Pergamon

Engineering Failure Analysis, Vol. 5, No. 2, pp. 99–104, 1998

Printed in Great Britain
1350–6307/98 $19.00 + 0.00

PII: S1350–6307(98)00006–5

USING THE DIRECT CURRENT VOLTAGE GRADIENT TECHNOLOGY AS A QUALITY CONTROL TOOL DURING CONSTRUCTION OF NEW PIPELINES

ZWENI MASILELA* and JOE PEREIRA

Advance Engineering and Testing Services, CSIR, Private Bag X28, Auckland Park 2006, Republic of South Africa

(*Received* 3 *February* 1998)

Abstract—External coatings on buried pipelines offer the first line of defence against corrosion with cathodic protection systems in place to protect bare metal at coating defects. Holiday detection, before pipelaying, does not guarantee pipelines are without coating defects after pipelaying. The coating is more than likely to be damaged during pipe construction. The DC voltage gradient (DCVG) method, to locate coating defects on underground pipelines, was initially used for rehabilitation of older pipelines. This technique is now increasingly gaining popularity as a good quality control tool when used on newly laid pipelines to detect coating damage, most of which could be attributed to construction work. On a recently built 50 km long gas pipeline coated with fusion bonded epoxy (FBE), it was proved that more than 80% of defects located after pipelaying were due to mechanical damage during construction. The factory related defects seen were in the form of pinholes or pimples most of which could not be seen by the naked eye and relied on holiday detection for identification.

Keywords: Cathodic protection, coating failures, corrosion monitoring, corrosion protection, surface coatings.

1. INTRODUCTION

The direct current voltage gradient (DCVG) method of delineating coating defects [1–3] is primarily used for rehabilitation of older underground pipelines. The technique is, however, rapidly gaining popularity worldwide as a good quality control tool for newly laid pipelines. It is well known that coatings are used as a primary means of external corrosion control on buried pipelines with cathodic protection (CP) systems in place for protecting minor defects on coatings. Only a certain number of coatings defects can be tolerated on new pipelines. Large defects on coatings can also pose problems for the CP system.

Whilst the original coating is usually applied and tested to high quality standards, this will in no way guarantee that newly laid pipelines will be free of coating defects. Damage to pipeline coatings may occur during pipe laying and backfilling. Field joint welding does take place and as a result of this, weld joints are often coated using manual systems which are sensitive to the standard of workmanship. In worst case scenarios, weld joints could be found to have been left uncoated. The DCVG technique allows the determination of all coating defects that occurred during construction of new pipelines. Defects can then be prioritised and decisions taken for excavations in order to carry out repairs. Preliminary survey results on different coating systems for new pipelines to date indicate that refurbishment criteria are coating specific.

The Advanced Engineering and Testing Services Programme of the CSIR recently completed a DCVG survey of a 50 km long new twin gas pipeline built from Witbank to Middelburg in the Mpumalanga province, South Africa. The pipeline is 200 mm in diameter and is coated in fusion bonded epoxy (FBE). The results of this survey are reported in this paper.

2. THE DCVG TECHNIQUE

When cathodic protection current flows through the soil to a coating defect on a pipeline, a voltage gradient is established in the ground due to the resistive nature of the soil. From Ohm's

* Author to whom correspondence should be addressed.

law, this voltage gradient will be higher in high resistivity soils. The DCVG techniques utilises a sensitive millivoltmeter to measure the voltage difference between two copper/copper sulphate half cells (probes) placed in the soil voltage gradient region. The voltage gradient is normally larger and more concentrated the greater the current flowing and the closer observations are made to a defect. When the half cells are spaced 0.5 m or so apart in this voltage gradient, one half cell will adopt a more positive potential than the other, allowing the direction of current flow to be established. To ease interpretation and to separate what is being monitored from the other DC sources, the DC signal is switched ON and OFF using an interrupter connected to a transformer rectifier unit. The signal is asymmetrically switched with a cycle of 2/3 s OFF and 1/3 s ON.

To survey a pipeline, the operator walks directly above or just to the side of the pipe, placing the probe tips on the ground one in front of the other. As the operator gets closer to a defect, the needle of the millivoltmeter will deflect in a direction towards the defect. The needle deflection will get stronger the nearer the defect. When the defect is passed, the needle will deflect in the opposite direction. By retracing steps, the meter can be nulled, i.e. no deflection of the needle in any direction. In this position the defect should be on a line mid-way between the probe tips. By turning at right angles to the pipe and repeating the same procedure, a point is found where the two lines cross. This point should be directly above the coating defect. It is thus not necessary to be directly over the pipeline since the technique allows the operator to always be located above the pipeline.

The DCVG technique at present does not give the exact physical size of a coating defect under stray current conditions. The technique does, however, enable comparison of located defects with other defects found in the same area. The % IR is used to reflect size/importance of a defect. It is important to realise that when excavating one does not look for direct correlation between % IR and physical defect size. For example if one takes two defects with the same % IR, one near a river bed (low resistivity area) and one in a high resistivity dry area, it is quite conceivable that there will be a difference in actual physical size. The % IR criteria is influenced by many parameters such as soil resistivity, depth of pipe, pH, gases in the soil, soil compaction, consumption of cathodic protection current, physical size and shape.

3. DETERMINING WHICH DEFECTS REQUIRE REPAIR

In order to ensure effective maintenance of pipelines, only those defects that really need it should be repaired.

This is done in such a manner as to bring back into balance the relationship between the size, number and distribution of coating faults, and the effectiveness of CP at all individual coating faults. The DCVG technique allows this to be achieved.

To prioritize defects for repair purposes, the following are considered important:

- Defect location—defects near houses, under city streets, railway lines etc. are of high priority when it comes to choosing those that should be repaired.
- Defect size/importance (% IR assessment)—DCVG surveys carried out on older pipelines have yielded the following guidelines for prioritizing defects during repairs.

% IR	Visual size	Action
0–15	Small	No repair
16–35	Medium	Consider repair
36–70	Medium/large	Consider early repair
71–100	Large	Consider immediate repair

  The situation is significantly different on new pipelines. The majority of defects have % IR less than 5. The approach to repair defects based on the % IR assessment can be different for different coatings but generally defects on new pipelines with % IR greater than 5 have been recommended for repairs.
- Corrosion status of defects—the most dangerous defects are those with anodic/anodic behaviour. Once found, these defects must be repaired and investigations carried out as to the occurrence of such status. Since DCVG readings are instantaneous, REVG (remote earth voltage gradient)

Table 1. DCVG survey results

Survey Distance	1 11.2 km	2 13.8 km	3 16.3 km	4 8.6 km	Total 49.9 km
Total defects	524	807	297	347	1975
Defect/km (both pipes)	46	58	18	40	39
Defect/km (each pipe)	23	29	9	20	19
Defects for repair	91	168	88	75	422

recordings are carried out at these defects to confirm anodic/anodic behaviour. These defects are used as reference points in adjusting the CP system to achieve protection at all other anodic/anodic defects.

- Stray current activity—defects in areas of high stray current activity should be carefully studied. Identification of those defects discharging stray currents is important and can be easily determined using the DCVG technique.

4. THE DCVG SURVEY

Afrox in South Africa have recently completed construction of a new twin gas pipeline from Witbank to Middelburg. The pipeline is 200 mm in diameter and is coated with FBE. The DCVG survey of this pipeline was done in four stages proceeding from Middelburg to Witbank. A total of 1975 defects (on both pipes) were found in a distance of 49.9 km.

As a general repair criteria, one or both of the following conditions applied:

(1) All defects with a % IR > 5 were repaired.
(2) All defects showing anodic/anodic behaviour were repaired.

Table 1 summarises the DCVG survey results for all four sections.

5. INSPECTION OF SELECTED DEFECTS

A total of 51 defect locations in the first 25 km were opened for inspection. Most of these defects had % IR > 5, but a few with smaller % IR were also selected. This exercise was done in order to agree on the selected repair criteria and also to define what is termed construction or factory related defects. On the basis of this, all defects repaired were classified accordingly and the repair costs carried by the two parties concerned, i.e. installer or supplier.

During inspection of these 51 selected defects, it was found that more than 80% of the defects were caused by mechanical damage during construction. The majority of the factory defects were very small and manifested themselves in the form of pimples or pinholes as is often the case with FBE coatings. Photographs of selected defects are shown in Figs 1–4.

6. CONCLUSION

The direct current voltage gradient (DCVG) technique is to date, beyond any reasonable doubt, the most accurate method of locating coating defects on underground pipelines. This technique is increasingly used on new pipelines as a good quality control tool.

The benefits of using the DCVG technique on new pipelines is clearly evident as more than 80% of coating defects were a direct result of mechanical damage during construction. On such evidence, the pipeline owner can then insist that the coating damage be repaired at the installer's cost. In the past, pipeline owners would have no idea as to the extent of coating damage to their buried pipe. However, with the DCVG technology, it is now possible to ensure that the external coating is of

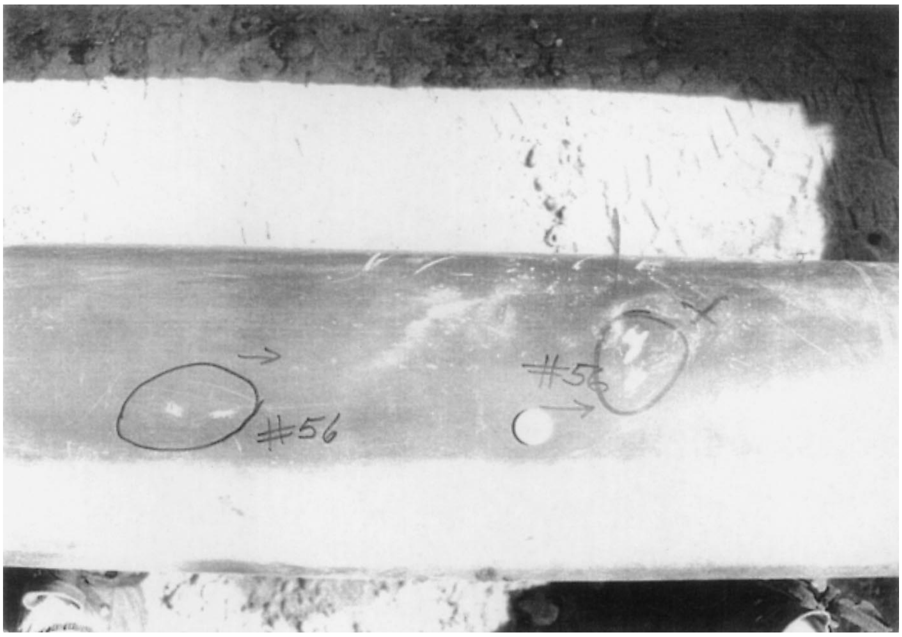

Fig. 1. Mechanical damage defects seen on one of the pipes.

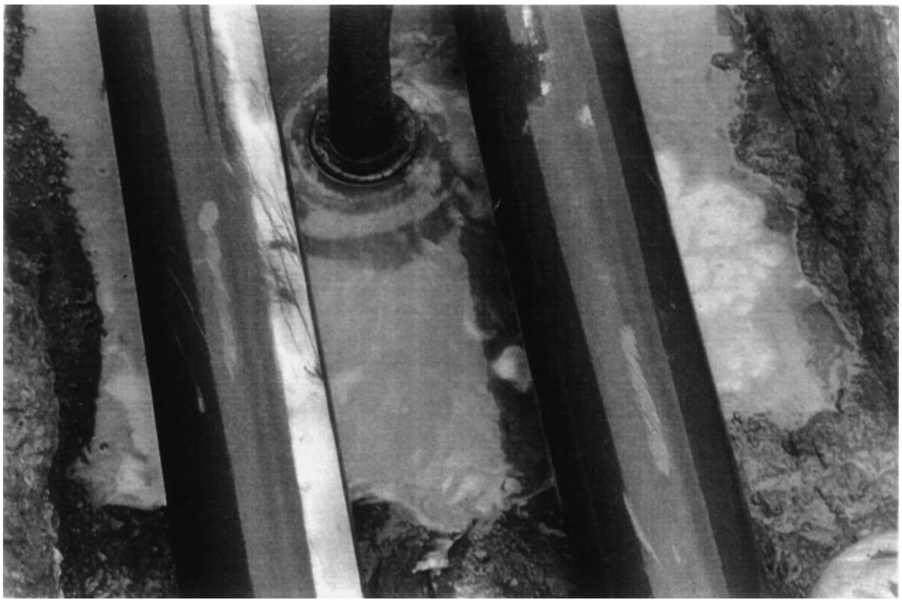

Fig. 2. Mechanical damage defects on both pipes

Fig. 3. A pimple defect, marked from factory in white but never repaired before pipelaying.

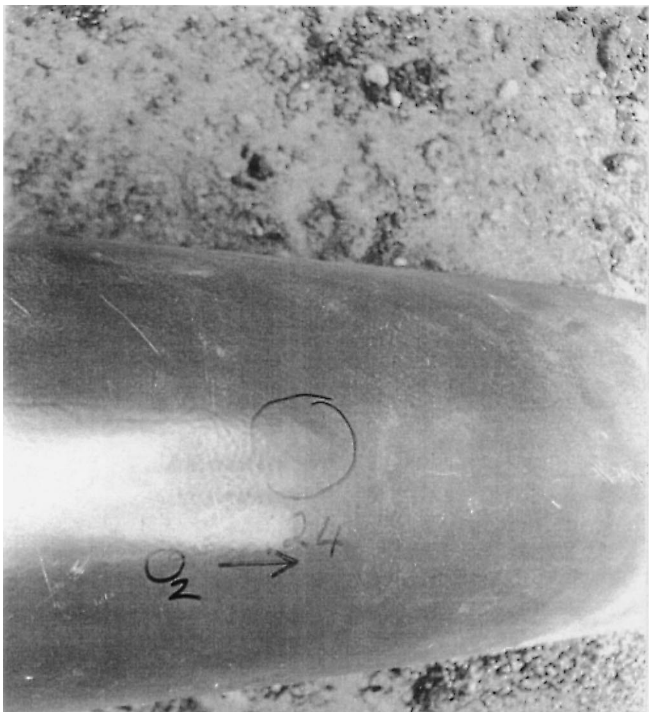

Fig. 4. Pinhole defect confirmed using a holiday detector.

high quality. The use of the DCVG technique has also resulted in improved quality control procedures followed during construction.

REFERENCES

1. Masilela, Z. and Sherratt, M., Paper presented at the Pipeline Interest Group (PIG) Seminar, Eskom Megawatt Park, Sandton, South Africa, August 1996.
2. Slatter, J. D., Davidson, M. C., Grapiglia, J. P. and Wong, W. T., *Journal of Materials Performance*, 1993.
3. Nabi-Zaden, H., Ten Years Experience with FBE and Mitigation of SCC in W. Australia. State Energy Commission of W.A.