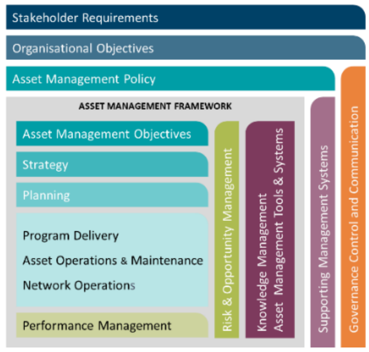
Western Power’s Asset Management System



Distribution Substation Plant Manual 2019
Chapter 5 – Substation Fire Risk

Original Issue: December 2019

Content Owner/Custodian: Distribution Design and Standards

This Revision: 1 – March 2021

Date for Next Review: March 2024

© Western Power
ABN 18540492861

Document control

Endorsement approvals

	Name	Title	Signature & Date
Author	Gareth Chadwick	Senior Standards and Technology Officer	Gareth Chadwick
Checked	Grant Stacy	Principal Engineer	Grant Stacy
Endorsed by	Lanka Thabrew	A / Engineering Team Leader	Lanka Thabrew
Approved by	Justin Marshall	Distribution Design Manager	Justin Marshall

Record of revisions

Revision No.	Date	DM version	Revised by	Description
0	December 2019	0	Gareth Chadwick	Original
1	March 2021	1	Gareth Chadwick	Name of Chapter updated to substation fire risk. Mitigation options updated to include oil containment and guidance included for a risk-based approach to distribution substation design / transformer fire risk mitigation.

Key documents providing direction and influencing this document

Doc #	Title of document
DM# 40304923	Asset Management System
DM# 41965928	Safety in Design Guidelines
DM# 50473207	DSPM Governance and Technical Documents Register (internal use only)

This document gives direction to and influences the following documents

Doc #	Title of document
Various DQM documents	Distribution Substation Design Projects

Stakeholders (people that were consulted when document was updated)

Position / Function / Section
Asset Management - Asset Performance
Asset Management – Safety Environment Quality and Training
Asset Management - Grid Transformation
Asset Operations – Network Operations
Asset Operations – Operational Services
Asset Operations – Customer Connection Services
Business and Customer Service – Customer Service

Notification list (people to be notified when document is updated)

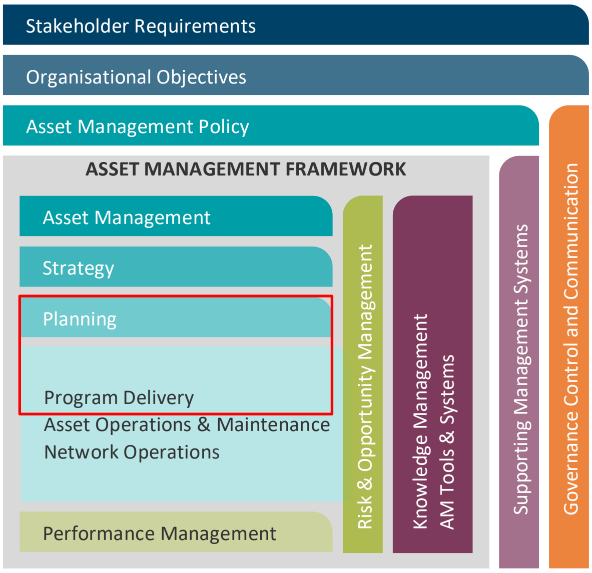
Position / Function / Section
Asset Management - Asset Performance
Asset Management – Safety Environment Quality and Training
Asset Management - Grid Transformation
Asset Operations – Network Operations
Asset Operations – Operational Services
Asset Operations – Customer Connection Services
Business and Customer Service – Customer Service

This document must not be made available to personnel outside Western Power without the prior written approval of Western Power.

Document classification and hierarchy

A key requirement of the Western Power Asset Management Policy (AMP) is to develop and maintain an Asset Management System (AMS). This Distribution Substation Plant Manual is defined as a technical document within the AMS document classification and structure and sits within the planning and Program Delivery components of the AMS.

The AMS and the interrelationships between the collection of documents, tools and systems that are used for asset management are described in the AMS document EDM# 40304923.



Contents

1. Introduction

This Chapter of the Distribution Substation Plant Manual (DSPM) forms an essential part of Western Power's ground mounted distribution substation design standard and other supplementary information regarding the fire risk associated with this ground mounted substation plant. This Chapter also includes guidelines on how this risk can be addressed.

Transformers and HV switchgear installed in distribution substations can pose a fire risk. At times of severe faults, the tanks of transformers can be damaged to the extent that the oil used for insulation and cooling could leak out. The oil could potentially be ignited by the arcs present during faults that result from loss of insulation (which could last for several seconds). The probability of a transformer fire across electricity utilities is in the order of 0.1 %[1] per transformer service year (i.e. 1 fire per 1000 in service transformers per year). This is not a high probability, but the consequence may be total loss of the transformer and often with potential collateral damage such as to adjacent assets, public impact, environmental pollution and/or loss of power supply to customers. Also, whilst a probability of 0.1 % may appear to be low, the accumulated probability of the event happening is on average 4 %[2] per transformer over a typical service life of 40 years. As such, it is essential that fire protection safeguards are provided in the design of distribution substations.

Generally, the fire risk associated with Distribution Transformers installed on Western Power's network is relatively low with few transformer fires occurring in the past. These incidents were mainly associated with lightning strikes on pole top transformers, in non-built up areas. However, there may be sites with ground mounted transformers where measures may be taken to further reduce the fire risk. An example of this is where it is not practical to maintain the required fire clearances between Western Power's substation equipment and other structures or buildings due to land size restrictions.

This Chapter of the DSPM provides guidance on the fire clearances that are required based on the volume of oil contained within the distribution transformers and fire risk mitigation options that must be considered by the Distribution Designer. Please refer to Chapter 4 of the DSPM – Plant General Arrangements for the oil volumes associated with specific transformers.

2. Disclaimer

The information contained within this Chapter must not be used for anything other than its intended purpose (as stated within this chapter). Other documents that refer to the information within this chapter must not change the intended purpose whether it is written or inferred.

This Chapter alone does not claim to demonstrate compliance with any Government Regulations or Industry Standards. This Chapter and its drawings are to be read in conjunction with the following Western Power documents:

- Western Australian Distribution Connections Manual (WADCM)
- Underground Distribution Schemes Manual (UDSM)
- Overhead Line Design Manual (OHLDM) for DSM 3-24 drawing.
- Distribution Design Catalogue (DDC)

The information within this Chapter is generic in nature and may not be suitable for all electricity network substation sites. It is the Distribution Designer's responsibility to make sure that the information in this Chapter and its drawings are suitable for the proposed substation site prior to use.

1 CIGRE 537 Risk Context Clause 1.2
2 CIGRE 537 Risk Context Clause 1.2

3. Identify the Hazard - Distribution Transformers as a Fire Hazard

Before documenting the hazards associated with a fire on a Western Power distribution transformer, it is important to understand some of the basic features incorporated into the design of the transformers and the possible causes of a failure.

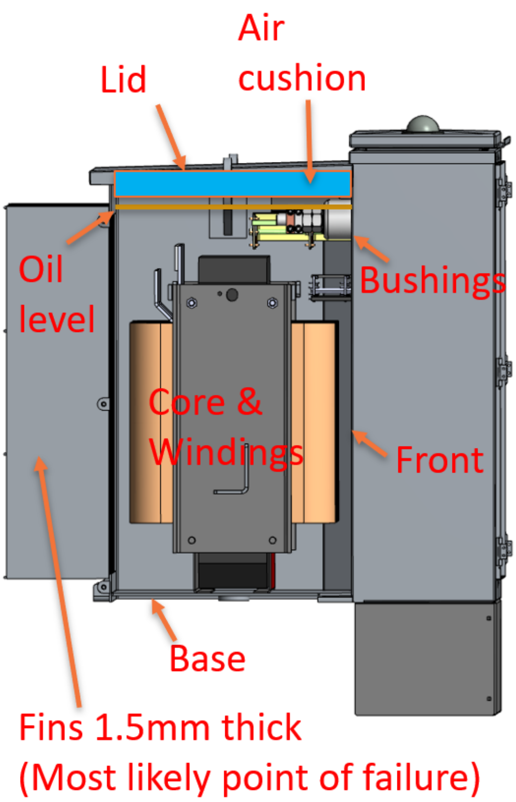
3.1 Design Features of Distribution Transformers

Ground mounted transformers procured by Western Power are Oil Natural Air Natural (ONAN) cooled, of a hermetically sealed steel tank design that contains the transformer core surrounded with the HV and LV foil type windings. These windings and the connecting leads are separated and insulated from each other using oil impregnated upgraded wood pulp insulation. The tank is filled with O class (mineral) oil that is used for insulation and cooling of the winding assembly and connecting leads. The tank is filled with oil to a level that ensures insulation is maintained and adequate cooling is provided during normal operating conditions. There is a cushion of air that sits above the oil and allows for thermal expansion as the transformer heats up and is also partially absorbed into the hot oil. As the transformer continues to heat up the pressure inside the tank will increase due to thermal expansion. The cooling fins at the rear of the tank are designed to expand to allow for this increase in volume of the oil and pressure.

These transformers are specified to have temperature rise limits of 60 Kelvin (K) for the oil in the top of the tank and 65K for the average winding temperature. This means when operated at the name plate rating of the transformer with a surrounding ambient temperature of 20°C the transformer is designed so the temperature rise limits will not be exceeded. Under normal operating conditions these transformers are expected to have a service life of approximately 35 - 40 years based on the aging rate of the upgraded wood pulp insulation at an average annual ambient temperature of 20°C.

Figure 3.1 below provides a basic diagram showing the design of the inside of a Non MPS transformer tank.

Figure 3.1: Typical Distribution Transformer Tank Design



3.2 Possible Failure Modes of a Distribution Transformer

If the ambient temperature is increased or the transformer is operated above the name plate rating, the oil temperature and winding temperature within the core and coil assembly will also increase. This will cause accelerated aging of the wood pulp insulation and an increase of the internal tank pressure. Overloading above the name plate limit will result in a condition that will cause the transformer to have an increased risk of failure. Short-time emergency overloading causes the winding conductor hot-spot temperature to reach a level likely to result in a temporary reduction in the dielectric strength (voltage withstand capability) of the insulation. Acceptance of this condition for a short time may be preferable to loss of supply. This type of loading is expected to occur rarely, and the load should be quickly reduced, or the transformer disconnected within a short time in order to avoid its failure. The permissible duration of this load is shorter than the thermal time constant of the whole transformer and depends on the operating temperature before the increase in loading; typically, it would be less than half-an-hour.

Overloading of the transformer within the cyclic rating or the emergency rating for short periods of time when starting from a cool condition can be tolerated as the transformer has a large thermal mass that can absorb and release large amounts of heat, however, this will cause accelerated aging of the wood pulp insulation.

Excessive or prolonged overloading over and above a top oil temperature limit of 105°C[3] or a winding temperature limit of a 140°C when the transformer is already hot will result in insulation breakdown or the tank pressure exceeding the serviceably limit of its mechanical design and fittings (e.g. bushings, gauges, gaskets, etc.). Temporary deterioration of the mechanical properties at higher temperatures could also reduce the short-circuit strength of the transformer. The transformer can be expected to catastrophically fail at any time during or after this overloading event without warning. Failures are mostly caused by a breakdown of insulation which can happen for many different reasons. These include normal ageing and deterioration, contamination (usually due to moisture ingress due to a failed gasket), cracking of the tank and bushings or other similar mechanical failure mechanisms, over-voltages such as lightning, overheating, vermin, mechanical stress due to through fault current or tank corrosion, etc.

Western Power has also experienced transformer failures due to leaking bushing gaskets on the high voltage and low voltage side of the transformer. These bushings provide an insulated path for the electricity to enter and exit the transformer tank below the oil level. Sideways, horizontal or vertical forces applied to the bushings can result in the gasket seal between the tank and the bushing to become compromised and cause oil to leak from the transformer. This loss of oil over a prolonged period can result on the bushing leads and in server cases the transformer core and windings becoming exposed to air and will result in insulation breakdown and possible flashover within the tank. Where leaking bushings are encountered the transformer will need to be listed as defective and needs to be removed from service and replaced.

3.3 Consequences of Distribution Transformer Failure

When a failure occurs, a large fault current (often many thousands or tens of thousands of Amps) flows through an electric arc at the point of failure. A large amount of energy (tens to hundreds of Mega Watts) is released in a small space, and the temperature of the arc can reach up to 20,000°C. The fault arc can be in open air, for air insulated components like LV switchgear and cable bushings, or under oil within the transformer tank. While relatively rare, the result may be an explosion, due to the large amount of energy released, with a high potential for fire. When the insulation breakdown occurs within the transformer tank the arc immediately dissociates the oil in the close vicinity into hydrocarbon gases and high local pressure is created which may split transformer tanks. The gases and oil vapour are expelled under pressure, and an explosive mixture of gases, vapour and oxygen can be created external to the tank. The mixture may

[3] Top oil temperature rise of 60°C plus an ambient temperature of 45°C

deflagrate[4] in the substation building or substation room within the host building, causing shock waves and pressure that can cause structural damage. In some examples around the world these events have been known to cause structural collapse of the building. An immediate and instant oil pool fire usually follows the oil vapour explosion as the remaining oil that is leaking from the transformer tank is hot and will most likely be close to the flash point temperature of the oil[5] and may be ignited by an arc.

3.4 Transformer Oil as the Fire Source

As the transformers used by Western Power contain a quantity of Nytro Libra oil, with a minimum flash point of 135°C, the hydrocarbon heating regime shown in Appendix B of AS/NZS 1530.4 shall be used instead of the standard curve to determine the fire resistance of any structure or building construction surrounding or within close proximity to the substation site.

This transformer oil has the following properties that can be used in radiated heat flux calculations[6]:

- Mass Burning Rate = 0.039 kg/m^2-sec
- Heat of Combustion = 46,000 kJ/kg
- Density = 760 kg/m^3
- Empirical Constant kb = 0.7 m-^{1}

The general arrangement (critical dimensions) of Western Power's distribution transformers as well as the quantity of oil contained in the transformers is provided within Chapter 4 of the DSPM.

3.5 Transformer Tank as a Pressure Vessel

Western Power's transformers are typically of a hermetically sealed steel tank design. Every tank is subject to routine pressure test during the manufacturing process. This pressure test involves applying an internal absolute pressure of 30kPA above atmospheric pressure (100kPA) for 30min (gauge pressure of 130kPa).

As the loading limitations by the mechanical design are not covered in the Australian standards, transformer manufacturers have been engaged to understand tank mechanical limits. These limits may vary slightly between manufacturers, but the following information can be used as a general guide.

Design of a transformer tank is based on two pressure limits[7];

1. Maximum serviceability limit (125kPa for fin wall designs and 135kPa for non-fin wall designs), and
2. Ultimate limit (135kPa for fin wall designs and 150kPa for non-fin wall designs).

A build-up of pressure beyond the serviceability limit, but within the ultimate limit, may cause permanent structural deformations of the fins or tanks (those with no fin walls). The extent of these deformations would not result in oil leaks or catastrophic failures unless the pressure exceeds the ultimate limits.

If the transformer is operated above serviceability limit the resultant permanent deformations may cause the insulation oil level within the transformer to drop below the energised parts when the oil cools. Under this situation, as the dielectric constant of the air cushion is much less than that of mineral oil, internal arcing can occur at the exposed energised parts increasing the transformer fire risk. Operating the transformer above the ultimate limit of the fin wall may result in failure of the fin wall (usually where the fin wall is welded

[4] Deflagration and detonation are two ways energy may be released. If the combustion process propagates outward at subsonic speeds (slower than the speed of sound), it's a deflagration. If the explosion moves outward at supersonic speeds (faster than the speed of sound), it's a detonation

[5] Nytro Libra oil, has a minimum flash point of 135°C

[6] Reference: SFPE Handbook of Fire Protection Engineering, 3rd Edition, 2002, Page 3-26.

[7] Loading of Oil-filled Distribution Transformers – DM# 13042326

to the tank) and can result in an oil jet spay that ignites or as previously discussed may deflagrate within a substation room or building.

The mechanical design of Western Power's distribution transformers is such that the most likely part of the transformer tank to rupture is at the rear where the cooling fin design requires a thinner gauge steel to be used (i.e. 1.5mm) to allow the cooling fins to do their job as intended. This has the benefit of reducing the risk to operational staff who will most likely be standing at the front of the transformer when it is energised and who will be protected by the thicker gauge steel used on the front of the transformer tank when standing at this location. Additionally, this allows Western Power to provide advice on how a transformer will act as a fire source so that Distribution Designers and Engineers working on behalf of property developers can mitigate the risk of a transformer fire.

Therefore, due to the design of these transformer tanks and the oil pressures within them, any passive fire protection measures used in a substation room or building shall withstand an oil jet fire and overpressures that occur when oil and gas mixtures deflagrate.

4. Assess the Risk – Transformer Fire Risk Assessment

For each electricity network substation installation, a fire risk assessment (FRA) should be undertaken and documented. The FRA is to demonstrate compliance to the requirements of this manual.

4.1 Transformer Fire Risk Control Measures

The following hierarchy of risk controls provide guidance on meeting these obligations:

1. Where possible elimination of the hazard.
    a. The hazards associated with Distribution Transformers are inherent in the design of the equipment and it is not possible to eliminate these hazards altogether where a transformer is installed. These hazards are documented within Western Powers Distribution Transformer and Metering Units Hazard Management Register and the DSPM Hazard Management Register. The Distribution Designer shall try to minimise the risk of a transformer fire by applying the guidance provided within this Chapter to their project. Where the hazard remains and cannot be eliminated the residual risk should be documented within the project hazard management register.
2. Minimising the risk by the following means:
    a. Substitution (to get a lower hazard). The Distribution Designer is to consider:
        (i) A customer HV supply may be more appropriate for a substation room located within a host building to meet the customers risk appetite. The customer can use their own transformers (such as dry type or FM Global approved transformers) if a lower risk level is required compared to what Western Power can offer.
    b. Isolation (from persons). Designer is to consider:
        (i) appropriate substation site selection, calculation and documenting fire clearance zones on the project drawings
        (ii) the use of a standalone 2hr fire rated substation building
        (iii) the use of oil and fire containment bund, kerbs or retaining walls for outdoor substations
        (iv) the use of outdoor substation site screening with 2hr fire rated walls
        (v) when required as a last resort, fire rating of adjacent buildings.
    c. Engineering controls. The Designer is to consider controls such as:
        (i) correct electrical protection settings, correct fuse sizes, correct loading and derating factors applied to the transformers based on the type of and method of installation (prevention).

(ii) Oil bunds, kerb stones, retaining walls and flame traps (crushed rock) to minimise the size of the oil pool and fire exposed to air (minimise the consequences).

(iii) Fire suppression systems like CO_2 or self-activated aerosol generator fire suppression systems for use in a substation room located within a host building (active fire suppression and fighting the fire remotely).

d. Administrative controls. Such as:

(i) access and egress routes should be documented and shown along with fire risk zones on the project design drawings.

(ii) Easements or restricted covenants may should be placed on the property title to ensure clearances are to be maintained by the landowner or a notification that 2hr fire rated structures are to be provided and maintained.

e. Personal protective equipment (PPE) for use during inspections and equipment operation. Refer to Western Power's Personal Protective Equipment (PPE) Procedure for guidance on the selection of PPE.

4.2 Transformer Fire Risk Assessment

The Fire Risk Assessment should consider the following:

1. Preventing the spread of fire, protect the general public and Western Power's personnel and to limit the consequential damage (provision of appropriate redundancy/security where appropriate). Methods may include the provision of one or two fire rated substation buildings or rooms, fire rated screen walls or oil containment kerbs and oil bunds.
2. The control or elimination of ignition sources. For example: Perhaps one transformer can meet the load requirements of the installation instead of two transformers (if the second transformer is installed for reliability reasons only). The customer can install mission critical infrastructure (such as onsite generation) or a replacement transformer may be readily available from Western Power should the need arise.
3. The detection and suppression of fires for all substations within host buildings shall meet and where needed exceed the requirements of the National Construction Code. Extinguishing media for transformer oil fires shall be dry chemical, CO_2, water spay (fog) or foam. Direct water jets cannot be used.
4. Protection of adjacent property. Fire clearances specified in Table 6.1 of this document should be maintained, or fire rated substation buildings or fire resisting screen walls should be used so as not to pose a fire risk to adjacent property.
5. Protection of public safety in the vicinity of HV installations against fire and explosion. The Designer should consider the likely hazards and associated risks when transformers are installed in areas that are frequented by members of the public, especially areas where there are large public gatherings such as schools and recreational areas. A stand-alone substation building or at least a fire rated screen walled substation may be the lowest risk option in these locations.

Where the substation is installed within a road reserve it is the Designer's responsibility to complete the FRA. The FRA is to be documented within the project specific HMR by the Distribution Network Designer in accordance with the Safety in Design Guideline. Further guidance on completing the HMR is provided in Chapter 1 (Introduction) of the DSPM.

Figure 4.1 below provides an example of the Assessment of Transformer Fire Risk using the Project HMR.

Figure 4.1: Example - Assessment of Transformer Fire Risk using the Project HMR

HAZARD MANAGEMENT REGISTER

Example - Install MPS transformer on customer's property

HMR Work | Enterprise Risk Assessment

DISCIPLINE: Distribution Design | Project Number: 1234567

IDENTIFICATION								INHERENT RISK			RISK MITIGATION		RESIDUAL RISK			
Item No.	Cover Cross REF No.	Discipline	DESIGN PHASE / TYPE	ASSET LIFECYCLE	HAZARD DESCRIPTION What could cause injury or damage to property or environment?	CONSEQUENCE What could go wrong and what might happen as a result?	Who/What is at Risk?	FOCUS AREA	Consequence	Likelihood	Inherent Rating	CONTROLS to Eliminate the Hazard or Reduce the Risk to ALARP	Hazard Eliminated Yes/No	Consequence	Likelihood	Residual Rating	Responsibility (Name)
1	1	Substation Design	DETAILED DESIGN	Design	Transformer oil fire	Injury or loss of life, damage to buildings and other equipment	Customer's, General public and Western Power employees	PUBLIC INTERACTION	4	D	High	Fire clearances determined in accordance with DSPM Chapter 5 and documented on the project design drawing. Oil is to be contained to within the substation site, flame trap is to be installed to reduce the size of the fire source	No	2	D	Medium	Distribution Designer (Scott Mates) & Customer (John Smiley)

4.3 Customer's Building Fire Safety Verification

When the substation is installed within a customer's premises a fire risk control strategy should also be developed by the building owner or entity responsible for the building in consultation with Western Power's Distribution Designer or Design Manager. Each substation site and its surroundings are subtly different in physical construction and operational requirements. The fire risk control strategy shall consider the conservation of property, continuity of operations, and life safety by adequate fire protection and fire prevention measures.

Where a substation is contained within a host building it is the building owners' responsibility to ensure the substation is considered in the buildings fire safety verification. This fire safety verification ought be in accordance with the requirements of the Schedule 7 of the National Construction Code that takes effect as of 1 May 2020. This Verification Method presents specific design scenarios that shall be considered in order to demonstrate that the fire safety aspects of a building design comply with the fire Safety Performance Requirements of NCC Volume One set out in Table 1.1. The level of safety achieved by the building design shall be at least equivalent to the relevant Deemed-to-Satisfy Provisions.

For the purposes of developing a Performance Solution, this Verification Method shall only be used by Fire Safety Engineers who are suitably qualified and experienced, have demonstrated competency in fire safety engineering, are proficient in the use of fire engineering modelling methods and are familiar with fire testing and validation of computational data.

An electricity network substation is classified as a Class 8 building within the National Construction Code.

NOTE: In addition to life safety and building protection, the insurer of the installation / building or entity may have additional requirements that need to be considered in locating and the design of the electricity network substation. These requirements shall be discussed with Western Power's substation designer prior to finalising the design of the substation.

5. Reduce the Likelihood of a Transformer Fire

It is possible to reduce the likelihood of a transformer fire using electrical protection to clear faults within the transformer (or on the LV network) before the transformer is damaged. It is also possible to control the amount of load seen by the transformer to reduce the relative aging rate of the internal insulation and prevent overloading that can result in premature failure. Bushing failures can be prevented by using cable clamps and mechanical supports to ensure mechanical pressure is not exerted on the bushings. The following sections provides advice to the Distribution Designer on these three topics regarding a reduction in the likelihood of a transformer fire.

5.1 Protection as the First Line of Defence

Fast HV winding fault clearance can in many cases prevent splitting of transformer tanks and prevent or lower the likelihood of fires. Fast fault clearance times limits the arc energy and thus limits the harm to people compared to a slow fault clearance. Fuses are used to clear faults in Western Power's distribution transformers. The sheer numbers required across the network dictate that an inexpensive form of protection be used, and the expendable nature of the fuse is not a concern because of the low number of faults. Fuses provide reliable protection and are not subject to issues with mechanisms, wiring, batteries, etc, as is the case with more complex relay and circuit-breaker systems. Fuses are not generally required to have back-up protection since they are thermally operated devices which can be relied upon to operate when excess current flows. Western Power uses fuses within Ring Main Units (RMUs) and Drop Out Fuse (DOFs) assemblies on transformer cable pole top terminations, to clear faults within the downstream HV windings of faulted transformers and some low voltage faults, where LV side protection is not provided. The fault current is detected and interrupted by the fuses, often instantaneously (meaning 20-40 milliseconds), or otherwise in a fraction of a second. The amount of energy released in the arc is directly proportional to the protection clearing time. A reliable and fast protection system is therefore the first line of defence in limiting the consequences of the transformer arcing fault.

The fuses in RMUs have a striker pin that clears all three phases even if only one phase sees fault current. DOFs will act independently and may result in a faulted three phase transformer remaining energised by one phase when a high impedance fault is not seen by the last fuse to operate (due to the absence of the other phases that have already been cleared). Therefore, an RMU provides a more reliable protection solution and should be used whenever a ground mounted transformer is installed in a location that requires the lowest risk option (e.g. a substation within a host building).

HV fuses have limited reach into the LV network and will not usually see a LV winding fault until catastrophic failure of the transformer has already occurred. The HV fuses can detect bolted LV faults in close proximity to the transformer where the LV fault level is high, however, most faults on the LV (440V) side of the transformer or within the LV windings are arc faults that will not be seen by the HV fuses. MKII Modular Package substations, that have been designed for installation in residential areas, have HRC fuses within the transformer fused switch disconnector that is used to isolate the transformer LV bushings from the LV assembly. These fuses provide short circuit protection and overload protection for the transformer as well as short circuit, overload and arc fault protection within the LV assembly.

MKII Non MPS transformers that are designed for larger commercial installations (630kVA and 1000kVA) have a three phase Moulded Case Circuit Breaker (MCCB. These MCCBs have a basic electronic relay inbuilt, they are robust, reliable and need little maintenance as they do not suffer from the complexities of HV side circuit breakers due to the lower insulation levels tolerated on the LV network. These MCCBs, provide overload, short circuit and arc fault protection and can clear faults within the damage limits required by AS/NZS 3000 even when low LV fault levels are experienced. Western Power's MPS and Non MPS transformers also have oil level indicators and oil temperature gauges that allows the operator to perform critical checks before a de-energised transformer is placed back into service.

Electrical Protection shall be provided for every transformer installed on Western Power's network. Western Power has published fuse tables within the Distribution Customer Connection Manual (DCCR). These fuse tables specify the maximum fuse size that is to be used on the HV and LV side of the transformer based on the size of the transformer (in KVA) and primary and secondary voltage. The Distribution Designer shall perform protection sensitivity checks to make sure that any faulted equipment will be disconnected from the network and that any network fault will be cleared by the outgoing protection device so as not to cause substation equipment damage. Smaller fuses may be required other than what is specified in the DCCR. Note that Western Power is not able to protect against LV winding faults as they are upstream of the LV protection device, will be seen as load by the HV fuses; and therefore, not all faults can be protected against.

5.2 Loading Limits for Distribution Transformers

As previously discussed, overloading of a transformer will lead to premature aging and ultimately to catastrophic failure. Western Power has undertaken an evaluation and determination of the overloading capability and limits of step-down distribution transformers used within the distribution network. This report[8] identified these risks and assessed the maximum loading limits of distribution transformers within their thermal and mechanical limits. Two types of maximum loading limits were determined, a continuous rating (i.e. such as for 24-hour industrial loads), and a cyclic rating for residential or commercial loads.

Calculation Tools[9] were developed to allow the maximum ratings and expected service life of distribution transformers to be determined. This tool uses data from the transformer manufactures, load profile data from existing transformer installations, ambient temperature data from the Bureau of Meteorology for each Planning Region and correction factors based on the method of installation (i.e. Outdoor installations, indoor substation rooms in host buildings and basements with forced ventilation). For most transformers with fin wall designs, the internal pressure withstand capability of the tank was found to be the limiting factor.

Therefore, to minimise the risk of transformer failure the loading limits as calculated using these Calculation Tools shall not be exceeded. The substation installation shall also be designed to allow for future replacement of the transformers that will be required due to the natural aging of the assets.

5.3 Cable Clamps and Supports

As previously discussed in Section 3.2 Western Power has experienced transformer failures due to leaking bushings on the high voltage and low voltage side of the transformer. To prevent damage to bushings and gaskets caused by the mechanical forces exerted to these bushings by the cables terminated to them, all cables shall be mechanically fastened to the transformer tank structure or cable trench with the use of cable clamps and supports. All Tyree and ETEL ground mounted MPS and Non MPS transformers are provided with this facility within the HV cable compartments. Where multi core wave concentric neutral screened cables terminate onto the LV switchgear of an MPS transformer (MPS are only installed outdoor) these cables do not terminate to LV bushings, are supported by the soil used for back fill and each phase is held together by the neutral screen and therefore do not exert pressure onto the bushings. However, where multiple single core cables terminate directly onto the LV bushings of a Non MPS transformer, like phases need to be fastened together and all phases need to be supported so as not to apply pressure to the bushings. Non MPS transformers are provided with cable supports in both the HV and LV cable compartments. Customer cables that terminate onto a Western Power transformer shall also be supported and fastened together using cable clamps.

6. A Guide to Mitigating the Consequences of a Transformer Fire

Once a transformer fire has started the equipment within the substation site may be damaged beyond repair but may be easily replaced from Western Power or third-party stock. Priority should be given to the protection of life and any surrounding buildings and structures. The most effective way to mitigate the consequences of a transformer oil fire, once it has occurred, is to minimise and contain the size of the oil pool. The larger the oil pool the more fuel there is that can burn; and more heat is released during the combustion process. The deeper the oil pool the longer the duration of the fire. This is because only the surface of the oil pool that is exposed to oxygen will sustain combustion.

The following sections of this document provides the substation designer with options and examples of transformer fire risk mitigation that shall be considered and included in the design of the substation where they are needed to reduce the fire risk.

6.1 Fire Clearances for Distribution Transformers

Table 6.1 provides the distances required for the separation of transformers without an enclosure and for the separation of transformers and buildings.

[8] EDM# 13042326 Loading of Oil filled Distribution Transformers

[9] EDM# 12795488 for ABB, EDM# 45013358 for ETEL, EDM# 45015154 for Tyree

The dimension WPG1 is measured from the outside edge of the fire source transformer to the nearest protrusion of the adjacent transformer. Western Power has interpreted the requirement of clearance (G1) within AS/NZS 2067:2016 Table 6.1 to be between transformers or transformers and other items of plant within the substation site and understands that there will possibly be a higher level of substation equipment damage in the event of a transformer fire where this clearance has not been met.

AS/NZS 2067:2016 Appendix C allows the combined oil volume of all transformers within the substation site to be used to determine the clearances to combustible structures outside of the substation site where transformers are not segregated by clearance G1. This will negate the requirement to provide the additional land required for fire clearance (G1) between transformers and other substation equipment and will not increase the safety risk of the substation site by still maintaining G2, G3, and G4, as is standard industry practice. Clearances G2, G3, and G4 are to be applied from the outside edge of any fire source (i.e. the outer edge of the oil pool or the tank of the fire source transformer). A diagrammatic representation of G2, G3, and G4 is shown in Section 7.1.

Table 6.1: Fire Clearances for Distribution Transformers

Combined Oil Volume of all transformers (L)	Horizontal clearance to other transformers or screen walls WPG_1 (m)	Horizontal clearance to combustible surface G_2 (m)	Reduced horizontal clearance to combustible surface. (Substation with oil containment & flame trap)[10]	Minimum Horizontal clearance to 2-hour fire rated building G_3 (m)	Vertical extent of 2-hour fire rated building G_4 (m)
100 ≤1000	1	6	4	1	4.5
>1000 ≤2000	1	7.5	4.5	1.5	7.5
>2000	1	10	4.5	4.5	15

When clearances G2, G3, and G4 are to be measured from the transformer tanks the measurements shall be from areas of the tank that contain oil (cooling fins, top, bottom and sides) as they are the most likely parts of the transformer tank to catastrophically fail during a high intensity fault, possibly resulting in the ejection of a large amount of oil. The front of the transformer that contains air insulated switchgear and cable terminations (e.g. cable termination box on MPS or non-MPS transformers) are not usually considered to be a fire risk. As previously discussed, this part of the tank is strengthened to protect the operator.

6.2 Minimum Requirements for Oil Containment of Outdoor (Non-Fire Rated) Substations

To mitigate the consequences of a transformer fire associated with an electricity network substation located near to a habitable building, all substation sites shall have some form of oil containment. Any potential flow of transformer oil spillage shall be prevented from escaping the substation site by means such as the provision of oil containment, using retaining walls, kerbs or fire rated barriers installed on the outside of the substation site. This oil may eventually soak into the soil immediately surrounding the substation where this method of oil containment is used. Therefore, where this oil containment solution is used the Distribution Designer shall ensure that all permanent structures are located far enough away from the substation site to allow safe excavation of the oil contaminated soil to a depth of at least 2m, and that any spill is accessible to machinery if required, following an oil leak. Any ground surface treatments (i.e. pea gravel, quartz chippings, crushed limestone or road base) within the site shall consider drainage for rainwater, vegetation maintenance and the overall aesthetics of the site.

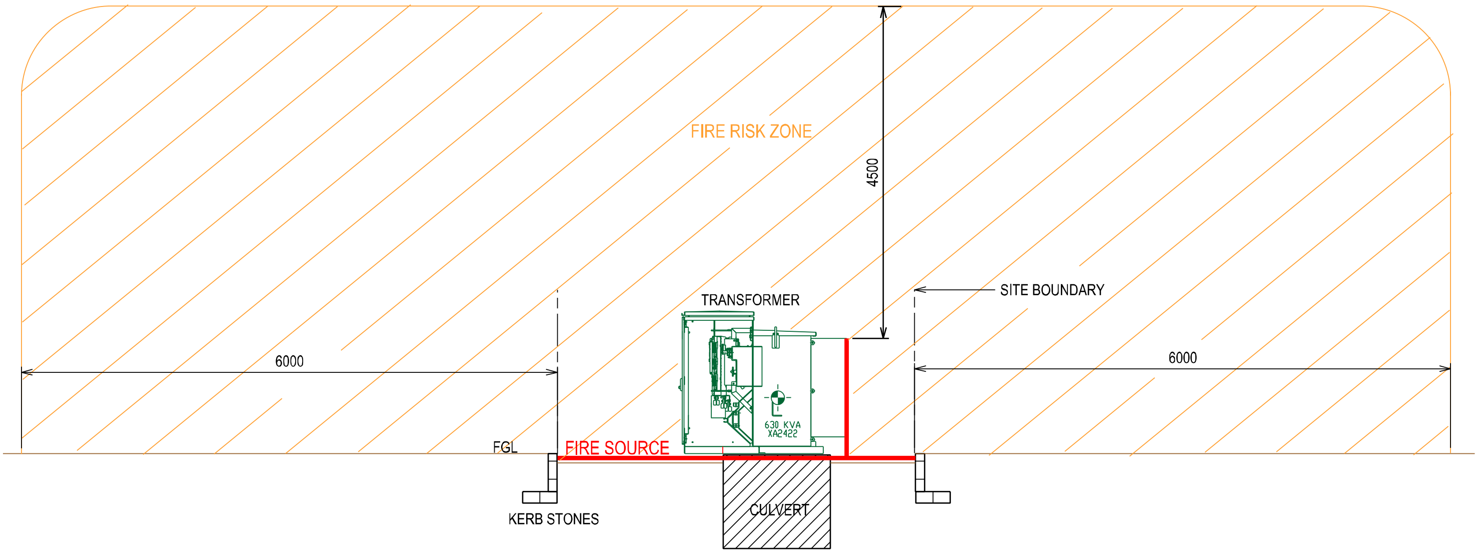
The fire source is deemed to be the transformer tank and also the ground surface area of the substation site on the inside of the oil containment walls, kerbs or fire rated barriers. The horizontal fire clearance shall be

[10] Radiated Heat Flux Calculations - For 630kVA MPS EDM# 51802615 & For 1MVA Non MPS EDM#51795103

as specified by distance G2 in Table 6.1 when measured from the inside edge of the oil containment walls, kerbs or fire rated barriers that are installed on the outside of the substation site.

In the following example where kerb stones are used for oil containment with a 630kVA MPS transformer the fire clearance is shown to be 6m from the inside edge of the oil containment kerb stones. The fire source is shown in red.

Figure 6.1: Example - Substation site with oil containment kerb or walls

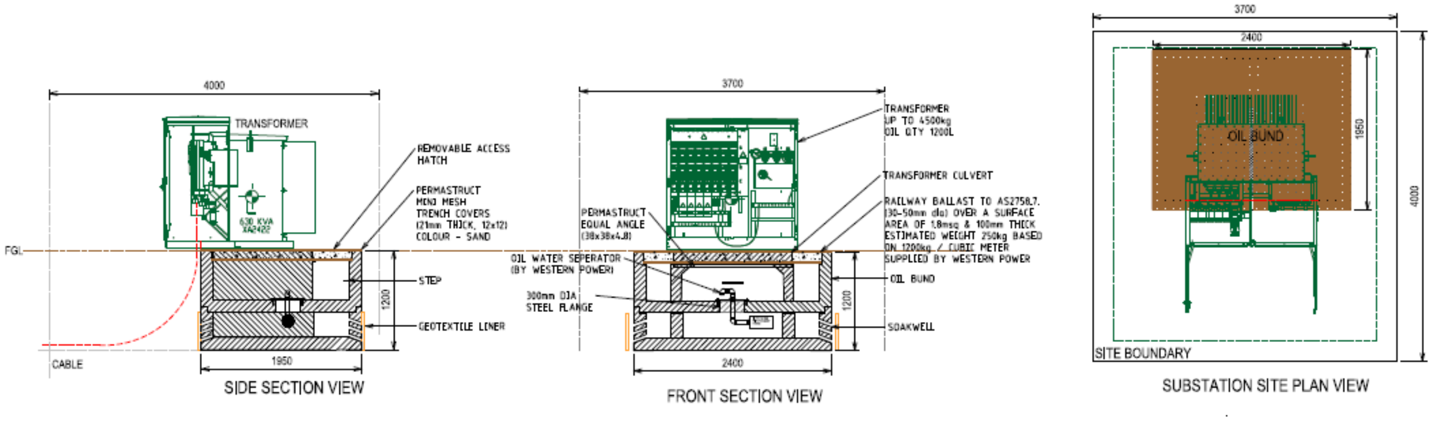


6.3 Oil containment for Outdoor (Non-Fire Rated) Substations in Environmentally Sensitive Sites or Sites with > 1000L of oil

In environmentally sensitive areas or where the combined quantity of oil within all transformer/s installed within the substation site exceeds 1000L; or where excavation of the substation site may not be possible in the future (due to the risk of undermining the foundations of surrounding structures), an oil containment bund is required. This oil containment bund, with oil / water separator shall be installed underneath the transformer/s to capture the oil and stop it entering the soil and any water course.

The oil containment bund is used instead of a precast concrete transformer culvert and shall incorporate a soak well to allow rainwater that enters the bund to drain into the surrounding soil. The oil / water separator consists of a prefilter element and chemical compound that allows water to pass from the oil containment bund into the soak well below. This chemical solidifies and forms a plug upon contact with hydrocarbons (transformer oil) preventing the oil from escaping the oil containment bund. The soak well below the oil containment bund is surrounded with a geotextile fabric that allows water to drain into the surrounding soil but also prevents sand from being washed back into it via the water outlets.

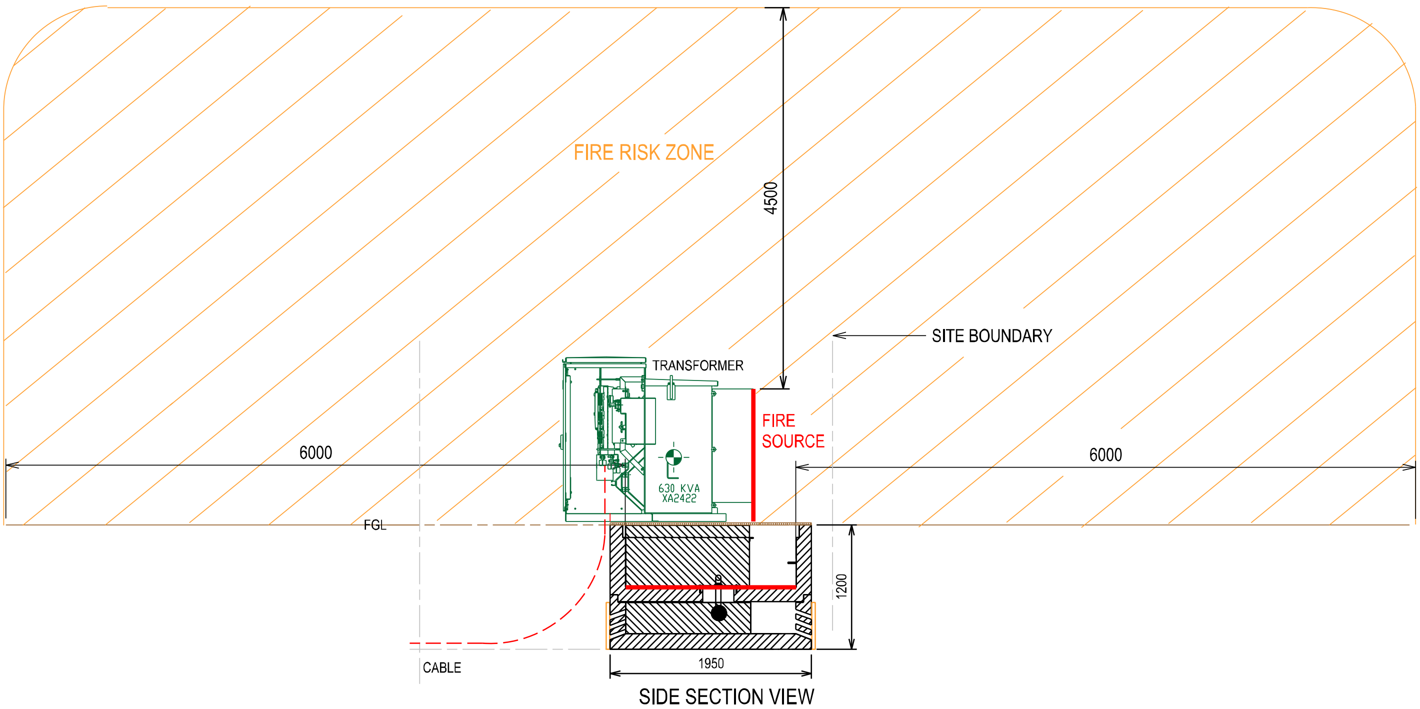
Figure 6.2: Example – Precast Concrete Oil Containment Bund



The fire source is deemed to be the surface area of the oil containment bund minus the surface area of the foundation culvert, plus the surface area of one side of the transformer tank. The horizontal fire clearance zone for this option shall be as specified by distance G2 in Table 6.1 when measured from the inside edge of the oil containment bund.

In the following example with an 630kVA MPS transformer the fire clearance (G2) is 6m from the inside edge of the oil containment bund. The fire source in red can be seen on the rear of the transformer tank and the floor of the oil containment bund.

Figure 6.3: Example - Oil Containment Bund for Environmentally Sensitive Areas



6.4 Flame Traps

To reduce the size of the oil pool that is exposed to oxygen, crushed rock (in the form of 40mm – 50mm sized railway ballast) can be used as a ground surface treatment within the substation site. Where an oil containment bund is not used but kerb stones or walls are used to contain the oil, the rock ballast will also be contained within the site by the walls or kerb stones.

Where a flame trap is provided and the transformer tank has ruptured, the oil will fill the voids between the individual pieces of rock. Railway ballast that is sized and graded in accordance with Australian Standard AS2758.7 will provide a 40% void ratio. This 40% void ratio shall be used to calculate the depth of the rock needed to contain 100% of the oil that could be spilled from the transformer tanks. A more aesthetically pleasing option of river rock is also acceptable if a uniform size of 40mm – 50mm is provided. To maintain the 40% void ratio between the rocks a geotextile barrier shall also be used between the compacted sand backfill and the layers of rock, so that the particles of sand do not fill the voids whilst still allowing rainwater to freely drain from the site. The substation designer is to calculate the depth of the railway ballast or river rock required to contain all the transformer oil using the surface area of the substation site (minus the footprint of the substation plant) plus an additional 100mm of rocks. The Designer shall base the calculation on the actual area of the substation site, size and number of the largest transformers that can be installed within the site (i.e. 630kVA for MPS or 1MVA for Non-MPS).

The following is an example calculation of the depth of the railway ballast required for an MPS Transformer site.

Oil volume of 630kVA MPS = 880L or 0.88 m^3, Area of substation site = 3.7m x 4m, Area of transformer culvert = 1.2m x 1.4m. Void Ratio of railway ballast = 0.4 (40%)

Usable area for oil containment = (3.7 x 4) – (1.2 x 1.4) = 13.12m^2.

Depth of railway ballast required to contain all the oil within the site = 0.88m^3 / 13.12m^2 / 0.4 = 167mm + 100mm of cover = 267mm.

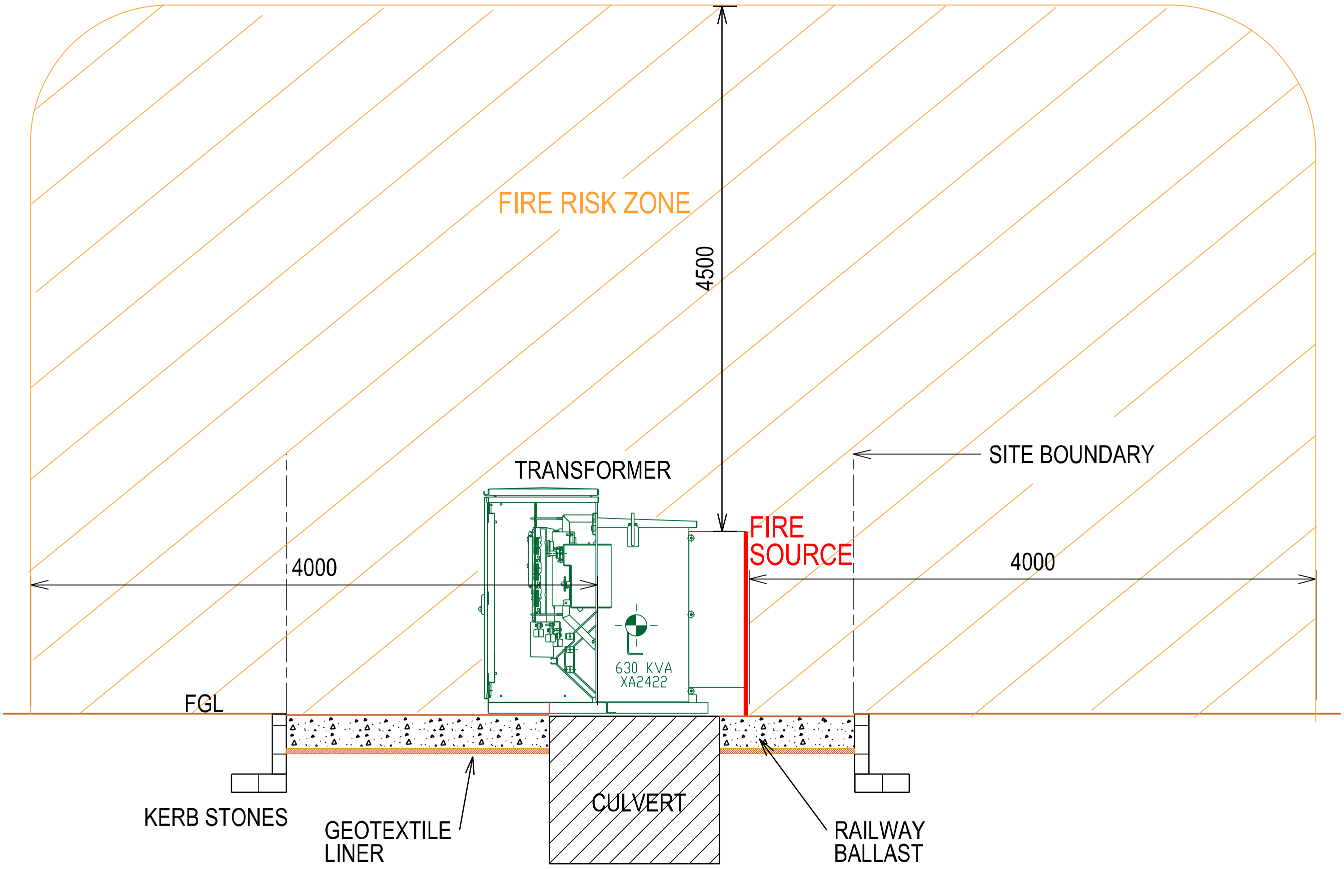
The quantity of railway ballast required for this site = 13.12m^2 x 0.267m = 3.52m^3.

Another option for specifying the depth of the flame trap is to just adopt a standard of 300mm of crushed rock across the entire site. A 300mm depth of crushed rock will provide adequate containment within all substation sites, prevent any vegetation growth (as the roots are usually within the top 300mm layer of soil), and this will align to the depth of the transformer cable skirt and height of a precast concrete panels used for retaining walls.

With this option the fire source is reduced to the surface area of the rear of the transformer tank only as there will be no oil pool that will be exposed to oxygen that is required to sustain the combustion process. The horizontal fire clearance may be as specified by the reduced horizontal fire clearance in Table 6.1 when measured from the edge of the transformer tank.

In the following example where a 630kVA MPS is installed, railway ballast is used as a flame trap and is contained within the site using kerb stones, the reduced horizontal fire clearances for a transformer <1000L of oil is shown as 4m from the edge of the transformer tank.

Figure 6.4: Example – Railway Ballast used as a Flame Trap in a site with oil containment

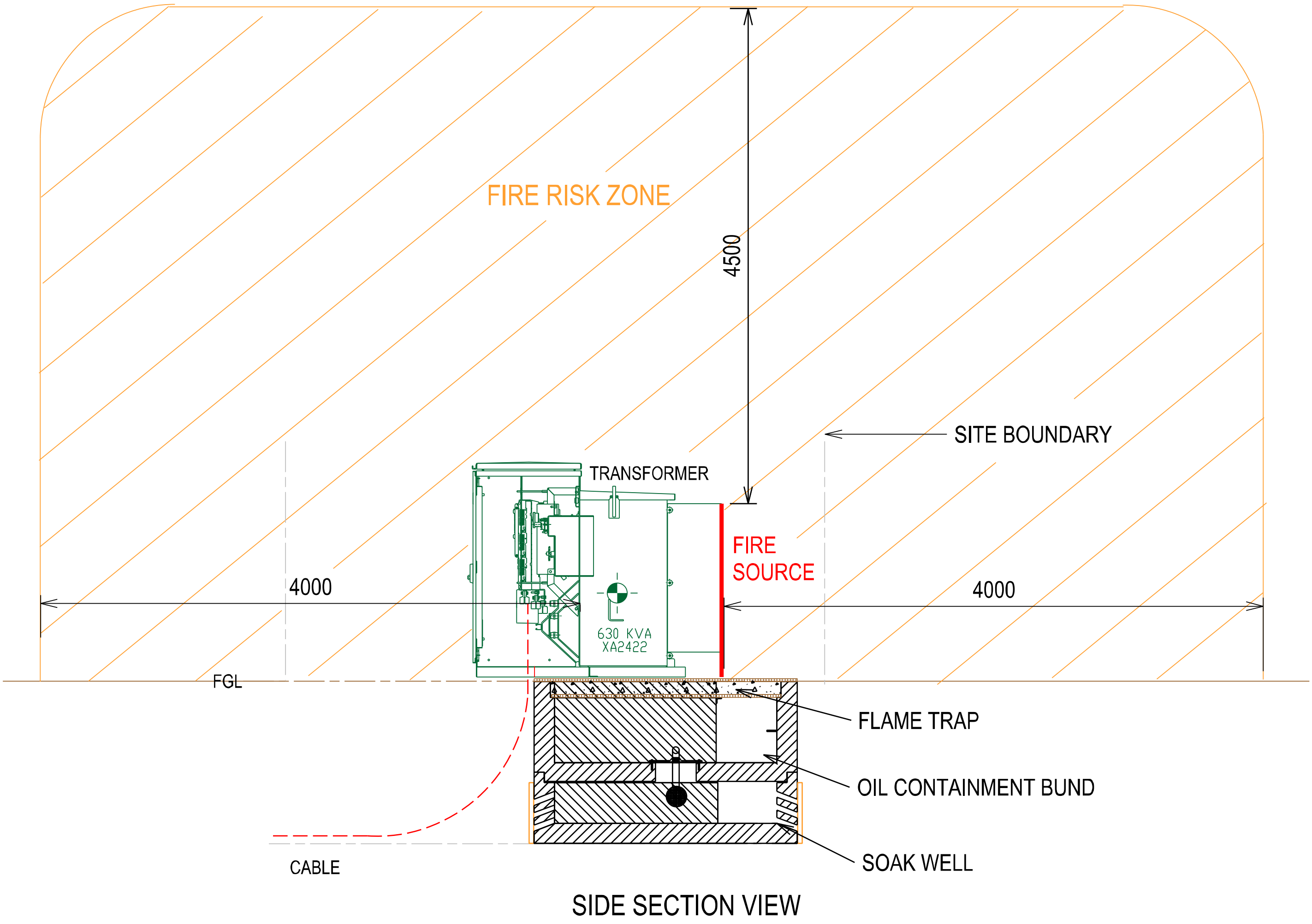


Where an oil containment bund is used, the flame trap (railway ballast) should be contained within the upper 100mm layer of the bund, sandwiched between trench covers to allow for maintenance and cleaning of the bund and replacement of the oil / water separator following an oil spill. The railway ballast is used to cool the transformer oil below its flash point as it passes through the rock into the bund below.

Where a flame trap is used with the oil containment bund the area of the fire source is reduced in size to the transformer tank only instead of the entire surface of the oil containment bund. When this option is chosen the reduced horizontal fire clearances as specified in Table 6.1 can be used because the oil containment bund combined with the flame trap reduce the heat flux radiated from the substation during a transformer fire.

In the following example with a 630kVA MPS transformer installed within an oil containment bund with a flame trap the reduced horizontal fire clearances are 4m from the edge of the transformer tank.

Figure 6.5: Example – Railway Ballast used as a Flame Trap in a site with an oil containment bund



6.5 Fire Screen Walls

Fire rated barriers in the form of a screen wall can be used around the outdoor substation at a distance of WPG1 (1m) as specified in Table 6.1, to reduce the size of the horizontal fire risk zone. These barriers shall take the form of a 2hr fire resisting screen wall that extends a minimum of 300mm higher than the transformer tank. However, the fire resisting screen wall shall be increased in height to a minimum of 1.8m if it is used to mitigate the transformer fire risk, as seen by an adjacent building, when it is constructed from combustible materials. An angle of 60° projected out from the fire source transformer above the screen wall[11] can be used to determine the projected height of the fire risk zone. Therefore, the height of the wall can be increased to provide the amount of screening that is required based on how far the combustible building is set back from the screen wall. As a minimum the combustible building shall be set back from the fire source a distance of G3 (1.5m) as specified in Table 6.1

The fire resisting construction of the screen wall shall have a fire risk level (FRL) of not less than 120/120/120 and shall be designed and constructed to meet the requirements of the National Construction Code (NCC). A building element with an FRL of 120/120/120 will maintain, when tested in accordance with AS 1530.4:

a. structural adequacy for a period of 120 min;

b. integrity for a period of 120 min;

[11] CIGRE C537 Figure 45

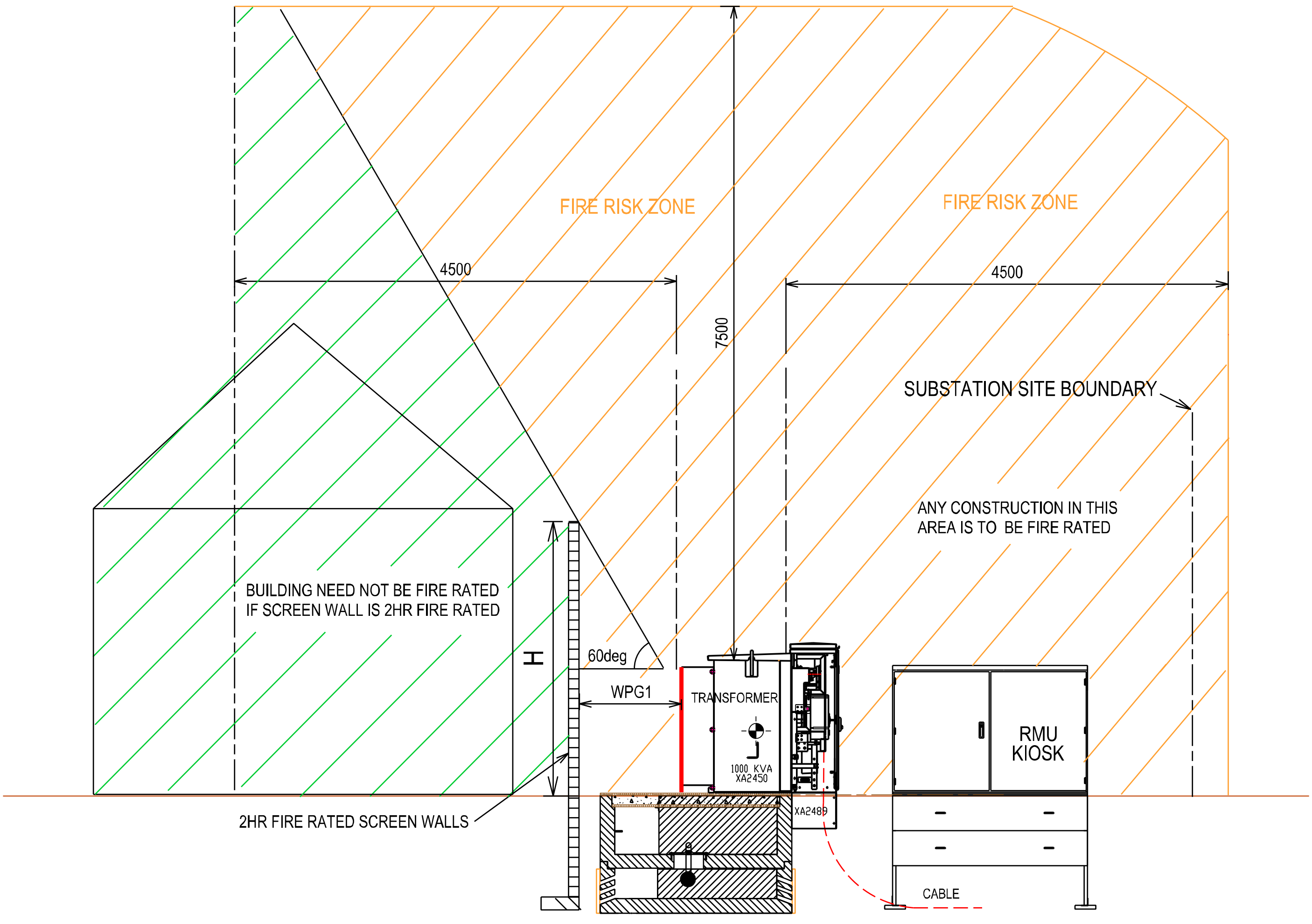
c. and insulation for a period of 120 min.

The fire resisting screen wall shall also be designed and constructed according to the requirements of the Australian Standard applicable to the type of construction used (refer to AS4100 for steel, AS3600 for concrete and AS3700 for a masonry structure). The general layout and features of the substation screen walls are shown in Chapter 3 of the DSPM for each substation site.

When this option is chosen, a restricted covenant should be placed on the property title of any effected property to inform any future landowner of the need for fire rated construction and for the maintenance of the screen wall by the owner.

In the following example a 1MVA transformer has been installed in an oil containment bund with a flame trap. This normally reduces the fire clearance from 7.5m (distance G2 in Table 7.1) to 4.5m. A 2hr fire rated screen wall is installed at the distance WPG1 (as specified in Table 6.1) from the fire source transformer and increased in height so that the effected building does not need to be fire rated. The screen wall reduces the fire clearance zone to just WPG1 plus the screen wall from the edge of the transformer tank to the combustible building.

Figure 6.6: Example – Fire screen wall



6.6 Fire Rating of the Effected Building

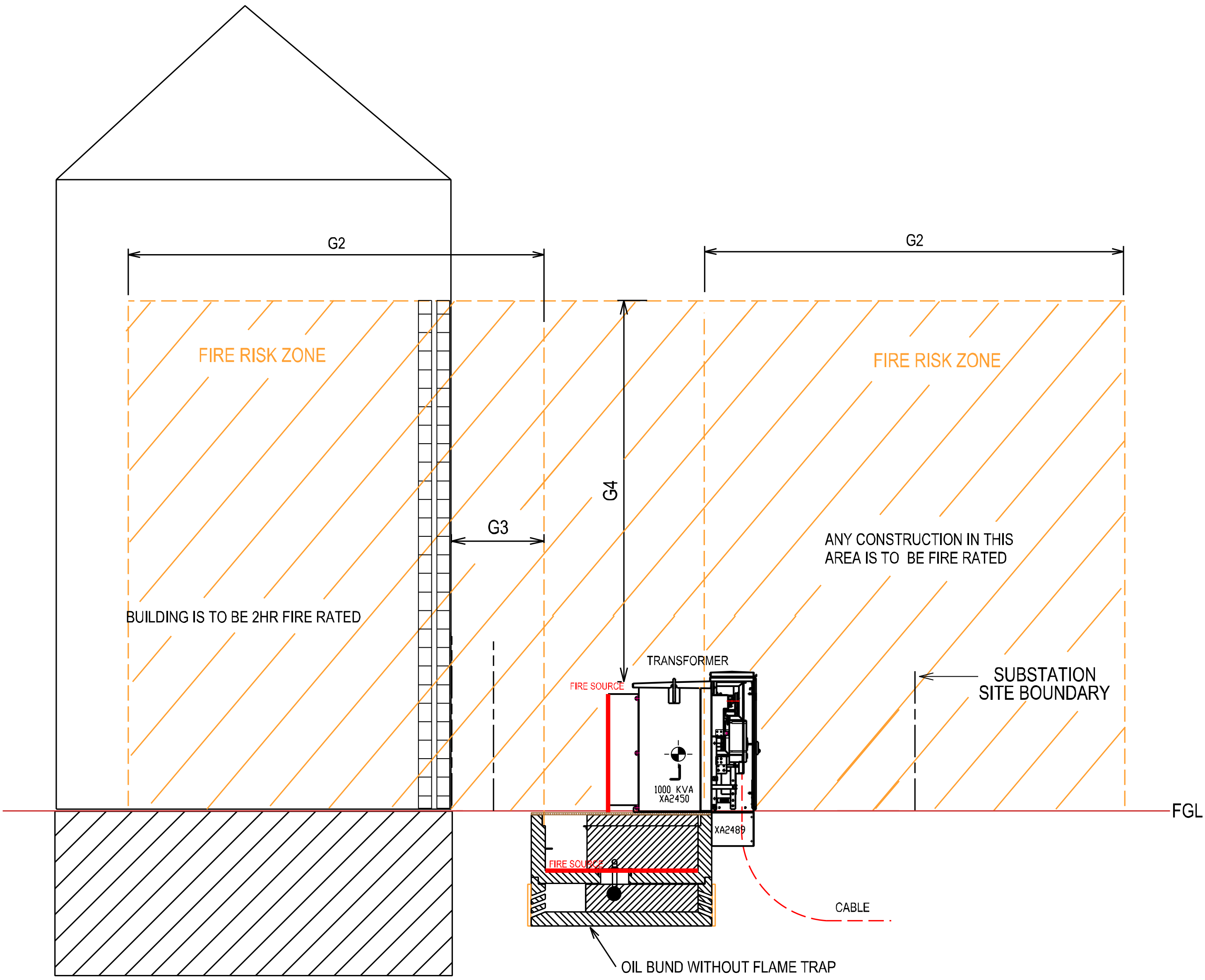
Where the landowner cannot provide adequate fire separation between the fire source transformers and the building, the option exists for the building itself to be of a fire resisting type of construction. The fire resisting section of the building needs to be located at a horizontal distance as specified by G3 within Table

6.1. away from the fire source, (i.e. when measured from the inner edge of the oil containment bund or from the transformer tank if a bund and flame trap is used). Oil containment within the substation site is still required to prevent oil from leaving the substation and reaching or entering any parts of the building.

The fire resisting construction shall extend in a vertical direction up to the dimension G4 within Table 6.1. and shall have a fire risk level (FRL) of not less than 120/120/120. Fire resisting construction of all building elements, within the electricity network substation fire risk zone, shall meet the requirements of the National Construction Code (NCC). When this option is chosen, a restricted covenant should be placed on the titles of all effected properties to inform any future landowners of the need to maintain the fire rated construction of their buildings.

In the following example a transformer is installed with an oil containment bund without a flame trap. As this transformer contains more than 1000L of oil the horizontal fire clearance zone (G2) is 7.5m from the transformer tank and the vertical fire clearance zone (G4) is 7.5m. As the effected building is located only 1.5m (G3) from the fire source, the building shall have a fire risk level (FRL) of not less than 120/120/120.

Figure 6.7: Example – Fire rating a building within the fire risk zone



6.7 Stand Alone Fire Rated Substation Building

An electricity network substation can be located within a standalone substation building (i.e. detached from the main habitable building) that is made from construction having a Fire Rating Level of not less than 120/120/120. The layout of the building and Western Power's equipment shall be in accordance with the standard design drawings for a fire rated substation as published within Chapter 3 of the DSPM. The fire resisting building structure shall be designed according to the requirements of the Australian Standard applicable to the type of construction used (refer to AS3600 for concrete and AS3700 for a masonry structure) in accordance with the requirements of the National Construction Code.

All doorways to the outside of that building shall be protected with an outward opening, self-closing fire door set that has a Fire Rating Level of not less than -/120/30. Doors and all associated hardware shall meet the requirements of AS/NZS 1905. A fire door set that meets the requirements of AS/NZS 1905, when tested in accordance with AS1530.4, is not expected to maintain structural adequacy. It will maintain integrity for a period of 120 min; and insulation for a period of 30 min.

Adequate vent openings shall be installed providing cross ventilation for cooling of substation equipment and for pressure relief of the substation building to prevent structural damage in the event of an explosion. For ventilation of the substation building, fire dampened vents shall be installed as prescribed within Chapter 3 of the DSPM. They shall be fitted with rotating type blades held in the open position by two thermal links in parallel and shall conform to AS1682 and AS/NZS 1668. The Fire Rating Level of the fire dampened vents shall be not less than /120/30.

As previously discussed, Western Power requires the building structure to have a fire rating of 120/120/120, however, it must be understood that this cannot be achieved where there is a fire rated doorway or vents within the outer structure of the building. It must be expected that the doors and vents can fail (structurally) during a fire and as such there can be no fire escape routes within the fire risk zone of a substation building.

In substations where one or more transformers are installed, the floor of the substation building shall have a fall of 5 -10mm across the room allowing oil to drain into the cable trench that shall also be used for the purpose of oil containment[12]. Removable (bolt down) aluminium oil containment bunds shall be installed around the transformers to prevent the oil coming into contact with the walls or other equipment in the event of a catastrophic transformer tank rupture. They shall also be installed on the inside of the outward opening doors to capture any oil in the building that is ejected from the transformer tank under pressure.

Figure 6.8: Example bolt on spill containment bund

Where ducts or other penetrations enter the cable trench within the substation building, the customer shall fit removable seals to both ends of the installed ducts or penetrations prior to hand over. The seals shall be water and oil tight before and after cable installation. Western Power's cable installation contractor or

[12] ENA Doc 18 -2015 Clause 11.2.3

representative will reseal all ducts and penetrations after installation of network cables. Where ducts are installed between fire segregated switch-rooms, the customer shall seal the ducts after the installation of all cables to maintain the required fire rating.

Fire resisting construction of all building elements, within the electricity network substation fire risk zone, shall meet the requirements of the National Construction Code (NCC). The general layout and features of the substation building are shown in the standard design drawings published within Chapter 3 of the DSPM for each fire rated substation building.

6.8 Fire Rated Substation Room in a Host Building

The consequences of a fire in a substation contained within a host building may be particularly severe. As such consideration should be given to:

- Reduction of the fuel available by using dry type transformers (customer to be provided with a HV metered supply and their own dry type transformer can be used); or
- The installation of a smoke detection and fire alarm system, additional to the minimum requirements of the National Construction Code (NCC).
- Portable extinguishers of the carbon dioxide or Dry Chemical Powder (DCP) type should be located in readily accessible locations.

An electricity network substation located within a host building shall be separated from any other part of the building by construction having an FRL of not less than 120/120/120. Fire resisting construction of all building elements, within the electricity network substation fire risk zone, shall meet the requirements of the National Construction Code (NCC). Electricity network substation buildings are generally deemed to be Class 8 buildings for the purposes of the NCC. Electricity substation buildings are required to comply with the relevant NCC provisions. The NCC Section C – Fire Resistance adopts a series of performance requirements to achieve the following overall objectives;

a. safeguard people from illness or injury due to a fire; and

b. safeguard occupants while evacuating a building during a fire; and

c. facilitate the activities of emergency services personnel; and

d. avoid the spread of fire between buildings; and

e. protect other property from damage caused by structural failure of a building due to fire.

The NCC also contains a number of "Deemed to Satisfy" provisions which relate directly to these objectives and to the performance requirements for fire resistance. The NCC also allows the use of an "Alternative Solution" approach where the "Deemed to Satisfy" provisions are considered to be inappropriate. For a substation within a host building an "Alternative Solution" is required to comply with the relevant NCC performance requirements. The fire resisting structure shall also be designed according to the requirements of the Australian Standard applicable to the type of construction used (refer to AS3600 for concrete and AS3700 for a masonry structure) in accordance with the requirements of the NCC.

The designer, architect and structural engineer for the host building shall consider; and where necessary action the following points in the design of the substation room:

1. A substation within a "host" building should be capable of surviving a credible substation fire event without collapse or major structural damage as there is a risk of a potential progressive collapse of the entire structure due to fire and/or explosion. Suitable mitigation measures should be employed including additional redundancy of key structural members (i.e. structures should be designed to prevent progressive collapse even in the event of failure of one structural element). Fire resisting walls of the substation building may need to consider some pressure shock wave effects due to a deflagration.

Reinforced concrete structures should have walls tied to the floor and roof slabs. Similarly, precast concrete wall slabs should be well tied to the floor and roof slabs. Note that unreinforced brick or block walls can be blown out.

2. Where the building structure fire protection involves intumescent paint systems, consideration should be given to its performance where deflagration may occur. In this case, a blast/abrasion may remove paint from building elements and hence the effectiveness of protection is seriously compromised. The performance of all passive fire protection systems i.e. fire rated cladding shall be assessed based on a hydrocarbon fire.

3. There should be no doors from the substation room leading into the "host" building unless justified by a site-specific risk assessment. Entrances should all be fully segregated from the "host" building. Exposed fire doors, fire dampers and air vents within the walls of the substation building may be blown out by the deflagration and therefore fire escape routes should be designed to keep people away from these features when there is a need to evacuate the host building. All doorways to the outside shall have outward opening, self-closing fire doors having an FRL of not less than /120/30. Doors and all associated hardware shall be fire rated to AS/NZS 1905.

4. Substation rooms should be provided with a dedicated ventilation system which is fire rated or has suitable provision for fire isolation from the "host" building (i.e. inlet and outlet openings should be external to the "host" building unless justified by a site-specific risk assessment). Adequate vent openings shall be provided for pressure relief of the substation building to prevent structural damage in the event of deflagration. In substations where a transformer is installed, the ventilation provided to cool the substation equipment will meet this requirement. For this ventilation, fire dampened vents shall be installed. They shall be fitted with rotating type blades held in the open position by two thermal links in parallel and shall conform to AS1682 and AS/NZS 1668. Provided there are no fire exits or areas set aside for fire escape purposes within 6 m, ventilation or pressure relief device openings in a substation room may vent to external free air; or normally unoccupied freely ventilated spaces such as car parks, including basement car parks. The requirement of the fitting of self-closing dampers will not apply when ventilation ducts of a suitable length are installed external to the enclosure and such ducts have an FRL of not less than 120/120/120.

5. The NCC also has requirements for a Network Operator's power cables supplying a substation within the building. These cables are required to be protected by fire rated construction where they pass through the host building.

6. In substations where one or more transformers are installed, the floor of the room shall have a fall of 5 -10mm across the room allowing oil to drain into the cable trench that shall also be used for purpose of oil containment[13]. Removable (bolt down) aluminium oil containment bunds shall be installed around the transformers and at each doorway to prevent the oil from escaping the room or coming into contact with the walls or other equipment in the event of a catastrophic transformer tank rupture. Where ducts or other penetrations enter the cable trench within the substation building, the customer shall fit removable seals to both ends of the installed ducts or penetrations prior to hand over. The seals shall be water and oil tight before and after cable installation. Western Power's cable installation contractor or representative will reseal all ducts and penetrations after installation of network cables. Where ducts are installed between fire segregated switch-rooms, the customer shall seal the ducts after the installation of all cables to maintain the required fire rating.

7. Basement type substations are difficult for the fire brigade to approach and consequently it is often necessary to provide some means of fighting the fire remotely. Adequate exit facilities should be provided, usually two (2) doors placed towards opposite ends of the substation and arranged for easy exit. Exits should lead, through self-closing fire doors, to fire isolated areas at the foot of the access stairs. Any passageway should lead directly to the exterior of the building. Where CO_2 or other self-

13 ENA Doc 18 -2015 Clause 11.2.3

activated aerosol generator fire suppression systems[14] are provided that allows fighting of the fire remotely, the gas should not be injected while personnel are in the substation. With automatic gaseous systems, AS6183 requires the system to be de-activated and locked-off prior to entry of personnel into the protected space. It is also mandatory to provide an audible and visual warning to personnel with a time delay before injection commences. These controls will address the risk where personnel are injured or physically incapacitated and are unable to evacuate when required. Additional safeguards, such as CO_2 detectors, could also be considered to detect potential malfunctions of automatic CO_2 systems. Possible scenarios include CO_2 leakage, or the accidental release of CO_2 without an alarm, both of which may create a hazard within the enclosure prior to entry. When CO_2 has been injected into a substation, the gas should be exhausted before the substation is re-entered. A build-up of other gases, such as Sf6, may also occur as a result of a Ring Main Unit fault. Adequate ventilation should be provided for the substation and suitable precautions taken when entering the enclosure following a significant electrical fault. Any basement substation where a CO_2 or other self-activated aerosol generator fire suppression systems are provided or Ring Main Units with Sf6 gas are installed shall be added to Western Power's Confined Entry Space Register[15] and adequately signposted in accordance with Western Power's Confined Space work procedure[16].

8. The design of the substation room should enable the substation equipment to be re-instated, reconnected and re-energised following an inspection, cleaning and repair of the room within a very short timeframe. Note that it is highly likely that the host building, and other customers connected to a district type substation will be without a power supply over this time.

The general arrangement (critical dimensions) of Western Power's distribution plant as well as the quantity of oil contained in the transformers is provided within Chapter 4 of the DSPM. The general layout and features of the substation room are as used for standalone fire rated substation buildings shown in Chapter 3 of the DSPM for each substation site. The Distribution Designer shall work with the Developers Engineers and Architects to develop a suitable layout for the substation room that includes the ventilation and access and egress routes. It is impractical for Western Power to impose a standard design that would be suitable within all developments, however, the standard layouts within Chapter 3 can be used as a guide.

6.9 Use of land within the Fire Clearances Zone

The following shall be considered by the designer when negotiating the location of the substation site / building with the landowner. The landowner shall ensure the use of the land around the substation does not contribute to an increase of the fuel load or fire risk associated with the substation site. No essential public access/exit/escape routes shall pass through or open into the fire risk zone. Generally, no other structure or building is permitted within the substation fire risk zone unless it has a two-hour fire rating. The substation shall be kept clear of all moveable combustible items including vegetation or refuse for a distance of at least 3m[17] from the transformers.

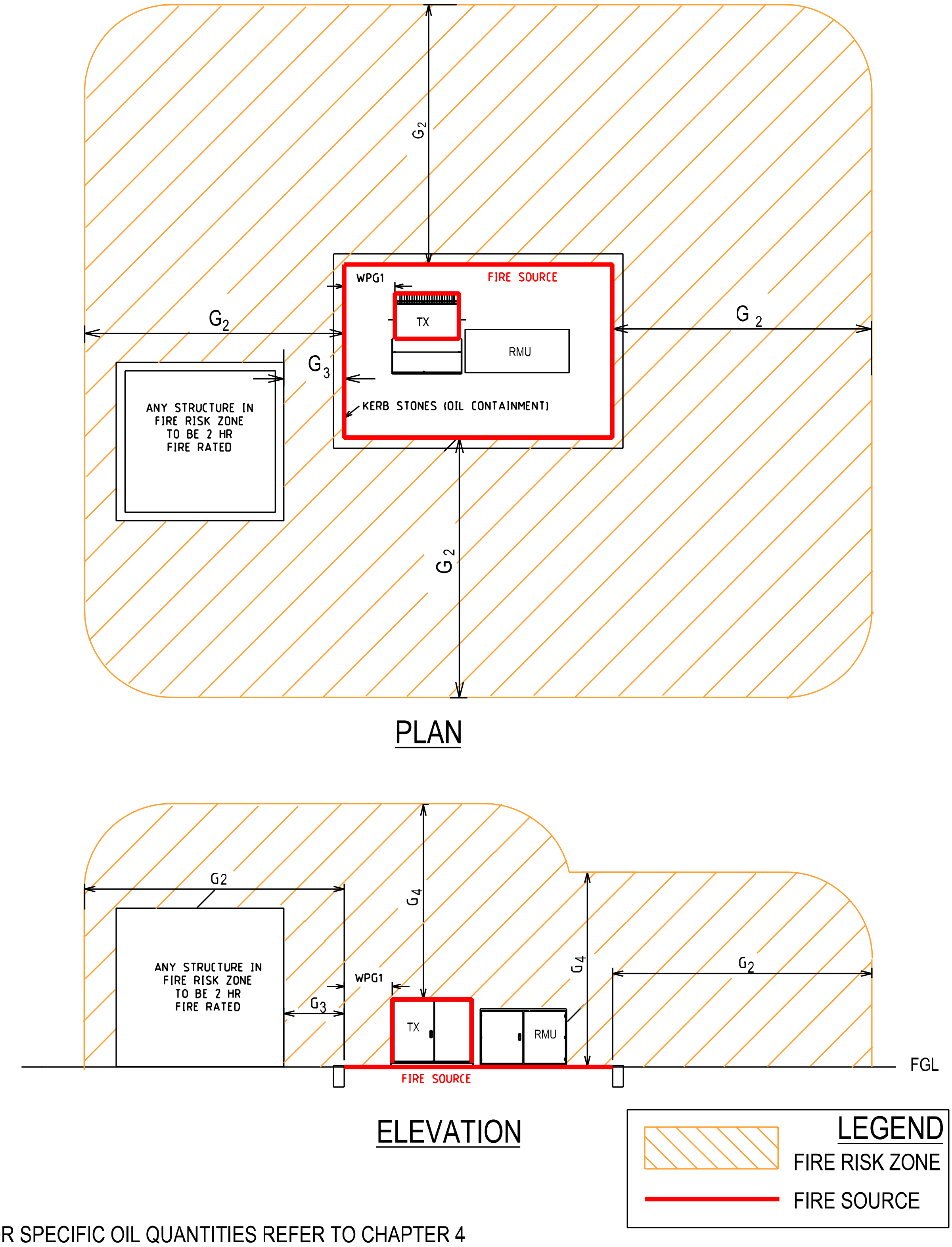
7. Standard Drawings

This Chapter of the DSPM also provides examples of fire clearance drawings that provide a diagrammatic representation of the fire source and fire clearances required around Western Power's distribution substation plant. The fire source and clearances are based on the minimum practical asset, before the use of any flame trap.

14 Example: Stat – X, Refer flamestop.com.au
15 EDM 44597965
16 EDM 43680274
17 AS 1940 Clause 2.2.5.1 (d)

The Distribution Substation Plant Manual (DSPM) is still under development using new distribution plant and equipment that is being procured or will be procured over the next contract period / plant tender cycle and will be available for use on Western Power's Network in the near future.

7.1 Fire Risk for Single Outdoor Transformer



FOR SPECIFIC OIL QUANTITIES REFER TO CHAPTER 4
OF DISTRIBUTION SUBSTATION PLANT MANUAL. FIRE RISK ZONE SHALL BE CALCULATED
FROM THE OUTER EDGE OF THE OIL POOL (FUEL SOURCE), CONTAINED WITHIN SUBSTATION AREA.

REV. No.	DATE	DESCRIPTION	ORIG	CHED.	APRD.
B	04.2020	UPDATED TO INCLUDE OIL CONTAINMENT	GC	CO	GS
A	08.2019	ORIGINAL ISSUE	GC	CO	GS

TITLE

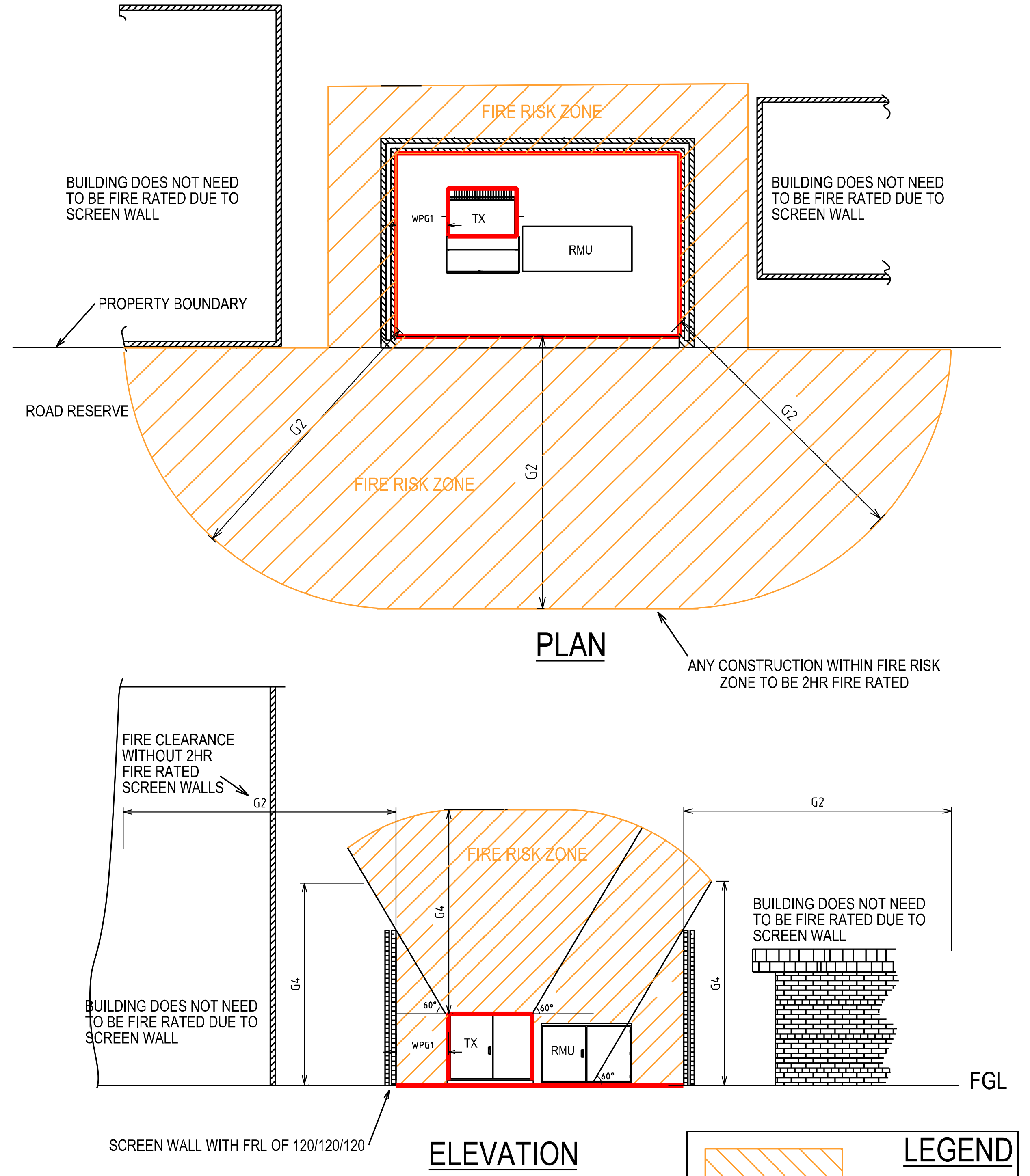
FIRE RISK ZONE FOR SINGLE
OUTDOOR TRANSFORMER

DISTRIBUTION SUBSTATION
PLANT MANUAL

westernpower

DRAWN: JRR	DATE: 08-2019	DRG. No.
ORIGINATED: GC	SCALE: NTS	DSPM-5-01
CHECKED: CO		
APPROVED: GRANT STACY		REV. B / SHT. 1

7.1.1 Fire Risk for Single Outdoor Transformer with Screen Walls



FOR SPECIFIC OIL QUANTITIES REFER TO CHAPTER 4 OF DISTRIBUTION SUBSTATION PLANT MANUAL. FIRE RISK ZONE SHALL BE CALCULATED FROM THE OUTER EDGE OF THE OIL POOL (FUEL SOURCE), CONTAINED WITHIN SUBSTATION AREA, WHEN PROJECTED AT AN ANGLE OF 60° FROM THE FIRE SOURCE ABOVE THE SCREEN WALL.

REV. No.	DATE	DESCRIPTION	ORIG	CHED.	APRD.
B	04.2020	UPDATED TO INCLUDE OIL CONTAINMENT	GC	CO	GS
A	08.2019	ORIGINAL ISSUE	GC	CO	GS

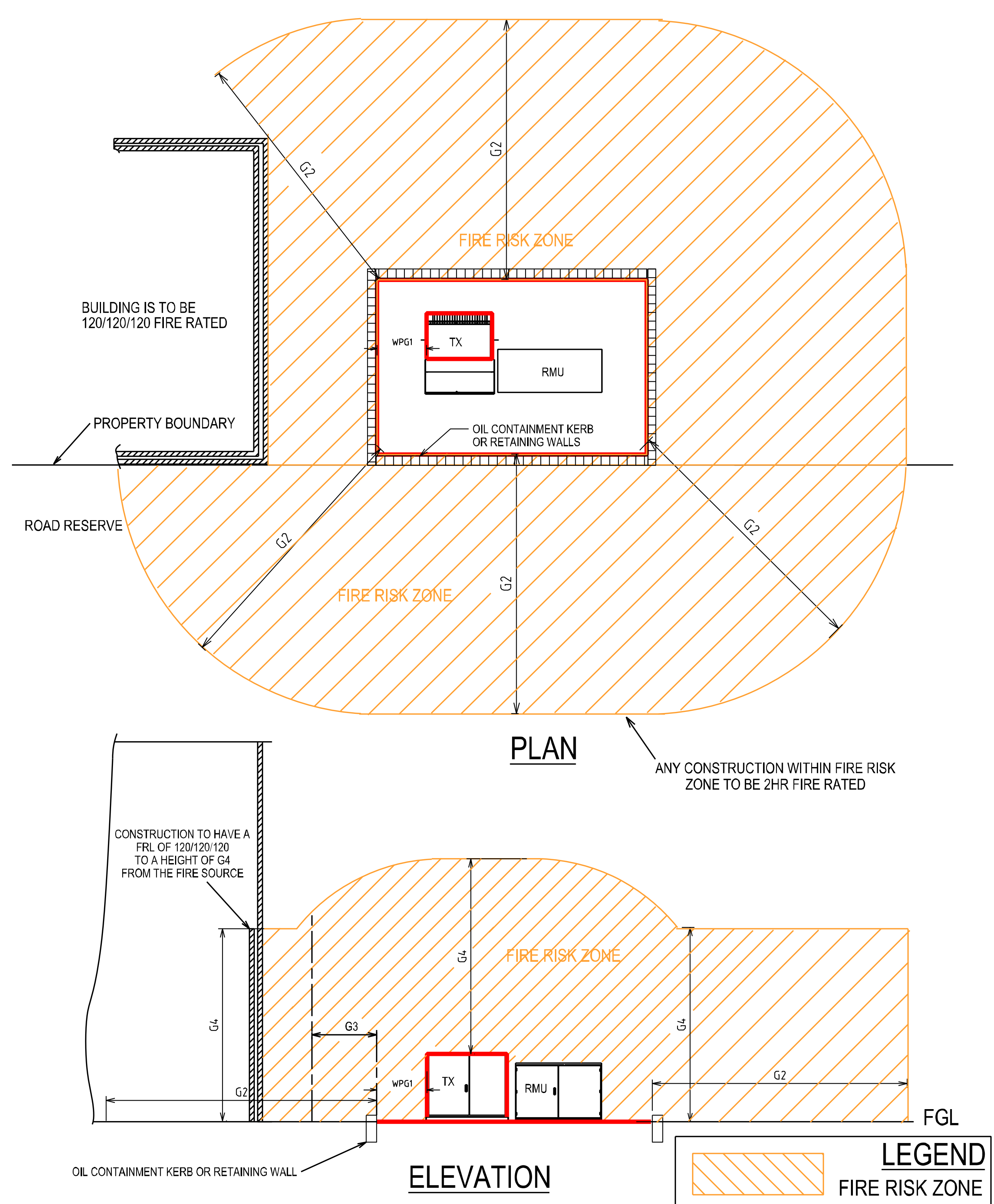
TITLE: FIRE RISK ZONE FOR SINGLE OUTDOOR TRANSFORMER WITH SCREEN WALLS THAT HAVE A FRL OF 120/120/120

DISTRIBUTION SUBSTATION PLANT MANUAL — westernpower

DRAWN: JRR	DATE: 08-2019
ORIGINATED: GC	SCALE: NTS
CHECKED: CO	
APPROVED: GRANT STACY	

DRG. No. DSPM-5-01 — REV. B — SHT. 2

7.1.2 Fire Risk Zone for Single Transformer Outdoor with Adjacent 2Hr Fire Rated Building



FOR SPECIFIC OIL QUANTITIES REFER TO CHAPTER 4 OF DISTRIBUTION SUBSTATION PLANT MANUAL. FIRE RISK ZONE SHALL BE CALCULATED FROM THE OUTER EDGE OF THE OIL POOL (FUEL SOURCE), CONTAINED WITHIN SUBSTATION AREA. 2HR FIRE RATED BUILDING REQUIRED FOR ANY CONSTRUCTION IN THE FIRE RISK ZONE AND SHALL NOT BE WITHIN DISTANCE G3 OF THE FIRE SOURCE.

REV. No.	DATE	DESCRIPTION	ORIG	CHED.	APRD.
A	04.2020	ORIGINAL ISSUE	GC	CO	GS

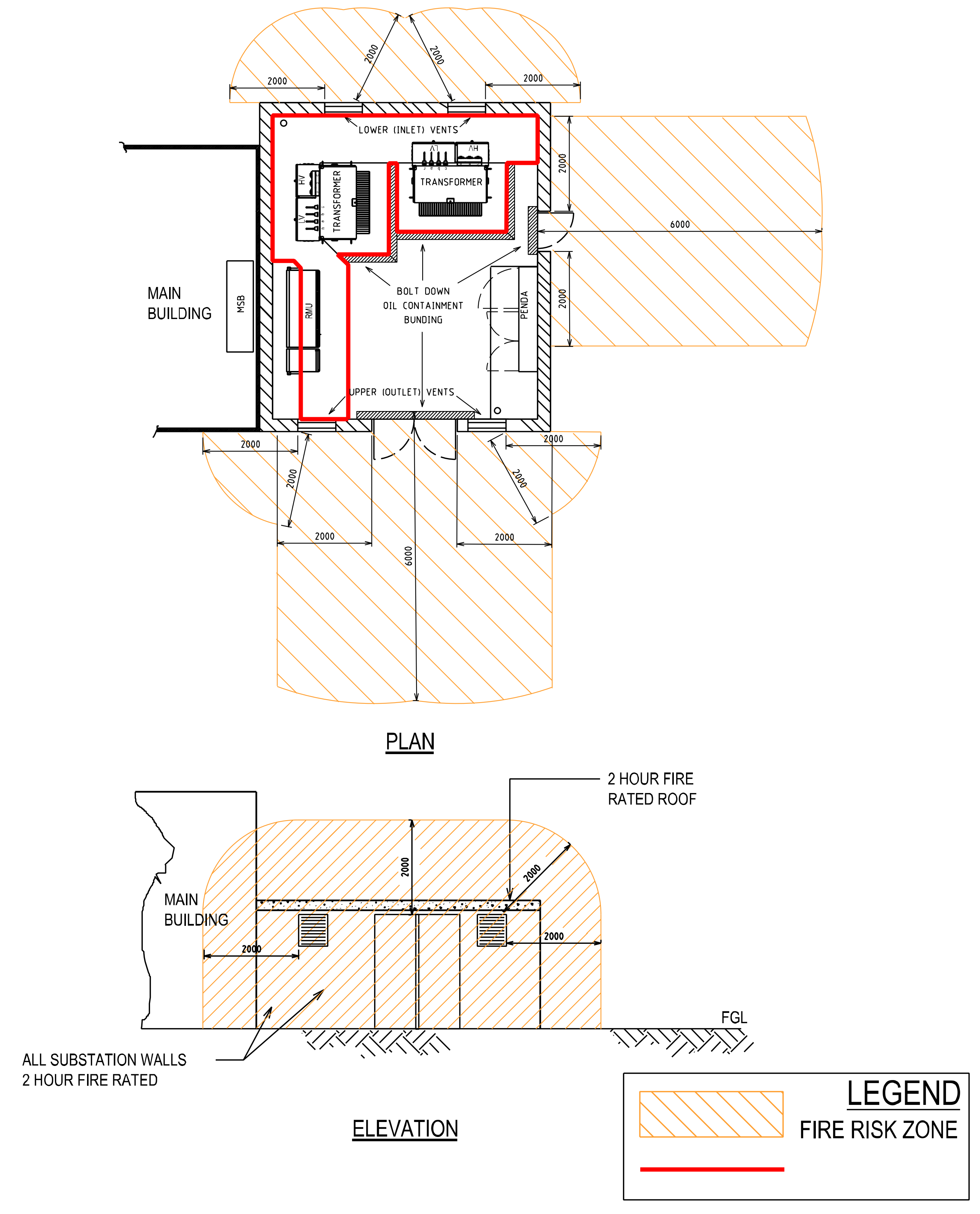
TITLE: FIRE RISK ZONE FOR SINGLE OUTDOOR TRANSFORMER WITH FIRE RATED BUILDING THAT HAS A FRL OF 120/120/120

DISTRIBUTION SUBSTATION PLANT MANUAL — westernpower

DRAWN: JRR | DATE: 04-2020
ORIGINATED: GC | SCALE: NTS
CHECKED: CO
APPROVED: GRANT STACY

DRG. No. DSPM-5-01 | REV. A | SHT. 3

7.2 Substation Building (fire rated building example)



FOR SPECIFIC OIL QUANTITIES REFER TO CHAPTER 4 OF DISTRIBUTION SUBSTATION PLANT MANUAL.
FIRE RISK ZONE SHALL BE CALCULATED FROM THE OUTER EDGE OF THE SUBSTATION DOORS AND VENTS. NO EMERGENCY EGRESS ROUTES PERMITTED WITHIN FIRE RISK ZONE.

REV. No.	DATE	DESCRIPTION	ORIG	CHED.	APRD.
A	05.2020	ORIGINAL ISSUE	GC	CO	GS

TITLE: ADJACENT SUBSTATION
WALLS HAVE FRL OF 120/120/120
DOORS HAVE FRL OF -/120/30
AIR VENTS HAVE FRL OF -/120/30

DISTRIBUTION SUBSTATION PLANT MANUAL		westernpower
DRAWN: JRR	DATE: 05-2020	DRG. No. DSPM-5-04
ORIGINATED: GC	SCALE: NTS	
CHECKED: CO		REV. A
APPROVED: GRANT STACY		SHT. 1