International Pipeline Conference
ASME 1996

IPC1996-1851

COATING INTEGRITY SURVEY USING DC VOLTAGE GRADIENT TECHNIQUE AT KOREA GAS CORPORATION

Y.B. Cho

K.W. Park, K.S. Jeon, H.S. Song, D.S. Won, S.M. Lee and Y.T. Kho

R&D center / Korea Gas Corporation277-1, I1-Dong Ansan, Kyonggi-Do 425-150 Korea

ABSTRACT

The reliablity and applicability of various coating defect detecting techniques are investigated utilizing mock pipe. It is shown that both close interval potential survey and dc voltage gradient methods are impertinent as field techniques : They require considerable cathodic polarization in order to effectively locate the coating defects. DC voltage gradient with current interruption technique is recommended as a viable field method in that it is able to precisely locate the defects irrespective of CP condition. Utilizing this method field survey was undertaken for the KGC's pipeline of 120 km and 106 assumed defects were located.

1. INTRODUCTION

The protection of underground pipelines from external corrosion relies on the external pipe coating. The application of coating having high dielectric constant isolates pipes from corrosive environment. The reliability and durability of coatings depend on their physio-chemical properties such as chemical stability, impact resistance and stress cracking resistance. Experience has shown, however, that the damage of organically coated structure is almost unavoidable during construction and service. Breaks or holidays in coating expose metal to corrosive environment, particulary in underground or immersion service. Elimination of coating defects is a costly job and is usually unwarranted. Thus, for systems whose protection become more critical, the combination of protective coating and cathodic protection provides better, more reliable and less costly corrosion protection.

In the case of coatings for use with cathodic protection, it is necessary to use those coatings that are based on the impervious coating concept, where the coatings to be relatively impervious to the transfer of moisture, oxygen and various ions. Among various coatings such as coal tar enamel, coal tar epoxy, fusion bonded epoxy, asphalt enamel and polyethylene, Korea Gas Corporation (KGC) has exclusively utilized polyethylene (PE). PE's having varying density (0.92-0.97g/cm^3) have been applied to the steel pipes by either fusion bonding or extrusion methods.

Recently, field workers came across the fact that there were so many coating defects, i.e, significant coating damages excluding unavoidable coating faults such as pinholes and holidays. Two types of defects were observed. One was a spot-like defect which seemed to be occurred by the mechanical impact during construction (Figure 1-(a)) and the other was crack-like defect which is likely to be a result of stress crack (Figure 1-(b)). Due to this recent observation it was deemed necessary to carry out a work detecting coating defects. This study presents results of the field survey conducted for about 120 km of KGC's pipeline.

2. COATING DEFECTS DETECTING TECHNIQUES

Prior to the field survey, a series of experiments were carried out for a mock pipeline. The objectives of this experiment were to identify the most appropriate techniques and to familiarize surveyors with this technique. A mock pipeline of total length of 48 m was consisted of PE coating pipes (dia. = 5 cm). PE coating of these pipes were intentionally removed resulting in artificial defects. Figure 2 shows the size and the location of eight defects in the mock pipeline. Pipes were buried at approximately 1 m below ground and connected to the cathodic protection system.

Techniques investigated in this experiment included close interval potential survey(CIPS)[1)], dc voltage gradient(DCVG) and dc voltage gradient with current interruption(DCVG/CI)[2,3,4)]. All these methods are based on the fact that the cathodic protection(CP) current will flow preferentially to the exposed metal at a coating fault where the resistance to earth is lowered than that of the coated pipe. As current flows through the soil to the coating defect, the resistive nature of soil results in a voltage gradient. The voltage gradient becomes maximum at a coating fault because of the increased current density around it.

Close interval potential survey(CIPS) is a method where the pipe-to-soil potential is continuously measured at a given interval as close as about 1-3m. Due to the preferential current to defects, the pipe-to-soil potential near defect becomes more noble compared to that of defect-free area. Figure 3 shows the results of CIPS. The dotted line in this figure indicates the location of eight intentional coating faults. It is shown that the potential profile behavior depends greatly upon the intensity of cathodic protection current. In case when the impressed current is large enough to cathodically polarize the pipe up to about -3200 mV, the pipe-to-soil potentials at defects becomes significantly more noble than those for the rest of pipe enabling one to locate the defect position(uptriangle). On the other hand, locating coating defects becomes erroneous when the pipe is mildly polarized(rectangle). This indicates that CIPS is impertinent as a field technique since it is often impossible, or costly if possible, to polarize a long pipeline below -3000 mV. It is also interesting to note that the magnitude of potential shift depends on the position and the size of defects. Defects positioned at the top of pipe(1, 5, 7) resulted in discernible potential peaks compared to those positioned at the bottom part(2 ,6).

DCVG technique, like the CIPS, is directly related to the cathodic protection applied to the pipeline. It is not the pipe-to-soil potential but the potential difference which play a role in DCVG technique. In this method, two reference electrodes are placed on the ground (typically separated 100 cm) and the potential difference between them is measured. Since the equipotential line in the soil electrolyte is concentric to the current entering point, i.e, the coating defect, the polarity of the potential difference is reversed at this point. Results of DCVG measurements are presented in Figure 4.

Like CIPS, the reliability of DCVG depends greatly on the intensity cathodic protection. The position of polarity reversal agrees well with that of coating defect only when the pipe is significantly ploarized (Figure 4-(c)) whereas when the pipe is mildly polarized, the former does not always corrospond to the latter. This is because that a voltage gradient is a consequence of current flow to the coating defect. In other words, DCVG requires sufficient amount of protection current in order that it may sucessfully locate coating faults. As mentioned earlier, however, polarizing pipes as much as -3000 mV is often impossible, or costly if possible.

Last method that have been tried in this study was dc voltage gradient with current interruption (DCVG/CI) technique. This is the same as DCVG technique except that the protection current is cyclically switched on and off (typically 1 second "on", 2 seconds "off"). Interrupting CP current enable one to distinguish the defect gradient from other spurious ground voltage, such as those caused by telluric currents or stray current.

Results of DCVG/CI measurements are presented in Figure 5. Data point in this figure were obtained by subtracting the potential difference between two electrodes during "on" periods from that of "off" periods. This potential, therefore, is free from ground voltage. In other words, potentials reported in this plot are referenced with respect to the identical datum point of the potential difference of "off" period. It is shown, in Figure 5, that the positions of polarity reversal agree very well with those of coating faults even though the pipe was polarized just up to -1200 mV.

3. FIELD SURVEY

DCVG/CI technique was applied to the natural gas transmission pipeline between Pyungtaek and Daejun (about 120 km). Figure 6 shows two major equipments utilized during the field survey. Current interrupter is a kind of switching device which cyclically switches "on" and "off" the CP current. Switching interval can be varied between 0.01 seconds and 5 seconds. Data capture is a potential recorder which digitally records the potential difference between two reference electrodes.

Following is the summary of survey procedure :

i) Identify the pipeline route through the map study : sometimes pipe locators were used within complex areas to accurately locate the pipeline.

ii) Connect current interrupter (Figrue 6-(a)) to the CP rectifier to switch CP current cyclically.

iii) Surveyors walk the pipeline route usually directly above or just side of pipe, placing the electrode ($Cu/CuSO_4$) tips on the ground one in front of the other at intervals of approximately 1 m.

iv) As a defect is approached, potential difference between two electrodes increases and just passing the defect , the polarity of the potential difference is reversed.

v) When the defect is placed center of two electrodes, potential difference between two electrodes becomes zero and surveyors can locate the coating defect.

For the natural gas pipeline of 120 km, surveyors have found 106 points of assumed defects. In order to confirm the presence of defect and to repair, these assumed defects were dug out. Among 106 assumed defect points, 99 points were turned out to be real defects. Various types of defects were found : 77 defects were spot-like (Figure 1-(a)) and 22 defects were crack-like (Figure 1-(b)). These defects were repaired utilizing heat-shrinkable tape.

REFERENCES

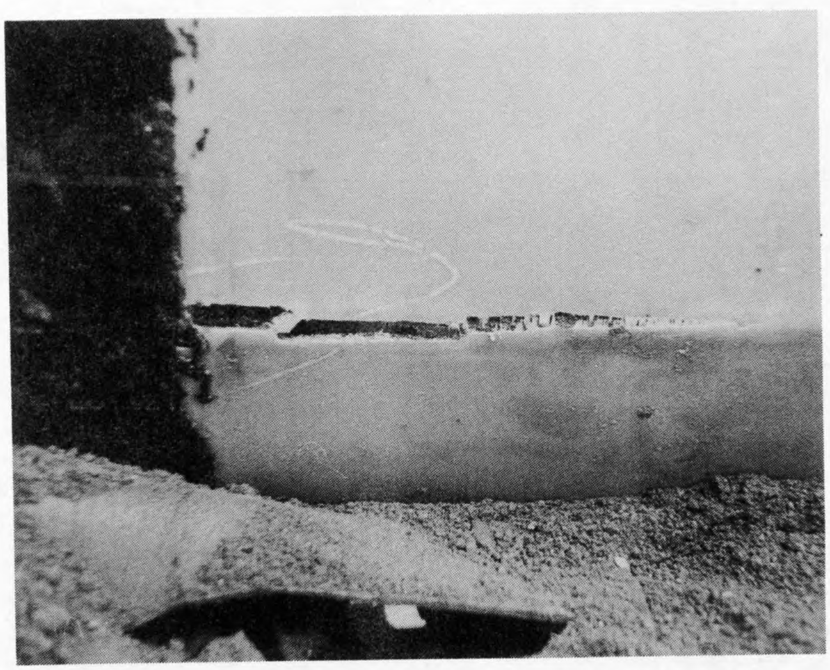
1. J. M. Leeds, Dec.,1992, "New corrosion detection method for buried pipe lines-Part 1," PIPELINE INDUSTRY, pp. 48-52.

2. J. M. Leeds, Jan.,1992, "New corrosion detection method for buried pipe lines-Part 2," PIPELINE INDUSTRY, pp. 68-70.

3. J. D. Slatter, M.C.Davidson, and J.P.Grapiglia, Feb.,1993, "DC Voltage Gradient Technique to Assess Coating Defects on Buried Pipelines," Materials Performance, Vol. 32, pp. 35-38

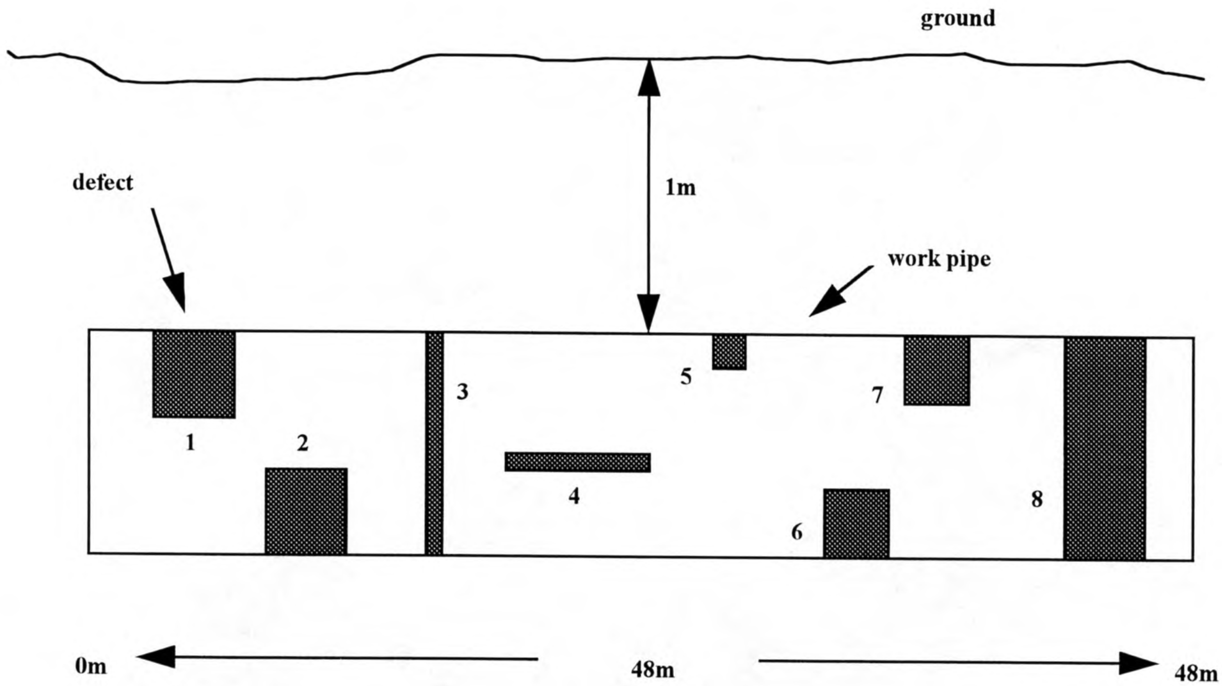
4. P. Davies, M. Richert, Aug.1, 1988, "Methodical approach key to cathodic-protection evaluation," Oil & Gas Journal, pp. 40-43.

(a) spot-defect



(b) crack - like defect

Figure 1. Two types of coating defects



Coating defect No.	Position of coating defect	Size of defect
1	45m, the upper part of pipe	$100cm^2$
2	39m, the lower part of pipe	$100cm^2$
3	33m, the side part of pipe	$18cm^2$
4	27m, the side part of pipe	$18cm^2$
5	21m, the upper part of pipe	$1cm^2$
6	15m, the lower part of pipe	$10cm^2$
7	9m, the upper part of pipe	$10cm^2$
8	3m, around part of pipe	$600cm^2$

Figure 2. Mock pipeline including various coating defects.

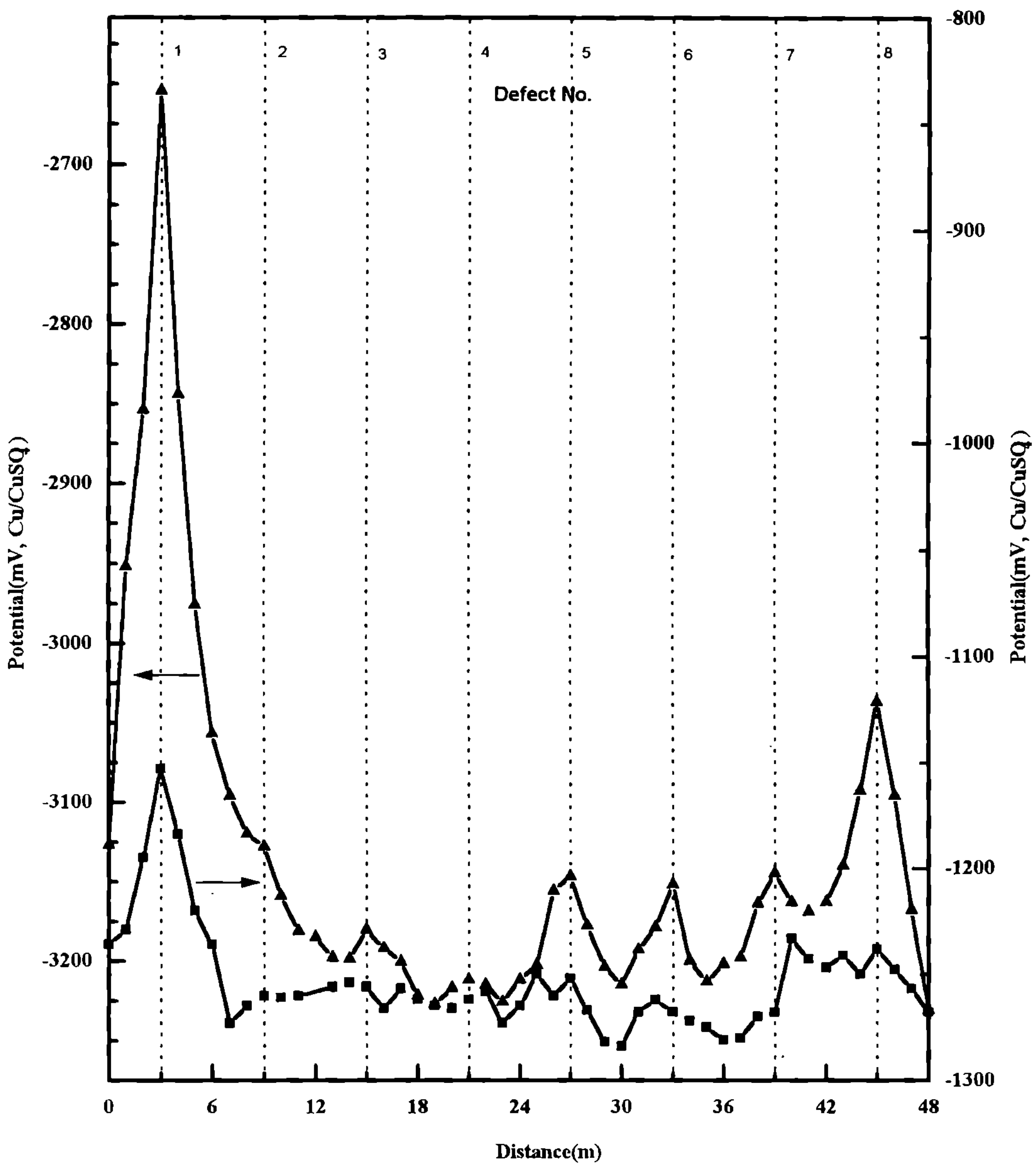


Figure 3. Pipe-to-soil potential along the pipelines showing the effect of the intensity of cathodic protection Pipe was cathodically polarized upto uptriangle : -3200mV, rectangle : -1200mV

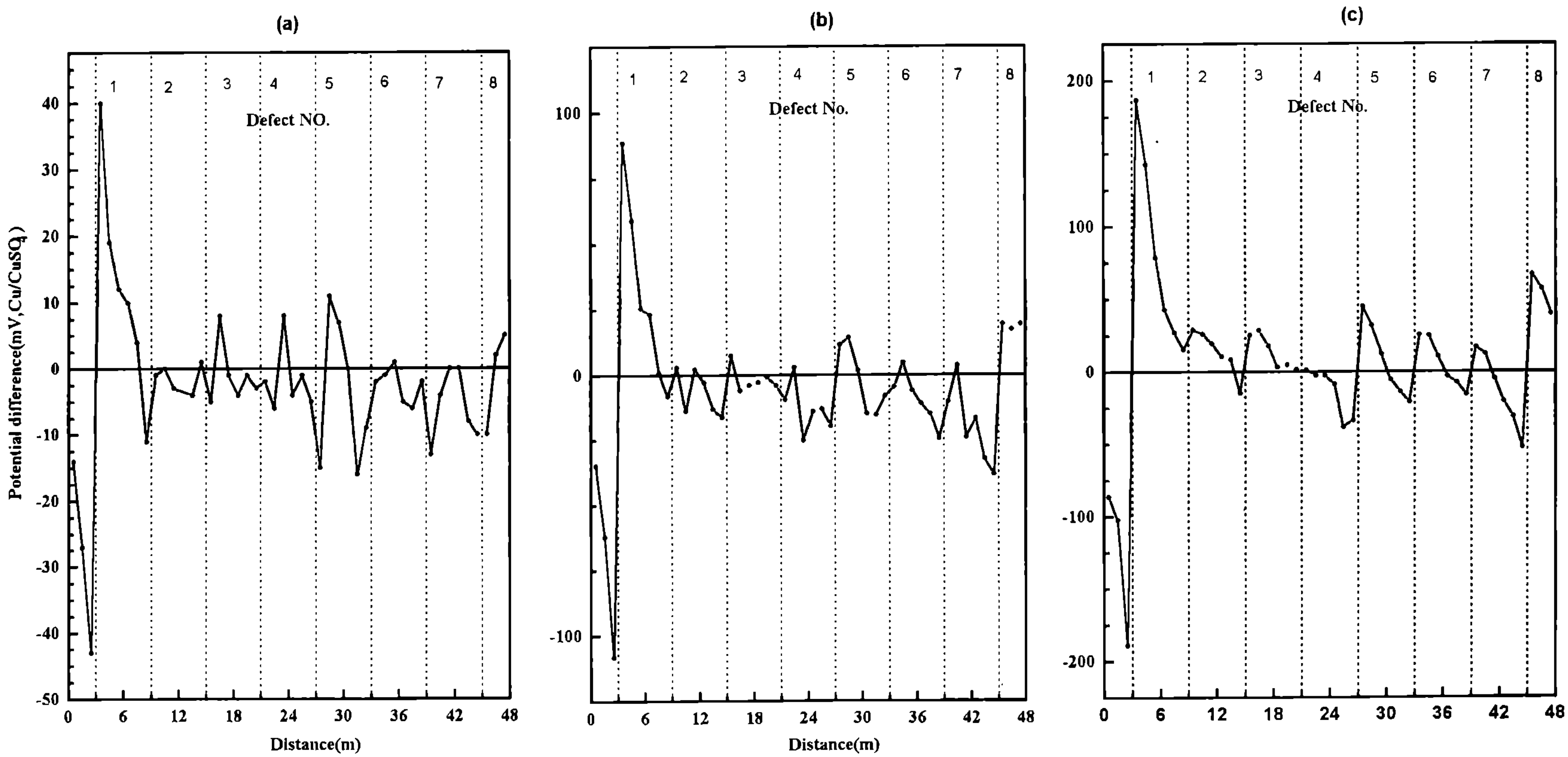


Figure 4. Potential difference vs. distance plot showing effect of the intensity of cathodic protection (Distance between two electrode is 1m. (a) : -1000mV, (b) : -2000mV, (c) : -3000mV)

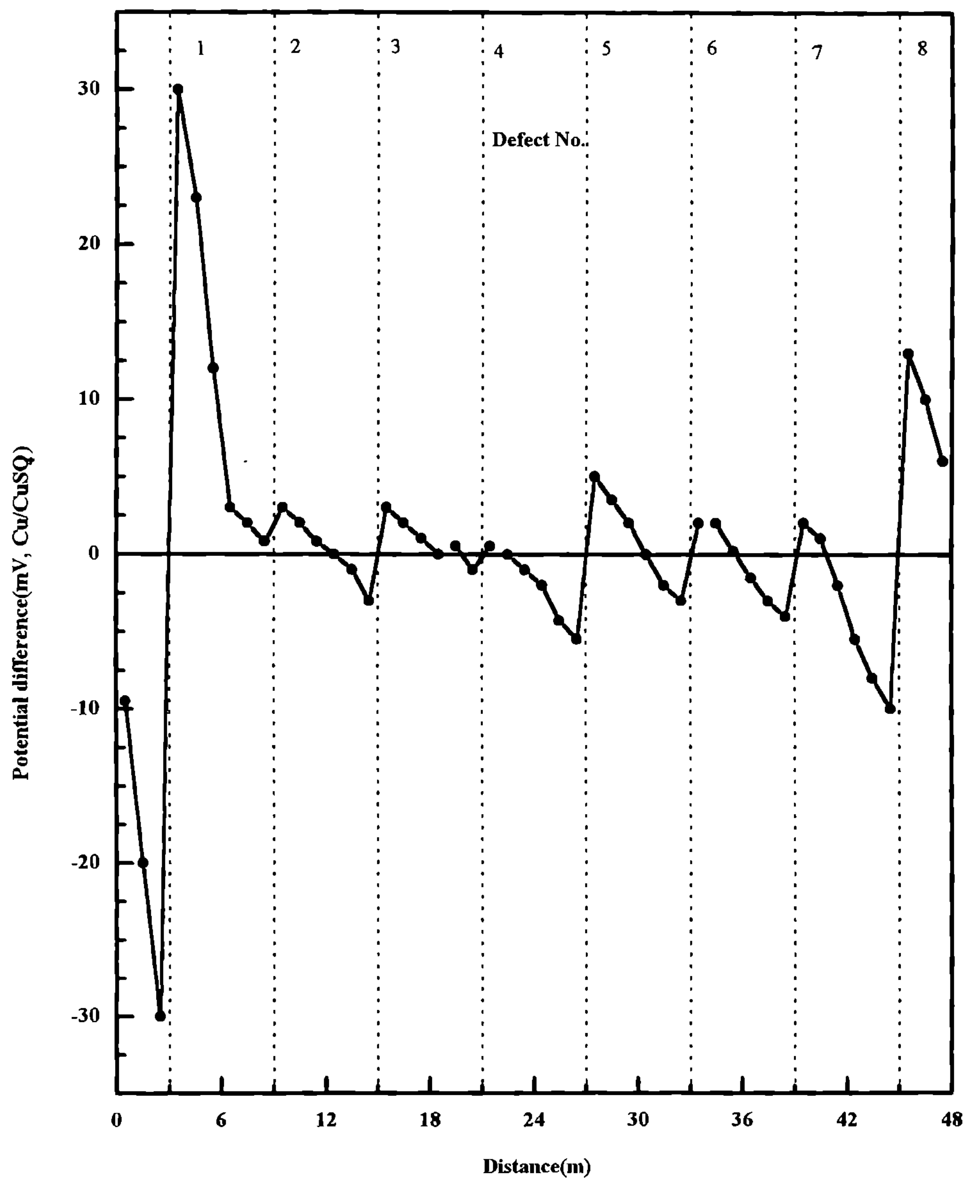
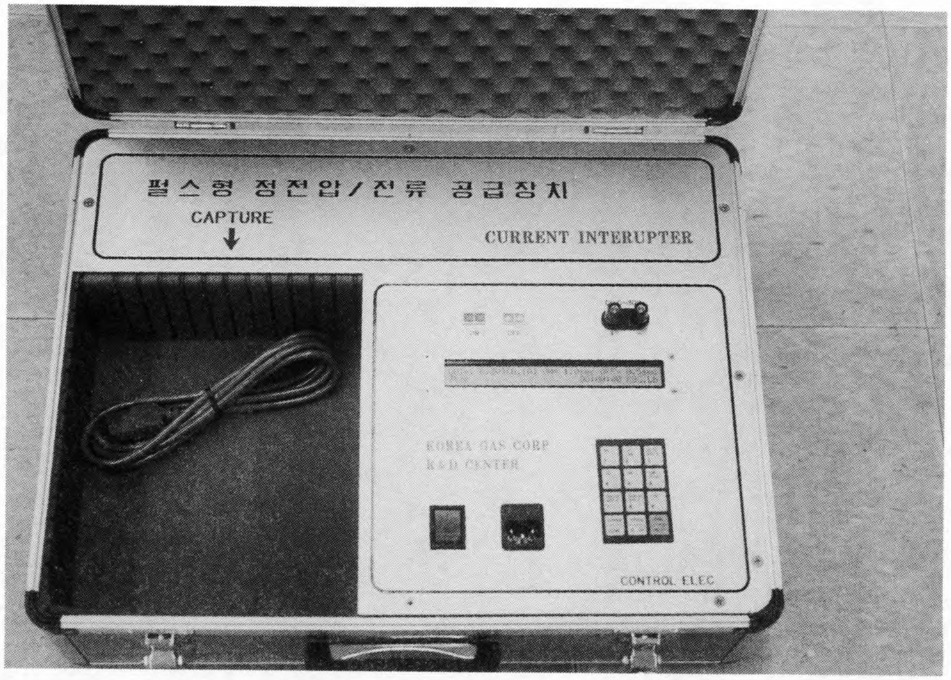


Fig.5. Potential difference vs. distance plot. Protection current was cyclically interrupted during measurement. Pipe-to-soil potentials at "off" and "on" periods were -800mV and -1200mV, respectively.



(a) Current interrupter

(b) Data capture

Figure 6. Photographs of field equipments