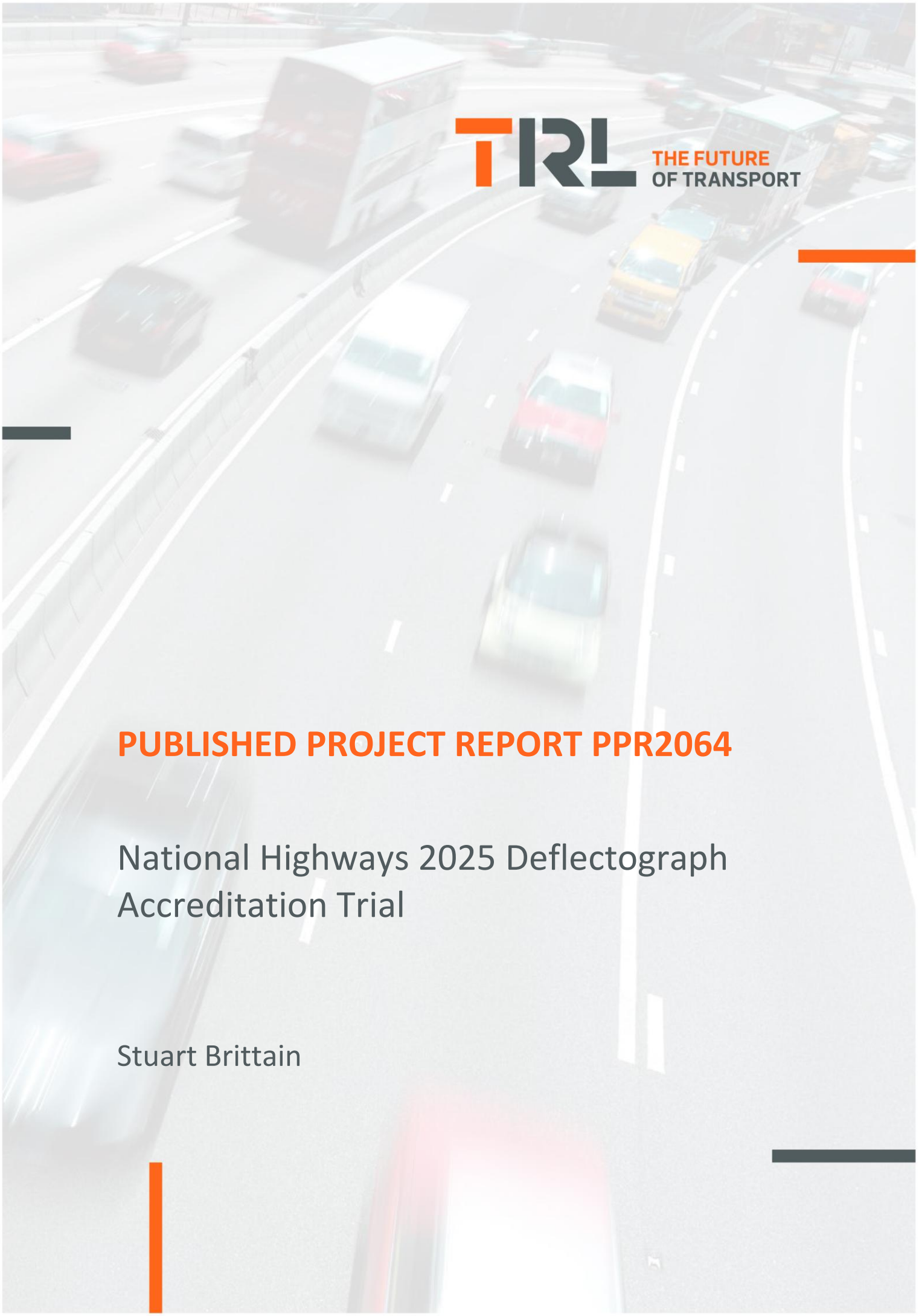

THE FUTURE OF TRANSPORT

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National Highways 2025 Deflectograph Accreditation Trial

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Executive summary

Deflectograph accreditation trials are held annually by TRL on behalf of National Highways. The objective is to monitor the performance of all Deflectographs operating on the UK road network and to ensure they are all measuring within the specified fleet tolerances. By examining and monitoring the results from the machines operating on specified test sections of the reference site, the performance of individual machines, and the performance of the whole UK fleet, are assessed.

The 2025 trial was held from the 4th to the 6th March 2025. The site used was the twin horizontal straights of the Horiba-MIRA proving ground. This was the thirtieth year in which TRL has taken full responsibility for the planning and running of the trials. Ten machines attended the trial which represents the entirety of the known UK fleet.

The first day was used to collect initial data to identify potential outliers. The second day was used to repeat the deflection assessment and to obtain distance and temperature assessments. The third day was used for testing a device that was unable to test on the first two days.

All ten machines met the mandatory requirements of the trial (i.e. weight, deflection measurement and distance measurement) and can therefore be considered for approval to survey the National Highways Strategic Road Network .

With regards to the measurement of pavement temperature at depth, nine of the ten machines achieved a high performance rating, and one machine achieved a medium performance rating.

Participants were also asked to provide surface and air temperature measurements (if they had the equipment fitted) and six machines provided these measurements. With regards to the measurement of surface temperature, four machines achieved a medium performance and two a low. With regards to measurement of air temperature, five machines achieved a high performance and one a medium.

1 Introduction

Deflectograph accreditation trials are held annually by TRL on behalf of National Highways. The objective is to monitor the performance of all Deflectographs operating on the National Highways Strategic Road Network. By examining and monitoring the results from the machines operating on specified test sections, the performances of individual machines, and the whole UK fleet can be assessed.

The 2025 trial was held from 4th to the 6th March 2025. The site used was the twin horizontal straights of the Horiba-MIRA proving ground - which is further discussed in Section 2. This was the thirtieth year in which TRL has taken full responsibility for the planning and running of the trials and the thirteenth full trial at Horiba-MIRA. Ten machines attended the trial. The trial process and the criteria used for the 2025 trial are discussed in Section 3 and Appendix D of this report, respectively. The results from the trial are discussed in Sections 4 to 6.

For convenience, throughout this report, the machines are referred to by their running numbers rather than by the owner. For ease of record keeping, running numbers are retained from year to year with any new machines being assigned new numbers. By agreement with National Highways, Appendix A lists the machines, owner and performance at the trial.

2 Test site

2.1 Details of the test site

The twin horizontal straights area of the Horiba-MIRA Proving Ground comprises two lengths of straight and essentially level track just over 1.5km long. They are joined by banked bends at either end. During October 2010, National Highways arranged for a length of the nearside lane on one of the straights to be reconstructed, in order to produce three sections of different constructions/strength levels. These three sections were designed specifically for use in the accreditation of Deflectographs and other pavement deflection measuring devices. These sections are referred to as NHCP_01, NHCP_02 and NHCP_03 (National Highways Calibration Pavement) in this report. The sections are each 70m in length (however the beginning and end 5m are excluded in the analysis to help avoid alignment issues, resulting in effectively 60m sections) and the layout and test route are shown in Appendix B. Nominal construction details of the test sections can be found in Appendix C.

2.2 Suitability of site and management of site-dependent between run variability

Prior to 2011, the Deflectograph accreditation trials were held on specially constructed sections of the Small Road System test track at TRL in Wokingham. In order to demonstrate the suitability of the sections constructed at Horiba-MIRA, a transitional trial was held on the 12th and 13th September 2011 (Brittain & Sanders, 2012). This trial compared a sub-set of the UK Deflectograph fleet, initially following the traditional approach using the historic test sections of the TRL track, and then moving to follow the proposed new procedures and sections at Horiba-MIRA. The work demonstrated that the Horiba-MIRA site was suitable for the accreditation of Deflectograph machines. Following the 2011 transitional trial, the trial process and the accreditation criteria were reviewed.

During the transitional trial it was found that there was a localised high deflection area on the site. This caused an increase in the between run variability in the data due to small changes in driving line. This was further investigated at the 2013 trial, and it was found that this variability could be removed by placing small cones on the test track to mark the survey test line for the whole test site. These cones were placed either side of the machines' test path (as shown in Figure 2.1), so that any deviation in the test line would cause a cone to be knocked over which could be recorded. It has been found that high levels of wind on the track can cause the cones to be moved or knocked over. Therefore, during some trials, paint lines are sprayed onto the surface marking the test line instead of using cones.



Figure 2.1: Image illustrating cone positions during testing

3 Trial format

In preparation for the 2021 trial, changes were made to the test programme to mitigate the risks from COVID-19. The changes made were also found to be beneficial for the efficiency of the trial. Therefore, a variation of this approach has been used in subsequent trials. The format applied to the 2025 trial is described in this section.

Each crew is required to carry out a machine inspection in advance of the trials and a certified checklist is submitted before the machine is allowed to take part in the running trials. In addition, all crews are asked to weigh their Deflectograph (with crew in position) before the trial and provide this data.

3.1 Day 1 – Distance calibration and test laps

On arrival, all personnel signed in at the Horiba-MIRA Gatehouse. They then reported to the TRL reception staff. When all participants had arrived, a briefing was given by TRL to ensure that everyone involved was aware of the programme and what was required of them to ensure that the testing was completed safely and correctly.

Following the briefing, a distance calibration on the test track was undertaken for each machine followed by beam calibrations.

After completion of the distance calibrations and beam calibrations, six test laps were undertaken by all devices. Two machines undertook two additional laps to further investigate their performance.

For this testing the machine running order was randomised and all machines completed the testing in convoy (with suitable gaps left between them) to cover all the sections in a single measurement run.

In addition, during this testing, operators were asked to record temperature measurements. The temperature measurements were taken in two pre-drilled holes (40mm depth) and also in a water bucket (set up after the marked-out length used in the day 2 testing). Crews were also asked to provide air and surface temperatures for the three measurement stations if their Deflectograph had these temperature sensors fitted.

To improve the alignment of the deflection measurements, crews were asked to stop their machines at the start of each run, and align the deflection beam frame to the forward-most position of the test cycle with the truck wheels at a defined “beam down” point.

CS 229 (DMRB CS 229, 2020) sets a maximum rate of temperature increase of 2.5˚C per hour at 40mm for deflection testing on the UK trunk road network. This requirement is intended to ensure that temperature corrections used to adjust deflections to a standard temperature of 20˚C stay within the validity of the equations.

Although temperature corrections are not carried out in analysing data from the accreditation trial, the pavement temperature is monitored before and after the deflection test sections (the same locations the operators measure) at 40 and 100mm depths, to inform any conclusions drawn. Air and pavement surface temperature measurements are also collected at these locations. Automatic data-loggers are used to provide a reading every minute during deflection testing.

While the machines were running, TRL staff observed the dynamic operation of each machine, including a timed section, in order to verify that operating speeds are acceptable.

Survey data, collected via USB memory sticks, was processed during the day at track side by TRL to allow interpretation of the performance to be carried out.

The initial conclusions of the testing on this day were provided to participants before clearing the site for the day.

3.2 Day 2 – Main testing

On arrival, all personnel signed in at the Horiba-MIRA Gatehouse and then a morning briefing was held.

Prior to the main testing with the whole fleet, the two machines identified as potential outliers during day 1 were given the opportunity to further investigate their machines.

Crews undertook a static calibration of their machines and then proceeded to undertake the main testing. This involved undertaking deflection test laps as on day 1. In addition, during this testing, operators were asked to measure the length of a marked-out section.

Six laps were undertaken on this day. As with day 1, data was collected and processed trackside by TRL so that updates on performance could be provided.

3.3 Day 3 – Additional testing

One machine (Machine 05) was unable to take part in testing on either day 1 or 2 due to issues with the clutch on the device. This machine was assessed on day 3, with a subset of the fleet to provide reference data.

The test procedure on this day was the same as day 2, however only the assessed machine undertook measurements of the distance check length. Six laps were undertaken on this day. As with days 1 and 2, data was collected and processed trackside so that updates on performance could be provided.

4 Inspections and wheel weights

4.1 Inspections

All ten machines arrived with completed inspection checklists and in an acceptable condition.

4.2 Wheel weights

Prior to the 2020 trial, Deflectographs had been weighed in the maintenance building on the HORIBA-MIRA proving ground. During the 2020 trial a member of staff slipped over during this process (on the smooth floor); this, coupled with the vehicle reversing operations within a tight space, meant that this site was deemed unsuitable on safety grounds.

Therefore, for the 2021 trial, the weight measurements were undertaken (successfully) on the twin straights. During the 2022 trial it was identified that it was too windy to obtain accurate measurements on the twin straights. Fortunately, it was possible to undertake measurements in a workshop on site (a different location to the one used prior to 2021). However, the availability of this workshop could not be guaranteed for future trials as it can only be booked a week in advance. It was therefore decided that operators would be asked to weigh their Deflectographs prior to the trial. If they did not have access to suitable, calibrated weigh pads they were asked to take their Deflectograph to TRL's offices in Wokingham prior to the trial so that they could be weighed.

For the 2025 trial, weight values were collected by the participants either using their own equipment or during the manufacturer's service. These weight values are given in Table 4.1. To aid comparison against the criteria, the percentage of the target weight (100% corresponds to the target) is shown in brackets beneath the Total front, Rear nearside (NS) and Rear offside (OS) values. Values outside of the criteria are highlighted in bold red text.

Table 4.1: Deflectograph weight distribution including crew (kg)

Machine	Front NS	Front OS	Total Front	Rear NS	Rear OS	Total rear	Total Machine
2	2514	2565	5079 (112.9%)	3064 (96.5%)	3372 (106.2%)	6436	11514
3	2306	2442	4748 (105.5%)	3345 (105.3%)	3387 (106.7%)	6731	11479
5	2261	2304	4565 (101.4%)	3127 (98.5%)	3266 (102.9%)	6392	10957
8	2237	2347	4584 (101.9%)	3183 (100.3%)	3220 (101.4%)	6404	10988
9	2376	2291	4667 (103.7%)	3255 (102.5%)	3347 (105.4%)	6602	11269
10	2379	2395	4774 (106.1%)	3438 (108.3%)	3158 (99.5%)	6596	11369
12	2224	2285	4508 (100.2%)	3233 (101.8%)	3318 (104.5%)	6552	11060
14	2399	2441	4840 (107.5%)	3230 (101.7%)	3400 (107.1%)	6630	11470
15	2424	2462	4886 (108.6%)	3384 (106.6%)	3448 (108.6%)	6831	11717
16	2307	2327	4634 (103%)	3236 (101.9%)	3237 (102%)	6473	11106

All machines are within the front axle and rear wheel limits given in the Accreditation and QA specification (TRL, 2020).

4.3 Beam calibration check

Prior to each set of testing, each crew carried out a static beam calibration check on their machine. Other than requiring an amended approach for M03 (discussed further in section 5.5) no machines were identified to TRL as not meeting the limits specified in the accreditation and QA specification (TRL, 2020).

5 Day 1 (4th March 2025) – Initial laps

On this day, each machine undertook six test laps and two machines undertook two additional laps. However, the first lap was disregarded (after analysis) to take account of the fact that the machines were likely to be warming-up.

5.1 Machine alterations

Machine 5 did not take part as there was an issue with its clutch.

Machine 12 had computer issues at the start of this day, and therefore could not provide data from the first two laps.

During the first few laps on this day it was identified that Machines 3 and 9 were potential outliers. Machine 3 was producing low values for the NS beam, and Machine 9 was producing high values for the OS beam. This information was provided to the operators of these devices so that they could investigate. Machine 3 did not take part in lap 5 due to this investigation process. After investigating, these two machines undertook two additional laps (laps 7 and 8) on their own to see if the performance was improved.

Therefore, the deflection results shown in this section are for laps 3, 4 and 6 (the laps where all nine machines took part in and before alterations).

5.2 Temperatures recorded by the data loggers

Data loggers connected to thermocouples recorded the 40mm and 100mm depth temperatures along with the air and pavement surface temperatures. The loggers were set to record the measurements once every minute. The data from the loggers has been smoothed by taking a 9-point moving average (4 points before the time, the time and 4 points after). This smoothed data is shown in Figure 5.1 and Figure 5.2.

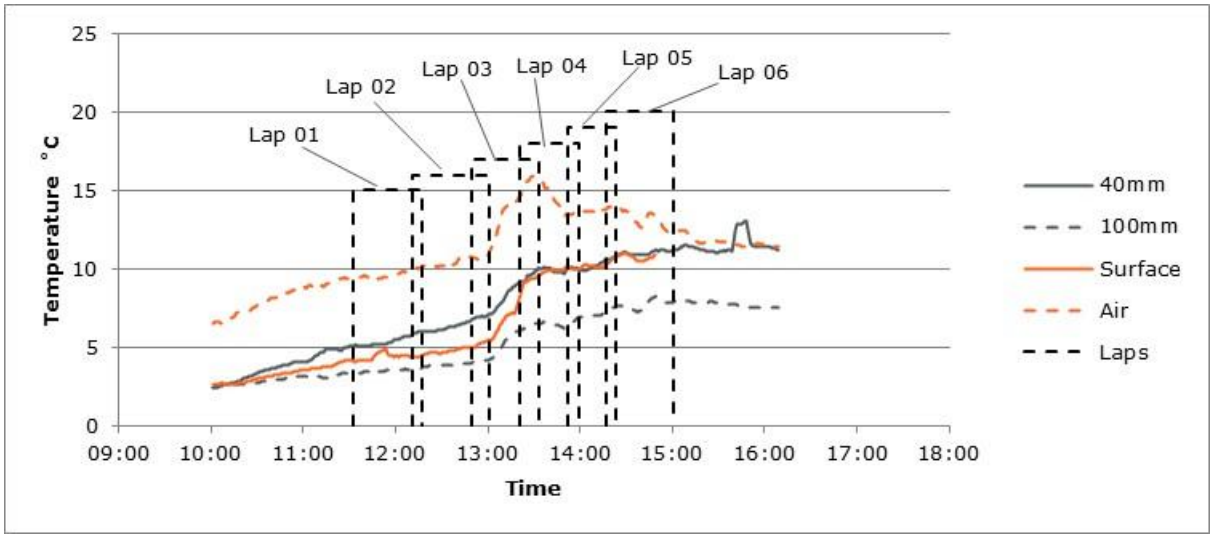

Figure 5.1: Temperature measurements from station 1 (before test sections) on day 1

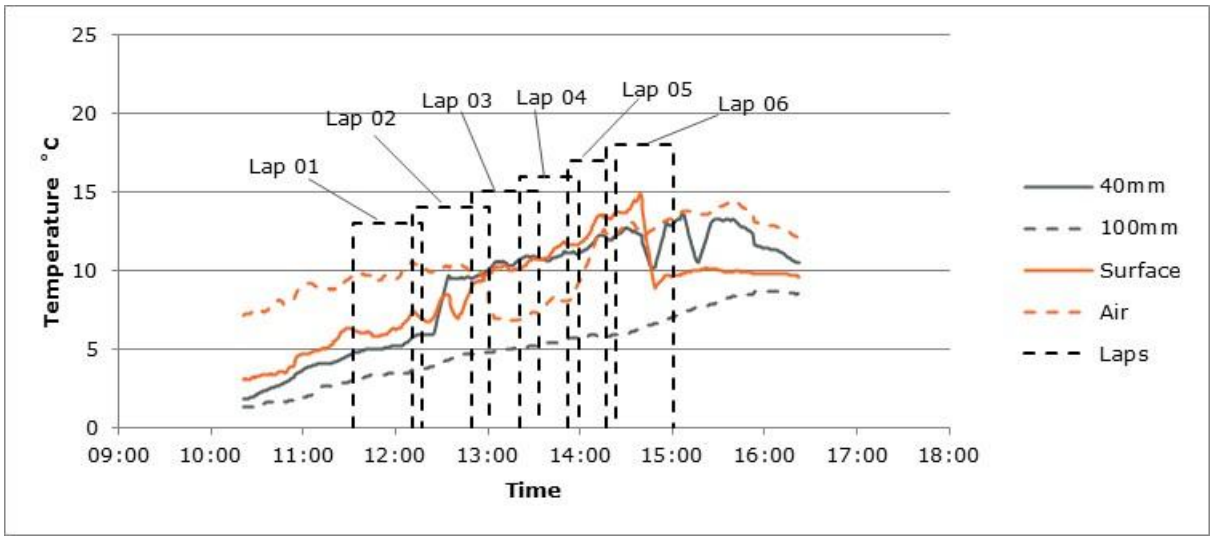

Figure 5.2: Temperature measurements from station 2 (after test sections) on day 1

In general, the temperatures on day 1 followed an upward trend throughout the testing.

As discussed in Section 3.1, CS 229 sets a maximum rate of temperature change of 2.5˚C per hour at 40mm for deflection testing. The temperature change per hour at 40mm (calculated for each 15-minute interval) for stations 1 and 2 (either side of the deflection sections) is shown in Figure 5.3.

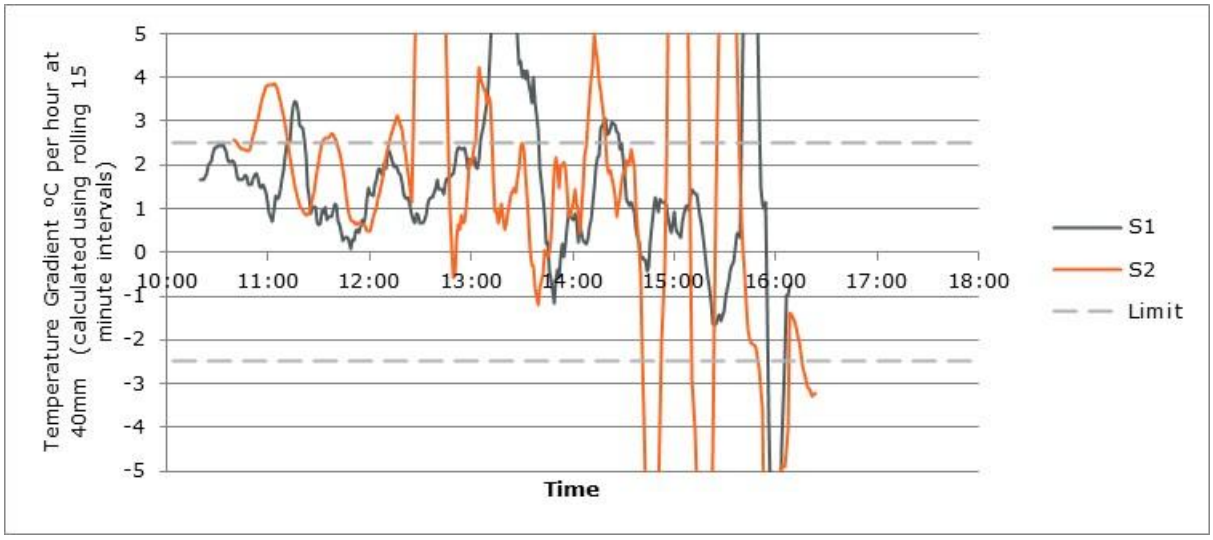

Figure 5.3: 40mm depth temperature changes day 1 (stations 1 and 2)

It can be seen from Figure 5.3 that the 2.5˚C per hour limit is exceeded several times. As such this temperature variation could result in increased variability and if a larger variation in the deflection results are seen then additional testing (when the temperatures stabilise) may be required.

5.3 Between-run standard deviation for deflection values

No criteria are set relating to the between-run standard deviation (BRSD) of each machine. This is due in part to the BRSD being affected by both the machine performance and also due to temperature changes over the testing period. It is, however, useful to consider this

parameter when investigating anomalies in the behaviour of machines in case an individual machine's mean result has been unduly influenced by variations between runs, perhaps as a result of a significant variation from the expected test line. The BRSD for each machine, is shown in Table 5.1. Values (where present) which are more than two times the fleet average for the section and wheel path are highlighted in bold red text.

Table 5.1: Between-run standard deviation for day 1 (laps 3, 4 and 6)

Machine Number	NHCP_01 NS	NHCP_01 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS
2	6.0	1.2	17.3	9.0	12.1	2.5
3	4.8	5.0	37.3	12.7	17.3	12.7
5	.	.	.	.	.	.
8	4.7	6.0	6.7	15.7	11.1	6.3
9	4.5	3.3	16.8	12.6	15.0	15.6
10	0.7	5.1	18.7	17.5	12.5	14.2
12	1.8	2.1	17.7	17.4	10.0	7.7
14	0.4	3.2	23.4	25.1	**32.0**	15.3
15	1.1	3.1	18.4	13.2	8.8	5.5
16	2.6	4.2	19.5	8.5	8.8	2.9

It can be seen from Table 5.1 that although there is a reasonably large spread of BRSD values, only one value (Machine 14 for the NS measurement on NHCP_03) was noticeably higher than the rest of the fleet for the section and wheel path combination. This machine is not noticeably higher for the other sections and wheel path combinations, therefore, this analysis did not raise any particular concerns.

5.4 Mean deflection values

Table 5.2 shows the mean deflections recorded on each section, together with summary statistics. Instances where the between-equipment standard deviation (BESD) meets the criterion are highlighted in green and instances where the criterion is not met are shown in red. This table is used to identify if the overall fleet distribution meets the BESD criterion.

Table 5.2: Mean deflection (µm) by section: day 1 (laps 3,4 and 6)

Machine number	NHCP_01 NS	NHCP_01 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS	Average NS	Average OS
2	55	48	290	228	173	156	173	144
3	27	41	236	214	112	142	125	132
5	.	.	.	.	.	.	.	.
8	49	42	272	221	171	163	164	142
9	51	77	259	276	156	195	155	183
10	57	55	274	231	174	185	168	157
12	47	47	268	234	166	160	160	147
14	67	53	290	225	202	171	186	150
15	59	49	297	208	180	145	179	134
16	49	46	256	231	151	156	152	144
Mean	51	51	271	230	165	164	163	148
BESD	10.8	10.9	19.4	19.2	24.5	17.6	17.7	15.0
BESD criterion	11.2	11.2	16.9	15.8	14.1	14.1	14.1	13.7
CoV	21.2%	21.4%	7.1%	8.4%	14.9%	10.8%	10.9%	10.1%

Table 5.3 shows the deviations from the overall mean and these are highlighted if they are more than 2 or 3 times the BESD criteria (orange and red respectively). This table helps to identify if any machines are significant outliers and provides further information on the distribution of the fleet.

Table 5.3: Deviation (µm) from overall mean deflection by section: day 1 (laps 3, 4 and 6)

Machine number	NHCP_01 NS	NHCP_01 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS	Average NS	Average OS
2	3.7	-2.5	18.8	-1.5	7.6	-7.7	10.0	-3.9
3	-23.8	-9.7	-35.3	-16.0	-52.8	-22.0	-37.3	-15.9
5	.	.	.	.	.	.	.	.
8	-1.9	-9.0	0.9	-8.5	6.3	-0.7	1.7	-6.0
9	-0.7	26.5	-12.3	45.8	-8.7	31.2	-7.2	34.5
10	5.3	4.3	2.3	1.5	8.7	21.7	5.4	9.2
12	-4.3	-4.5	-3.6	4.0	1.4	-3.7	-2.1	-1.4
14	15.5	1.7	18.6	-4.7	36.6	7.8	23.6	1.6
15	8.1	-2.1	25.6	-22.2	15.3	-18.9	16.4	-14.4
16	-2.0	-4.9	-15.0	1.5	-14.3	-7.8	-10.5	-3.7
2x BESD criterion	22.4	22.4	33.7	31.6	28.2	28.2	28.1	27.4
3x BESD criterion	33.6	33.6	50.6	47.4	42.4	42.2	42.2	41.1

From Table 5.2 it can be seen that the BESD criterion is not met for the average of the site on either wheel path. On examination of Table 5.3, it can be seen that two machines are consistent outliers (Machine 3 for the NS and Machine 9 for the OS).

The operators of these two machines were notified of this performance and given the opportunity to investigate their machines and conduct two additional laps (without the rest of the fleet) to confirm if the issue appeared to be resolved following their alterations.

5.5 Alterations at the end of day 1

The operators of machine 9 undertook a recalibration and replaced the winch.

The operators of machine 3 adjusted the gain on the NS beam effectively increasing the deflection values calculated during the static calibration in order to obtain measured deflections more consistent with the rest of the fleet during the dynamic measurements. Although this resulted in deflection values closer to the fleet mean, it is noted that this approach is tackling the symptoms of the fault and not the cause of the fault. In addition, due to this amendment it is necessary to undertake an amended approach to the beam calibration to account for the increased values.

Alterations which address symptoms rather than causes are strongly discouraged. This is due to the fact that, as the cause is not known, there is an increased risk of further changes during the survey season. Therefore, should the device be found to be performing suitability against the fleet in the testing on day 2 then additional monitoring and investigation during the survey season would need to be undertaken to confirm that it provides data consistent with the fleet and to identify the cause. This would include:

- Contractor's calibration checks carried out no more than 3 weeks apart (instead of the 6 weeks identified in the specification)

- A thorough investigation of the device (without making permanent alterations) to identify the cause of the differences between the static and dynamic measurements. This may require discussions with the manufacturer. Regular updates on this investigation are to be provided to the Auditor. This should detail what has been identified as the cause of the issue and the measures put in place to ensure that the device does not drift any further during the year.
- At completion of the survey season and prior to next year's accreditation undertake work to fix the cause of the issue. Adjusting the gain so that the device provides consistent results with the fleet during dynamic measurements but incorrect results during the static calibration is not acceptable as a long-term fix.

6 Day 2 (6th March) – Main test Laps

To differentiate from the testing on day 1, the laps on day 2 were prefixed with a 1 so the first lap on day 2 was labelled as lap 11. Six laps were undertaken on this day. The first lap (after analysis) was disregarded to take account of the fact that the machines were likely to be warming-up.

6.1 Machine alterations

No additional alterations were undertaken in the morning of day 2. However, the operators of machines 3 and 9 were given the opportunity to undertake additional laps before the main testing to confirm their fixes remained suitable. Machine 5 did not take part due to the ongoing issue with its clutch.

6.2 Temperatures recorded by the data loggers

The set-up of thermocouples used on day 1 (discussed in section 5.2) was repeated on day 2. The smoothed data is shown in Figure 6.1 and Figure 6.2.

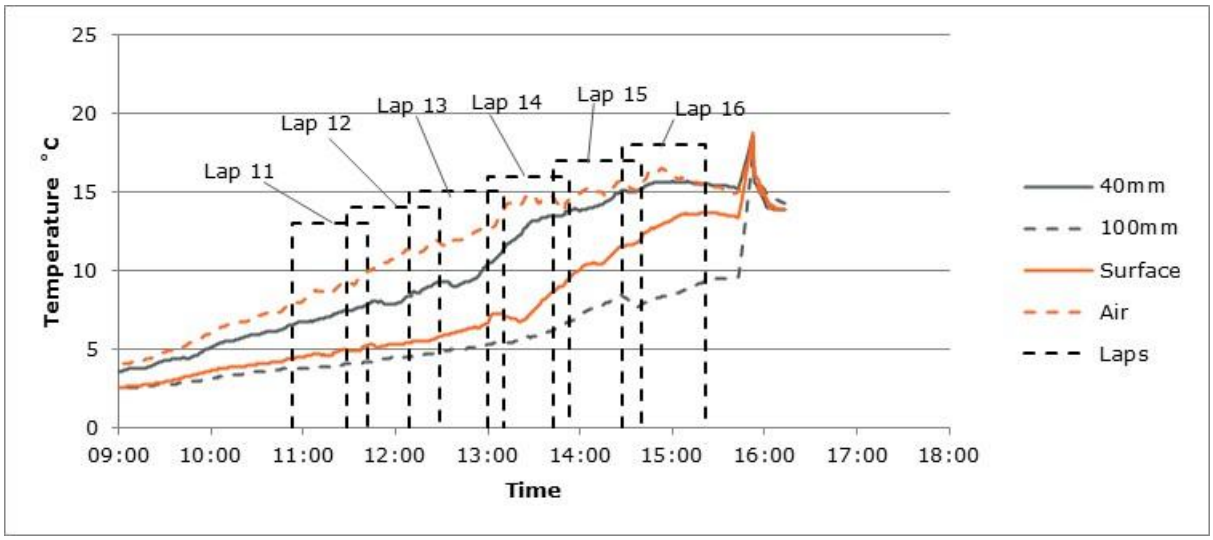

Figure 6.1: Temperature measurements from station 1 (before test sections) on day 2

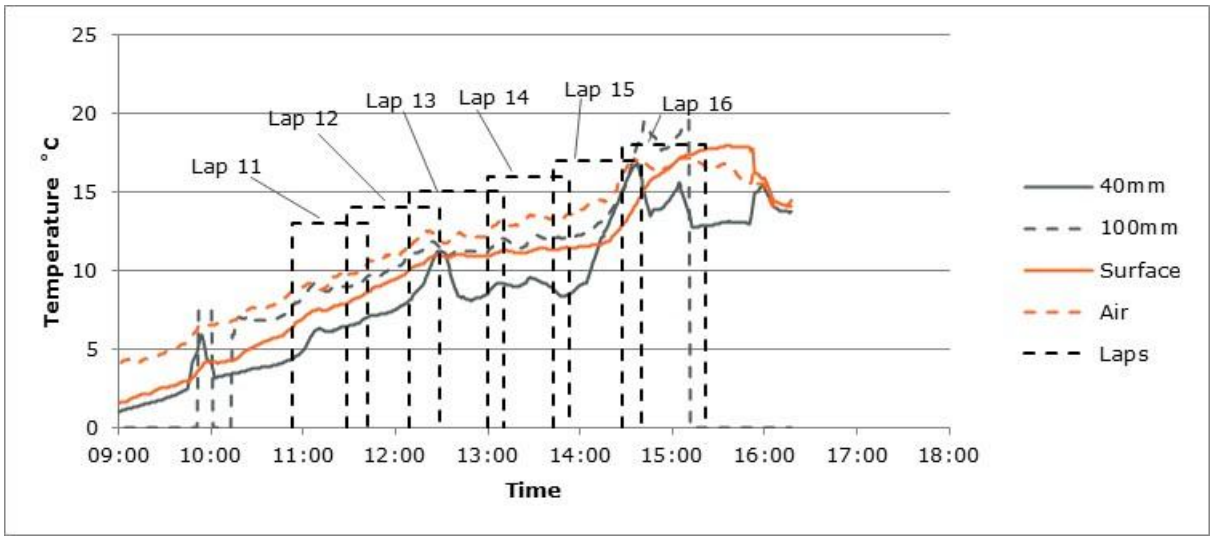

Figure 6.2: Temperature measurements from station 2 (after test sections) on day 2

In general, the temperatures on day 2 followed an upward trend throughout the testing.

The temperature change per hour at 40mm (calculated for each 15-minute interval) for stations 1 and 2 (either side of the deflection sections) is shown in Figure 6.3.

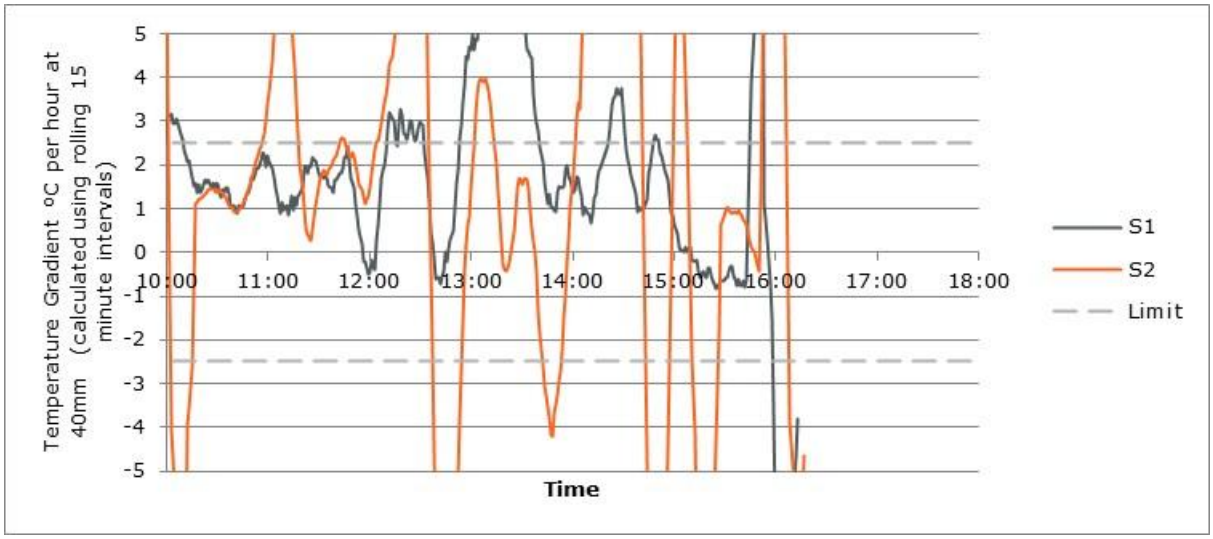

Figure 6.3: 40mm depth temperature changes day 2 (stations 1 and 2)

It can be seen from Figure 6.3 that as with day 1 the rate of change in temperature exceeds the limit several times. As such this temperature variation could result in increased variability and if a larger variation in the deflection results is seen then additional testing (when the temperatures stabilise) may be required.

6.3 Between-run standard deviation for deflection values

The between-run standard deviation (BRSD) results for each machine, are shown in Table 6.1. Values (where present) which are more than two times the fleet average for the section and wheel path are highlighted in bold red text.

Table 6.1: Between-run standard deviation for day 2 (laps 12 to 16)

Machine number	NHCP_01 NS	NHCP_01 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS
2	5.1	5.5	14.1	11.9	12.9	6.6
3	4.5	1.8	21.9	10.6	11.6	11.4
5	.	.	.	.	.	.
8	3.3	3.0	14.4	19.3	12.2	5.8
9	2.8	6.9	31.5	10.0	13.0	2.9
10	4.8	3.4	18.8	19.5	2.2	4.4
12	4.3	3.0	20.2	22.8	14.9	12.3
14	5.0	6.1	20.9	16.6	8.0	6.2
15	1.3	6.2	19.2	11.7	4.4	8.5
16	2.6	3.4	22.3	16.9	11.0	9.0

It can be seen from Table 6.1 that no machine was more than two times the fleet average for any section and wheel path combination.

6.4 Mean deflection values

The mean deflections recorded on each section, together with the summary statistics for the testing on day 2 (laps 12-16) can be seen in Table 6.2. As with the analysis for the data on day 1, instances where the between-equipment standard deviation (BESD) is within the criterion are highlighted in green and instances where the criterion is not met are in red. Table 6.3 shows the deviations from the overall mean and these are highlighted if they are more than 2 or 3 times the BESD criteria (in orange and red, respectively).

Table 6.2: Mean deflection (µm) by section: day 2 (laps 12-16)

Machine number	NHCP_01 NS	NHCP_02 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS	Average NS	Average OS
2	58	51	291	231	173	151	174	144
3	40	41	324	219	177	143	180	134
5	.	.	.	.	.	.	.	.
8	53	50	284	227	177	165	171	147
9	50	60	296	246	183	189	177	165
10	58	58	276	229	168	166	167	151
12	41	34	276	228	161	150	159	137
14	69	57	288	229	186	160	181	149
15	58	47	288	216	182	145	176	136
16	50	49	272	234	159	164	161	149
Mean	53	50	288	229	174	159	172	146
BESD	9.0	8.2	15.5	8.5	9.7	14.2	8.0	9.4
BESD criterion	11.2	11.2	17.3	15.8	14.4	14.0	14.3	13.6
CoV	16.9%	16.5%	5.4%	3.7%	5.6%	8.9%	4.7%	6.4%

Table 6.3: Deviation (µm) from overall mean deflection by section: day 2 (laps 12-16)

Machine number	NHCP_01 NS	NHCP_02 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS	Average NS	Average OS
2	5.2	1.4	3.2	2.1	-0.7	-7.9	2.6	-1.5
3	-12.6	-8.4	35.5	-10.0	2.6	-16.1	8.5	-11.5
5	.	.	.	.	.	.	.	.
8	-0.3	0.5	-4.6	-2.0	2.6	5.4	-0.8	1.3
9	-3.1	9.9	7.8	17.0	9.5	30.0	4.7	19.0
10	4.5	8.2	-12.2	0.4	-6.3	7.0	-4.7	5.2
12	-11.9	-15.7	-12.5	-0.2	-13.2	-9.7	-12.5	-8.5
14	16.1	7.0	0.0	0.2	11.9	1.2	9.3	2.8
15	4.6	-2.3	-0.7	-12.6	8.3	-14.2	4.1	-9.7
16	-2.6	-0.6	-16.5	5.2	-14.7	4.4	-11.3	3.0
2x BESD criterion	22.5	22.3	34.6	31.5	28.7	27.9	28.6	27.3
3x BESD criterion	33.7	33.5	51.9	47.3	43.1	41.9	42.9	40.9

From Table 6.2, it can be seen that the BESD criteria is met for the average of the site for both wheel paths (and five of the six wheel path and section combinations). On examination of Table 6.3, it can be seen that no machine is more than 3 times the BESD criterion away from the fleet mean, and there are only two instances of machines being more than 2 times the BESD criterion away from the fleet mean.

As such all of these devices were identified as having met the trial criteria for deflection measurement. However, as noted in section 5.5 Machine 3 will require additional monitoring during the course of the year.

7 Day 3 (7th March) – Additional testing

One machine (Machine 5) was unable to take part in testing on day 1 and 2 due to issues with the clutch on the device. This machine was assessed on day 3, with a subset of the fleet to provide reference data (machines 2, 8 and 10). The test procedure on this day was the same as day 2, however only the assessed machine undertook measurements of the distance check length.

To differentiate from the testing on the previous days, the laps on this day were prefixed with a 2 so the first lap on day 3 was labelled as lap 21. Six laps were undertaken on this day. The first lap (after analysis) was disregarded to take account of the fact that the machines were likely to be warming-up.

7.1 Machine alterations

No machine alterations were undertaken on this day.

7.2 Temperatures recorded by the data loggers

The thermocouples were set up as per day 1 and 2 and the smoothed data is shown in Figure 7.1 and Figure 7.2. The temperature change per hour at 40mm (calculated for each 15-minute interval) for stations 1 and 2 (either side of the deflection sections) is shown in Figure 7.3.

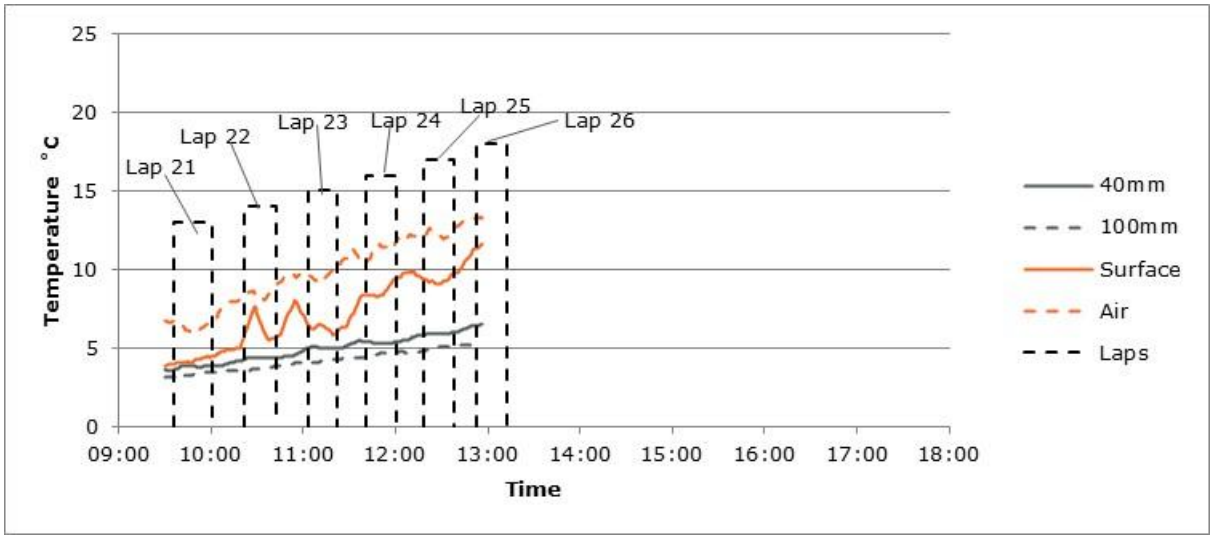

Figure 7.1: Temperature measurements from station 1 (before test sections) on day 3

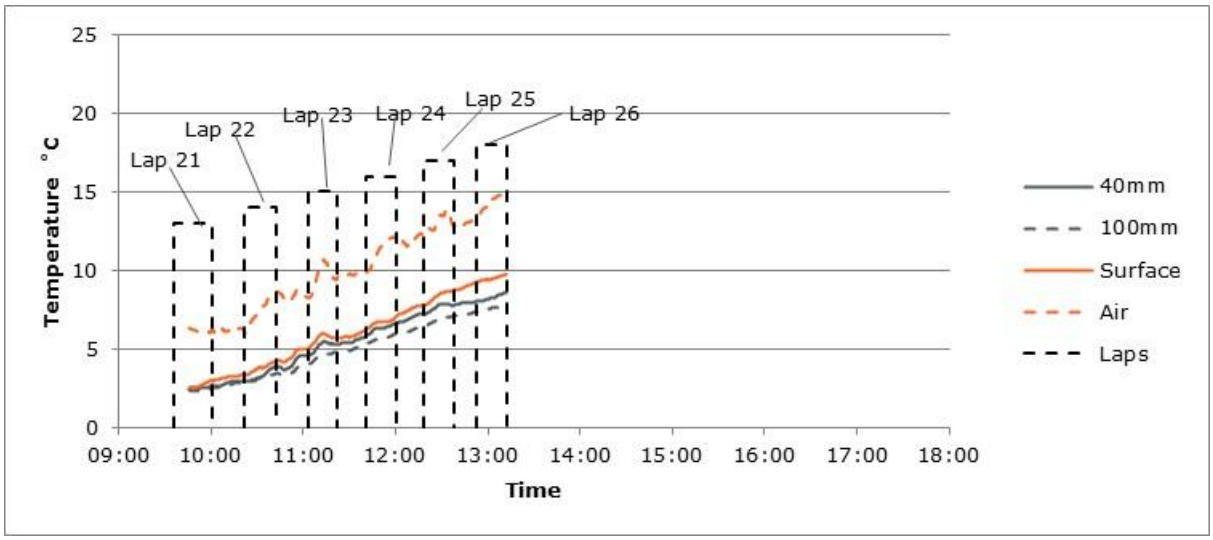

Figure 7.2: Temperature measurements from station 2 (before test sections) on day 3

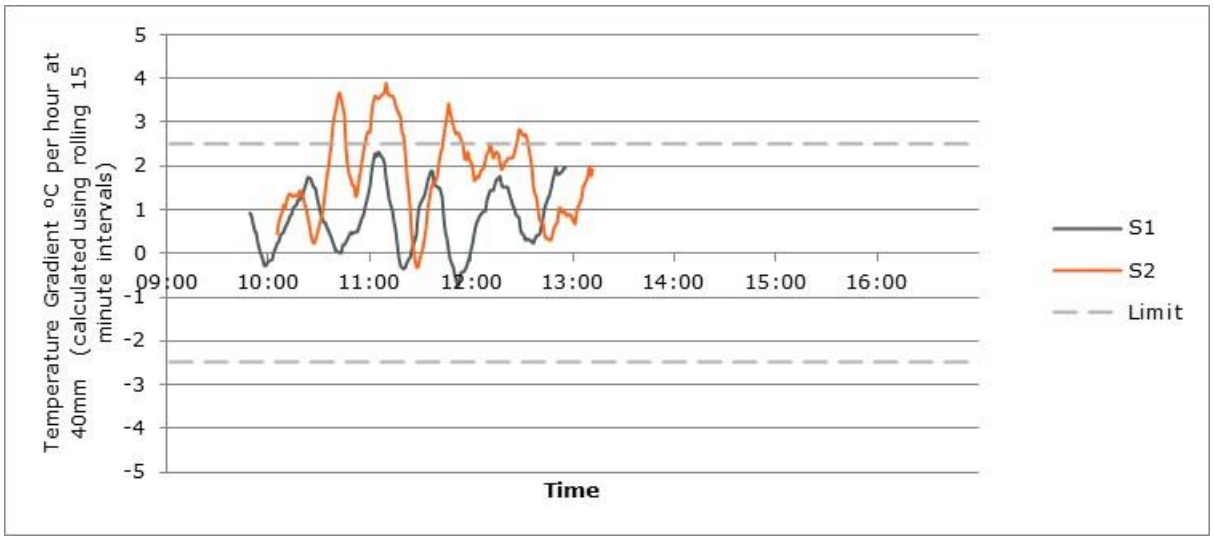

Figure 7.3: 40mm depth temperature changes day 3 (stations 1 and 2)

It can be seen from Figure 7.1 and Figure 7.2 that the temperatures on day 3 followed a upward trend throughout testing. It can also be seen (from Figure 7.3) that the rate of change in temperature exceeded the limits for four periods on station 2 but remained within the limits on station 1.

7.3 Between-run standard deviation for deflection values

The between run standard deviation for laps 22 to 26 is shown in Table 7.1.

Table 7.1: Between-run standard deviation for day 3 (laps 22 to 26)

Machine number	NHCP_01 NS	NHCP_01 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS
2	3.6	3.6	12.2	15.1	7.8	8.6
5	5.7	2.6	19.2	15.8	8.3	10.0
8	4.9	3.6	15.0	13.5	12.6	13.3
10	3.3	1.4	9.7	11.5	16.0	11.8

It can be seen from Table 7.1 that no machine was obviously more variable than the others.

7.4 Mean deflection values

The mean deflections recorded on each section together with summary statistics for laps 22 to 26 for these machines are shown in Table 7.2. The deviations from the overall mean are shown in Table 7.3.

Table 7.2: Mean deflection (µm) by section: day 3 (laps 22-26)

Machine number	NHCP_01 NS	NHCP_02 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS	Average NS	Average OS
2	57	49	269	212	160	144	162	135
5	56	44	263	198	157	134	159	125
8	54	50	245	200	149	145	150	132
10	52	53	259	216	153	153	154	140
Mean	55	49	259	207	155	144	156	133
BESD	2.3	3.7	10.0	8.6	4.5	7.7	5.3	6.3
BESD criterion	11.3	11.1	16.5	15.2	13.9	13.6	13.9	13.3
CoV	4.2%	7.6%	3.9%	4.2%	2.9%	5.4%	3.4%	4.7%

Table 7.3: Deviation (µm) from overall mean deflection by section: day 2 (laps 12-16)

Machine number	NHCP_01 NS	NHCP_02 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS	Average NS	Average OS
2	1.9	-0.2	9.9	5.3	4.8	0.2	5.5	1.8
5	1.6	-5.1	4.2	-8.4	2.4	-10.1	2.7	-7.9
8	-0.5	1.5	-13.7	-6.2	-5.4	1.3	-6.5	-1.1
10	-3.0	3.7	-0.4	9.3	-1.9	8.7	-1.8	7.2
2x BESD criterion	22.6	22.3	33.1	30.4	27.7	27.2	27.8	26.6
3x BESD criterion	33.9	33.4	49.6	45.6	41.6	40.8	41.7	39.9

From Table 7.2 it can be seen that the BESD criterion is met for the average of the site in both wheel paths. As the other machines in this testing have performed suitably previously in the trial, this would initially suggest that Machine 5 has met the trial criteria. However, this analysis is based on a subset of the fleet which means that it might not reflect the average of the whole fleet. Therefore, it is necessary to combine this data with the data from day 2 before making the final decision.

In order to combine the data from the two datasets, the average deflection values for each wheel path and section for the reference machines was calculated for each dataset (i.e. laps 12 to 16 and 22 to 26). The ratio between these values was then applied to the data from

Machine 5 (for laps 22 to 26) to provide an estimate of the likely deflections that this machine would have measured if it had operated during the testing on day 2.

The average deflections from the two datasets for the machines acting as reference and the calculated ratios are shown in Table 7.4.

Table 7.4: Reference data values and estimation ratio

	NHCP_01 NS	NHCP_02 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS
Average laps 12 to 16	51	45	284	229	170	155
Average laps 22 to 26	55	50	257	206	155	145
Ratio	0.92	0.91	1.10	1.11	1.10	1.07

The mean deflections recorded on each section together with summary statistics for the combined dataset are provided in Table 7.5. The deviations from the overall mean are shown in Table 7.6. In both of these tables, Machine 5 is denoted in blue italic text to highlight that it is a predicted value.

Table 7.5: Mean deflection (µm) by section: Combined dataset

Machine number	NHCP_01 NS	NHCP_02 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS	Average NS	Average OS
2	58	51	291	231	173	151	174	144
3	40	41	324	219	177	143	180	134
5	*52*	*40*	*290*	*220*	*173*	*144*	*172*	*134*
8	53	50	284	227	177	165	171	147
9	50	60	296	246	183	189	177	165
10	58	58	276	229	168	166	167	151
12	41	34	276	228	161	150	159	137
14	69	57	288	229	186	160	181	149
15	58	47	288	216	182	145	176	136
16	50	49	272	234	159	164	161	149
Mean	53	49	289	228	174	158	172	145
BESD	8.5	8.3	14.6	8.5	9.1	14.3	7.5	9.6
BESD criterion	11.2	11.1	17.3	15.7	14.4	13.9	14.3	13.6
CoV	16.0%	17.1%	5.1%	3.7%	5.2%	9.1%	4.4%	6.6%

Table 7.6: Deviation (µm) from overall mean deflection by section: Combined dataset

Machine number	NHCP_01 NS	NHCP_02 OS	NHCP_02 NS	NHCP_02 OS	NHCP_03 NS	NHCP_03 OS	Average NS	Average OS
2	5.4	2.3	3.0	3.0	-0.6	-6.3	2.6	-0.3
3	-12.4	-7.4	35.3	-9.1	2.6	-14.6	8.5	-10.3
5	*-1.3*	*-8.8*	*1.8*	*-8.0*	*-0.7*	*-14.1*	*-0.1*	*-10.3*
8	-0.2	1.4	-4.8	-1.2	2.7	6.9	-0.8	2.4
9	-2.9	10.9	7.6	17.9	9.5	31.6	4.7	20.1
10	4.7	9.1	-12.4	1.3	-6.3	8.5	-4.7	6.3
12	-11.8	-14.7	-12.7	0.7	-13.1	-8.1	-12.5	-7.4
14	16.3	8.0	-0.2	1.1	12.0	2.8	9.4	3.9
15	4.8	-1.3	-0.9	-11.7	8.4	-12.7	4.1	-8.6
16	-2.5	0.4	-16.7	6.0	-14.7	5.9	-11.3	4.1
2x BESD criterion	22.5	22.3	34.6	31.5	28.7	27.9	28.6	27.2
3x BESD criterion	33.7	33.4	51.9	47.2	43.1	41.8	42.9	40.8

It can be seen from Table 7.5 that the BESD criterion is met for the average of the site for both the NS and OS wheel paths. In addition (Table 7.6), there were only two instances where the result was more than 2 times the BESD criterion away from the fleet mean for a section and wheel path combination. Therefore, following the additional testing, Machine 5 has been identified as meeting the trial criteria for deflection measurement.

8 Temperature measurement assessment

8.1 Temperatures at depth and water bucket, recorded by operators

The Deflectograph crews made measurements of temperature from the two temperature test stations at 40mm depth and, in addition, they measured the temperature of a water bucket at the third temperature measurement station.

Examination of the logger data identified that the results obtained at 40mm depth for stations 1 and 2 were unsuitable for undertaking the assessment of the operator measurements. Therefore, for these stations the operator measurements were assessed against the fleet average. For station 3 (the water bucket) the logger measurements were suitable and as such the operator measurements were assessed against the logger measurements.

The day 3 measurements were used to assess Machine 5 against the other devices, as such this machine was excluded from the fleet average.

The results for these three stations for each day are shown in Figure 8.1 to Figure 8.9.

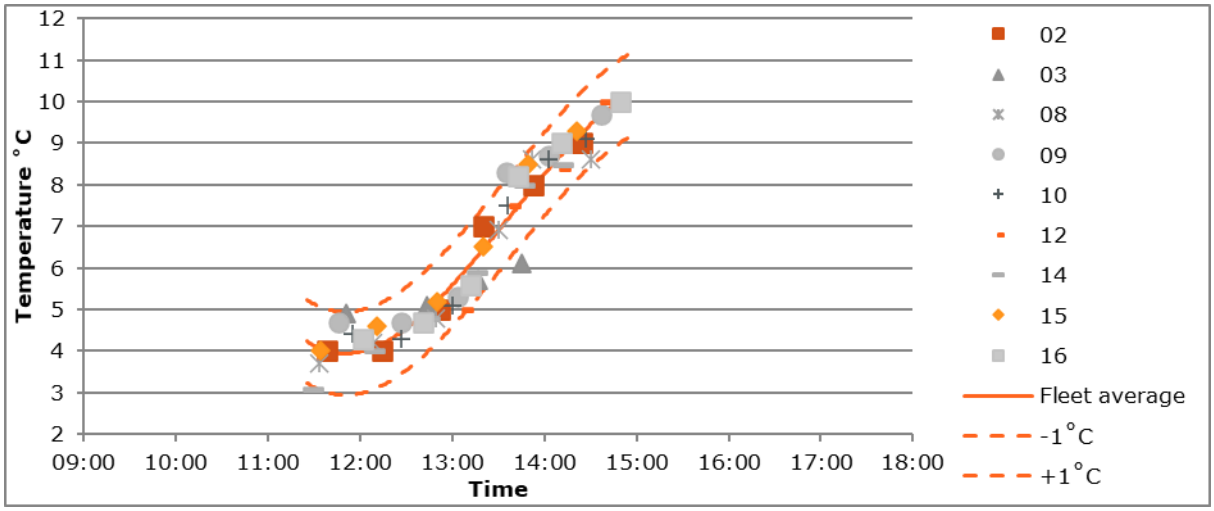

Figure 8.1: Comparison of operators' measurements against reference – Temperature test station 1, day 1

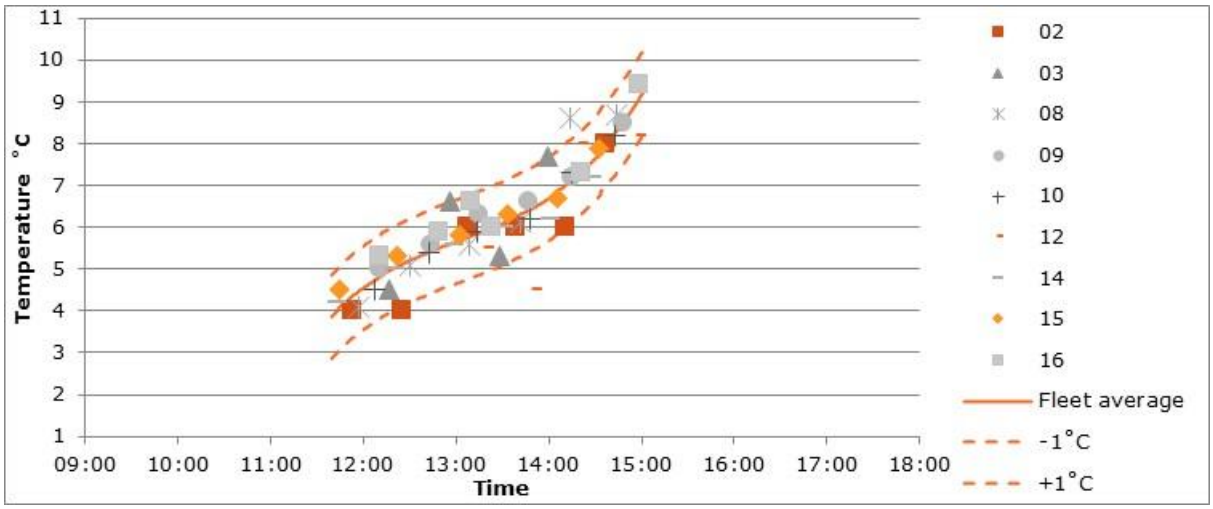

Figure 8.2: Comparison of operators' measurements against reference – Temperature test station 2, day 1

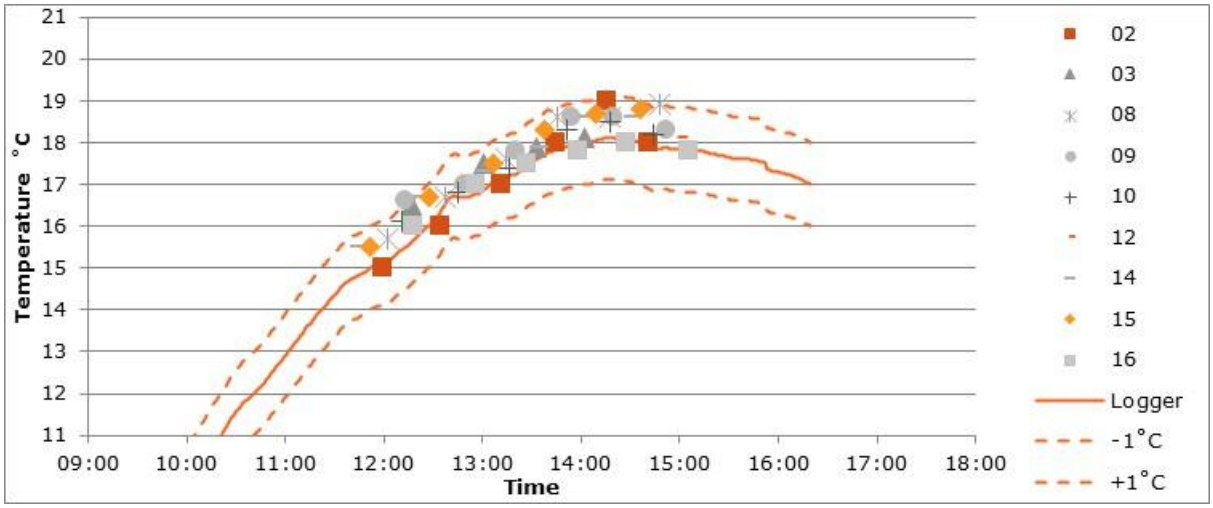

Figure 8.3: Comparison of operators' measurements against reference – Temperature test station 3 (water bucket), day 1

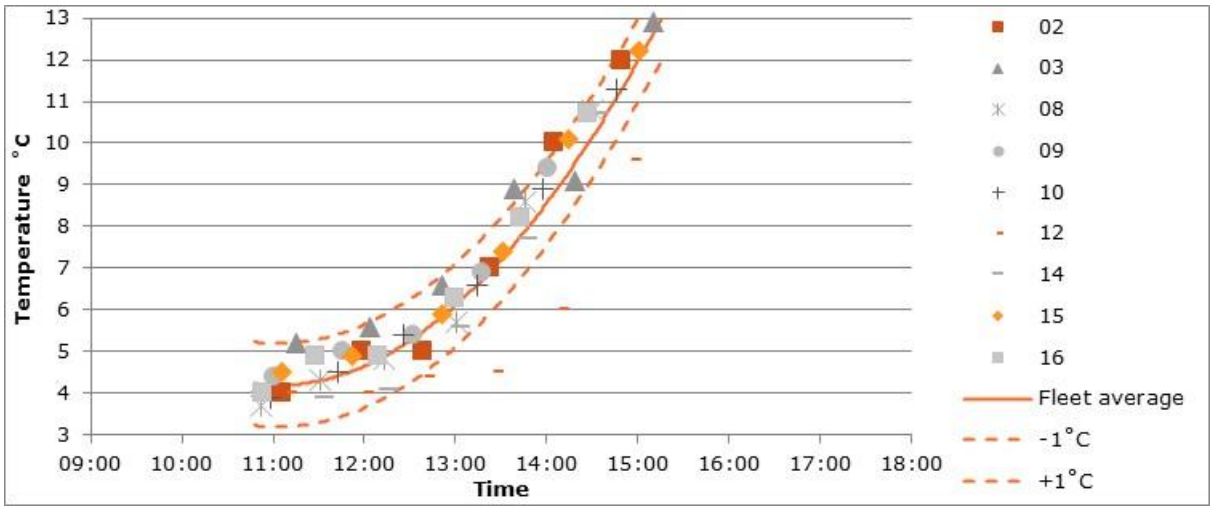

Figure 8.4: Comparison of operators' measurements against reference – Temperature test station 1, day 2

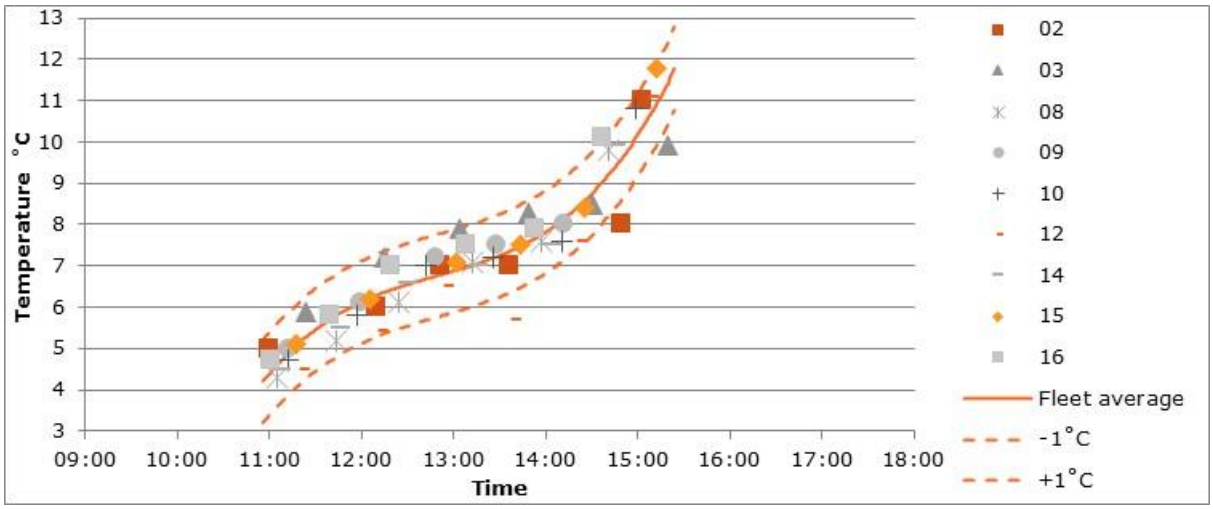

Figure 8.5: Comparison of operators' measurements against reference – Temperature test station 2, day 2

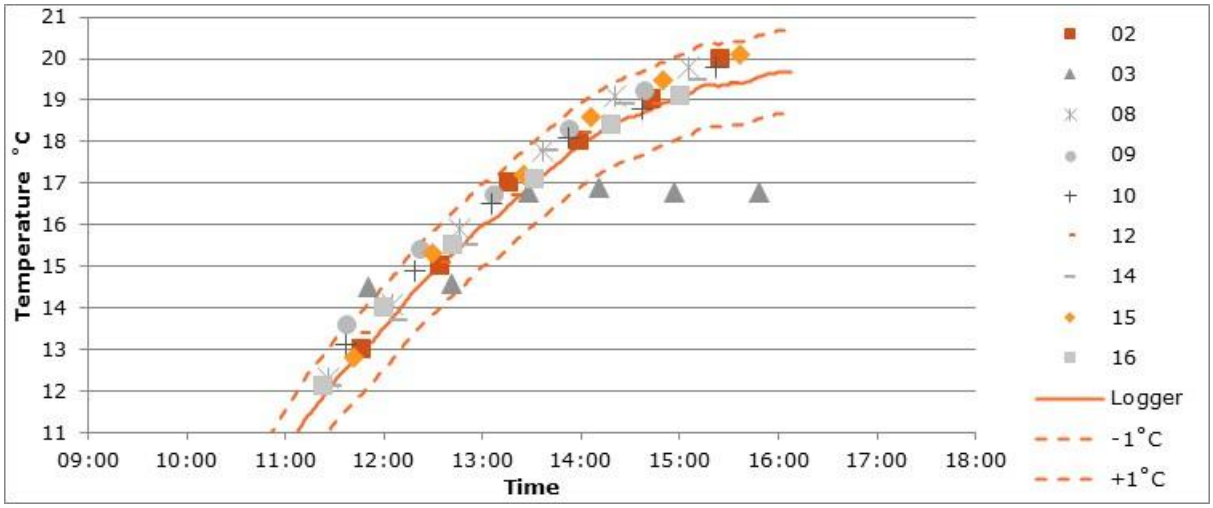

Figure 8.6: Comparison of operators' measurements against reference – Temperature test station 3 (water bucket), day 2

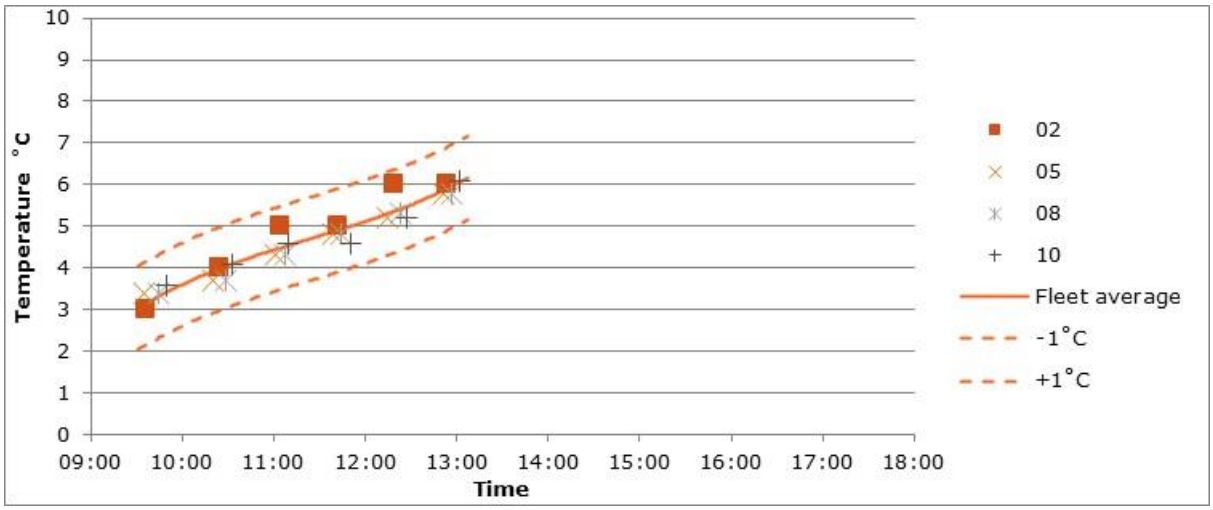

Figure 8.7: Comparison of operators' measurements against reference – Temperature test station 1, day 3

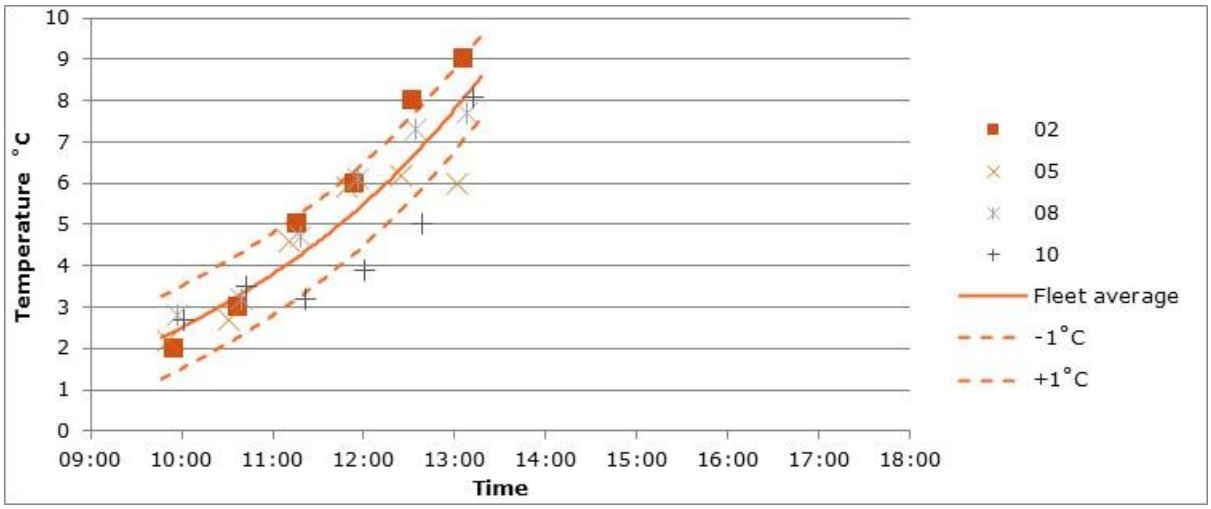

Figure 8.8: Comparison of operators' measurements against reference – Temperature test station 2, day 3

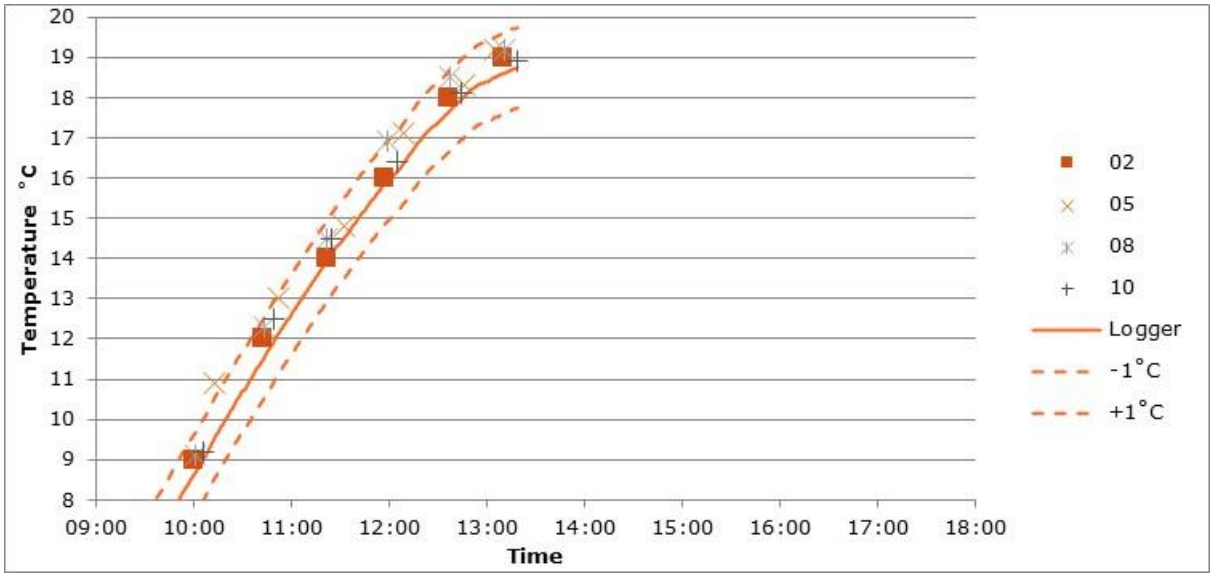

Figure 8.9: Comparison of operators' measurements against reference – Temperature test station 3 (water bucket), day 3

The differences between the operators' measured values and the reference are shown in Table 8.1 for station 1 , Table 8.2 for station 2 and Table 8.3 for the water bucket. Any measurements outside of the criterion are highlighted in red bold text. The overall summary performance for these measurements and performance band awarded to the operator is presented in Table 8.4.

Table 8.1: Difference between operators' 40mm measured values and the reference: station 1

ID	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	% within criteria
2	0.0	-0.2	-0.3	0.6	0.1	-0.2	-0.2	0.4	-0.5	0.1	1.2	0.7	92
3	1.0	0.1	-0.6	-1.5	.	.	1.0	0.9	0.8	1.3	-0.4	0.3	80
5	0.3	-0.2	-0.1	-0.1	-0.1	-0.1	.	.	.	.	.	.	100
8	-0.4	0.1	-0.4	0.0	0.7	-0.8	-0.5	0.0	-0.1	-0.4	0.7	0.6	100
9	0.7	0.2	-0.4	1.2	0.3	0.0	0.2	0.5	0.1	0.2	0.8	.	91
10	0.4	-0.2	-0.5	0.3	0.2	-0.2	-0.3	0.1	0.2	0.0	0.5	0.2	100
12	.	.	-0.9	0.2	-0.3	0.3	-0.2	-0.7	-1.1	-2.6	-3.0	-2.2	60
14	-1.0	-0.1	-0.2	-0.4	0.3	-0.3	-0.2	-0.4	-0.8	-0.6	-0.3	0.3	92
15	-0.1	0.5	0.0	0.1	0.7	0.2	0.3	0.4	0.1	0.1	0.8	0.2	100
16	0.3	-0.2	-0.5	0.7	0.3	0.0	-0.2	0.6	0.1	0.2	0.4	0.7	100

Table 8.2: Difference between operators' 40mm measured values and the reference: station 2

ID	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	% within criteria
2	-0.3	-1.1	0.3	-0.2	-1.0	0.0	0.6	-0.3	0.2	-0.3	-1.6	0.6	83
3	-0.5	1.0	-0.8	1.0	.	.	0.6	0.8	1.0	0.7	-0.3	-1.5	70
5	-0.1	-0.4	0.5	0.8	-0.2	-1.9	.	.	.	.	.	.	83
8	-0.4	-0.1	-0.2	-0.2	1.5	0.4	-0.3	-0.6	-0.4	0.1	-0.2	0.6	92
9	0.2	0.2	0.4	0.2	0.1	0.0	0.1	0.0	0.5	0.3	-0.1	.	100
10	-0.2	0.0	0.1	-0.2	0.2	0.0	-0.2	-0.3	0.3	0.0	-0.5	0.7	100
12	.	.	-0.4	-2.0	0.7	-0.8	-0.7	-0.9	-0.3	-1.7	-0.8	0.4	80
14	0.2	0.0	0.0	-0.1	-0.5	-0.4	-0.2	-0.4	0.1	-0.1	-0.4	0.5	100
15	0.4	0.2	0.1	0.2	-0.1	0.2	0.1	0.0	0.2	0.0	-0.2	0.9	100
16	0.5	0.4	0.0	0.8	0.0	0.3	0.3	0.1	0.6	0.5	0.2	1.1	92

Table 8.3: Difference between operators' measured values of water bucket and the reference

ID	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	% within criteria
2	-0.1	-0.3	-0.1	0.2	0.9	0.1	0.1	0.0	0.5	0.1	0.2	0.6	100
3	0.9	0.6	0.3	0.1	.	.	1.4	-0.7	-0.1	-1.3	-2.2	-2.8	60
5	1.4	0.8	0.3	0.7	0.3	0.7	.	.	.	.	.	.	83
8	0.5	0.2	0.4	0.8	0.5	1.0	0.3	0.3	0.4	0.6	0.7	0.7	92
9	1.1	0.3	0.6	0.7	0.5	0.4	1.0	0.8	0.5	0.6	0.5	.	82
10	0.7	0.1	0.2	0.4	0.4	0.3	0.6	0.5	0.4	0.4	0.1	0.4	100
12	.	.	0.1	0.1	-0.1	0.3	0.5	0.0	0.2	0.2	0.1	0.0	100
14	0.7	0.8	0.4	0.2	0.6	0.6	-0.1	-0.2	-0.2	0.5	0.3	0.2	100
15	0.5	0.7	0.5	0.6	0.7	0.8	0.1	0.4	0.4	0.5	0.6	0.7	100
16	0.3	0.2	0.0	-0.2	-0.1	0.0	0.2	0.5	0.2	0.1	0.0	0.0	100

Table 8.4: Summary of operators' at depth/water bucket performance

ID	% within criteria: Station 1	% within criteria: Station 2	% within criteria: Water bucket	Overall % within criteria	Performance band
2	92	83	100	92	High
3	80	70	60	70	Medium
5	100	83	83	89	High
8	100	92	92	94	High
9	91	100	82	91	High
10	100	100	100	100	High
12	60	80	100	80	High
14	92	100	100	97	High
15	100	100	100	100	High
16	100	92	100	97	High

Therefore, for the direct measurement of pavement temperature, nine machines achieved a high performance and one a medium.

8.2 Surface and Air temperatures, recorded by operators

Methodologies for estimating pavement temperature from measurements of surface and air temperatures have been developed for use with deflection surveys. These are included in CS 229 (DMRB CS 229, 2020) which permits Deflectograph survey contractors to use surface and air temperature measurements collected by devices fitted to the machines to estimate 40mm pavement temperatures.

At the trial, surface and air temperature data was supplied from six machines. Data was collected from the same two locations as the 40mm temperature holes (before and after the test sections) and next to the water bucket (after the distance measurement lengths). However, due to variations in vehicle positions at station 3 (which involves a layby with a different surfacing) this station has been excluded from the surface temperature assessment.

As with 40mm at depth measurements, it was identified that the logger measurements for air and surface were unsuitable for undertaking the assessment of the operator measurements. Therefore, for these assessments the operator measurements were assessed against the fleet average.

The day 3 measurements were used to assess Machine 5 against the other devices, as such this machine was excluded from the fleet average.

8.2.1 Surface temperatures recorded by operators

The results for stations 1 and 2 for the three days are shown in Figure 8.10 to Figure 8.15.

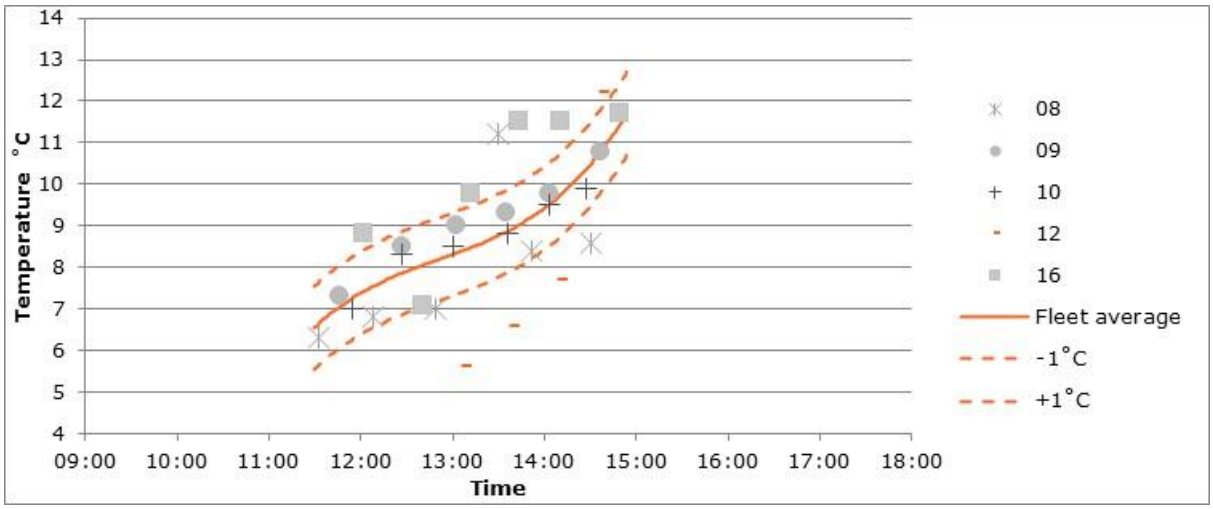

Figure 8.10: Comparison of Deflectograph recorded surface temperatures against reference – Temperature test station 1, day 1

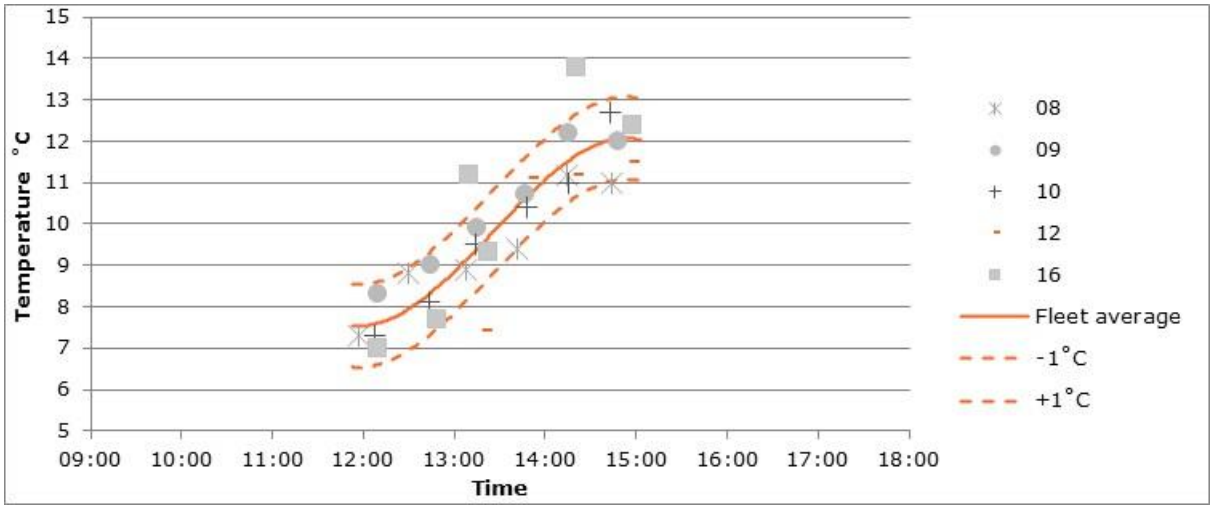

Figure 8.11: Comparison of Deflectograph recorded surface temperatures against reference – Temperature test station 2, day 1

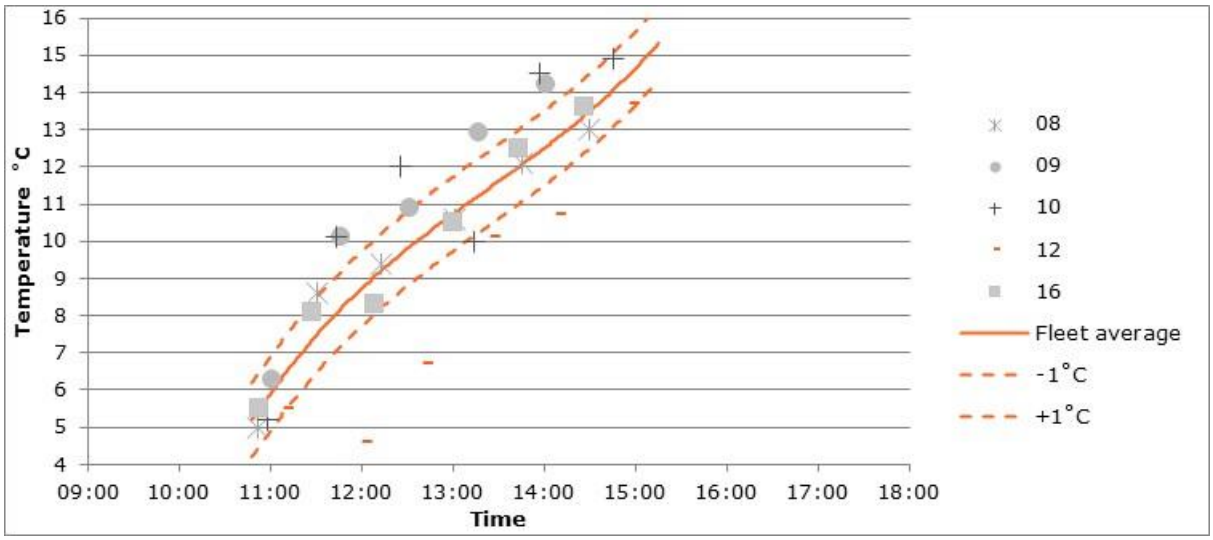

Figure 8.12: Comparison of Deflectograph recorded surface temperatures against reference – Temperature test station 1, day 2

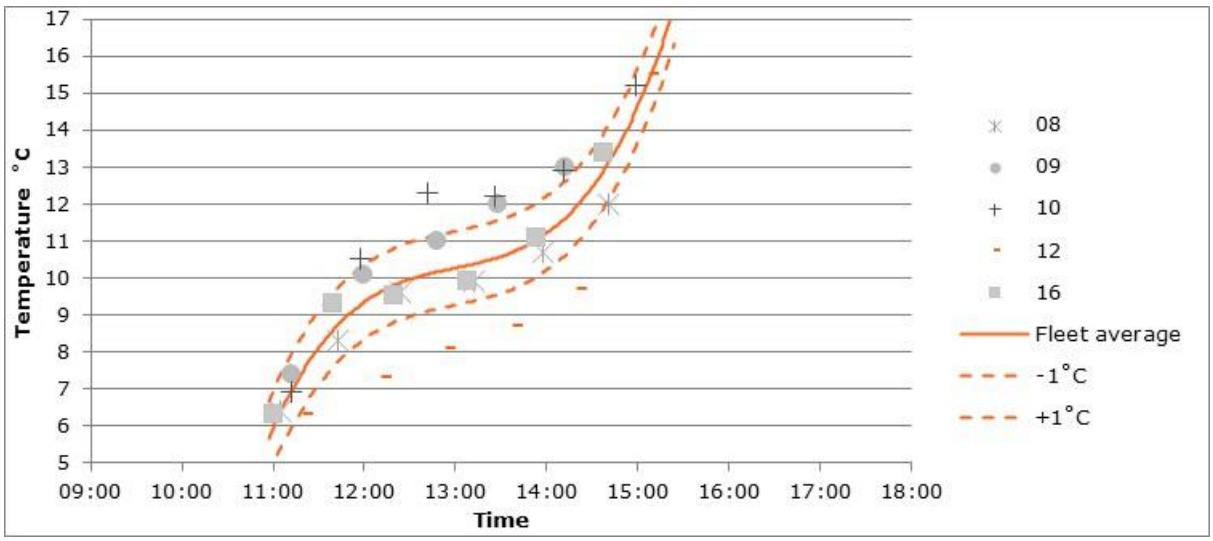

Figure 8.13: Comparison of Deflectograph recorded surface temperatures against reference – Temperature test station 2, day 2

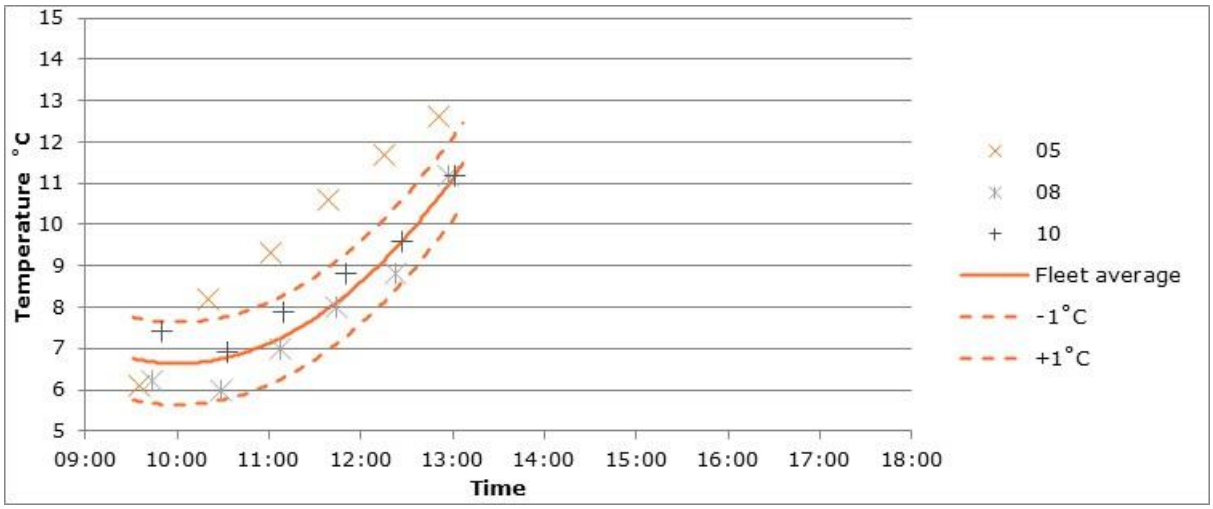

Figure 8.14: Comparison of Deflectograph recorded surface temperatures against reference – Temperature test station 1, day 3

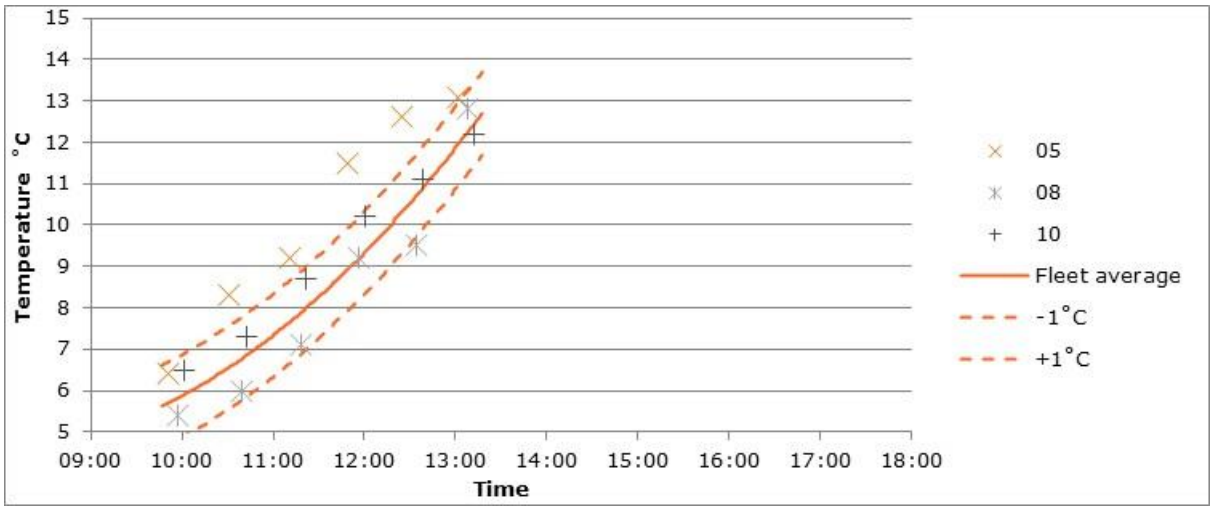

Figure 8.15: Comparison of Deflectograph recorded surface temperatures against reference – Temperature test station 2, day 3

The differences between the operators' measured surface temperatures and the reference values (the fleet mean) are shown in Table 8.5, and Table 8.6 for station 1 and 2 respectively. Any measurements outside of the criterion are highlighted in red bold text. The overall summary performance for these measurements and performance band awarded to the operator is presented in Table 8.7.

Table 8.5: Difference between operators' surface temperature values and the reference: station 1

ID	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	% within criteria
5	-0.6	**1.5**	**2.2**	**2.6**	**2.6**	**1.9**	.	.	.	.	.	.	17
8	-0.4	-0.7	**-1.2**	**2.4**	-0.8	**-1.9**	-0.4	**1.1**	0.2	-0.2	0.0	-0.5	67
9	0.3	0.6	0.6	0.4	0.3	0.0	0.3	**1.9**	**1.0**	**1.7**	**1.7**	.	64
10	-0.3	0.4	0.2	-0.1	0.0	-0.5	-0.6	**2.1**	**2.3**	**-1.1**	**2.1**	0.8	67
12	.	.	**-2.8**	**-2.3**	**-2.0**	**1.4**	**-1.0**	**-4.2**	**-3.5**	**-1.4**	**-2.1**	-0.8	20
16	**1.4**	**-1.0**	**1.3**	**2.5**	**1.7**	0.3	0.0	0.7	-0.8	-0.2	0.5	0.2	67

Table 8.6: Difference between operators' surface temperature values and the reference: station 2

ID	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	% within criteria
5	0.7	**1.7**	**1.5**	**2.6**	**2.3**	**1.1**	.	.	.	.	.	.	17
8	-0.2	0.9	-0.2	**-1.0**	-0.3	**-1.0**	0.0	-0.4	-0.3	-0.5	-0.4	**-1.1**	75
9	0.7	0.7	0.5	0.1	0.7	-0.1	0.4	0.8	0.8	**1.4**	**1.4**	.	82
10	-0.3	-0.2	0.1	-0.3	-0.5	0.7	-0.1	**1.2**	**2.2**	**1.7**	**1.3**	0.6	67
12	.	.	**-2.2**	0.4	-0.4	-0.6	**-1.3**	**-2.4**	**-2.1**	**-2.0**	**-2.3**	0.0	40
16	-0.6	-0.8	-0.4	**2.0**	**2.1**	0.3	0.3	0.7	-0.3	-0.4	0.1	0.5	83

Table 8.7: Summary of operators' surface temperature performance

ID	% within criteria: Station 1	% within criteria: Station 2	Overall % within criteria	Performance band
5	17	17	17	Low
8	67	75	71	Medium
9	64	82	73	Medium
10	67	67	67	Medium
12	20	40	30	Low
16	67	83	75	Medium

For surface temperature measurements, four machines achieved a medium performance, and two a low.

8.2.2 Air temperatures recorded by operators

The air temperature data supplied from the operators are shown in Figure 8.16 to Figure 8.24.

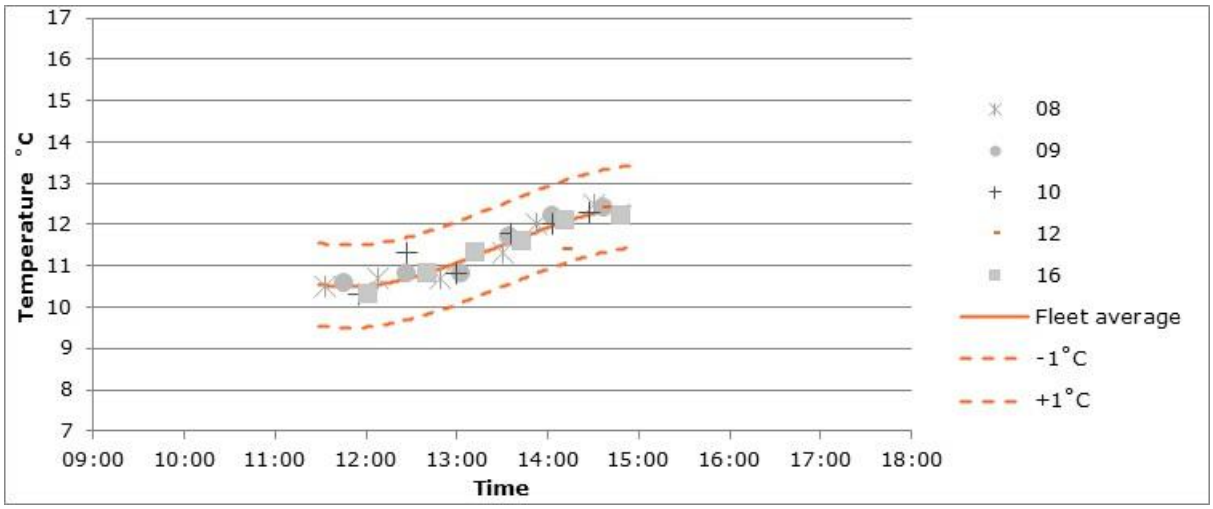

Figure 8.16: Comparison of Deflectograph recorded air temperatures against reference – Temperature test station 1, day 1

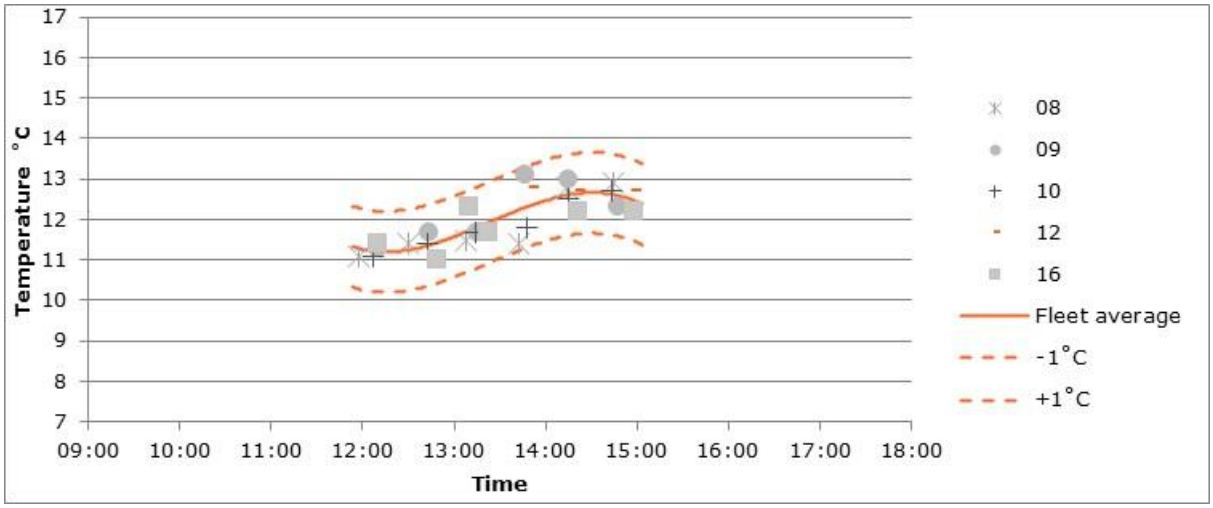

Figure 8.17: Comparison of Deflectograph recorded air temperatures against reference – Temperature test station 2, day 1

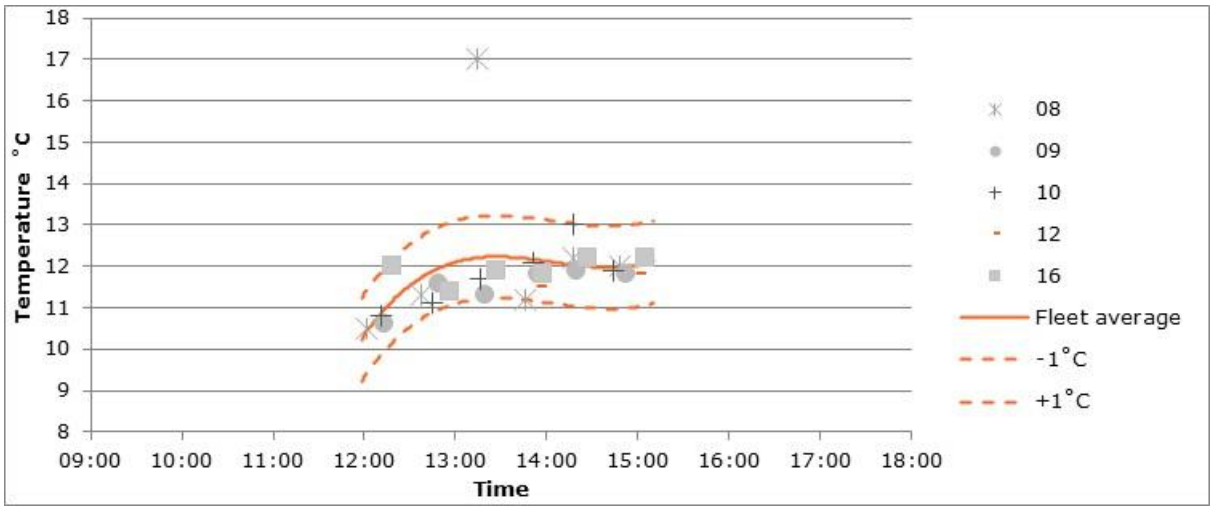

Figure 8.18: Comparison of Deflectograph recorded air temperatures against reference – Temperature test station 3, day 1

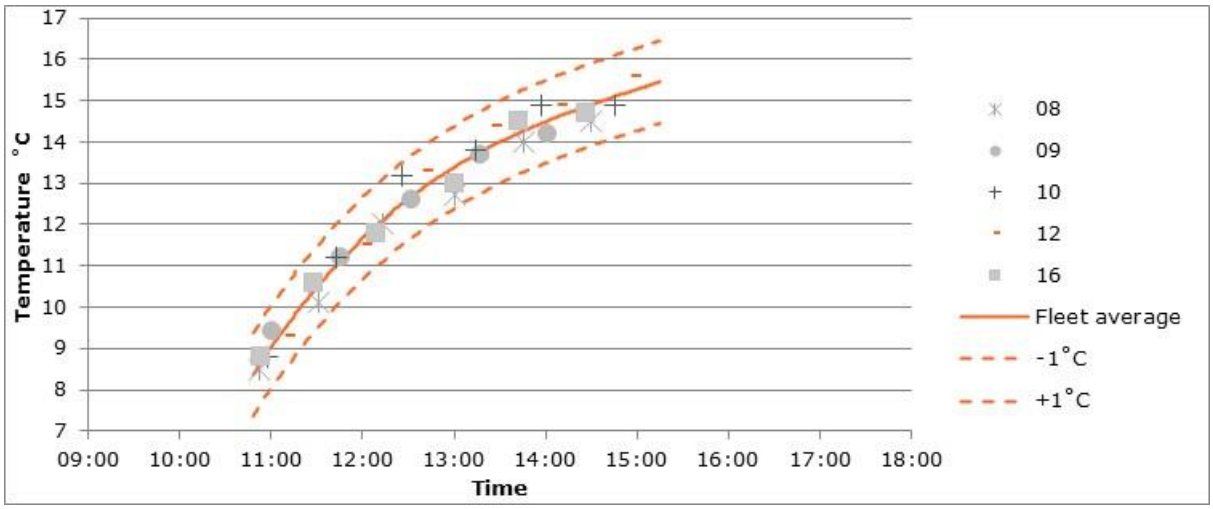

Figure 8.19: Comparison of Deflectograph recorded air temperatures against reference – Temperature test station 1, day 2

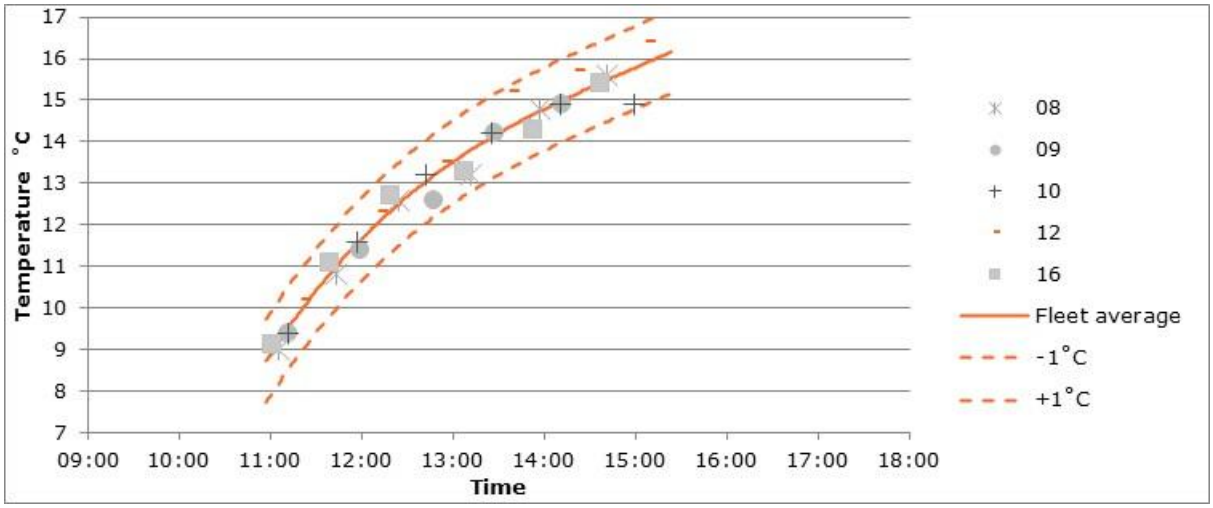

Figure 8.20: Comparison of Deflectograph recorded air temperatures against reference – Temperature test station 2, day 2

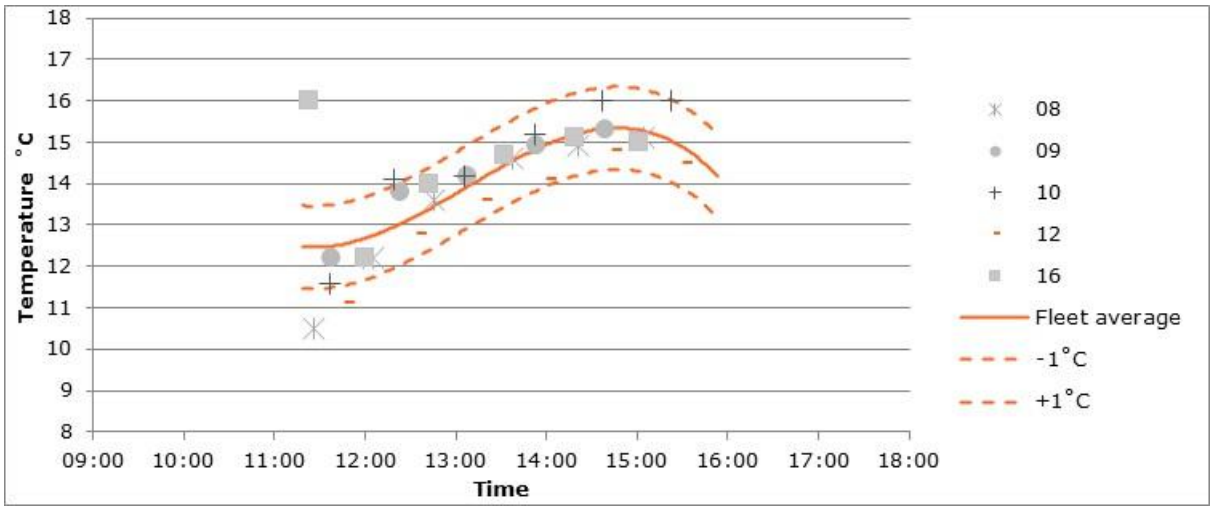

Figure 8.21: Comparison of Deflectograph recorded air temperatures against reference – Temperature test station 3, day 2

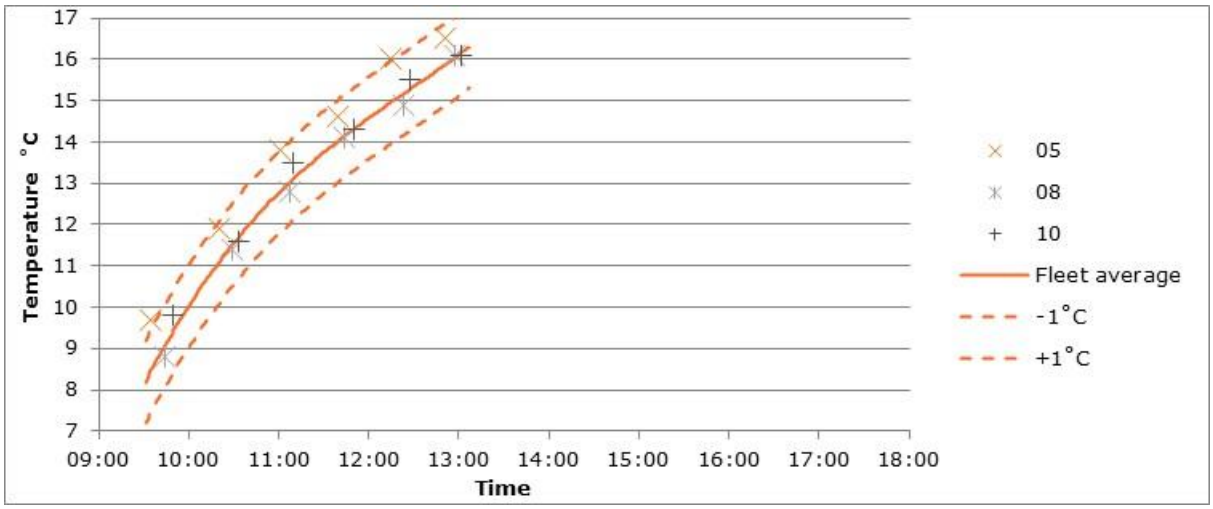

Figure 8.22: Comparison of Deflectograph recorded air temperatures against reference – Temperature test station 1, day 3

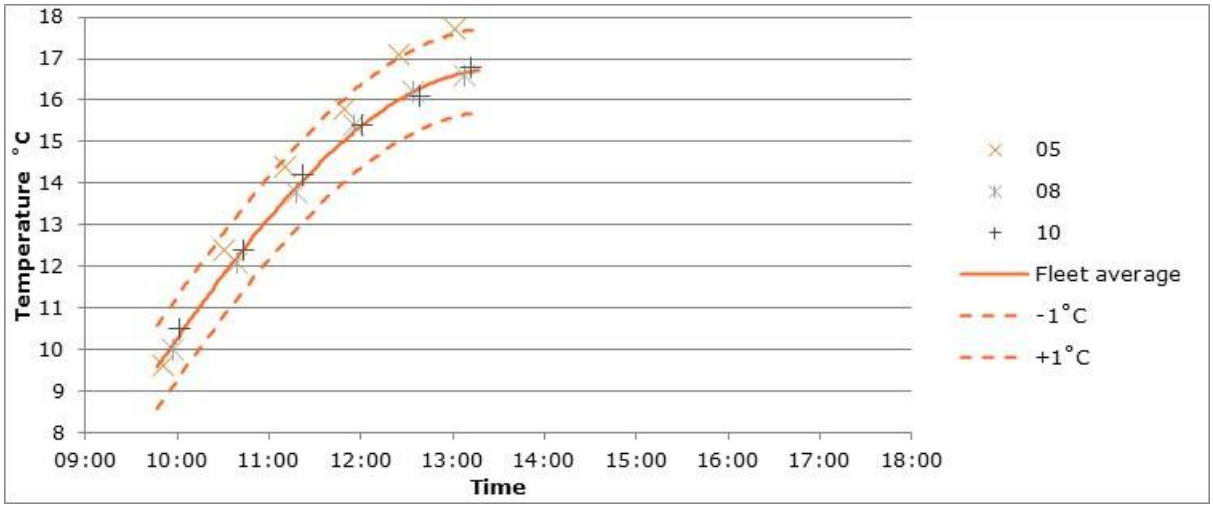

Figure 8.23: Comparison of Deflectograph recorded air temperatures against reference – Temperature test station 2, day 3

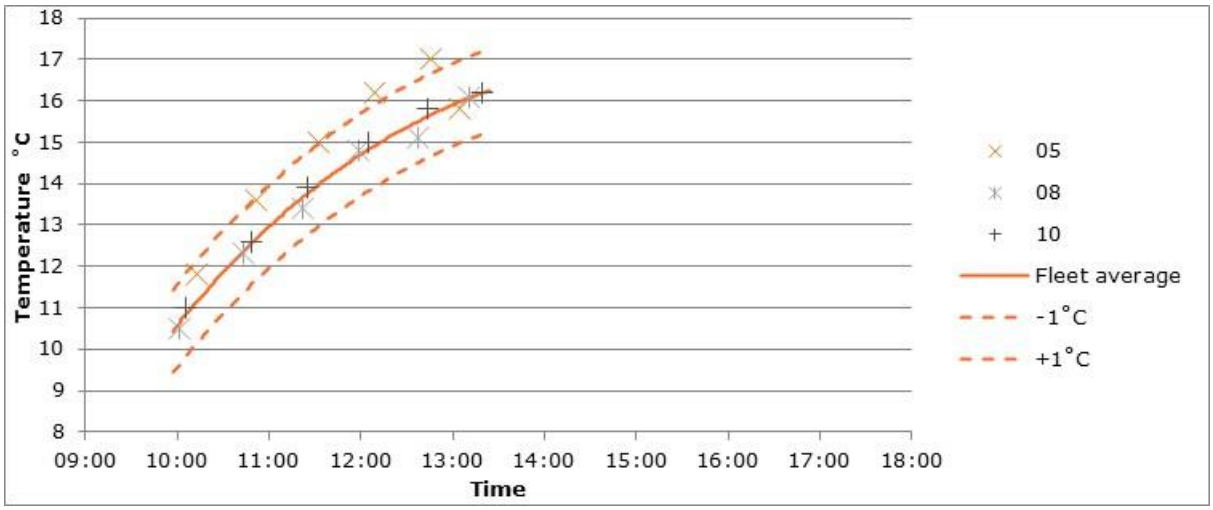

Figure 8.24: Comparison of Deflectograph recorded air temperatures against reference – Temperature test station 3, day 3

The differences between the operators' measured air temperatures and the reference values (the fleet mean) are shown in Table 8.8 for station 1, Table 8.9 for station 2 and Table 8.10 for station 3. Any measurements outside of the criterion are highlighted in red bold text. The overall summary performance for these measurements and performance band awarded to the operator is presented in Table 8.11.

Table 8.8: Difference between operators' air temperature values and the reference: station 1

ID	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	% within criteria
5	**1.2**	0.8	1.0	0.6	**1.0**	0.6	.	.	.	.	.	.	67
8	0.0	0.2	-0.2	-0.2	0.2	0.2	-0.1	-0.4	-0.1	-0.7	-0.3	-0.4	100
9	0.1	0.1	-0.3	0.1	0.2	0.1	0.3	0.1	-0.1	-0.1	-0.3	.	100
10	-0.2	0.6	-0.3	0.2	0.0	0.1	-0.1	0.2	0.7	0.1	0.5	-0.2	100
12	.	.	0.0	0.1	-0.7	0.1	-0.2	-0.2	0.4	0.5	0.3	0.4	100
16	-0.2	0.0	0.1	-0.1	0.0	-0.2	0.2	0.2	-0.2	-0.4	0.3	-0.2	100

Table 8.9: Difference between operators' air temperature values and the reference: station 2

ID	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	% within criteria
5	-0.2	0.6	0.8	0.8	**1.1**	**1.1**	.	.	.	.	.	.	67
8	-0.2	0.1	-0.2	-0.8	0.2	0.3	-0.2	-0.2	0.1	-0.6	0.1	0.1	100
9	0.1	0.3	-0.1	0.8	0.4	-0.3	-0.1	-0.2	-0.6	0.0	-0.1	.	100
10	-0.1	0.0	-0.1	-0.5	-0.1	0.1	-0.1	0.1	0.2	0.1	-0.1	-0.9	100
12	.	.	-0.1	0.5	0.1	0.2	0.2	0.2	0.1	0.8	0.6	0.5	100
16	0.2	-0.4	-0.2	0.6	-0.4	-0.3	0.1	0.3	0.4	-0.4	-0.4	0.0	100

Table 8.10: Difference between operators' air temperature values and the reference: station 3

ID	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	% within criteria
5	0.7	0.9	**1.0**	**1.3**	**1.3**	-0.2	.	.	.	.	.	.	50
8	0.1	-0.4	4.8	**-1.0**	0.2	0.0	**-2.0**	-0.5	0.1	0.1	-0.3	-0.2	83
9	-0.3	-0.4	-0.9	-0.4	-0.1	-0.2	-0.3	0.8	0.3	0.1	0.0	.	100
10	-0.1	-0.8	-0.5	-0.1	1.0	-0.1	-0.9	**1.1**	0.3	0.4	0.7	1.0	92
12	.	.	-0.1	-0.7	0.3	-0.2	**-1.4**	-0.4	-0.5	-0.9	-0.5	-0.4	90
16	0.9	-0.7	-0.3	-0.3	0.2	0.1	**3.5**	-0.5	0.6	0.3	-0.1	-0.3	92

Table 8.11: Summary of operators' air temperature performance

ID	% within criteria: Station 1	% within criteria: Station 2	% within criteria: Station 3	Overall % within criteria	Performance band
5	67	67	50	61	Medium
8	100	100	83	94	High
9	100	100	100	100	High
10	100	100	92	97	High
12	100	100	90	97	High
16	100	100	92	97	High

For air temperature measurements, five machines achieved a high performance, and one a medium.

9 Distance measurement assessment

The main testing on distance measurement was undertaken on day 2, apart from Machine 5 (which was not present on day 2) which undertook the distance measurement assessment on day 3. For this assessment a distance check length was set up on the track and the survey crews were asked to test the length and to note down the distance measured. This involves reviewing the survey file and identifying the length between the two marker points. The crews were also asked to provide these survey files. During day 2, the reference length used was 572m and on day 3 it was 485m.

The differences between the measured length from each machine and the reference length, along with the overall performance, are given in Table 9.1. Where the difference between the machine and the reference exceeds the threshold for the criteria as set out in Section D.1, it is highlighted in red.

Table 9.1: Difference between operator's distance measurements and the reference

ID	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	% within criteria	Performance
2	1.0	0.0	0.0	-1.0	-2.0	-2.0	100	Pass
3	-4.0	-3.0	-4.0	-4.0	-3.0	-4.0	100	Pass
5	**-7.0**	1.0	1.0	-2.0	1.0	.	80	Pass
8	0.0	-3.0	-2.0	-2.0	-4.0	-3.0	100	Pass
9	-2.0	-5.0	-3.0	-3.0	-4.0	-2.0	100	Pass
10	-2.0	-2.0	-2.0	-2.0	-4.0	-1.0	100	Pass
12	-3.0	0.0	-2.0	-2.0	-5.0	-5.0	100	Pass
14	0.0	-1.0	0.0	-1.0	0.0	-1.0	100	Pass
15	-4.0	-2.0	-4.0	-5.0	-4.0	-2.0	100	Pass
16	-2.0	-4.0	-2.0	-3.0	-2.0	-4.0	100	Pass

From Table 9.1 it can be seen that all ten machines met the distance measurement requirement.

Note: test 1 for machine 5 was noticeably different to the other tests due to the operator misunderstanding the positions of the start and end points for the test.

10 Conclusions

The 2025 National Deflectograph accreditation trials were held on the Horiba-MIRA proving grounds by TRL on behalf of National Highways in the week beginning the 3rd March 2025. Ten machines, which is thought to constitute the whole of the current UK fleet of Deflectographs, attended the trial.

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

(I) Wheel Weights

All ten machines that participated in the trial were within the wheel and axle limits.

(II) Deflection measurement

All ten machines that participated in the trial met the criteria for deflection measurement. One machine (Machine 03) has been identified as requiring additional monitoring during the year.

(III) Distance measurement

All ten machines that participated in the trial met the criteria for distance measurement.

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

(IV) Temperature measurement – measurement at depth

Nine of the ten operators achieved a high performance with regards to the measurement of temperature at depth. One machine achieved a medium.

(V) Temperature measurement – surface temperature

Surface temperature data from six machines was supplied at this trial. Four machines achieved a medium performance, and two achieved a low.

(VI) Temperature measurement – air temperature

Air temperature data from six machines was supplied at this trial. Five machines achieved a high performance, and one achieved a medium.

A summary of the machines that attended the 2025 accreditation trial and the criteria that they met/performance achieved can be found in Appendix A.

References

Brittain, S., & Sanders, P. (2012). *Deflectograph accreditation transitional trial (CPR1299).* Crowthorne: TRL.

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

TRL. (2020). *Accreditation and Quality Assurance of Deflectograph Survey Devices [online]. [Accessed 22nd February 2021].* https://ukrlg.ciht.org.uk/ukrlg-home/guidance/road-condition-information/data-collection/deflectograph/.

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Appendix A Machine identification

Table A.1: Machine identification

ID	Operator at trial date	Registration number	Deflection	Distance	Temperature at 40mm	Surface temperature	Air temperature
2	PTS Ltd	L697 BKR	Pass	Pass	High	No data	No data
3	TRL Ltd	B180 FBL	Pass*[1]	Pass	Medium	No data	No data
5	WDM Ltd	D962 JRU	Pass	Pass	High	Low	Medium
8	WDM Ltd	BYW 80V	Pass	Pass	High	Medium	High
9	WDM Ltd	VGV 182X	Pass	Pass	High	Medium	High
10	WDM Ltd	F569 JBB	Pass	Pass	High	Medium	High
12	WDM Ltd	EOU 230W	Pass	Pass	High	Low	High
14	Lincolnshire County Council	B195 CFW	Pass	Pass	High	No data	No data
15	DFI Roads	ACZ 3268	Pass	Pass	High	No data	No data
16	WDM Ltd	B880 XOU	Pass	Pass	High	Medium	High

[1] Subject to additional monitoring during the course of the year.

Appendix B Layout of test sections at Horiba-MIRA

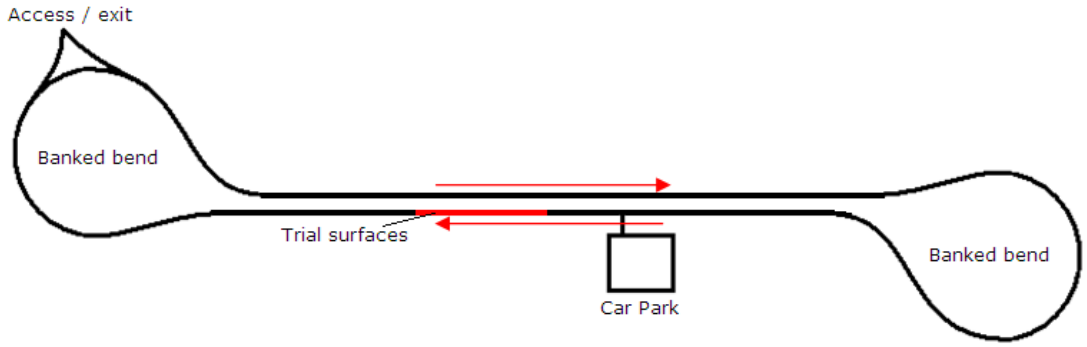

Figure B.1: Test route on the Horiba-MIRA twin straights

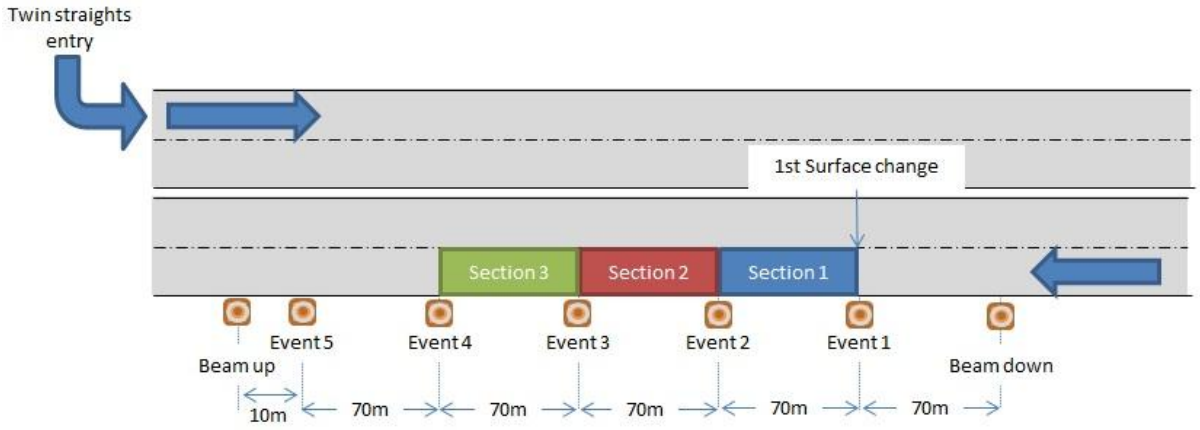

Figure B.2: Location of marker cones and test sections on Horiba-MIRA twin straights

Appendix C Construction details for Horiba-MIRA test sections

Table C.1: Nominal construction details for design construction of Horiba-MIRA site

Section	Surface course (mm)	Binder course (mm)	Total asphalt thickness (mm)	Sub-base (mm)
NHCP_01	30 TSC	235 EME2	270	200mm C8/10 HBM
NHCP_02	35 TSC	170 DBM	200	250mm 6F1 granular capping material
NHCP_03	30 TSC	170 EME2	200	200 Type 1 granular material

Notes: TSC = Cl 942 Thin Surface Course EME2 = Enrobé à Module Élevé, DBM = Dense Bitumen Macadam, HBM = Hydraulically Bound Material, 6F1 = Selected granular capping.

Table C.2: Post construction details for Horiba-MIRA site from cores

Section	Surface course (mm)	Binder/ Binder+ base courses (mm)	Total asphalt thickness (mm)	Base (mm)
NHCP_01	42 TSC	228	270	217 (HBM)
NHCP_02	37 TSC	158	192	-
NHCP_03	35 TSC	191	226	-

Notes: TSC = Cl 942 Thin Surface Course EME2 = Enrobé à Module Élevé, DBM = Dense Bitumen Macadam, HBM = Hydraulically Bound Material

Table C.3: Construction details for Horiba-MIRA site from GPR (mm)

Section	Minimum	Average	Maximum	Material
NHCP_01 (Asphalt)	192	242	272	Asphalt
NHCP_01 (HBM)	166	188	215	HBM
NHCP_01 (Total bound thickness)	388	431	468	Total bound thickness
NHCP_02	167	192	240	Asphalt
NHCP_03	167	199	240	Asphalt

Notes: HBM = Hydraulically Bound Material

Appendix D Criteria for acceptability

The accreditation trial criteria are specified in "Accreditation and Quality Assurance of Deflectograph Survey Devices" (TRL, 2020). This document is a live document (i.e. is subject to change) and the most recent (June 2020) version of the document was used for the trial. The relevant section of the document is reproduced verbatim (including the corresponding section labels in the document) below in Section D.1. Note in the text below, "Equipment" is a defined term and refers to the overall machine being assessed, incorporating the measuring systems and the survey vehicle. "System" refers to an individual measurement system installed on the Equipment e.g. the NS deflection measurement system, temperature 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. Note that the copied text refers to other parts of the accreditation document which are not reproduced in this report.

D.1 Trial criteria from the Accreditation and QA document

E3. Equipment inspection

E3.1 Contractors should be provided with an inspection check sheet which they shall complete and provide to the Auditor *in advance* of the Trial. The Contractors should also be asked to supply evidence that the required Calibrations have been performed (see section C.4).

E3.2 Equipment should also be inspected at the trial to ensure that they are in a suitable condition to conduct the tests. This should include verifying that the Equipment appears to be in good general mechanical order.

E3.3 Equipment shall be weighed so that Load normalisation of the survey data can be carried out. The Equipment shall be within the limits given in Table 1.

Table 1 – Criteria for wheel weights

Parameter	Acceptability Limit
Front Axle	4500 kg ±5%[2]
Twin rear wheel	3175 kg±10%

[2] It has been the experience in the Accreditation Trials that Equipment falling within 15% above the target limit for the front axle has performed acceptably with regards to deflection measurements. This matter has been investigated by TRL and Highways England. It has been concluded that, while consideration may be given to revising the specification limits at an appropriate point in the future, for the time being Equipment falling within this expanded front axle range would continue to be regarded as acceptable provided that they performed satisfactorily in the dynamic tests.

E3.4 A simple assessment of the temperature probe used for the direct measurement method should be carried out to make sure that it is producing consistent results.

E3.5 Equipment which has infra-red temperature sensors for determining surface temperature fitted should be checked to confirm that the emissivity settings have been set to the manufacturer's recommended setting for asphalt.

E.4 Running Trials

E4.1 Overview

E4.1.1 As detailed in in Appendix B, trials shall be carried out on a test site separated into test stations, and laid out such that "laps" of the set of test sections can be undertaken by the Fleet for the purposes of repeating the measurements.

E4.2 Deflection testing – Mandatory Requirement

E4.2.1 The assessment for Deflection measurements is described below, and a worked example is provided in Appendix C

E4.2.2 The Equipment shall undertake laps so that the following criteria are met:

- At least 5 laps are undertaken that comply with the requirements for Reference Data (see Appendix B, App B.3)
- Survey data shall be collected at a test speed of 2.4±0.1 km/h. Equipment shall be checked by measuring the time taken to travel a known length. If the Equipment is found to be surveying outside the test speed range, the survey operator shall be asked to adjust their speed accordingly. Laps for Equipment where the survey speed requirements are not met shall be excluded from the assessment.
- Instances where the rate of change in temperature measured at 40mm is greater than 2.5˚C per hour measured over a period of 15 minutes shall be investigated. If the variation of deflection data is seen to be to large then the lap should be disregarded and an additional lap undertaken.

E4.2.3 The Contractor shall supply the deflection measurements for their Equipment from each test lap in the file formats specified by the Auditor.

E4.2.4 The Auditor shall calculate:

- The load corrected mean for the Equipment for each wheel path and test section.
- The standard deviation of these mean values for the Fleet and for all of the Equipment at the trial, referred to as the Fleet between-Equipment standard deviation (BESD) and the Trial BESD. These values shall be used to assess the consistency of the Equipment at the Trial.
- The standard deviation of the deflection values between laps for the Equipment for each wheel path and test section. This data is referred to as the between-run standard deviation (BRSD). These values shall be used to assess the repeatability of each individual Equipment.

E4.2.5 The BRSD shall be used in the initial assessment of each Equipment. During the Tests, the BRSD values will be affected by the variability of pavement temperatures during the course of the testing. Therefore the performance shall be assessed by comparison against the performance of the other Equipment undertaking the Re-accreditation/Accreditation Tests.

E4.2.6 Where the BRSD values of the Equipment are significantly higher than the BRSD values of other individual Fleet Equipment, the data from the Equipment shall undergo further investigation by the Auditor to determine if the Equipment is suitable for Accreditation.

E4.2.7 The Trial BESD is acceptable if it is below the criterion given in Table 2. If the trial BESD exceeds this criterion then the data shall be further examined to identify outlying Equipment. This shall include examining the Fleet BESD and data from individual Equipment. Outlying Equipment shall be rejected and the data reassessed until the performance is acceptable.

E4.2.8 In addition, any Equipment that deviates by more than 3 times the BESD criterion from the Fleet Mean shall fail Accreditation. Any Equipment that is between two and three times the BESD criterion from the Fleet mean shall undergo further investigation by the Auditor to determine if the Equipment is suitable for Accreditation.

E4.2.9 The data from any Equipment rejected due to BRSD, BESD or otherwise identified as an outlier shall not be used in the calculation of the Reference Data (App B.3.1).

Table 2 – Criterion for Deflection measurements

Parameter	Acceptability Limit
Between Equipment standard deviation (BESD)	≤0.0257 * Reference Data+9.88 (µm)

E4.2.10 The performance shall be assessed for both wheel paths separately. To achieve Accreditation the Equipment shall meet the requirements for both the NS wheel path and the OS wheel path.

E4.2.11 In addition to the above assessments the Auditor should review the profiles of the Survey Data over the site for each Equipment and investigate any anomalies. Based on the results of the investigation the Auditor may withhold Accreditation for Equipment and/or issue an Improvement Notice as detailed in Section H.

E4.3 Location Referencing (Distance) – Mandatory Requirement

E4.3.1 Accreditation of an Equipment's ability to measure distance is carried out by comparing its measurements of a test length with the Reference Data (App B.3.2), repeated at least five times. The criteria applied to the test measurements are given in Table 3. Note: the tolerance allows for the basic method by which events are recorded in Deflectograph Survey Data.

Table 3 – Criteria for Measurement of Distance travelled

Parameter	Acceptability Limit
Distance measured	≥80% within 5m

E.5 Additional Tests

E5.1 Overview

E5.1.1 The criteria in this sub-section are specified as High, Medium and Low levels of performance. This reflects the lower level of maturity of this test. In future revisions to this document these may become mandatory criteria.

E5.1.2 Some Employers may require a specific level of performance in some or all of these additional tests to carry out Accredited Surveys on their Network.

E5.2 Temperature measurement – direct measurement method

E5.2.1 If undertaking this test, the Contractor should be required to make measurements from holes supplied by the Auditor (40mm depth) so that at least eight measurements are taken during the course of the test laps. These probes are required to provide results to a resolution equal to or better than 0.1˚C. Therefore if the probe does not then it shall 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 the direct measurement method are given in Table 4.

Table 4– Criteria for direct measurement method

Performance level	Measurement of temperature
High	≥80% of the measurements are within 1.0ºC of the reference
Medium	≥50% of the measurements are within 1.0ºC of the reference
Low	≥15% of the measurements are within 1.0ºC of the reference
Not Suitable	Otherwise

E5.3 Temperature measurement –Contactless measurement

E5.3.1 If undertaking this test, the Contractor shall be required to make measurements of the air and surface temperature (at locations specified by the Auditor) so that at least eight pairs of measurements are taken during the course of the test laps. These sensors are required to provide results to a resolution equal to or better than 0.1˚C. Therefore if the sensor does not then it shall 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 surface temperature measurement are given in Table 5 and the assessment of air temperature measurement are given in Table 6.

Table 5– Criteria for surface temperature measurement

Performance level	Measurement of temperature
High	≥80% of the measurements are within 1.0ºC of the reference
Medium	≥50% of the measurements are within 1.0ºC of the reference
Low	≥15% of the measurements are within 1.0ºC of the reference
Not Suitable	Otherwise

Table 6– Criteria for air temperature measurement

Performance level	Measurement of temperature
High	≥80% of the measurements are within 1.0ºC of the reference
Medium	≥50% of the measurements are within 1.0ºC of the reference
Low	≥15% of the measurements are within 1.0ºC of the reference
Not Suitable	Otherwise

E5.3.2 In addition to providing the air and surface temperatures the Survey Contractor shall provide the predicted temperature at 40mm depth using this data. The Auditor may allow Survey Contractors to provide these predicted temperatures after the trial to allow for processing time. The Auditor shall confirm on the Accreditation Certificate whether the calculations have been accurately calculated.

National Highways 2025 Deflectograph 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 Deflectograph devices by ongoing QA for the devices. In order to undertake accredited surveys, the survey devices are required to meet the mandatory criteria of the trial.

This report covers the 2025 accreditation trial run by TRL and held on the HORIBA-MIRA proving ground between 4th and 6th of March 2025.

Other titles from this subject area

PPR2041 National Highways 2024 Deflectograph Accreditation Trial. S Brittain. 2026

PPR2040 National Highways 2023 Deflectograph Accreditation Trial. S Brittain. 2026

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