

Technical Briefing Note

Discussing the Corrosion Control Issues

Associated with ISS Fence Projects

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1. INTRODUCTION

Following the construction of high security electrified fencing at a number of above ground gas installations, it has been discovered that such installations can affect the cathodic protection (CP) applied to buried pipe and plant within the installations, but also on the pipelines that enter and leave the sites.

The term 'above ground installations' may be confusing because such installations generally include significant lengths of buried pipework and other complications which includes connection to the site electrical earth and may include connection to other metallic structures such as steel platform supports, lighting columns and inadvertent or deliberate connection to re-bar in concrete structures. In these circumstances the installation may be defined as a complex structure.

Additional equipment is also installed as part of the fence system design. This includes motorised operation of the main gates, camera towers, lighting columns, keypad / security card readers and satellite communication dishes. This additional infrastructure is likely to increase the current drain on the CP system.

To promote improved understanding of the technical challenges created by these new installations, this technical note expands upon and discusses these effects in more detail.

As there are very few techniques currently available for direct (i.e., intelligent pigging) condition monitoring of buried above ground installation (AGI) pipework, (noting that indirect techniques, such as long-range ultrasonics are available). Survey techniques, which include direct current voltage gradient (DCVG), and current attenuation, are used to identify coating defects and cathode faults¹ in pipeline networks. However, due to connection with other buried metallic structures, such techniques may be unreliable for survey of congested areas of pipelines plant and complex structures on an AGI.

Following construction of ISS security fencing, it is essential to ensure that the CP systems remain compliant with adopted protection criteria. This will require a "fingerprint" survey of the cathodic protection system before any work is carried out and a repeat survey after ISS fence construction with the fence electrical security system operational and non-operational.

¹ A cathode fault is a situation whereby the surface area of pipeline and plant intended to be included within the cathodic protection system becomes increased by inadvertent connection to other metallic structures. This may occur via direct contact with another structure, earth system or due to failure of an insulating joint or flange where the remote side becomes included in the CP system.

2. BACKGROUND

Buried steel pipe and plant within installations is protected against corrosion by a combination of factory and field applied coatings supported by CP. These installations comprise numerous lengths of buried pipe separated by sections of above ground pipework and plant such as filters, metering equipment, pressure reduction equipment, valves etc.

In terms of corrosion control, AGI's are more complex than pipelines' and generally require a higher CP current density for effective cathodic protection. This is due to AGI's having more field applied coatings due to cut pipe lengths, fabrications, the inclusion of electrical earthing, and possibly deliberate or inadvertent contact with re-bar in concrete structures. Due to the requirement to limit the CP current drain to manageable levels, original palisade fences were also earthed separately from the site earth.

It should be noted that earthing practices in the UK gas industry for AGI's are different to those in the petrochemical industry. In the UK gas industry, the external AGI fence may have its own earthing system independent of the site earth. This ensures that any ground potential rises in the event of an electrical fault are not transferred to the fence but contained within the AGI and any lightning strike on the fence is not transferred to the AGI pipework. In the petrochemical the external fences and AGI earthing are typically common, so they are not isolated.

As cathodic protection system designs for buried pipework within AGI's evolved, two concepts were developed, the first treating the buried pipework as a single entity for the purpose of applying CP. This was possible because the installations were of welded steel construction, thus electrically continuous throughout, including the below and above ground pipework. This design concept also avoids the need for numerous insulating joints around the sites but the negative affect of this is that the CP system includes the site electrical earthing. As this could significantly increase the CP current demand, making it difficult to deliver an effective CP system, the problem is reduced by the installation of a 1:1 isolating transformer on the site incoming electrical supply, to separate site earth from the electrical supply earthing.

The second concept utilised on UK gas AGI's has IJ's fitted at risers at the transition of the above and below ground pipework sections, which has the advantage of separating the earthed above ground pipework from the CP protected below ground pipework, reducing the CP current requirement to a more manageable level. Insulating joints installed at AGI's are generally located within the perimeter of the installation and may be above or below ground. In some cases the insulating joints will be fitted outside the AGI. It is important to be aware of the IJ location and give due consideration to possible interference scenarios and the required interaction testing.

The earthing systems employed within AGIs should be either TN-S or TT systems to comply with the guidance given in BS EN 60079, BS 7671 and EL13. This is to limit the spark risk from AC current flowing in pipework when pipes or earth connections are disconnected. The use of TT or TN-S earthing also limits the extent of the earthing system and thus the current drain from any CP system. The use of TN-S or TT earthing systems applies to both the UK gas industry and petrochemical industry.

In this way the CP current demand of entire sites becomes manageable and realistic to deliver an effective CP system. However, the practical consequences of this is that sacrificial anode CP systems are unlikely to provide sufficient current to be effective. Therefore, most of these installations will have dedicated impressed current CP systems. Occasionally, cathodic protection may be provided by a hybrid system which utilises the CP system on a pipeline passing through the site.

2.1 Impressed CP Systems for Gas Installations

Ideally, impressed current CP groundbeds should be located at remote electrical earth which could be 100m from the pipework. However, it is rarely possible to achieve such a separation distance within AGI's. To maximise the available separation to the AGI pipework, groundbeds are often located near site fencing. Where connecting cables cannot be located within site ducting, they are buried, often at shallow cover.

3. CONSIDERATIONS OF CONSTRUCTION & SUPPORTING INFRASTRUCTURE

Evidence has shown that the effect on cathodic protection systems is not fully understood by fencing designers and construction managers. The following should all be considered as part of the design and installation of fencing.

3.1 Excavations

In some cases, excavation of the trenches for the concrete foundation beam or for instrumentation and electrical power cables have often damaged CP groundbeds and cables. Such damage could result in partial or complete failure of the CP system which, in some cases, would not be identified until the next routine CP monitoring check.

3.2 Electrical Fence Earthing

It is recommended that the new fences associated with the ISS system are earthed separately from the site earth as cross connection is likely to result in a massive drain of CP current to the rebar in the concrete ring beam foundation for the fence. This may result in total loss of CP for the site but could also result in stray current interference on any pipelines or buried pipework or plant in the vicinity of the fence. Where this is not possible due to electrical safety requirements such as touch potentials and separation distances, then special design consideration of the earthing and CP systems should be undertaken.

3.3 Motorised Site Gates

Post fence construction monitoring checks sometimes indicate that the fence earth is not separated from site earth. Experience has indicated that the electric motor for the site gates is not always suitably isolated and may be the cause of electrical cross connection. Another possible cause is the failure to effectively isolate by suitable glanding at the security card reader or bonding between CCTV cameras or lighting columns fixed to the fence.

3.4 Supporting ISS Fence Infrastructure

Supporting infrastructure includes motorised gates, camera towers, additional lighting stands, security card readers and satellite communication dishes. There is concern that including additional equipment and earthing within the CP system may increase the current demand such that effective CP becomes difficult. Experience has indicated that camera towers and lighting stands become included within the CP system, probably via their electric earthing arrangements. In many cases the CP current drain to these structures is limited and does not substantially affect the CP systems, although some minor adjustment of the CP current may be required to maintain the required protection level. Where the resultant level of CP is within acceptable upper and lower limits, it is considered that this situation may be acceptable as corrosion protection is applied to the buried parts of the installations and any detrimental interference effects from the CP system can be avoided.

However, in some cases the current drainage to supporting infrastructure may be unacceptable. Where this arises, adjustment of the current required to maintain protection can result in over-polarisation at other locations around the site. Hybrid systems which utilise pipeline CP systems as the current source may not be able to support such increase in CP current demand, also due to unacceptable over-polarisation, possibly for significant lengths along the pipeline.

It is recommended in some circumstances that glass reinforced plastic (GRP) support columns are utilised to reduce touch potential issues. Consideration can also be given to other contact mitigation barriers, such as Perspex, or other high dielectric strength material, which can be used to form barriers of baffles between two touch potential sources.

4. CLOSE INTERVAL POTENTIAL SURVEY DATA

4.1 Original Palisade Fence Crossings

Close interval potential surveys (CIPS) over pipelines' that enter or leave installations often indicate a small positive excursion in the pipe-to-soil potential coinciding with the crossing of original design palisade site fences. It is difficult to carry out effective coating surveys or current attenuation mapping in these areas due to proximity to complex plant arrangements and electrical earthing. Attempts to do this have resulted in spurious results, where excavations at the fence crossing point to investigate the CIPS features have revealed perfectly sound coating.

Speculation as to the cause of these potential excursions included the possibility that the fences were connected to the site electrical earth and that feature were due to an interference effect. Further investigation showed that the site fences were earthed independently from the site electrical earth, and this was not the cause of the apparent features.

A possible explanation is that as both pipelines and palisade fence foundations exhibit low electrical resistance to remote earth, the phenomenon of small positive potential excursions is due to electrolytic connection between the structures causing a small CP current drain resulting in the observed positive pipe-to-soil potential excursion. There are other views that it could be due to CP 'shielding' or interference effects.

4.2 High Security Electrical Fence Crossings

The phenomenon described in section 4.1 has also been noted where pipelines' cross high security electrical fence, where it is noted that the positive pipe-to-soil potential excursions are generally of greater magnitude than with the original palisade fence crossings.

5. CORROSION CONTROL IMPLICATIONS

5.1 Operation of High Security Electrical Fence System

Electrified fence energisation is achieved by a pulsed direct current (DC) system. When operating in high voltage mode, positive pipe-to-soil potential excursions have been observed on some sites during site close interval potential surveys and routine measurements at fixed CP test posts. There have been reports of potential shifts of up to +200mV, (wrt to Cu/CuSO₄ reference electrode.)). It is essential to carry out pipe-to-soil potential measurements with the fence in operational and non-operational mode. Risk assessments will need to be carried out and method statements developed to prevent personnel from contacting a live fence.

This effect can be attributable to stray current from the DC fence electrification, (but measurement errors attributed to high voltage pulses should also be considered), which is likely to be exacerbated where the independent fence earthing, (i.e. earth rods), are located close to buried pipework. High risk locations are typically where pipelines enter or leave the sites.

6. CONCLUSIONS

1. Construction of high security electrical fence foundations and cable routing can damage cathodic protection groundbeds and connecting cables resulting in failure of CP systems which may take a significant amount of time to identify and remediate. All cases of CP downtime are cumulative and increase the corrosion risk.
2. To ensure that site CP systems remain effective, it is preferred, where possible, that the design intent for new electric security fencing to be earthed separately from the site electric earth is delivered. Electrical cross connection has been identified at the following locations.
 - Lack of suitable isolation at the electric motor for the site gates.
 - Lack of suitable isolation at security card readers.
 - Incorrectly terminated or glanded steel wire armoured cables connected to security fences.
3. New camera towers, lighting stands and satellite communication dishes installed as part of the enhanced security project, often become connected to the CP system. This generally arises due to connection with the site electrical earth. The consequential impact on the CP current requirement, due to additional current drainage, will need to be assessed in each case. Where the additional CP current is excessive and results in over-polarisation of pipework in some areas, further work will be necessary to manage the current drain at acceptable levels. It is considered that, wherever possible, inclusion of these secondary metallic non-gas carrying structures in the CP system is beneficial as it will extend their service life.
4. As a consequence of pipelines and fence foundations both having a low resistance to remote electrical earth, there may be electrolytic coupling between pipeline and fence at crossing points. This can cause a localised drain of CP current, characterised by a positive pipe-to-soil potential excursion on the pipeline. As a result of such potential shifts, the pipeline may be at risk of corrosion at any open coating features in the vicinity. This phenomenon has been observed at original palisade fences but, where it occurs, seems to be of greater magnitude at high security electrical fences. This may be due to the dimensions of and materials of construction of the concrete foundations for the latter. Where, despite the effect of the electrolytic coupling, the pipe-to-soil protective potentials remain compliant, no further action is deemed necessary. However, where acceptable levels of protection are compromised, further work will be necessary to ensure that the system is CP compliant.
5. Stray current from operation of the electrified fences in high voltage mode can cause positive potential excursions to pipe-to-soil potentials, where shifts of up to +200 mV (wrt Cu/CuSO₄ reference electrode) have been observed. Such potential shifts may cause the CP system to be ineffective and increase the corrosion risk.
6. Complex installations, discussed in the introduction, present challenges with the interpretation of CP data. Other metallic structures connected to plant and pipework can result in balancing potentials where measurements may give pessimistic results. Other complications arise where surface potential measurements are made closer to re-bar in concrete structures than the pipeline under test. Occasionally, buried structures, typically palisade fences, having a zinc or aluminium, (anodic), coating may contribute to the pipe-to soil potential measurement. This is considered to be a very rare event where the current available from such sources is unlikely to have any significant effect on AGI CP systems with a relatively large CP current demand. Generally palisade fences will not have any influence because that are earthed independently.

7. Data interpretation may be improved with the use of polarisation coupons, reference electrodes and electrical resistance probes

7. RECOMMENDATIONS

1. The planning stage of high security fencing projects should include a pre-construction review of all CP records (CP groundbeds, CP protection levels and cable locations) and where required conduct a 'fingerprint survey'. CP equipment in the vicinity of proposed construction work should be traced out to confirm its location. Where it is confirmed to be directly affected by the proposed work, arrangements should be made to re-design the CP system. Management of change requirements should be implemented which will include Approval and Appraisal of the re-designed system. To ensure continuity of the applied CP, the modified system should be installed and commissioned before construction of the new fence begins.
2. The status of the CP systems on incoming, outgoing pipelines and site pipework before new high security fences are installed should be confirmed by a "fingerprint" survey. The survey should consist of a polarised close interval potential survey on all pipelines' entering or leaving the site. The surveys should be conducted with the pipelines' CP system being synchronously switched and extend from the AGI insulating joint to 50m beyond the site fence line.

In exceptional circumstances, where pipeline insulating joints are located outside of the site fence, it will be necessary to conduct the work in two phases, where in phase 1 the AGI CP system is switched to permit survey to the insulating joint and phase 2 with the pipeline CP system switching, such that the survey can be conducted from the AGI fence to the location of the insulating joint. It is recommended that CP data is collected from above ground pipework in the AGI to a minimum of 50m beyond the fence line. (Where ISS fences are installed, it may be difficult to use a test facility within the AGI for pipeline survey outside the fence. If a groundbed is in close proximity to the 50 mtr section, it is recommended that this length be extended by up to a further 50 mtrs. It may be necessary for special arrangements to facilitate this or to install a suitable CP test facility outside the AGI fence.)

3. The "fingerprint" survey should include a CP "ON" and "OFF" survey at test points within the AGI, including reference electrode pots. The survey should include polarisation coupon data where applicable. A sample of fixed test posts, generally ones closest to the existing fence line, should be selected for logging of the pipe-to-soil potential for 24 hours.
4. Following construction of the high security fencing, the actions described in sections 6.1 to 6.3 above should be repeated. It will then be possible to identify any significant changes which are attributable to the new fencing system and to allocate responsibility for investigation and remediation as appropriate. The post fence construction survey should also check for cathodic interference on the earth rods associated with the new fence.
5. All surveys will be subject to approved method statements and risk assessment and shall take account of any special safety requirements relating to the operation of the electrical systems associated with the high security fencing. The risk of electric shock should be considered, and personal protection and ways of working should be included in the method statements and risk assessments. All details of survey works should be fully documented, and CP drawing updated to as-built conditions.