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1 Purpose

The purpose of this Guideline is to provide guidance on the management of electrical hazards for designers and constructors of metallic pipelines.

Note: It is not the intention of this Guideline to prescribe detailed measures to reduce electrical hazards associated with pipeline construction. For most electrical hazards there are industry standard mitigation measures which should be followed. Where specific Water Corporation expertise exists, the appropriate Corporation documents will be referenced in Safety in Design Reports. The availability of this document (as a reference document) is highlighted to Contractors in the [Health Safety and Environment \(HSE\) Handbook for Contractors](#) and can be made available upon request to the Water Corporation Contract Manager where relevant.

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2 Scope

This guideline applies to electrical risks in the construction of metallic pipelines by Water Corporation personnel or Contractors performing works under contract. This includes, but is not limited to, inductive coupling or conductive coupling from adjacent power lines.

The management of induced voltages in existing metallic pipelines for operations and maintenance activities are separately described in the [Pipeline Voltage Mitigation](#) procedure.

3 Discussion

Pipelines can exist in various configurations throughout the construction works, such as at various stages during construction, following pipeline installation, and following voltage mitigation installation, each of which can present hazards that are unique to the respective pipeline configuration. Above and below ground

metallic pipelines are frequently installed in locations or easements in close proximity to overhead high voltage transmission and distribution power lines, underground high voltage cables, and other electrical infrastructure. Pipelines and construction equipment located within an area of influence of these electrical sources can be subjected to hazardous voltages which may have the potential to cause injury or death. Electrically powered tools also present potential electrical hazards regardless of the pipeline location with respect to electricity networks.

The intent of the Guideline is to give an overview of the types of electrical hazards that exist, whether the Water Corporation has specific expertise in that hazard, and therefore, what specific mitigation measures should be adopted, and which hazards should be considered and assessed.

4 Safety in Design Report

Since every workplace and situation will be different, it is the **responsibility of the designer and/or construction contractor** to evaluate and implement suitable safety measures that would suit the specific worksite. Identified hazards and respective control measures shall be documented in a project specific 'Safety in Design' report. If there is no 'Safety in Design' report for the project, then work on the pipeline installation and/or hazard mitigation should not proceed.

Typical sources of potential electrical hazards during pipeline construction works are:

- Overhead High Voltage Transmission and Distribution Power Lines,
- Underground Power Cables,
- Portable Electrical Welding Machines,
- Portable Generators,
- Electrically Powered Tools,
- Electrical Extension Leads,
- Static Electrical Energy,
- Lightning,
- Induced Voltage (AC Interference)
- Capacitive Voltage (AC Interference)
- Rail Traction Systems

It is recommended, for pipelines that have been identified as affected by induced voltages from overhead or underground high voltage, that an electrical engineer, as part of the Project Management team, and familiar with pipeline voltage mitigation concepts, be present during the preparation stages of the pipeline installation to give direction, guidance and interpretation of the electrical safety in design documentation. Refer to the [Safety in Design](#) Work Instruction (#4460582).

5 Electrical Hazards and Risk Management Considerations

5.1 Electricity Transmission and Distribution Infrastructure

5.1.1 AC Interference

Inductive Coupling

Metallic structures located near high voltage transmission and distribution lines are subject to induced potentials due to the magnetic fields associated with the current carrying components of the power system. Inductive coupling is greatest when the metallic pipeline is parallel to the power system over a long distance. There is no inductive coupling when the metallic structure traverses the power system orthogonally (i.e. at right angles).

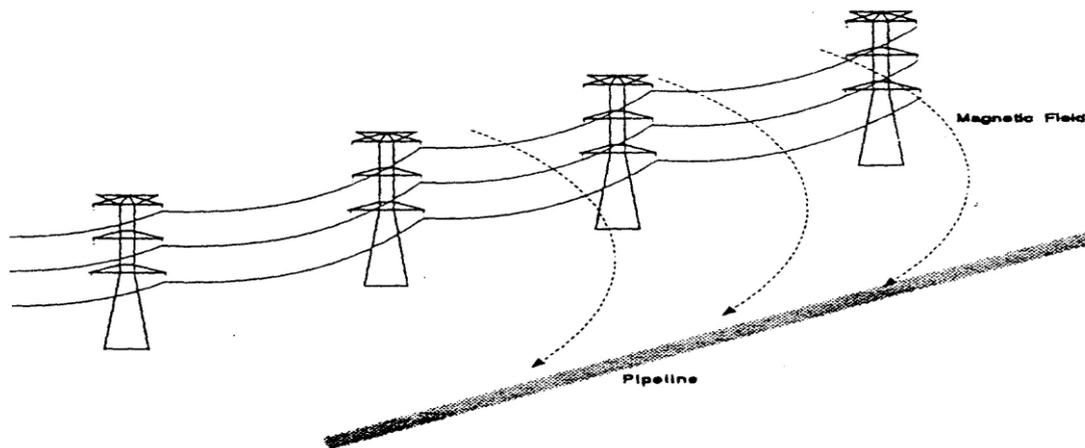
Induced potentials during normal load conditions are relatively small due to low normal load line currents and balanced line currents causing low resultant magnetic fields. However, safe touch voltage limits are also lower due to the body's ability to withstand such touch voltages for extended periods of time. Hazardous touch voltages due to steady state load currents are less likely than those during fault conditions but should still be analysed and included in the 'Safety in Design' report.

Single phase to earth faults result in the largest magnitude induced potentials due to the large magnitude fault current and the associated large current imbalance and therefore represent the worst case source of induced potentials on pipelines.

The worst-case touch voltage due to LFI occurs when a person touches an unearthed accessible conductive part on a pipeline that is insulated from earth. In this case, touch voltage is equal to the pipeline potential. It is not uncommon, during fault conditions, for the touch voltage on a pipeline to exceed 1000 volts.

Conductive Coupling

When phase to earth faults occur at electrical infrastructure such as substations and earthed poles or towers, large currents are injected into the soil through the associated earthing systems, thus raising the potential of the surrounding soil. Conductive coupling becomes a hazard wherever electricity network earthing systems exist near a pipeline and does not depend on the orientation of the pipeline to the electricity feeder. See diagram below.



The worst-case touch voltage at a pipeline due to conductive interference occurs when a well-insulated and remotely earthed pipeline passes near a faulted pole or tower. In this case, the resultant touch voltage is equal to the local soil potential adjacent to the pipe.

Total Touch Voltage Hazard

The total touch voltage hazard is the potential difference between the pipe and the adjacent soil as a result of both inductive and conductive coupling mechanisms. The hazards arising from LFI and conductive coupling are additive and therefore the resultant total touch voltage hazard can be higher than the touch voltages produced by each coupling mechanism independently.

It must be noted that hazardous touch voltages on pipelines cannot be attributed exclusively to very high voltage transmission feeders. It is commonly the case that 22kV distribution feeders provide the worst case fault scenario due to the use of less sophisticated feeder protection and higher outage rates as compared with transmission networks.

Action:

- An AC Interference analysis shall be performed by designers to quantify the total touch voltage hazards that will exist at the worksite. The results from this analysis shall be included in the project specific 'Safety in Design' report.
- The project specific 'Safety in Design' report prepared by the designers should consider:
 - Mitigation strategies for Earth Potential Rise (EPR) on earthing systems adjacent to the pipeline.
 - Maximum lengths of continuous pipeline sections before temporary mitigation measures are necessary to mitigate the effects of AC Interference. This includes sections of rubber ring jointed (RRJ) pipes where RRJs are bridged by deliberate bonds, or water within the pipeline. Note that RRJs cannot be considered to break the continuity of the pipeline whilst the pipeline is full of water as the contents of the pipe can provide an alternative path for current which bypasses the RRJ.
 - Mitigation strategies for sections of pipeline that exceed the maximum safe lengths specific to the project.

- Personal Protective Equipment (PPE) requirements for construction works. This may include the use of insulated safety boots and insulated gloves with a voltage level specified as per AS 2225-1994 dependant on the maximum expected touch voltages. Note that with the use of PPE, care has to be taken that no part of the body not directly protected by the PPE can make contact with either the pipeline or the ground, thus providing a conductive path for fault current.
 - The establishment of temporary work area earthing, such as equipotential mats bonded to the pipeline, for specific tasks where additional protection is required, or where electrical PPE requirements cannot be fulfilled, depending on the nature of the task at hand or expected touch voltage levels.
 - In some extreme cases a power line that gives rise to hazardous touch voltages that cannot be made safe may need to be de-energised by the electricity Supply Authority to remove the hazard for the duration of the works.
 - It must be noted that hazards may still exist on the pipeline during construction if the AC Interference analysis has only considered the final pipeline configuration. Analysis should therefore be undertaken by designers to determine electrical hazards on the pipeline throughout the various stages of construction, and additional mitigation earthing systems or work procedures may need to be implemented for the duration of the construction works.
- The considerations of Water Corporation OSH document [Pipeline Voltage Mitigation](#) should be read in conjunction with this document.

Capacitive Coupling with Overhead High Voltage Power Lines

Metallic objects positioned near high voltage electricity feeders, which are insulated from ground, can develop a voltage with respect to earth through capacitive coupling with the high voltage lines. This can be particularly pronounced when lengths of pipe are suspended below high voltage lines using cranes, especially with rubber or similar insulating tyres and/or where outriggers are insulated from ground with timber or similar material. Loads suspended with non-conductive lifting slings can also develop a hazardous touch voltage whether or not the crane is earthed.

Action:

- Whenever high voltage transmission or distribution power lines exist near¹ the work site, capacitive coupling can potentially produce hazardous touch voltages to cranes and pipe sections when the pipe sections are suspended below or near to the overhead high voltage line. As such, all cranes and conductive loads must be earthed via an earthing electrode whenever a lift is taking place.
- A JSEA (Job Safety Environment Analysis) shall be carried out with all construction site staff, who shall be conversant with all safety hazards and emergency procedures.

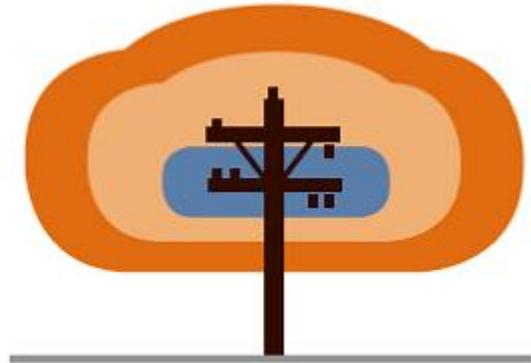
5.2 Direct Contact with Overhead Power Lines

Overhead power lines adjacent to pipelines present a significant hazards in terms of possible contact with the power line with cranes, trucks etc. during construction works.

Electric shocks can result where a person is touching a piece of machinery which comes into contact with a live overhead power line. Additionally, if a rubber tyred vehicle comes in contact with energised power lines and the tyres blow out, persons nearby can be seriously injured by the resultant heat, light and mechanical energies released. Allowable proximity to overhead power lines is illustrated below:

¹ Depending on the voltage of the overhead transmission line, the allowable clearance to the worksite may vary. This distance should be specified in the 'Safety in Design' report.

Danger zones near overhead powerlines



| | | |
|--|-------------------------------------|-----------|
| | Less than 1,000 volts (low voltage) | 0.6 – 1 m |
| | 1,000 - 33,000 volts (high voltage) | 3 m |
| | 33,000-330,000 volts (transmission) | 6 m |

Action:

- Before engaging in any work activity in the vicinity of overhead power lines, a [Request to Work Near Overhead Power Lines - Western Power](#) must be completed and sent to Western Power (this document is available from the Western Power website).
- The *Occupational Safety and Health Regulations 1996* states that a person having control of the workplace must ensure that an employee or any plant or material used or controlled by an employee does not enter the danger zone of an overhead power line as defined in Regulation 3.64.
- If it is anticipated that any task associated with the works will result in an employee, plant or material entering the danger zone, coordination with the local Electricity Supply Authority must be made to remove the hazard for the duration of the task.
- Vehicle heights and crane reaches (including loads) must be accurately known before works commence to determine the possibility of any employee, plant or material encroaching within the danger zone during any of the construction works.
- In some cases the overhead power lines may need to be de-energised by the electricity Supply Authority to remove the hazard. In this case the power line must still be treated as being alive unless work is being carried out under a Supply Authority permit to work whereby the Supply Authority has proven the feeder dead and all phases of the feeder has been earthed either side of the worksite.
- Specific details of hazards for each project shall be addressed by the designers in the respective 'Safety in Design' report.
- JSEAs (Job Safety Environment Analysis) shall be carried out with all construction site staff, who shall be conversant with all safety hazards and emergency procedures.

5.3 Underground Power Cables

The digging up of energised underground power cables during pipeline construction works and during drilling and boring operations, may be infrequent but still can occur. Coming in contact with the cable by operating machinery may damage the cable insulation which may result in electrical energy being discharged through the machinery and any persons in contact with the machinery.

Action:

- DBYD (Dial Before You Dig) to locate all underground service and power cables.
- Cables may need to be manually exposed and protected before pipeline work commences.

- In some cases the power cables may need to be de-energised by the electricity Supply Authority to remove the hazard.
- JSEAs (Job Safety Environment Analysis) shall be carried out with all construction site staff who are conversant with all safety hazards and emergency procedures.
- See Water Corporation document S033 [Avoid Contact with Services](#).

6 Lightning

As pipelines are generally electrically continuous over a significant length, they present a significant collection area for lightning both through direct strike to the pipeline, appurtenances, or plant metallicity bonded to the pipe, and through electrical induction in the pipe due to lightning electromagnetic pulses. As pipelines that have modern coatings or are installed above ground are generally well insulated from earth, the effects of lightning are not able to be readily dissipated to earth and can therefore propagate over large distances along the pipeline. This can manifest itself as hazardous touch voltages at exposed locations along the pipe and can also lead to coating damage where pipe potentials exceed the breakdown voltage of the coating.

Action:

- AS/NZS 4853 recommends that an earth electrode with a nominal resistance of 5 ohms be installed at each end of a pipeline section. This would be satisfactory for a pipeline that is in sections during construction works. The required location of lightning protection earth terminations at various stages throughout the construction works should be identified by the designers in the project specific 'Safety in Design' report. Temporary lightning protection earthing systems may be integrated into the permanent voltage mitigation earthing system design.
- As the occurrence of power line faults and lightning-induced surges is increased during lightning activity, pipeline construction work shall be suspended whenever thunderstorms can be seen or heard.

7 Rail A.C. & D.C. Traction Systems

A.C. Traction systems

A.C. traction systems can produce similar effects on pipelines as those resulting from LFI caused by high voltage electricity networks. The analysis however is made more complex due to the fact that the traction current has a variable location due to the movement of the traction car and variable magnitude with variation in acceleration.

D.C. Traction Systems

Hazards can arise on pipeline as a result of 'stray' current from d.c. traction systems. This will be particularly pronounced for modification works to pipelines which have drainage bonds designed to mitigate the effects of traction return currents on pipeline cathodic protection systems. These drainage bonds bring conductors from the pipeline and the d.c. traction rail via control equipment designed to drain stray d.c. current from the pipeline to the rail. The drainage bonds can exacerbate the effects of LFI from electricity networks and can also introduce further hazards resulting from faults on the d.c. traction system.

Action:

Analysis of hazards arising from a.c. or d.c. traction systems should be undertaken by designers to quantify total touch voltage hazards that will exist at the worksite. The results from this analysis shall be included in the project specific 'Safety in Design' report.

10 Portable Electrical Equipment

The following applies to:

- Portable electrical power tools,
- Portable electrical generators,
- Portable electrical welders,
- And all associated leads, etc.

General Electrically Powered Tools

On construction sites the most common cause of electric shock comes from defective portable electrical hand tools and extension leads.

Action:

Typical workplace safety requirements for portable tools should be employed. A list of typical requirements has been reproduced below.

- Pre-use inspections
- Earthing
- Portable RCDs
- Housekeeping
- Test and tagging program
- Tagging and isolation
- Resuscitation qualified electrical personnel
- All electric leads kept dry
- All electric leads kept insulated
- No live work situations

Industry accepted mitigation measures shall be adopted for all of the above electrical hazards, except where specific Water Corporation procedures apply.

Welding and Allied Processes

Applicable general hazard considerations discussed above apply also to welding, however additional hazards specific to welding need to be addressed.

Welding typically utilises an electrical current to produce the energy required to form a bond between materials being welded. As such an electrical circuit is formed which includes the work pieces and welding leads, all of which have to be considered as electrically alive. As with all electrical circuits, hazards arise for persons when they become part of the electrical circuit and therefore form a path for current to flow through the body.

Open circuit voltages between a welder electrode and 'work' lead typically exceed safe touch voltage limits and therefore present a hazard should simultaneous contact between the two occur. In addition, welders fitted with high-frequency arc-starting devices can deliver voltages up to 6500V at a current up to 100mA during operation. Currents of this magnitude can well exceed heart fibrillation current limits dependant on the period of exposure, and may result in death or serious injury.

Action:

- Safe work procedures in line with AS 1674.2 should be discussed in the 'Safety in Design' report and implemented for welding operations.

11 Static Electrical Energy

A build-up of static electrical energy in coated metallic pipelines can typically result from dry materials being blown across the pipe such as from preparation of the pipeline using sandblasting or from debris blown over the pipe by wind. The discharge of static electricity itself is not typically considered to present a significant hazard to workers; however the resultant physical response of a person experiencing a discharge may cause associated physical injuries. An arc resulting from discharge to an earthed conductor may possess enough energy to cause ignition of flammable substances.

Earthing system mitigation for the effects of LFI and lightning usually far exceed the earthing system requirements for the control of static electricity, however this should be assessed for each project and should be included by designers in the 'Safety in Design' report.

Action:

- Safe work procedures in line with AS/NZS 1020 'The Control of Undesirable Static Electricity' should be discussed in the 'Safety in Design' report and recommended for implementation where static electricity is likely to be present.

8 Definitions

| Term | Description |
|---|--|
| Appurtenances | Equipment installed in a pipeline, usually a valve, or fitting. In this Guideline, an appurtenance is a pipeline fitting that is above ground whilst the mains structure (the pipeline) is underground. |
| Earth Potential Rise (EPR) | The electrical potential difference between an earthing system and a remote earth reference point ideally assumed to be at zero volts. EPR is equal to the earth grid current multiplied by the grid resistance. |
| Job Safety Environment Analysis (JSEA) | A documented risk assessment which breaks down the job into work steps with the identified hazards and required control measures formally recorded for each step. |
| Low Frequency Induction (LFI) | Voltages induced in metallic pipelines due to their proximity to power lines carrying high voltage electricity. |
| Potential | Voltage between an observation point and reference earth. |
| Safety in Design Report | A written report on the occupational safety and health requirements of the design, as per the requirements of the <i>Occupational Safety and Health Regulations 1996</i> . |
| Touch Voltage | A potential difference between a conductive object and soil separated by a horizontal distance of one (1) metre, a person's normal horizontal reach |

9 Compliance Mapping

| Task | Legislation |
|---|---|
| Metallic pipeline design and construction | Occupational Safety and Health Act 1984 |
| | Occupational Safety and Health Regulations 1997 |
| | Electricity (Licensing) Regulations 1991 |
| | AS/NZ 2225 Insulating Gloves for Electrical Purposes |
| | AS/NZ1319 - Safety Signs for the Occupational Environment |
| | AS/NZS4853 - Electrical Hazards on Metallic Pipelines |
| | AS/NZ1674.2 - Safety in Welding and Allied Processes - Electrical |

10 References

| Document Number | Title |
|-----------------|--|
| S022 | Personal Protective Equipment and Clothing |
| S033 | Avoid Contact with Services |
| S133 | Electrical Safety |
| S145 | Machinery, Plant and Equipment |
| S216 | Excavations |
| | Pipeline Voltage Mitigation procedure |
| WC-OSH 109 | Tagging and Isolation |

| Document Number | Title |
|-----------------|--|
| WC-OSH-007 | Safe Job Planning |
| | Safety in Design Work Instruction |
| WC-OSH 024 | Selection and Management of Contractors |
| | Health Safety and Environment (HSE) Handbook for Contractors |
| WC-OSH-SWMS-034 | Working in the vicinity of overhead power |

| Document Revision History | |
|---------------------------|--|
| 22 Apr 2014 | Original version. Refer to MOC # 10241700 |
| 15 Feb 2017 | Low level review with no change in the body of the document. |