Tampereen ammattikorkeakoulu

# Leak Detection Systems in Finnish District Heating Network

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## ABSTRACT

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The objective of this thesis was to present available leak detection methods in the context of Finland's district heating networks, emphasizing their impact on operational reliability, cost efficiency, and customer satisfaction.

The first part of this thesis provides an overview of district heating systems in Finland, emphasizing the critical importance of addressing pipeline leaks. The theoretical framework then explores various leak detection methods and their underlying technologies, including two types of alarm cabling systems one based on resistance measurement and the other on time-domain reflectometry (TDR) pulse technology along with thermal imaging and external notification methods. Each method’s technical principles, benefits, and limitations are discussed in detail.

The research methodology centers on qualitative interviews with industry experts to assess the operational effectiveness and user experiences with these technologies. Additionally, the thesis includes a case study on the implementation of the Vexve iSense system in a district heating facility, offering practical insights into its utility and environmental impact.

The findings demonstrate that advanced leak detection systems significantly enhance the efficiency and reliability of district heating operations. These technologies not only reduce operational disruptions and maintenance costs but also improve customer satisfaction through increased service reliability.

In conclusion, this thesis underscores the critical role of advanced leak detection technologies in supporting sustainable and efficient district heating. The research offers valuable guidance for district heating providers in making informed decisions about technology selection and infrastructure investment, ultimately contributing to greater resilience and customer satisfaction within Finland’s evolving energy market

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Key words: district heating, leak detection systems, TDR Pulse

**TIIVISTELMÄ**

Tampereen ammattikorkeakoulu
Talotekniikan tutkinto
LVI-talotekniikka

TUIKKA, LIJUN:
Vuotohavaintojärjestelmä Suomen Kaukolämpöverkostossa

Opinnäytetyö 49 sivua, joista liitteitä 9 sivua
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Tämän opinnäytetyön tavoitteena oli esittää Suomessa käytettävissä olevia vuodonhavaintojärjestelmiä kaukolämpöverkostossa, painottaen niiden vaikutusta toiminnan luotettavuuteen, kustannustehokkuuteen ja asiakastyytyväisyyteen.

Tämän opinnäytetyön ensimmäinen osa antaa yleiskatsauksen Suomen kaukolämpöjärjestelmistä ja korostaa putkistojen vuotojen ratkaisemisen tärkeyttä. Teoreettinen viitekehys tutkii sitten erilaisia vuotohavaintojärjestelmä ja niiden taustalla olevia tekniikoita, mukaan lukien kahden tyyppiset hälytyskaapelointijärjestelmät, joista toinen perustuu resistanssimittaukseen ja toinen aika-alueen reflektometrian (TDR) pulssiteknologiaan sekä lämpökuvaukseen ja ulkoisiin ilmoitusmenetelmiin. Jokaisen menetelmän tekniset periaatteet, edut ja rajoitukset käsitellään yksityiskohtaisesti.

Tutkimusmetodologia keskittyy kvalitatiivisiin haastatteluihin alan asiantuntijoiden kanssa arvioidakseen näiden teknologioiden toiminnallista tehokkuutta ja käyttäjien kokemuksia. Lisäksi opinnäytetyö sisältää tapaustutkimuksen Vexve iSense -järjestelmän käyttöönotosta kaukolämpölaitoksessa, joka tarjoaa käytännön näkemyksiä sen hyödyllisyydestä ja ympäristövaikutuksista.

Tutkimus tarjoaa arvokasta ohjeistusta kaukolämpötoimijoille teknologian valinnassa ja infrastruktuuri-investoinneissa, mikä lisää resilienssiä ja asiakastyytyväisyyttä Suomen kehittyvillä energiamarkkinoilla.

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Key words: district heating, leak detection systems, TDR Pulse

**CONTENTS**

**GLOSSARY or ABBREVIATIONS AND TERMS (choose one or other)**

| | |
|---|---|
| TDR | Time Domain Reflectometer |
| DN | Diamètre Nominal |
| Mpul | Two freely moving flow pipes with polyethylene protective sheath and polyurethane foam |
| 2Mpul | Freely moving flow pipes with polyethylene protective sheath and polyurethane foam |

# 1 INTRODUCTION

In Finland, as of the end of 2021, district heating pipelines extend approximately 16,000 kilometers beneath the ground, experiencing hundreds of leaks on an annual basis (Energiateollisuus ry.). The cost of repairing these leaks is considerable, aside from the disruption they cause to district heating customers. In an increasingly competitive market that offers a variety of heating sources, maintaining system reliability is crucial for district heating providers.

This thesis addresses the question: How do the leak detection systems used in Finland impact the reliability, cost-effectiveness, and customer satisfaction of district heating networks? The study will begin with an overview of district heating in Finland, highlighting key challenges in the distribution network that affect efficiency, particularly pipeline leakage. This will be followed by a theoretical section that reviews the current leak detection systems in use. After the theoretical part, a survey-based analysis will compare the listed systems to assess which is most suitable for different pipeline conditions.

This thesis, commissioned by Vexve Oy, a provider of valves and leak detection systems for district energy pipelines. The outcome of this research is expected to benefit district heating companies by equipping them with the knowledge to choose the most appropriate leak detection system for their specific needs, ultimately leading to improved service reliability and customer satisfaction in the face of the evolving energy market.

# 2 DISTRICT HEATING IN FINLAND

## 2.1 What is distract heating

District heating is the most widely used heating system in Finland. It works by centrally producing heat for buildings and supplying hot water to properties. This heat is then distributed through a network to customers. Water or steam is typically used for as the medium. District heating can service wide range of customer, for example residential buildings, factories, shops, and public facilities. Heating is used for warming spaces and heating water for everyday needs (Koskelainen 2006, 25).

## 2.2 Finnish district heating history and current state

The first district heating systems in Finland were started as early as the 1950s. After the war, Finland faced an energy shortage, and it was realized that there was excess waste heat generated during industrial electricity production, which could be utilized, for instance, for heating residential buildings. (Koskelainen 2006, 34)

The importance of district heating began to increase during the 1970s energy crisis and prompting restrictions on energy consumption. This period brought district heating's energy-efficient advantages to the forefront. Available fuels at the time included oil, peat, wood chips, and natural gas. While price remains a primary factor in fuel selection, people also consider efficiency and emissions. For instance, oil usage has gradually declined, while natural gas has become increasingly popular and competitive. This shift is not only due to price reductions but also because of its ease of use and environmentally friendly combustion products. In the 1980s, it was the main time of district heating expansion, with the model being combined heat and power (CHP). (Koskelainen 2006, 35)

In Finland, in 2022, the total supply of district heating amounted to 36,900 GWh, which is shown in table 1 with networks spanning approximately 16,200 km across the country. This represented a 0.9% increase compared to the previous year. (Energiateollisuus ry, District heating in Finland 2022)

TABLE 1. General information on district heating year 2022 (Energiateollisuus ry, District heating in Finland 2022)

| | Year 2022 | Change compared to 2021 |
|---|---|---|
| Total supply | 36 900 GWh | - 6,0 % |
| DH production by fuels | 31 800 GWh | - 5,5 % |
| Net production of electricity in CHP production | 8 100 GWh | - 18,8 % |
| Fuel energy consumed | 48 600 GWh | - 6,5 % |
| Heat recovery and heat produced by heat pumps | 4 900 GWh | - 9,1 % |
| DH consumption | 33 000 GWh | - 6,6 % |
| of which the share of dwelling houses | 54,1 % | + 0,8 p.p. |
| Customers: | | |
| ❖ The contracted heat power | 19 400 MW | + 0,8 % |
| ❖ Building volume | 1030 million $m^3$ | + 0,8 % |
| ❖ of which the share of dwelling houses | 46,1 % | + 0,1 p.p. |
| Average selling price | | |
| ❖ Arithmetic value | 88,22 €/MWh | + 6,6 % |
| ❖ Weighted by sales | 91,32 €/MWh | + 10,2 % |
| Total length of DH networks | 16 200 km | + 0,9 % |

## 2.3 Key Components of a District Heating System

A modern district heating system consists of three main components: Heat production facilities, district heating distribution network, and district heating customer equipment.

### 2.3.1 Heat production

District heating is generated at a production facility, which can be either a combined heat and power (CHP) or a heating center. Additionally, district heating can be produced using the back - pressure steam from industrial power plants, showcasing the utilization of waste heat. Typically, district heating is generated through combined heat and power (CHP) production, to maximizing the efficiency of energy utilization and minimizing environmental impacts. The fuels utilized in these production facilities can vary and may include coal, natural gas, oil, wood, and peat, while there is also a growing trend towards utilizing renewable energy sources such as biomass, solar, geothermal energy and electricity in district heating systems, reflecting a commitment to sustainability and reducing carbon emissions.( LVI 10-10398, Kaukolämmitys, 2006)

### 2.3.2 District heating distribution network

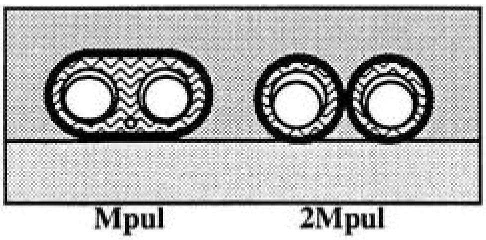
The district heating distribution network comprises a system of pipelines designed to transport heat from heat production facilities to customers' heating systems. It serves as a crucial link between district heating companies and their customers.

The medium transported through this distribution network is typically hot water or steam. This network is a sophisticated infrastructure composed of pipes of different diameters from DN20 – DN1000 and types, valves for regulation flow and pump stations for maintaining pressure. The strategic placement of district heating pipes, often buried 0.5–1 m underground, beneath urban infrastructure such as streets and sidewalks, or integrated into larger tunnels alongside other utility pipelines, to protect these pipes and ensure higher thermal efficiency. To optimize energy efficiency, these pipes are carefully insulated to reduce heat loss along the transmission route. (Energiamaailma.)

Due to their unique location, constructing the distribution pipelines is very expensive, and detecting any damage or leakage in the pipeline is also very difficult.

### 2.3.3 Different Types of District Heating Pipes

Freely moving plastic-cased district heating pipes, referred to as Mpul pipes, were extensively implemented in Finland's district heating networks from the 1960s until the early 1980s. Mpul pipes typically comprise an insulation element, which may either consist of a casing for two flow pipes or two separate casings, each intended for one flow pipe. The casing is made of plastic and includes polyurethane insulation, with the flow pipes installed freely within the insulated casing as shown in Picture 1. This design allows for improved flexibility and adaptation in varying operational conditions. (Kaukolämpöverkon suunnitelmanllinen perusparantaminen L7/2016)




Picture 1. Freely moving plastic-cased district heating pipes

Concrete prefabricated channel systems are commonly used for large-scale, high-priority transmission pipelines within district heating networks. In these systems, steel pipes acting as flow pipes are encased within a concrete shell and supported on brackets. The steel pipes are secured to the concrete walls and base through embedded steel supports to accommodate movement and thermal expansion as shown in Picture 2. The walls of the concrete shell are thick enough to allow for adequate insulation between the flow pipes and the outer casing. (Koskelainen 2006, 144)

PICTURE 2. Concrete duct district heating line (Jari Randell)

In Picture 3 the insulation used in these ducts is typically made of mineral wool or polyurethane foam channels.

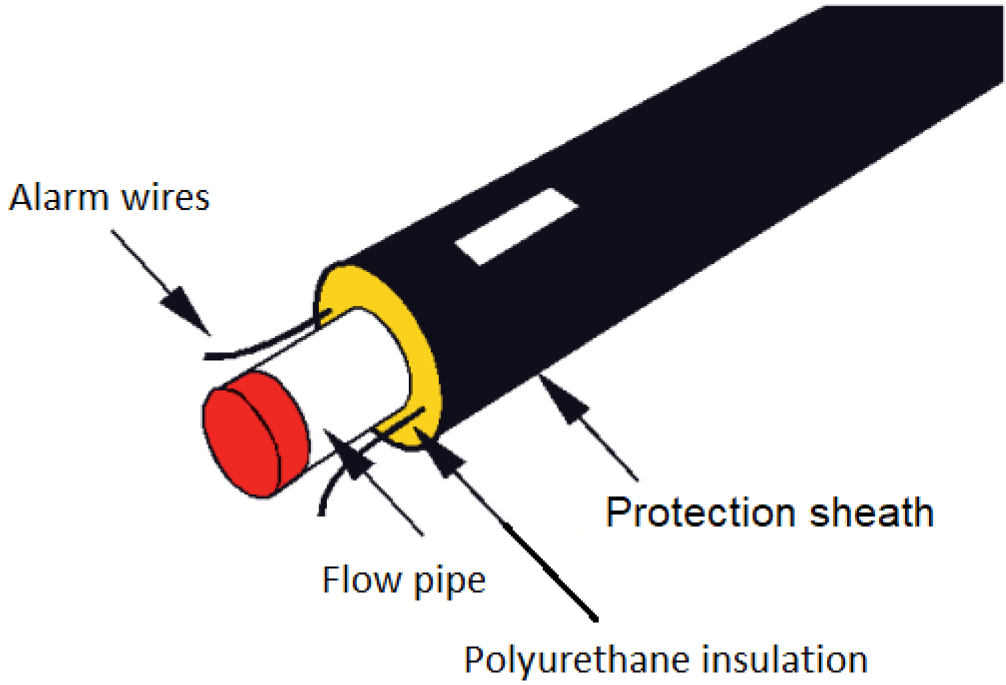
PICTURE 3. Concrete duct district heating line (Henrikki Nuutinen, Helen Oy)

Bonded district heating pipes consist of a flow pipe encased in a layer of polyurethane insulation, protected by an outer shell made of polyethylene. Introduced in Finland in the mid-1970s, this bonded piping system rapidly replaced other pipe types in use at the time. Since the mid-1980s, nearly all district heating systems in Finland have relied on this type of pipe. (Koskelainen 2006, 138)

Bonded pipes generally come in two configurations: a single casing that houses two flow pipes or separate casings, each designed for an individual flow pipe. These pre-insulated pipe elements feature a durable plastic casing, polyurethane insulation, and flow pipes that are securely bonded to the casing with polyurethane foam, ensuring structural integrity and effective thermal insulation. (Kaukolämpöverkon suunnitelmallinen perusparantaminen L7/2016)

PICTURE 4. Bonded pipes (Jari Randell)

Pre-insulated district heating pipes can be equipped with built-in moisture alarm cables, allowing continuous monitoring of the pipe's condition and detecting any moisture ingress into the insulation as shown in Picture 5. (Koskelainen 2006, 142)

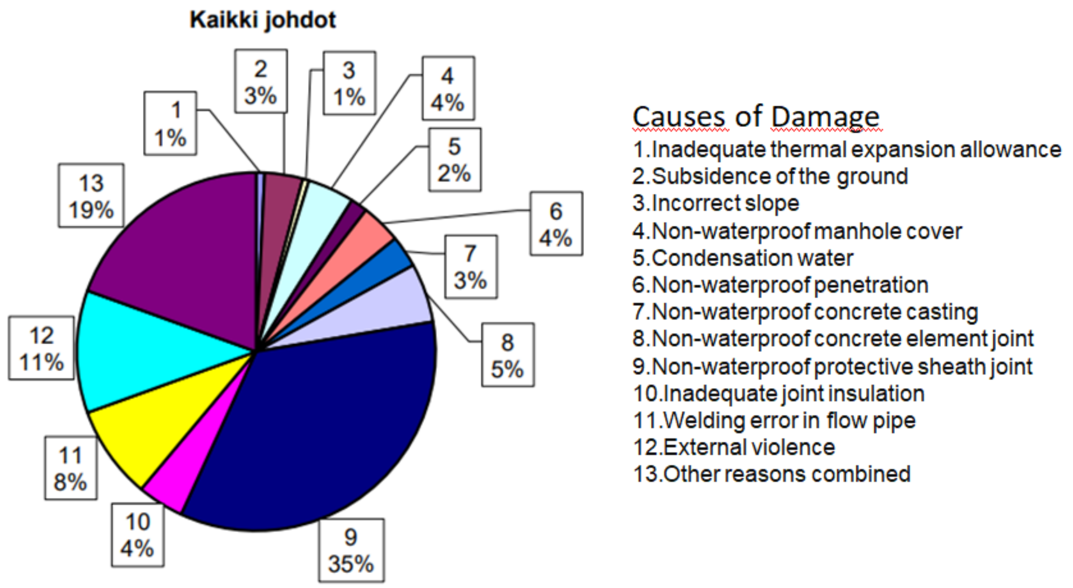



PICTURE 5. Parts of pre-insulated district heating pipe (Logstor Kaukolämpökäsikirja-2015)

## 2.4 Damage occurring in the distribution network and their repair costs

### 2.4.1 Pipeline damage

The causes of pipeline damage can vary, but the most frequent cause is an "improperly sealed protective sheath joint," as shown in Picture 6, regardless of the type of pipelines (Energiateollisuus ry. Stastics on district heating 2019). An improperly sealed protective sheath joint allows outside water to penetrate the protective sheath and polyurethane insulation, gradually over time leading to corrosion of the steel pipe and resulting in perforations.




Picture 6. Distribution of damage causes for year 2019 (District heating network damage statistics 2019)

### 2.4.2 Repairing costs

According to a survey conducted by Energiateollisuus ry in 2019, there were 105 damages, and the average repair cost per damage in 2019 was approximately €9,000. The estimated total repair cost for the year 2019 would be €13.2 million for the whole of Finland, calculated using the average repair cost of €14,000 from the year 2005 and assuming a 100% response rate to the damage survey. The same survey was also conducted by Energiateollisuus ry from 2018 to 2014, showing repair costs per damage for the whole of Finland as follows: €11.2 million, €12.6 million, €15.4 million, €12.3 million, and €12.5 million respectively. (Energiateollisuus ry. Stastics on district heating 2014 to 2019)

The repair costs usually consist of the loss of district heating water, material expenses such as replacement pipes, valves insulation. Labor costs for repairs, which are excavating the surrounding area, cutting the leaking pipes, welding and insulation of the new pipes and reburying the pipeline. Additionally, there is the impact of lost billing in certain cases. Should there be a need to start a backup district heating plant, the operational and fuel costs are also included.

If leaks are detected at an early stage, specifically when only the sealed joints of the protective sheath are broken and outside water begins to penetrate the protective sheath and polyurethane insulation, the repair costs are significantly lower. This is because there is no loss of district heating water, and the material costs involve only the insulation, while labor costs are also reduced. Furthermore, repair work can be scheduled in advance.

The repair cost in the context of district heating maintenance is a significant aspect of the overall operational and maintenance budget, which can be estimated to represent a substantial portion, such as roughly 40% of total expenditures (Energiateollisuus ry. Statistics on district heating 2019 - Economic indicators of district heating usage). This significant allocation highlights the impact that repair activities have not only on the financial aspects of district heating operations but also on the service quality experienced by customers. When repair works are necessary, they can lead to inconveniences such as heat outages, which directly affect the comfort and satisfaction of the customers. Such disruptions have the potential to lead to customer attrition, as consistent service quality is a critical factor for customer retention in the utility sector.

Moreover, the high proportion of repair costs in the maintenance budget underlines the importance of efficient and proactive maintenance strategies. By investing in regular maintenance and adopting advanced monitoring technologies, companies can potentially reduce the frequency and severity of repairs, thereby minimizing downtime and enhancing customer satisfaction. In addition, such strategies could lead to long-term cost savings by extending the lifespan of the infrastructure and avoiding the need for more significant and costly repairs in the future.

Given these considerations, it's clear that while repair costs constitute a large portion of maintenance expenses for district heating systems, strategic investments in maintenance and technology could mitigate these costs and improve overall service reliability and customer satisfaction.

# 3 LEAKAGE DETECTION METHOD

The significance of addressing pipeline leaks cannot be understated, given their environmental impacts and the substantial costs associated with pipeline repair. An in-depth understanding of the common causes of leaks necessitates the exploration of innovative technologies aimed at early detection and prevention.

## 3.1 Alarm cabling

The alarm cabling system is designed with a set of alarm wires, which are embedded into the polyurethane insulation. Typically, there are two pieces of wire, either both made of copper or one copper and the other tinned. These alarm wires are placed into the insulation during the pre-insulation process of the flow pipe at the factory.

The operation of the alarm cabling system relies on two technologies: resistance measurement and Time Domain Reflectometry (TDR) pulse technology, which involves analyzing the reflections of signals transmitted along the wires.

### 3.1.1 Resistance Measurement

Resistance measurement is crucial for evaluating two key aspects of a system: the continuity of the alarm loop and the condition of the foam insulation. These parameters are assessed using wire resistance for the alarm loop and insulation resistance for the foam insulation, respectively. There are parts of pre-insulated district heating pipe.

The continuity of the alarm loop is essential for ensuring that the system operates without disruptions. This loop is configured to allow resistance measurements that include checking the resistance of the entire circuit. Typically, copper wire with a cross-sectional area of 1.5 mm² is used, with an approximate resistance of 1.2 ohms per 100 meters. By measuring this, the total resistance of the loop can be determined. (Logstor, Surveillance Manual)

After calculating the expected resistance, it should be measured by using a multimeter, and a comparison chart should be constructed using these values. If a discrepancy exists between the calculated and the measured resistance, the nature of this discrepancy could indicate one of three potential issues. For instance, if the measured resistance is significantly lower than expected, this may suggest a short circuit. Conversely, if the resistance is higher than anticipated, it could point to a poor wire connection. Moreover, if the measured resistance is infinitely large, it likely indicates a broken wire, signifying an absence of conductive material to carry the current. In Picture 7, the resistance is measured using a multimeter.

PICTURE 7. Resistance measurement of alarm wire loop (Jari Randell)

After confirming the continuity of the alarm loop, the next step is to measure the resistance between the wire and the flow pipe. This measurement determines the dryness of the polyurethane insulation and whether the alarm wire is in contact with the flow pipe. In Picture 8, a worker is shown using a multimeter to measure the resistance between the alarm wire and the flow pipe. In insulation resistance measurement, a test voltage of 1000 V is used, and the resistance value must exceed 0.5 mega ohms.

PICTURE 8. Resistance measurement between alarm wire and flow pipe (Jari Randell)

When the insulation is dry, no current flows between the alarm wire and the flow pipe, as dry polyurethane insulation does not conduct electricity. According to Ohm's Law, when the current approaches zero, the resistance becomes infinitely large.

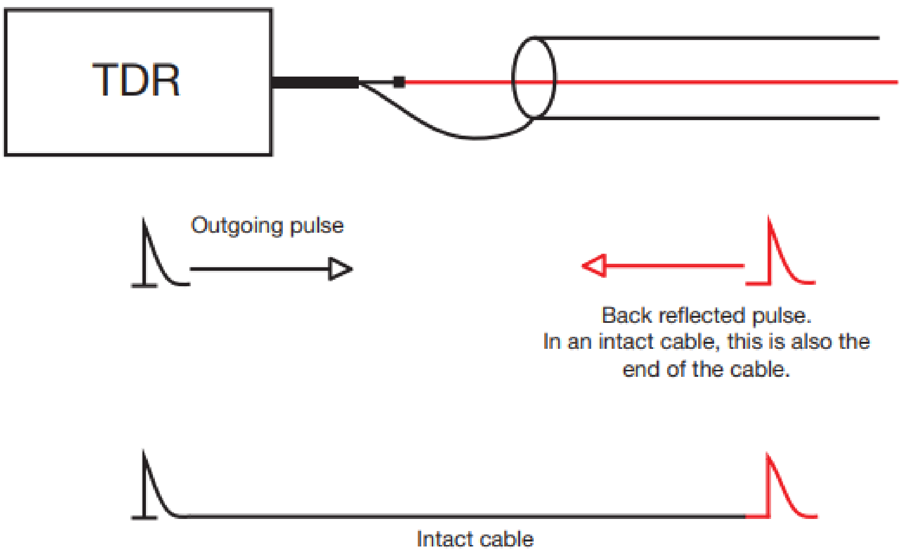
$$R = \frac{U}{I} \tag{1}$$

In the equation 1, where R = resistance, U= voltage and I= current. However, if the insulation is moist, measurable resistance will be observed, as the moisture facilitates electrical conductivity.

Resistance measurement was one of the first systems that was used to find possible problem areas in district heating pipelines. The problem was that the accuracy of the resistance measurement was poor. This is due to the small resistance of the copper wires, in which case the positioning accuracy is not sufficient. Another weakness was that the reading had to be done in the field. Because of this, many energy companies abandoned the installation of copper wires.

### 3.1.2 Time Domain Reflectometer – Pulse

Time Domain Reflectometry (TDR) is a technology employed to identify faults within metal cables. In district heating systems, these metal cables are typically two pieces of copper wire, each with a cross-sectional area of 1.5 mm² and length of 1-3 kilometer, functioning as alarm cables. The process initiates with the generation of a traveling wave, produced by a low voltage pulse generator. As this wave propagates through the conductor, it encounters varying types of wave impedances—a metric that quantifies the resistance faced by the wave within the cable. (Megger n.d.) The pulse of intact cable is shown in the Picture 9.

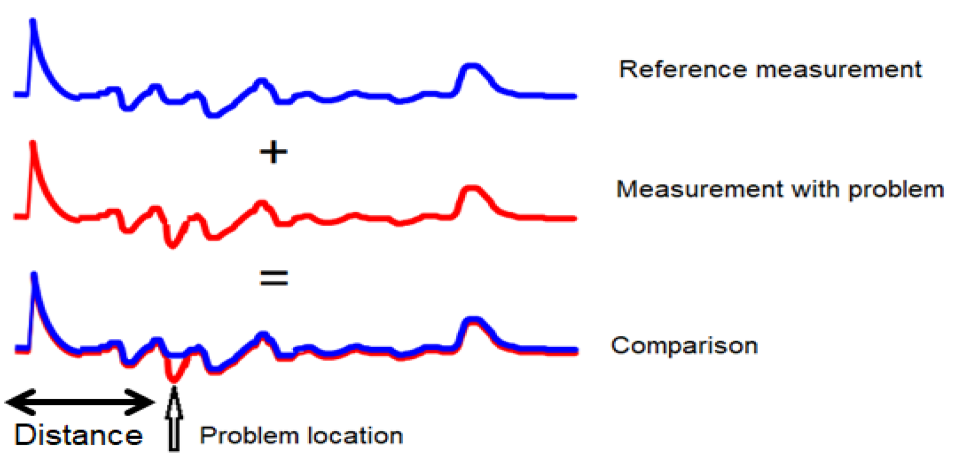



PICTURE 9. TDR – Pulse measuring (Megger)

At any point where there is a change in wave impedance, due to variations in the cable's physical or electrical properties, part of the wave's energy is reflected back towards the source while the rest continues to propagate along the cable. These points of change can be natural terminations, like the end of a cable, or irregular such as joints, breaks, bifurcations, or areas where additional resistance is introduced, for instance by moisture.

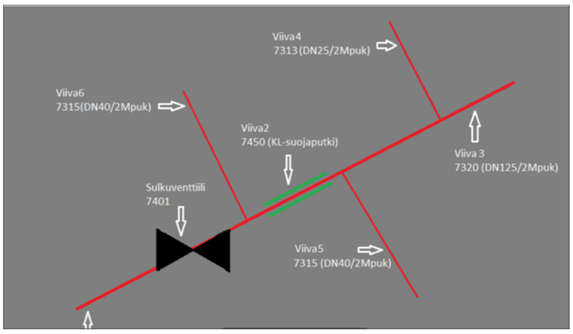
By analyzing these reflections, TDR devices can accurately identify and locate faults. The time it takes for the reflections to return is measured, and this data helps determine the exact location of the impedance changes, thus pinpointing fault locations within the cable system.

Before beginning measurements, this system must undergo an inspection to evaluate two key aspects: the continuity of the alarm loop and the condition of the foam insulation. The methods employed are the same as those used in resistance measurement. After confirming the continuity of the alarm loop and the dryness of the insulation layer, initiate the first pulse test to obtain a reference measurement. If there is a problem in the cable, the measurement will differ. By comparing these measurements, we can accurately determine the location of the problem. In Picture 10, there are pulses of reference pulse of alarm loop and pulse of the same alarm loop but with a problem. In the lower of the picture, is the combination of these two pulses and location of the problem can be found easily.




PICTURE 10. Comparison of measurements and location of the problem (Megger)

During the installation phase, a wiring diagram shall be drawn of each pipeline section, allowing for precise pipe length determination. This enables expedited fault localization and improved accuracy of the location process. With the exact pipe length obtained, the following formula can be utilized to calculate its distance from the starting point. In the Picture 11, in the left is the wiring diagram of district heating pipeline and valves, in the right side is location in Cartesian coordinates, numbering of co-responding pipes.



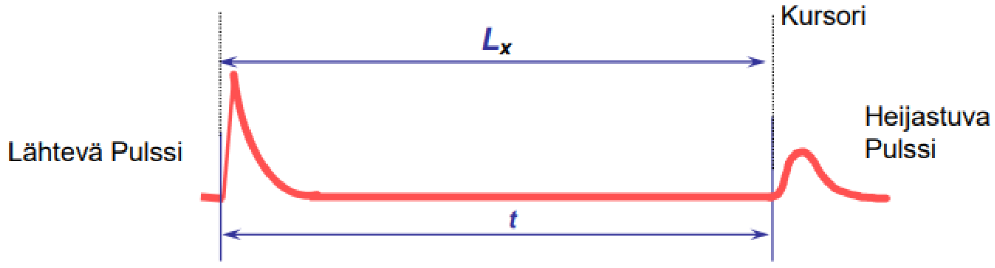

Mattilantie 5

| T1(pinta) | T2(viiva) | Koodi | Pno | X | Y | Z |
|---|---|---|---|---|---|---|
| 1 | 1 | 7317 | 1 | 7380379.475 | 26489899.401 | 77.365 |
| 1 | 1 | 7317 | 2 | 7380374.554 | 26489898.295 | 77.847 |
| 1 | 2 | 7305 | 3 | 7380373.810 | 26489896.986 | 77.977 |
| 1 | 0 | 7401 | 4 | 7380368.208 | 26489895.404 | 77.999 |
| 1 | 2 | 7305 | 5 | 7380363.122 | 26489883.334 | 78.022 |
| 1 | 2 | 7305 | 6 | 7380356.851 | 26489858.735 | 77.887 |
| 1 | 2 | 7305 | 7 | 7380356.988 | 26489859.287 | 77.167 |
| 1 | 3 | 7304 | 8 | 7380344.932 | 26489864.547 | 77.193 |
| 1 | 3 | 7304 | 9 | 7380333.717 | 26489869.011 | 77.305 |
| 1 | 3 | 7304 | 10 | 7380318.460 | 26489857.476 | 77.217 |
| 1 | 3 | 7304 | 11 | 7380317.334 | 26489875.378 | 77.377 |
| 1 | 4 | 7303 | 12 | 7380305.234 | 26489874.170 | 77.273 |
| 1 | 4 | 7303 | 13 | 7380288.533 | 26489872.033 | 77.133 |

PICTURE 11. Wiring diagram of pipeline sections (Jari Randell)

Pulses travels at nearly the speed of light and has different correction factors when traveling in different surroundings. Once the precise length of the pipeline is determined, a pulse is transmitted, and the time it takes for the pulse to travel is measured. Using the exact pipeline length, we can then calculate the precise correction factor for the speed when traveling through the polyester insulation. After getting the corrected speed, we can accurately calculate the fault location when it occurs.

The calculation method relies on the corrected speed of the transmitted pulse and the time it takes to return. By measuring these parameters, we can determine the distance to the fault location from the starting point of the wire. In Picture 12, the scenario is illustrated, showing the initial outgoing pulse (lähtevä pulssi) and the resulting reflected pulse (heijastuva pulssi), along with their respective distances and the time taken for the pulse to travel divided by 2.( Megger n.d.)




PICTURE 12. Calculating the distance of initial pulse and reflected pulse (Megger)

$$L = \frac{1}{2}tv \quad (2)$$

L is the distance and is the time for the pulse to travel back and forth, v is the correct speed of the pulse. A reflected pulse is an electrical signal that bounces back along the wire when it encounters a change in impedance. In an intact cable, this reflection generally happens only at the end of the cable, where the signal reaches the cable’s termination. However, if there are branching points, changes in wire geometry, or a break in the wire, the pulse will instead reflect back from these locations. The specific cause of the reflected pulse can be determined by comparing it to the pipeline wiring diagram.

With TDR measurement, the measurement accuracy became so good that the new systems are based on this. The accuracy is about 0.5% of the measured distance. If satellite positioning has been used in the construction of the pipeline, it is usually possible to locate the moisture in the insulation with an accuracy of one meter.

In addition to this, the new systems are remotely readable and send data continuously. For instense, iSENSE system from VEXVE company sends data directly from the ground using the LoRaWan or NB IoT system. Unfortunately, due to bad experiences with resistance measurement, many pipelines were made without copper conductors before. Now, in practice, new pipes are always equipped with copper wires.

## 3.2 External Notification

District heating water is treated and often dyed green to facilitate leak detection. In the supply pipe, the temperature of the district heating water varies between 65 and 115° C, depending on the weather and heating demand, while in the return pipe, it usually ranges from 40 to 60 °C. Over 20 % of pipeline leaks are detected through external notification (Energiateollisuus ry. Statistics on district heating 2019). This method is particularly effective because when a leak occurs, the escaping green water and the resulting steam are highly visible, especially during winter. This distinct visual cue helps in quickly identifying and differentiating district heating system leaks from those in domestic water pipes.

## 3.3 Inspections of District Heating Chamber

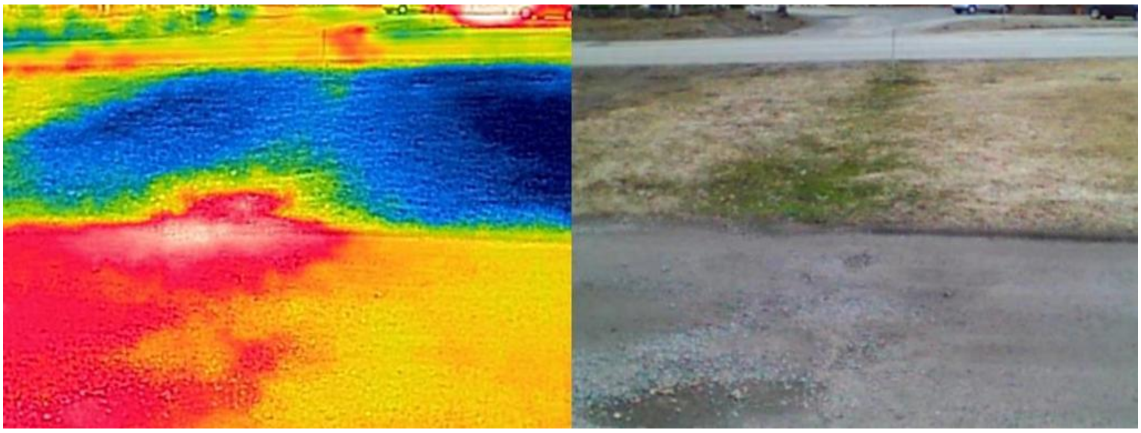
District heating pipelines feature various types of chambers, equipped with valves, drains, and air vents (Koskelainen 2006, 146). These valves are operated by actuators, such as manual, electrical, or hydraulic actuators. Typically, there are multiple welding seams and seals at the protective sheath joints as these components are welded onto the pipelines and insulated on-site during construction.

A potential leak in the district heating pipe may be revealed by water accumulating in the chambers. In some cases, these inspections may require pumping the well dry if necessary. This is usually the case in chambers where groundwater or rainwater causes problems.

## 3.4 Thermal Cameras

A thermal camera works by detecting the infrared radiation emitted by objects, which is invisible to the human eye. All objects emit some level of infrared energy, and thermal cameras use this energy to create an image. The camera captures the infrared radiation and translates it into electronic images that indicate the temperature of the object's surface, displayed in various colors.(Fluke n.d.)

For district heating pipelines, a leak involving hot water can raise the temperature of the surrounding soil, making this area warmer than its surroundings. This temperature difference causes the soil to appear in different colors when viewed through a thermal camera. Thermal camera is used to detect leaks via aerial surveys, often conducted using helicopters or nowadays drones. These inspections are typically carried out once or twice a year to ensure the integrity of the heating system. In Picture 13, the right side shows no indication of leaking pipes. However, on the left side, a thermal camera image reveals an unusually high temperature in a specific area of the ground.



PICTURE 13. Thermal camera for leak detection (Jari Randell)

# 4 ANALISIS OF SURVEY RESULTS

This chapter aims to analyze the responses collected from a survey distributed to experts in district heating companies across Finland. Although the survey was sent to eight individuals, only three responses were received. Despite this small sample size, these responses offer a unique and diverse perspective on the practices and challenges related to leakage detection in district heating networks. The survey encompassed a wide array of topics, ranging from background information to detailed questions about various leakage detection methods and maintenance practices.

## 4.1 Background Information

In the background information section, the first question addressed the frequency of leaks per year, while the second asked about the proportion of leaks caused by corrosion in the flow pipe. Although the total number of leaks varies based on the length of each district heating network, converting the responses into percentages reveals a consistent trend across networks: a significant portion of leaks result from corrosion in the flow pipes. This suggests that corrosion is a major factor driving maintenance costs. Preventing corrosion could reduce these costs and extend the lifespan of the piping system.

The third question focused on repair costs, and the fourth inquired about what is included in these costs. Two respondents provided specific monetary figures for repairs, while one noted that this information is a company secret. Of the two responses, one included both the total annual repair cost and the average cost per leak, estimated at around €10,000. This figure is closely aligned with the data from the survey conducted by Energiateollisuus ry in 2019, considering that this survey was conducted five years later, in 2024. The responses to question four on repair costs reflect different perspectives on the cost components related to district heating network leak repairs. Two respondents provided detailed breakdowns, listing factors such as material and repair labor costs, the cost of replacement water, and additional operational costs.

They note that while the cost of lost sales due to leaks is minimal, repair costs are treated separately from operational expenses. One respondent mentioned that they do not track these costs extensively. This suggests that leakages lead to complex and costly repair processes within district heating networks.

In the fifth question, four available leak detection methods were presented and in the end is an open response field. The four methods included alarm cable systems, external notification mechanisms, inspection of district heating chambers, and thermal imaging using cameras. Respondents were asked to specify which of these methods are currently in use and write down additional methods if is not listed. This inquiry aimed to understand the common practices in leak detection and maintenance among district heating companies in Finland.

Company 1 uses alarm cabling external notifications, district heating chamber inspections, thermal imaging and helicopter imaging for leak detection. Company 2 uses alarm cabling, external notifications, and thermal imaging, along with network monitoring. Company 3 uses alarm cables, external notifications, district heating chamber inspections, thermal imaging and thermal imaging by drones.

The responses indicate a diversified approach to leak detection. All three companies rely on multiple methods. The use of alarm cables highlights a proactive approach to early leak detection, while regular inspections and thermal imaging technology demonstrate a commitment to maintaining system efficiency. All companies rely on external notifications, which indirectly suggests that leaks can sometimes grow severe enough for customers to detect them before the company does.

After the background questions, there are questions specifically targeting each detection method.

## 4.2 Questions About Alarm Cabling

There are four targeted questions from different perspectives for companies that use alarm cabling. The four angles are the technical basis, accuracy, measurement frequency, and user experiences.

The first question addresses the working principle of the alarm cabling. All three companies use alarm cabling; however, the operating principles differ. The alarm cabling for Companies 1 and 2 is based on resistive measurement, whereas Company 3 uses Time-Domain Reflectometry (TDR) pulse technology.

The second question investigates whether each company's leak detection system can identify pipeline exposure to corrosion and accurately locate damage points. Company 1 does not utilize continuous monitoring, and they did not specify the accuracy of their system, suggesting a less detailed approach to corrosion detection and damage localization. Company 2 does not specifically monitor for corrosion as part of their regular process. However, they do have the capability to perform targeted assessments when needed, using techniques like ultrasound to gather precise information on specific sections of the pipeline.
Company 3 reports that their system can detect external moisture, which can indicate potential pipeline exposure to corrosion over time. They achieve this with automated readings that allow them to pinpoint moisture locations with an accuracy of a few meters, which helps to identify problem areas before significant corrosion occurs.

The third question is regarding frequency of each company utilizes their measurement system for leak detection. Company 1 employs their measurement system randomly or when there is suspicion of a leak. Company 2 operates their measurement system only once or twice in their district heating pipelines. Company 3 uses their system everyday reflecting a routine and systematic approach to monitoring.

The forth question is regarding the experience of using alarm cabling. In response to question nine about their experiences with the leak detection methods used, Company 1 provided no specific experiences. Company 2 noted that all methods are different, expressing that there is no single correct solution and that each method addresses issues in its own way. Company 3 indicated that the method works well, particularly after pipeline installation, as it allows immediate correction of any potential installation errors.

The last questions is about the reason not using alarm cabling if is not in sue. Companies provided several reasons for not using alarm cabling in their systems. Company 1 noted that alarm cabling had been trialed in the past but did not yield significant benefits at the time, leading to its discontinuation.
Company 2 indicated that this decision aligns with the overall policy of the organization and company 3 mentioned that older pipelines do not have alarm cabling, though new installations, particularly larger ones, now include it according to current regulations.

### 4.3 Questions External Notification

The question addresses the percentage of leak detections that comes from external reports.

The companies reported varying percentages of leak detections that originate from external reports. Company 1 estimated that around 60% of their detections still come from external reports. Company 2 estimated that between 40-50% of their leak detections are identified through external notifications. Company 3 noted that the percentage of external reports has decreased over time, largely due to the adoption of aerial thermal imaging. They reported that before implementing this technology, external reports accounted for over 50% of detections, but now this figure has dropped to approximately 10-15%. This suggests that the cable alarming has greatly improved the company detection capabilities, allowing the company to identify leaks earlier and more independently.

## 4.4 Questions Inspections of District Heating Chamber

These three companies provided varying responses to question, which addresses the regularity of district heating well inspections and their frequency. Company 1 noted an ongoing effort to implement a consistent inspection schedule, with the goal of inspecting all wells within one to two years. Company 2 indicated that inspections are conducted once a year as part of their maintenance plan, depending on the condition of the well. Company 3 reported that the type of well frequency of inspections ranges from twice a year to once every five years.

In response to question 12, which inquires about potential environmental or other constraints affecting the inspection process, the companies identified different limitations. Company 1 mentioned that winter conditions pose challenges for inspections. Company 2 indicated no known restrictions, while company 3 specified that inspections are not performed during the heating season due to high temperatures in the pipeline water, highlighting this as a safety issue.

For question 13, which explores the challenges encountered in district heating well inspections, the companies described various issues. Company 1 highlighted several issues, including the location of the wells, restricted space, traffic and parked cars, and extreme heat, water, or dirt within the wells, which often necessitate cleaning before inspections can proceed. Company 2 listed resource constraints and competing network tasks, such as leak detection, as primary challenges. Company 3 indicated challenges include difficulties in locating the chambers or gaining access to them. However, once the chamber is found and opened, the inspection process and the digital recording of the chamber's condition are relatively easy to carry out.

### 4.5 Questions Thermal Cameras

The companies provided insights into the use of thermal imaging for leak detection, including frequency, usage scenarios, and limitations. Regarding the frequency of thermal imaging, company replied once per year. Company 2 reported conducting imaging twice a year using a helicopter, while company 3 indicated twice a year. These responses indicate that thermal cameras are used quite rarely.

In question 15, question about the situations in which thermal imaging is applied. Company 1 replied that thermal cameras are used in autumn but before the snowfall begins. Company 2 and company 3 both specified its use for general leak monitoring.

The question 16, concerning environmental conditions or other constraints on thermal imaging, emphasized weather-related limitations. Company 1 replied clear visibility up to 200 meters is necessary, and heavy snow cover can block the imaging process. Company 2 noted that imaging requires optimal weather for safe helicopter flights, and company 3 as well weather-related restrictions on flying a helicopter, and then rain and wet conditions impact visibility process.

Finally, in question 17 regarding the accuracy of thermal imaging for locating leaks. Company 1 Another company estimated an accuracy range of one to two meters, depending on the terrain, and noted that continuous imaging allows them to monitor changes over time. Company 2 simply responded that thermal imaging works well for this purpose. Company 3 indicated a high level of precision, stating that helicopter-assisted thermal imaging can effectively confirm the leak location.

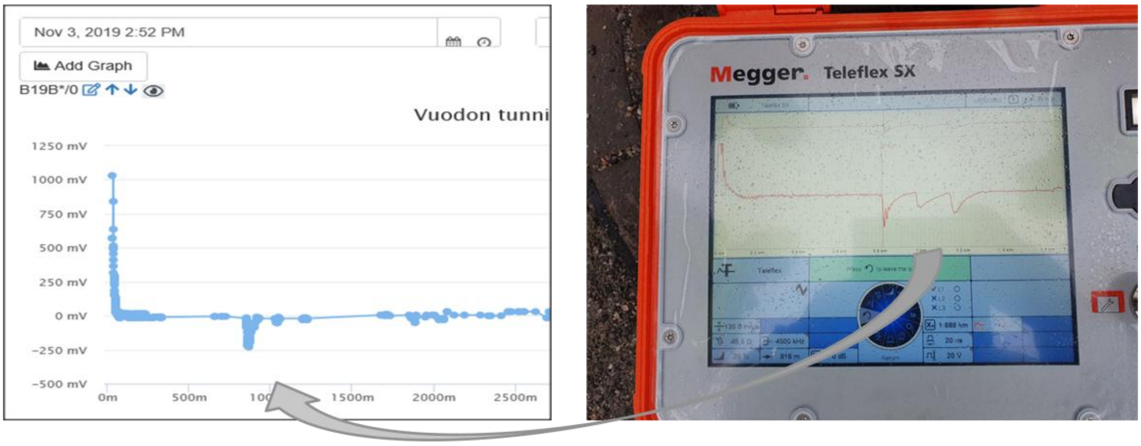
For thermal camera imaging, there are weather-related restrictions to ensure it is safe to fly and suitable for capturing images. Imaging the network with a thermal camera from a helicopter or car requires the right conditions, as well as considerable time and planning. This method is expensive. In terms of accuracy, it is not suitable for assessing the overall condition of the district heating network. However, in cases of leaks or damage, it is highly effective for pinpointing the exact location of the problem. Assessing the condition refers to a method where, for example, the degradation of the insulation material's insulating ability could be verified through measurements.

# 5 CASE EXAMPLE - USAGE OF TDR PULSE MEASUREMENT

A Finnish district heating company, Fortum, constructed a 5.5 km district heating line in the city of Espoo. The new heat transmission line, which starting from the Kivenlahti biomass plant. Pipelines are equipped with three iSENSE Pulse divice and alarm cabling supplied by Vexve's iSENSE Pulse leakage detection system. This system is based on TDR (Time-Domain Reflectometry) Pulse technology and data transmission uses LoRaWAN data transmission network. Real-time monitoring of iSense solutions is conducted through the iSense Online cloud service. The system transmits data to the cloud once per day, enabling regular updates while maintaining energy efficiency. This platform is accessible from any device, at any time, and from any location. Secure login using SSL encryption guarantees the safety of the system and the data it processes.

Toward the end of the construction phase, the pipelines were installed underground, and after installation, the contractor used a multimeter to verify that the copper wires in the cabling were properly connected and intact. Vexve then conducted a calibration of the system, establishing a baseline reference measurement by zeroing out all initial disturbances. From this point onward, daily measurements were taken and compared against this reference to monitor any deviations.

On the following day, three different points showed deviations from the reference line. All of these deviations were measured at over 50 mV, indicating the presence of water within the insulation layer, not just moisture. Given that it had rained during the pipeline installation, the insulation was likely moist in certain areas. In Picture 14 on the left part of the figure, the computer interface displays the measurement, with the y-axis showing millivolts and the x-axis indicating the distance from the device. On the right side, there is an image of the handheld device used for on-site measurements.




PICTURE 14. View of pulse in iSENSE interfaand handheld device (Jari Randell)

Upon observing these deviations, Vexve notified the Fortum workers and dispatched personnel to inspect the first identified leak site. Vexve personnel accounted for the fact that the distance displayed on the handheld device corresponds to the length of the copper wire, not the pipeline itself, as the copper wire is not tightly positioned within the insulation or at connection points. After identifying these additional meters, Vexve personnel successfully located the leak at a nearby pipe seam. The first leak site was located beneath a riverbed. Due to the soft, muddy soil, the pipeline had settled, leading to a rupture in the protective sheath at a joint. In the Picture 15 and 16, one shows the damaged protective sheath joint, while the other reveals the corroded flow pipe after the insulation was removed.

PICTURE 15. Broken protective sheath joint (Jari Randell)

PICTURE 16. Corroded flow pipe (Jari Randell)

Worker from Fortum noted that the pipeline's is located near to a road, where salt is used during winter, which accelerate corrosion through the damaged insulation, finally causing perforation to the flow pipe within three years. Seven workers were involved in this repair, with labor costs estimated at around 20,000€. Additionally, a material cost of treated water about 5,000€. This DN 500 line, with a length of 1.9 km, costs approximately 13€ per cubic meter.

The second leak was detected approximately 1,200 meters from the initial iSENSE Pulse device, at a seam where a sharp metal rod in the soil had punctured the protective insulation during the pipeline installation. Vexve's technicians accounted for discrepancies between the actual length of the copper cable and the pipeline’s physical length, due to the expansion and contraction of the flow pipe with temperature changes, to pinpoint the precise location of the leak.

The third leak was identified under a traffic artery, where the district heating pipes were encased in a metal conduit to protect them from traffic. This location could not be repaired immediately; instead, the repair was deferred to a more suitable time.

All three leak locations were identified within 2 meters of the actual leak points in the pipeline. As these issues arose during the warranty period, the contractor covered the full repair costs. Although the third leak was not repaired immediately, its identification within the warranty period obligated the contractor to fund its eventual repair.

## 6 DISCUSSION AND CONCLUSION

The primary significance of this study lies in its examination of the leak detection systems currently available on the market, highlighting their technical principles, conditions of use, and operational limitations. By providing feedback from real users, this thesis connected theoretical knowledge and practical applications, allowing district heating companies to make more informed decisions. Although the sample size was small, each response contributed unique perspectives and insights, enriching the understanding of these systems from a real-world context.

The responses indicate specific restrictions in the use of TDR pulse technology, as it can only operate effectively in certain conditions, such as within insulated pipelines equipped with alarm cables. For networks lacking pre-installed alarm cabling in the insulation, it raises the question of whether installing cable retroactively is worthwhile or if it would be more cost-effective to wait for full pipeline replacement. Future research could focus on evaluating these options to determine the most economical and effective approach.

Additionally, this study was limited to leak detection technologies currently in use in Finland. Future studies could expand to examine emerging technologies from around the world, evaluating their potential to be adapted for Finnish district heating networks.

In my opinion, this research provides a valuable technical overview of various leak detection systems, supplemented with user feedback and practical examples. The integration of both theoretical aspects and practical insights offers a solid understanding, presenting district heating companies with information that supports more effective decision-making in selecting appropriate leak detecting systems.

This qualitative analysis provides insight into the diverse perspectives of district heating professionals; however, the small sample size limits the broader applicability of the findings. A larger sample would help to validate observed trends and improve the reliability of the conclusions. With more time or resources, it would be beneficial to gather additional responses to ensure a more comprehensive analysis.

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# APPENDICES

## Appendix 1. Questionnaire from company 1

7.5.2024 21.54 Lijun Tuikan oppinnäytetyön kysely 1(3)

View results

Respondent
7 Anonymous

154:08
Time to complete

1. Kuinka monta vuotoa tapahtuu keskimäärin vuosittain laitoksenne verkostossa?

Noin 60 kpl vaurioita joista vuotoja noin 45kpl.

2. Kuinka monta näistä vuodoista johtuu virtausputken läpisyöpymisestä?

Noin 40.

3. Mikä on laitoksenne vuotojen keskimääräinen kokonaiskustannus vuodessa?

2023 vuonna 260 000 euroa. Tämä vaihtelee vuosittain, mutta noin 10 000 euroa/korjattu vuoto keskimäärin.

4. Mikä sisältyy vuotojen korjauskustannuksiin, kuten kaukolämpöveden menetys, materiaalikustannukset, korjaustöiden kustannukset ja menetetty laskutus?

Maanrakennus, putkityöt, eristystyöt ja omat henkilöstökulut.

Jos joudutaan käynnistämään varalämpölaitoksia niin niiden käyttö- ja polttoainekustannukset.

5. Millä tavoilla vuodot havaitaan? Alla on lueteltu yleisimmistä vuodonhavaitsemistavoista. Vastaa onko käytössänne kyseinen menetelmä ja siihen liittyen lisäkysymyksiin.

- [ ] Hälytyskaapelointi
- [x] Ulkopuolinen ilmoitus
- [x] Kaukolämpökaivojen tarkastukset
- [x] Lämpökameran käyttö
- [x] Kaivovalvonta järjestelmät, vihreä vesi, helikopterikuvaus

Mikäli teillä on käytössä hälytyskaapelointi, tässä on siihen liittyvä lisäkysymys.

6. Mihin hälytys perustuu? Resistanssimittaus vai TDR-pulssiteknologia?

Muutaman kohde on kaapeloitu ja resistanssimitattu.

7. Pystyykö käytössänne olevalla vuodonhavaitsemismenetelmällä havaitsemaan virtausputken altistumisen syöpymiselle ja paikantamaan vauriokohdan? Mikä on menetelmän tarkkuus?

Jatkuvaa mittausta ei käytössä. Tarkkuus ei tiedossa.

8. Kuinka usein mittaus suoritetaan?

Satunnaisesti tai jos epäillään vuotoa.

9. Minkälaisia kokemuksia on käytetystä vuodonhavaitsemismenetelmästä?

Ei mainittavia.

## Ulkopuolinen ilmoitus

10. Kuinka suuri prosenttiosuus tulee ulkopuolisista ilmoituksista?

Noin 60%

## Kaukolämpökaivojen tarkastukset

11. Tehdäänkö tarkastuksia säännöllisesti? Jos kyllä, kuinka usein?

Pyritään, mutta siihen ei olla vielä päästy. 1-2 vuoden sisällä pitäisi kaikki kaivot tarkastaa.

12. Onko menetelmällä olosuhteisiin tai muihin tekijöihin liittyviä rajoituksia?

Talven olosuhteet.

13. Minkälaisia haasteita kaukolämpökaivojen tarkastuksissa esiintyy?

Kaivojen sijainnit, kaivojen ahtaat tilat, pysäköydyt autot ja liikenne (liittyy sijaintiin), kaivoissa voi olla välillä todella kuuma, kaivossa voi olla vettä ja likaa runsaasti (vaatii kaivon pesun ennen tarkastusta).

## Lämpökameran käyttö

14. Tehdäänkö lämpökuvauksia säännöllisesti? Jos Kyllä, kuinka usein?

Kerran vuoteen.

15. Missä tilanteissa lämpökamerakuvausta käytetään?

Syksyllä kun maa viilenee, mutta ei ole vielä lunta.

16. Onko käyttämisessä olosuhde tai muita rajoituksia?

Pitää olla hyvä lentosää 200m näkyvyyttä, eikä maassa voi olla paksua lumikerrosta.

17. Minkälaisella tarkkuudella lämpökamerakuvauksella pystytään paikantamaan vuodon kohta?

1-2m tarkkudella lämpötilaeron muuhun maastoon. Jatkoanalytiikalla voidaan verrata eri vuosien tuloksia joista nähdään muutokset ja alkavat vuodot.

18. Mikä on syy siihen, jos ette käytä hälytyskaapelointia?

Kaapelointia on joskus aikoinaan kokeiltu eikä siitä silloin saatu merkittäviä hyötyjä.

# Appendix 2. Questionnaire from company 2

7.5.2024 21.54 | Lijun Tuikan oppinnäytetyön kysely | 1(3)

View results

Respondent

6 Anonymous

96:43
Time to complete

1. Kuinka monta vuotoa tapahtuu keskimäärin vuosittain laitoksenne verkostossa?

   Vuotokorjauksia v.2023 oli 39 kpl, jotka korjattu ns. vikakohta. Vuodosta laajentuneita peruskorjauksia oli 2023 15 kpl.

2. Kuinka monta näistä vuodoista johtuu virtausputken läpisyöpymisestä?

   Ei ole kirjattu tarkemmin vian alkuperää. Käytännössä suurin osa. Vika yleensä lähtee vauriosta tai kulumisesta johtuvista vaurioista, jossa ulkopuolinen vesi pääsee putkirakenteisiin.

3. Mikä on laitoksenne vuotojen keskimääräinen kokonaiskustannus vuodessa?

   Vuodolle n. 15000-20000€

4. Mikä sisältyy vuotojen korjauskustannuksiin, kuten kaukolämpöveden menetys, materiaalikustannukset, korjaustöiden kustannukset ja menetetty laskutus?

   Mielestäni kokonaiskustannusta ei seurata esitetyllä laajuudella.

5. Millä tavoilla vuodot havaitaan? Alla on lueteltu yleisimmistä vuodonhavaitsemistavoista. Vastaa onko käytössänne kyseinen menetelmä ja siihen liittyen lisäkysymyksiin.

   - [ ] Hälytyskaapelointi
   - [x] Ulkopuolinen ilmoitus
   - [ ] Kaukolämpökaivojen tarkastukset
   - [x] Lämpökameran käyttö
   - [x] Verkon etävalvonta

Mikäli teillä on käytössä hälytyskaapelointi, tässä on siihen liittyvä lisäkysymys.

6. Mihin hälytys perustuu? Resistanssimittaus vai TDR-pulssiteknologia?

Resistanssimittauksiin. Tätä käytetään jäähdytysverkon putkistoissa. Kaukolämmössä kohdennetusti.

7. Pystyykö käytössänne olevalla vuodonhavaitsemismenetelmällä havaitsemaan virtausputken altistumisen syöpymiselle ja paikantamaan vauriokohdan? Mikä on menetelmän tarkkuus?

Syöpymistä ei seurata. Kohdennetusti voidaan mittaus tehdä, esim. silloissa oleviin putkiin.
Käytössä voi olla mm. ultraäänitekniikka. Tällä saadaan ainevahvuus tietoon.

8. Kuinka usein mittaus suoritetaan?

Kerran tai kaksi on kyseistä tekniikkaa käytetty kaukolämpöverkossa.

9. Minkälaisia kokemuksia on käytetystä vuodonhavaitsemismenetelmästä?

Kaikki erilaisia. Mielestäni yhtä ainoaa oikeaa menetelmää ei ole. Kokonaisuus ratkaisee tässäkin asiassa.

## Ulkopuolinen ilmoitus

10. Kuinka suuri prosenttiosuus tulee ulkopuolisista ilmoituksista?

40-50%

## Kaukolämpökaivojen tarkastukset

11. Tehdäänkö tarkastuksia säännöllisesti? Jos kyllä, kuinka usein?

Kunnossapitosuunnitelman mukaisesti. 1 kertaa vuodessa, riippuen kaivon kunnosta.

12. Onko menetelmällä olosuhteisiin tai muihin tekijöihin liittyviä rajoituksia?

Ei tietääkseni.

13. Minkälaisia haasteita kaukolämpökaivojen tarkastuksissa esiintyy?

Resurssit, muut verkolla olevat työt esim. vuotokorjaukset

## Lämpökameran käyttö

14. Tehdäänkö lämpökuvauksia säännöllisesti? Jos Kyllä, kuinka usein?

Kaksi kertaa vuodessa helikopterilla

15. Missä tilanteissa lämpökamerakuvausta käytetään?

Vuotojen havainnoinnissa

16. Onko käyttämisessä olosuhde tai muita rajoituksia?

Säätila pitää olla oikea lentojen toteutukselle

17. Minkälaisella tarkkuudella lämpökamerakuvauksella pystytään paikantamaan vuodon kohta?

Hyvin

18. Mikä on syy siihen, jos ette käytä hälytyskaapelointia?

Yhtiön linjaus ollut

# Appendix 3. Questionnaire from company 3



View results

Respondent

5 Anonymous

27:47
Time to complete

1. Kuinka monta vuotoa tapahtuu keskimäärin vuosittain laitoksenne verkostossa?

n. 90-150 kpl.

2. Kuinka monta näistä vuodoista johtuu virtausputken läpisyöpymisestä?

noin 85-90 prosenttia.

3. Mikä on laitoksenne vuotojen keskimääräinen kokonaiskustannus vuodessa?

Tätä ei ole lupaa julkaista. Linjauksemme mukaisesti rahaa/kustannuksia käsitteleviä lukuja ei luovuteta edes ET:n vuositilastointiin.

4. Mikä sisältyy vuotojen korjauskustannuksiin, kuten kaukolämpöveden menetys, materiaalikustannukset, korjaustöiden kustannukset ja menetetty laskutus?

Korjaus kustannukset sisältävät meillä materiaalien ja korjaustöihin liittyvät kustannukset. Vuotoveden määrää pyritään kuukausittain arvioimaan, mutta sen kustannus pidetään erillisenä operointikustannuksena muun lisäveden mukana. Menetetty myynti on suurmmassa osassa tapauksia erittäin vähäinen, joten sitä ei huomioida.

5. Millä tavoilla vuodot havaitaan? Alla on lueteltu yleisimmistä vuodonhavaitsemistavoista. Vastaa onko käytössänne kyseinen menetelmä ja siihen liittyen lisäkysymyksiin.

- [x] Hälytyskaapelointi
- [x] Ulkopuolinen ilmoitus
- [x] Kaukolämpökaivojen tarkastukset
- [x] Lämpökameran käyttö
- [x] Lämpökamerakuvaus ilmasta

Mikäli teillä on käytössä hälytyskaapelointi, tässä on siihen liittyvä lisäkysymys.

6. Mihin hälytys perustuu? Resistanssimittaus vai TDR-pulssiteknologia?

Vexve iSense pulssiteknologia (onko TDR ?)

7. Pystyykö käytössänne olevalla vuodonhavaitsemismenetelmällä havaitsemaan virtausputken altistumisen syöpymiselle ja paikantamaan vauriokohdan? Mikä on menetelmän tarkkuus?

Hälytyslangoilla havaitsee mahdollisen kosteuden (ulkopuolinen vesi eristeessä), joka johtaa virtausputken läpisyöpymään ajan kuluessa. Automaattisella luennalla kosteus jää kiinni jo ennen syöpymän alkamista. Kostea kohta löytyy muutaman metrin tarkkuudella.

8. Kuinka usein mittaus suoritetaan?

kerran vuorokaudessa

9. Minkälaisia kokemuksia on käytetystä vuodonhavaitsemismenetelmästä?

Toimii ja on erinomainen varsinkin uuden putkilinjan käyttöönoton jälkeen, jolloin mahdolliset asennusvirheet saadaan heti korjattua.

## Ulkopuolinen ilmoitus

10. Kuinka suuri prosenttiosuus tulee ulkopuolisista ilmoituksista?

Tämä on vaihdellut vuosien varella. Kun lämpökamera kuvaus ilmasta otettiin käyttöön niin ulkopuolisten ilmoitusten määrä väheni dramaattisesti. Nykyisin ollaan varmaan jossain 10-15 % luokassa. Ennen ilmasta tehtäviä lämpökamerakuvauksia ilmoitusten osuus oli yli 50 %.

## Kaukolämpökaivojen tarkastukset

11. Tehdäänkö tarkastuksia säännöllisesti? Jos kyllä, kuinka usein?

Kaivo tyypistä riippuen 2 krt/vuosi - 1 krt / 5 vuotta

12. Onko menetelmällä olosuhteisiin tai muihin tekijöihin liittyviä rajoituksia?

Kaivotarkastuksia ei tehdä lämmityskaudella, jolloin verkoston vesi on kuumimmillaan. Tämä on työturvallisuus asia.

13. Minkälaisia haasteita kaukolämpökaivojen tarkastuksissa esiintyy?

Kaivoja ei löydetä tai niihin ei päästä käsiksi. Jos kaivo löytyy ja sen saa auki niin tarkastamistoimenpide ja digitaaliset havainnot kaivon kunnosta on melko helppo tehdä.

## Lämpökameran käyttö

14. Tehdäänkö lämpökuvauksia säännöllisesti? Jos Kyllä, kuinka usein?

Ilmasta tehtävä lämpökamerakuvaus tehdään 2 kertaa vuodessa

15. Missä tilanteissa lämpökamerakuvausta käytetään?

Säännöllisessä vuodon etsinnässä. Jonkun tietyn sietämättömän vuodon löytämiseksi ei ole tarvinnut meillä käyttää.

16. Onko käyttämisessä olosuhde tai muita rajoituksia?

On monia sääolosuhteisiin liittyviä rajoituksia, milloin ei voi lentää helikopterilla. Lisäksi sateella / märällä kelillä ei kannata muutenkaan kuvata. Lumi maassa ei haittaa.

17. Minkälaisella tarkkuudella lämpökamerakuvauksella pystytään paikantamaan vuodon kohta?

Kun helikopterilla tehty havainto käydään kannettavalla lämpökameralla varmistamassa on vuoto kohdan paikannus paras mahdollinen.

18. Mikä on syy siihen, jos ette käytä hälytyskaapelointia?

Vanhoissa putkissa ei ole. Uusiin isompiin ne asennetaan nykyisin säännön mukaisesti.