Arup**Acoustics**

London & Continental Stations & Property Ltd.

St Pancras Station

Baseline Internal Noise Monitoring

Report No. AAc/112460/R01-SJ

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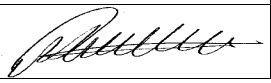
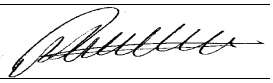
		Signature			
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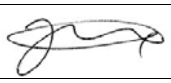
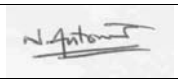
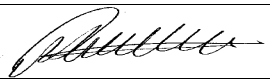
		Signature			
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EXECUTIVE SUMMARY

The purpose of this report is to establish the typical internal noise level inside the Barlow Shed at St Pancras that can then be used in a further exercise to predict and assess the impact of noise from the future CTRL construction work inside the station on station users and occupiers.

Arup Acoustics carried out an internal noise survey at St Pancras Station's Barlow Shed over five days, from 12.30 hrs Friday 25 October 2002 to 12.30 hrs Tuesday 29 October 2002. Additional measurements were also obtained on Friday 8th November.

Two different types of measurement were undertaken:

- unattended continuous noise monitoring during the five days, to evaluate diurnal variation in the internal noise levels; and
- attended monitoring at two key positions: one on the main concourse and the other part of the way along the Barlow Shed, to evaluate any variation in the internal noise levels within the train shed.

The five day record included the noisiest period on Friday evening (1700 hrs to 1800 hrs) and full diurnal variation Monday 0600 hrs to Tuesday 0600 hrs. Whilst monitoring was also undertaken over the weekend, the station was closed over this period to enable some advanced construction works associated with the CTRL project to be progressed and for the occupiers of the east side offices to be moved to temporary offices between platforms 5 and 6. The measured noise levels are therefore not representative of the stations typical usage (without CTRL).

This document states the measurement procedures and results of the noise surveys.

The surveys identified that general operation of the station results in high noise levels on the concourse and platform areas particularly at peak-hours. The main noise sources are train diesel engines.

1. ENVIRONMENTAL NOISE SURVEY DETAILS – ARUP ACOUSTICS

1.1 Date and Times of Surveys

Arup Acoustics undertook the survey on the following dates;

- Friday 25 October 2002, 12.30 hrs to Tuesday 29 October 2002 12.30 hrs; and
- Friday 8 November 2002, 14:30 hrs to 18:15 hrs.

The unattended monitoring equipment operated without interruption between Friday 25 October and Tuesday 29 October.

1.2 Personnel

- Seb Jouan, of Arup Acoustics;
- Rory Huston of Arup Acoustics; and
- Vahndi Minah of Arup Acoustics.

1.3 Equipment

1.3.1 Unattended Survey Equipment

- Brüel & Kjaer 2231 Modular Precision Sound Level Meter;
- Brüel & Kjaer BZ 7115 Statistical Analyser; and
- Brüel & Kjaer 4320 Calibrator.

1.3.2 Attended Survey Equipment

- Brüel & Kjaer 2260 Modular Precision Sound Level Meter; and
- Brüel & Kjaer 4231 Calibrator.

1.4 Procedure

1.4.1 Unattended Survey

Equipment was set up behind the construction temporary hoarding that blocks the original staircase that provided access to the London Underground's concourse and ticket hall areas. The hoarding is located on the east side of the WH Smith shop, see Picture 1.

PICTURE 1: Position 1 of the microphone for the unattended survey

This position was chosen as it represents the noise levels experienced in the main concourse areas but enabled unattended data logging equipment to be kept secure.

The noise levels were measured using the Brüel & Kjaer 2231 Modular Precision Sound Level Meters set up with the Brüel & Kjaer BZ 7115 Statistical Analyser and the Brüel & Kjaer ZI 9101 Interface Module in order to download data directly to computer. The meters were set to 'random incidence'. The calibration of the equipment was checked before and after measurements with no significant calibration drift.

The microphone was installed on a pole 3 m above the ground linked to the sound level meter by a cable. This ensure that the noise levels recorded were unaffected by acoustic shadowing or reflections from the hoarding or the side of the WH Smith retail unit.

1.4.2 Attended Survey

Attended monitoring was also undertaken at three positions, see Pictures 2 to 4.

PICTURE 2: Position 2 and logging microphone at Position 1 (in the background)

Position 2 was positioned opposite to platforms 3 and 4, about 10 meters from platform entrance, underneath train arrival/departure boards, thus a busy pedestrian area. The sound level meter was located on a tripod at a height of 0.9 m above the ground.

PICTURE 3: Position 2a facing platforms 3 & 4

Position 2a was opposite platforms 5 and 6, on zebra crossing about 7.5 meters from platform entrance. The sound level meter was located on a tripod at a height of 0.9 m above the ground.

PICTURE 4: Position 3 part way along platforms 1 & 2

Position 3 was on platforms 1 and 2, approximately halfway down the platforms. The sound level meter was located on a tripod at a height of 1.2 m above the ground.

The attended noise measurements were made using a Brüel & Kjaer 2260 Modular Precision Sound Level Meter. The calibration of the equipment was checked before and after measurements with no significant calibration drift.

2. RESULTS

2.1 Unattended Survey

Figure 1 below shows a statistical overall result of the noise levels monitored every 15 minutes in terms of $L_{max,F}$, L_{eq} and L_{90} over the 5 day period.

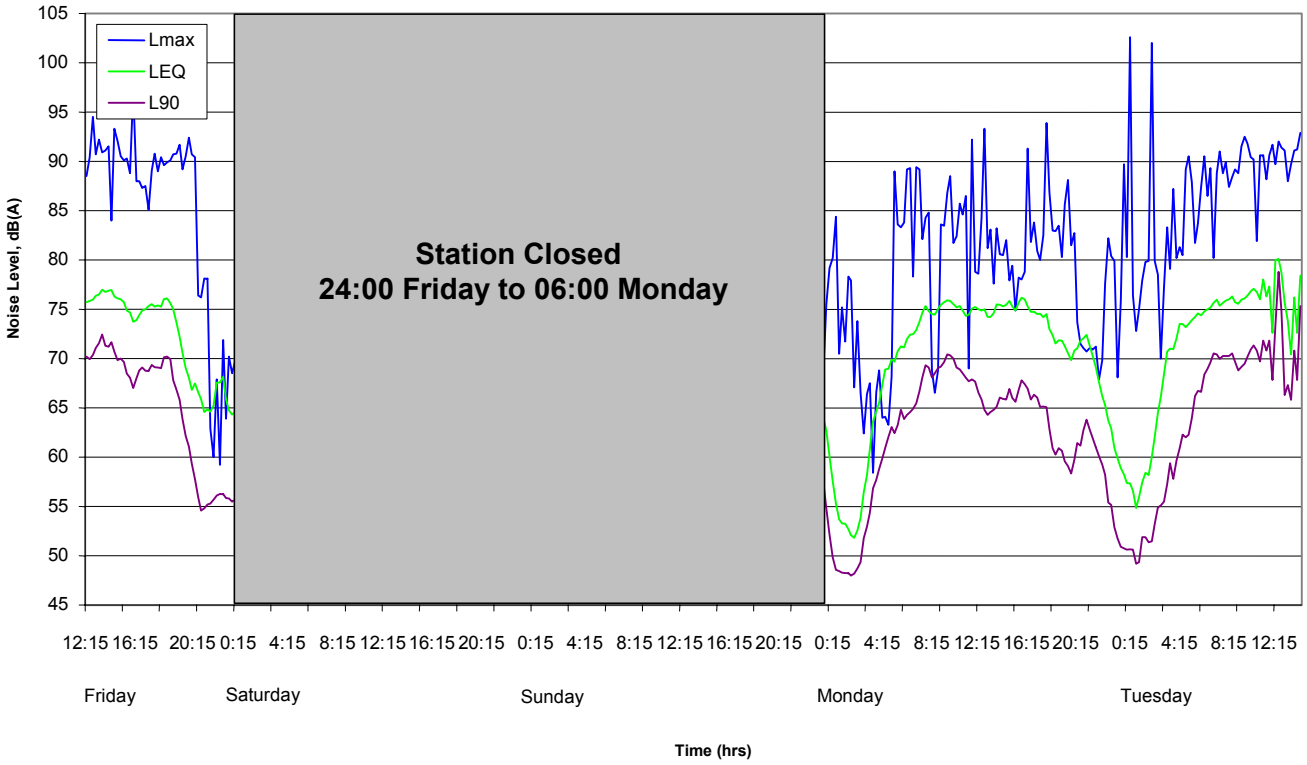

FIGURE 1: Typical Noise Levels Monitored at Position 1 over the 5 days period.
(NOTE: L_{eq} and L_{90} values are 10 point moving averages to identify typical values)

There is some variability in the individual 15 minute measurements. To identify typical values for the peak and off peak periods, a 10 point moving arithmetic average was applied to L_{eq} and L_{90} the data sets. Each L_{eq} and L_{90} data point on Figure 1 therefore represents the typical (average) noise level for a 2.5 hr period (1.25 hrs before and 1.25 hrs after each time record). A period of 2.5 hrs was selected as it reflects the typical duration of the peak-hours in the morning and evening on a typical weekday.

From figure 1, it can be seen that the typical peak hours noise levels are in the range of 75 dB(A) to 80 dB(A) $L_{eq,15min.}$ (note: because of the 10 point moving average, some 15 minute periods will be noisier).

The quietest typical levels recorded during the normal operational period for the station (0600 to 2400) are typically between 70 and 75 dB(A) $L_{eq,15min}$ and the lowest recorded was around 65 dB(A) $L_{Aeq,15min}$ (note: because of the 10 point moving average, some 15 minute periods will be quieter).

2.2 Attended Survey

2.2.1 Statistical Noise Levels Results

Tables 1, 2, 3 and 4 show the statistical noise levels results recorded on Friday 25, Monday 28, Tuesday 29 October 2002 and Friday 8 November.

				Statistical Noise Levels (dB(A))						Comments
Position	**Start**	**Elapsed**	**End**	**L1**	**L10**	**L50**	**L90**	**L99**	**Leq**	
2	12:35:58	00:15:00	12:50:58	83	77	71	68	66	74	
2a	12:53:20	00:15:00	13:08:20	84	77	74	68	65	76	
2	13:09:36	00:15:00	13:24:36	84	74	71	67	65	74	2 announcements. 3 buggies
2a	13:26:18	00:15:00	13:41:18	85	78	75	72	64	76	1 buggy. 2 announcements.
2	13:42:51	00:15:00	13:57:51	85	78	75	68	65	77	4 buggies. 1 announcement
2a	13:59:11	00:15:00	14:14:11	87	81	80	79	79	81	Train noise increases due to engine being turned on/revved up.
2	14:19:54	00:15:00	14:34:54	85	82	81	73	68	80	Noise increased as above for 10 minutes. On 10 minutes noisy train left, reducing levels. 2 buggies. 1 announcement.
2a	14:36:28	00:15:00	14:51:28	86	75	73	70	68	75	Less train noise than previous reading at pos 2. 2 buggies.

TABLE 1: Statistical Measurements recorded on Friday 25 October (dB(A) re 2 x 10^{-5} Pa)

				Statistical Noise Levels (dB(A))						Comments
Position	**Start**	**Elapsed**	**End**	**L1**	**L10**	**L50**	**L90**	**L99**	**Leq**	
2	18:29:17	00:15:00	18:44:17	84	77	75	65	63	75	3 trains idling – large number of pedestrians.
2a	18:46:36	00:15:00	19:01:36	87	80	77	75	66	79	2 trains idling

TABLE 2: Statistical Measurements recorded on Monday 28 October (dB(A) re 2 x 10^{-5} Pa)

				Statistical Noise Levels (dB(A))						Comments
Position	**Start**	**Elapsed**	**End**	**L1**	**L10**	**L50**	**L90**	**L99**	**Leq**	
2	18:00:57	00:15:00	18:15:57	84	80	78	75	74	79	3 trains idling – large amount of pedestrians.
2a	18:19:19	00:15:00	18:34:19	85	79	73	69	63	76	2 trains idling

TABLE 3: Statistical Measurements recorded on Tuesday 29 October (dB(A) re 2 x 10^{-5} Pa)

				Statistical Noise Levels (dB(A))						Comments
Position	**Start**	**Elapsed**	**End**	**L1**	**L10**	**L50**	**L90**	**L99**	**Leq**	
3	14:27:54	0:15:00	14:42:54	88	80	72	64	63	77	Occasional "clattering" from buggy/delivery trucks
2	14:48:30	0:15:00	15:03:30	86	81	72	71	69	76	One train idling. 3 announcements.
3	15:08:05	0:15:00	15:23:05	87	80	78	76	76	79	Two trains idling. One train leaves and new train pulls in.
2	15:30:20	0:15:00	15:45:20	82	77	67	64	63	73	Two trains idling. 1 train pulls away
3	17:15:53	0:15:00	17:30:53	87	79	74	58	57	77	One train idling on power. Leaves after 5 minutes. 2 trains pulls in.
2	17:35:22	0:15:00	17:50:22	85	80	77	75	73	78	Lots of passengers on concourse. 2 trains idling on power. 2 trains pull in. 2 trains pull away. 4 announcements. Several buggies.
3	17:51:58	0:15:00	18:06:58	86	82	77	58	55	79	Two trains idling. Train warms up and leaves . 1 train leaves.
2	18:09:09	0:15:00	18:24:09	85	82	77	71	70	79	One train idling. 2 trains pull in. 4 announcements.

Table 4: Statistical Measurements recorded on Friday 8th November (dB(A) re 2 x 10^{-5} Pa)

3. DISCUSSION

Measurements at position 2 took place on three occasions: 12:30 to 14:30 hrs on Friday the 25 October, 17:30 to 18:30 hrs on Monday the 28 October and 17:00 to 18:00 hrs on Tuesday 29 October. Measurements at position 3 were undertaken on Friday 8 November between 14:30 and 18:15 hrs.

The different times of the measurements reflects different levels of activity within the station. Measurements on the 25 October can be considered "off-peak" and measurements on the 28 and 29 October can be considered "peak". The measurements on the 8 November included peak and off-peak periods.

The main difference between "peak" and "off-peak" measurements was the number of trains idling or revving on the platform. At peak times, there were typically 2-3 trains, where as at off peak times, there were 1 or 2 train engines were the dominant local noise sources in the station shed**. Additional noise sources proportional to the number of trains were station car/buggies (see picture 4) with sounders, and also station announcements. [** All trains using St Pancras station are diesel powered. Trains are generally a mix of Cl 170 DMUs and HST 125s.]

At "peak" times, the main noise source in the station is the diesel train noise. At "off peak" times, whilst some CTRL construction noise was audible at the quieter intervals, the train noise and noise from other station activities still dominated (i.e. some limited CTRL construction noise was audible but visual checks of the sound level meter display during the measurements confirmed that it did not affect the measured noise indicators – L_{eq}, L_{10} etc).

PICTURE 4: Buggy with sounder siren

Tables 1 to 4 and Figure 1 demonstrate that there is little variation in the noise levels measured at different locations within the Barlow Shed. For example the ambient noise levels recorded during peak hours at all of the locations considered varied, with time, from 75 to 80 dB(A) $L_{eq,15min}$.

As a reference, 75 dB (A) L_{eq} is the daytime external environmental noise level at which CTRL offers noise insulation to residential properties as a consequence of CTRL construction noise (provided that this value is exceeded for a significant period of time – 10 days in any consecutive period of 15 days or 40 days in any 6 months). When experienced continuously over an 8 hour period, 85 dB(A) L_{eq} is the level above which Noise At Work Regulations advise there is a requirement for employers to monitor and, where reasonably practical, reduce the noise levels to protect against the risk of hearing damage. 75 to 85 dB(A) L_{eq} is also the range of noise levels at

which speech intelligibility starts to be become difficult even when communicating over short distances (e.g. 1 or 2 m) and with raised voices.

4. CONCLUSION

Measurements have been undertaken inside St Pancras station to quantify the ambient noise levels that station users are exposed to as a consequence of station operations. This is to provide a baseline against which the potential impact, or otherwise, of CTRL construction noise can be assessed. The measurements have demonstrated that the station is a noisy environment particularly during peak periods, primarily as a consequence of diesel locomotive noise.

The typical peak hours noise levels are in the range of 75 dB to 80 dB(A) $L_{eq,15min.}$ These levels do not vary significantly over the concourse and platform areas (in terms of either time or space).

The quietest levels typically recorded during the normal operational period for the station (0600 to 2400) are typically between 70 and 75 dB(A) $L_{eq,15min}$ and the lowest typical level recorded was around 65 dB(A) $L_{eq,15min}$.

The surveys have identified that general operation of the station results in high noise levels in the concourse and platform areas particularly at peak-hours. The main noise sources are diesel trains.

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APPENDIX A

Spectral Noise Level Results

A1. SPECTRAL NOISE LEVEL RESULTS

Tables 5, 6, 7 and 8 shows spectral noise level results recorded on Friday 25, Monday 28 and Tuesday 29 October.

				Octave Band Centre Frequency (Hz)									
Position	**Start**	**Elapsed**	**Index**	**31.5**	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**	**dB(A)**
2	12:35:58	00:15:00	L90	66	70	70	66	65	61	59	54	45	68
	12:35:58	00:15:00	L10	83	80	80	75	74	71	68	65	58	77
	12:35:58	00:15:00	L1	84	82	84	76	82	76	76	68	64	83
	12:35:58	00:15:00	Leq	77	76	76	71	72	68	67	62	55	74
2a	12:53:20	00:15:00	L90	68	71	67	65	63	62	61	53	42	68
	12:53:20	00:15:00	L10	86	85	82	77	75	72	68	64	55	77
	12:53:20	00:15:00	L1	88	87	89	80	81	80	74	67	59	84
	12:53:20	00:15:00	Leq	83	82	80	75	73	71	67	61	52	76
2	13:09:36	00:15:00	L90	66	71	77	64	64	60	58	52	43	67
	13:09:36	00:15:00	L10	71	77	79	68	69	68	68	63	56	74
	13:09:36	00:15:00	L1	74	80	81	70	82	79	77	67	60	84
	13:09:36	00:15:00	Leq	69	75	79	67	71	68	67	61	52	74
2a	13:26:18	00:15:00	L90	70	75	71	66	65	65	64	56	45	72
	13:26:18	00:15:00	L10	84	86	82	74	74	72	71	62	50	78
	13:26:18	00:15:00	L1	87	90	89	78	84	82	76	67	56	85
	13:26:18	00:15:00	Leq	83	85	81	72	73	72	69	60	49	76
2	13:42:51	00:15:00	L90	69	71	73	65	65	62	58	53	45	68
	13:42:51	00:15:00	L10	88	83	81	76	75	73	71	61	52	78
	13:42:51	00:15:00	L1	92	86	88	78	84	78	78	67	60	85
	13:42:51	00:15:00	Leq	86	81	80	74	75	71	69	59	52	76
2a	13:59:11	00:15:00	L90	82	87	82	78	77	74	69	61	51	79
	13:59:11	00:15:00	L10	90	90	87	81	79	76	71	64	53	81
	13:59:11	00:15:00	L1	91	91	90	82	84	83	74	68	56	87
	13:59:11	00:15:00	Leq	89	90	85	80	79	76	71	63	53	81
2	14:19:54	00:15:00	L90	77	74	74	70	69	69	64	58	48	73
	14:19:54	00:15:00	L10	82	84	86	81	80	77	72	64	55	82
	14:19:54	00:15:00	L1	84	86	88	82	83	80	76	69	60	85
	14:19:54	00:15:00	Leq	81	82	84	79	79	76	71	63	53	80
2a.	14:36:28	00:15:00	L90	67	72	74	69	67	63	61	54	43	70
	14:36:28	00:15:00	L10	83	77	77	74	72	70	67	61	51	75
	14:36:28	00:15:00	L1	84	82	83	77	84	82	75	69	59	86
	14:36:28	00:15:00	Leq	79	76	77	72	74	71	66	59	49	75

TABLE 5: Spectral Noise Levels recorded on Friday 25 October (dB(A) re 2 x 10^{-5} Pa)

				Octave Band Centre Frequency (Hz)									
Position	**Start**	**Elapsed**	**Index**	**31.5**	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**	**dB(A)**
2	18:29:17	00:15:00	L90	68	69	72	63	63	58	54	48	41	65
	18:29:17	00:15:00	L10	86	95	80	76	75	70	67	60	51	77
	18:29:17	00:15:00	L1	86	95	87	78	82	81	73	65	57	84
	18:29:17	00:15:00	Leq	83	93	79	74	73	70	66	58	49	75
2a	18:46:36	00:15:00	L90	75	77	82	74	73	69	64	54	41	75
	18:46:36	00:15:00	L10	81	84	85	79	79	73	71	61	50	80
	18:46:36	00:15:00	L1	86	90	86	79	85	85	75	68	57	87
	18:46:36	00:15:00	Leq	80	82	84	77	78	74	69	60	48	79

TABLE 6: Spectral Noise Levels recorded on Monday 28 October (dB(A) re 2 x 10^{-5} Pa)

				Octave Band Centre Frequency (Hz)									
Position	**Start**	**Elapsed**	**Index**	**31.5**	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**	**dB(A)**
2	18:00:57	00:15:00	L90	81	79	78	74	73	68	65	58	48	75
	18:00:57	00:15:00	L10	87	86	87	80	78	74	70	62	53	80
	18:00:57	00:15:00	L1	88	89	90	81	83	80	75	67	59	84
	18:00:57	00:15:00	Leq	85	84	84	78	77	74	69	61	52	79
2a	18:19:19	00:15:00	L90	70	65	63	61	61	59	54	47	39	64
	18:19:19	00:15:00	L10	81	81	82	77	77	73	68	60	49	79
	18:19:19	00:15:00	L1	85	85	86	79	84	81	72	67	56	85
	18:19:19	00:15:00	Leq	77	76	76	73	75	71	65	57	47	76

TABLE 7: Spectral Noise Levels recorded on Tuesday 29 October (dB(A) re 2 x 10^{-5} Pa)

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APPENDIX B

Terminology

B.1 TERMINOLOGY

dB(A)

The unit generally used for measuring environmental, traffic or industrial noise is the A-weighted sound pressure level in decibels, denoted dB(A). An A-weighting network can be built into a sound level measuring instrument such that sound levels in dB(A) can be read directly from a meter. The weighting is based on the frequency response of the human ear and has been found to correlate well with human subjective reactions to various sounds. It is worth noting that an increase or decrease of approximately 10 dB corresponds to a subjective doubling or halving of the loudness of a noise, and a change of 2 to 3 dB is subjectively barely perceptible.

EQUIVALENT CONTINUOUS SOUND LEVEL

The index most commonly used for the assessment for overall noise exposure is the equivalent continuous sound level, L_{eq}. This is a notional steady level that would, over a given period of time, deliver the same sound energy as the actual time-varying sound over the same period. Hence fluctuating levels can be described in terms of a single figure level.

STATISTICAL NOISE LEVELS

For levels of noise that vary widely with time, for example road traffic noise, it is necessary to employ an index that allows for this variation. The L_{10}, the level exceeded for ten per cent of the time period under consideration, has been adopted in this country for the assessment of road traffic noise. The L_{90}, the level exceeded for ninety per cent of the time, has been adopted to represent the background noise level. The L_1, the level exceeded for one per cent of the time, is representative of the maximum levels recorded during the sample period. A weighted statistical noise levels are denoted L_{10}, L_{90} etc.

MAXIMUM NOISE LEVEL

The maximum noise level, L_{max}, is the instantaneous maximum level recorded during a measurement period. The maximum level is often evaluated using a time response functions that 'damp' the rate of change of the sound pressure level with time. One of two time weighting are typically used: 'fast' time response which replicates the time response of the human ear and 'slow' time response which was originally introduced to allow visual identification of maximum noise levels on sound level meters.