# Upgraded Characteristics of Water Leakage Sensor of Ni-Cr Wire for Pre-Insulated-Pipe Heat Transfer System

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**Abstract:** The leakage detection device for heat transfer pipe line for large apartment site or chemical plant factory is developed. The leakage sensor of Ni-Cr cable is very useful and stable for long life. Simple theory with wet material has lower resistance is applied by Voltage measurement through tow cable along the steel pipe outer wall. It showed the leakage current signal from insulation resistance change by water leak. The study is to analyze relevance of damaged Pre-insulated pipe by exposure to moisture infiltration rate and out load characteristic.

***Key-Words:*** *Ni-Cr Sensor Cable, Pre-Insulated Pipe, Water Leak, Insulation Resistance, Leakage Current, Relative Resistance*

## 1. Introduction

In the heat transfer pipe line system for a large apartment area and chemical plants factories the steam and hot water leakage problems are always headache. The pre-insulated pipe system has risk factors of water leaks. It is divided into two risk factors, external environment and internal friction behaviors. First, external environment is mainly the inflow of ground-water, earth pressure, and subsidence of ground. Second, internal factors are high temperature and pressure in the flowing water. The two items cause crack, distortion, and damage in the pipelines [3-4].

For detecting system, Ni-Cr leakage sensor cable is used for leak water of pre-insulated pipe. But it is not clear and enough information for accident range and position of damaged pipeline. The pipelines are installed widely and it has limitation of low accuracy of detecting cable [1-2].

The leakage sensor of Ni-Cr cable are experimentally used. The conventional theories and methods are used by voltage measurement of wet part resistance change. The leakage current is generated by the insulation resistance of water leak part of the wire. We want to make specified standard chart for leakage water position and range because it is not clear in the standard chart. We conducted experiments to measure changes of the output value and minimize error rates.

The study is to analyze relevance of damaged pre-insulated pipe by exposure to moisture infiltration rate and out load characteristic. We predict Economic Impact as rapid maintenance and reduced expense of construction and prevent pre-insulated pipe from risk with corrosion [1-2].

## 2. Method

### 2.1 Theory of leakage water detection

The pre-insulated pipelines are inflicted by internal and external environments after they are buried under ground. The damage of the pre-insulated pipelines is caused by changes of electric resistance between polyurethane, Ni-Cr, and internal pipelines. Changes of electric resistance are happened if water is inputted in from the outside and output into the exterior [2].

If specific voltage ($V_{CC}$) is supplied to an expectable position to leak water, we can measure leakage currents ($I_p$) created by changes of electric resistance ($R_p$) inter cables to detect leakage water and internal pipelines. Relative resistances can be calculated by amount and position of

Received: 2013/11/20, Accepted: 2013/12/3
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leakages water [1-2].

The method to measure relative resistance using amount of leakages water can be computed by Ohm's law calculating changes of insulation resistances vs leak currents. The method to measure position of leakages water using relative resistance can be calculated by the distributive law of voltages multiplying total measuring distance($L_l$) the voltage($\square_p$) of a specific position divided by total voltages($V_{CC}$) across cables of leakage water [1-3].

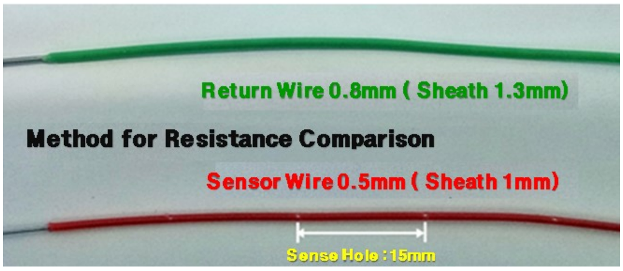



Fig.1 Water leak sensor cable (specification and detection method)

The Sensor wire for water leak detection, as shown in Fig.1, is wrapped within a 1mm insulated tube. The tube has 0.5 mm perforation for every 15mm for detecting changes in the resistance caused by water contact to the Ni-Cr [1-2].

The return wire, which transfers measured changes in resistance, is made of copper wire insulated by 1.8mm insulation. The Ni-Cr water leak detector wire sensors any leaks between the interior and exterior before filling them in with polyurethane [1-2, 4].

### 2.2 Experiment environment setup for water leakage detection

As shown in Fig.2 (a), in this first experiment, the exterior plastic tube is 1000cm long, the interior Ni-Cr wire, which measures damage range caused by water leakage, is also 1000cm long and 1cm think.

Next we install the Ni-Cr water leakage detector wire. Then we put a shell over the wire, fill in the gap with polyurethane. Fig.2 (b) is the 1000cm long cylindrical experimental pipeline made from a recyclable plastic bottle with the carbon steel wire on the interior. The top half of the cylinder is cut open to make it easier to simulate water leakage. The water is dyed in red to help easily control the range and amount of water leakage and measure the resistance and current correctly.

The experiment is carried out by measuring changes of current and resistance for every 10cm length of simulated water leakage, repeating 10 times until it reaches 100cm. From the 100cm point, the experiment is carried out by measuring for every 1000cm. First apply 10vdc onto the water leakage detector, simulate water leakage, and measure the total resistance and leakage current between the leakage detector wire and the interior with a Multi-meter. Calculate the insulation resistance which is disproportionate to the leakage current and check if it is linear as the proposed theory.

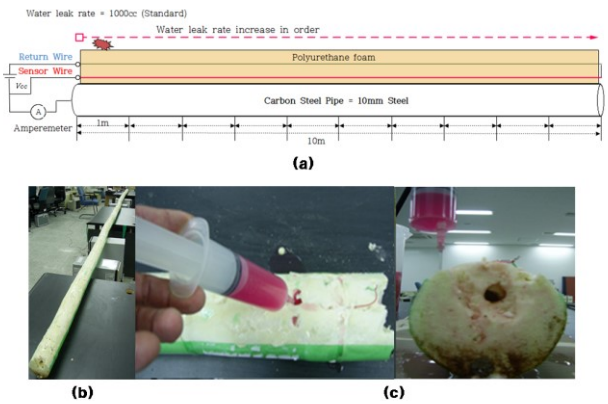
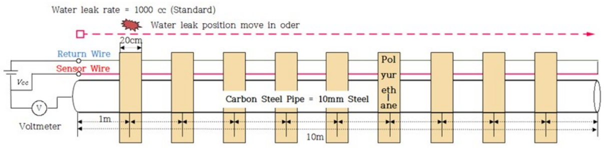



Fig.2 (a) Experiment setup for measuring damage compared to the degree of water leakage (b) Completed experimental pipe made of plastic, polyurethane, carbon steel wire and water leakage detector wire. (c) Measuring leakage current and resistance in the pipe after simulated water leakage

The second experiment is to detect the leakage point. As shown above in Fig.3 (a), design experiment using the same material but this time install a shell as a leakage point on the 1000cm interior carbon steel wire for each 100cm.

As shown above Fig.3 (b), install a 20cm long sealed cylinder for each measure point. The 1000cm leakage detection wire is placed in a sealed cylinder, 3cm away from the carbon steel wire. Measure the changes in insulation resistance and load voltage for each leakage point. In this experiment we analyze the changes in voltage as we simulate water leakage for each sealed cylinder. The exact leakage point is calculated by multiplying values from each sealed cylinder and the total length of the whole experiment pipeline. Also analyze accuracy of the leakage point measured by the proposed method by comparing the differences between the conventional methods.




(a)

(b)

Fig.3 (a) Experimental design for water leak position measurement (b) Install Ni-Cr leakage detector for each sector and detect leakage point

## 3. Result

The Electric resistance of water is known to be 18.2MΩ per cubic centimeter. In the first experiment, we measure and present any changes of insulation resistance in the pre-insulated pipe.

Fig.4. Changes in measured value for 7 submerged sensor holes (10 cm), 14 holes (20 cm), 21 holes (30cm), 35 holes (50cm). The proposed idea is theoretically proven as 18.2M resistance is lowered to 1.82M for 10cm as connected parallel.

Table 1 shows some differences in the measurement as there are distances between the carbon steel wire and the leakage detector and irregularity of water absorption in the polyurethane. Thus in the experiment, we confirm that leakage current and insulation resistance are changeable. Compared to The insulation resistance level index, this experiment presents more detailed measurements of the changes in leakage current and insulation resistance.

Fig.5 (a) shows a linear, steady change of the measured leakage current from 0 to 100cm and steeper change from 100cm to 1000cm where the leakage interval had got wider. Fig.5 (b) the insulation resistance disproportionately decreases in a smooth curve as opposed to the steep change in the leakage interval. The reason for the smooth curve is thought to be the result of the change in the measurement from Mega to Kilo Ohm and the wider leakage interval from 100 to 1000cm range.

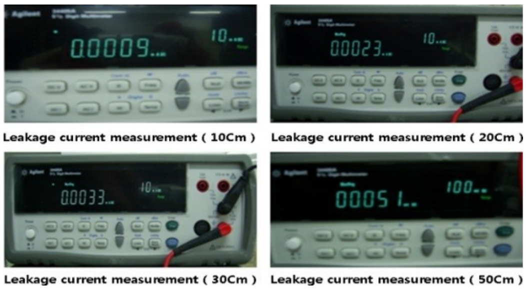



Fig.4 The result of current measurement with a 10cm interval in the damaged experimental body

Table 1 The result of the amount of leakage of water

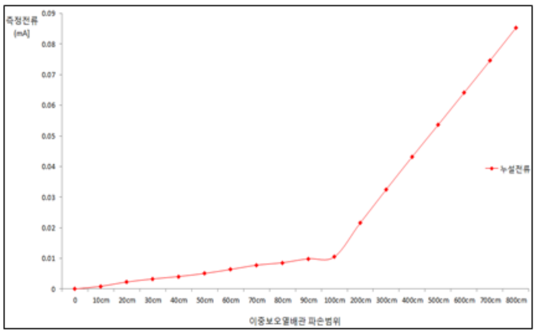
| Damage range | Measuring current($I_p$) | Resistance calculation ($R_p$) | Comparison of existing water leak rate |
|---|---|---|---|
| 0Cm | 0.00001mA | 1000MΩ | No problem |
| 10Cm | 0.0009mA | 11MΩ | Few or no water leak rate |
| 20Cm | 0.0023mA | 4.347MΩ | |
| 30Cm | 0.0033mA | 3.03MΩ | |
| 40Cm | 0.0041mA | 2.439MΩ | |
| 50Cm | 0.0051mA | 1.96MΩ | |
| 60Cm | 0.0064mA | 1.562MΩ | |
| 70Cm | 0.0078mA | 1.282MΩ | |
| 80Cm | 0.0086mA | 1.162MΩ | |
| 90Cm | 0.0099mA | 1.01MΩ | |
| 100Cm | 0.0105mA | 952KΩ | Marginal water leak rate |
| 200Cm | 0.0216mA | 462KΩ | |
| 300Cm | 0.0325mA | 307KΩ | |
| 400Cm | 0.0432mA | 231KΩ | |
| 500Cm | 0.0536mA | 186KΩ | A little water leak rate |
| 600Cm | 0.0641mA | 156KΩ | |
| 700Cm | 0.0746mA | 134KΩ | |
| 800Cm | 0.0853mA | 117KΩ | |

Table 2 shows the result of the second experiment. In this experiment we confirm that the changes in insulation resistance ($R_P$) is almost undetectable as we change leakage points to each 20cm sealed cylinder.

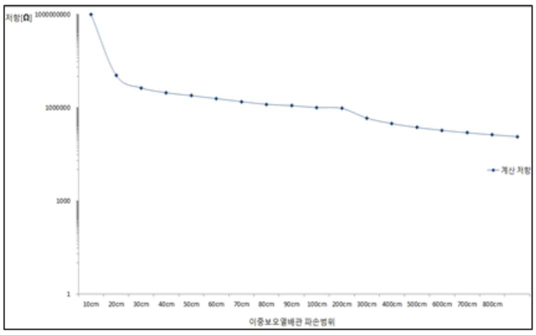
The proposed method shows 0.2 ~ 0.4 % lower error rate than the conventional leakage point measurement index, thus showing higher accuracy.

## 4. Conclusion

The conventional measurement methods for leakage amount and point have been used, however the leakage point and damage range of the pre-insulated pipe have been divided and measured in a finer scale. Although the accuracy of the results cannot be guaranteed for in this experiment, the pre-insulated pipe was an experimental one. However this paper suggests a possibility of a quicker way to find the cause of the leakage and a quick solution for it through studying the characteristics of the output load of leakage. More accurate experiment settings would yield better results later on. The proposed method could be used to find the leak point of the pre-insulated pipe. Also the collected data in this paper can be used to find a leakage faster when the positions of the leakage detector wire or specifications have been changed. Continuous management of pre-insulated pipes would prove to be economical on both aspects of maintenance and installation [7-8].



**(a)**



**(b)**

Fig.5 (a) measurement of leakage current for each leakage in a unit (b) the graph shows insulation resistance calculation of each unit leakage

## References:

[1] Kyu Dok Cho, "Introduction to Pipe Monitoring System by Measuring the change of Insulation Resistance in underground Pre-Insulated Pipe", SAREK, 2004, pp. 212-217

[2] Hun Lee, Yeon Hong Kim, “District heating network maintenance”, SAPEK, 1999, pp. 59-77

[3] Ho Bum Kim, “The Structural Stability Analysis of District Heating Pipe by varying thickness of Carrier Part”, INHA Univ, Master Thesis, 2009, pp. 1-99

[4] Min Kyu Lee, “A study on the establishment distance for district heating pipe” INHA Univ, Master Thesis, 2010, pp. 1-126

[5] Kwang Min Yu, Sang Hwa Lee, Kwon Soo Han, Jeon Hong Kang, Wan Seop Kim, Mun Seog Kim, “Leakage Effect on insulation resistance measurements”, KIEE, 2010, pp. 14-16

[6] Hyung geun Kim, “Development of leakage detection technique using the unsteady and frequency analysis in a simple pipe” Pusan National Univ, Master Thesis, 2005, pp. 1-94

[7] Yildiz Kalinci, Arif Hepbasli, Ismail Tavman, Determination of optimum pipe diameter along with energetic and exergetic evaluation of geothermal district heating systems Modeling and application, Energy and Building, vol. 40, No. 2010, pp. 742-755

[8] Jooyong Kim, Hobum Kim, Hyun Il Ko, Yong Mo An and Chongdu Cho, 2009, "Design Validation and Improvement of District Heating Pipe Using FE Simulation", Trans. of the KSME(A), Vol. 33, No. 4, pp. 337~345

Table 2.The result of water leak point

| Range | Insulation resistance ($R_g$) | Voltage measurement ($V_g$) | Estimated position | Standard JIG |
|---|---|---|---|---|
| 20Cm | 0.0024mA | 0.0201V | 0.21m | 0.0201% |
| 100Cm | 0.0025mA | 0.1003V | 1.003m | 10.03% |
| 200Cm | 0.0024mA | 0.2001V | 2.001m | 20.01% |
| 300Cm | 0.0024mA | 0.3002V | 3.002m | 30.02% |
| 400Cm | 0.0023mA | 0.4003V | 4.003m | 40.03% |
| 500Cm | 0.0022mA | 0.5001V | 5.004m | 50.01% |
| 600Cm | 0.0024mA | 0.6005V | 6.005m | 60.05% |
| 700Cm | 0.0023mA | 0.7001V | 7.001m | 70.01% |
| 800Cm | 0.0024mA | 0.8002V | 8.002m | 80.02% |
| 900Cm | 0.0024mA | 0.9004V | 9.004m | 90.04% |
| 1000Cm | 0.0025mA | 0.9998V | 9.908m | 99.98% |

## Appendix

This paper is the result of the support of the Small and Medium Business Administration of the academic and research technical development project (No. CD034327)