1.0*	*0.3*	***2.5***
1	*8*	*729.1*	*0.5%*	*219*	*194*	*157*	*121*	*86*	*63*	*33*	*0.4*	*0.3*	*0.4*	*0.3*	*0.4*	*0.4*	*0.2*
1	*13*	*723.3*	*0.3%*	*117*	*107*	*89*	*74*	*59*	*46*	*31*	*0.6*	*0.3*	*0.2*	*0.2*	*0.4*	*0.3*	*0.2*
2	*2*	*733.8*	*0.4%*	*67*	*55*	*50*	*44*	*36*	*30*	*21*	*0.4*	*0.1*	*0.2*	*0.3*	*0.3*	*0.3*	*0.3*
2	*5*	*733.4*	*0.1%*	*489*	*389*	*250*	*153*	*92*	*56*	*31*	*1.7*	*0.8*	*1.0*	*0.7*	*0.5*	*0.2*	*1.1*
2	*8*	*724.9*	*0.4%*	*221*	*195*	*158*	*121*	*89*	*64*	*33*	*0.4*	*0.9*	*0.5*	*0.7*	*0.7*	*0.2*	*0.9*
2	*13*	*717.8*	*0.3%*	*118*	*107*	*91*	*75*	*60*	*46*	*32*	*0.4*	*0.3*	*0.4*	*0.4*	*0.7*	*0.3*	*1.1*
3	2	746.9	0.2%	63	54	48	43	36	30	21	0.2	0.4	0.5	0.3	0.2	0.5	0.6
3	5	735.7	0.2%	456	365	242	157	99	62	36	2.3	0.5	0.7	0.5	0.2	0.4	0.2
3	8	731.2	0.4%	213	189	153	119	87	63	33	0.5	0.1	0.6	0.5	0.5	0.3	0.5
3	13	735.5	0.4%	123	108	92	75	60	47	34	0.7	0.3	0.3	0.2	0.2	0.4	1.0
4	2	739.6	0.4%	62	55	49	44	37	30	21	0.2	0.4	0.4	0.5	1.2	0.4	0.8
4	5	732.1	0.2%	459	367	242	157	96	63	35	1.3	0.7	0.5	0.4	0.3	0.6	0.7
4	8	728.3	0.2%	212	188	153	120	87	66	33	0.6	0.4	0.8	0.5	0.5	0.2	1.1
4	13	733.2	0.6%	124	112	95	78	63	51	37	1.3	0.7	0.4	0.2	0.3	0.7	**2.2**

E.12 Machine 38

Lap	Station	Mean Load	SD of Load as %	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	702.7	0.5%	72	61	55	50	42	37	23	0.2	0.1	0.1	0.2	0.4	0.1	0.1
1	5	707.1	1.1%	491	399	265	163	97	61	33	2.7	1.2	0.9	0.6	0.4	0.4	0.3
1	8	706.9	1.1%	234	206	169	131	97	71	35	0.8	0.7	0.6	0.6	0.4	0.2	0.2
1	13	702.7	1.0%	128	113	97	82	65	54	35	0.4	0.3	0.2	0.2	0.3	0.2	0.2
2	2	699.3	0.9%	72	61	55	50	42	37	23	0.3	0.2	0.1	0.4	0.1	0.3	0.1
2	5	699.4	0.7%	500	393	264	163	97	61	33	1.4	0.7	0.5	0.4	0.3	0.3	0.1
2	8	703.7	0.7%	239	208	170	132	97	72	35	1.0	0.5	0.5	0.4	0.5	0.4	0.3
2	13	702.0	0.8%	131	114	98	83	66	55	36	0.4	0.3	0.3	0.2	0.3	0.6	0.3

E.13 Machine 39

Lap	Station	Mean Load	SD of Load as %	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	697.3	0.4%	70	61	55	49	41	35	24	0.4	0.4	0.2	0.4	0.5	1.0	0.4
1	5	681.6	0.3%	502	402	268	164	95	58	34	1.6	0.7	0.4	0.3	0.7	0.4	0.4
1	8	691.7	0.5%	235	208	169	131	96	69	37	0.7	0.7	0.3	0.4	0.5	0.3	0.3
1	13	714.6	0.3%	128	115	99	83	67	54	38	0.7	0.3	0.1	0.4	0.7	0.5	0.5
2	2	705.1	0.2%	71	61	55	48	42	35	24	1.0	0.3	0.4	0.4	0.6	0.9	1.4
2	5	684.6	0.2%	514	410	271	165	96	61	35	1.1	0.5	0.3	0.5	0.9	0.3	0.6
2	8	700.4	0.3%	235	208	170	131	97	70	37	0.4	0.3	0.6	0.5	1.1	0.5	1.4
2	13	713.1	0.4%	124	111	96	79	64	51	37	0.7	0.2	0.4	0.4	0.3	0.2	1.3

E.14 Machine 45

Lap	Station	Mean Load	SD of Load as %	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*	*714.8*	*0.4%*	*73*	*62*	*55*	*47*	*42*	*36*	*24*	*0.3*	*0.5*	*0.5*	*1.0*	*0.5*	*0.2*	*0.5*
1	*5*	*719.4*	*0.2%*	*522*	*404*	*266*	*167*	*101*	*62*	*33*	*1.6*	*1.1*	*0.7*	*0.7*	*0.5*	*0.1*	*0.7*
1	*8*	*705.9*	*0.2%*	*244*	*214*	*175*	*135*	*99*	*71*	*36*	*0.5*	*0.4*	*0.3*	*0.5*	*0.4*	*0.5*	*0.5*
1	*13*	*688.9*	*0.3%*	*133*	*116*	*99*	*82*	*66*	*54*	*36*	*0.4*	*0.4*	*0.7*	*0.4*	*0.4*	*0.6*	*0.4*
2	2	699.6	0.2%	71	61	54	49	41	35	24	0.4	0.3	0.5	0.1	0.1	0.5	0.0
2	5	704.6	0.2%	486	382	256	167	102	66	33	1.0	0.4	0.3	0.4	0.3	0.4	0.5
2	8	689.3	0.1%	233	206	168	132	97	71	36	0.3	0.4	0.3	0.3	0.1	0.1	0.0
2	13	682.7	0.3%	140	123	105	88	70	58	39	0.6	0.3	0.3	0.2	0.2	0.2	0.1
3	2	700.2	0.3%	71	61	54	48	41	34	24	0.2	0.2	0.5	0.6	0.4	0.1	0.1
3	5	706.6	0.2%	457	374	255	166	101	63	34	1.4	0.9	0.6	0.5	0.9	0.3	0.4
3	8	691.3	0.2%	236	208	171	134	99	70	37	0.2	0.5	0.5	0.4	0.4	0.7	0.7
3	13	685.1	0.5%	139	121	103	86	69	56	37	0.6	0.6	0.7	0.4	0.6	0.3	0.2

E.15 Machine 47

Lap	Station	Mean Load	SD of Load as %	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	720.3	0.1%	72	61	56	50	42	36	25	0.3	0.5	0.2	0.4	0.2	0.5	0.3
1	5	709.5	0.1%	498	404	260	159	93	55	31	0.7	0.6	0.9	0.4	0.2	1.7	0.4
1	8	716.8	0.1%	237	209	168	130	94	68	36	0.4	0.6	0.6	1.1	0.7	0.3	0.4
1	13	723.5	0.1%	129	113	98	84	67	53	37	0.5	0.5	0.1	0.6	0.2	0.1	0.3
2	2	721.8	0.2%	71	62	56	50	42	35	25	0.3	0.4	0.5	0.3	0.5	0.8	0.2
2	5	707.6	0.1%	490	391	256	157	90	56	33	0.5	0.4	0.6	0.9	0.2	0.4	0.7
2	8	716.4	0.2%	240	211	170	131	96	68	38	0.5	0.4	0.1	0.2	0.4	0.3	1.6
2	13	723.9	0.1%	125	111	95	81	64	51	37	0.1	0.3	0.2	0.3	0.1	0.4	0.5

E.16 Machine 48

Lap	Station	Mean Load	SD of Load as %	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	698.8	0.2%	70	61	54	48	41	35	24	0.3	0.3	0.1	0.1	0.2	0.1	0.2
1	5	684.6	0.2%	468	376	248	154	89	60	34	0.6	0.5	0.4	0.2	0.2	0.4	0.5
1	8	688.7	0.1%	234	207	166	129	95	69	36	0.4	0.7	1.3	0.5	0.6	0.9	0.9
1	13	686.5	0.1%	129	113	101	83	68	54	37	0.3	1.1	0.5	0.2	0.3	0.4	0.4
2	2	705.4	0.1%	72	62	55	49	42	35	24	0.7	0.1	0.1	0.4	0.7	0.2	0.2
2	5	691.3	0.2%	522	406	262	159	94	58	36	0.9	0.6	0.2	0.2	0.2	0.3	0.4
2	8	680.2	1.7%	237	207	167	128	95	68	36	0.3	0.2	0.3	0.2	0.2	0.3	0.3
2	13	668.3	0.1%	130	117	98	81	68	54	36	0.4	0.1	0.1	0.2	0.1	0.1	0.0

E.17 Machine 50

Lap	Station	Mean Load	SD of Load as %	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	727.1	0.2%	68	57	51	45	39	32	22	0.4	0.5	0.4	0.4	0.6	0.4	0.3
1	5	700.8	0.4%	483	381	250	152	92	59	31	1.0	0.6	0.3	0.4	0.2	0.1	0.4
1	8	710.1	0.3%	227	199	161	123	91	65	35	0.3	0.2	0.3	0.2	0.5	0.5	0.4
1	13	712.2	0.3%	118	105	90	74	60	47	34	0.2	0.2	0.2	0.3	0.2	0.3	0.3
2	2	715.7	0.5%	68	58	52	45	39	32	22	0.2	0.2	0.2	0.2	0.2	0.2	0.2
2	5	701.6	0.3%	522	391	251	154	94	61	33	1.3	0.6	0.5	0.4	0.5	0.3	0.8
2	8	712.3	0.4%	227	200	161	123	91	66	35	0.5	0.3	0.2	0.3	0.3	0.5	0.3
2	13	713.4	0.3%	122	109	93	76	62	49	38	0.2	0.2	0.2	0.2	0.1	0.3	0.2

E.18 Machine 52

Lap	Station	Mean Load	SD of Load as %	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	726.0	0.2%	68	60	53	47	40	34	23	0.2	0.1	0.2	0.1	0.1	0.1	0.1
1	5	714.5	0.1%	457	373	246	152	90	57	35	0.7	0.4	0.4	0.3	0.3	0.1	0.1
1	8	717.3	0.1%	232	205	165	126	93	67	35	0.3	0.3	0.2	0.3	0.2	0.2	0.2
1	13	719.9	0.2%	133	122	103	86	70	56	39	0.3	0.2	0.3	0.2	0.3	0.2	0.1
2	2	720.7	0.1%	70	60	54	47	40	34	23	0.8	0.1	0.1	0.2	0.1	0.1	0.2
2	5	709.4	0.1%	483	387	253	154	90	59	36	0.5	0.2	0.1	0.2	0.2	0.2	0.3
2	8	714.1	0.1%	233	206	166	128	93	67	35	0.2	0.3	0.2	0.2	0.3	0.1	0.2
2	13	715.8	0.1%	126	115	101	83	67	54	38	1.3	0.3	0.1	0.2	0.1	0.2	0.2

E.19 Machine 53

Lap	Station	Mean Load	SD of Load as %	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	705.1	0.2%	66	59	52	46	40	33	24	0.5	0.2	0.4	0.2	0.3	0.2	0.6
1	5	690.4	0.1%	506	409	259	158	95	61	36	0.5	0.4	0.5	0.2	0.3	0.3	0.4
1	8	695.6	0.2%	228	205	166	127	94	68	35	0.9	0.3	0.5	0.4	0.3	0.3	0.3
1	13	699.6	0.3%	122	111	95	78	63	50	35	0.2	0.2	0.2	0.3	0.1	0.3	0.3
2	2	699.2	0.3%	72	59	53	47	40	34	23	0.6	0.2	0.6	0.3	0.1	0.2	0.2
2	5	684.5	0.2%	486	405	262	159	95	59	37	0.6	0.5	0.9	0.7	0.3	1.3	0.6
2	8	691.5	0.1%	230	204	165	126	93	67	36	0.6	0.3	0.4	0.3	0.3	0.4	0.3
2	13	694.3	0.2%	119	107	92	76	61	47	31	0.4	0.6	0.3	0.3	0.3	0.2	0.3

Appendix F Reproducibility trial data

Note: In the tables below, bold red text indicates that the value is outside of acceptable limits. Data from laps disregarded in the accreditation analysis are shown in grey italics (accept where the value is outside of acceptable limits). To clearly distinguish between the two test days, the first lap on Day 2 was labelled as 11.

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*	*0.990*	*0.972*	*0.984*	*0.976*	*0.976*	*0.966*	*0.969*	*0.976*	*0.032*	*0.006*	*0.008*	*0.007*	*0.008*	*0.014*	*0.029*	*0.015*
2	*N*	*0.998*	*0.980*	*0.984*	*0.981*	*0.980*	*0.962*	*0.979*	*0.981*	*0.036*	*0.010*	*0.011*	*0.010*	*0.018*	*0.018*	*0.033*	*0.019*
3	*N*	*0.984*	*0.975*	*0.979*	*0.977*	*0.981*	*0.957*	*0.983*	*0.977*	*0.017*	*0.008*	*0.013*	*0.012*	*0.017*	*0.015*	*0.021*	*0.015*
4	*N*	*0.989*	*0.973*	*0.982*	*0.975*	*0.989*	*0.965*	*0.989*	*0.980*	*0.017*	*0.009*	*0.010*	*0.011*	*0.007*	*0.008*	*0.029*	*0.013*
11	*N*	*0.993*	*0.982*	*0.994*	*0.988*	*0.993*	*0.975*	*0.993*	*0.988*	*0.030*	*0.016*	*0.007*	*0.011*	*0.009*	*0.017*	*0.030*	*0.017*
12	*N*	*0.996*	*0.979*	*0.983*	*0.986*	*0.988*	*0.978*	*0.997*	*0.987*	*0.019*	*0.014*	*0.010*	*0.010*	*0.013*	*0.014*	*0.027*	*0.015*
13	*N*	*0.998*	*0.978*	*0.985*	*0.981*	*0.988*	*0.968*	*0.986*	*0.983*	*0.022*	*0.008*	*0.009*	*0.009*	*0.009*	*0.015*	*0.023*	*0.014*
14	Y	0.984	0.974	0.983	0.981	0.989	0.969	0.972	0.979	0.022	0.007	0.010	0.012	0.011	0.010	0.028	0.014
15	Y	0.994	0.971	0.977	0.976	0.990	0.967	0.988	0.980	0.025	0.014	0.016	0.020	0.012	0.016	0.023	0.018

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*	*1.069*	*1.065*	*1.062*	*1.064*	*1.048*	*1.059*	*1.065*	***1.062***	*0.018*	*0.015*	*0.015*	*0.021*	*0.025*	*0.038*	*0.057*	*0.027*
2	*N*	*1.070*	*1.077*	*1.076*	*1.076*	*1.063*	*1.061*	*1.071*	***1.071***	*0.028*	*0.021*	*0.024*	*0.029*	*0.034*	*0.043*	*0.059*	*0.034*
3	*N*	*1.065*	*1.074*	*1.070*	*1.074*	*1.054*	*1.061*	*1.065*	***1.066***	*0.030*	*0.018*	*0.021*	*0.023*	*0.029*	*0.044*	*0.052*	*0.031*
4	*N*	*1.072*	*1.077*	*1.073*	*1.073*	*1.060*	*1.063*	*1.059*	***1.068***	*0.029*	*0.018*	*0.018*	*0.023*	*0.027*	*0.037*	*0.044*	*0.028*
4.5	*N*	*1.066*	*1.060*	*1.059*	*1.058*	*1.042*	*1.050*	*1.036*	***1.053***	*0.021*	*0.022*	*0.021*	*0.025*	*0.034*	*0.050*	*0.056*	*0.033*
11	*N*	*1.028*	*1.042*	*1.040*	*1.040*	*1.023*	*1.026*	*1.039*	*1.034*	*0.027*	*0.024*	*0.023*	*0.024*	*0.032*	*0.044*	*0.056*	*0.033*
12	*N*	*1.038*	*1.040*	*1.041*	*1.042*	*1.020*	*1.029*	*1.030*	*1.034*	*0.023*	*0.025*	*0.025*	*0.029*	*0.034*	*0.047*	***0.075***	*0.037*
13	*N*	*1.038*	*1.045*	*1.046*	*1.044*	*1.024*	*1.026*	*1.025*	*1.035*	*0.019*	*0.018*	*0.018*	*0.024*	*0.027*	*0.045*	*0.053*	*0.029*
14	Y	1.035	1.039	1.038	1.040	1.025	1.022	1.013	1.030	0.019	0.020	0.023	0.028	0.029	0.041	0.068	0.032
15	Y	1.036	1.041	1.039	1.038	1.025	1.029	1.035	1.035	0.019	0.018	0.023	0.027	0.031	0.042	0.057	0.031

Table F.3: 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*	*0.968*	*0.979*	*0.986*	*0.978*	*0.982*	*0.983*	*0.960*	*0.976*	*0.015*	*0.009*	*0.010*	*0.011*	*0.021*	*0.016*	*0.040*	*0.018*
2	*N*	*0.970*	*0.984*	*0.988*	*0.985*	*0.989*	*0.987*	*0.977*	*0.983*	*0.012*	*0.006*	*0.006*	*0.005*	*0.013*	*0.013*	*0.025*	*0.011*
3	*N*	*0.969*	*0.983*	*0.984*	*0.983*	*0.979*	*0.986*	*0.968*	*0.979*	*0.021*	*0.010*	*0.010*	*0.011*	*0.010*	*0.012*	*0.050*	*0.018*
4	*N*	*0.976*	*0.992*	*0.993*	*0.989*	*0.990*	*0.996*	*0.976*	*0.987*	*0.015*	*0.010*	*0.008*	*0.008*	*0.008*	*0.014*	*0.025*	*0.013*
11	*N*	*1.034*	*0.983*	*0.987*	*0.981*	*0.981*	*0.986*	*0.967*	*0.988*	*0.033*	*0.010*	*0.009*	*0.009*	*0.010*	*0.014*	*0.025*	*0.016*
12	*N*	*1.025*	*0.988*	*0.991*	*0.989*	*0.989*	*0.991*	*0.974*	*0.992*	*0.042*	*0.011*	*0.011*	*0.011*	*0.022*	*0.014*	*0.029*	*0.020*
13	*N*	*1.024*	*0.989*	*0.995*	*0.994*	*0.989*	*0.991*	*0.975*	*0.994*	*0.040*	*0.011*	*0.009*	*0.014*	*0.011*	*0.015*	*0.033*	*0.019*
14	Y	1.030	0.989	0.996	0.991	0.999	0.990	0.974	0.996	0.040	0.017	0.021	0.020	0.021	0.023	0.035	0.025
15	Y	1.027	0.996	1.001	0.993	0.998	0.987	0.971	0.996	0.035	0.010	0.011	0.008	0.013	0.015	0.030	0.018

Table F.4: 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*	*0.967*	*0.968*	*0.968*	*0.980*	*0.968*	*0.986*	*0.959*	*0.971*	*0.011*	*0.006*	*0.005*	*0.011*	*0.010*	*0.022*	*0.029*	*0.013*
2	*N*	*0.977*	*0.975*	*0.964*	*0.982*	*0.980*	*0.979*	*0.951*	*0.973*	*0.014*	*0.007*	*0.010*	*0.011*	*0.018*	*0.015*	*0.055*	*0.019*
3	*N*	*0.975*	*0.984*	*0.970*	*0.987*	*0.978*	*0.996*	*0.989*	*0.983*	*0.012*	*0.013*	*0.011*	*0.007*	*0.015*	*0.041*	*0.053*	*0.022*
4	*N*	*0.974*	*0.985*	*0.974*	*0.988*	*0.982*	*0.993*	*0.948*	*0.978*	*0.028*	*0.010*	*0.014*	*0.014*	*0.016*	*0.027*	*0.049*	*0.023*
11	*N*	*0.978*	*0.983*	*0.971*	*0.988*	*0.985*	*0.993*	*0.957*	*0.979*	*0.013*	*0.010*	*0.020*	*0.008*	*0.012*	*0.020*	*0.053*	*0.020*
12	*N*	*0.989*	*0.987*	*0.975*	*0.994*	*0.992*	*1.008*	*0.981*	*0.989*	*0.011*	*0.008*	*0.011*	*0.011*	*0.019*	*0.040*	*0.047*	*0.021*
13	*N*	*0.977*	*0.983*	*0.978*	*0.993*	*0.977*	*0.994*	*0.965*	*0.981*	*0.013*	*0.008*	*0.007*	*0.008*	*0.009*	*0.028*	*0.034*	*0.015*
14	Y	0.980	0.980	0.975	0.992	0.984	0.994	0.952	0.980	0.011	0.008	0.008	0.010	0.020	0.024	0.028	0.016
15	Y	0.975	0.980	0.969	0.994	0.984	0.999	0.949	0.979	0.020	0.015	0.018	0.013	0.012	0.030	**0.080**	0.027

Table F.5: 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*	*1.034*	*1.026*	*1.026*	*1.029*	*1.033*	*1.027*	*1.035*	*1.030*	*0.035*	*0.009*	*0.010*	*0.013*	*0.024*	*0.027*	*0.046*	*0.023*
2	*N*	*1.037*	*1.033*	*1.029*	*1.035*	*1.037*	*1.036*	*1.061*	*1.038*	*0.021*	*0.012*	*0.015*	*0.017*	*0.023*	*0.030*	***0.089***	*0.030*
3	*N*	*1.034*	*1.032*	*1.027*	*1.034*	*1.034*	*1.022*	*1.020*	*1.029*	*0.020*	*0.010*	*0.016*	*0.016*	*0.024*	*0.027*	*0.052*	*0.024*
4	*N*	*1.049*	*1.031*	*1.031*	*1.033*	*1.032*	*1.025*	*1.019*	*1.031*	*0.028*	*0.011*	*0.016*	*0.019*	*0.023*	*0.031*	*0.056*	*0.026*
11	*N*	*1.043*	*1.030*	*1.030*	*1.037*	*1.039*	*1.030*	*1.067*	*1.040*	*0.015*	*0.014*	*0.014*	*0.018*	*0.028*	*0.033*	*0.063*	*0.026*
12	*N*	*1.034*	*1.035*	*1.035*	*1.040*	*1.045*	*1.025*	*1.051*	*1.038*	*0.023*	*0.013*	*0.014*	*0.015*	*0.025*	*0.027*	***0.074***	*0.027*
13	*N*	*1.039*	*1.039*	*1.040*	*1.039*	*1.034*	*1.038*	*1.056*	*1.041*	*0.011*	*0.011*	*0.018*	*0.017*	*0.025*	*0.029*	*0.063*	*0.025*
14	Y	1.037	1.040	1.040	1.052	1.042	1.043	1.083	1.048	0.035	0.012	0.016	0.022	0.022	0.036	0.052	0.028
15	Y	1.040	1.038	1.036	1.046	1.043	1.036	1.078	1.045	0.026	0.013	0.016	0.022	0.020	0.026	0.040	0.023

Table F.6: 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*	*0.987*	*0.992*	*0.994*	*1.014*	*1.005*	*1.008*	*1.009*	*1.001*	*0.028*	*0.021*	*0.021*	*0.026*	*0.029*	*0.031*	*0.049*	*0.029*
2	*N*	*0.984*	*0.995*	*0.997*	*1.015*	*1.013*	*1.009*	*1.013*	*1.004*	*0.019*	*0.013*	*0.017*	*0.025*	*0.024*	*0.027*	*0.052*	*0.025*
3	*N*	*1.010*	*1.000*	*1.003*	*1.002*	*0.998*	*1.005*	*0.991*	*1.001*	*0.020*	*0.014*	*0.011*	*0.011*	*0.012*	*0.011*	*0.023*	*0.015*
4	*N*	*0.985*	*0.999*	*0.999*	*1.021*	*1.014*	*1.014*	*1.014*	*1.007*	*0.019*	*0.019*	*0.018*	*0.025*	*0.032*	*0.031*	*0.051*	*0.028*
11	*N*	*0.992*	*1.000*	*1.001*	*1.019*	*1.013*	*1.011*	*1.016*	*1.008*	*0.031*	*0.022*	*0.020*	*0.027*	*0.029*	*0.031*	*0.043*	*0.029*
12	*N*	*0.990*	*1.000*	*1.001*	*1.023*	*1.017*	*1.016*	*1.028*	*1.011*	*0.018*	*0.016*	*0.015*	*0.020*	*0.024*	*0.027*	*0.041*	*0.023*
13	*N*	*0.983*	*1.002*	*1.004*	*1.025*	*1.013*	*1.011*	*1.014*	*1.007*	*0.022*	*0.018*	*0.017*	*0.024*	*0.028*	*0.027*	*0.041*	*0.025*
14	Y	0.990	1.008	1.008	1.033	1.030	1.022	1.032	1.018	0.023	0.014	0.016	0.021	0.019	0.030	0.035	0.023
15	Y	0.994	1.003	1.006	1.024	1.022	1.017	1.018	1.012	0.019	0.019	0.018	0.024	0.027	0.028	0.049	0.026

Table F.7: 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*	*0.974*	*0.983*	*0.989*	*0.993*	*0.988*	*1.007*	*0.986*	*0.988*	*0.038*	*0.011*	*0.011*	*0.018*	*0.019*	*0.027*	*0.026*	*0.021*
2	*N*	*0.984*	*0.982*	*0.991*	*0.989*	*0.982*	*1.004*	*1.001*	*0.990*	*0.018*	*0.011*	*0.008*	*0.013*	*0.009*	*0.030*	*0.049*	*0.020*
3	*N*	*0.978*	*0.981*	*0.997*	*0.989*	*1.001*	*1.015*	*1.020*	*0.997*	*0.034*	*0.025*	*0.019*	*0.017*	*0.023*	*0.031*	*0.053*	*0.029*
4	*N*	*0.992*	*0.984*	*0.995*	*0.990*	*0.988*	*0.995*	*1.019*	*0.995*	*0.023*	*0.018*	*0.013*	*0.017*	*0.013*	*0.036*	*0.030*	*0.021*
11	*N*	*0.982*	*0.987*	*1.001*	*0.996*	*0.990*	*1.010*	*1.000*	*0.995*	*0.022*	*0.014*	*0.020*	*0.030*	*0.033*	*0.030*	*0.051*	*0.029*
12	*N*	*0.984*	*0.978*	*0.995*	*0.996*	*0.994*	*1.010*	*1.026*	*0.998*	*0.027*	*0.015*	*0.014*	*0.017*	*0.018*	*0.022*	*0.034*	*0.021*
13	*N*	*0.978*	*0.983*	*0.991*	*0.992*	*0.980*	*1.009*	*1.011*	*0.992*	*0.013*	*0.012*	*0.012*	*0.016*	*0.015*	*0.018*	*0.032*	*0.017*
14	Y	0.980	0.983	0.990	0.996	0.985	1.014	1.008	0.994	0.011	0.012	0.010	0.017	0.015	0.030	0.058	0.022
15	Y	0.989	0.988	0.997	0.989	0.988	1.007	0.983	0.992	0.014	0.015	0.014	0.016	0.016	0.018	0.029	0.018

Table F.8: 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*	*0.969*	*0.969*	*0.971*	*0.962*	*0.966*	*0.951*	*0.968*	*0.965*	*0.043*	*0.015*	*0.010*	*0.013*	*0.015*	*0.025*	*0.031*	*0.022*
2	*N*	*0.972*	*0.966*	*0.973*	*0.969*	*0.967*	*0.958*	*0.969*	*0.968*	*0.015*	*0.015*	*0.016*	*0.010*	*0.018*	*0.021*	*0.020*	*0.017*
3	*N*	*0.972*	*0.973*	*0.976*	*0.973*	*0.971*	*0.957*	*0.977*	*0.972*	*0.016*	*0.009*	*0.011*	*0.012*	*0.011*	*0.024*	*0.023*	*0.015*
4	*N*	*0.969*	*0.979*	*0.981*	*0.978*	*0.983*	*0.965*	*0.980*	*0.976*	*0.037*	*0.006*	*0.011*	*0.011*	*0.012*	*0.023*	*0.026*	*0.018*
11	*N*	*0.974*	*0.971*	*0.974*	*0.972*	*0.975*	*0.960*	*0.962*	*0.970*	*0.009*	*0.012*	*0.015*	*0.009*	*0.012*	*0.020*	*0.019*	*0.014*
12	*N*	*0.977*	*0.983*	*0.977*	*0.976*	*0.980*	*0.970*	*0.965*	*0.975*	*0.012*	*0.010*	*0.007*	*0.012*	*0.012*	*0.015*	*0.034*	*0.014*
13	*N*	*0.973*	*0.979*	*0.980*	*0.972*	*0.974*	*0.960*	*0.964*	*0.972*	*0.018*	*0.007*	*0.010*	*0.015*	*0.013*	*0.020*	*0.031*	*0.016*
14	Y	0.983	0.982	0.974	0.979	0.980	0.959	0.984	0.977	0.018	0.008	0.014	0.011	0.012	0.022	0.024	0.015
15	Y	0.971	0.976	0.971	0.968	0.970	0.955	0.958	0.967	0.021	0.015	0.016	0.018	0.023	0.019	0.025	0.020

Table F.9: 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*	*0.999*	*1.033*	*1.034*	*1.039*	*1.026*	*1.038*	*1.029*	*1.028*	*0.027*	*0.017*	*0.014*	*0.009*	*0.012*	*0.018*	*0.054*	*0.022*
2	*N*	*1.027*	*1.040*	*1.038*	*1.037*	*1.034*	*1.042*	*1.032*	*1.036*	*0.036*	*0.014*	*0.013*	*0.016*	*0.021*	*0.025*	*0.045*	*0.024*
3	*N*	*1.007*	*1.034*	*1.034*	*1.037*	*1.028*	*1.033*	*1.045*	*1.031*	*0.029*	*0.010*	*0.008*	*0.016*	*0.017*	*0.026*	*0.041*	*0.021*
4	*N*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	*N*	*1.023*	*1.044*	*1.042*	*1.043*	*1.036*	*1.046*	*1.041*	*1.039*	*0.032*	*0.014*	*0.011*	*0.014*	*0.021*	*0.020*	*0.034*	*0.021*
12	*N*	*1.009*	*1.029*	*1.040*	*1.043*	*1.035*	*1.042*	*1.057*	*1.036*	*0.070*	*0.063*	*0.054*	*0.042*	*0.036*	*0.024*	*0.045*	*0.048*
13	*N*	*1.037*	*1.053*	*1.054*	*1.050*	*1.043*	*1.059*	*1.067*	***1.052***	*0.015*	*0.017*	*0.018*	*0.025*	*0.025*	*0.028*	*0.057*	*0.026*
14	Y	1.018	1.047	1.049	1.049	1.040	1.048	1.074	1.047	0.022	0.016	0.014	0.020	0.026	0.033	0.050	0.026
15	Y	1.024	1.044	1.042	1.037	1.039	1.046	1.051	1.040	0.029	0.012	0.015	0.013	0.022	0.020	0.049	0.023

Table F.10: 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*	*1.066*	*1.048*	*1.051*	*1.038*	*1.041*	*1.044*	*1.049*	*1.048*	*0.034*	*0.017*	*0.013*	*0.015*	*0.016*	*0.022*	*0.047*	*0.024*
2	*N*	*1.061*	*1.052*	*1.056*	*1.035*	*1.051*	*1.050*	*1.050*	***1.051***	*0.038*	*0.018*	*0.020*	*0.017*	*0.016*	*0.028*	*0.056*	*0.027*
3	*N*	*1.065*	*1.052*	*1.049*	*1.048*	*1.041*	*1.059*	*1.051*	***1.052***	*0.028*	*0.014*	*0.016*	*0.013*	*0.014*	*0.022*	*0.068*	*0.025*
4	*N*	*1.050*	*1.036*	*1.033*	*1.029*	*1.034*	*1.045*	*1.015*	*1.035*	*0.024*	*0.012*	*0.013*	*0.017*	*0.021*	*0.035*	*0.057*	*0.026*
11	*N*	*1.036*	*1.028*	*1.029*	*1.019*	*1.024*	*1.037*	*1.059*	*1.033*	*0.025*	*0.014*	*0.017*	*0.015*	*0.017*	*0.027*	*0.057*	*0.025*
12	*N*	*1.047*	*1.037*	*1.032*	*1.040*	*1.040*	*1.056*	*1.024*	*1.040*	*0.016*	*0.011*	*0.016*	*0.016*	*0.014*	*0.032*	*0.067*	*0.025*
13	*N*	*1.032*	*1.039*	*1.039*	*1.032*	*1.039*	*1.046*	*1.071*	*1.043*	*0.032*	*0.015*	*0.018*	*0.018*	*0.016*	*0.019*	*0.064*	*0.026*
14	Y	1.038	1.031	1.034	1.026	1.032	1.055	1.064	1.040	0.021	0.010	0.009	0.013	0.019	0.050	0.069	0.027
15	Y	1.026	1.030	1.031	1.021	1.027	1.040	1.015	1.027	0.024	0.013	0.013	0.015	0.018	0.018	0.067	0.024

Table F.11: 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*	*1.043*	*1.044*	*1.053*	*1.050*	*1.058*	*1.070*	*1.024*	*1.049*	*0.023*	*0.020*	*0.018*	*0.024*	*0.025*	*0.031*	*0.068*	*0.030*
2	*N*	*1.030*	*1.039*	*1.042*	*1.042*	*1.067*	*1.034*	*1.073*	*1.047*	*0.019*	*0.021*	*0.018*	*0.025*	*0.033*	*0.044*	*0.041*	*0.029*
3	*N*	*1.042*	*1.039*	*1.024*	*1.034*	*1.052*	*1.067*	*1.043*	*1.043*	*0.024*	*0.018*	*0.015*	*0.021*	*0.025*	*0.022*	*0.052*	*0.025*
4	*N*	*1.052*	*1.045*	*1.044*	*1.042*	*1.056*	*1.080*	*1.074*	***1.056***	*0.023*	*0.019*	*0.019*	*0.018*	*0.024*	*0.034*	*0.044*	*0.026*
4.5	*N*	*1.021*	*1.023*	*1.024*	*1.029*	*1.043*	*1.047*	*1.043*	*1.033*	*0.015*	*0.021*	*0.016*	*0.017*	*0.023*	*0.029*	*0.044*	*0.024*
11	*N*	*1.032*	*1.032*	*1.023*	*1.030*	*1.054*	*1.049*	*1.040*	*1.037*	*0.012*	*0.020*	*0.018*	*0.014*	*0.023*	*0.022*	*0.064*	*0.024*
12	*N*	*1.033*	*1.038*	*1.042*	*1.042*	*1.054*	*1.062*	*1.083*	***1.050***	*0.031*	*0.027*	*0.021*	*0.030*	*0.021*	*0.036*	*0.056*	*0.032*
13	*N*	*1.030*	*1.033*	*1.030*	*1.036*	*1.051*	*1.039*	*1.059*	*1.040*	*0.022*	*0.016*	*0.016*	*0.022*	*0.025*	*0.038*	*0.070*	*0.030*
14	Y	1.037	1.029	1.036	1.031	1.041	1.045	1.027	1.035	0.025	0.022	0.019	0.022	0.023	0.034	0.056	0.029
15	Y	1.044	1.032	1.037	1.030	1.050	1.063	1.042	1.043	0.028	0.020	0.019	0.017	0.020	0.027	0.060	0.027

Table F.12: Machine 38 - 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*	*0.979*	*0.977*	*0.966*	*0.949*	*0.957*	*0.931*	*1.015*	*0.968*	*0.033*	*0.018*	*0.014*	*0.023*	*0.015*	*0.026*	*0.029*	*0.023*
2	*N*	*0.974*	*0.974*	*0.967*	*0.947*	*0.955*	*0.921*	*1.010*	*0.964*	*0.025*	*0.019*	*0.014*	*0.022*	*0.018*	*0.032*	*0.036*	*0.024*
3	*N*	*0.985*	*0.978*	*0.967*	*0.953*	*0.955*	*0.928*	*1.016*	*0.969*	*0.035*	*0.018*	*0.015*	*0.026*	*0.017*	*0.028*	*0.030*	*0.024*
4	*N*	*0.985*	*0.985*	*0.974*	*0.955*	*0.964*	*0.933*	*1.018*	*0.974*	*0.022*	*0.017*	*0.014*	*0.023*	*0.020*	*0.027*	*0.022*	*0.021*
11	*N*	*0.972*	*0.984*	*0.972*	*0.951*	*0.968*	*0.937*	*1.019*	*0.972*	*0.021*	*0.016*	*0.013*	*0.021*	*0.012*	*0.022*	*0.031*	*0.020*
12	*N*	*0.980*	*0.984*	*0.974*	*0.958*	*0.968*	*0.942*	*1.024*	*0.976*	*0.030*	*0.016*	*0.014*	*0.023*	*0.016*	*0.028*	*0.022*	*0.021*
13	*N*	*0.978*	*0.988*	*0.979*	*0.961*	*0.968*	*0.939*	*1.020*	*0.976*	*0.017*	*0.016*	*0.012*	*0.021*	*0.013*	*0.021*	*0.019*	*0.017*
14	Y	0.985	0.981	0.971	0.955	0.962	0.931	1.018	0.972	0.037	0.021	0.015	0.023	0.016	0.029	0.026	0.024
15	Y	0.986	0.990	0.982	0.961	0.972	0.939	1.019	0.978	0.012	0.015	0.012	0.020	0.016	0.023	0.027	0.018

Table F.13: 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*	*0.977*	*0.967*	*0.959*	*0.958*	*0.947*	*0.961*	*0.953*	*0.960*	*0.021*	*0.010*	*0.008*	*0.010*	*0.013*	*0.012*	*0.025*	*0.014*
2	*N*	*0.984*	*0.968*	*0.960*	*0.960*	*0.956*	*0.963*	*0.963*	*0.965*	*0.023*	*0.015*	*0.017*	*0.015*	*0.017*	*0.019*	*0.038*	*0.021*
3	*N*	*0.973*	*0.969*	*0.962*	*0.963*	*0.958*	*0.963*	*0.964*	*0.964*	*0.020*	*0.009*	*0.008*	*0.008*	*0.009*	*0.018*	*0.029*	*0.014*
4	*N*	*0.990*	*0.973*	*0.962*	*0.961*	*0.959*	*0.968*	*0.948*	*0.966*	*0.019*	*0.008*	*0.010*	*0.009*	*0.013*	*0.025*	*0.037*	*0.017*
11	*N*	*0.981*	*0.977*	*0.969*	*0.968*	*0.963*	*0.972*	*0.965*	*0.971*	*0.010*	*0.009*	*0.005*	*0.007*	*0.015*	*0.009*	*0.025*	*0.011*
12	*N*	*0.982*	*0.977*	*0.966*	*0.974*	*0.962*	*0.973*	*0.947*	*0.969*	*0.015*	*0.010*	*0.011*	*0.031*	*0.015*	*0.026*	*0.039*	*0.021*
13	*N*	*0.982*	*0.974*	*0.970*	*0.965*	*0.962*	*0.967*	*0.967*	*0.969*	*0.018*	*0.012*	*0.011*	*0.012*	*0.015*	*0.018*	*0.030*	*0.017*
14	Y	0.981	0.973	0.968	0.965	0.964	0.965	0.958	0.968	0.013	0.005	0.006	0.008	0.011	0.018	0.027	0.013
15	Y	0.987	0.979	0.972	0.966	0.965	0.969	0.954	0.970	0.014	0.008	0.008	0.009	0.015	0.018	0.029	0.014

Table F.14: 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*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	*N*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	*N*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	*N*	*0.963*	*0.971*	*0.958*	*0.941*	*0.953*	*0.955*	*0.967*	*0.958*	*0.030*	*0.022*	*0.024*	*0.028*	*0.051*	***0.072***	***0.159***	***0.055***
11	*N*	*0.936*	*0.954*	*0.954*	*0.937*	*0.947*	*0.949*	*0.986*	*0.952*	*0.020*	*0.018*	*0.018*	*0.014*	*0.017*	*0.017*	*0.050*	*0.022*
12	*N*	*0.951*	*0.955*	*0.953*	*0.943*	*0.947*	*0.956*	*0.983*	*0.955*	*0.016*	*0.015*	*0.016*	*0.016*	*0.014*	*0.016*	*0.031*	*0.018*
13	*N*	*0.961*	*0.959*	*0.958*	*0.946*	*0.947*	*0.946*	*0.972*	*0.956*	*0.035*	*0.022*	*0.021*	*0.021*	*0.021*	*0.023*	*0.046*	*0.027*
14	Y	0.956	0.960	0.957	0.948	0.953	0.950	0.972	0.957	0.030	0.016	0.014	0.014	0.014	0.017	0.034	0.020
15	Y	0.967	0.961	0.961	0.949	0.952	0.949	0.975	0.959	0.021	0.013	0.016	0.019	0.020	0.012	0.045	0.021

Table F.15: 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*	*0.961*	*0.959*	*0.959*	*0.953*	*0.964*	*0.985*	*0.983*	*0.966*	***0.082***	*0.024*	*0.027*	*0.031*	*0.040*	*0.041*	*0.055*	*0.043*
2	*N*	*0.964*	*0.961*	*0.961*	*0.956*	*0.971*	*0.974*	*0.978*	*0.966*	*0.028*	*0.026*	*0.024*	*0.027*	*0.035*	*0.044*	*0.067*	*0.036*
3	*N*	*0.963*	*0.959*	*0.957*	*0.952*	*0.962*	*0.966*	*0.983*	*0.963*	*0.048*	*0.029*	*0.029*	*0.034*	*0.037*	*0.049*	*0.070*	*0.042*
4	*N*	*0.975*	*0.968*	*0.971*	*0.960*	*0.975*	*0.990*	*0.987*	*0.975*	*0.028*	*0.022*	*0.020*	*0.026*	*0.028*	*0.034*	*0.063*	*0.031*
11	*N*	*0.974*	*0.975*	*0.976*	*0.970*	*0.981*	*0.987*	*0.989*	*0.979*	*0.028*	*0.016*	*0.021*	*0.018*	*0.027*	*0.034*	*0.061*	*0.029*
12	*N*	*0.962*	*0.974*	*0.973*	*0.967*	*0.983*	*0.990*	*0.983*	*0.976*	*0.035*	*0.019*	*0.021*	*0.022*	*0.018*	*0.042*	*0.057*	*0.031*
13	*N*	*0.980*	*0.980*	*0.982*	*0.967*	*0.982*	*0.990*	*0.986*	*0.981*	*0.032*	*0.025*	*0.021*	*0.033*	*0.029*	*0.040*	*0.067*	*0.035*
14	Y	0.961	0.968	0.970	0.967	0.979	0.981	0.981	0.973	0.031	0.019	0.020	0.021	0.028	0.039	**0.074**	0.033
15	Y	0.966	0.973	0.973	0.966	0.980	0.988	0.990	0.976	0.029	0.017	0.021	0.022	0.029	0.033	0.059	0.030

Table F.16: 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*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	*N*	0.965	0.965	0.968	0.969	0.972	0.970	0.978	0.970	0.019	0.018	0.019	0.022	0.025	0.036	0.035	0.025
3	*N*	0.975	0.966	0.965	0.968	0.967	0.951	0.977	0.967	0.034	0.018	0.020	0.021	0.027	0.065	0.036	0.032
4	*N*	0.975	0.977	0.979	0.979	0.982	0.981	0.984	0.979	0.014	0.009	0.012	0.015	0.020	0.022	0.025	0.017
11	*N*	0.980	0.978	0.977	0.976	0.978	0.976	0.983	0.978	0.026	0.010	0.016	0.015	0.018	0.023	0.025	0.019
12	*N*	0.969	0.968	0.971	0.971	0.968	0.975	0.977	0.971	0.015	0.019	0.020	0.022	0.028	0.034	0.029	0.024
13	*N*	0.966	0.967	0.971	0.972	0.969	0.976	0.983	0.972	0.017	0.017	0.019	0.022	0.027	0.036	0.042	0.026
14	Y	0.967	0.969	0.972	0.974	0.977	0.975	0.980	0.973	0.019	0.013	0.017	0.020	0.023	0.036	0.038	0.024
15	Y	0.972	0.968	0.971	0.969	0.974	0.977	0.970	0.972	0.024	0.016	0.020	0.027	0.028	0.033	0.041	0.027

Table F.17: 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*	*1.002*	*1.012*	*1.018*	*1.021*	*1.015*	*1.015*	*1.009*	*1.013*	*0.053*	*0.015*	*0.014*	*0.016*	*0.019*	*0.027*	*0.044*	*0.027*
2	*N*	*1.004*	*1.017*	*1.022*	*1.024*	*1.021*	*1.016*	*1.014*	*1.017*	*0.063*	*0.016*	*0.015*	*0.018*	*0.020*	*0.031*	*0.045*	*0.030*
3	*N*	*1.004*	*1.026*	*1.029*	*1.038*	*1.023*	*1.024*	*1.016*	*1.023*	*0.049*	*0.015*	*0.016*	*0.016*	*0.016*	*0.023*	*0.031*	*0.024*
4	*N*	*1.011*	*1.031*	*1.034*	*1.040*	*1.031*	*1.031*	*1.015*	*1.028*	*0.050*	*0.016*	*0.016*	*0.017*	*0.017*	*0.025*	*0.036*	*0.025*
11	*N*	*1.012*	*1.026*	*1.028*	*1.031*	*1.028*	*1.031*	*1.032*	*1.027*	*0.040*	*0.019*	*0.018*	*0.018*	*0.020*	*0.020*	*0.047*	*0.026*
12	*N*	*1.002*	*1.021*	*1.024*	*1.029*	*1.021*	*1.021*	*1.010*	*1.018*	*0.039*	*0.013*	*0.011*	*0.013*	*0.016*	*0.026*	*0.067*	*0.026*
13	*N*	*1.010*	*1.026*	*1.029*	*1.034*	*1.027*	*1.025*	*1.017*	*1.024*	*0.027*	*0.014*	*0.013*	*0.013*	*0.012*	*0.016*	*0.027*	*0.018*
14	Y	1.012	1.025	1.029	1.035	1.031	1.026	1.020	1.025	0.027	0.014	0.013	0.010	0.013	0.012	0.033	0.018
15	Y	1.009	1.025	1.033	1.035	1.036	1.031	1.022	1.027	0.018	0.011	0.008	0.008	0.010	0.019	0.026	0.015

Table F.18: 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*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	*N*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	*N*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	*N*	1.006	0.989	0.999	1.003	1.007	1.002	1.005	1.002	0.024	0.012	0.008	0.009	0.007	0.014	0.018	0.013
11	*N*	1.002	0.977	0.987	0.984	0.989	0.987	0.999	0.989	0.045	0.026	0.026	0.026	0.027	0.031	0.044	0.032
12	*N*	0.994	0.975	0.984	0.988	0.990	0.992	0.992	0.988	0.036	0.021	0.018	0.017	0.019	0.024	0.023	0.022
13	Y	1.001	0.982	0.987	0.988	0.988	0.991	0.991	0.990	0.055	0.029	0.024	0.022	0.025	0.027	0.030	0.030
14	*N*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	Y	1.001	0.980	0.985	0.990	0.998	0.995	0.994	0.992	0.037	0.016	0.018	0.016	0.016	0.017	0.021	0.020

Table F.19: 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*	*1.020*	*0.995*	*0.998*	*0.995*	*0.994*	*0.999*	*0.983*	*0.998*	*0.024*	*0.013*	*0.012*	*0.014*	*0.013*	*0.011*	*0.026*	*0.016*
2	*N*	*1.005*	*0.999*	*1.004*	*1.001*	*0.995*	*0.999*	*0.985*	*0.998*	*0.020*	*0.015*	*0.016*	*0.016*	*0.016*	*0.015*	*0.029*	*0.018*
3	*N*	*1.010*	*1.000*	*1.003*	*1.002*	*0.998*	*1.005*	*0.991*	*1.001*	*0.020*	*0.014*	*0.011*	*0.011*	*0.012*	*0.011*	*0.023*	*0.015*
4	*N*	*1.012*	*1.009*	*1.008*	*1.009*	*1.007*	*1.009*	*0.984*	*1.006*	*0.020*	*0.015*	*0.016*	*0.016*	*0.017*	*0.016*	*0.036*	*0.019*
11	*N*	*1.011*	*1.019*	*1.024*	*1.023*	*1.017*	*1.020*	*0.997*	*1.016*	*0.032*	*0.014*	*0.012*	*0.016*	*0.018*	*0.022*	*0.039*	*0.022*
12	*N*	*1.017*	*1.022*	*1.024*	*1.024*	*1.012*	*1.017*	*1.004*	*1.017*	*0.026*	*0.030*	*0.026*	*0.021*	*0.019*	*0.018*	*0.030*	*0.024*
13	*N*	*1.015*	*1.005*	*1.012*	*1.014*	*1.003*	*1.004*	*0.995*	*1.007*	*0.030*	*0.013*	*0.013*	*0.016*	*0.015*	*0.021*	*0.029*	*0.020*
14	Y	1.016	1.007	1.011	1.011	1.011	1.010	0.993	1.008	0.020	0.014	0.016	0.017	0.024	0.023	0.042	0.022
15	Y	1.005	1.004	1.008	1.009	1.005	1.006	0.992	1.004	0.028	0.015	0.013	0.014	0.016	0.015	0.028	0.019

F.2 Final reproducibility trial data for selected laps

Table F.20: 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	14	0.984	0.974	0.983	0.981	0.989	0.969	0.972	0.979	0.022	0.007	0.010	0.012	0.011	0.010	0.028	0.014	
2	15	0.994	0.971	0.977	0.976	0.990	0.967	0.988	0.980	0.025	0.014	0.016	0.020	0.012	0.016	0.023	0.018	
5	14	1.035	1.039	1.038	1.040	1.025	1.022	1.013	1.030	0.019	0.020	0.023	0.028	0.029	0.041	0.068	0.032	
5	15	1.036	1.041	1.039	1.038	1.025	1.029	1.035	1.035	0.019	0.018	0.023	0.027	0.031	0.042	0.057	0.031	
10	14	1.030	0.989	0.996	0.991	0.999	0.990	0.974	0.996	0.040	0.017	0.021	0.020	0.021	0.023	0.039	0.026	
10	15	1.027	0.996	1.001	0.993	0.998	0.987	0.971	0.996	0.035	0.010	0.011	0.008	0.013	0.015	0.029	0.017	
11	14	0.980	0.980	0.975	0.992	0.984	0.994	0.952	0.980	0.011	0.008	0.008	0.010	0.020	0.024	0.028	0.016	
11	15	0.975	0.980	0.969	0.994	0.984	0.999	0.962	0.980	0.020	0.015	0.018	0.013	0.012	0.030	0.061	0.024	D7 station 9
13	14	1.037	1.040	1.040	1.052	1.042	1.043	1.083	1.048	0.035	0.012	0.016	0.022	0.022	0.036	0.052	0.028	
13	15	1.040	1.038	1.036	1.046	1.043	1.036	1.078	1.045	0.026	0.013	0.016	0.022	0.020	0.026	0.040	0.023	
15	14	0.990	1.008	1.008	1.033	1.030	1.022	1.032	1.018	0.023	0.014	0.016	0.021	0.019	0.030	0.035	0.023	
15	15	0.994	1.003	1.006	1.024	1.022	1.017	1.018	1.012	0.019	0.019	0.018	0.024	0.027	0.028	0.049	0.026	
16	14	0.980	0.983	0.990	0.996	0.985	1.014	1.008	0.994	0.011	0.012	0.010	0.017	0.015	0.030	0.058	0.022	
16	15	0.989	0.988	0.997	0.989	0.988	1.007	0.983	0.992	0.014	0.015	0.014	0.016	0.016	0.018	0.029	0.018	
28	14	0.983	0.982	0.974	0.979	0.980	0.959	0.984	0.977	0.018	0.008	0.014	0.011	0.012	0.022	0.024	0.015	
28	15	0.971	0.976	0.971	0.968	0.970	0.955	0.958	0.967	0.021	0.015	0.016	0.018	0.023	0.019	0.025	0.020	
32	14	1.018	1.047	1.049	1.049	1.040	1.048	1.074	1.047	0.022	0.016	0.014	0.020	0.026	0.033	0.050	0.026	
32	15	1.024	1.044	1.042	1.037	1.039	1.046	1.051	1.040	0.029	0.012	0.015	0.013	0.022	0.020	0.049	0.023	
33	14	1.038	1.031	1.034	1.026	1.032	1.055	1.064	1.040	0.021	0.010	0.009	0.013	0.019	0.050	0.069	0.027	
33	15	1.026	1.030	1.031	1.021	1.027	1.040	1.015	1.027	0.024	0.013	0.013	0.015	0.018	0.018	0.067	0.024	
34	14	1.037	1.029	1.036	1.031	1.041	1.045	1.027	1.035	0.025	0.022	0.019	0.022	0.023	0.034	0.056	0.029	
34	15	1.044	1.032	1.037	1.030	1.050	1.063	1.042	1.043	0.028	0.020	0.019	0.017	0.020	0.027	0.060	0.027	
38	14	0.985	0.981	0.971	0.955	0.962	0.931	1.018	0.972	0.037	0.021	0.015	0.023	0.016	0.029	0.026	0.024	
38	15	0.986	0.990	0.982	0.961	0.972	0.939	1.019	0.978	0.012	0.015	0.012	0.020	0.016	0.023	0.027	0.018	

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
39	14	0.981	0.973	0.968	0.965	0.964	0.965	0.958	0.968	0.013	0.005	0.006	0.008	0.011	0.018	0.027	0.013	
39	15	0.987	0.979	0.972	0.966	0.965	0.969	0.954	0.970	0.014	0.008	0.008	0.009	0.015	0.018	0.029	0.014	
45	14	0.956	0.960	0.957	0.948	0.953	0.950	0.972	0.957	0.030	0.016	0.014	0.014	0.014	0.017	0.034	0.020	
45	15	0.967	0.961	0.961	0.949	0.952	0.949	0.975	0.959	0.021	0.013	0.016	0.019	0.020	0.012	0.045	0.021	
47	14	0.961	0.968	0.970	0.967	0.979	0.981	0.993	0.974	0.031	0.019	0.020	0.021	0.028	0.039	0.057	0.030	D7 Station 8
47	15	0.966	0.973	0.973	0.966	0.980	0.988	0.990	0.976	0.029	0.017	0.021	0.022	0.029	0.033	0.059	0.030	
48	14	0.967	0.969	0.972	0.974	0.977	0.975	0.980	0.973	0.019	0.013	0.017	0.020	0.023	0.036	0.038	0.024	
48	15	0.972	0.968	0.971	0.969	0.974	0.977	0.970	0.972	0.024	0.016	0.020	0.027	0.028	0.033	0.041	0.027	
50	14	1.012	1.025	1.029	1.035	1.031	1.026	1.020	1.025	0.027	0.014	0.013	0.010	0.013	0.012	0.033	0.018	
50	15	1.009	1.025	1.033	1.035	1.036	1.031	1.022	1.027	0.018	0.011	0.008	0.008	0.010	0.019	0.026	0.015	
52	13	1.001	0.982	0.987	0.988	0.988	0.991	0.991	0.990	0.055	0.029	0.024	0.022	0.025	0.027	0.030	0.030	
52	15	1.001	0.980	0.985	0.990	0.998	0.995	0.994	0.992	0.037	0.016	0.018	0.016	0.016	0.017	0.021	0.020	
53	14	1.016	1.007	1.011	1.011	1.011	1.010	0.993	1.008	0.020	0.014	0.016	0.017	0.024	0.023	0.042	0.022	
53	15	1.005	1.004	1.008	1.009	1.005	1.006	0.992	1.004	0.028	0.015	0.013	0.014	0.016	0.015	0.028	0.019	

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 100mm	Surface Temperature[2]	Air Temperature[1]	OSGR (Horizontal)
2	Dynatest FWD 8002 SN 102	Pass	Pass	Pass	Pass	Pass	Pass	Low	*No data*	*No data*	*No data*
5	Dynatest HWD 8082 SN 050	Pass	Pass	Pass	Pass	Pass	Pass	Medium	*No data*	*No data*	No data
10	Dynatest FWD 8002 SN 192	Pass	Pass	Pass	Pass	Pass	Pass	Medium	*Not suitable*	*Not suitable*	*No data*
11	Dynatest FWD 8002 SN 187	Pass	Pass	Pass	Pass	Pass	Pass	High	*No data*	*No data*	High
13	Dynatest HWD 8082 SN 029	Pass	Pass	Pass	Pass	Pass	Pass	Medium	*No data*	*No data*	*No data*
15	Dynatest FWD 8002 SN 203	Pass	Pass	Pass	Pass	Pass	Pass	High	*Not suitable*	*Not suitable*	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
32	Dynatest HWD 8082 SN 069	Pass	Pass	Pass	Pass	Pass	Pass	High	*Not suitable*	*Not suitable*	High
33	Dynatest HWD 8082 SN 070	Pass	Pass	Pass	Pass	Pass	Pass	Medium	*Not suitable*	*Not suitable*	High
34	Dynatest HWD 8082 SN 108	Pass	Pass	Pass	Pass	Pass	Pass	High	*Not suitable*	*Not suitable*	High
38	SWECO FWD PRI1500 SN 1111-448	Pass	Pass	Pass	Pass	Pass	Pass	High	Low	Low	Low
39	Dynatest FWD 8002 SN 388	Pass	Pass	Pass	Pass	Pass	Pass	Medium	Low	Medium	High
45	SWECO HWD PRI2100 0903-088	Pass	Pass	Pass	Pass	Pass	Pass	High	Not suitable	Not Suitable	*No data*
47	Dynatest FWD 8002 SN 452	Pass	Pass	Pass	Pass	Pass	Pass	Medium	Not suitable	Low	*No data*
48	Dynatest FWD 8002 SN 424	Pass	Pass	Pass	Pass	Pass	Pass	Medium	Low	Low	Medium
50	RINCENT HeavyDyn HVY-101A	Pass	Pass	Pass	Pass	Pass	Pass	High	Low	Medium	Medium
52	Dynatest FFWD 8012 SN 057	Pass	Pass	Pass	Pass	Pass	Pass	Medium	Not suitable	*Not suitable*	High
53	Dynatest FWD 8002 SN 098	Pass	Pass	Pass	Pass	Pass	Pass	Medium	*Not suitable*	*Not suitable*	*No data*

[2] If the machine data included values for air or surface but did not have it fitted or was not identified as calibrated, then it has been assigned as “Not suitable”. To differentiate these from the devices which were identified as calibrated, the text is displayed as grey text in italics.

National Highways 2022 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 2022 trial run by TRL held on the Horiba-MIRA proving ground in the week beginning the 26th September 2022.

Other titles from this subject area

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
PPR976	Highways England 2019 National Dynamic Plate Test device Accreditation Trial. S Brittain. 2022
PPR1017	Highways England 2018 National Dynamic Plate Test device Accreditation Trial. S Brittain, 2022

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