Application of RFID to Underground LNG Supply System

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Abstract—**In order to reduce the gas accident due to third party digging, applicability of RFID to underground facility was investigated. Stable recognition depth of RFID tag were measured to be 60, 50, 50, 25 cm in the medium of acrylic resin, soil, 5 cm-thick-concrete + soil, and water respectively. And 24 bit RFID metal tag can hold the LNG pipe data of construction date, material and thickness, burying depth, and ID No. Application of RFID to underground LNG supply system will not only reduce the gas accidents due to third party digging but also improve the maintenance efficiency.**

Key words*—*RFID metal tag; recognition depth; LNG supply network; frequency analysis; third-party digging

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IT recognition techniques have been used widely in various fields: environmental & safety, public transportation, stockbreeding, and material circulation etc. In most cases, the IT application was limited to the facility installed over the ground. And IT to underground is very little. Since the medium under the surface consists of soil, sand, water, and concrete, recognition technique like Barcode and QR code method is not applicable. RFID only seems to be applicable to the underground facility[1].

Among many underground pipelines and cables, the biggest accident has been caused by the LNG supply system[2,3]. In representative example, a gas explosion that killed 101 people and injured 202 has happened at Daegu in 1995. The cause has been found as the gas pipe damage by third party(department store) digging.

Therefore this research was undertaken to apply IT to the underground facility. Specifically LNG supply underground system[4].

In this research, we measured the stable recognition distances of various components under the surface. From experimental results, we proposed the practical methods to apply RFID to LNG supply system. In addition to safety sector, we devised the method to input the pipe information to RFID tag and it will increase the maintenance efficiency of the LNG supply facility.

1 Literature survey

1.1 Underground pipes and cables and the gas accidents

Under the main roads of the city, there are so many supply lines and cables buried altogether very closely.

Fig. 1 shows the complexity of underground lines and cables. Most lines and cables are buried in the depth from 120 cm to 180 cm.

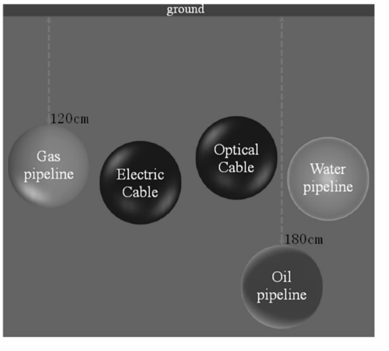

Fig. 1 Various pipelines and cables under the ground

Tab. 1 lists the types of supply lines, cables, and the regulation depth and minimum distance between lines or cables.

Tab. 1 Corresponding regulation depths of 3 pipelines and 2 cables respectively

Type	regulation depth	Note
Gas Pipeline	More than 1.2 m	Distance between tubes more than 0.3 m
Water Pipeline	More than 1.2m	
Oil Pipeline	More than 1.8 m	
Electric Cable	More than 1.2 m	
Optical Cable	More than 1.2 m	

Burying depth of oil line is more than 1.8 m and the burying depth of other lines is more than

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1.2 m. Excepts oil lines, other lines usually buried very closely between 120 cm and 180cm[5]. Therefore there exists the danger due to the circumferential piping excavation work.
Tab.2 lists the statistics on gas accidents. During 5 years from 2006 to 2010, 24 surroundings excavation work gas accidents were occurred in Korea, which is about 22% of total 110. As we concerned from the complexity of underground line array, the highest portion of accidents was caused by the third party digging[6,7].

Tab. 2 Total gas accidents and accidents due to surrounding excavation work for last 5 years

Year	Total No. of city gas accidents	Accidents due to surroundings excavation work
2006	16	6
2007	30	5
2008	24	7
2009	15	1
2010	25	5
Summation	110	24

'Korean gas safe construction' accident statistical data

1.2 IT recognition device

RFID recognition device consists of RFID reader and tag. Tags can be classified as active or passive. Active tag should have its own power supply to be detected, but passive tag can be detected without its own electric power. Tab. 3 lists the features of RFID[8].

Tab. 3 Lists the features of the various ranges of RFID

Frequency	UHF		Microwave
	433.92 MHz	900 NHz	2.45 GHz
Reading Range	50~100 m	3.5~10 m	Within 1m
Specific	· Long Reading range · Real-time tracking Sensing the internal humidity and shock	· Lowest cost Super to the reading range and of the multi-tag and performance	· Similar to 900 MHz tag · sensitive to the environment
Operation	Active	Active/ Passive	Active/ Passive
Typical Use	· Container Tracking Management · RTLS	· SCM · Toll payment	· Anti Counterfeit

Frequency of RFID ranges from 433.92 MHz to 2.45 GHz. Among them, 900 MHz is reported to be more effective when applying to underground recognition research. Thus we selected the 900 MHz Reader and tag for this study[9].

2 Experimental methods

2.1 Experimental devices

The specifications of The RFID reader and 2 types of tags are listed in Tab. 4.

Tab. 4 The specifications of the RFID reader

	Specifications
model	AT870(with a handled reader)
Frequency	900 MHz
Protocol	ISO18000-6C

2.2 Experimental procedures

2.2.1 Procedures for measuring recognition depth of RFID tag buried in soil

The schematic diagram of experimental apparatus is shown in Fig. 2. α stands for the depth of the tag buried and β stands for the distance from the surface to the bottom of RFID reader.

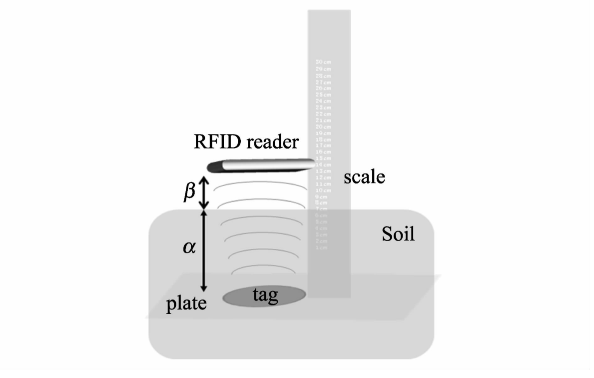

Fig. 2 Schematic diagram of RFID tag in soil medium

1) First we put single metal tag on the bottom of the box and stand 100 cm ruler vertically.
2) Then we piled 5 cm soil on the bottom.
3) Next, we piled 5 cm thickkness concrete on the soil.
4) Then measured the stable and maximum recognition distance.
5) We repeated the procedure 3, 4, 5 by adding the soil by 5 cm thickness until the reader could not recognize the metal tag.

2.2.2 Procedures for measuring recognition depth of RFID tag buried in 5 cm concrete + soil

The Schematic diagram of experimental apparatus is shown in Fig. 3. At this figure, gamma stands for the depth of the tag buried in soil and beta stands for the distance from the surface to the bottom of the RFID reader.

1) First, we made 5 cm thickness concrete plate out of cement, sand and water mixture.

2) Then we put single metal tag on the bottom of the box and stand 100 cm ruler vertically (refer to Fig. 3).

3) Then we piled 5 cm soil on the bottom Next we piled 5 cm thickkness concrete on the soil.

4) Then measured the stable and maximum recognition distance.

5) We repeated the procedure 3, 4, 5 by adding the soil by 5cm thickness until the reader could not recognize the metal tag.

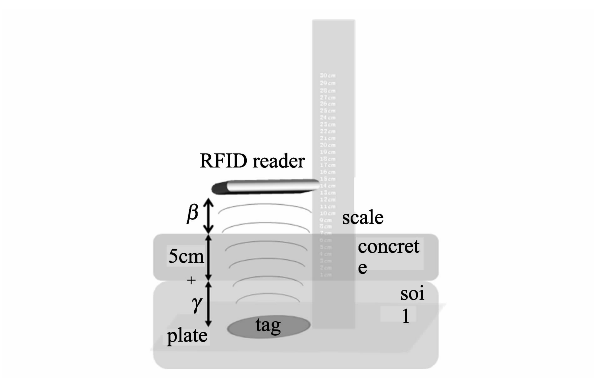

Fig. 3 Schematic diagram of RFID tag in concrete + soil medium.

By Similar procedures previously mentioned, we measured the recognition depth of RFID tag immersed in water.

2.3 Data input method

We can input 24 bit data on the commercial metal tag. One bit is equivalent to 4 bytes(0～9, A～F). And the necessary data on the LNG pipe thought to be construction date, pipe material and diameter, buried depth and Pipe ID. We conceptually divided the 24 bit into 3 pieces of 8 bit info. Then we allocate the first 8 bit for construction date, the second 8 bit for pipe material & size, and allocate the last 8 digit for LNG source plant & specific ID of each pipe.

3 Results & discussion

3.1 Recognition distance in various medium

Tabs. 5, 6 and 7 list the recognition distances when the metal tag in soil, 5 cmconcrete + soel and water. Figs. 4～6 are the corresponding bar charts to Tabs. 5～7 respectively. In the air, the metal tag was detected by the RFID reader at about 300 cm distance. But the recognition distances in other medium were shorter than that. But the distances are longer than 30 cm which is the safety distance from the other kind of tubes or cables. Therefore the application of RFID to underground LNG supply seems to be meaningful to prevent third party digging accident.

Tab. 5 Detectable Reader height from the surface when metal tag buried in soil from 5 to 55 cm

α^{*}	β^{**}	
	Effective***	Maximum****
5 cm	49 cm	55 cm
10 cm	46 cm	52 cm
15 cm	39 cm	47 cm
20 cm	32 cm	40 cm
25 cm	26 cm	33 cm
30 cm	17 cm	26 cm
35 cm	15 cm	22 cm
40 cm	13 cm	19 cm
45 cm	10 cm	15 cm
50 cm	7 cm	11 cm
55 cm	Unstable	3 cm

α^{*}: The depth of the tag buried.
β^{**}: The distance from the soil surface.
Effective***: The distance of the consistent tag detection.
Maximum****: The distance of the intermittent tag detection.

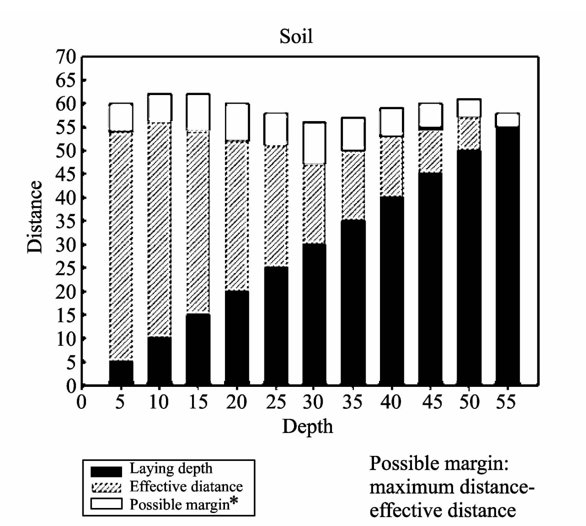

Fig. 4 Corresponding bar graph to Tab. 5

Tab. 6 Reader height from the surface when metal tag buried in (concrete 5 cm + soil) from 5 to 50 cm

γ^{*}	β^{**}	
	Effective	Maximum
5cm	46 cm	50 cm
10cm	40 cm	46 cm
15cm	35 cm	39 cm
20cm	29 cm	33 cm
25 cm	22 cm	29 cm
30 cm	16 cm	23 cm
35 cm	11 cm	18 cm
40 cm	9 cm	13 cm
45 cm	5 cm	9 cm
50 cm	unstable	2 cm

γ^{*} : The soil part depth of the tag.
β^{**} : The distance from the soil surface.

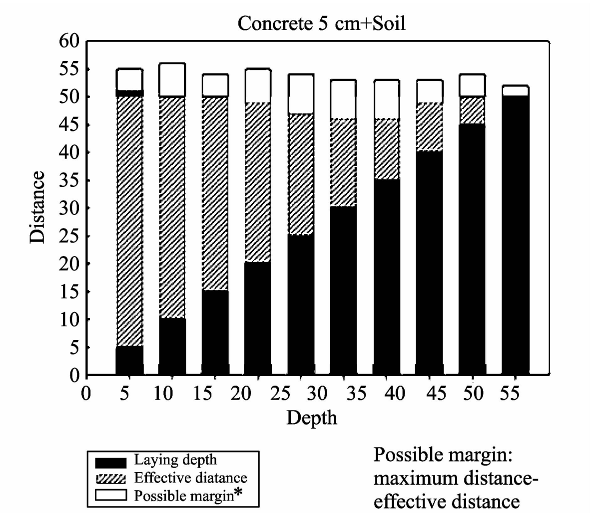

Fig. 5 Corresponding bar chart to Tab. 6

Tab. 7 Reader height from the surface when metal tag immersed in water from 5 to 30 cm

α^{*}	β^{**}	
	Effective	Maximum
5 cm	37 cm	39 cm
10 cm	35 cm	38 cm
15 cm	22 cm	24 cm
20 cm	26 cm	28 cm
25 cm	32 cm	35 cm
30 cm	unstable	2 cm

α^{*} : The depth of the tag buried.
β^{**} : The distance from the soil surface.

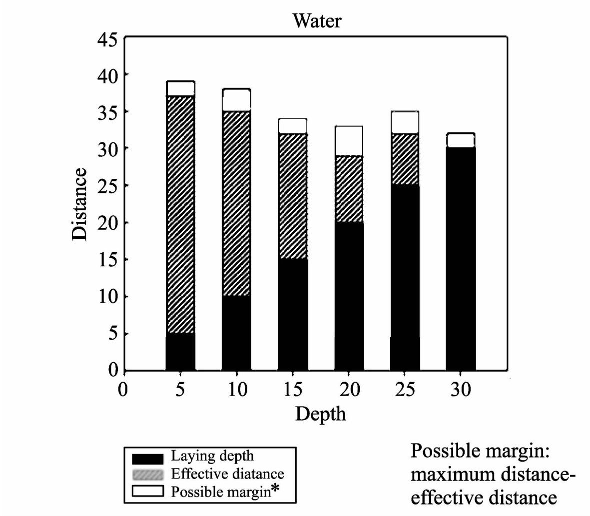

Fig. 6 Corresponding bar chart to Tab. 7

3.2 Data input example

Three input examples of RFID tag is shown in Fig 7. In Fig 7(a), the numbers and alphabet means the following information: The former part stands for the Date. The LNG gas lines was constructed on January 14th of the year of 1991.

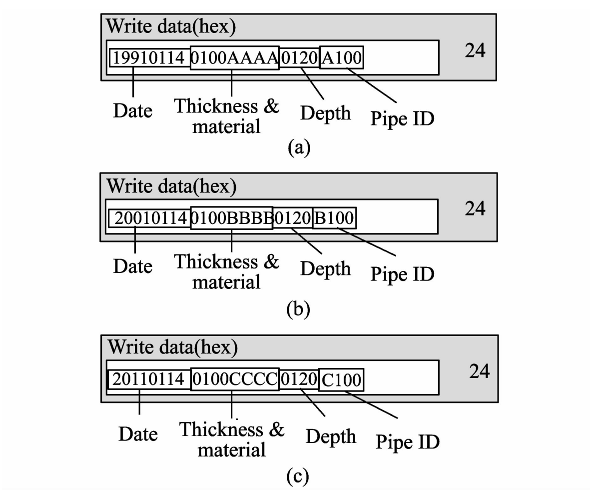

Fig. 7 Systematic 24 bit input of RFID tag

The middle part stands for the material and diameter. Thus the diameter of the pipe is 100 mm and both insides and outside of the pipe are made out of carbon steel, The last part stands for the burying depth and ID. Thus the pipe was buried in 120 cm from the surface and the line came from Incheon LNG Plant and ID No of line is '100' Similarly, the 24 bit information of Fig. 7(b), and 7(c) could be interpreted. The corresponding material of each alphabet and corresponding LNG source plant are listed in Tab. 8.

Tab. 8 Corresponding material and LNG source of each Alphabet from A to D

Middle part	Last part
AA: Carbon steel	A: Incheon
BB: Alloy steel	B: Pyeongtaek
CC: Stainless	C: Tongyeong
DD: Polyethylene	D: Samcheok

We can manage underground LNG supply system systematically through onsite tag information. For example, the pipe replacement time could be calculated from the construction date.

In Tab. 8, there are four LNG plants. Three of them are being operated, the other one is now under construction. Fig. 8 shows the location of New 4th Plant and LNG lines under construction[7].

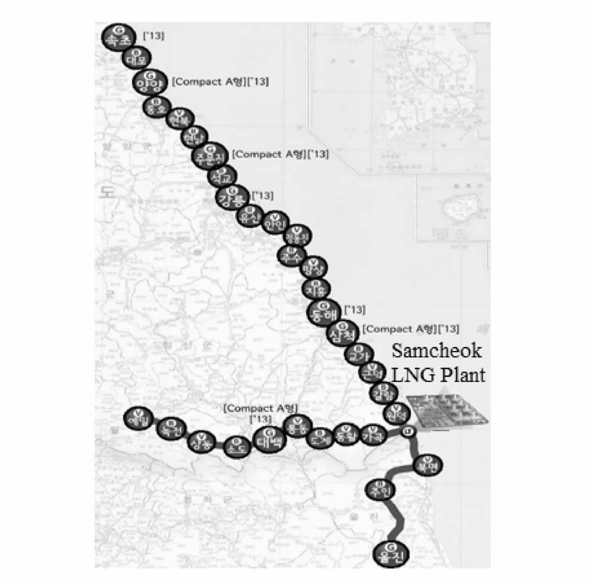

Fig. 8 The 4th plant and LNG supply system under construction

4 Conclusions

Applicability of RFID technique to underground LNG line was investigated. The results showed that RFID can not only reduce the gas accident but also improve maintenance efficiency. The three conclusions were drawn as follows:

1) Stable recognition depth of RFID tag were measured to be 60, 50, 50, 25 cm in the medium of acrylic resin, soil(sand), 5 cm concrete + soil, and water respectively. Thus the attachment of the RFID tag on the Underground LNG Pipe is technically meaningful.

2) Construction date, Pipe material and thickness, burying depth, and ID No. of the LNG pipe can be input in the 24 bit RFID tag. The information from the RFID tag enables us to recognize the replacement time and it can reduce the third party digging accidents.

3) The 4th LNG plant is under construction in Samcheok, located in east coast of Korean peninsula. The project will be completed in 2014 and the total length of LNG pipe lines will be 1 040 km. Suppose we install RFID tag every 10 m of this new lines, the required no of tags will be about 100 000.

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