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Installation Technology Transition Program

Evaluation of Non-Destructive Testing (NDT) Methods for Wood Power Poles

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Abstract

This technical report aims to test the effectiveness of several non-destructive testing (NDT) technologies on wood utility poles to detect deterioration. The project will assess commercially available devices using sound velocity and drilling resistance methods for in-field measurements. The goal is to extend the lifetime of wood poles, prevent unexpected failure, and enhance their in-service life beyond the current 75-year expectation. Despite the benefits of wood poles, it is difficult to obtain reliable deterioration metrics on in-service poles, which can lead to premature decommissioning or pole failure. NDT methods have been developed to replace labor-intensive methods, but none have been largely adopted in common practice. Therefore, creating a database of validated data would expedite adoption. Integrating precise and efficient wood utility pole NDT can increase installation energy resiliency and facility sustainment in a fiscally responsible way, ensuring high standards of delivery of services.

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Preface

This study was conducted for Headquarters, US Army Corps of Engineers, Installation Technology Transition Program, US Army Assistant Chief of Staff for Installation Management (ACSIM) Management Support Office, under MIPR 11681660. The technical monitor was Ms. Natalie R. Myers, Engineer Research and Development Center-Construction Engineering Research Laboratory (ERDC-CERL).

The work was performed by the Engineering Resources Branch of the Research and Engineering Division, ERDC-Cold Regions Research and Engineering Laboratory (CRREL). At the time of publication, Dr. Melisa Nallar was branch chief; and Dr. John W. Weatherly was acting division chief. The deputy director of ERDC-CRREL was Dr. Ivan P. Beckman, and the director was Dr. Joseph L. Corriveau.

COL Christian Patterson was commander of ERDC, and Dr. David W. Pittman was the director.

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1 Introduction

1.1 Background

With the increasing frequency of cold snaps and extreme weather, illustrated by events such as Winter Storm Uri in February of 2021, which exposed the vulnerabilities of energy infrastructure in Texas and caused widespread blackouts, it is more important than ever that the DoD adopt practices to maintain reliable and resilient energy infrastructure. As climate change continues to contribute to extreme weather events, ensuring cold weather resiliency of infrastructure becomes a critical priority for the DoD to safeguard its operations and mitigate potential disruptions. Wood utility poles continue to be one of the most affordable, easily constructed, sustainable, renewable, resilient, and widely used material for electrical lines. Newly adopted materials such as steel or concrete poles require complicated systems and installation, whereas wood poles remain extremely feasible. For example, wood poles are inherently and electrically insulated, and are installed by simply excavating and tamping around the pole to the appropriate density. Other materials require an engineered foundation and insulating measures to protect both wildlife and the poles themselves. Given this, wood poles can be easily installed or moved, making them useful in difficult terrain, environmentally sensitive areas, or areas experiencing rapid change, such as with contingency and main operating bases overseas, or installations facing Base Realignment and Closure. Additionally, wood pole lifetime is essentially equal to other materials used for utility pole structures (over 75 years), making them especially affordable and sustainable. In this time, a new tree can be grown to replace the aging poles. Each year in the US, six trees are planted for each one used. Trees sequester carbon and treated wood poles store that carbon indefinitely. Finally, wood poles are resilient. Engineered products are usually manufactured to a 5% lower exclusion limit, meaning that 95% of products exceed design strengths. However, because of wood's natural variability, it has a much wider coefficient of variance, meaning that a greater portion of wood poles will greatly exceed design strength when compared to engineered products, making it more resilient in the face of changing and more extreme climate patterns. Loads due to severe weather, wind, and ice are not reliably quantified, which makes wood an ideal material for utility poles.

Despite these benefits, it is difficult to obtain reliable deterioration metrics on in service poles. Poles can become damaged after exposure to freezing cycles, extreme weather, deteriorates from inside out, usually at ground level or approximately 18 inches underground, where bacteria grow. This makes decay difficult to detect and quantify. Common Operations and Maintenance (O&M) practice is to conduct highly subjective visual or sounding assessments. Inaccurate measurements lead to prematurely decommissioned poles or pole failure. Additionally, these inspection processes can be labor intensive. Detecting underground voids requires excavation of the poles, and climbing is often necessary to detect voids on upper portions of the poles.

Non-Destructive Testing (NDT) methods have been developed to replace these labor-intensive methods, but none have been largely adopted in common practice. This is in part due to variable results, unfamiliarity, and unvalidated data. This combined with up-front procurement and training costs make NDT methods more difficult to adopt. Several NDT methods have, however, been researched and evaluated as more effective and accurate than traditional methods. This includes electromagnetic or mechanical wave technologies, as well as minimally invasive methods like drilling resistance. Creating a database of validated data would expedite adoption. Finally, most poles at or approaching failure can be rehabilitated by adding preservatives or using mechanical means (e.g., steel trusses and fiber reinforcing sleeves), extending usable life far beyond 75 years.

NDT data will better inform engineers on when, how, and where to reinforce existing poles. The NDT data can also provide insight into deterioration mechanisms at work in cold regions, and how the mechanisms vary with species and preservative treatments. This can inform future research on the longevity of treated wood poles and mechanical reinforcing systems in cold or extreme regions. Because wood pole reinforcing systems are fairly new, little data exist to quantify their cold weather durability.

Integrating precise and efficient wood utility pole NDT with preventative O&M can increase installation energy resiliency and facility sustainment in a fiscally responsible way. Whether poles are owned and maintained by utilities or the installation, NDT ensures delivery of services at a high standard. NDT can provide more predictable investment cycles by incorporating quantifiable results into Installation Status Report–Infrastructure (ISR-I) ratings.

Any DoD power lines subjected to unpredictable ice or wind loads, wood-damaging insects and wildlife, or wet seasons, can benefit from adoption of NDT. In 2018, for example, Fort McCoy experienced a far-reaching electrical outage when prolonged exposure to –40°F weather caused a wooden utility pole to snap.* Picatinny Arsenal is another installation served by above-ground electrical lines. The installation is unable to underground a large area of its utilities because of rocky terrain. Additionally, its privatized utility provider is changing the preservatives used in their wooden utility poles. Providing detailed information on the composition and concentration of preservatives, and the associated effects on wood degradation would help Picatinny and other installations make informed decisions when working with their utility providers. The large-scale climatic conditioning facilities at the Cold Regions Research and Engineering Laboratory (CRREL) are also served solely by above-ground power lines.

Providing estimated deterioration, the resulting remaining strength and lifetime, and methods to reinforce the poles would provide near-term, cost-effective solutions to increase infrastructure longevity and prevent outages. Many installations under similar circumstances would benefit from a more informed preventive maintenance program to prolong utility pole lifetime and increase resiliency.

1.1.1 Non-Destructive Testing (NDT)

NDT covers a broad range of methods but fundamentally tests a subject without damaging it. NDT includes methods that use electromagnetic, radiographic, ultrasonic, and visual principals.

One method applied to the testing of wooden utility poles is ultrasonic. Ultrasonic NDT uses high frequency sound waves sent from a transmitter to a receiver to measure the speed of sound of the material. The speed of sound in the material defines the elastic moduli of the material along when combined with density. The stiffness of an object is a combination of the

* For a full list of the unit conversions used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office, 2016), 345–47, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

shape and the elastic moduli of its material. A Micro Hammer is one commercially available ultrasonic NDT device. Ultrasonic testing between one transmitter on one side of a medium and one receiver on the other gives one value. No resolution of differences along the material is seen.

Another type of NDT is using resistance drilling. The term *Resistograph* is a trademarked name owned by Rinntech Inc. of North Carolina, and it represents a type of resistance drill. A resistance drill works by using a long, small-diameter drill bit to drill into a material, while measuring the resistance encountered by the drill. Using resistance drilling is also considered NDT because the overall competency of the item measured is not compromised. Resistance drilling gives a profile of the resistance measured along the tested location. The more durable the material, the higher the resistance.

Few previous projects have investigated NDT methods for investigating utility pole strength. One study was undertaken in Turkey (Gezer et al. 2015). The Resistograph and Micro Hammer were used on utility poles along with visual inspection. While this study demonstrated the applicability of these methods to wood utility poles, no recommendations on criteria for determining the lifetime of a pole were given.

1.1.2 Standards

Several standards exist for wood utility poles. American National Standards Institute (ANSI) O5.1 Wood Poles specifies the dimensions and specifications, including strength parameters. These describe the properties when selecting a processed tree for use as a utility pole. National Electrical Safety Code (NESC) describes use of poles and an extreme wind requirement for poles.

United States Department of Labor Occupational Safety and Health Administration (OSHA) has methods for workers inspecting and testing wood poles in *Appendix D to § 1910.269—Methods of Inspecting and Testing Wood Poles* (2014). The pole must be deemed safe to climb or work on. Besides visual inspection, *§ 1910.268(n)(3)* outlines acceptable methods of testing wood poles as using a hammer or screwdriver to detect decay or attempting to rock the pole using physical force.

1.2 Objective

The objective of this project is to test the efficacy of various NDT technologies on wood utility poles to detect deterioration, analyze in-field measurements, and provide data to incentivize the adoption of NDT methods in operations and maintenance programs, to extend the wood pole lifetime, prevent unexpected failure, and enhance their in-service life beyond the current 75-year expectation.

1.3 Approach

The project involved conducting NDT on wood utility poles with the aim of estimating their remaining strength. The team worked with CRREL's Hanover, New Hampshire, and Alaska offices to gain access to in-service utility poles, which were then examined using NDT methods such as resistance drilling and sound velocity measurements. During the in-field testing, the team took detailed notes on the testing processes and observed the practicality of using each of these devices in the field. The results were recorded in this report detailing the accuracy, precision, and viability of these testing methods, along with recommendations for further research and how to implement NDT in a wood utility pole operations and maintenance program. Further research could include development of recommendations for wood preservative treatments, development of a model to accurately predict wood pole lifetime, examination of climatic effects on current poles, mechanical reinforcement methods, and development of new reinforcement methods and materials tailored towards cold and extreme environments.

2 Methods

2.1 Micro Hammer

The Micro Hammer method involves the use of a specially designed hammer with a small, hard tip, which is used to strike the surface of the pole. The sound waves generated by the impact are recorded using a microphone, and the resulting data is analyzed to determine the condition of the pole. The hammer is typically struck at multiple locations along the length of the pole, and the resulting sound waves are compared to determine the presence and severity of internal defects. Figure 1 shows the Micro Hammer in use.

While the Micro Hammer method is an effective technique for assessing the condition of wood utility poles, it does have some limitations. For example, the method is only effective for detecting internal defects and decay, and may not be useful for assessing the external condition of the pole. In addition, the technique may not be effective for detecting defects in poles that are heavily treated with preservatives, as the treatment can impact the sound waves generated by the hammer.

Figure 1. Micro Hammer in use.

2.2 Resistograph

The Resistograph method is an NDT technique that has been widely used in the evaluation of wood utility poles. The method involves the use of a needle-like probe that is drilled into the pole at a constant speed while measuring the resistance encountered by the probe. The measurement of resistance as a function of depth is recorded and analyzed to provide information about the internal structure of the pole. Figure 2 shows the Resistograph in use.

Figure 2. Resistograph in use.

This method proves valuable in detecting and locating internal decay, assessing the overall condition, and estimating the remaining strength. Additionally, it provides insights into the size and location of any defects or anomalies inside the pole. It offers quick results and is relatively user-friendly. However, it's essential to note that the Resistograph method is not a substitute for laboratory testing. To conduct the Resistograph test, a small pilot hole is initially drilled at the desired location. The Resistograph probe is then inserted and driven into the pole at a constant speed. Equipped with a sensor, the probe records resistance encountered during penetration, generating a graphical representation of resistance as a function of depth. This graph enables the detection of internal decay or anomalies.

The Resistograph method is particularly useful in identifying areas of decay that are not visible on the surface of the pole. The method can also be used to identify areas of decay that are not visible on the surface of the pole, but that are located deeper within the pole. In addition, the method can be used to identify areas of cross-grain tension, which can be a precursor to pole failure.

The method is relatively easy to use and provides quick results. However, it is important to note that the Resistograph method is not a substitute for laboratory testing and should be used in conjunction with other NDT methods for a more comprehensive evaluation of the pole.

2.3 Field testing

Tests were conducted on utility poles with the Micro Hammer and Resistograph systems in New Hampshire at the CRREL campus and in Alaska at Fort Wainwright and the CRREL Permafrost Research Tunnel. In total seven poles were tested in Alaska with five of them at Fort Wainwright and two at the CRREL Permafrost Research Tunnel. Five more utility poles were tested at CRREL in New Hampshire.

Poles were tested in similar locations with both NDT methods. Four repeat measurements were taken with the Micro Hammer, while for the Resistograph, two measurements were taken with for redundancy. Measurements were repeated at a different height along the pole.

3 Results

Twelve poles were tested with the Micro Hammer and Resistograph, as well as visually inspected. Among the poles a variation was observed in the size of the pole and the type of physical load on the pole. Some of the poles were line carriers, while others had transformers mounted to them. Table 1 lists the tested poles and their respective location, diameter, and notes from visual inspection.

Poles were tested at two heights. All poles in New Hampshire were tested at 1 ft above the ground, while some poles in Alaska had to be tested at 1.5 ft above ground level due to the amount of snow on the ground impeding access to the lower portion of the pole. All poles were tested at 3 ft above ground. The following sections contain the results of the tests.

Table 1. Tested wooden utility poles, locations, and pole diameters.

Pole	Location (State)	Diameter (cm)	Notes
1	AK	29	Used for light and electricity
2	AK	35	Appears relatively new
3	AK	33	Reasonably good condition
4	AK	33	Multiple conduit along length
5	AK	27	Guy wire holding back pole
6	AK	27	Appears relatively new
7	AK	21	Appears older
8	NH	33	• Multiple conduit along length • Exterior appears in bad condition
9	NH	25	• Used for electricity only • Appears in good condition
10	NH	33	Appears in good condition
11	NH	33	Used for electricity only
12	NH	33	Used for electricity and has 3 large conduits

Due to the climate difference between Alaska and Hanover, the ambient conditions while testing were different among the sites. It is possible that the wood utility poles in Alaska and New Hampshire may have different properties related to moisture content due to seasonal differences during testing. The climate variation between Alaska and New Hampshire can result in significantly different environmental conditions, including temperature, humidity, and precipitation patterns.

Seasonal changes, especially in regions with distinct climates like Alaska and New Hampshire, can impact the moisture content of wood utility poles. During the testing period, factors such as rain, snow, thawing, and freezing cycles can affect the moisture levels in the wood. Wood is a porous material that can absorb and release moisture depending on environmental conditions.

Higher humidity levels in one region may lead to increased moisture absorption by the wood poles, potentially causing them to have higher moisture content compared to poles in a drier region. Conversely, in a colder region, freezing temperatures may cause moisture within the wood to freeze, resulting in a reduction of moisture content.

The moisture content in wood can influence its mechanical properties, such as strength and durability. High moisture content can lead to decreased strength and increased susceptibility to decay, rot, or insect infestation. On the other hand, wood with low moisture content may be more prone to cracking or splitting.

Therefore, when evaluating the properties and conditions of wood utility poles in different locations, it's important to consider the potential impact of seasonal differences on moisture content and how it might affect the poles' structural integrity and performance over time. Proper assessment and maintenance strategies should be implemented to account for these variations and ensure the reliability and safety of the utility poles in their respective climates.

In Figure 3 through Figure 14, snow can be seen on the ground around Alaska poles, but green grass around poles in New Hampshire.

Figure 3. Pole 1 (viewed from multiple angles).

Figure 4. Pole 2 (viewed from multiple angles).

Figure 5. Pole 3 (viewed from multiple angles).

Figure 6. Pole 4 (viewed from multiple angles).

Figure 7. Pole 5 (viewed from multiple angles).

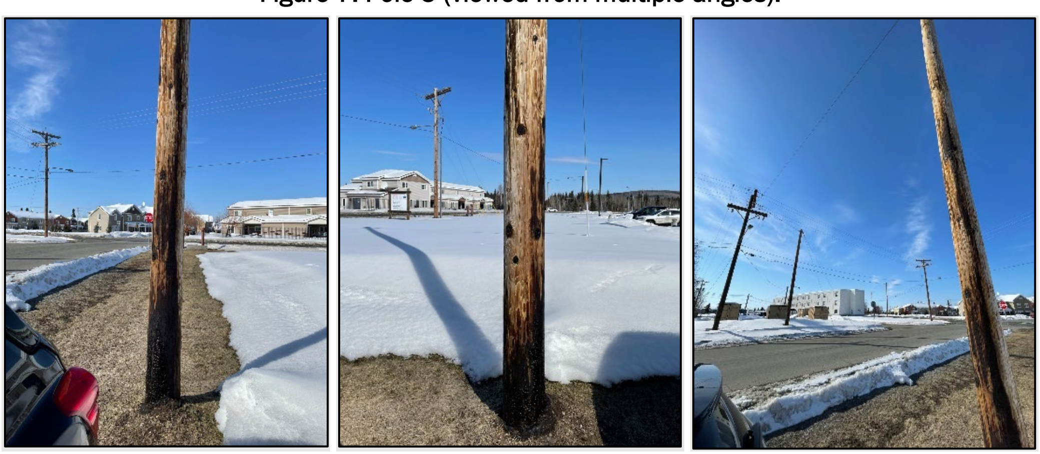


Figure 8. Pole 6 (viewed from multiple angles).

Figure 9. Pole 7.

Figure 10. Pole 8 (viewed from multiple angles).

Figure 11. Pole 9 (viewed from multiple angles).

Figure 12. Pole 10 (viewed from multiple angles).

Figure 13. Pole 11 (viewed from multiple angles).

Figure 14. Pole 12 (viewed from multiple angles).

3.1 Micro Hammer

The Micro Hammer gave a measured velocity of wooden utility in meters per second. Pole 11 sounded hollow when hit with the Micro Hammer. Pole 12 sounded like under tension load with a metallic-like sound. Repeat measurement values are averaged into a single value for the pole. Table 2 shows the resultant average velocity for the pole as measured in meters per second for the various heights along the pole above the ground.

Table 2. Measured velocity of wooden utility poles in meters per second as measured by the Micro Hammer.

Pole	Height of Test on Pole (ft)					
	1	1	1.5	1.5	3	3
1	—	—	1988	2019	1976	1978
2	—	—	1985	1909	1924	1891
3	—	—	1559	1558	1577	1569
4	—	—	1804	1802	1788	1796
5	1787	1841	—	—	1872	1826
6	1676	1701	—	—	1730	1720
7	1739	1791	—	—	1791	1758
8	1621	1627	—	—	1632	1585
9	1867	1917	—	—	1889	1900
10	1699	1655	—	—	1714	1702
11	1110	1110	—	—	1118	1151
12	1634	1583	—	—	1603	1602

The resultant pole velocity is plotted against pole diameter (Figure 15) and pole height (Figure 16) to investigate any correlation. No clear trend is seen. Measurements at different heights do not show an obvious trend of higher or lower velocity with higher measurement locations on a pole as shown with dotted trendlines in Figure 16.

Figure 15. Measured average velocity of pole against pole diameter.

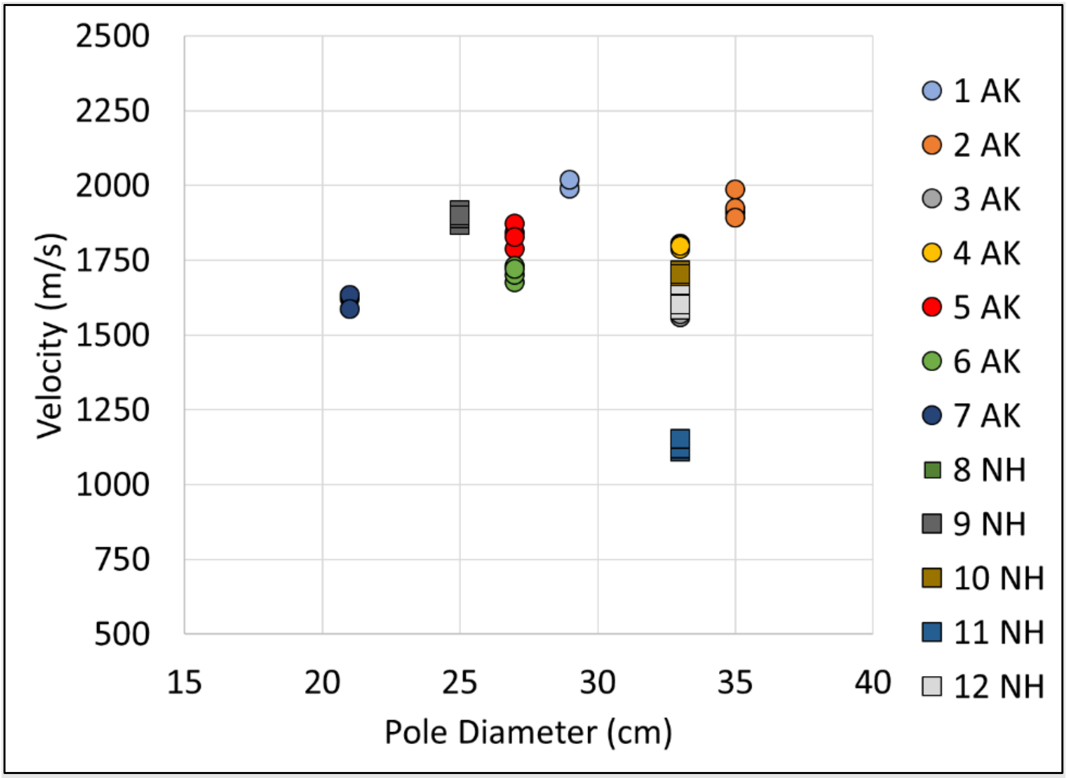
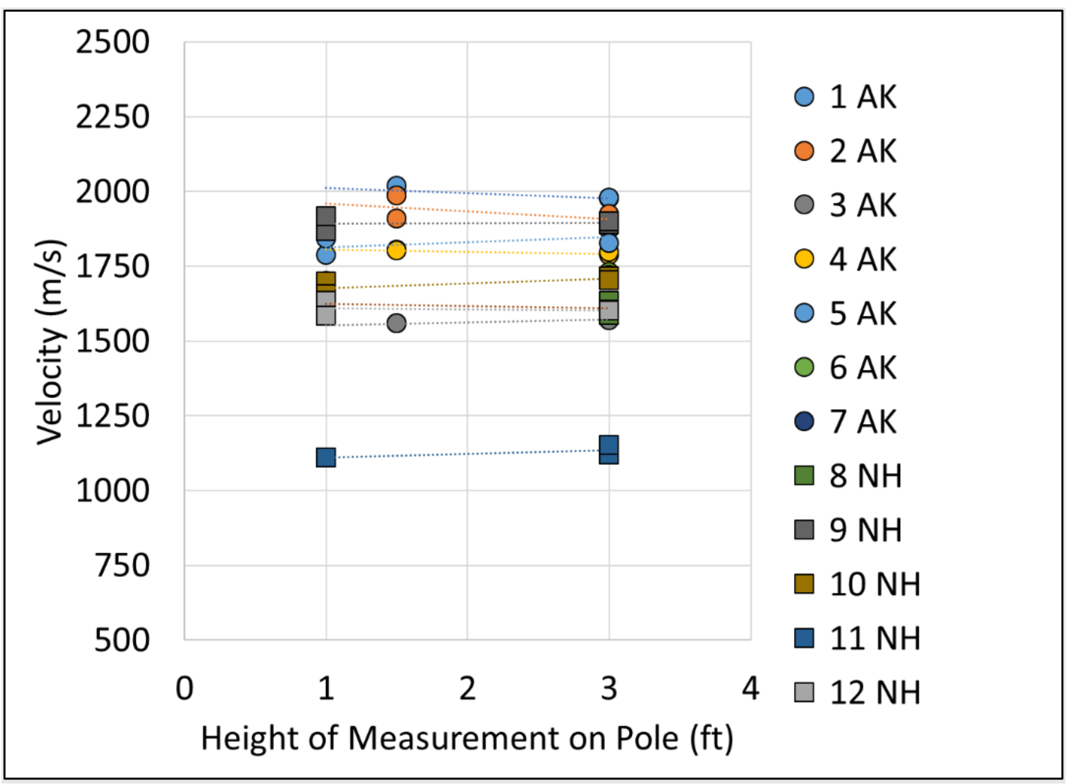


Figure 16. Measured average velocity of pole against height of measurement.



3.2 Resistograph

The Resistograph was recorded data on a physical strip chart. The chart is broken into four 25% quadrants. The chart is fragile and can be easily marked when pressure is applied. Poles 7 and 11 had notably smooth Resistograph curves. When testing Pole 8, the run with the Resistograph at 3 ft from the ground caused the exterior of the pole to flex. Pole 9 drill appeared to deflect and curve in pole. Pole 10 felt like a big hole or crack in middle when running the Resistograph into the pole. Pole 11 had short peaks in the Resistograph. Pole 12 had weak response on Resistograph.

Figure A-1 through Figure A-12 in the Appendix show images of the resultant strip chart produced by the Resistograph during NDT. For each pole, there are two plots, one for each measurement at a different height. On each plot, there are two repeat runs for redundancy and confirmation of the measurement.

The results for each pole are averaged and shown in Table 3.

Table 3. Measured resistance of wooden utility poles in average percentage as measured by the Resistograph.

Pole	Height of Test on Pole (ft)		
	1	1.5	3
1	—	40	35
2	40	—	45
3	35	—	35
4	45	—	40
5	50	—	35
6	50	—	35
7	35	—	35
8	30	—	30
9	55	—	60
10	60	—	50
11	50	—	50
12	50	—	50

4 Discussion

Results from the Resistograph instrument did not have a number value to them, however using the Resistograph did provide insight into the internal structure of the material. During the test with the Resistograph, the drill would provide audible and physical feedback representative of what the needle was recording on the chart. This was also the case with the Micro Hammer. Using the device produces an audible note. Denser poles sound different than less dense ones.

Similarities were noticed between the two NDT methods applied. Pole 11 had both short peaks in the Resistograph and sounded hollow when hit with the Micro Hammer, which both indicate less dense wood. Pole 12 had a notably weak response on Resistograph and had a noticeably different sound with the Micro Hammer.

Visual inspection did not always indicate what the measured values would be. Specifically, pole 11 in New Hampshire had the lowest recorded values compared to other poles with both methods and sounded very hollow when the Micro Hammer was used, however was not visually identified as different. All the poles at CRREL appeared to have voids in the middle of them at about 7 to 8 in into them.

On poles that did not appear to be in good condition, but it was recorded to have a high velocity the operator would be able to hear the pole sing denoting the pole could be under tensile load. This will affect the measured velocity as it can make the pole act denser. If a pole is denser the measured velocity will increase as there is less to slow down the sound wave as it passes through the pole.

Other observations that would affect the way the results would be recorded is the temperature at time of test. As the poles tested in Alaska were done at below freezing and this will also change the way the pole reacts as this will make the pole denser. Humidity may also have an effect as the speed of sound in water is different from the speed of sound in wood and therefore may affect Micro Hammer results at high water contents.

Overall, the poles that had higher velocities also had more sharp peaks on the Resistograph results and the poles that had flatter, or no peaks had lower recorded velocities. An example of this was found both in Alaska and in New Hampshire with pole number 7 in Alaska and pole number 11 in New Hampshire. Pole 7 with the Resistograph had a very flat line with no large peaks and similar result was found with pole 11.

This study tested twelve poles. It would be valuable to run tests on more poles including the various difference tree species that make up utility poles. Furthermore, additional repeat tests could be done of each measurement type on each pole.

No standards were found for determining the point at which to retire a utility pole from use. States and electricity companies may have their own specifications for wood utility poles.

5 Conclusions and Recommendations

5.1 Conclusions

The use of NDT methods for assessing wood utility poles is critical for the effective and efficient management of power distribution networks. The traditional subjective visual inspection method is unreliable, time-consuming, and expensive. NDT methods have the potential to detect deterioration accurately and provide critical information for deciding when and where to repair, replace, or reinforce the poles. The results of the project indicate that Micro Hammer and Resistograph NDT methods have significant potential for detecting deterioration in wood utility poles. The project's results also show that NDT can provide more predictable investment cycles by incorporating quantifiable results into ISR-I ratings. While the initial findings are promising, it is essential to acknowledge that the current sample size (*n* value of 12) may not be sufficient to fully support and generalize the application of these methods.

By conducting additional tests and validation, researchers can gain a deeper understanding of the correlation between NDT results and actual pole conditions. This process would help establish a stronger basis for incorporating NDT data into ISR-I ratings, leading to more accurate and predictable investment cycles for managing and maintaining wood utility poles.

5.2 Recommendations

Based on the project's results, we highly recommend the adoption of NDT methods in regular operations and maintenance programs for wood utility poles. NDT methods provide more accurate deterioration metrics and enhance the in-service life of wood poles. Additionally, we suggest incorporating X-ray fluorescence spectroscopy with NDT methods to create a calibrated database of data that can be used to assess the effects of preservatives on deterioration.

Furthermore, we recommend conducting additional research to improve the longevity of treated wood poles and mechanical reinforcing systems in cold and extreme regions. This would require gathering data on the durability of wood pole reinforcing systems, which are relatively new, to quantify their cold weather performance accurately. By adopting NDT methods and implementing the suggestions outlined in this report, the DoD can maintain reliable and resilient energy infrastructure for decades to come.

To further the research in this area, we propose developing recommendations for wood preservative treatments, building a model to accurately predict wood pole lifetime, examining the climatic effects on current pole, mechanical reinforcement methods, and developing new reinforcement methods and materials tailored towards cold and extreme environments. These steps will help improve the overall understanding of the longevity and durability of wood poles and mechanical reinforcing systems in challenging environments.

Examples of further research could include the development of recommendations for wood preservative treatments, development of a model to accurately predict wood pole lifetime, examination of climatic effects on current pole, mechanical reinforcement methods, and development of new reinforcement methods and materials tailored towards cold and extreme environments.

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Appendix: Resistograph Images

Figure A-1. Pole 1 Resistograph chart at 1.5 ft (*top*) and 3 ft (*bottom*).

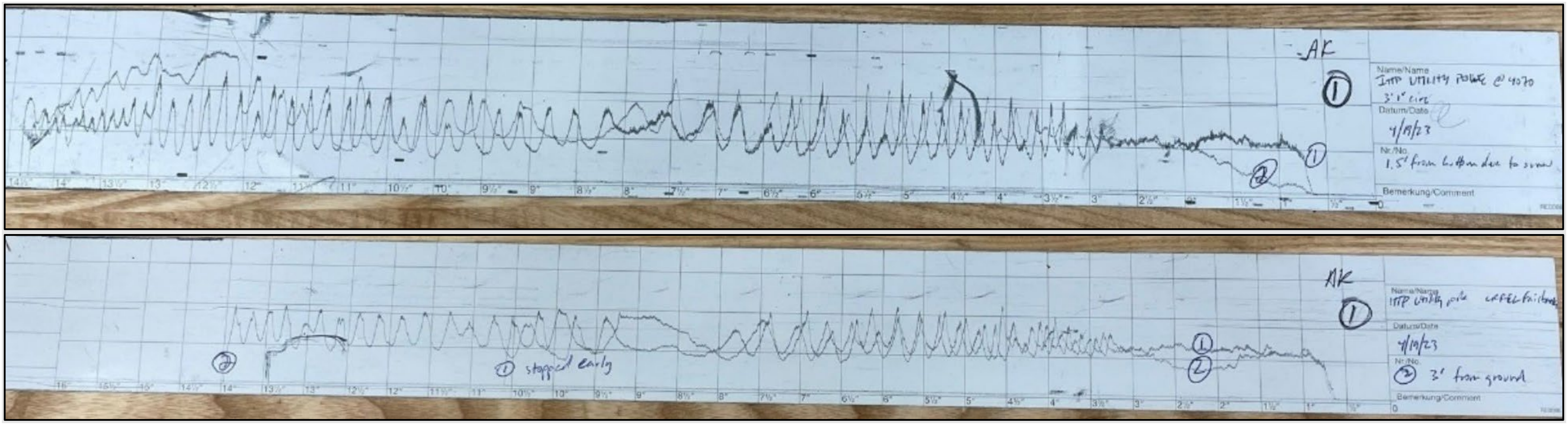


Figure A-2. Pole 2 Resistograph chart at 1 ft (*top*) and 3 ft (*bottom*).

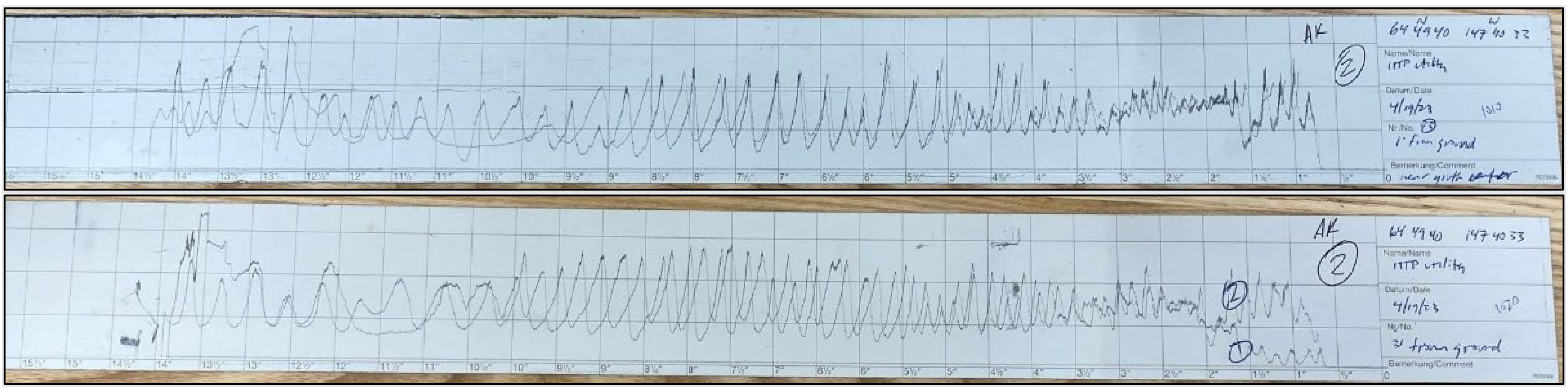


Figure A-3. Pole 3 Resistograph chart at 1 ft (*top*) and 3 ft (*bottom*).

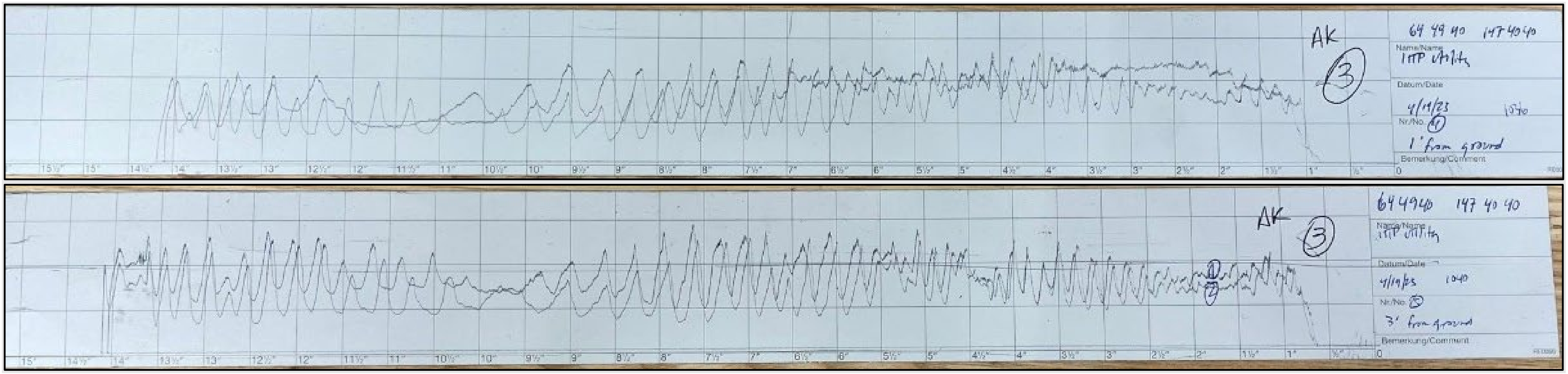


Figure A-4. Pole 4 Resistograph chart at 1 ft (*top*) and 3 ft (*bottom*).

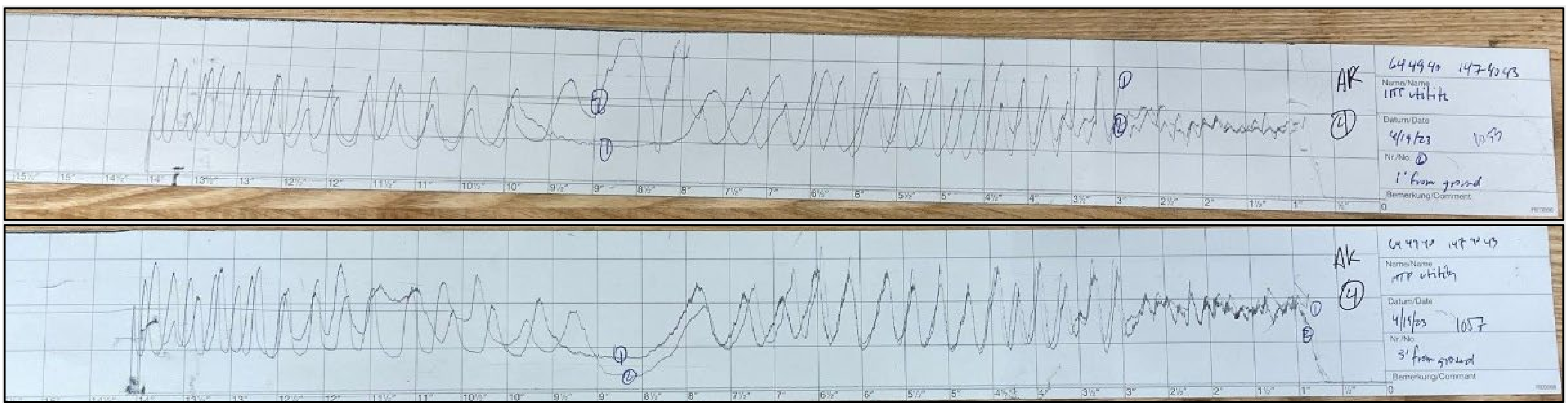


Figure A-5. Pole 5 Resistograph chart at 1 ft (*top*) and 3 ft (*bottom*).

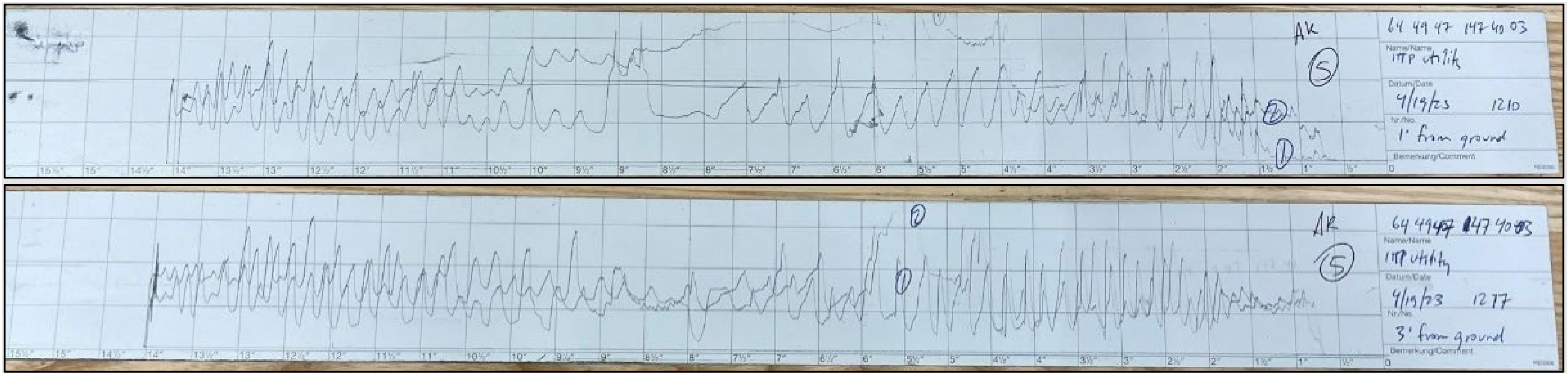


Figure A-6. Pole 6 Resistograph chart at 1 ft (*top*) and 3 ft (*bottom*).

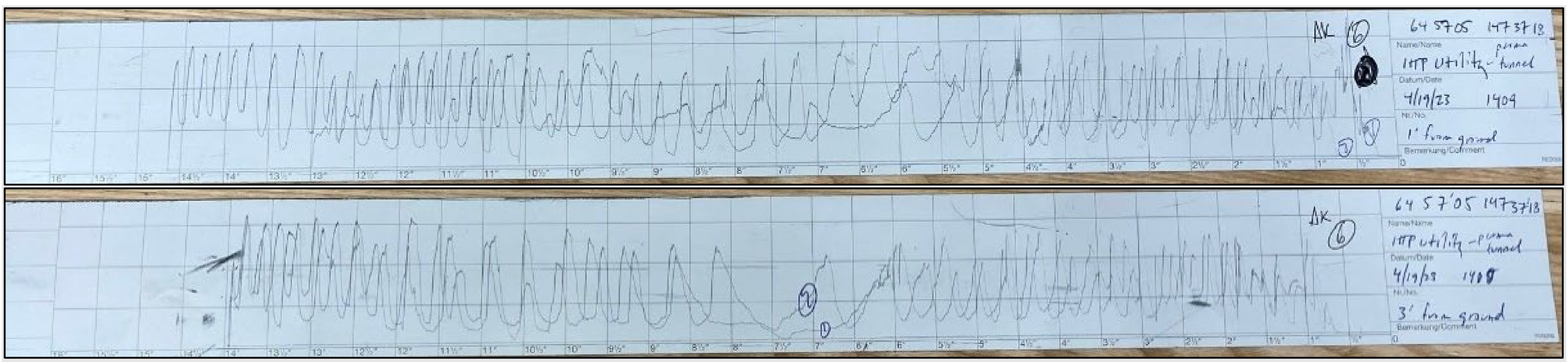


Figure A-7. Pole 7 Resistograph chart at 1 ft (*top*) and 3 ft (*bottom*).

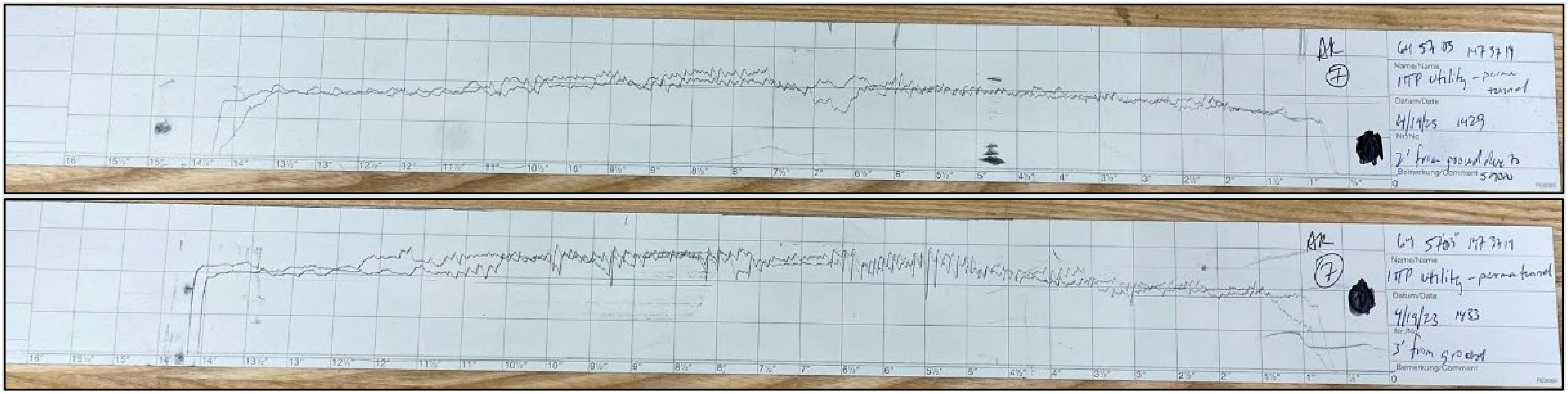


Figure A-8. Pole 8 Resistograph chart at 1 ft (*top*) and 3 ft (*bottom*).

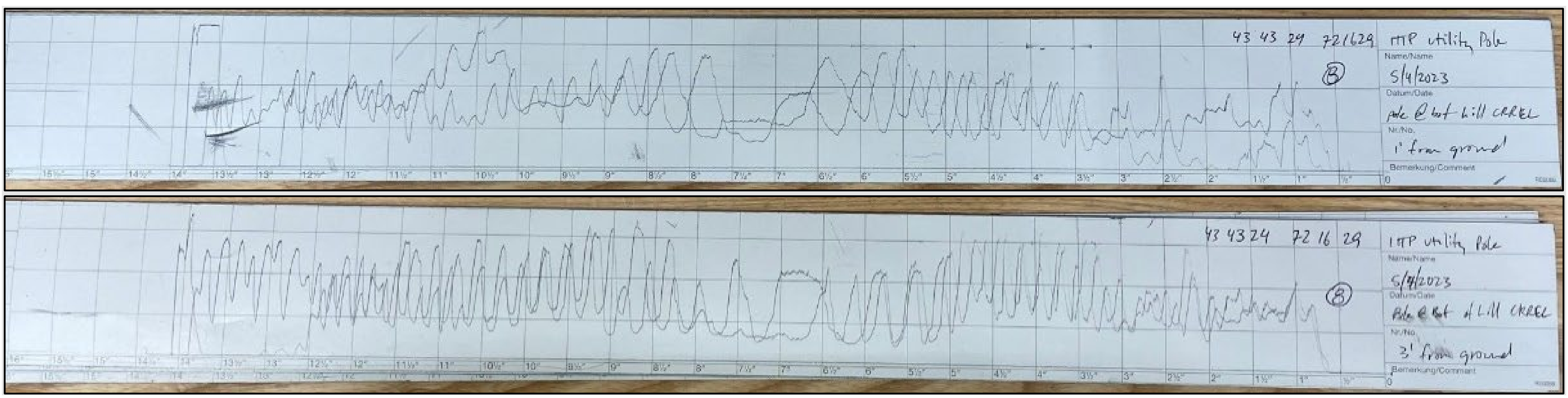


Figure A-9. Pole 9 Resistograph chart at 1 ft (*top*) and 3 ft (*bottom*).

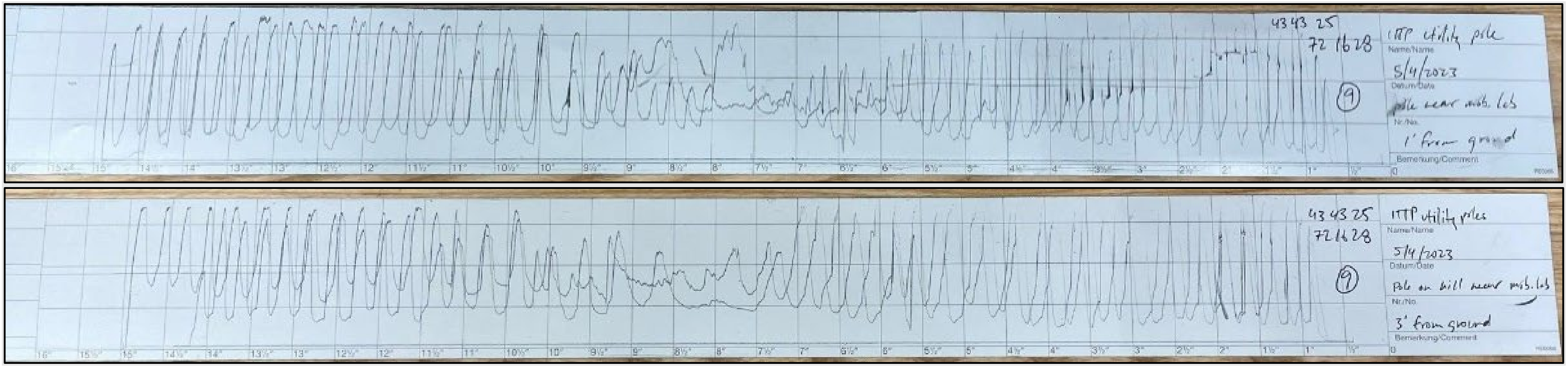


Figure A-10. Pole 10 Resistograph chart at 1 ft (top) and 3 ft (bottom)

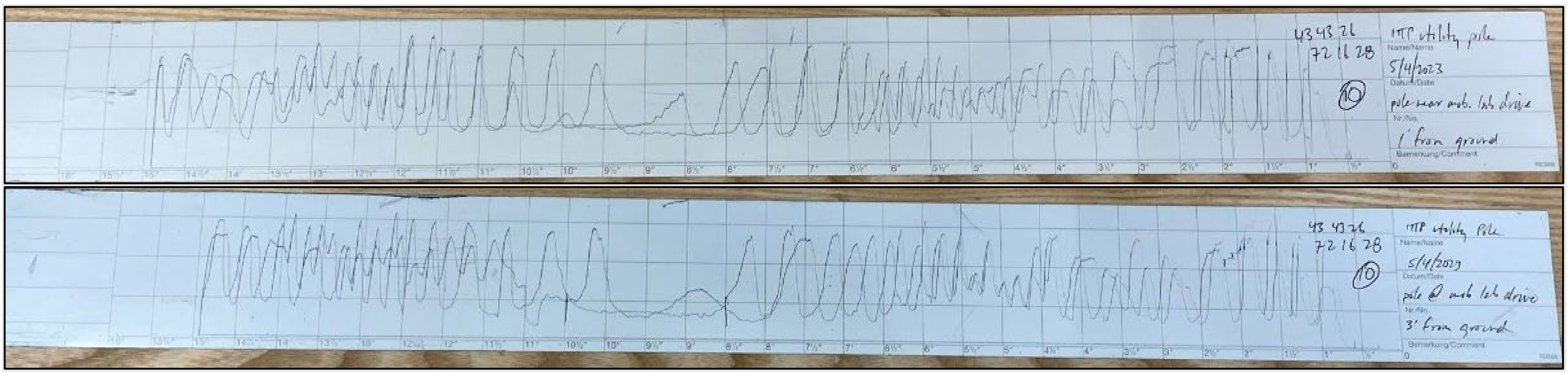


Figure A-11. Pole 11 Resistograph chart at 1 ft (*top*) and 3 ft (*bottom*).

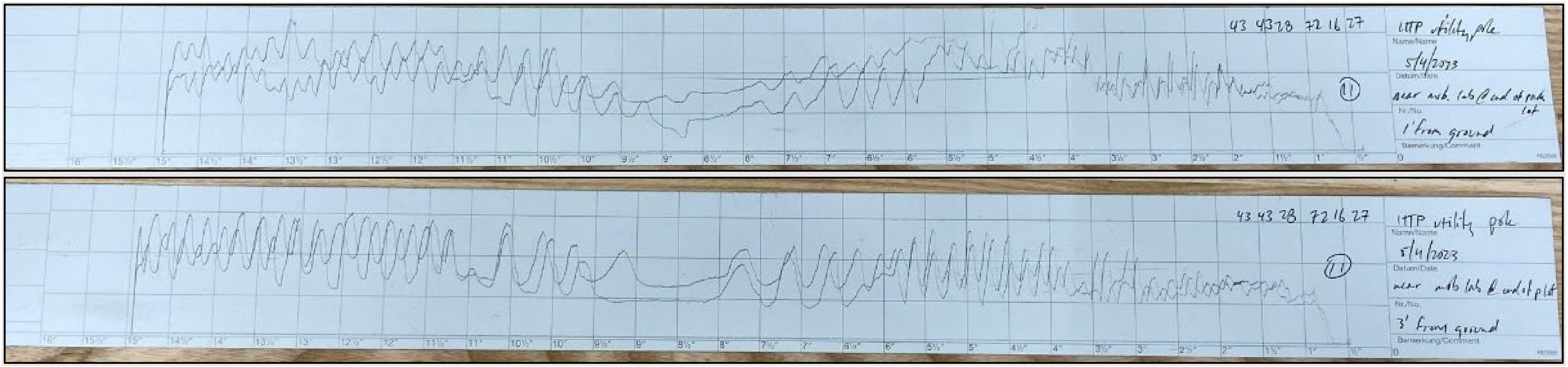
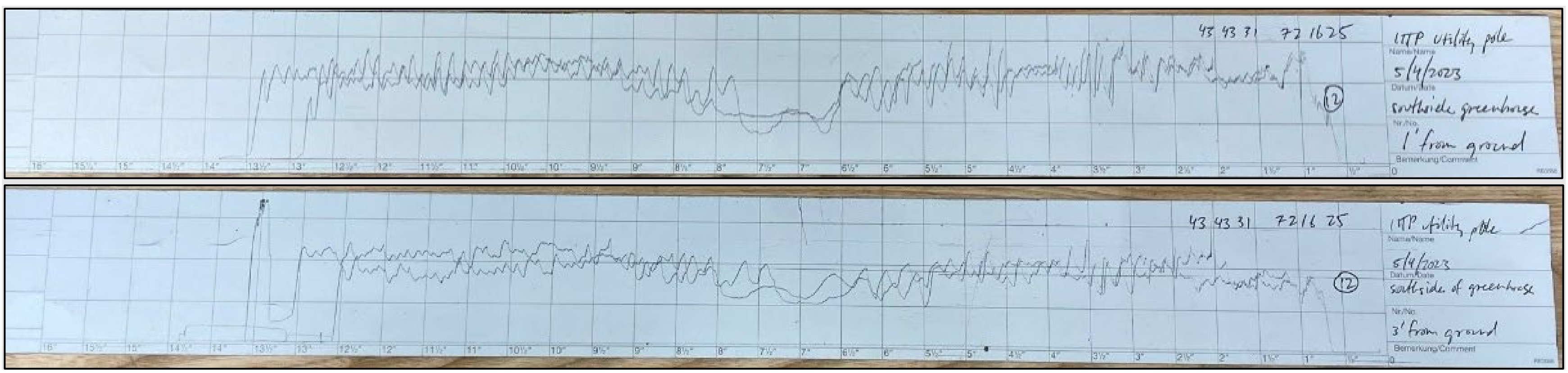


Figure A-12. Pole 12 Resistograph chart at 1 ft (*top*) and 3 ft (*bottom*).



Abbreviations

ANSI	American National Standards Institute
CRREL	Cold Regions Research and Engineering Laboratory
ISR-I	Installation Status Report–Infrastructure
NDT	Non-Destructive testing
NESC	National Electrical Safety Code
O&M	Operations and maintenance
OSHA	Occupational Safety and Health Administration

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14. ABSTRACT
This technical report aims to test the effectiveness of several non-destructive testing (NDT) technologies on wood utility poles to detect deterioration. The project will assess commercially available devices using sound velocity and drilling resistance methods for in-field measurements. The goal is to extend the lifetime of wood poles, prevent unexpected failure, and enhance their in-service life beyond the current 75-year expectation. Despite the benefits of wood poles, it is difficult to obtain reliable deterioration metrics on in-service poles, which can lead to premature decommissioning or pole failure. NDT methods have been developed to replace labor-intensive methods, but none have been largely adopted in common practice. Therefore, creating a database of validated data would expedite adoption. Integrating precise and efficient wood utility pole NDT can increase installation energy resiliency and facility sustainment in a fiscally responsible way, ensuring high standards of delivery of services.

15. SUBJECT TERMS
Energy resilience; Inspection methods; Non-Destructive testing (NDT); Pole maintenance; Safety assessment; Structural health assessment; Utility poles; Wood power poles

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