UKOPA

United Kingdom Onshore Pipeline Operators' Association

Technical Note

Issues associated with overhead pipeline crossings of electrified and non-electrified railway lines

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GUIDANCE ISSUED BY UKOPA:

The guidance in this document represents what is considered by UKOPA to represent current UK pipeline industry good practice within the defined scope of the document. All requirements should be considered guidance and should not be considered obligatory against the judgement of the Pipeline Owner/Operator. Where new and better techniques are developed and proved, they should be adopted without waiting for modifications to the guidance in this document.

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Contents

EXECUTIVE SUMMARY

This document is intended to provide guidance to pipeline and railway traction system operators on the electrical and corrosion protection issues that may occur on overhead pipeline crossings of railway lines. It specifically applies to electrified railway lines, but some of the information contained in this document is also relevant to non-electrified railway line crossings.

This technical note does not specifically address the AC corrosion risks on pipelines as these are covered in BS EN ISO 18086 [1].and UKOPA/GPG/027 [2]., whilst the DC stray current interference risks on pipelines are covered by BS EN ISO 21857 [3], and UKOPA/GPG/031 [4],

This document provides information for pipeline and railway traction system operators on applicable standards and best practice. It gives guidance on how to minimise the touch potential safety risks on overhead pipeline crossings of electrified and non-electrified traction systems and identifies issues that railway system operators need to be aware of.

The safety and electrical interference risks may occur because of inductive, capacitive, and resistive coupling between pipelines and railway traction systems and the presence of different metallic structures installed in close proximity to railway lines. In the case of overhead electrified power cables the risks of pantographs failing, or electrical cables being detached from the pylons will also need to be addressed by the rail system operator.

Details of electrical hazards on pipelines from other sources e.g. electrostatic risks, lightning, electrically operated equipment, and high frequency mobile communication systems are given in UKOPA/TBN/005 [5].

The document covers the management of the electrical hazards on existing and new overhead pipeline crossings of rail traction systems. It identifies various situations that could lead to risk, which operational personnel need to be aware of to ensure that appropriate mitigation measures are implemented. Touch potential risks and appropriate mitigation methods should be agreed with the rail, system operator.

Electrical interference on pipelines can result in safety and/or incendive ignition risks. It can affect operational personnel, contractors working on pipelines, the public and railway traction system personnel, who may come into contact with a pipeline or its metallic supporting structure.

This document aims to identify the specific risks associated with overhead pipeline crossings of railway lines and advise appropriate mitigation methods where applicable.

It provides guidance on the requirements that the rail system operator has in relation to mitigation of electrical safety hazards.

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1. INTRODUCTION

1.1 Background

This document has been prepared to provide pipeline and railway traction system operators with guidance on the requirements for the management of the inspection, corrosion protection and electrical safety hazards on above ground pipelines, where they cross railway infrastructure.

Guidance on the possible impact of rail electrification systems on pipeline CP systems and the AC corrosion risks to the buried sections of pipelines, where they are routed parallel to, or cross railway lines is also provided.

The measures to be adopted in relation to evaluation of AC corrosion risk on buried pipelines are detailed in BS EN ISO 18086 [1] and additional guidance is given in UKOPA/GPG/027 [2].

In relation to the DC stray current interference risks on pipelines guidance is given in UKOPA/GPG/031 [4] and BS EN ISO 21857 [3]. It should be noted that BS EN ISO 21857 has now replaced BS EN 50162 [6] in relation to pipelines. However, BS EN 50162 is still current and is in the process of being revised. It is intended to be kept as a standard specifically for railway traction system stray current interference issues.

It should be noted that the installation of Major Accident Hazard Pipelines (MAHP)s, petroleum product and indeed low and medium pressure gas pipelines over railway lines would generally not be permitted today. Thus, new pipeline designs should, wherever possible avoid the use of overhead pipeline crossings of railway infrastructure.

However, overhead pipeline crossings of rail traction systems have been permitted in the past and there are a number of locations in the UK, where overhead crossings exist.

The safety aspects of AC interference from AC power lines and traction systems on pipelines are detailed in BS EN 50443 [7] and are supplemented by the guidance given in UKOPA/TBN/005 [5]. It should be noted that the safety guidance in UKOPA/TBN/005 is different to that in BS EN 50443, where lower touch potential limits are specified than in BS EN 50443.

Other international standards and publications e.g., AS/NZS 4853:2012 [8]. CAN/CSA-C22.3 No. 6-M91 [9] and NACE SP0177 [10] also provide guidance on electrical hazards on pipeline systems.

This document is intended to provide information on the requirements to minimize and manage the risk of electrical hazards on above ground metallic pipelines within the vicinity of railway infrastructure and the corrosion protection requirements.

It is aimed at providing guidance to developers, operators, and promoters of new rail electrification systems on the issues that pipeline operators may face associated with the installation of rail traction electrification systems. It provides information on the factors that pipeline operators will need to consider as a result of rail electrification.

This document is also intended to provide guidance to rail system operators on the issues that they will need to consider in relation to overhead pipeline crossings and the steps that can be taken to mitigate the touch potential risks, which the presence of overhead pipelines will pose.

Different situations that can lead to risk are identified and appropriate mitigation methods, where applicable are described.

1.2 Scope

The guidance in this document is applicable to all steel pipelines operated by UKOPA members and provides information on good practice for construction, operation, and maintenance.

This Technical Note provides information on the electrical hazards that should be considered in certain specific situations to ensure all risks to the general public, the rail traction system operator, pipeline and rail system operational personnel and pipeline systems are effectively managed. This Technical Note applies to both new and existing overhead pipeline crossings.

Every effort has been made in the preparation of this document to identify relevant risks. However, some risks may not be included, and it is the duty of pipeline and railway system operators to carry out their own assessment of situations that may lead to risk and implement appropriate mitigation methods.

The rail traction system operators should identify any specific concerns they may have to the pipeline system operator.

A list of abbreviations used in this document is given in Appendix A, whilst a glossary of terms used is given in Appendix B as rail operators may not be familiar with the terms commonly used in the pipeline industry and vice versa.

This document applies to electrified and non-electrified railway lines but concentrates on the additional risks that rail electrification may impose.

1.3 Application

The document is considered by UKOPA to represent current UK pipeline and rail industry good practice within the defined scope of the document. All requirements should be considered to be guidance and should not be considered to be obligatory against the judgement of the pipeline Owner/Operator. Where new and better techniques are developed, they should be adopted without waiting for modifications to the guidance in this document.

Within this document:

Shall: indicates a mandatory requirement

Should: indicates good practice and is the preferred option

2. NON-ELECTRICAL INTERFERENCE ISSUES

Non-electrical interference issues on overhead pipeline crossing or railway lines

2.1 General

The design requirements for overhead pipeline crossings are given in certain pipeline design codes e.g. IGEM/TD/1 Edition 6 [11], IGEM/TD/3 [12] and PD 8010-1 [13]. Section 6.15.2 of IGEM/TD/1 Edition 6 provides the following guidance on overhead pipeline crossings namely.

Overhead pipe crossings, for example of rivers, canals, railways, and roads, should be avoided, wherever possible.

Where an overhead crossing is unavoidable, it shall be designed, located, and maintained to:

- Accept the stresses imposed on the pipe, carrier system and foundations and supports, within acceptable limits. Reference should be made to IGEM/TD/12 [14]
- Be acceptable in environmental aspects
- Have sufficient headroom to ensure the piping system is secure from possible damage due to the movement of vehicles, rail stock or shipping beneath them
- Have suitable barriers to restrict access, except to those concerned with maintenance
- Touch potential and AC interference risks need to be considered near electrified railway lines
- Maintain security and discourage vandalism
- Have suitable accessibility to all components for the purpose of painting and lubrication
- Avoid interference between the CP system for the pipeline and any supporting structure, including temporary CP systems
- Have suitable barriers or protection to prevent damage to the carrier pipe by vehicles have supports whose bases are on firm ground and incapable of being weakened by scouring

PD 8010-1 [13] does not specifically address overhead pipeline crossings but does have a section on pipe bridge crossings and states in Section 6.5.4 entitled Pipe bridge crossings.

“The preferred design for pipeline crossings is for the buried installation of pipe. Where it is necessary to utilise pipe bridges, these should be designed in accordance with good structural engineering practice. Pipe bridge design should take into account thermal and structural stresses, pipe carrier stresses and foundation loadings.

Sufficient headroom should be provided to avoid possible damage from the movement of traffic or shipping beneath the pipe bridge. Account should be taken of accessibility requirements for maintenance and security, and of restrictions on access to the general public. The design should take account of potential cathodic protection interference between the pipeline and bridge supporting structure.”

None of the pipeline design standards specifically address in detail the specific the issues associated with overhead pipeline crossings of railway lines.

Although IGEM/TD/1 Edition 6 [11] does require that operators assess the touch potential risks associated with railway electrification systems. PD 8010-1 [13] also recommends that the possibility of cathodic protection interference between the pipeline and a bridge supporting structure should also be considered.

IGEM/TD/3 [12] gives limited guidance on crossing of railway infrastructures but does indicate that where pipelines cross at bridges and waterways that isolation joints should be considered at each side of the crossing.

2.2 Overhead Pipeline Crossings of Railway Lines

The method of overhead pipeline crossings of railway lines will vary, as a number of different pipe crossing designs and methods have been adopted in the past. These requirements apply to whether the rail line is electrified or not.

New pipelines would not be routed over railway lines but cross by a suitable trenchless crossing technique approved by Network Rail (NR). However, there are a number of instances in the UK where overhead pipeline crossings of rail lines have been employed. Certain issues have come to light in recent years when the rail system operator has decided to electrify a railway traction system and there is an overhead pipeline crossing present.

It is a requirement of the rail system operators, typically NR that all metallic structures within 5.2m of the centre line of the railway lines are equipotential bonded to the railway traction earth to eliminate specific electrical safety risk.

The 5.2m requirement is the limits of the Overhead Contact Line Zone (OCLZ) and is defined as 'zone whose limits are in general not exceeded by a broken overhead contact line'. The 5.2m is the horizontal distance at track level,

This requirement can create issues for pipeline operators, where there are overhead pipeline crossings.

The electrical interference issues are discussed in detail in the remaining sections of this technical note.

The following overhead pipeline crossing methods on railways have been encountered.

1. A pipeline may be supported on pillars at each side of the rail crossing and freely suspended across the rail crossing

2. A pipeline may cross the railway line on a specifically designed pipe support bridge or structure

3. A pipeline may be attached to a permanent structure such as an existing road or pedestrian foot bridge

A picture of an overhead 39 barg gas pipeline crossing of a railway line immediately prior to rail electrification is shown on Figure 1 The pipeline is supported on a pipe bridge, which was repainted immediately prior to the construction of the rail electrification system.

The repainting operation was carried out prior to the construction of the electrification systems to facilitate the construction of the support scaffolding as subsequent to the construction of the rail electrification system future coating operations would be extremely difficult and costly.

The pipeline crossing method would need to be assessed at an early stage of any new rail electrification project to determine its suitability and the factors that need to be considered to ensure the future long term and safe operation of the pipeline and rail electrification system.

Consideration should be given to the impact of any rail electrification system on the ability to carry out future inspection and maintenance on the pipeline system at the above ground crossing.

Figure 1 Pipe Bridge at Rail Crossing

2.3 Pipeline and Rail Operator Inspections

It is important that the railway and pipeline operator have discussions at the early stages of any rail electrification project and carry out a joint inspection of assets at any overhead pipeline crossing location.

Pipeline operators may have in the past not had access to the Rail Operator's land to carry out detailed inspection and any initial inspection of a pipeline system should include some of the checks identified in the following sections. This would minimise the requirement for a number of inspections and give the pipeline operator the opportunity to carry out detailed inspection.

If it is identified that there is insufficient clearance between the rail line and the overhead pipeline, then a pipeline diversion may be required and if that is the case it could take time to arrange.

2.4 Pipeline Coating

Where existing pipelines are routed above railway infrastructure the pipeline coating system that has historically been employed is typically a continuation of the buried pipeline coating and the girth weld coating.

Buried pipeline coatings systems include coal tar enamels, fusion bonded epoxy (FBE), polyethylene cladding and occasionally tape systems. All of these systems are thermo-plastic coatings which have limited resistance to direct UV radiation and will degrade over time and may even suffer disbondment.

Disbonded coatings can create an atmospheric corrosion risk to a pipeline, act as water entrapment locations and the pipeline coating would need to be inspected and maintained/repaired in accordance with existing pipeline operator inspection standards.

The presence of a railway electrification system may severely limit a pipeline operators' ability to carry out coating inspection.

There could be corrosion under disbonded coatings, at supports or other areas of metallic contact and where the pipeline coating has detached, exposing the bare steel surface.

Coating repair should be carried out in accordance with an approved and pre-qualified coating procedure supervised by inspection personnel with a recognised painting inspection qualification. Appropriate risk assessment and procedures will be required for coating removal, as such materials may be carcinogenic.

Risk assessments and method statements for any coating repair operations would need to consider all electrical safety risks.

If a new rail electrification system is to be employed, then consideration needs to be given to the condition of any existing coating at an early stage. This would include not just the coating on any overhead pipeline but on any pipe support structure.

The coating system applied would need to be established and the health and safety implications of any coating removal or repair operations would need to be assessed.

It would be prudent to replace or repair defective coating on any pipeline or support structure prior to the installation and energisation of any electrification system. (Generally, paint systems are preferable to thermo-plastic coatings which are normally specified for buried pipelines.) This is to ensure that no electrical isolations of the rail electrification system are required in the immediate future to gain access but also so that any temporary scaffolding can be safely installed.

Any above ground coating system should have a good resistance to UV radiation and be a very high durability coating system, compatible with the corrosion environment classification determined in accordance with BS EN ISO 12944-2 [15] with a maintenance free life of >25 years.

The coating system employed should meet the requirements of BS EN ISO 12944-5 [16].and would need to be applied by specialist contractors having the requisite coating application competencies. Suitably qualified painting inspectors should oversee the coating application process.

2.5 Pipeline Identification

BS 1710 [17]. Specification for identification of pipelines gives the colour code requirements for the product that is contained within a pipeline. The colour coding given in BS 1710 [17] is not often used in practice on overhead railway crossings or indeed a number of other exposed pipeline crossings. Railway inspection personnel cannot easily identify the product that is being transported in a pipeline system unless it is identified.

It is recommended that the colour band for product being transported as identified in BS 1710 [17] is applied at selected locations, so that it can be clearly visible from personnel on the ground or inspecting structures from the railway embankment.

The pipeline operator shall ensure that the pipeline product, owner and emergency contact details are clearly displayed.

2.6 Civil Engineering Considerations

Any pipe bridge and associated supports should be inspected prior to any planned electrification works.

A major concern is embankments, where side slope failure in close proximity to any pipe bridge abutment may occur in the future. London Clay is often present on railway embankments, which has a low permeability. Clays with low permeability generally take many years to dissipate the pore water pressures within.

Note that a significant number of railway embankments that were constructed in the 1960's and 1970's in low permeability clays around the London area experienced failures after 20 to 30 years.

Since cohesive materials such as clay are able to hold water for long periods of time, unlike non-cohesive soils such as sands, embankment side slopes are generally designed on the basis of undrained conditions. However, clay over a period of time can dry out and thus behave in an undrained state. The friction angle in a wet clay is much greater than that in an undrained state, hence steeper sided slopes are achievable for stability in clay in the short term. However, if the clay dries out then the friction angle reduces, and the material may subside.

Vegetation on the embankment side slopes may be providing sufficient suction to prevent further slippage; should the ground water table rise during heavy rainfall, then this will remove the suction, which could lead to further slippage failure.

Geotechnical and site investigations should be considered to understand the risks of future ground movement. If the possibility of movement is identified then remedial measures, such as the introduction of a sheet piled wall at the toe of the embankment to intercept the slip circle, may be required to prevent a possible collapse of any embankment. A collapse of an embankment could result in undermining of the pipe bridge foundations and collapse of the bridge structure and gas lines onto the railway track.

Should pipeline or pipe bridge movement occur over time then this could reduce the separation distance between the rail electrification system and the metallic components associated with the overhead pipeline crossing.

2.7 Mechanical Assessment

It is important to ensure that the stresses imposed on a pipe, carrier system and foundations and supports are within acceptable limits. A suitable code for stress assessments e.g. IGEM/TD/12 [14]. should be used for this purpose.

If coating removal operations are conducted and welds are exposed, then these should be subject to NDT using suitable inspection techniques and inspection personnel with a recognised inspection certificate. MPI inspection at the very least should be carried out to determine if there is any cracking on a pipeline at girth welds.

The pipeline operator should carry out a detailed inspection of any pipe support structure at agreed inspection intervals. To carry out these checks access to the railway infrastructure will be required. The inspection should check any bolting materials for evidence of cracking, pipe support movement and any evidence of cracking or movement.

2.8 Cathodic Protection Status

The CP status of any buried pipework and support structures within the rail operators land boundaries should be established. If there are buried pipe sections, then CIP surveys may not have in the past been carried out on any short, isolated sections of pipework within the rail operator's land.

The CP status of any pipe supports should also be confirmed, and it should be established if there is any direct connection between a pipeline and its pipe supports.

Checking the CP status of pipe supports will confirm if the pipeline is effectively isolated from the support structure or there is electrical isolation between the two.

CP test facilities should be located each side of the pipe crossing. The CP test facilities should confirm the CP status of the pipeline at the crossing.

Consideration should be given the installation of separate connections to the pipeline and support structure.

If new cable connections are installed to carry current the cable conductor size should be sufficient to carry the anticipated fault current and be a minimum of 25mm^2 single core copper conductor.

If electrical isolation devices e.g. I/Fs or I/Js are installed each side of a rail crossing the effectiveness of the I/Js should be established. It should also be confirmed that even short sections of buried pipeline have CP applied.

2.9 Air to Soil Interface Inspection

Air to soil interface inspections should be carried out on the pipeline each side of any rail crossing, where the buried pipe exits the ground. If coating defects are identified or there is a risk of corrosion, then the existing coating should be repaired using a suitable repair procedure for a distance of at least 500mm.

2.10 Signage and Anti Vandal Protection

Pipeline operators should ensure appropriate signage is present each side of a crossing to warn of the presence of a pipeline and the pipeline contents. Anti-vandal and climb protection should in place on overhead pipelines to ensure that a pipeline cannot be used to gain access to the railway infrastructure and high voltage electrical hazard signs posted and be clearly visible.

2.12 Existing Buried Pipelines at Rail Crossings

Pipeline operators should review the impact of any new rail electrification system on existing buried pipelines that either cross railway infrastructure or are routed in rail operator land.

There may be instances where lower pressure pipelines, particularly gas are routed on rail infrastructure land. If operating at pressures less than 2 barg some gas pipelines may not even have any CP system applied and thus there may be a higher risk of failure due to corrosion. This could result in the release of a flammable product close to a railway.

In respect to pipelines, railway electrification would create a hazard, namely an ignition source, in close proximity to a pipeline containing a flammable product. The corrosion protection status of any buried pipeline with flammable products in the vicinity of the railway should be established and fully effective levels of CP applied.

2.13 CP System Operation

Pipeline design standards highlight the difficulties of gaining access to land owned by rail system operators. Thus, the CP status of any buried pipelines on railway land should be established even if operating a low pressure.

CIP surveys are often not conducted on pipelines installed in rail operator land but wherever practical they should be conducted.

Pipelines carrying flammable product buried near railway infrastructure should be identified and their corrosion protection status confirmed.

If there was to be a leak of flammable product close to a railway line that in itself would create a hazard as even non electrified traction vehicles can act as an ignition source but once a rail system is electrified there will be an additional ignition source present.

3. ELECTRICAL INTERFERENCE ISSUES ON PIPELINES

3.1 General

AC interference on overhead pipeline systems from crossing of railway traction systems is a concern. There are two main issues associated with this phenomenon:

1. The electrical safety risk to railway and pipeline operator personnel from short term or long-term interference on a pipeline, if any contact is made to a pipeline or its above ground appurtenances, which includes CP test cables, at the time that there is short term interference event or also long-term AC voltages present on a pipeline system.

2. The AC corrosion risk on buried pipelines, which is a phenomenon that has been identified on cathodically protected pipelines. Problems arise where there are alternating currents, above defined limits, present on a pipeline; even if the cathodic protection levels are satisfactory and meet the criteria defined in BS EN 12954 [18], there can still be ongoing corrosion.

There are a limited number of instances in the UK where there are overhead pipeline crossings of railway lines. If the traction systems are not electrified, then there are no specific issues other than the ones that would be managed by standard pipeline monitoring and inspection procedures carried out in accordance with the pipeline design code requirements and written schemes of examination prepared under the Pressure System Safety Regulations [19] or the Pipelines Safety Regulations [20].

If a traction system is to be electrified by either an AC or DC traction power source, then additional risks will be created. The pipeline operator would need to discuss and agree the appropriate mitigation measures with the railway authorities in a timely manner.

The presence of an electrified system close to an above ground operational pipeline will create a new electrical safety hazard for the pipeline operator. It can also create a touch potential risk for the railway authority and in certain circumstances if the rail pantographs contact the overhead pipeline or the pipeline support structure then the traction system protective devices might not be able to operate if a pipeline or its supporting structure are not effectively earthed.

Thus, there will be electrical safety risks that both the pipeline and the rail system operator will need to address.

3.2 Railway Traction System

Operators should be aware that new railway electrifications system utilises a 25 kV 50 Hz supply that is provided from substations located at distances about 40 to 50 km apart along the train line route. These substations typically utilise a 132kV connection off the UK's nationwide electricity transmission network

The AC voltage is transformed to 25 kV 50 Hz typically employed for the overhead electrification systems.

Mass transit DC systems using overhead power cables would operate at voltages up to 3kV.

3.3 Safety Issues

The primary safety issues in relation to AC interference from overhead and buried power lines on pipelines relate to the touch potential risk.

Electrical safety risks should be considered for any work that will involve personnel coming in contact with a pipeline or any appurtenance or structure electrically connected to the pipeline.

Induced voltages on pipeline systems can occur when pipelines are routed close proximity to overhead power lines. The induced voltages created in such situations can affect personnel safety and could be present on the exposed section of pipeline at a railway crossing.

There may also be long line DC and AC currents in buried pipelines. Where long line currents exist, and a pipeline section is cut, then there may be a spark hazard at the discontinuity due to the disruption to the current flow.

3.4 Short term a.c interference

Short term interference is the voltage that can be created on a pipeline from a phase to earth or phase to phase fault in an overhead power line at a pylon in close proximity to a pipeline, on an AC traction system, at an electrical substation or traction system pylons or from lightning strikes. Short term interference events will only exist for a short period of time before the protective devices on the power lines operate. The disconnection time is typically within 200ms for 132kV to 400kV circuits and may up to 1 second for up for 11 to 33 kV circuits.

On railway systems the protection devices disconnection time for the 25kV systems is typically 200ms. However, not all protective devices on the rail circuit may operate within this disconnection time and longer disconnection times may exist. NR should confirm the applicable disconnection times for a given location.

Short term interference effects create a higher touch potential voltage than in the long-term interference case, but the voltage excursions are present for shorter durations.

In order to reduce the risk to personnel the time in contact with a pipeline or above ground appurtenances does need to be limited and personnel need to be made aware of this.

In relation to electrical hazards there will, in the case of a new AC traction system, be a touch potential risk on a pipeline at the pipeline rail line crossing point that may be created by any traction system fault current. This touch potential risk would apply to any part of the pipeline or steel work electrically connected to the pipeline within a specified distance of the rail system earth or a rail power system pylon.

BS EN 50122-1 [21] provides guidance on safe distances and maximum touch potential limits. The maximum touch potential is 645V for a fault clearance within 200ms based upon the guidance given in BS EN 50122-1.

In the case of railway systems, the separation distance between metallic structures connected to different earthed systems is 5.2m, which is greater than the 3m distance typically considered in the pipeline industry.

NR in the UK bases its earthing system requirements on NR/L2/ELP/21085 Rev 4 [22].

The rail operator should ensure that ground potential rise limits from a fault on an overhead pylon do not result in touch potential risks on the pipeline. This can be achieved by ensuring any new power supply pylons are located as far as practical away from the pipeline or the use of touch potential mitigation systems.

If a train pantograph was to make contact with a pipeline, then the circuit impedance for any fault needs to be of a sufficient value to enable the protective devices on the AC traction system to operate to clear the fault within the required time frame. If not the pipeline could reach an unsafe voltage for a period of time in excess of the specified clearance time for the rail traction system protective devices and this could present a serious safety concern.

The pipeline resistance to remote earth must be of a sufficient value to enable the traction system protective devices to operate within the required disconnection time and should generally be less than 1 ohm. However, the resistance to remote earth of any pipe support structure may be considerably higher than 1 ohm.

3.5 Touch potential

A touch potential is the voltage between the energized object and the feet of a person in contact with the object. In the case of pipelines, it is the voltage between the pipeline and the feet of anyone making electrical contact with the pipeline, who is in contact with the ground.

There may also be a touch potential risk between an operative's hand in contact with the pipeline and another earthed object. This will result in current flow from hand to hand rather than from hand to feet during a fault condition.

BS EN 50122-1 [21] is the standard the rail industry uses to determine touch potential limits and does give guidance on touch potential risk and that is different to the guidance in BS EN 50443 [7].

For detailed guidance on permissible touch potentials on pipelines reference should be made to UKOPA/TBN/005

The touch potential limits given in BS EN 50122-1 [21] should be adopted for short term interference situations on pipelines routed close to rail infrastructure. The touch potential limits given in BS EN 50443 [7], shall not be used.

BS EN 50122-1 [21] applies to the railway industry and parts of a railway electrical installation are accessible to the general public and can be linked to the traction return system. These include equipment at level crossings and enclosures for signalling and other systems on platforms.

They are also intended for outdoor situations where the general public may have access and where there is a mixed workforce, many of whom will not be 'electrically instructed'

The touch voltages given in BS EN 50122-1 [21] are reproduced on **Error! Reference source not found.**

Power system fault duration time (seconds)	BS EN 50122-1 safe voltage limit (Volts)
0.02	865
0.05	835
0.1	785
0.2	645
0,3	480
0,4	295
0,5	220

Power system fault duration time (seconds)	BS EN 50122-1 safe voltage limit (Volts)
0,6	180
<0.7	155
0.7	90
0.8	85
0.9	80
1.0	75
300	65
>300	60

Table 1 Maximum Touch Potential Limits for Different Disconnection Times extracted from BS EN 50122-1

3.6 Long Term Interference

Long term AC interference on pipelines from overhead powerlines can in certain circumstances result in AC voltages in the region of 100V present at some CP posts on buried pipelines that are routed in close proximity to high voltage overhead power lines or AC traction systems for appreciable distances under certain extreme conditions.

The AC voltage levels observed in practice are generally much lower than 100V, but they can often exceed the safety limit on pipelines of 15Vrms in certain circumstances on some pipelines at certain times.

The long-term voltage is due to inductive coupling between pipelines and power lines. The 15V rms limit has generally been considered by the UK pipeline industry as the maximum AC voltage level to aim for in regard to electrical safety on pipelines and it is the safe touch potential voltage value on pipelines that is advised in this technical note.

The touch potential risk on pipelines routed close to power lines that may exist in normal operation is termed the long-term touch potential risk and is the voltage induced on the pipeline from the inductive coupling between a pipeline and power lines routed close to each other. The magnitude of induced AC voltage is primarily related to the length of parallelism, separation distance between power line and pipeline, power line voltage and power line load.

It should be noted that following electrification of any railway system if a pipeline is routed in parallel with a railway line, then AC voltages in excess 15V rms could occur for short periods of time up to a few minutes due to the influence of traction return current flowing in the general mass of earth.

3.7 NR Requirements

NR standard NR - GE/GN8646 [35] provides guidance on hazard management and requires that all metallic pipework installed within 5.2.m of the centres of the rail line is bonded to the rail earth 5.2m is the horizontal boundary for bonding at track level. In this case the pipe sections running parallel to the track would not need bonding as far as NR are concerned as it is buried and would therefore not be made live by a falling conductor. The more relevant measurement would be the vertical distance to the pipeline on the bridge i.e. the CCZ and this is dictated by the wire heights.

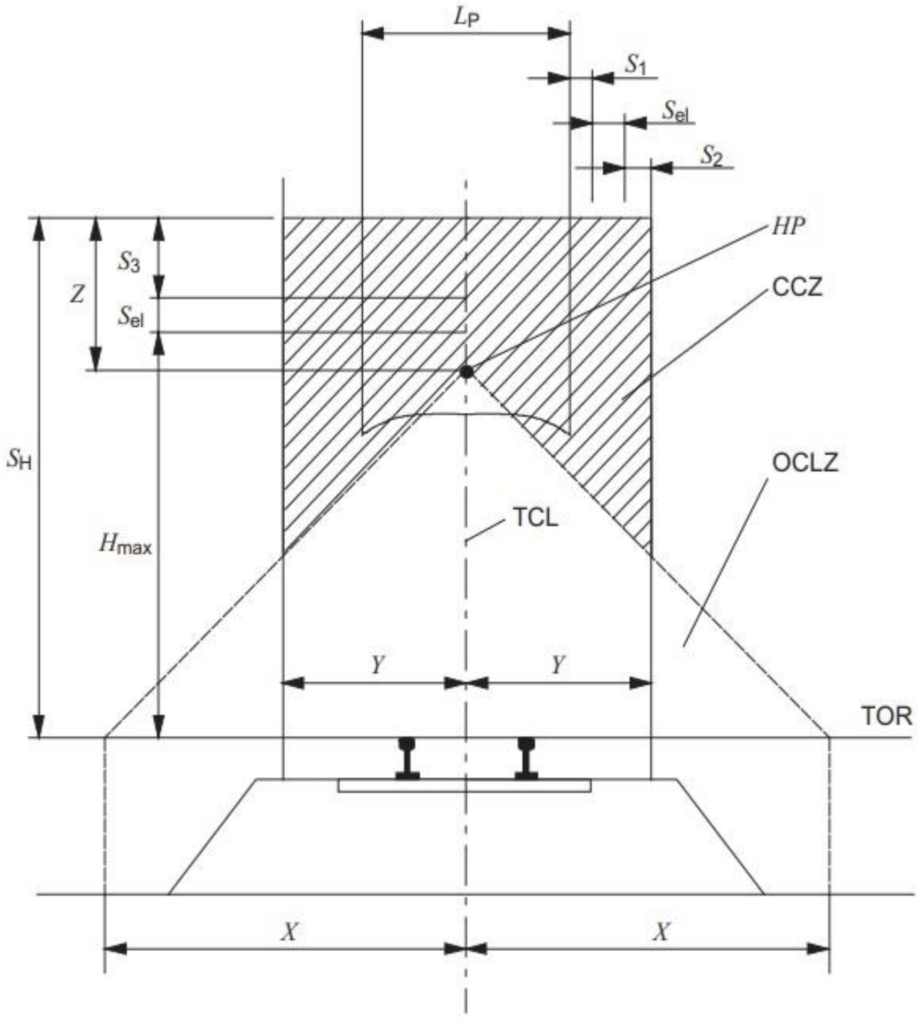

Figure 2 Details of Extent of Overhead Contact Line Zone (OCLZ) and Current Collector NE Zone (CCZ) from BS EN 50122-1 [21]

The key from Figure 2 is

TOR - top of rail

HP - highest point of the overhead contact line

OCLZ - overhead contact line zone

CCZ- current collector zone

TCL- track centre line

X- maximum unidirectional (half) horizontal OCLZ, top of rail level

Y- maximum unidirectional (half) horizontal CCZ

Z- distance between HP and S_H

S_1 width of lateral movement of the current collector

S_2 lateral safety distance for the broken or dewired current collector

S_3 - vertical safety distance for the broken or dewired current collector

S_{CL}- electrical clearance in accordance with BS EN 50119 [21]

S_H - maximum height of current collector zone

L_P current collector width

H_{MAX} maximum height of the fully uplifted current collector

The requirement for bonding applies to overhead structures as well as structures adjacent to rail infrastructure .

NR - GE/GN8646 states " Conductive parts and equipment on AC electrified railways shall be assessed to determine if they are located within the OCLZ and/or CCZ" .

The OCLZ and the CCZ define the likely area or zones that could become energised from a live broken contact line or live parts of a broken current collector. Consequently, conductive parts within this area are subject to protective provisions such as bonding of the conductive part to the traction return circuit or protection by means of an obstacle or bare conductive part."

The CCZ shall be determined by the dimensions of CCZ parameters Y, SH and Z, where:

- Y = 1.4 m either side of the track centre line
- SH ≤ 6.8 m from top of rail
- Z ≤ 0.6 m (limited by the maximum value of SH)

CCZs are zones whose limits are in general not exceeded by a broken overhead contact line or an energised dewired or broken current collector and its fragments. Structures and equipment may accidentally come in contact with a live broken overhead contact line or live parts of a broken or de-wired current collector and thereby become live.

A current collector which has become disconnected from the overhead contact line due to a mishap may nevertheless be alive if a train has multiple current collectors which are electrically connected or if the train is braking using a regenerative brake.

4. AC INTERFERENCE FACTORS TO CONSIDER

Electrification of rail lines ac interference factors to consider

4.1 Timescales

It is important that the rail traction system and pipeline operator allow sufficient time to assess the issues associated with any rail electrification project and the impact existing overhead pipeline crossings may have on any proposed works.

Overhead pipeline crossings need to be identified by the designers of rail electrification project at an early stage in any proposed electrification scheme and the pipeline operator notified with details of the rail electrification system.

Early engagement by the Rail Operator with the Pipeline Operator is essential.

NR also need to consider the clearance distances between a pipeline and the rail electrification system and also what the effect of a train pantograph hitting a pipeline, or its supporting structure will be.

If the pipeline or its supporting structure do not have the requisite impedance to remote earth, then there could be a risk that the 25 kV traction system protective devices may not trip within the required disconnection time and that the pipeline system could experience a hazardous voltage and the safety of personnel involved in any emergency response could be affected if the traction circuit remains live.

4.2 Factors to Consider

There are a number of factors that pipeline operator and rail system operator need to consider in relation to overhead pipeline crossings of new rail electrification systems.

These are summarised in Appendix C.

The precise height of any pipeline and supporting infrastructure would need to be established to ensure that there is the necessary clearance between the pipeline and any proposed rail electrification cables.

The separation distance of the pipeline from the railway system metallic services would also need to be established.

Pipeline operators would need to consider future inspection activities on above ground pipe crossings following rail electrification and how they can be conducted going forward.

The Pipeline Operator would also need to determine whether any changes or modifications to the pipeline system would need to go through the pipeline operators Management of Change procedure.

4.3 Long Term AC Interference

If pipelines cross AC traction systems at right angles and do not run in parallel with the traction system for any appreciable distance, then the long-term levels of AC interference from a 25kV traction system should be low.

Where a pipeline crosses a rail line, the crossing should be at right angles and the pipeline should be routed so that it is equi-distant between rail line pylons. This will limit the ground potential rise on the pipeline during fault conditions on the traction system. Fault currents on rail traction systems vary with distance from the substation, with typical values being in the region to 2 to 12 kA. The higher fault currents are experienced closer to the substation.

The fault current at the specific location where a pipeline is present should be established.

The AC interference risk in relation to pipelines in close proximity to railway systems occurs where the pipeline is routed in a parallel with the traction circuits and can collect traction return currents by resistive coupling and also inductive/capacitive coupling from the live traction cables.

BS EN 50443 [7] advises that capacitive coupling from a railway system must be considered in case of proximity lower than

- 10 m in case of 15 kV, 16,7 Hz systems
- 50 m in case of 25 kV, 50 Hz systems

BS EN 50443 advises that conductive or resistive coupling from an AC electric traction system shall be considered in case of crossing or proximity within 50m of a traction system.

Once railway lines are electrified there will be AC traction current flowing in the return rails. This traction current can be picked up by buried metallic structures and where pipelines are routed in parallel with the railway line there may be an enhanced AC corrosion risk.

Guidance on the risk of AC corrosion risk is given in BS EN ISO 18086 [1] and UKOPA/GPG/027 [2].

Modelling of the effects of AC interference from AC traction systems where required should be undertaken by specialists experienced in this field.

The nature of the rail electrification system would need to be established and information provided on the location of any AC booster stations, train frequencies on the rail line and operating currents for different scenarios. The relative positions of feed and return conductors including earth wires should be confirmed, together with the number of substations and distance the traction circuit runs parallel with a pipeline and separation distance between the two.

The maximum and normal loads on the rail system and fault current at substations and on pylons close to pipeline should be confirmed and the rail operator should provide information on the number of track circuits and power lines operating at 25 kV and their physical location.

The contact resistance between the traction return rails and the soil is also an important factor as would be data on the soil resistivity along the pipeline route.

Analysis of AC traction system interference is made complex by the fact that that the traction current has a variable location due to the movement of the trains and variable magnitude of current load associated with variation in acceleration and breaking. The current loads can change over a relatively short period of time.

The overhead aerial earth wire also has a shielding effect in reducing the levels of interference.

All apparatus, cabling and earth systems associated with a pipeline system installed on railway property or connected to rail lines must be approved by the rail authority.

A HAZOP and HAZCON should be carried out between the pipeline operator and railway operator for new construction activities in the vicinity of rail crossings to ensure safe operation of the pipeline and railway.

4.4 Hazardous Areas

It is important to establish if there are any flanges or discontinuities in the pipeline system that would create a hazardous area within the vicinity of any rail lines or electrification power sources.

If there any expansion joints, valves, flanges, Viking Johnson couplings or similar connections such that the pipeline is not of a fully welded construction these could create a hazardous area in the vicinity of railway and any new electrical infrastructure.

IGEM/SR/25 [23] gives guidance for pipelines carrying natural gas, whilst BS EN 60079-10 [24] provides guidance on hazardous area assessments for other pipelines. Some pipeline operators may utilise different hazardous area classification codes.

The pipeline operator competent person under the DSEAR [25] should assess the hazardous areas on pipelines that are exposed.

In the case of flanges on freely exposed cross-country pipelines the area around the flange would be classed as a Zone 2 negligible extent (NE) area. Hazardous areas are classified into zones based on the frequency of the occurrence and the duration of an explosive gas atmosphere.

In the case of a secondary release, the relevant zone is Zone 2 and is defined as a place where an explosive atmosphere is not likely to occur in normal operation but, if it does occur, will persist for a short period only. In areas where the ventilation can be regarded as ‘high’ relative to the leak size, BS EN 60079:10 recommends that the area classification is Zone 2 but of negligible extent (NE) such that no action is required to control sources of ignition within it. Thus, on overhead pipe systems if there is a flange present this would create a Zone 2 NE area.

On high pressure pipelines operating at pressures above 7 barg there are unlikely to any flanges or discontinuities in the pipeline at a rail crossing. However, on lower pressure pipeline systems there may be flanges or similar fittings that could create a hazardous area.

Adverse conditions apply to situations where pipework is exposed to additional forces e.g. vibration and as such a condition could occur on a rail bridge from vehicle and rail movement then the appropriate hazard radius will need to be considered.

4.5 Training and awareness

Pipeline Operators should ensure that personnel and contractors working on pipelines are aware of the electrical safety risks on pipelines routed in close proximity to electrified and non-electrified rail lines.

This can be achieved by the provision of suitable training to personnel that operate and maintain pipelines, toolbox talks and the development of safe working procedures.

However, rail system operator personnel should also be made aware that work on pipelines or contact with them should cease when there is a lightning or storm risk. They should also be advised that there could be situations where a hazardous AC voltage may be present on a pipeline due to resistive or inductive coupling from overhead powerlines located along the pipeline route often some distance from the rail traction system.

Thus, pipelines and any structure electrically connected to a pipeline should be treated as potentially live until proven otherwise.

The probability of a hazardous voltage being present is low but nevertheless the rail system operator and any inspection personnel should be made aware of this risk.

There are personnel protective equipment requirements in certain situations that should be adopted to reduce risk and specifications that apply to electrical test equipment when carrying out testing on pipelines e.g. routine measurement of pipe to soil potentials or conducting over the line surveys.

Lightning activity or high voltage power line faults many kilometres away can result in a hazardous voltage being created on a pipeline some distance from the voltage surge location. It is not possible to predict when such events will occur. They will be relatively rare, but the consequences for personnel in contact with a pipeline can be potentially fatal. Thus, limiting personnel contact times with a pipeline is important as is ensuring appropriate training to personnel is provided.

Where there are overhead pipeline crossings of railway traction systems it is the duty of the pipeline operator to make the rail system operator aware that there may be occasions where a significant or hazardous AC voltage may be present on a cross country pipeline. Thus, railway personnel should check an overhead pipeline using a suitable measurement device e.g. Voltstick to ensure that there is not a hazard voltage present.

4.6 Electrification Issues

Pipeline industry standards typically require a minimum separation of 3m from independent earthed structures. Thus, there will need to be at least 3m separation between any pipe bridge supports and the High Voltage Alternating Current (HVAC) stanchions on the traction system or the rail traction system returns. However, NR require an even greater separation in the region of 5.2m from the rail centre line.

NR work to 2.5m separation between independently earthed structures for touch potential reasons outside the OCLZ. However, within the OCLZ a separation distance of 5.2m between different earthed structures would typically apply. The rail operators' requirements for separation distance will take precedence and should be confirmed.

There is an earth conductor associated with any new HVAC traction power system that too should be at least 3m from the pipe crossing.

At overhead pipeline crossings the requisite 3m separation between different earthed structures will most certainly not be achieved in practice.

However, as access to the pipeline and the rail traction system earth when any new electrification system is installed will be controlled by NR then NR should be aware of the reduced separation risk and take appropriate action. Pipeline operator personnel are not likely to have access to any pipe support bridge and if they do it will be controlled by NR rail and the touch potential risk will be addressed at that time.

The minimum separation distance that pipeline operators should require between live conductors and power lines would be at least 0.8m for voltages between 1 to 33 kV based upon the guidance given in the Electricity Networks Association Publication Technical Specification 43-8 Issue 4 [26].

This is the actual ENA guidance if there is anti-vandal protection. It is believed that the latter clearance distance is not practical for most new electrification situations.

The relevant Table from ENA 43-8 [26] is given on Figure 3.

Table 6.2 - Clearances to Objects

Item	Description of Clearance	Nominal System Voltage (kV) Minimum Clearance (m)				
		≤ 33	66	132	275	400
6.2.1	Line conductor to any object which is normally accessible (including permanently mounted ladders and access platforms) or to any surface of a building. (Note 1 and Fig. 1)	3.0	3.2	3.6	4.6	5.3
6.2.2	Line conductor to any object to which access is not required AND on which a person cannot stand or lean a ladder. (Note 2)	0.8	1.0	1.4	2.4	3.1

Figure 3 Recommended Clearance Distances between Overhead Powerlines and Objects from ENA 43-8 [26]

Pipeline operators must ensure that anti vandal protection is in place at any overhead rail crossing to mitigate the electrical shock risk**.**

BS EN 50341-1 [27] also provides guidance on recommended clearance distances and should also be consulted. There are situations where clearance distances less than 0.8m can be accepted based upon the ENA guidance.

These apply to buildings and structures and it can be seen that 0.5m can be accepted as the minimum clearance under certain circumstances. In air the separation distance between the pipeline and any live conductor before any arc will occur in dry air is 25mm for a 37kV voltage at the peak rms voltage of the rail traction system.

However, when the air is wet or if there are any conductive particles in the air then the atmospheres dielectric strength will reduce, and the minimum separation distance will increase significantly. The separation distances given in codes and standards do include a significant safety margin.

Table 6.4 - Clearance to Buildings and Structures

Location	Minimum Clearance (m)
Vertical clearance to any surface or structure that is accessible without access equipment (see Fig. 5).	3.0
Horizontal distance to any surface of a building or structure which is accessible without access equipment (see Fig. 5).	1.0
Clearance to parts of a building or structure not normally accessible (see Fig. 5). See note 1.	0.5
Clearance to free-standing apparatus such as street lighting columns, traffic signs, British Telecom poles or columns (see Fig. 5).	0.3

Notes:

1. This clearance is to prevent mechanical abrasion of the conductor. When connecting from a pole to a building it is only necessary to ensure that the attachment route avoids risk of abrasion.

Figure 4 Recommended Clearance Distances between Overhead Powerlines and Buildings and structures from ENA 43-8 [26]

The pylons associated with the rail electrification system should be located as far as possible from the pipeline crossing, so that during an earth fault the GPR close to the pylon will not exceed a safe voltage of either 645V if the protection devices operate within 200ms or if the protection devices on the line conductors do not operate within 200ms then the pipeline will not be exposed to the touch potential limits in BS EN 50122-1.

The GPR fault contour lines for the stanchions closest to the pipeline will need to be established.

4.7 Lightning Risk Assessment

BS EN 62305-3 [28] provides guidance on avoidance from injury from touch potentials caused by lightning. In certain conditions, the vicinity of the down-conductors of a lightning protection system, may be hazardous to life even if the lightning protection system has been designed and constructed according to the BS EN 62305-3 [28] requirements.

The hazard is reduced to a tolerable level if one of the following conditions is fulfilled

a) Under normal operation conditions there are no persons within 3 m from the down conductors

b) A system of at least 10 down-conductors complying with Section 5.3.5 of BS EN 62305-3 [28] are employed

c) The contact resistance of the surface layer of the soil, within 3 m of the down-conductor, is not less than 100 kΩ

NOTE A layer of insulating material, e.g. asphalt, of 5 cm thickness (or a layer of gravel 15 cm thick) generally reduces the hazard to a tolerable level. If none of these conditions is fulfilled, protection measures shall be adopted against injury to living beings due to touch voltages as follows: – insulation of the exposed down-conductor is provided giving a 100 kV, 1,2/50 µs impulse withstand voltage, e.g. at least 3 mm cross-linked polyethylene; – physical restrictions and/or warning notices to minimize the probability of down-conductors being touched. Protection measures shall conform to the relevant standards (see ISO 3864-1 [29]).

Similar measures are recommended in relation to mitigation of step potential hazards protection measures shall be adopted against injury to living beings due to step voltages as follows: equipotentialization by means of a meshed earth-termination system; - physical restrictions and/or warning notices to minimize the probability of access to the dangerous area, within 3 m of the down-conductor

There have been incidents where lightning has struck a buried pipeline. These events are relatively rare but do occur. It is often difficult to determine whether any damage was caused by lightning or a phase to earth fault on an overhead power line.

Evidence of a lightning strike damage will be indicated by either damage to cables in CP test facilities or from damage to CP T/R units connected to pipelines. The fault current magnitude in a lightning strike can be up to 100kA but whilst the magnitude of the lightning current may be high the duration of the current flow is in the range of microseconds to a few milli-seconds. In certain circumstances through wall metal loss can be experienced.

There should be a Lightning Risk assessment for any pipe support bridge to comply with the relevant parts of BS EN 62305 [28]. Rail system operators' views are as the asset does not belong to Network Rail. the onus for any lightning risk assessment rests with the pipeline operator.

4.8 Quantified Risk Assessments

If there any locations on a pipeline where it has been identified that there is high risk in terms of electrical safety, and the touch potential limits exceed safe values, then prior to undertaking any work on pipelines in these locations then a quantified risk assessment (QRA) should be conducted by a competent body. The QRA should consider the nature of the activities on the pipeline to be conducted, the number of personnel involved in the activities, and time spent in possible contact with the pipeline.

The measures that could be employed to mitigate risk in any QRA should identified e.g. PPE, avoidance of different earthed structures, temporary earthing, trench construction etc.

Any risk assessment should be based upon the requirements of the Management of Health and Safety Regulations 1999 [30]. The risk assessment should include an assessment of the most exposed individual, identification of a range of risk mitigation, quantification of the level of risk reduction provided by these risk mitigation measures and a cost-benefit analysis to demonstrate that the chosen measures reduce risk levels to as low as reasonably practicable.

4.9 Overhead Pipeline Crossings of Railway Lines

The protective devices on the AC traction circuit typically operate with a disconnection time of 0.2 seconds. Table 4 of BS EN 50122-1 [21] indicates that the maximum permissible touch potential for such a disconnection time is 645V.

There could be a situation where the pantograph was to fail and the 25kV conductor could make contact with the pipeline on the bridge. If such a situation were to arise the earth fault circuit impedance would need to be of a sufficiently low enough value to ensure that the protective devices would operate. If the impedance was not sufficiently low enough, then there is a risk that the fault would not clear.

It should be noted that a pipeline is not a perfect insulator and will in fact have a resistance to remote earth by virtue of its length and the fact that there are defects in the coating system. A typical value for the resistance to remote earth for buried continuous pipelines is in the region of less than 1 Ohm.

In the event of a fault condition there will in effect be two means of mitigating the touch potential risk. One will be the natural resistance of the pipeline system to remote earth and the other the use of Voltage Limiting Devices (VLDs) connected between the pipe bridge and the rail system earth.

4.10 AC Interference on Pipeline

Once a railway line is electrified there will be AC traction current flowing in the return rails.

This traction current can be picked up by buried metallic structures and guidance on the risk of AC corrosion and induced voltages is given in BS EN ISO 18086 [1]. If a pipeline and rail line crossing is at right angles and the pipeline is not routed parallel with the rail line, then the levels of induced voltage on a pipeline should be low.

If pipeline does run parallel with the rail line for any appreciable distance, then the levels of induced AC interference from the railway traction system on any buried pipeline would need to be considered to ensure that the pipeline is not exposed to an AC corrosion or touch potential risk.

5. MITIGATION OF TOUCH POTENTIAL RISKS ON PIPELINES

5.1 Introduction

This section provides information on the methods that may be employed to mitigate the touch potential risks on exposed pipelines and ensure that the rail traction system electrical devices operate within the required disconnection time.

To ensure that there is not a hazardous touch potential between the rail line earth and the pipeline in the event of an electrical fault i.e. the 25 kV AC supply on the rail traction system making contact with the overhead metallic gas pipeline and any bridge structure. The pipeline and any supporting structure should be directly connected to the rail system earth. This would provide a low resistance path for the fault current and ensure the protective devices operate within the required disconnection time.

However, for the reasons identified in Section 5.2 a direct bond to the rail traction is not a practical option then alternative methods need to be employed to mitigate touch potential risk.

5.2 Direct Bond Between Pipeline and Rail Earth

If there was a direct electrical connection between a pipeline and the rail line earth the pipeline corrosion protection system could be compromised.

Pipelines are a coated steel structure, and the buried cross-country pipeline would have a potential that would be more negative than the rail system earth as the pipeline system would have cathodic protection (CP) applied to it.

Where pipelines have a CP system applied the pipeline should not be connected directly to the rail earth, as that could compromise the CP system on the cross-country pipeline.

The rail system earth would act as a significant current drain on the CP system and that would mean the CP system on the pipeline would be compromised, as it would have insufficient current capacity to cathodically protect both the pipeline and the rail system earth. The pipeline would effectively be at a natural potential in such an instance close to the rail line and be at risk of corrosion. Indeed, a considerable section of the pipeline route either side of the rail crossing could also be affected by the resultant drop in the CP levels.

Furthermore, during normal operation the voltages on the rail traction system earth can approach at least 25Vrms based upon the guidance given in BS EN 50122-1 [21], Thus, a direct connection to the rail system earth could increase the AC voltage on a pipeline to 25Vrms in certain circumstances.

The maximum permitted AC voltage on a pipeline is 15V rms as stated in BS EN ISO 18086 [1], and it often needs to be considerably lower than 15Vrms to ensure that the AC discharge current density on a pipeline does not exceed 30A/m^{-2}.

There could also be traction return currents flowing in the pipeline caused by the resistive coupling. Thus, if there is AC current leakage off a pipeline, then the pipeline could be exposed to an AC corrosion risk in addition to any galvanic or free corrosion risk due to the direct connection to the traction earth. Thus, it is not possible to bond a pipeline directly to the rail system earth, particularly if a pipeline has a CP system installed. There are however various options available to ensure that the protective devices on the 25kV rail system supply can operate within the required disconnection time and these are discussed in the following sections.

5.3 Methods to Mitigate Touch Potential Risk on Pipelines From Rail Electrification Systems

There are different options available to ensure that the protective devices on a 25kV rail electrification system supply can operate within the required disconnection time and that any hazardous touch potential risks on a pipeline and railway metallic structures are mitigated.

These are.

a) Rely on the pipeline and or pipe support structure resistance to remote earth being sufficient to cause the protective devices to operate in the event of a fault situation e.g. a rail pantograph hitting a pipe bridge or pipeline.

b) Connect a low resistance earth to the pipeline that is compatible with the pipeline CP system e.g. zinc ribbon to reduce the pipeline resistance to remote earth. The zinc earth would be connected through a decoupling device, which must be rated to take the maximum likely fault current

c) Bond the pipeline directly to the railway earth but this option has been disconnected as it would impact on the pipeline CP system.

d) Use a VLD connected between the pipeline/pipe bridge and the rail traction earth, which will discharge the fault current to the rail earth.

BS EN 50122-1 Section 6.2.1 [21] does permit the use of a Voltage Limiting Device between the pipeline and the rail line each as an alternative means of discharge of fault current to ensure that the safe touch potential limits defined in BS EN 50122-1 are achieved.

5.4 Voltage Limiting Devices

VLDs permit fault currents to discharge from a pipe to the rail traction earth, if the voltage exceeds a pre-determined value. The use of VLDs is identified in BS EN 50122-2 [30]. and they are used to prevent hazardous voltages being present on other earthed structures.

VLDs can be provided for both AC and DC circuits and act in a similar way to surge protection or spark gap devices.

Where the devices are used, they require inspection at pre-determined intervals.

Only devices suitable for use on AC circuits should be used for AC traction systems and devices specified as being suitable for DC circuits should be used on DC circuits.

The VLD device must be able to safely conduct the rated fault current for the rail electrification system at the pipe crossing location. These devices can fail short circuit and result in direct contact with a pipeline and rail earth. The latter risk needs to be evaluated and where they are employed remote monitoring devices should also be installed to monitor the CP status on a pipeline.

The ORR Tramway Stray Current Management guide states [32].

"All voltage limiting devices used shall meet the requirements of Clause 7.4 of EN 50122-2 in terms of reset after operation. Ideally this should have the facility to be monitored through the SCADA system.

Experience has shown that there is a particular failure mode with some types of voltage limiting devices. If they experience a high fault current or a large number of operational duty cycles due to short-term impermissible accessible voltages, then they may fail in the short circuit mode. This then creates a direct path to earth for the traction return, which could if undetected for some time lead to corrosion on other nearby metallic structures.

Testing and maintenance procedures must take account of this failure mode.

For this reason, hybrid switching types composing of a solid-state control and separate DC contactor are preferred".

In the case of DC traction systems direct connection of the pipeline to the rail return can have serious consequences in terms of damage to a pipeline. Thus, wherever possible the use of VLDs on DC traction systems should be avoided due to the enhanced corrosion risk.

If there is a direct connection between a pipeline and a DC traction system return rail, then the maximum permissible DC potential where no protection against direct contact is required is up to 60 V DC as stated in BS EN 50122-1. If the pipe potential was to reach +60V then significant rates of corrosion can occur.

Thus, if a VLD device is considered then the risks of direct connection to a pipeline must be fully evaluated and a remote monitoring device should be installed on the pipeline system to warn the pipeline operator of an alarm situation. The installation of a remote monitoring device applies to both AC and DC traction systems.

If a VLD is installed, then the pipeline operator must ensure any alarm systems are effectively monitored and managed to warn of a direct connection between rail system and buried metallic utilities.

If a VLD failed closed circuit, there would be a direction connection between the pipeline and the traction system earth. Where a VLD is installed, it should be maintained in accordance with the manufacturer's guidance.

The VLD must have Railway Authority certification for use on the applicable voltage circuits. The spark over voltage would generally be in the region of 220V, which is below the maximum touch potential limit and the working voltage of VLD devices would generally in the region of 75V. The VLD must be capable of carrying the expected fault current.

Figure 5 shows a picture of a typical VLD for connection between pipelines and rail system earths, whilst the typical electrical characteristics of a device are given on Table 2.

Any cable used to carry fault current should have a sufficient conductor size to accommodate the projected fault current with suitable derating factors employed to size the conductor.

It should be noted that in the UK the rail authorities prefer to use aluminium rather than copper earths and an aluminium conductor cross section area typically in the region of 150mm sq. for earthing purposes

VLD devices should ideally be maintained and checked by NR personnel as pipeline operator personnel do not have the necessary levels of competency or experience on the use of VLD devices.

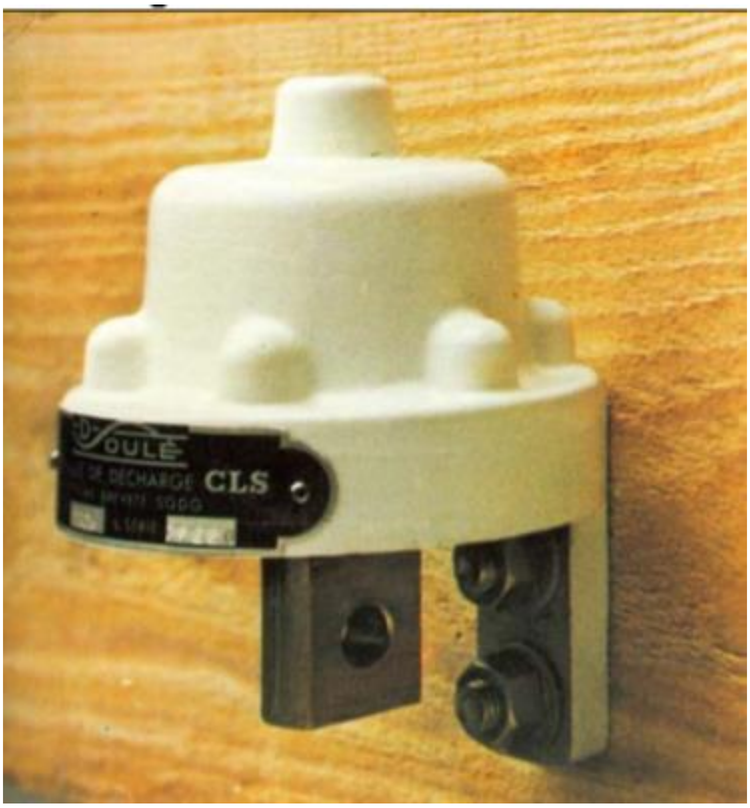

Figure 5 Typical voltage limiting device employed to discharge current to earth on AC Systems

Parameter	Value
Working voltage	**75 V AC**
Withstand voltage	**150 V AC**
Maximum sparkover voltage	**220 V AC**
Maximum leakage current under working voltage (mA)	**50**
Short duration flow capability (A / s)	**8 000 / ---**
Continuous flow capability (A / 30 min)	**4 000**

Table 2 Typical voltage limiting device characteristics for use on 25kV traction systems

5.5 Remote Monitoring

Where a VLD is installed to mitigate the touch potential risks between a pipeline and the rail traction system earth it is recommended that a remote monitoring device is installed.

VLDs can fail closed circuit and if such a failure did occur then the pipeline could be connected directly to the rail traction earth. The consequences of this would be that the pipeline CP levels close to the rail crossing could be compromised and because the pipeline would be connected to the rail earth the AC levels on the cross-country pipeline could increase.

There have also been cases where railway personnel have observed metal work close to a rail traction system that has been unintentionally connected to the rail system earth as routine inspection has identified a metallic structure in the CCZ.

Remote monitoring devices specifically design for monitoring pipeline CP systems should be used to monitor the AC current density to ensure it is within the limits described in BS EN ISO 18086 [1].

An AC coupon and reference electrodes should be installed at CP test facilities close to the railway so that the AC interference levels can be monitored following energisation of the traction system. The remote monitor shall be able to record the DC pipe to soil potential at any VLD installation so that an advance warning of loss of CP may be indicated.

5.6 Pipeline Connection

If there is no data on whether the pipeline is in direct electrical contact with any metallic components on the bridge. Then checks need to be conducted to determine whether there is effective isolation between the pipeline and the pipe support structure.

This is typically achieved by either a review of the pipeline and pipe support structure drawings or by testing.

A low earth resistance meter should be used to perform such testing and the device should be capable of providing a current of at least 50A to carry out the testing.

NR requirements are that a minimum of two connections from the structure to the traction return circuit shall be provided.

For structures that are not designed to carry current (such as overline pipes) the separate bonds shall be connected at a common point of connection on the structure. Where the construction of the structure is such that electrical continuity cannot otherwise be demonstrated, continuity bonds shall be installed across jointed sections.

If the pipeline is electrically connected to a bridge, then bonding the bridge metal work directly to the rail earth would effectively connect the gas pipeline to the railway earth.

Connection to the pipe bridge avoids the need to make any connection to the pipeline.

Where pipe bridges are of bolted construction it should not be assumed that the structure will be electrically continuous along its entire length and checks should be carried out to confirm the continuity of the bridge support structure.

Only fully welded connections should be used for connection to the pipeline so that they can take the fault current. Pin brazing or other pipe connection methods may not be able to withstand the likely fault current.

When determining if an impedance of a connection is low enough to prevent the existence of hazardous voltages, the maximum impedance of the connection to the traction return circuit should be less than 0.05 Ω. The impedance can be verified by measurement with a constant current of 50 A, whereby the open-circuit voltage should not exceed 50 V. Alternatively, where the impedance is determined by means of calculation, the calculated value should not exceed 0.02 Ω. (Based on the requirements of Clause 6.4.4 of BS EN 50153:2014 [33]).

6. DOCUMENTATION REQUIREMENTS

There should be a legal agreement in place between the pipeline operator and rail system operator to cover the maintenance of any touch potential mitigation measures.

The agreement should cover sharing of information particular in relation to access to the pipeline operator's data on its remote monitoring system and the NR information on operation of its remote monitoring via SCADA systems on any VLDs.

As built drawings for any mitigation system design should be updated and produced. Where VLDs are installed the rail system operator should be responsible for checking this and providing the data to the pipeline operator.

It is essential that the rail system operator and pipeline operator have agreed inspection procedures for the maintenance of any voltage limited devices going forward, and inspection arrangements are agreed to ensure the safety and integrity of any touch potential mitigation measures.

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APPENDIX A: ABBREVIATIONS

Abbreviation	Meaning
3LPE	Three Layer Polyethylene
A	Amps
AC	Alternating Current
AGI	Above Ground Installation
ALARP	As Low As Reasonably Practical
ATEX	Appareils destinés à être utilisés en ATmosphères EXplosibles.
BS	British Standard
CCTV	Closed Circuit Television
CCZ	Current Collector Zone
CIGRE	Conseil International des Grands Réseaux Électriques,
CIP	Close Interval Potential
CP	Cathodic Protection
CPR	Cardiopulmonary Resuscitation
CSA	Canadian Standards Association
DC	Direct Current
DNO	Distributed Network Operator
DSEAR	Dangerous Substances Explosive Atmospheres Regulations
EI	Energy Institute
ELV	Extra Low Voltage
EN	European Norm
ENA	Energy Networks Association
EPR	Earth Potential Rise
GPG	Good Practice Guide
GPR	Ground Potential Rise
GSM	Global System Mobile Communication
HAZCON	Hazards of Construction
HAZOP	Hazards of Operation
HSE	Health and Safety Executive
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
IEC	International Electrotechnical Commission
IET	Institute of Engineering Technology
IGEM	Institute of Gas Engineers and Managers
I/F	Isolation Flange
I/J	Insulation Joint
ILI	Inline Inspection
ISG	Insulated Spark Gap

Abbreviation	Meaning
ISO	International Standards Organisation
kA	Kilo Amps
kV	Kilo Volts
LEF	Longitudinal Electric Field
LFI	Low frequency Induction
MPI	Magnetic Particle Inspection
NACE	National Association of Corrosion Engineers
NDT	Non-Destructive Testing
OCLZ	Overhead Contact Line Zone
NE	Negligible Extent
OHL	Overhead Line
OLE	Overhead Line Equipment
ORR	Office of Road and Rail
PCR	Polarisation Cell Replacement
PD	Published Document
PSR	Pipelines Safety Regulations
PSSR	Pressure System Safety Regulations
QRA	Quantified Risk Assessment
rms	Root Mean Square
ROSPA	Royal Society for Protection of Accidents
SCADA	System Control and Data Acquisition
SGD	Spark Gap device
SSD	Solid State Decouplers
TBN	Technical Briefing Note
T/R	Transformer Rectifier
TS	Technical Standard
UV	Ultraviolet
V	Volts
VLD	Voltage Limiting Device

APPENDIX B: GLOSSARY

The definitions applying to this TBN are given below:

AC corrosion: corrosion caused by alternating current, which originates from an external current source.

AC discharge device: a device blocking DC current but allowing the flow of AC current; used in the connection between a cathodically protected pipeline and an earthing electrode.

AC Coupon: A circular 1 cm^2 surface area representative metal sample used to quantify the extent of corrosion, current discharge off the pipeline both AC and DC or the effectiveness of applied cathodic protection.

Barg, a unit of gauge pressure, i.e. pressure in bars above ambient or atmospheric pressure.

Bond: A piece of metal, usually in the form of rectangular strip, circular solid wire or stranded conductor, usually of copper, connecting two points on the same or on different structures to prevent any appreciable change in the potential of one point in respect of the other.

Capacitive coupling - the transfer of alternating electrical signals or energy from one segment of a circuit to the other using a capacitor.

Cathode: Electrically – the negative electrode of a cell. In the cathodic protection context it is the term given to the structure to be protected and where the cathodic reaction occurs, which in soil is reduction of dissolved oxygen in water.

Contact line: contact line conductor system for supplying traction units with electrical energy via current-collection equipment

NOTE This includes all current-collecting conductors and conducting rails or bars, including the following:

- reinforcing feeders
- cross-track feeders
- disconnectors
- section insulators
- over-voltage protection devices
- supports that are not insulated from the conductors
- insulators connected to live parts; but excluding other conductors, such as,
    - along-track feeders
    - earth wires and return conductors

Continuity bond: A bond designed and installed specifically to ensure the electrical continuity of a structure. This may be permanent or temporary, in the latter case it is used to connect two sections of a structure, which would otherwise be disconnected during the course of modification or repair.

Copper/copper sulphate reference electrode: A reference electrode consisting of copper in a saturated copper sulphate solution.

Coupon: A representative metal sample of known bare surface area used to quantify the extent of corrosion or the effectiveness of applied cathodic protection or AC interference.

Counterpoise: buried wires following an AC power line from tower to tower. The counterpoise arrangement is often used for reduction of the tower footing resistance in areas with high soil resistivity. Copper or galvanised steel can be used as counterpoise material. When made of copper, the counterpoise may be connected to the towers via spark gaps to avoid galvanic corrosion.

Current collector equipment fitted to the vehicle and intended to collect current from a contact wire or conductor rail.

Current density (on metal surface): current per unit metal surface area, usually expressed as Am^{-2}

DC decoupling device: A protective device that will conduct D.C. current when pre-determined threshold DC voltage levels are exceeded but will allow A.C. current to flow at all A.C. voltages.

DC withstand voltage - value of a D.C. voltage that the ISG can withstand during tests made under specified conditions and for a specified time.

Depolarisation: The change in the potential of the cathode as a result of cessation of current flow and is a time dependent process.

Drain point: The location of the negative cable connection to the protected structure through which the protective current returns to its source.

Earthing resistance: the electrical resistance between a metal surface (e.g. the steel surface in a coating holiday on a buried pipe, or an earthing electrode or an AC power line pole foundation) an remote earth.

Earth Potential Rise (EPR): the increased potential of an AC tower earthing point and the surrounding soil due to earth currents, especially the high fault current at a phase-to-earth fault in an AC. power line tower. The potential rise may also be caused by a lightning strike to the tower, and which may result in a phase-to-earth fault. The EPR is a function of the AC tower earthing and the soil resistivity.

(electrically) instructed person; Person adequately advised or supervised by electrically skilled persons to enable him or her to perceive risks and to avoid hazards which electricity can create

Groundbed: A system of buried or submerged electrodes connected to the positive terminal of an independent source of direct current, in order to lead to earth the current used for the cathodic protection of a buried or immersed metallic structure.

Ground potential rise (GPR): The maximum electrical potential that a substation grounding grid may attain relative to a distant grounding point assumed to be at the potential of remote earth. This voltage, GPR, is equal to the maximum grid current times the grid resistance.

NOTE—Under normal conditions, the grounded electrical equipment operates at near zero ground potential. That is, the potential of a grounded neutral conductor is nearly identical to the potential of remote earth. During a ground fault the portion of fault current that is conducted by a substation grounding grid into the earth causes the rise of the grid potential with respect to remote earth.

High voltage nominal voltage exceeding AC 1 000 V or DC 1 500 V

Holiday: A hole, break or other discontinuity in the coating on a pipeline, which causes the pipe surface to be exposed.

impulse sparkover voltage - impulse voltage of the waveshape 1,2/50 to classify the sparkover behaviour of the ISG.

Inductive coupling the coupling between two electric circuits through inductances linked by a common changing magnetic field.

Insulated flange: A flanged joint between adjacent lengths of pipe in which the nuts and bolts are electrically insulated from one or both of the flanges by the use of insulating sleeves and the jointing gasket is non-conducting, so that there is an electrical discontinuity in the pipeline at that point.

Insulated joint: A manufactured joint or coupling between two lengths of pipe, inserted in order to provide electrical discontinuity between them.

Interference phenomenon resulting from conductive, capacitive, inductive coupling between systems, and which can cause malfunction, dangerous voltages, damage, etc.

interference voltage - voltage caused on the interfered system by the conductive, inductive and capacitive coupling with the nearby interfering system between a given point and the earth or across an insulating joint.

Minor rail line: A rail line that **does not comply** with the definition of a Major Rail line.

Major Rail line All dual or multi-track rail routes with an average of more than 4 trains an hour, in either direction, measured over the busiest 8 hour period in any one day (Extracted from IGEM/TD/1 similar definition in PD-8010).

overhead contact line contact line placed above (or beside) the upper limit of the vehicle gauge and supplying vehicles with electric energy through roof-mounted current collection equipment.

overhead contact line zone (OCLZ) - Zone whose limits are in general not exceeded by a broken overhead contact line.

Pantograph apparatus for collecting current from one or more contact wires, formed of a hinged device designed to allow vertical movement of the pantograph head.

Permanent reference electrode: A permanently buried or immersed reference electrode designed for long life and installed close to the structure to enable the structure potential to be measured.

Power frequency withstand voltage - rms value of a sinusoidal power frequency voltage that the ISG can withstand during tests made under specified conditions and for a specified time.

Rated impulse sparkover voltage manufacturer's declaration of the ISG sparkover voltage.

Rated withstand voltage - value of a withstand voltage declared by the manufacturer to characterize the isolating behaviour of an ISG.

Rated power frequency withstand voltage - value of a power frequency withstand voltage declared by the manufacturer to characterize the isolating behaviour of an ISG.

Reference electrode: A device used to compare potentials at various locations by providing a standard for potential measurement. Electrodes may be made of zinc, copper in a saturated copper sulphate solution or silver and silver chloride in a chloride ion solution of known concentration.

Sparkover voltage - maximum voltage value before disruptive discharge between the electrodes of the ISG.

Stray current: Incidental current picked up by a structure from adjoining foreign sources.

Soil resistivity: specific resistance of a soil to carry electric current. Soil resistivity is expressed in Ω m (earlier in Ω cm). The lower the soil resistivity, the easier it is for electric current to flow through the soil. Fine-grained soils with water holding capacity (clay, silt, peat etc.) usually have low resistivity, whilst coarse grained and water draining soils (sand, gravel, till etc.) usually have a high resistivity. The water and salt content of the soil have a large influence on the resistivity. A high water and a high salt content results in a lower resistivity. Road de-icing salt, which is drained through the soil, lowers the soil resistivity.

Sparkover voltage - maximum voltage value before disruptive discharge between the electrodes of the ISG.

Touch voltage: The potential difference between the ground potential rise (GPR) and the surface potential at the point where a person is standing while at the same time having a hand in contact with a grounded structure.

Voltage-limiting device (VLD) protective device whose function is to prevent existence of an impermissible high touch voltage.

Withstand voltage - value of the test voltage to be applied under specified conditions in a withstand test, during which a specified number of disruptive discharges is tolerated.

APPENDIX C: FACTORS TO BE CONSIDERED

A summary of factors to be considered with rail electrification

Item	Factor to be Considered
1.0	The nature of the new rail electrification system i.e. whether AC or DC.
2.0	The electrical parameters of any new system, operating voltage, power loading and in particular the available fault current at the pipeline crossing location.
3.0	The touch potential risks associated with rail electrification on above ground structures associated with the pipeline system need to be considered by both the pipeline operator and the rail system operator.
4.0	The height of the pipeline and any supporting structure above the rail line and its electrification system.
5.0	The location of rail traction system pylons in relation to a pipeline and its associated supports together with the GPR rise during fault conditions on pylons in close proximity to any metallic structures associated with the pipeline system.
6.0	The separation distance between the overhead powerline conductor, earthing wires and the pipeline and any pipe supports.
7.0	Whether any I/Js or I/Fs are present each side of the railway line to electrically isolate the buried from the above ground pipework.
8.0	If there are any flanges or fittings that can create a flammable atmosphere associated with the overhead pipeline system, then the nature and extent of any hazardous areas created needs to be confirmed.
9.0	The condition of the above ground pipeline coating and the coating on any pipeline support structure.
10.0	The condition of any pipe support structure, whether any fixings bolts need to be replaced or have suffered degradation and if there are signs of deterioration on the support structure. Consideration may need to be given to conducting a stress analysis.
11.0	Ascertain that the overhead pipeline and any metallic support structure is electrically continuous along its entire length.
12.0	Confirm that any pipe support structure has sufficient levels of electrical continuity along its entire length, as often these are of a bolted construction and electrical continuity on the entire structure may vary.
13.0	Determine whether the pipe support structure is electrically isolated from the pipeline or other earthed structures.
14.0	Determine if the pipe support structure is cathodically protected i.e drains CP current from the pipeline.
15.0	Determine the CP status of any buried pipework on rail system operator property.

Item	Factor to be Considered
16.0	Is the pipeline suitably identified with details of the product being transported and are emergency contact details identified?
17.0	Ensure the adequate anti-vandal protection measures are in place and electrical hazard signs are installed.
18.0	Will any proposed rail electrification system change the number of trains and passengers that use the railway and thus change the railway line classification from a Minor to a Major rail line as defined in the pipeline design standard e.g. IGEM/TD/1 or PD 8010-1, as that could affect the extent of pipeline proximity wall thickness pipe required each side of any rail crossing?
19.0	Does the pipeline coating or the coating of any support structure need to be repaired and if so, can it be replaced before the railway line is electrified?
20.0	Will there need to be any changes to the pipeline CP system as a result of any rail electrification system.
21.0	Does the buried section of any pipeline run parallel with the rail line for any appreciable distance and would the long-term AC interference on the pipeline increase as a result of the rail electrification system?
22.0	Ensure overhead pipeline crossings are included in vantage point surveys and line walks and the condition of a pipeline at any rail crossing is included in pressure affirmation reports.
23.0	If any pipeline girths weld will be exposed as part of any coating application or repairs? Some pipeline operators classify girth welds before a specified date as of unknown quality and require either radiography or phased array inspection to confirm girth weld quality.
24.0	The requirements for a lightning risk assessment should be considered – BS EN 62305-3.