How Have NR Locomotive Noise Levels Changed Over Time?

David Hanson (1), Pri Pandey (2) and Kate Flint (3)

(1) Acoustic Studio, Sydney, Australia
(2) GHD, Sydney, Australia
(3) Pacific National, Newcastle, Australia

Abstract - Since mid-2020 when new Environment Protection Licenses (EPLs) were introduced, Pacific National has conducted noise tests on each locomotive following major engine overhaul. Pacific National has thus developed an unprecedented database of locomotive noise levels, with results from standardised noise tests on approximately 130 locomotives across six locomotive classes. Some of these locomotive classes have been in service for more than 25 years. The scale and quality of this database allows fundamental questions about locomotive noise to be explored. In this paper we discuss how locomotive noise has changed over time by comparing the noise levels of the NR Class locomotive when it was first introduced in the late 1990s with its noise emissions today. We also compare the noise emissions recorded trackside in revenue service with those captured in the standardised stationary tests, to better inform how locomotive noise is modelled and impacts predicted.

1 INTRODUCTION

Pacific National (PN) is one of Australia's leading freight rail operators. PN's operations span the continent, and therefore they must comply with a number of state-based regulatory regimes, including environmental regulation covering noise emissions. In NSW, the environmental regulation is administered by the NSW Environment Protection Authority (EPA).

The EPA licenses railway activities through EPLs. Since the early 1980s, locomotives have been subject to noise limits in order to gain approval to operate on the NSW rail network. Prior to mid-2020, EPLs applied only to the rail network, and compliance with the noise limits was required only when the locomotive was first introduced to the network. This involved a type test on a single locomotive from the particular class, i.e. a one-off test on only one locomotive. Based on the Locomotive Class Register (NSW Environment Protection Authority, 2024), we estimate there were around 20 locomotive noise type tests conducted prior to the introduction of rolling stock operator EPLs.

In mid-2020, the EPA introduced a new licensing regime where rolling stock operators have their own EPLs which require compliance with noise limits not only when the locomotive is first introduced, but also following each major engine overhaul. As a result, there have been many more locomotive noise tests conducted since mid-2020 than in the nearly 40 years prior. Indeed, Pacific National alone has conducted more than 130 locomotive noise tests in the past four years, including more than 20 tests in several locomotive classes.

Pacific National now has an unprecedented database of locomotive noise levels from tests conducted under controlled conditions. For the first time, therefore, PN has insights into not only how locomotive noise levels compare with the original class type test, but also into the variability that exists across each locomotive class.

This paper examines the NR Class locomotives, shown in Figure 1, which were introduced in 1996. One hundred and twenty NR Class locomotives were produced, and 117 remain in service with PN. They have a General Electric prime mover and can generate 3MW of power and 520kN of torque, and operate at 115km/h. The NR

Class was type tested in 1996 and since 2020 when the rolling stock operator EPLs were introduced, PN has conducted 52 post-overhaul noise tests.

Figure 1 NR Class locomotive

2 LOCOMOTIVE NOISE TESTS

Noise tests for locomotives in NSW involve measurements at 15m from the track centreline and 1.5m above top-of-rail, in accordance with rolling stock operator EPLs[1]). For type tests, these measurements are recorded at twelve locations around the locomotive. For post-overhaul tests, only measurements adjacent to the middle of the locomotive are required, as shown in Figure 1, which is typically the loudest position.

The locomotives are stationary during the test and operate under self-load whereby all of the traction energy is diverted through the dynamic braking system. This is an artificial configuration that would never occur in service.

[1] The EPLs reference AS2377:2002 (Standards Australia, 2002). Whereas AS2377 specifies measurements at both 1.5m and 3.5m above rail height, the EPLs require only measurements at 1.5m above rail height. In our experience, the same noise level occurs at both heights, hence it appropriate for only the 1.5m measurements to be stipulated in the EPLs.

The automotive equivalent would be simultaneously holding down both the accelerator and the brake in a car. Nevertheless, it provides a standardised test configuration that is repeatable and agnostic to the test location.

The locomotive noise limits for type tests are set out in the rolling stock operator EPLs and repeated in Table 1.

Table 1 – Limits for noise, from Pacific National's EPL (NSW Environment Protection Authority, 2021)

Operating Condition	Location of Measurement	Noise Limit
Low idle with air compressor, all cooling fans and air conditioning operating at maximum load occurring at low idle	Stationary 15 metre contour, except end positions (front and rear)	70 dB LAFMax, 30 seconds 85 dB LZFMax, 30 seconds (Microphone Height: 1.5 Metres Above)
All other throttle settings under self load with air compressor, all cooling fans and air conditioning operating	Stationary 15 metre contour, except end positions (front and rear)	87 dB LAFMax, 30 seconds 95 dB LZFMax, 30 seconds (Microphone Height: 1.5 Metres Above)

Note: locomotive throttle settings include eight notches for propulsion and (typically) up to three idle settings (low-idle, idle and high-idle)

Noise limits for post-overhaul noise tests are 5dB above those for type tests. There are also limits for tonality.

3 RESULTS

3.1 Stationary Noise Tests

Pacific National has conducted post-overhaul noise tests on 52 NR Class locomotives. The results are shown in Figure 2. Overlaid are the results from the initial type test of the NR Class, conducted on NR5[2] (A. Goninan & Co. Limited, 1997), the noise limits for type tests and post-overhaul tests, and the 95th percentile noise level in each engine notch.

There is a considerable range in noise levels between locomotives in each engine notch. The LZFmax varies by up to 15dB in the lower engine notches, and by 5dB in the higher engine notches. The LAFmax varies by more than 20dB in the lower engine notches, and by more than 10dB in the higher engine notches. We don't know the reasons for this variability, particularly in the A-weighted noise levels. It is possible that some noise sources on the locomotive that emit higher frequency noise, and hence have more influence on the A-weighted levels, may have been operating differently during some tests. There are several noise sources on the locomotive that would be candidates, such as the radiator fans, dynamic brake fans, traction motor blowers, and the compressor. The operation of these systems can vary as they are controlled by the engine management system in response to environmental conditions and a range of internal parameters such as water and oil temperature. They cannot be precisely controlled for a noise test, hence some degree of variability is to be expected, even when the test is conducted under ostensibly identical conditions in accordance with the standard.

The highest noise levels occur when the locomotive is in notch 8, i.e. when the locomotive is producing maximum power. The distribution of notch 8 noise levels is shown in Figure 3. These results show that the brand-new NR locomotive in 1996 was louder than the average NR locomotive today. The type test levels are approximately equivalent to the 75th percentile NR locomotive today in A-weighted terms, and 100th percentile in Z-weighted terms. This should provide some comfort to regulators and the community that the noise levels from the NR Class have not increased over time.

[2] 120 NR Class locomotives were built, and were numbered NR1 – NR120. NR3 was damaged in an accident and ultimately rebuilt as NR121.

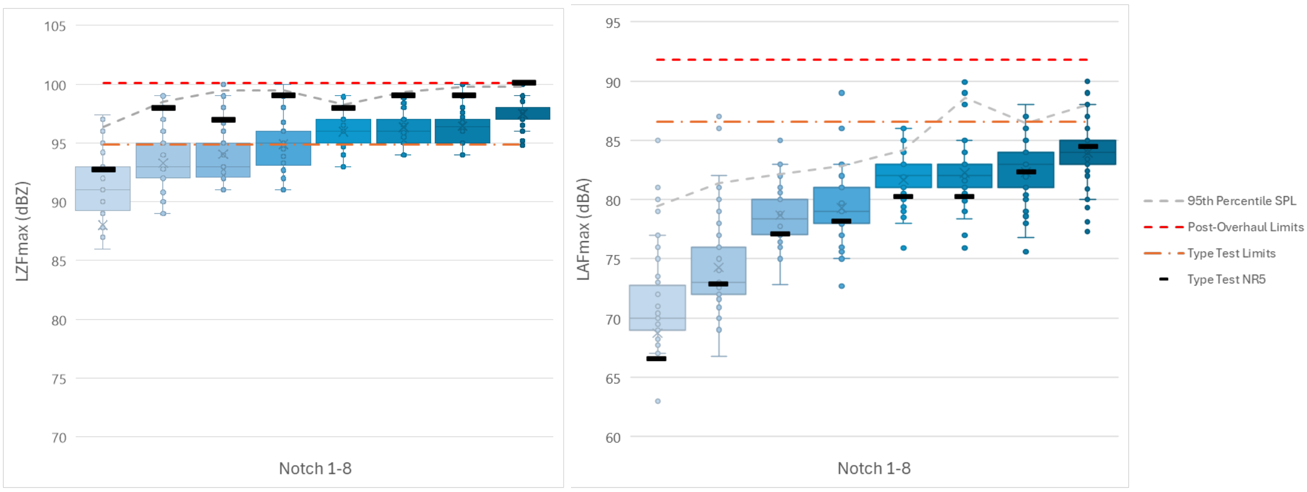

Figure 2 Z-weighted (left) and A-weighted (right) noise levels from post-overhaul noise tests of NR locomotives.

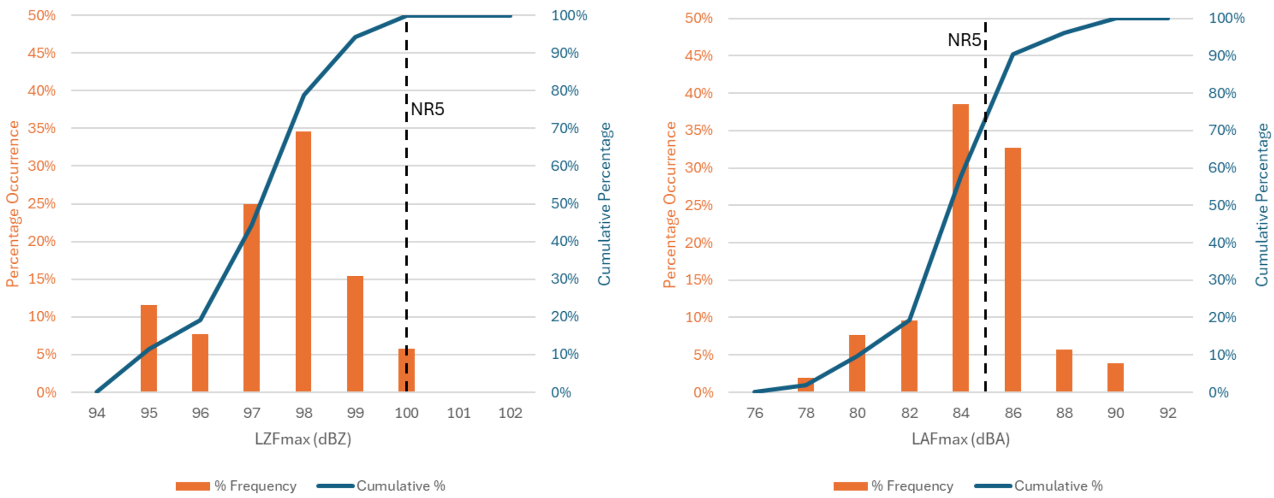

Figure 3 Distribution of NR locomotive noise levels in notch 8 compared with the original type test noise levels (NR5)

3.2 Trackside Noise Measurements

Trackside locomotive noise contributions have been extracted from various measurements undertaken over the years. The full methodology for this extraction (and the selected sites) is described in Pandey (2021). The data was filtered to the NR class locomotives. The analysis excludes mixed locomotive consists- i.e. where one locomotive belonged to the NR class but there were other locomotives, the data has been excluded. The analysis also excludes locomotive noise significantly affected by squeal, including all data from sites A02, A10 and A11. A total of 442 locomotive consists with one or more NR class locomotives were identified.

The data is presented in Figure 4. All measurements have been corrected to a distance of 15 m and a microphone height of 1.5 m. The noise levels may include contributions from adjacent NR class locomotives where the consist comprises of more than one locomotive (although our analysis shows little difference in LAFmax noise levels for consists comprising 1-4 locomotives). For comparison, the post-overhaul noise results are overlaid. As the locomotive notch in-service is not known, this comparison includes noise levels recorded in all notches 1 to 8.

The measured trackside noise levels are generally higher than those observed in the post-overhaul tests. Noise levels for approximately 25% of locomotive passes were found to be greater than the upper bound observed within the post-overhaul tests. We listened to the individual audio recordings from these louder locomotives – the LAFmax in most cases was associated with wheel/brake squeal, gearbox whine, wheel flats or bunching/stretching noise, i.e. noise sources that do not occur in stationary tests. With the exception of gearbox whine and wheel flats, these noise sources are typically accounted for separately in noise models with specific correction factors applied to predicted levels. As gearbox whine and wheel flats occur only for a minority of locomotives and are defects that would be addressed through routine maintenance, they are not considered representative. The stationary noise test results therefore appear to provide a reasonable accounting of the likely noise levels encountered in service in the absence of defects. There is an excellent opportunity to mine this dataset more deeply, however, and to expand the analysis to other locomotive classes.

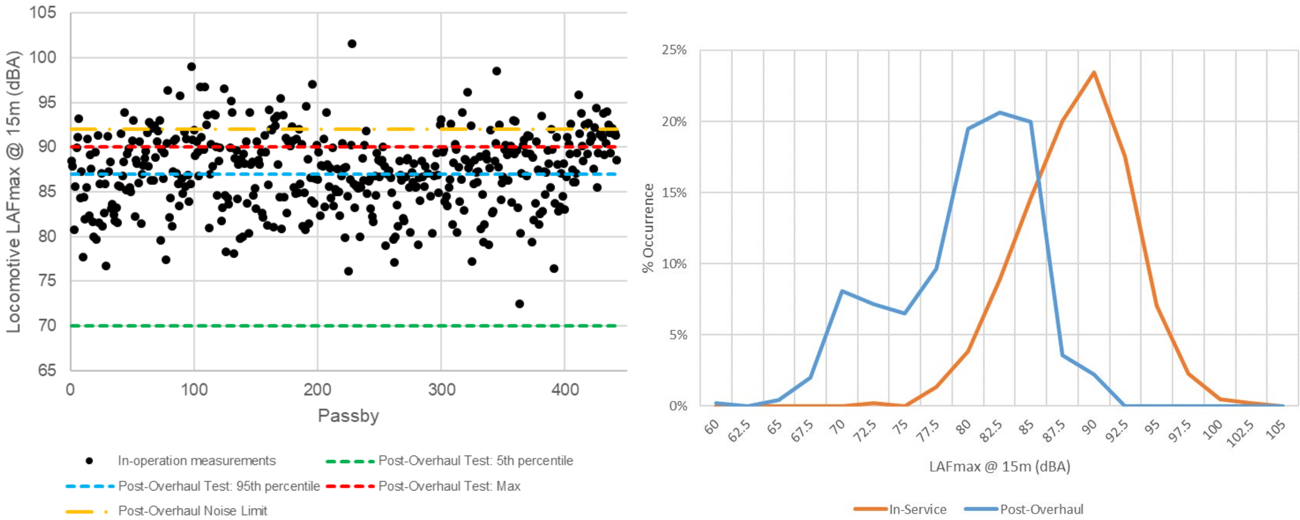

Figure 4 Comparison of in-operation and post-overhaul NR locomotive noise levels – all passbys (left) and histogram (right)

4 DISCUSSION

This paper has considered the large noise dataset now available via the requirement to test locomotives following engine overhaul. This large dataset of locomotive noise levels provides, for the first time, interesting insights such as:

- The locomotive type testing regime. The principle of a type test is that the unit is representative of the population. This principle is potentially undermined, at least in part, by the newfound understanding of the variability across a class. The original NR type test was compliant with the A-weighted limits but exceeded the Z-weighted limits in several notches. Although it was not known at the time, NR5 represented a conservative case in Z-weighted noise levels – most of the NR locomotives tested recently were quieter than NR5 was in 1996. It is easy to imagine the inverse case, however, where the particular unit selected for type testing was substantially quieter than the majority of its class. Indeed, if the type test was repeated today, the recent results suggest that around 12% of locomotives would be fully compliant in Z-weighted terms and 95% in A-weighted terms.
- The difference between noise levels recorded in-service and from stationary tests. In-service noise levels are typically higher than noise levels recorded at the same distance from the tracks in a stationary test. Part of this difference can be attributed to sources that only occur in-service, such as those from wheel/rail interaction and longitudinal train dynamics. Another contributor could be slight deterioration in

noise performance as components wear – the stationary noise tests are conducted when the locomotives are new (type tests) or newly overhauled (post-overhaul tests).

- The variability of noise levels across the operating range. This is particularly evident in the A-weighted noise levels which are used in noise models for assessing impacts in accordance with the Rail Infrastructure Noise Guideline (NSW Environment Protection Authority, 2013). This highlights the importance of understanding the typical engine notch of locomotives at each track section and tailoring the source levels accordingly. For example, on flat terrain, a source level akin the Notch 1 noise levels may be suitable, whereas on a long ascending grade, Notch 8 noise levels may be more appropriate.
- The change in noise levels over time. The post-overhaul tests provide as close to a like-for-like comparison with the original type test as possible. For the NR Class, this shows that the noise levels have not increased over time, which should provide regulators and the community some comfort that locomotive noise is being appropriately managed and the current, expensive and onerous regime of testing every locomotive following overhaul can be relaxed.

The additional noise testing required under the rolling stock operator EPLs has imposed a substantial cost on operators like Pacific National. It is hoped nonetheless that the results can help to improve locomotive noise regulation in the future by providing a solid evidence base for updates to, and implementation of, the EPLs. This could include moving to a sample-based post-overhaul testing regime rather than requiring every locomotive to be tested. Marrying the post-overhaul and in-service datasets can contribute to this process.

ACKNOWLEDGEMENTS

We would like to acknowledge the contributions made by SLR Consulting and UGL Pty Limited who conducted many of the post-overhaul locomotive noise tests reported in this paper.

REFERENCES

A. Goninan & Co. Limited. (1997). *External Commissioning Noise Measurements of NRC Locomotive NR05.* Newcastle: A. Goninan & Co. Limited.

NSW Environment Protection Authority. (2013). *Rail Infrastructure Noise Guideline.* Sydney: NSW Environment Protection Authority. Retrieved from https://www.epa.nsw.gov.au/~/media/EPA/Corporate%20Site/resources/noise/20130018eparing.ashx

NSW Environment Protection Authority. (2021, November 25). Environment Protection Licence 21364.

NSW Environment Protection Authority. (2024, July 10). *Locomotive Class Register*. Retrieved from NSW EPA: https://www.epa.nsw.gov.au/licensing-and-regulation/licensing/environment-protection-licences/amendment-regulation-for-scheduled-activities/locomotive-class-register

Pandey, P. (2021). Freight rail noise in NSW: Comparisons of recent measurements against the rail noise database. *Acoustics 2021 Wollongong: Making Waves.*

Standards Australia. (2002). *AS2377 Acoustics - Methods for the Measurement of Railbound Vehicle Noise.* Standards Australia.