Introduction

Globally, there are wood preservation standards which define the minimum requirements for preservatives, their application to wood products, and the outcomes which must be achieved for those products to perform as expected.

While the existence of such standards is laudable, naturally they must be achieved to realise performance expectations and continued acceptance of treated wood as a building material.

Treatment outcomes are far from self-assured – it takes knowhow and effort to present wood in an appropriate condition to a process which will effectively treat it.

Some minimum level of control is necessary, extending to formal compliance testing programs. Arch Wood Protection New Zealand provides a level of analytical service to its clients to support their internal and external compliance activities.

Such service is not and should not be bound by the absolute requirements of standards, to allow complementary systems to be applied – which may be more cost effective, or to increase the sampling rate, or both. Some examples of this, and the background for them, are discussed here.

Systems advocated by AS/NZS1605

The main purpose of this Standard is to describe the preferred methods for disclosing penetration and analyzing retention. However, it also outlines a number of different approaches which may be used to demonstrate compliance by a manufacturer or supplier of treated wood:

**Statistical sampling**

The manufacturer carries out a sampling plan which is derived on sound statistical grounds, and can demonstrate that the product is consistent with the materials and practices on which the plan is based.

**Product Certification**

An independent assurance provider supports the claim by a manufacturer that their product(s) meet the standard. While the provider conducts independent sampling, the manufacturer must maintain appropriate control of production.

**Suppliers quality system**

The manufacturer adheres to an audited and independent quality system (e.g. ISO 9000 or ISO 14000) which includes quality assurance requirements agreed to by the manufacturer and its client(s) – including a quality and testing plan.

**Other means**

Assessment by testing in addition to the 'manufacturers guarantee of compliance.
Examples of current compliance sampling activity

The objective here is to describe the current situation, how it came to be, and from that identify limitations and opportunities to improve or support current practices. The following text is a brief starter outline to this effect:

**New Zealand**

NZS3640 identifies recognised Quality Assurance providers, namely AsureQuality and the Timber Preservation Council. Sampling and assessment for compliance to NZS3640 is built around a “10-sample” regime which is written into the Standard, whereby 10 distinctly different pieces from a nominated treatment batch or charge are randomly selected, then assessed first for penetration, then active content. If at least nine of the 10 samples meet or exceed the stated “characteristic” values, the charge is deemed compliant.

It is important to understand the historical development of wood preservation standards in New Zealand, at least in outline. At one time, treatment specifications were process based, and required retention outcomes were simply stated as nominal charge retentions (mass/volume). Through experience and sample analysis an appreciation was gained of within-charge (piece) treatment variability and retention (mass/mass basis). Nominally, it was understood that 90% of individual samples should equal or exceed 2/3 of the charge retention as expressed on a mass/mass basis - in view of wood basic density.

This is the origin of the characteristic values specified today. That understanding, and the dramatic shift to result based specifications empowered a flurry of process improvement and development of alternate processes, with the aim of better economy without compromising the minimum standard of treatment.

Unfortunately, the imposition of the 10-sample regime has led to some inherent issues in the current day, exacerbated by the transition to – and constraints associated with - a National Standard. Those of particular concern are the unreliability of any given determination on statistical grounds, and the analytical burden presented by such sampling at a frequency which might be regarded as statistically acceptable.

**Australia**

The penetration and retention requirements of AS1604.1 (and associated joint standards AS/NZS1604.2 to 1604.5 for engineered wood products) read as absolute – literally, any sample analysed must meet the minimum requirements.

In Australia, there are no QA providers allied to the active standard in the same sense as in New Zealand. In the past there was significant marketplace sampling activity by organisations with an enforcement role in the Timber Utilisation and Marketing Act 1987 (TUMA) of Queensland, and the Timber Marketing Act 1977 (TMA) of New South Wales. While that activity has been affected for various reasons, particularly funding, it continues. For example, despite funding cuts and expiry of Regulations of the TMA in 2005, the sampling and inspection service provided by Forests NSW has continued, and has been supported by specific commercial interests.

Manufacturers, particularly larger organisations and those producing use-critical items such as poles, are more inclined to use an in-house system from AS/NZS1605 as outlined earlier. One driver for this is the understanding that liability (for product failure) rests on the manufacturer (treater), in the words of the standard:

“Irrespective of acceptable quality levels (AQL’s) or testing frequencies, the responsibility remains with the manufacturer or supplier to supply product which conforms to the full requirements of the Standard.”
The reference to AQL’s is significant – it is at least a tacit indication that a treater could operate at some level other than that which would absolutely ensure that ALL material met requirements. Unfortunately, circumstances are such that some degree of compromise is necessary.

**Initial Assessments – Treatment plant data and Penetration**

**Treatment Process metrics**

Conditioning and treating a wood resource in a particular way will result in a treatment outcome which can be repeated by re-applying that process. Monitoring and controlling key aspects of the process enables consistent treatment, and data recorded allows the overall treatment result to be determined.

The most useful indicators are fluid uptake and, from that and solution strength, charge retention.

Some of the influences which will undermine the reliability of charge retention are:

- Variation in treatable volume – due to variation in proportions of sapwood and heartwood present.
- Variation in wood density, either whole-charge or within-charge.
- Inconsistencies in condition which affect uptake, such as presence of sapstain or high moisture content.

**Penetration Assessment**

Assessment of penetration is the leading step in checking treatment compliance. If the preservative has not reached as far as it should, service performance of the treated product will be seriously compromised – regardless of retention. The typical requirement is complete sapwood penetration, and often some degree of heartwood penetration.

If penetration requirements are met and process metrics, particularly charge retention, are in order, then there is reasonable confidence that individual sample retentions will be compliant.

![Flowchart of treatment sampling regime](image)

**Figure 1: Historical treatment sampling regime (from TPA Specifications)**

The classic model for a system which relies on these basic principles is the stepped regime developed by the NZTPA, a rendition of which is shown in the flowchart in . Note
the heavy emphasis on penetration assessment, with calls for analysis only in the event of a penetration failure, or a determination to step to a longer sampling cycle.

Figure 2 may be an extreme example of inadequate penetration, but it serves to show an obvious example of outright failure from a penetration standpoint, and the consequent effect on retention. Although penetration failures would not usually be analysed, the outer 25mm of these samples were analysed and most failed on retention also - despite apparent weight of preservative near the surface.

![Figure 2: Penetration spot test of CCA treated posts](image)

The heartwood-sapwood boundary for these posts has been marked with a heavy black line.

Full cross-sections provide much better certainty with regard to assessment of penetration and retention, and may disclose shortcomings which might not be realised with borings. For example, scrutiny of the sections in Figure 2 shows that the penetration outcome for a boring will be influenced by the point it happens to be taken from. Presentation of borings is also important, for example, they should disclose the full extent of sapwood.

### Retention Analysis - opportunities for rationalisation

There is no question that when samples are taken for assessment according to wood preservation standards in Australasia the way those samples are taken and analysed is prescribed, and that some level of such sampling should be done.

However, the frequency of such sampling is not prescribed. This presents the possibility of conducting a minimum of that activity, and developing supplementary schemes which are designed to support base QA programs, which either conserve analytical effort or extend sampling for the same cost – or both.

#### Multiple actives

For many years, prior to the promulgation of NZS3640, CCA treated material was first analysed for copper content, which allowed a determination as to whether a sample complied, failed, or required analysis of remaining actives.

For example, for CCA treatment to H4 the “first call” criteria were:

- Cu was less than 0.16 %m/m was a failure
- Cu greater than 0.17% m/m deemed a pass
- Cu of 0.16 to 0.17 %m/m deemed indeterminate
Indeterminate samples were analysed for remaining actives and judged against the 0.72% m/m requirement only if they were pivotal to the overall “10-sample” outcome for the charge. For example, if two or more samples had been deemed as failures based on copper-first there was little point in further analysis – the charge was already an outright failure.

The current standards require analysis of all actives in all cases from the outset. The challenge in this case is: In view of the previous protocol for CCA, is this always necessary?

Table 1: Example of Copper-first vs TAE determination for CCA

<table>
<thead>
<tr>
<th>No</th>
<th>Cu, %m/m</th>
<th>Copper-first</th>
<th>All actives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Initial call</td>
<td>Final call</td>
</tr>
<tr>
<td>1</td>
<td>0.27</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>2</td>
<td>0.23</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>3</td>
<td>0.38</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>4</td>
<td>0.26</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>5</td>
<td>0.17</td>
<td>Extend</td>
<td>Pass</td>
</tr>
<tr>
<td>6</td>
<td>0.33</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>7</td>
<td>0.15</td>
<td>Fail</td>
<td>Fail</td>
</tr>
<tr>
<td>8</td>
<td>0.34</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>9</td>
<td>0.17</td>
<td>Extend</td>
<td>Fail</td>
</tr>
<tr>
<td>10</td>
<td>0.27</td>
<td>Pass</td>
<td>Pass</td>
</tr>
</tbody>
</table>

The sample data in Table 1 suggest that it is not. The final outcomes according the copper-first and full analysis regimes are identical, even though the first requires substantially less analytical effort – noting that this material was badly treated - production which is adequately treated presents far fewer calls for full analysis.

We have yet to find an exception to this, noting that if one was to occur that could simply be accommodated by adjusting the bounds.

Admittedly this approach depends on the source preservative being within the specified compositional range, so some level of full analysis - either of the supplied preservative or of treated wood - is needed. The point is, not ALL analysis needs to be of all actives.

Statistical Development – base evaluations

Reference Data

ArchWPNZ has a substantial archive of analysis data from its QA support and development programs. This data was collated – with anonymity – and analysed with the assistance of Scion statistical services.

Statistical analysis was aimed at testing apparent characteristics of the data, and possible schemes consistent with these and the framework of treatment and compliance testing practice.

Appropriate distribution model

The standard normal distribution has been commonly regarded as appropriate represent the spread of retention. However, there are a number of reasons why this may not be so:

- Proximity to zero (retention). In view of specified values for retention and inherent variability of treatment, the lower tail of the normal distribution – fit aside – tends to extend to, and below, zero retention. This is not sensible.
Minimum retention presented by simple contact during treatment. Although work is usually effected on wood to achieve treatment outcomes, simple contact between the wood and the preservative results in a substantial base retention.

Elimination of poorly treated material by penetration assessment. Such assessment is done prior to any commitment to chemical analysis, if penetration is sub-standard then the treatment is deemed to fail. This effectively raises the minimum retention which is likely to be presented for analysis even further.

These points suggest that a skewed statistical distribution might be more appropriate. One such distribution is the Weibull, which is characterised by a “shape factor” which allows it to mimic a variety of distributions (Figure 3).

One difficulty with the data with regard to determining appropriate distribution is that although there is a lot of it, it is grouped in sets of 10. This needs to be recognised in the routines applied to the data.

To date, analysis of the variation within each set of 10 samples suggests that the Normal distribution may often be most appropriate, as shown in Figure 4 for some of the assessment data, although the distribution of the set means is often positively skewed.

Distributional analysis makes it possible to simulate the performance of the existing test decision rules. For example, NZS3640 requires at least nine of 10 retention results to meet or exceed the specified characteristic value. Figure 5 shows the probability that a
test set of CCA treated samples will fail under the existing rules versus the actual 10th percentile of the retention distribution. These determinations are based on the assumption that retention is normally distributed and variation is consistent with that of the data used in these assessments.

For example, if the true 10th percentile for copper content of H3 CCA is 0.07% m/m (i.e., 10 percent of samples are less than 0.07% m/m copper in the population), there is a 90% chance that a test set of ten samples will fail (i.e., that 2 or more samples will fall below the specified limit). Conversely, if the 10th percentile is 0.11%, there less than a 10% chance that a test set will fail.

**Possible approaches, including statistical application**

Analysis of existing decision rules, as in the previous section, indicates that those rules are reasonably reliable. However, current systems depend on analysis of multiple samples, and whether or not individual sample values satisfy specific criteria.

For alternative methods to be more efficient they will most likely require less intensive analytical effort combined with reasoned statistical approaches. Some of the possibilities we have identified and have either considered or are evaluating as cost-effective supplementary systems for sampling and interpretation are as follows:

**Limit testing**

This would be determined by the nominated distribution in view of the intent of a treatment standard. Generally, the most important requirement will be to accommodate the retention specification, including any allowance for variation. In New Zealand, this is formalised in NZS3640 as a “characteristic value”, where a minimum proportion of samples must meet the specification, typically nine samples in ten. While there is no such allowance in AS1604, there may be an informal acceptance that some exceptions will arise given the inherent variability of treatment – as indicated by the reference to AQL’s in AS/NZS 1605.

Our view is that in principle a tolerance limit is consistent with the goal of indicating the degree to which a treatment subsample is compliant. This should not be confused with confidence limits which apply to population parameters - such as the range within which a mean is expected to lie. In particular, an estimate of lower (one-sided) tolerance limit seems appropriate, represented by the following equation:

\[ Y_L = \bar{Y} - k \sigma \]
Where $\bar{Y}$ is the sample mean, $s$ is the sample standard deviation, and $k_1$ is derived in relation to a nominated proportion of the population $p$ and confidence value $\gamma$, sample size, and associated critical value for the appropriate distribution.

There are two main applications of interest for a tolerance limit:

1. Whether or not the calculated lower tolerance limit, for a given proportion of the population and nominated level of confidence, of a production (charge) sample meets or exceeds the specified retention.

2. The level of confidence associated with the point where the calculated lower tolerance limit, for a given proportion of the population, of a production (charge) sample equals the specified retention.

For NZS3640, the value of $p$ can be taken to be 0.90 (or 90%) since that is consistent with the nine-out-of-ten philosophy. For AS1604, an appropriate value for an Acceptable Quality Level could apply, e.g., an estimate of the value currently associated treatment performance, acceptance, and risk - it simply has not been formalised.

Another important input parameter in the determination of a tolerance limit is the confidence value $\gamma$. While the value for this should be high given the performance expectation on treatment, it could possibly be moderated by reservations about the statistical model, or to produce outcomes which are reasonably consistent with current determinations.

**Composite analysis – of total retention**

This is actually practised elsewhere, e.g., as a base requirement in the USA, where penetration of a number of individual samples (20 increment borings) is first assessed, and if compliant then the retention zone for each sample is combined to form a single sample for analysis.

That analysis basically indicates actual sapwood charge retention, by accounting for the variation in treatable volume, density, and other influences mentioned previously.

A potential disadvantage of this approach as a base standard is that it makes no allowance for variation in treatment variability. If treatment variability (represented by $s$ in the tolerance limit equation) is consistent regardless of resource or process then this is not an issue, since there is nothing a treater could do to manage treatment variability to his advantage. In this case, $s$ could be established using historical data, and a tolerance limit calculated using the mean retention from a composite sample.

However, analysis shows that treatment variability does vary considerably between treaters and/or operations. This is mixed news: Although this removes some of the justification for composite sampling, it confirms the opportunity to pursue more efficient treatment by managing treatment variability.

**Composite analysis – supporting individual component retention**

Composite sampling could still be widely applied to multiple active preservatives, where a key active is analysed for all samples while the other active (or actives) are analysed from a single composite.

For this to be valid, the ratio of actives in each and all samples in a group should be the same. In fact, there is little or no reason for active ratios to vary, and results which do vary substantially are a strong sign of analytical error.

**Tiered sampling**

Multiple samples from a charge will define within-charge variability to some extent, though this has several limitations:

- Considerably more than ten samples (as prescribed by NZS 3640) may be needed to reliably estimate distributional properties.
Multiple sampling reduces the amount of analytical effort which can be directed at between charge variability.

One approach would be to periodically benchmark or index treatment variability for a given plant/product/process combination with a sufficient number of samples, supported by more frequent assessments of individual penetration and analysis of single combined (composite) sample.

**Sequential sampling from process/operation**

This proposal (if valid) would be more appropriate for the Australian situation, where there is an expectation that any given piece of treated wood taken from the production pool will meet the specified retention.

Those results should contain the combined effects of practically all treatment variables – within charge, between charge, treatment process and wood resource. As such data collected in this way promises much value with regard to capturing net variability, even if it fails to define the individual contributions. It is suggested that older data is displaced by new data in “rollover” fashion, so that the evaluation is not biased by obsolete data.

The main aim here would also be to generate some indicator of performance relative to treatment specification. Arch has collected some data which shows promise, though more extensive data and statistical assessment is needed.

**Sampling method**

Samples are either taken as full cross sections, or as part sections (increment borings or plug cuttings).

Owners of treated product are understandably reluctant about writing off valuable stock, especially if it compromises value or records of the whole pack from which samples are removed. The disincentive to sample is even stronger if the wood is not owned by the treater.

Non-destructive or less destructive sampling is preferable to not sampling at all, and may be more reliable than the practice of using “test samples”. Framing is a product which may lend itself to sampling as borings instead of full section samples.

![Figure 6: Effect of sample type and location on retention outcome](image)

Results to date are promising. As seen in Figure 6, while retentions of edge borings are considerably lower than cross-section retentions, the differences are reasonably consistent, which may allow a standard correction to be made. Additionally, the correlation is far better for borings taken from the edge than a face, which would be an advantage for sampling made up packs.
Summary and Conclusions

Numerous opportunities and approaches for supplementary assessment to base compliance activity, or as the basis for options outlined in AS/NZS 1605 are identified. Some of these may also have value in streamlining aspects of base requirements as currently defined in Standards.

With regard to current practices, periodic sampling is acceptable provided that reliable charge-to-charge process information is recorded and monitored.

Statistical analysis evidences the Normal distribution as an appropriate model, although there are some grounds for skew to occur. Regardless of the model, derivation of a lower tolerance limit may be a useful method for assessing retention outcomes.

Compositing of samples - after penetration assessment and within statistical limitations - promises substantial reduction in analytical effort, which could then be extended to more frequent sampling without increasing cost, or simply reducing cost.

Acknowledgements

The input and assistance of M Hedley and M Kimberley, both of Scion, in the development of this project to date is much appreciated.