INNOVATIONS IN PUBLIC LIGHTING INSPECTION AND ASSET MANAGEMENT

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Abstract
There have been several failures in recent years of street light poles, including a high profile one on the Anzac Bridge in Sydney. Combined with failure rates of power poles, there is well founded concern among public lighting asset owners about the condition of their assets. At the same time, traditional inspection methods, particularly for steel and timber poles, are being proven ineffective in a growing number of situations. Fortunately, non-destructive testing (NDT) techniques are coming-of-age and are starting to provide significant cost-benefit. This paper provides a brief review focussed on the practical aspects of old and new inspection methods. The review is backed by case studies from Australia and New Zealand that show significant financial and risk reduction benefits to asset owners based on the use of improved inspection techniques and record keeping.

Introduction
Pole failures of all types are making headlines more and more frequently in time. A simple browse of my weekly Google alert for “Pole Failure” over the last 10 years or so has been eye-opening in this regard.

In Australia, there have been some very high-profile power pole failures and resulting court cases and Parliamentary orders incurred by Western Power in WA, Australia. Aurora Energy’s experienced, and still experiences, extensive media attention in relation to power pole failures in their New Zealand Network. Currently, Powercor in Victoria are also the focus of considerable media attention due to a power pole failure near Warrnambool, Victoria. Something which is accentuated by previous bushfires that were caused by power pole failures.

Electrical Power networks get the majority of the attention because the loss of power is a significant consequence to a large proportion of the population, on top of the risk to life and property. But this does not mean that street, road and public lighting pole owners are immune to failures or media attention. In June 2015 a pole fell over on the Anzac Bridge in Sydney [1] around midday on a public holiday. Fortunately nobody was injured and there was no significant property damage, but it still made the news because it was relatable for all the pedestrians who regularly use that bridge. From the experience of the power industry, all it takes is one failure where there is significant injury or proerty damage caused by a pole failure for the media pressure on the asset owner to go from one article in a newspaper to months of media coverage and scrutiny from the public, politicians and more.

Much like the power pole networks, asset age profiles are increasing, and some owners are seeing significant increases in failure rates. It is only a matter of time before a significant failure occurs, unless regular, well planned and thorough inspections are implimented.

Fortunately, there are a number of Non-Destructive Testing (NDT) techniques that are reaching a level of maturity such that they can significantly improve the cost effectiveness, accuracy, completeness and speed of inspection of the two most common pole materials – steel and timber.

For concrete and fibreglass, the most practical inspection methods are currently still visually based, so these materials are not covered by this paper. The focus is on NDT techniques for Steel and timber poles.

Steel Pole Inspection Techniques

There are three main NDT technologies that have been found useful for steel pole inspections;

1. Ultrasonic Testing (UT) for thickness
2. Pulsed Eddy Current (PEC)
3. Guided Wave Ultrasonics

UT Thickness Inspection

Thickness testing using ultrasonics can further be split into the more common Piezoelectric (Piezo) probes that require an ultrasonic gel to transmit the sound into the material, Dry-Coupled UT (DCUT) piezo that uses a rubberised couplant (no gel required), and EMAT (Electro-magnetic Acoustic Transducer) probes which are contactless and generate the sound inside the steel.

The cost of the DCUT and EMAT probes are more expensive from a hardware perspective, but require no consumables and are generally quicker to use and scan large areas quickly.

UT thickness tools are the most commonly used tools for steel pole inspection. This is likely to continue for flange-based poles on concrete footings. For Flange based poles the corrosion typically occurs at or just above the base plate due to a build-up of moisture on the inside of the pole (Figure 1).

Figure 1: Typical location and result of corrosion for base plate mounted poles.

However, the primary concern for direct-buried steel poles is the below ground region. Unlike wood poles where the majority of decay and insect attack occurs above 400mm below ground line, steel can deteriorate anywhere below or above ground line, and in our experience there is an increasing instance of corrosion failures more than 400mm below ground (typical depth an inspector may dig to inspect a pole). Figure 2 shows some examples of the extent that corrosion can occur below ground. In this case the UT thickness methods become cumbersome, time consuming and inaccurate (depending on whether there is access to the worst location or not).

Figure 2: Examples showing corrosion of steel poles can occur anywhere below ground.

Pulsed Eddy Current

There are two devices that have been designed specifically for steel pole inspection that use PEC technology. PEC devices measure the response of a section of steel to the induction of eddy currents. This response can be measured against a baseline to give an indication of mass loss. The mass loss is then related to a strength reduction which is used to assess risk of failure and priority for replacement.

The RLS Meter is designed to be used around ground line and can detect corrosion within approximately 200mm of the scan location. The “Dipstik” device uses a stick that is inserted inside the pole (requires an access hatch) that can give indications as far below ground as you can reach, although reports are that the accuracy goes down with distance from the ground (as with most devices).

Besides the access and proximity issues with both of the devices that limits the range of applicable poles, there are two other main issues with PEC devices;

1. They can be significantly affected by cables, steel brackets and other steel sources in and around the pole. This can mask issues or make them seem worse depending on where you take the baseline.
2. Because the devices are detecting mass loss, pitting corrosion, cracks and other localised defects can be overlooked by the device.

Despite the drawbacks, these devices are commonly used during regular inspections, and are suitable where conditions and corrosion profiles are well known.

Guided Wave UT

This technology uses ultrasonic sound waves travelling in the plane of the steel, guided by the faces of the steel plate. The reflections from the signal give an indication of location relative to the probe and the speed of sound in the material, and they can also give an indication of severity. Conventional Piezo systems like the Sonotest device are typically limited to a range of 1.2m penetration or less due to their highly attenuative sound wave (Lamb or shear vertical). However, EMAT systems like the Innerspec MRUT system that uses a Shear horizontal wave commonly reach the bottom of the pole.

Even though the guided wave techniques give an indication of severity, a system that involves rules around size, distance from ground and severity, as well as any lack of indications that would normally be visible. The lack of indication of the bottom of the pole for instance, could mean that the corrosion is through the wall thickness completely, but it could also mean there is something about the ground that is highly attenuative to the UT signal. This is why a risk-based system is the best approach, and why any potential indications are to be confirmed with further investigation.

Whilst the PEC method has proven very valuable for the likes of Horizon Power, SA Power Networks, NT PowerWater and others, the Innerspec MRUT system is proving to be an excellent tool for speed and detectability, particularly where corrosion is more than 400mm below ground line.

<u>Wood Pole Inspection Techniques</u>

There are a range of wood pole NDT techniques on the market today. They can be generally broken into the following categories;

1. Resistance drilling
2. Seismic
3. X-Ray
4. Tomography (usually with an acoustic signal)
5. Ground Penetrating Radar (GPR)
6. Proof-loading

Resistance Drilling

Resistance drilling is not considered an NDT technique. It still produces a hole through the treated sapwood and has the potential to transfer pathogens. In reality, the act of drilling is the problem because the appropriate location to give a representative strength assessment is too difficult to determine. So an improved drill doesn't actually provide any significant benefit to the asset owner.

I personally see no practical benefit to resistance drilling systems like the Polux or Resistograph. Not because they are not good at what they do, but because what they do is not what is required.

Seismic

These devices include the Thor, Vonaq and some other lesser known systems developed in Europe. It also includes the PoleWatch system and an as-yet unnamed system out of UTS in Sydney, both of which are still under development at the time of writing.

Seismic devices use the response of a structure to load to determine whether the pole is behaving normally or not. Because of the variability in material stiffness, strength, size and the weight and stiffness provided by the overhead line hardware, they are tools that cannot give a quantification of residual capacity, but can generally tell if a pole has a potential significant structural deficiency and requires further testing. In the case of the Thor in particular, as the fastest of the tools to use currently, it can provide a fast screen of the poles and in the case of 70% or more that (depending on the system design) are green from Thor, preservative treated and less than 40 years old, nothing more is required.

Since the seismic methods are based on statistical distributions and relationships between response and stiffness and stiffness and strength, care needs to be taken when assessing the devices for suitability. The more data you have to enter, and the more assumptions that are made, means less repeatability, less accuracy, less reproduceability than might be required.

A major benefit of these devices is the ability to test poles that are embedded in concrete or similar difficult to excavation foundations, without having to dig.

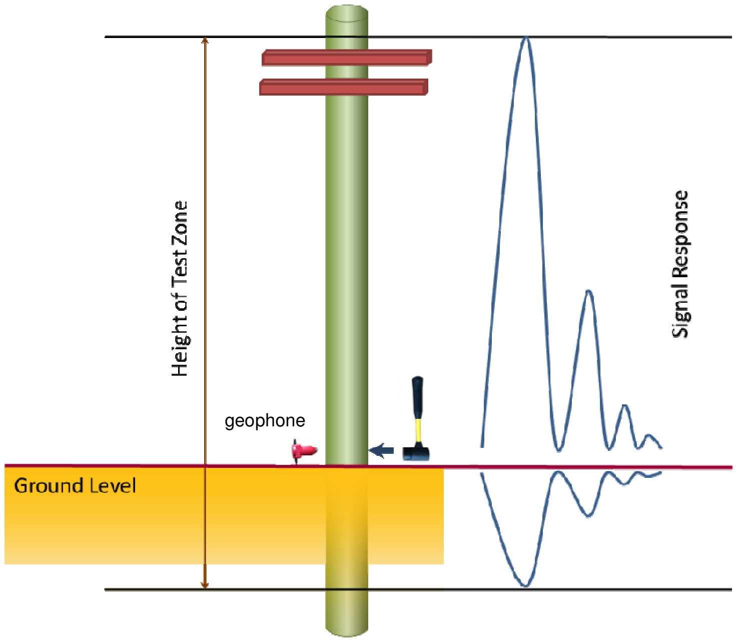

Figure 3: Schematic of how the Thor device works

X-Ray

Many different types of X-Ray devices have been trialled in the past. However, most have been bulky and time consuming and limited to a cross-section at a particular location along a pole. These were severe limitations. However, the PortaSCAN XBS uses the back-scatter from the beam to measure the density of the wood. This density is affected by both decay and loss of wall thickness. The benefit of this device is it is hand-held and very mobile and can be used to scan an entire pole relatively quickly to find the area of most concern.

Whilst the XBS device gives more quantification than the Seismic device, it is still not intended to give a fully accurate picture of representative cross-section or timber fibre strength, because it is essentially representing an average density over a thickness of approximately 100mm from the external surface. What it is used for, is to confirm and provide urgency to the results of the seismic device.

Figure 4 gives an example of the type of results that are given by the PortaSCAN XBS device. One of the major benefits of this device is that it can be used on any type of timber structure, not just poles.

It is worth noting that the next iteration of this device is just around the corner and will improve on this technique again.

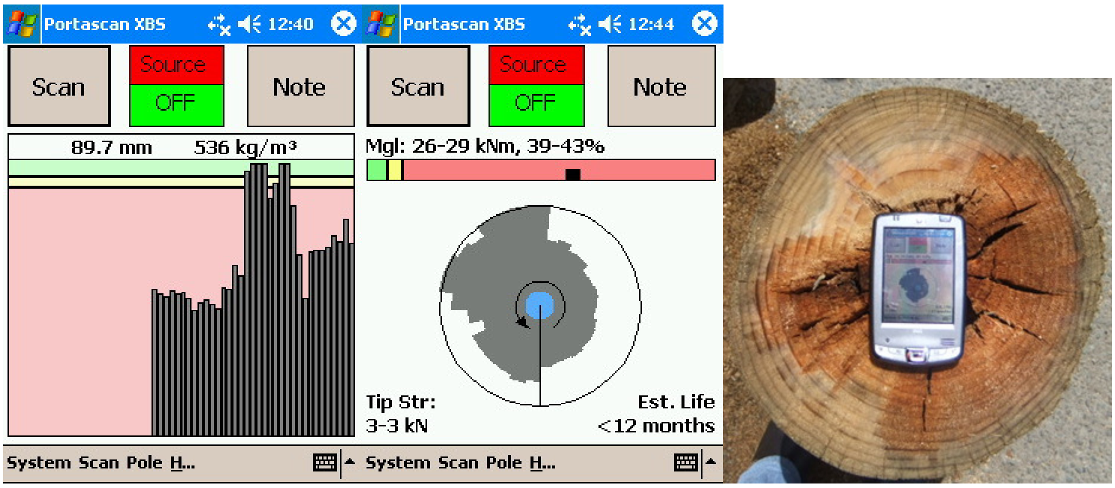

Figure 4: PortaSCAN XBS density readings around the circumference, a form of cross-section representation, and the pole that was scanned.

Tomography

There are a number of devices on the market that use ultrasound, electrical pulses or other signals to map the cross-section of a timber pole. These devices are very good at determining the residual section modulus at a particular cross-section, but are more time consuming, and rely on other methods to determine the most appropriate level to test at. They can have issues with Carroty decay and/or moisture internally, as the density changes can be too small to notice. But are generally the best performers in terms of accuracy. The downside is you still have to assume a residual fibre strength, which can be highly variable for old poles (fibre strength of good wood reduces with time), and this can make the device less accurate.

Figure 5 shows an example of the Woodscan unit, the signal paths, and an example of the end result.

In talking with our clients though, most don't see a need to use these types of devices except on poles where the cost of replacement is significant, in which case they are looking for cost deferment.

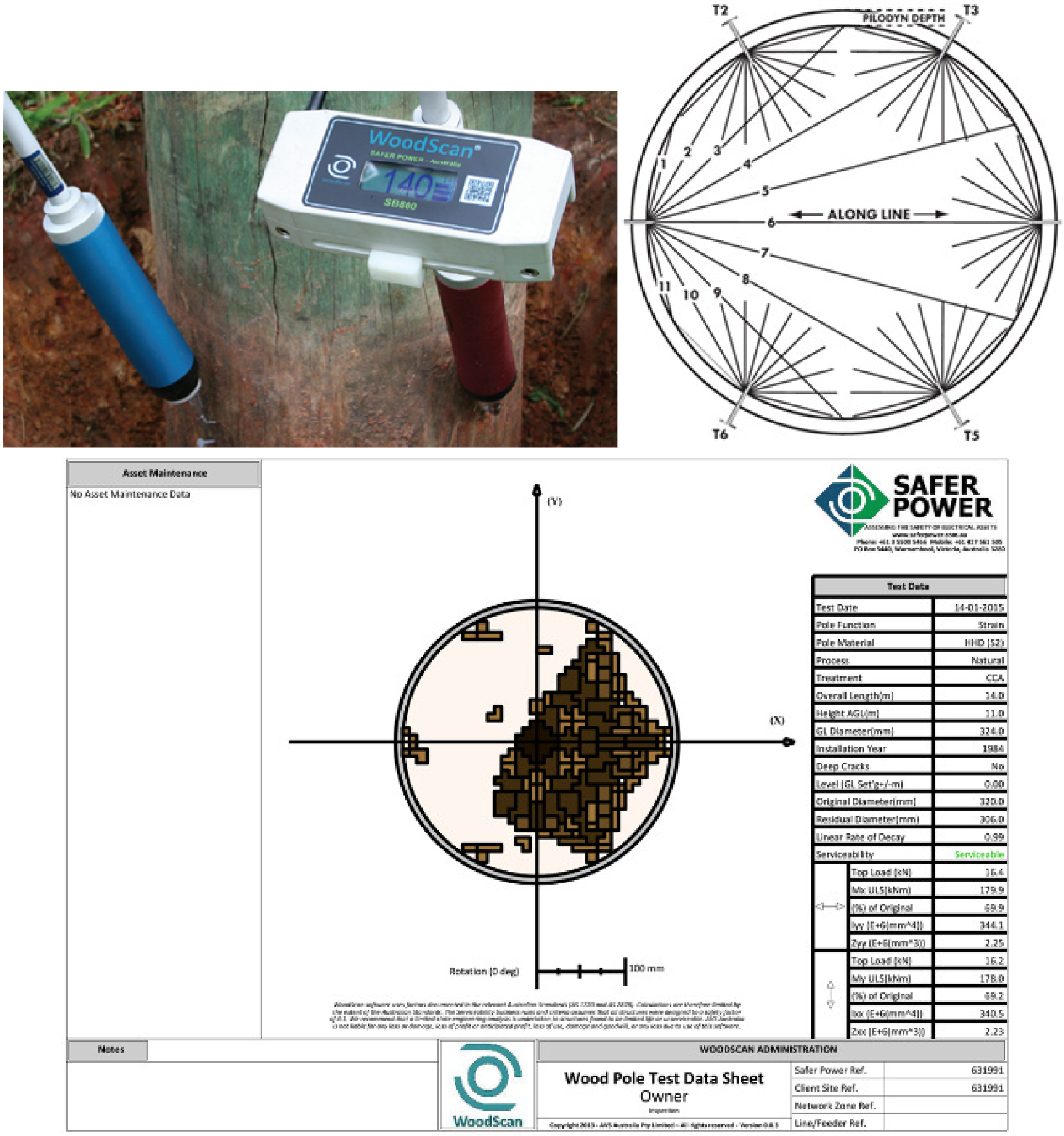

Figure 5: Example device, signal paths that produce the tomographic image, and an example result.

Ground Penetrating Radar

GPR has been trialled for the detection of decay and residual cross section of wooden power poles. However, it has never been commercialised for this application. This is mainly due to the lack of resolution of the results, issues with certain foundation types, and the cost/time taken to do an inspection. The technology is also difficult to apply to above ground inspection.

Proof Loading

Proof loading is a technique that has found favour with some utilities in Australia and New Zealand in particular. The two main technologies in this space are the Deuar MPT, and the Rei-Lux device. The Rei-lux device is probably more suited to steel poles, but it is simpler to group it in this area for the purposes of this discussion.

The technology normally performs well in comparative tests, as it gives an “almost” direct measurement of residual strength. In reality, it is determining the stiffness of the pole with a bias towards the ground line, and comparing that to an assumed stiffness vs. strength relationship. The technique is one of the more time consuming techniques and can be very sensitive to small errors in setup/operator input. One of the issues to be aware of, is that the determination of load on the pole can be a downfall of this method, and it has been known to turn an otherwise good measurement of residual strength, into an incorrect result for serviceability index (strength divided by design load). There have been concerns raised around repeatability and reproducibility from some users as well. There is also concern over the techniques causing failure of the pole due to the exerted loads.

The theory is good, but the implementation needs to be managed well, and ultimately there does not appear to be a significant benefit in using these devices over the quicker, more cost-effective techniques.

Figure 6: The Deuar MPT device set up for a test.

Example Deployments

A summary of a few known outcomes for asset owners that use NDT techniques for their poles is given in Table 1. This is a brief summary from information conveyed to me by the asset owners.

Table 1: Summary of NDT application outcomes

Location	Owner Type	NDT tools	Proportion of "unassisted failures"[1] per annum	Notes
WA	Utility	PortaSCAN XBS, RLS	<0.01%	Inspectors feel naked without the devices in the field. Network is a mix of steel and hardwood poles (mainly steel). Significant drop in unassisted failures.
VIC	Utility	Woodscan	<0.05%	Only been using for a short time, and only after Sound, Dig & Drill condemns the pole. Use has reduced required pole replacements by 60% or more, saving considerable REPEX. Looking at alternatives to improve

[1] Unassisted failures are defined differently for different asset owners, but can be generally defined as failures resulting from the condition of the pole, rather than an event impacting the pole that was greater than its design capacity. This is the percentage of unassisted failures compared to the size of the network, per annum (approximately).

				efficiency.
NZ	Utility	Thor, PortaSCAN XBS	<0.01%	Been using for a short time, inspectors are very happy. Mainly use Thor, rarely need PortaSCAN but has been useful to confirm a few Thor results. Have been looking closely at poles when removed and happy that they were appropriate.
NZ	Utility	Deuar MPT	<0.02%	Failure rate has reduced, but only been using for a short period. Some issues with speed and useability in some locations, but otherwise it is preferred.
QLD	Council	Thor, PortaSCAN XBS, RLS	<0.01%	Very happy with the results and the data that they get back which allows them to make appropriate decisions.

Conclusions

This paper was intended to highlight key pole inspection technologies that are now available and economically useful. Given the emphasis on safety and asset management budgets, the importance of NDT is increasing. From a legal perspective, if an asset owner does not have an appropriate inspection system in place and a failure occurs, there is little legal defence that can be raised. There is far too much evidence available to claim ignorance. Even employing external inspectors can still leave an owner vulnerable if they do not set appropriate rules for those inspectors.

The technology types presented are the most common types but not the only options. The reason they are the most common tends to be because they are the most commercially viable and well supported, as well as having adequate performance. The trick is finding a solution that works best for your asset, because none of them are infallible on their own.

References

[1] P. Begley, “Anzac Bridge light pole crashes over footpath,” Sydney Morning Herald, 9 June 2015. [Online]. Available: https://www.smh.com.au/national/nsw/anzac-bridge-light-pole-crashes-over-footpath-20150609-ghjosg.html. [Accessed June 2015].