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A Study of Optimizing Cathodic Protection in Comparison of Design Methodologies

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Abstract

The principal factor determining an optimum design method for cathodic protection is finding the protection current for preventing the corrosion of existing, already laid pipe. Some factors currently used to test designs include the sizes and lengths of pipes, soil resistivity, and the coating damage rate. We believe this method and current formulae are not optimum due to the uncertainty of determining the coating damage rate and the corrosion protection current's density.

This paper analyzes the amount of protection current obtained by performing a temporary current test using data describing existing laid pipe. We then propose determining the corrosion protection current by using the temporary current test after modifying the formula. In addition, we suggest a way to choose optimized cathodic protection and the process of design by executing the design and taking account of such factors as a site condition of 34km-long non-protected water supply pipe lines (stages Ⅰ and Ⅱ) in ○○ region, climate, interferences, and durability.

Key Words : Cathodic Protection, Corrosion Protection Current

1. Introduction

1.1 Purpose and Method of the study

As industrial development continues, the number of facilities made of metal are increasing. As a result, potential dangers of large accidents (e.g. a gas explosion, soil polluted by an oil pipe leakage, a water pipe leaking accident, a power failure of an underground pipe-type cable filled with oil, a collapse of a big steel-skeleton building, a safety-related accident, etc.) are growing. For this reason, more facility owners are trying to obtain cathodic protection systems which prevent corrosion

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of their facilities and avoid large accidents[1]. To obtain this cathodic protection, an optimized design method is needed: first, a design of existing laid pipe and second, a, design for laying new pipe[2].

Presently, a temporary current test is used to find the corrosion protection current., a method which uses a formula including size and length of pipe, soil resistivity, coating damage rate. This is the core factor of the cathodic protection design method for designing equipment to prevent corrosion of pipe already laid. However, the method using the current formulae is not appropriate now, due to the uncertainty of determining the coating damage rate and corrosion protection current density.

This paper analyzes and examines the current obtained by using formulae and a temporary current test about existing laid pipe. We then propose determining corrosion protection current by using a temporary current test in addition to modifying the formula.

Further, we suggest a way to choose optimized cathodic protection and the process of design through executing the design while taking account of a site condition of 34km-long non-protected water supply pipe lines (stages I and II) in ○○ region, climate, interferences, durability, and other circumstances.

1.2 Scope

As it is shown in <Table 1>, the subjects are ○○ area water supply 1 tunnel exit~2 tunnel entrance, 2 tunnel exit~3 tunnel entrance, 3 tunnel exit~end of subject section.

Sections are illustrated in Figures 1, 2 and 3 below. In each section, the left side of a proceeding pipe way is stage I, the right side of it is stage II, and each are proceeded with 2 rows. From the 3 tunnel exit, there are stage I and 2 rows, stage II and 1 row, and the three sections are totally separated, except that the pipe is continuous from the 3 tunnel exit to the end of the section.

Table 1. Piping status for cathodic protection

stage I section	STA. No [from~to]							Lenght (m)	Dia. (㎜)	Total lenght(m)
1Texit~2Tentrance	83	+	20	~	111	+	36	1,136	2,200×2	2,272
2Texit~3Tentrance	129	+	20	~	191	+	35	2,495	2,200×2	4,990
3Texit~Banpo Bridge	208	+	35	~	278	+	0	2,775	2,200×2	2,206
	278	+	0	~	344	+	0	2,640	2,200×2	5,280
	344	+	0	~	407	+	30	2,550	2,200×2	5,100
	407	+	30	~	446	+	0	1,530	2,200×2	3,060
										22,908

stage II section	STA. No [from~to]							Lenght (m)	Dia. (㎜)	Total lenght(m)
1Texit~2Tentrance	83	+	20	~	111	+	36	1,136	2,400×2	2,272
2Texit~3Tentrance	129	+	20	~	191	+	35	2,495	2,400×2	4,990
Gwangam junction	208	+	35	~	278	+	0	2,775	2,000	1,245
3Texit~GwacheonBooster Pump Station	278	+	0	~	344	+	0	2,637	2,000	2,637
	344	+	0	~	411	+	0	2,680	2,000	2,680
										13,824

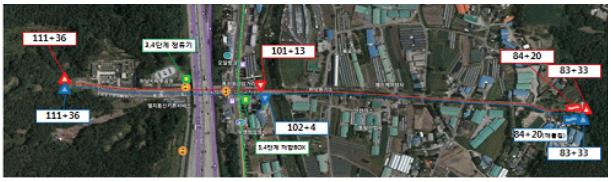

Fig. 1. 1 tunnel exit~2 tunnel entrance

Fig. 2. 2 tunnel exit~3 tunnel entrance

Fig. 3. 3 tunnel exit~the end of section

We would like to draw the way of an optimized cathodic protection design method about this non-protected pipe lines subject sections.

2. Research of the environment for cathodic protection

2.1 Measurement of soil resistivity and pH, humidity

We measured soil resistivity, pH and humidity at around ○○ broad water supply 1, 2 non-protected pipe lines for 12days (2010, April 5~16). The average temperature for the period was 8.9℃. It rained and was cloudy. The results of our measurements were:

(1) Soil resistivity of pipes was measured on the basis of soil depth every 500m distances.<Fig. 4> The result, 3,014~33,518[Ω · cm], appeared to be spread over a relatively broad range. The resistivity where the pipe is positioned turned out to be 9,730 [Ω · cm] - similar to the domestic average soil resistivity. If the soil corrosion degree was assessed by resistivity, it was included with a range of “aggressive~weak to aggressive". Although soil characteristics differed, it is generally believed to be effective for protecting against pipe corrosion.

(2) For soil resistivity on a site expected to become an anode bed, we measured up to 60m every 5m and found a declining economic utility at each layer. We then selected the depth of holes. Resistivity in deep-well type anodes including all three applied sites was high after 45m depth. As a result their economic value decreased. We set up a deep-well type for use up to 45m. Soil resistivity of expected anode beds ranged 29,150~33,175[Ω · cm]. Since deep-wells are used as spare beds, we made it focus on a relatively low corrosion protection current.

(3) A shallow bed type was designed by installing two anodes per hole after drilling 10m to ensure economical feasibility and workability. Then we measured soil resistivity. Average resistivity at 2~10m depth where an anode was built turned out to have a range of 11,000~12,000[Ω · cm]. It is not believed to be a problem to install a deep-well type anode based on this .

(4) Overall soil pH in subject area ranged from 5.5 to 7.0 pH. The value of each section was similar. Humidity was 55~70[%] which is close to the value of domestic average pH, humidity.<Fig. 5> They are not significant numbers when determining the need to consider additional corrosion protection current.

Fig. 4. Soil resistivity

Fig. 5. pH, humidity

2.2 Determination of corrosion protection current

2.2.1 Corrosion protection current test

(1) This test is performed with an installed temporary power device to determine the current density for preventing corrosion of a pipe. The test requires the installation of a maximum of 2 rectifiers for each section to find accurate corrosion protection current in every each protection section, and simultaneously to send protection current so that we could get corrosion protection current which is close to a real value of one.

(2) Corrosion protection current gains during the temporary current test are shown in <Table 2>

Table 2. Result of temporary current test

No	Section	Sta.No.	stage	V (V)	I (A)	Adoption I (A)	Section total I (A)	Lenght(m)
1	1T~2T	89 + 00	2	30	20	20	20	4,544
2	2T~3T	140 + 00	1	52	10	10	40	9,980
		167 + 17	2	35	16.8	30		
3	3T~ end(1)	278 + 0	1	60	30	30	77	8,160
		291 + 0	1	30	15	15		
		307 0	2	40	32	32		
4	3T~ end(2)	322 + 0	1	50	32	32	32	2,640
5	3T~ end(3)	360 + 0	1	58	40	40	65	3,760
		386 + 0	1	41	25	25		
6	3T~ end(4)	417 0	1	30	10	6.8	26.8	2,560
		446 0	1	45	20	20		
7	3T~ end(5)	325 + 0	2	45	25	25	25	1,440
8	3T~ end(6)	358 + 0	2	40	30	30	55	2,560
		393 + 0	2	50	25	25		
							340.8	

2.2.2 Corrosion protection current using resistivity

Corrosion protection current is calculated by formulae shown below, based on a technical standard of K-water. In this phase, we measured average soil resistivity and applied a coating damage rate of 5[%] (the norm for asphalt protective coating for steel water pipe).

(1) corrosion protection current density

$\log(i) = 2.7 - 0.428\log(\rho)$

here, : average soil resistivity ([Ω · cm])

: corrosion protection current density ([㎃/m^2])

(2) corrosion protection current(I)

$I = \pi \times D \times L \times C \times \rho$

here, D : pipe Diameter(m)

L : pipe Length(m)

C : coating damage rate(5[%])

ρ : corrosion protection current density ([㎃/m^2])

The results are shown in the following <table 3>

Table 3. The result of comparison with calculation of corrosion protection current and formula

No	Average soil resistivity	Temporary current test (A)	log(i) = 2.7-0.428log(ρ)			log(i) = 2.966-0.428log(ρ)		
			Corrosion protection current density	Corrosion protection current	Deviation ([%])	Corrosion protection current density	Corrosion protection current	Deviation ([%])
1	11,285	20	9.23	15.2	-24	17.0	25.5	27
2	8,952	40	10.1	36.8	-8	18.8	61.9	54
3	1,684	77	20.8	56.1	-27	38.8	103	34
4	1,451	32	22.2	19.3	-40	41.0	35.7	11
5	5,147	65	12.9	16.0	-75	23.8	29.6	-54
6	17,025	26.8	7.74	6.5	-75	14.2	12.1	-54
7	1,451	25	22.2	10.6	-57	41.0	19.5	-22
8	1,332	55	23.0	19.5	-64	42.5	35.9	-34
		340.8		179.9	-47		323.2	5

The corrosion protection current calculated by formula was -8~-75[%] smaller than the one by derived from the temporary current test. Thus, when calculating corrosion protection current using formula, there is concern for corrosion due to the possibility protection might not be high enough. To prevent this, we see a need to modify the formula and calculate using the temporary current test.

When calculating with $\log(i) = 2.966 - 0.428\log(\rho)$, the deviation comparing to the corrosion protection current using the temporary current test is decreased -54~54[%] , Total deviation of corrosion protection current is shortened to 5[%]

2.3 Research for interference effect of other pipes

There are ○○ broad water supply stages Ⅲ and Ⅳ pipes, daehan city gas pipes, Korea gas corporation pipes in 1T~2T section. So, we executed the assessment of interference test for these pipes. The others showed cathode interference, there is need of action in respect of design corresponding to this. The result of other pipes interference effect test is <Table 4>

Table 4. Other pipes interference effect test

Section	Sta.NO.	Pipes	Interference on/off	Effect	Location	Design Method
1T ~ 2T	104+00	daehan city gas1	-1150/-2400	negative Interference	the circumference of stages Ⅲ,Ⅳ pipe an intersection	resistance box design
		daehan city gas2	-2050/-2150			
		daehan city gas3	-500/-1700			
	103+00	stage Ⅲ,Ⅳ	-840/-1160			bonding

2.4 Research for interference effect of other facilities

The effect of interference from other facilities can be a high voltage transmission line, a tower or a subway. <Table 5> shows the potential effect of interference at night from stoppages of the subway.

Table 5. Interference effect by subway

Site	Minimum value(mV)	Maximum value(mV)	The range of fluctuation(mV)
247+5(1)	-1300	-1200	100
307+2(2)	-660	-520	140
282+0(1)	-480	-420	60
315+0(1)	-900	-550	350
322+0(1)	-600	-400	200
325+0(2)	-630	-380	250
342+0(1)	-650	-550	100
376+0(2)	-750	-350	400

Measurements of the night potential suggest that there is no interference effect. Based on that, we may assume that the interference effect shown in daytime measurements is subway interference.

3. Cathodic protection optimized design

3.1 Electrical bonding

Since both proceed in a parallel way, there are benefits to installing pipes in the ○○ broad water supply stages Ⅰ and Ⅱ electrically. They are more workable and feasible economically when installed in this manner.

3.2 Selection of cathodic protection

(1) The cathodic protection system has shown improvement over the current method and the sacrificial anode method, because each of these methods require a large amount of corrosion protection current,

It is not possible to protect when using the sacrificial anode method. Therefore it is a rule to choose an impressed current system which has enough capability for the needed output and is much easier to adapt to changes in the environment.

There are shallow-bed and deep-well types for the impressed current method. Both types have a spread positioning and a concentrated positioning method. The concentrated positioning method is more economically beneficial because there is less possibility for claims and digging scale in the pipe line area. For these reasons, it is better to apply an impressed current system which installs anode in concentrated method in subject sections.

Cathodic protections for different sections are listed below.

① In case of 1T~2T section, we install anode in shallow bed type using shore of stream in this section. The shallow bed type is able to give out more current than the deep-well type.

② For the 2T~3T section, we apply the shallow bed type which is more efficient for corrosion protection and is a possible way to secure ground. At the end of the 3T supplement, when impressing protection current by deep-well type, it is considered to be generally equal and more economical. We therefore apply the impressed current method with deep-well & shallow bed mixed types.

③ After the 3T section, because there is a shortage of ground for using the shallow bed type, we would use the deep-well type. For just some beds, it cannot give out enough corrosion protection current due to the lack of ground space so that it needs to be considered to find proper supplying method.

(2) Based on corrosion protection current allotted when installing the shallow bed type, we calculated the most economical depth of using shallow type showing minimum number of holes and drilling depth. The results suggest that it is more beneficial to use a selected depth from 45m to 55m for each anode bed there is before soil resistivity becomes too high.

(3) We estimated the optimal cathodic protection method <Table 6> through a design calculation based on measured data on the site, the insulation ability of corrosion protection current and pipe, and a check about expected bed.

3.3 Ways to complement cathodic protection

We made applying the deep-well type a rule in the city area after the 3T section, but we complemented the following matters considering solution of the short of corrosion protection current and profitability in some non-protected sections.

Table 6. Estimation of optimal protection method

BED No.	Anode bed Type	Location of Anode Bed	Corrosion protection current(A)	Rectifier		Anode		Hole		Amount of anode per hole (ea)
				V (V)	I (A)	spec (lb)	quantity (ea)	depth (m)	quantity (ea)	
B1	S	102+4(1,2)	20	60	30	44	14	10	7	2
B2	S	152+14(1,2)	30	60	50	44	26	10	13	2
B3	D	184+00(1,2)	10	60	30	44	18	45	3	6
B4	D	261+00(1,2)	27	60	50	44	54	45	9	6
B5	D	280+00(1,2)	50	60	80	44	186	50	31	6
B6	D	333+0(1,2)	57	60	90	44	228	45	38	6
B7	D	362+0(1)	30	60	50	44	60	55	10	6
B8	D	387+0(1)	35	60	60	44	66	50	11	6
B9	D	419+0(1)	7.8	60	30	44	18	45	3	6
B10	D	430+0(1)	19	60	30	44	36	45	6	6
B11	D	349+0(2)	35	60	60	44	72	50	12	6
B12	D	390+0(2)	20	60	30	44	30	55	5	6

※ S : Shallow bed ; D : Deep-well

3.3.1 The Use of compulsory drainage current system

The cathodic protection method using compulsory drainage current system is considered when the interference between subways and some non-protected pipe lines is due to a difficulty in choosing bed site ground having local special property in ○○ area. There is just little interference effect of a subway in these sections. We complement corrosion protection current by using the compulsory drainage current system because there is a ventilating hole near the pipe line, making it a workable condition for installing a current drainage system.

3.3.2 Way to apply new technology

When it comes to some sites selected as bed site, it demands many anode holes to make corrosion protection current for cathodic protection. This is the case when using the HSCI(High Silicon Cast

Iron) anode and it needs to be tried in the MMO(Mixed-Metal Oxide) anode, etc. for saving building cost.

4. Conclusion

In designing a cathodic protection for corrosion protection of stages I and II of ○○ broad water supply line, we executed the design while considering overall conditions and environment which included condition of the site, climate, cost, interference, durability etc. We suggested a method and design procedures for optimal corrosion protection installation while applying an impressed current method with deep-well & shallow bed mixed type.

It is most important when designing a cathodic protection system to select the cathodic protection method (deep-well or shallow bed) after considering soil conditions and economic feasibility, and then to develop countermeasure(s) for the effects of interference from other facilities (pipe, subway, etc.).

It is possible to design optimal cathodic protection by applying design methods suggested in this paper. A cathodic protection system design about new buildings laying pipe lines is expected to improve the credibility of a project if the formula for corrosion protection current density is completed based on information in this paper.

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Biography

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