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DESIGNING AN IMPROVED CORROSION CONTROL SYSTEM FOR NATURAL GAS PIPELINE NETWORK IN MUNSHIGANJ AREA

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ABSTRACT

Underground steel pipelines for natural gas distribution are subject to corrosion. Good quality coating, together with cathodic protection is the usual practice to protect these pipelines. Titas Gas Transmission & Distribution Company Ltd. is the oldest and largest gas distribution and marketing company in Bangladesh. It is now supplying about 74% of the total gas consumed in the country through a vast network of pipelines. Some parts of this pipeline are about 30 to 40 years old, and are often subject to severe corrosion. This paper presents the findings of a study conducted on the gas distribution network in the Munshiganj area. It is found that the existing corrosion control system is not adequate. An improved system is designed which should incorporate both impressed current and sacrificial anode methods. Financial analysis shows that the investment required for the proposed system is viable.

Keywords: Pipeline Corrosion, Cathodic Protection, Impressed Current, Sacrificial Anode.

1. INTRODUCTION

Natural gas pipelines are mostly made of steel, and usually laid underground. These are susceptible to corrosion in the subsoil environment. Cathodic Protection (CP) techniques, together with different types of coatings (most common being PVC and Epoxy) is applied to protect these structures. Titas Gas Transmission & Distribution Company Ltd. (TGTDCL) is the oldest and largest natural gas distribution and marketing company in Bangladesh. Its franchise area covers Greater Dhaka, Greater Mymensingh and Brahmanbaria Districts. As of April 2011, the total length of its network is about 12,150 kilometers [1]. Some parts of this network are about 30 to 40 years old, and are often subject to severe corrosion. Therefore an assessment of the present status of the distribution network is essential for effective corrosion control strategy and monitoring system.

It is an extremely difficult task to evaluate the entire network. Selecting a small, isolated but representative portion of the network can provide a good understanding and basis for further studies. This paper presents the findings of the study conducted to evaluate the effectiveness of the CP system in the Munshiganj area, and propose an improved design [2]. The work was carried out during 2004-05.

2. CATHODIC PROTECTION (CP)

The common type of corrosion in the gas pipelines is electrochemical or galvanic corrosion. It takes place when two different metals come into contact with a conductive medium, or electrolyte, resulting in a flow of direct current. It requires three conditions for galvanic corrosion to occur: i) two different metals to act as anode and cathode, ii) an electrolyte to provide a path for current to flow, iii) a direct electrical contact between the two metals to complete the electrical circuit. The flow of current through the electrolyte is always from the anode to the cathode. In this process the anode is corroded, but not the cathode.

For buried pipelines, the moisture in the soil acts as the electrolyte. The anode and the cathode areas are both on the same pipe structure. The pipe itself provides the return circuit. Thus higher conductivity soil will cause more corrosion and vice versa. Localized corrosion cells can occur within the same pipeline, caused by the various elements of iron, manganese, carbon and trace elements which all occur within the typical composition of carbon steel. The principle of CP for pipelines is to convert all anodic areas of the pipeline metal to cathode, which can be achieved in two different ways as discussed next [3-5].

2.1 Impressed current method

In this method an electrolytic cell is developed artificially, where the entire structure to be protected is made to be the cathode of the cell, and an installed ground bed is the anode. The current is made to flow from the ground bed to the structure by impressing direct current from a separate power source into the earth through the ground bed. Figure 1 shows a schematic of the system.

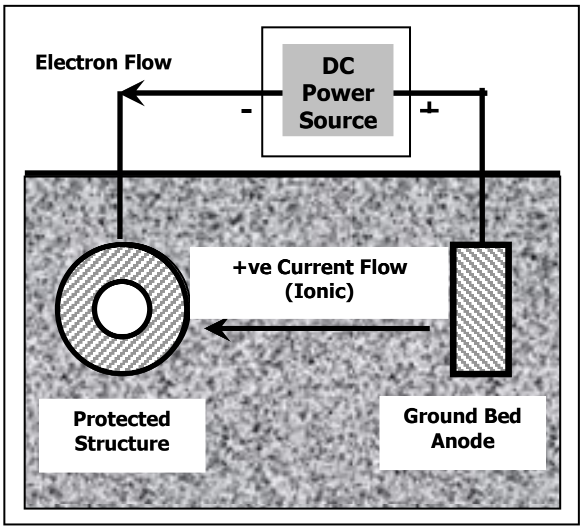

Fig 1. Schematics of Impressed Current CP System

The ground bed consists of a number of carbon, graphite, cast iron or junk steel anodes buried in the ground at various depths and configurations. Commonly, the ground bed consists of cast iron anodes, installed in augured holes about 15 feet apart, and backfilled with carbon dust to lower the anode-to-earth resistance. These anodes will all be connected together in parallel, with the header cable attached to the positive terminal of the rectifier. A Transformer-Rectifier (TR) device lowers the voltage to the required level and converts the AC power to DC. A second cable is attached to the buried pipeline and connected to the negative terminal of the TR to complete the return circuit. Voltage adjusting linkage is provided on the rectifier so that the DC current output can be adjusted to any value as may be required to provide an adequate protective potential on the pipe structure. As with other galvanic cells, the impressed current collects on the bare steel surfaces, or at the voids in the coating, and the pipe is used as a return to the negative terminal of the rectifier to complete the circuit.

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2.2 Sacrificial Anode Method

In this method a galvanic anode is buried in the ground and connected to the pipeline. The anode is made from a metal alloy with a more negative electrochemical potential than the metal of the structure. Thus a galvanic cell is established (in the soil as electrolyte) having a certain potential, which is sufficient to overcome all other naturally existing galvanic cells on the pipeline in the immediate vicinity of the anode. Thus all of the anodes of the small naturally existing cells on the pipe are converted to cathodes. The anode will corrode instead of the pipe. Since the anode metal is deliberately being allowed to corrode, it is called “sacrificial” anode. Figure 2 shows a schematic of the system.

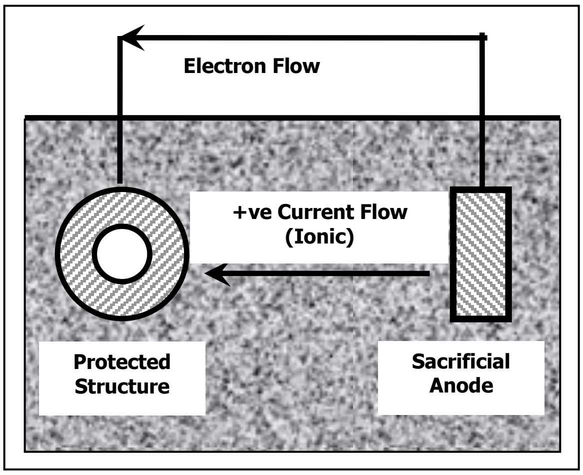

Fig 2. Schematics of Sacrificial Anode CP System

There are three main alloys used as galvanic anodes: i) Magnesium, ii) Aluminum, and iii) Zinc. These are available as blocks, rods, plates or extruded ribbons.

3. DESIGN FACTORS

For an effective design of either system, following factors must be considered:

(1) Soil resistivity: Survey must be conducted using a standard procedure. As mentioned earlier, this is a very important factor affecting the rate of corrosion. Table 1 shows the relation between soil resistivity and corrosion of steel based on 12 years of testing [5].

Table 1: Corrosion of steel in soil

Soil Type	Soil Resistivity (ohm-cm)	Corrosion Rate (mpy)	Remark
Average of 44 soils	1,000-2,000	61	Moderately corrosive
Tidal Marsh	500-1,000	100	Corrosive
California Clay	<500	137	Very corrosive
Sandy loam (New England)	2,000-10,000	21	Mildly corrosive
Desert sand	> 10,000	5	Progressively less corrosive

(2) Pipe to Soil Potential (PSP): The efficiency of the cathodic protection system is checked by PSP at various points along the structure. A threshold value of -0.85 volts is referred as the standard Copper-Copper Sulphate electrode. If PSP is found above this value, the structure is believed to be fully protected. Other reference electrodes are also available for PSP testing, such as saturated calomel, Silver-Silver Chloride, pure Zinc, etc, with appropriate conversion tables and charts.

(3) Coating: it is a common practice to use PVC or epoxy coating, along with the cathodic protection system.

A coated pipeline can be protected for a longer period of time with minimal power costs. In a coated pipeline, current flows more uniformly. Generally the cost is about 10% of that for bare metal.

(4) Current requirement: The amount of current depends on the corrosivity, and varies greatly. A well coated pipeline in high resistivity soil may need only 0.5 mA/ft^2, whereas a bare pipeline in low resistivity soil may need 2 mA/ft^2 of current flow. Therefore field survey is required to determine the current requirement.

4. ANALYSIS OF THE EXISTING SYSTEM

The gas supply network and the CP system for Munshiganj was laid and commissioned in 1992. Most of the pipeline is distributed in two parts of the town:

i) Munshiganj town, and
ii) Mirkadim area.

Both of these areas are often flooded by the surge of the two adjacent rivers- Dhawlwshwari and Meghna. Impressed current CP is implemented to protect this network. Soil resistivity survey was not conducted before or during the construction of the network. However, it was done in 1995. The design considerations followed at that time, and detailed calculations performed are not available today. Following are the salient features of the area and the CP system:

(1) CP System: The system was installed in 1992, but soil resistivity was not performed until 1995. Transformer-Rectifier (TR) is installed inside the regional sales office. The TR has a rating of 30A X 20V DC output. The Ground bed was installed 250 ft away from the 6" diameter pipeline main (parallel to the Munshiganj-Tongibari road) in front of the office. It was installed in the playground of the Panchasar Government Primary school. In the later years the school authority constructed a new building on top of it.

(2) Ground Bed: It was made of 2 pieces of 40 ft long, 10" diameter scrap iron pipe, which was placed at a depth of 10 ft 6". This is the anode part, which is supposed to be corroded at a certain rate. To estimate the state of the anode, calculations were made assuming a time span of 13 years, metal consumption rate of 9.1 kg/A.y, maximum current consumption 11A, and minimum current consumption 8A. Calculations show that the total amount of consumed metal is about 1,123.85 kg, which is greater than the weight of the installed iron pipes. This indicates that the ground bed is entirely eaten up, therefore must be rehabilitated immediately.

(3) Pipeline data: Table 2 shows the pipeline lengths and diameters as laid in the study area in 1992 and 2005. Data for ¾" pipes in 1992 was not available. The projected length of pipes of various diameters up to the year 2025 is also included in this table. From ¾" to 3" diameter pipe material is locally manufactured, whereas pipes of 4" and above diameter are procured through international tender. The quality is specified as per the API 5L grade B.

Table 2: Pipeline Data

Pipe Size (inch)	Length (ft) 1992	surface area (ft^2)	Length (ft) 2005	Length (ft) 2025
¾	-	-	99,860	150,790
1	30,100	8270	39,882	59,823
2	41,275	21,600	54,689	82,033
3	27,880	2,886	36,941	55,441
6	22,000	34,450	22,000	33,000
8	32,800	68,661	32,800	49,200
12	3,000	9,420	3,000	4,500

(4) Distribution Network: It consists of mostly ¾" to 3" pipes. There is a 12 km long section from Pachabati Moor, Narayanganj, to the Munshiganj DRS. This section is composed of an 11km X 8" section, and a 1km X 12" river crossing. In addition, there are two 6" pipeline from the DRS as the distribution main.

(5) Soil condition: It is composed of a variety of soils such as clay, ash soil, sandy soil and reddish soil. Soil analysis showed following results [2]:

pH = 7.4 – 8.1,
SO_4 = 32 – 41 ppm,

Two types of bacteria were also found- i) Thiobacillus ferro-oxidants, and ii) Thiobacillus thio-oxidants.

(6) Soil Resistivity data: This was collected at about 63 different points along the distribution network. The values ranged from 800 to 12,800 ohm-cm. The calculated logarithmic mean value is 2455 ohm-cm.

(7) PSP data: There are 61 test points in the distribution network for this measurement. It is supposed to be carried out every 3 months; however, in reality such practice is not in place. The data were collected for 10 discrete months of 10 consecutive years (from 1994 to 2003). It was observed that at a given Drainage Test Point (DTP), the PSP is deceasing with time. This is a clear indication that the TR is not able to keep up with the requirement of the increasing network.

(8) Current requirement: For accurate calculation the correct pipeline data is required. Unfortunately the data of ¾" diameter was not available. It was assumed that 20ft of ¾" pipe per customer, and was multiplied by the number of customers as of September 2005. Calculations thus made indicated that for the entire network the current requirement was about 59.31 Ampere. A future projection was also made by the author, assuming 50% growth of pipeline for every 20 year. It shows that current requirement will be 84.85 Amperes in the year 2025.

5. IMPROVED SYSTEM DESIGN

The previous discussions indicate that the existing system of CP is not adequate to protect the gas pipeline network under study. Given the conditions described above, there are three possible solutions to implement a more effective CP system:

(1) A 3-TR based impressed current system. For this configuration, one TR for the 12 km section including the river crossing will be needed. A second one will be

needed for the Munshiganj area, and another one for the Mirkadim part of the network

(2) Sacrificial anode system for the entire region: For this configuration, the entire network will be protected by a number of sacrificial anodes only. No TR device will be necessary.

(3) Composite system: For this configuration, sacrificial anode system will be installed for Munshiganj and Mirkadim areas. A single drain point impressed current system for the 12 km section including the river crossing.

Option 2 is not practical because Mg anodes are not suitable for the river crossing section. Besides Mg anodes are readily used up when resistivity is too low. Length of the total section is 12 km, with 1 km of river crossing. This part consists of 8" to 12" diameter pipes, which results in a large surface area to be protected. Moreover, the current requirement may increase due to damage to the casing, intrusion of water, and corrosion of casing and pipe in the river crossing section. Impressed current system is more suitable for this section. Therefore options only 1 and 3 are investigated. Design specifications and costs for these options are presented next.

5.1. Option A: 3-TR based CP

Results from calculations for this system are summarized in table 3. The TR is selected to the nearest of calculated current and voltage requirements. The anodes are 60" X 3" Silicon-Iron rods, which are to be placed in augured holes. The holes will be backfilled with hard coke powder. The number, size and spacing of the holes, and hard coke requirement are also shown in the table. .

Table 3: Design Specification for 3-TR System

	TR-1	TR-2	TR-3
Current requirement (calculated)	35.65A	18.96A	21.81A
Selected TR	50A 50V	20A 24V	25A 20V
Ground Bed Specification			
Number	10	10	10
Spacing (ft)	10	10	15
Hole Size	10 ft X 8"	10 ft X 8"	10 ft X 8"
Anode size	60" X 3"	60" X 3"	60" X 3"
Anode wt (kg)	450	450	450
Hard Coke (kg)	690	690	690

Total cost of the system including material, installation and operation is about Taka 54,33,500 according to the prevailing rates in 2005..

5.2. Option C: Composite CP

This design will have 3 components

(1) A single drain point impressed current system for the 12 km section including the river crossing. This part will have one TR and the ground bed. The specification of the TR and the ground bed is already mentioned in the previous section (Table 3: TR-1).

(2) Rest of the network, mainly in two parts (Munshiganj Town and Mirkadim) will be protected by sacrificial anodes, based on Mg anode. The number and size of the Mg anodes are as shown in Table 4.

Table 4: Number of Mg Anodes

Area	Number of Anodes (17 lbs each)
Munshiganj	329
Mirkadim	338

Total cost of the system including material, installation and operation is about Taka 53,21,260.

6. COST BENEFIT ANALYSIS

Since the work was carried out in 2005, the cost figures are those prevailing at that time. Following factors were considered for the cost benefit analysis:

(1) Annual value output: It is the total revenue earned per year. It includes customer forecasting for next 20 years (starting from 2005), gas consumption by each type of customers, wellhead price of gas, excise duty, and end user price for each year.

(2) Operating cost: It is calculated in two ways:

(i) Assuming that the proposed investment would stop further deterioration of the CP system, and the future operating cost would follow the present trend.

(ii) Assuming that with no further investment, the future operating cost would increase progressively for leakage repairing and pipeline replacement. The value of unaccounted for gas (UFG) is also included here.

Items considered for operating cost include Payment of long time loans, Taxes and duties, Manpower, Cost of leakage repairing (which includes costs of fixtures, clamps etc), Cost of pipe and pipe laying, etc.

Financial analysis performed based on the above factors and appropriate cost figures are summarized in table 5.

Table 5: Results of Financial Analysis

	No Investment	Improved CP
IRR (%)	23.25	23.35
NPV (Lakh Taka)	27,330.7	29,414

It shows that the proposed improved design is financially viable. Although the financial parameters are not very different between the two options, i.e., implementing the improved system versus leaving the system as it is, the improved system is more justifiable because i) leaving the system as is will result in more operational problems such as supply interruptions, added complications of repairing and rehabilitating the damaged portions, etc, ii) increasing loss of gas through leakage, iii) negative environmental impact from leaking gas, and iv) accident and fire hazards from leaking gas. A well protected pipeline network, on the other hand, should minimize these worries for a long time.

7. CONCLUSIONS AND RECOMMENDATIONS

The existing impressed current system of corrosion protection for the natural gas distribution network at Munshiganj is not functioning adequately. The TR is undersized and cannot keep up with the growing load. The ground bed is almost eaten up. Given the soil properties, the impressed current method is not the most suitable technique for this area. A carefully designed new system is worth the investment against the increased operating costs for progressively worn out pipelines and the loss of gas through leakage.

A composite system consisting of both impressed current and sacrificial anode methods is recommended for this area.

8. REFERENCES

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9. NOMENCLATURE

Symbol	**Meaning**
mA/ft^2	milli ampere per square foot
kg/A.y	kilogram per ampere per year
mpy	mils per year (40 mils = 1 mm)

10. MAILING ADDRESS

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