ELECTRICAL ARC FLASH HAZARD MANAGEMENT GUIDELINE

March 2019

This publication is supported by AGL pursuant to an enforceable undertaking between AGL Macquarie ACN 167 859 494 and SafeWork NSW, dated 16 April 2018.

This document has been prepared by a cross section of Electricity generation industry practitioners and professionals and is endorsed by the Australian Energy Council (AEC). The contribution of AGL Macquarie, Alinta Energy, Synergy, Delta Electricity, Stanwell, CS Energy, Hydro Tasmania, Snowy Hydro, Thomson Bridge, Origin Energy, ENGIE, HIESN and Palisade Asset Management is appreciated.

This document was published by the Australia Energy Council (AEC) Level 14, 50 Market Street, Melbourne, VIC, 3000.

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1.0 PREFACE

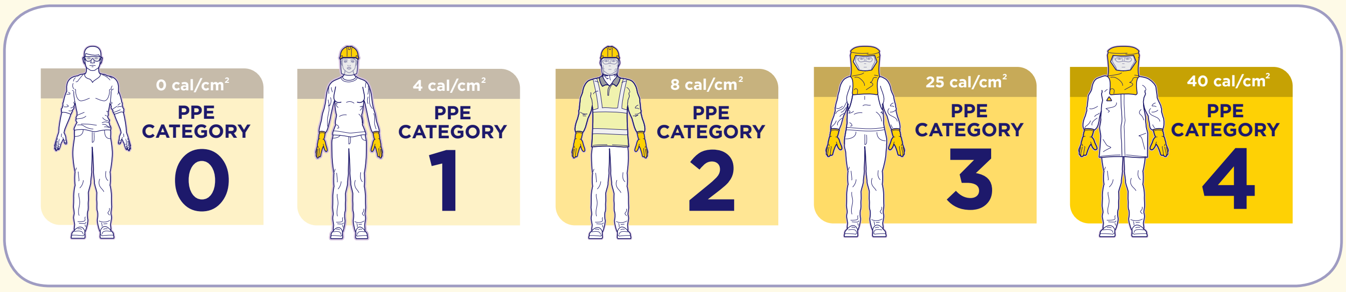
Electric arc flash is a serious hazard which has the potential for personnel injury, equipment damage and loss of business objectives. In Australia, it has been found that there is a need for increased awareness and greater education within the Energy Industry to eliminate or minimise the risk of injury to persons from an arc flash.

The guidance material on the elimination or minimisation of arc flash hazards across Australian workplaces is not available in an accessible or practical form and is not available free of charge. Currently there are several national and international standards and a large volume of technical material published by standards organisations, industry associations and equipment manufacturers on electric arc flash. There is a need however for a consolidated guideline that incorporates the collective electric arc flash hazard knowledge and experience and the presentation in an easy-to-read guideline that can be easily accessed and shared by in the Australian Energy Industry.

Further, there is a need for consideration of the general effect of human factors and of the specific requirements of young workers and workers deemed 'vulnerable' (such as workers with an inadequate amount of training or competency in arc flash risk controls) in the Energy Industry in managing electric arc flash hazards.

This Guideline recommends minimum industry standards, is advisory only and does not substitute for, or override, any legislation, regulation or safety rules implemented by jurisdictional regulators or Energy Industry operators.

Supporting and detailed technical information has been provided in several annexes to assist the development and implementation of Energy Industry organisations' specific arc flash hazard management systems. They have been provided for the purpose of information and guidance only.



Icons in this guideline. Refer to Diagram 18 in Annex B for a more detailed description of correct PPE categories.

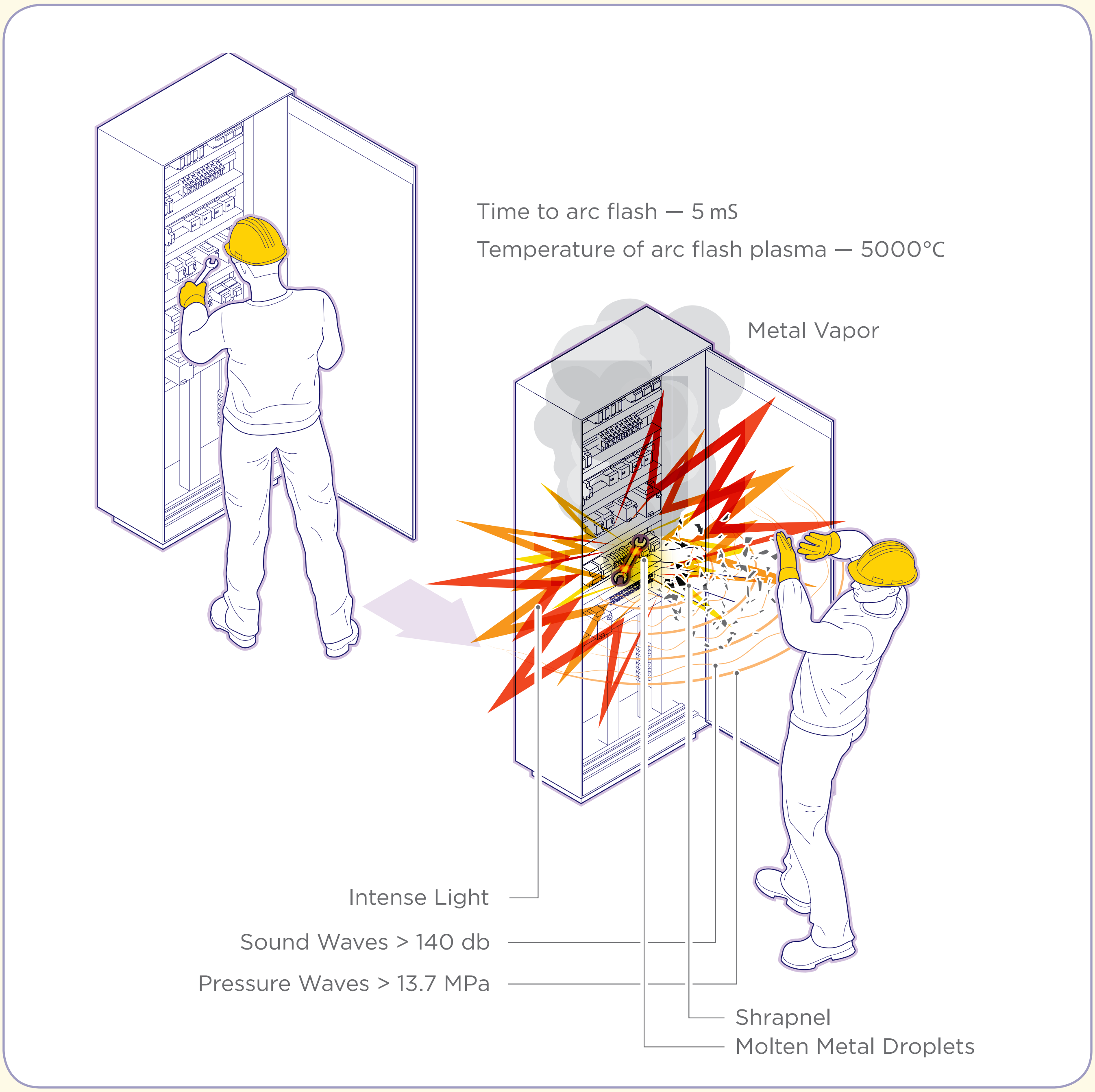


Diagram 1. Arc flash effects

2.0 OBJECTIVES

The objectives of this Guideline are to:

- > Provide an effective hazard management process and set of recommended practices appropriate to the Australian context, for application where electrical arc flash hazards may be encountered across the construction, operation, and maintenance of electrical apparatus within the Energy Industry.
- > Progressively eliminate or minimise the risk of arc flash hazards through improving understanding and application of arc flash hazards, their assessment and their control.
- > Provides an explanation as to how human factors (that being the interaction of individuals with each other, in teams, with equipment and with management systems) and workplace safety culture and attitudes contribute and can be influenced to eliminate or minimise the risk associated with arc flash.
- > Advance the current arc flash literature with the specific requirements of people deemed ‘vulnerable’ working within the Energy Industry.
- > Provide education on arc flash hazards and their assessment (through the calculation of incident energy or heat flux and other technical information that is considered beneficial to the Energy Industry).

This Guideline supports the objectives of the This Guideline supports the objectives of the National Electricity Network Safety Code (ESAA NENS 09) to promote nationally consistent practices within the Energy Industry for arc-rated clothing and Personal Protective Equipment (PPE) for all work on or near electrical equipment where there is a possibility of exposure to residual arc flash incident energy above 5J/cm2 (1.2cal/cm2).

Supporting and detailed technical information has been provided in several annexes, namely:

- Annex A: Arc Flash Risk Assessment
- Annex B: Arc-Rated Clothing and Personal Protective Equipment
- Annex C: Do's and DON'T's of Arc Flash Labelling
- Annex D: Arc Flash Incident Energy Calculation Methods ('Theory')
- Annex E: Calculating Incident Energy or Heat Flux ('Practice')
- Annex F: Electrical Arc Flash Hazards Management Guideline Checklist
- Annex G: References
- Annex H: Definitions

It is not the intent of this guideline to set out a detailed procedure, and as such, procedures should be developed by each Energy Industry organisation in accordance with the principles contained in this Guideline.

This guideline is supported by an online video on electrical arc flash hazards and potential control measures to reduce or eliminate the risk of arc flash occurring. Like this Guideline, the online video is published by the Australia Energy Council (AEC) Level 14, 50 Market Street, Melbourne, VIC, 3000.

3.0 SCOPE

These Guidelines apply when Energy Industry workers are required to perform any activity on or near electrical equipment where arc flash and electric shock hazards exist [and as a guide relates to minimum work on or near energized equipment above Extra Low Voltage (ELV) limits, i.e. 50 V ac (rms) or 120V dc (ripple free)].

Recommendations within these Guidelines relate to core electrical arc flash hazard management as well as electrical hazards (e.g. electrocution) and other workplace hazards (e.g. working at height) where relevant.

This guideline includes high voltage and low voltage. Arc flash risk is often incorrectly only associated with high voltage equipment. Whilst the probability of initiating an arc flash is greater the higher the voltage (due to the greater ability to breakdown insulation), arcs can initiate at low voltage. Low voltage arc flash often results in higher incident energy at the working position, due to the increased fault currents and a range of other factors.

This guide does not cover specific live line work techniques, such as glove and barrier or bare hand live line techniques.

Other workplace hazards and associated controls required for effective hazard identification and risk management not covered within these Guidelines are to be identified and effectively implemented by risk assessment and subsequent application of the hierarchy of control, and as referenced in respective to applicable Acts, Regulations, Codes of Practice, Standards and Guideline.

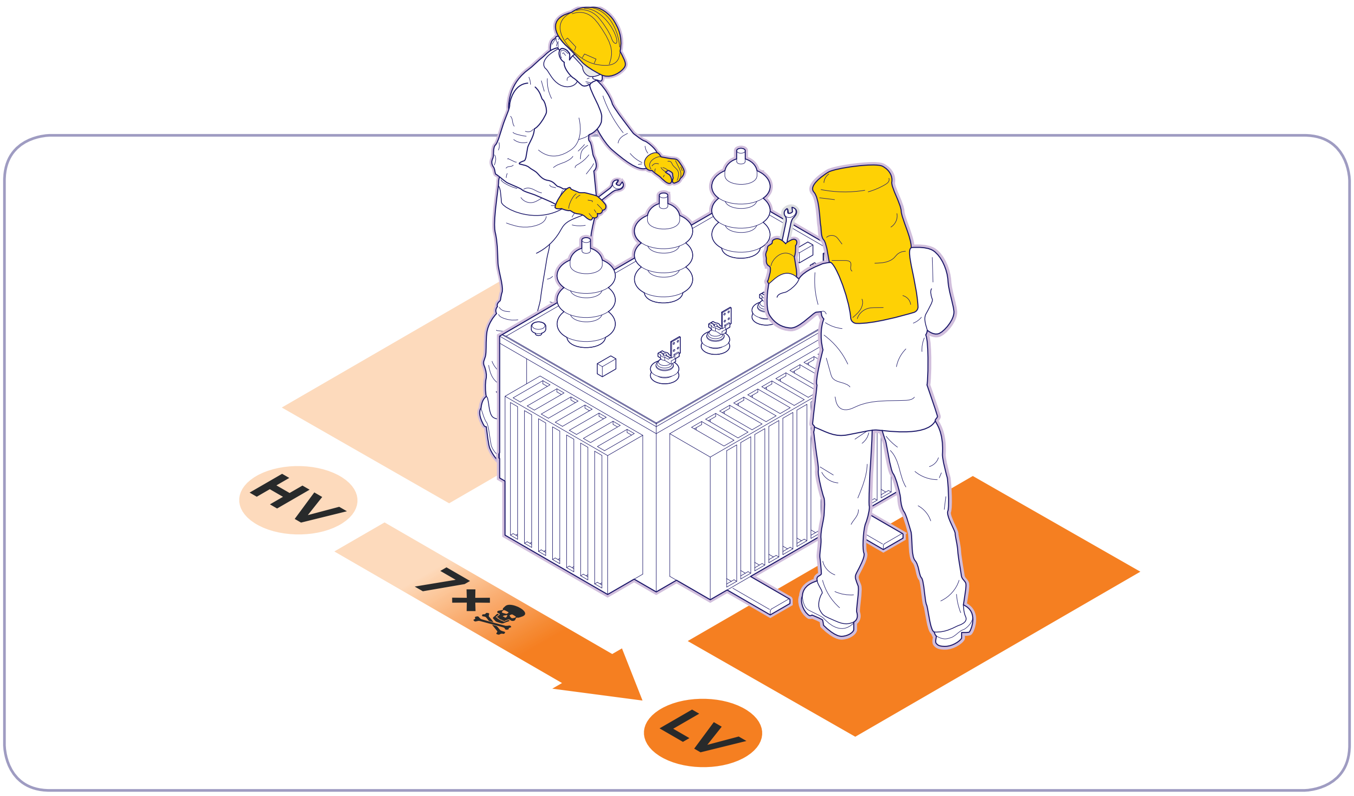


Diagram 2. Low Voltage is far more dangerious than High Voltage

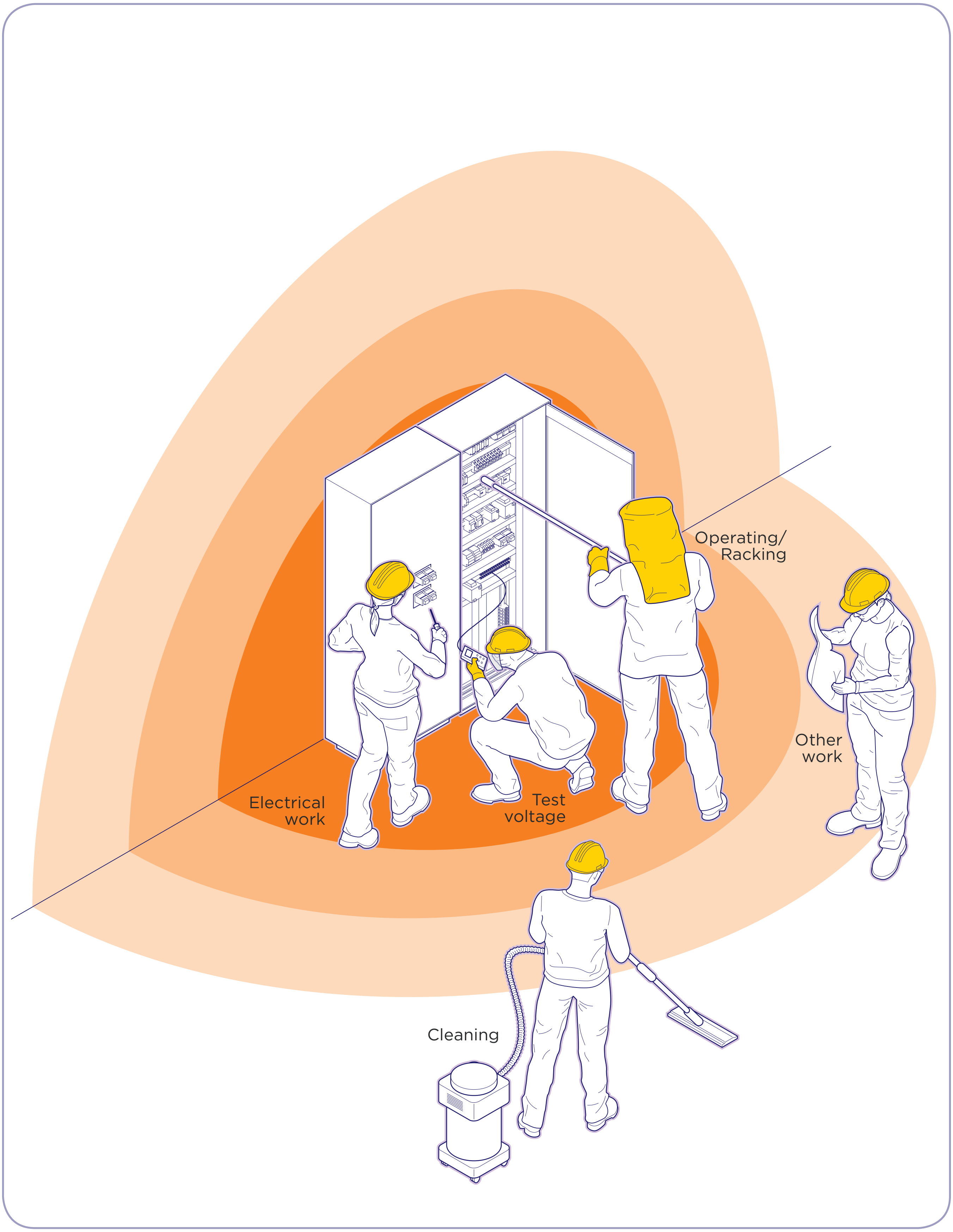


Diagram 3. Exposure to arc flash

4.0 CONSIDERATION OF HUMAN FACTORS

Across Australia, the risk of arc flash incidents or incidents involving electrical hazards (such as working on energised equipment when permitted by law) are affected by any range of human factors in people who perform tasks as electrical workers.

On occasion, electrical work is performed by people who are young (such as apprentices who are largely less than 25 years of age) or who are deemed 'vulnerable' – perhaps as a result of their age, experience or length of service, their level of skill and competence or as a result of relevant and potentially multiplied 'human factors' that are present across the Energy Industry. As these human factors may contribute to electrical incident and accidents the management of (and training in) human factors is an important issue for all electrical workers occurring in the Energy Industry.

By definition, human factors are the wide range of issues that affect how people perform tasks in their work (and non-work environments); how they interact with each other across teams, equipment and workplaces and how they interact with management systems and technology. Human factors are the social and personal skills which can complement (but also distract from) technical skills and they are important for safe and effective electrical work.

Electrical workers in the Energy Industry are deemed 'vulnerable' workers as they are a type of worker that has a greater exposure and are at increased risk of fatality or injury / incident than most - due to both the types of electrical work that they perform and in recognition of the many 'human factors' that interact with their safe and effective performance of technical work in the Energy Industry.

The types of human factors that can interfere with safe and effective electrical arc flash risk controls being implemented by electrical workers can include (but are not limited to):

1. Training and competency: where electrical workers are not educated and competent in the arc flash hazard, they are unaware of the potential for an arc flash incident to cause harm ;
2. Errors, mistakes and lapses: where people make errors in process (across a very wide range of reasons) that results in compromising the effectiveness of an arc flash risk control;
3. Complacency: both with the risks and with the process of arc flash risk controls;
4. Time pressure: where the ability to properly implement an administration control (such as a permit to work) is compromised;
5. Violations: where people deliberately and willingly work 'outside' known risk controls and expected skills and competencies.
6. Information overload: where the information is unclear, overwhelming or duplicated to people leading to confusion and errors (this often affects a contracted workforce who are commonly assigned higher risk work);
7. Distractions: that are both work and non-work related and all lead to a 'breaking' or a person's concentration resulting in error (such as non-work related distractions resulting from mobile phones);
8. Mental health issues and concerns;
9. Peoples whose actions are affected by the interaction of (actual or perceived) workplace culture, being bullied or facing peer pressure from team-members and/or their Supervisors / Team Leaders and a lack of accountability across all aspects of electrical works.

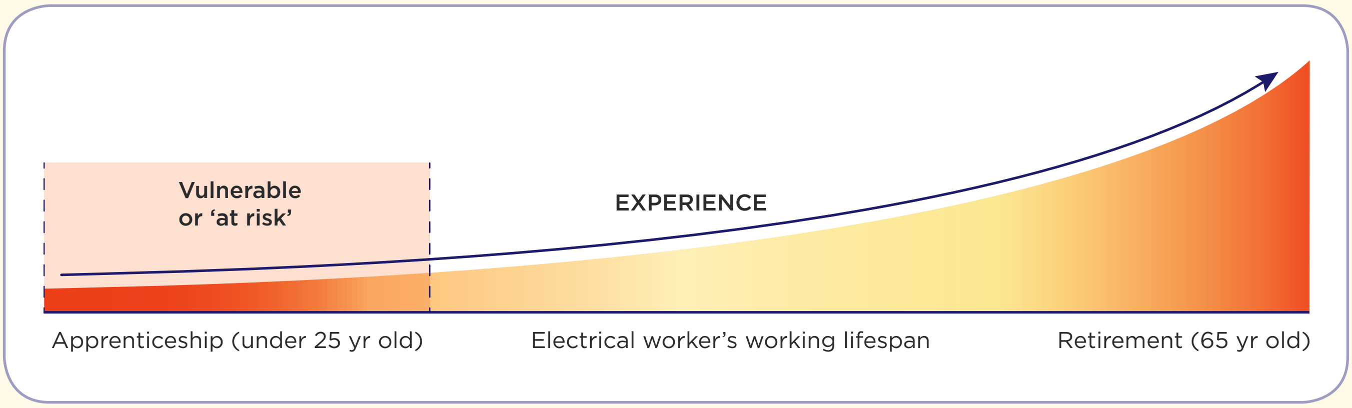


Diagram 4. Vulnerable or 'at risk' worker

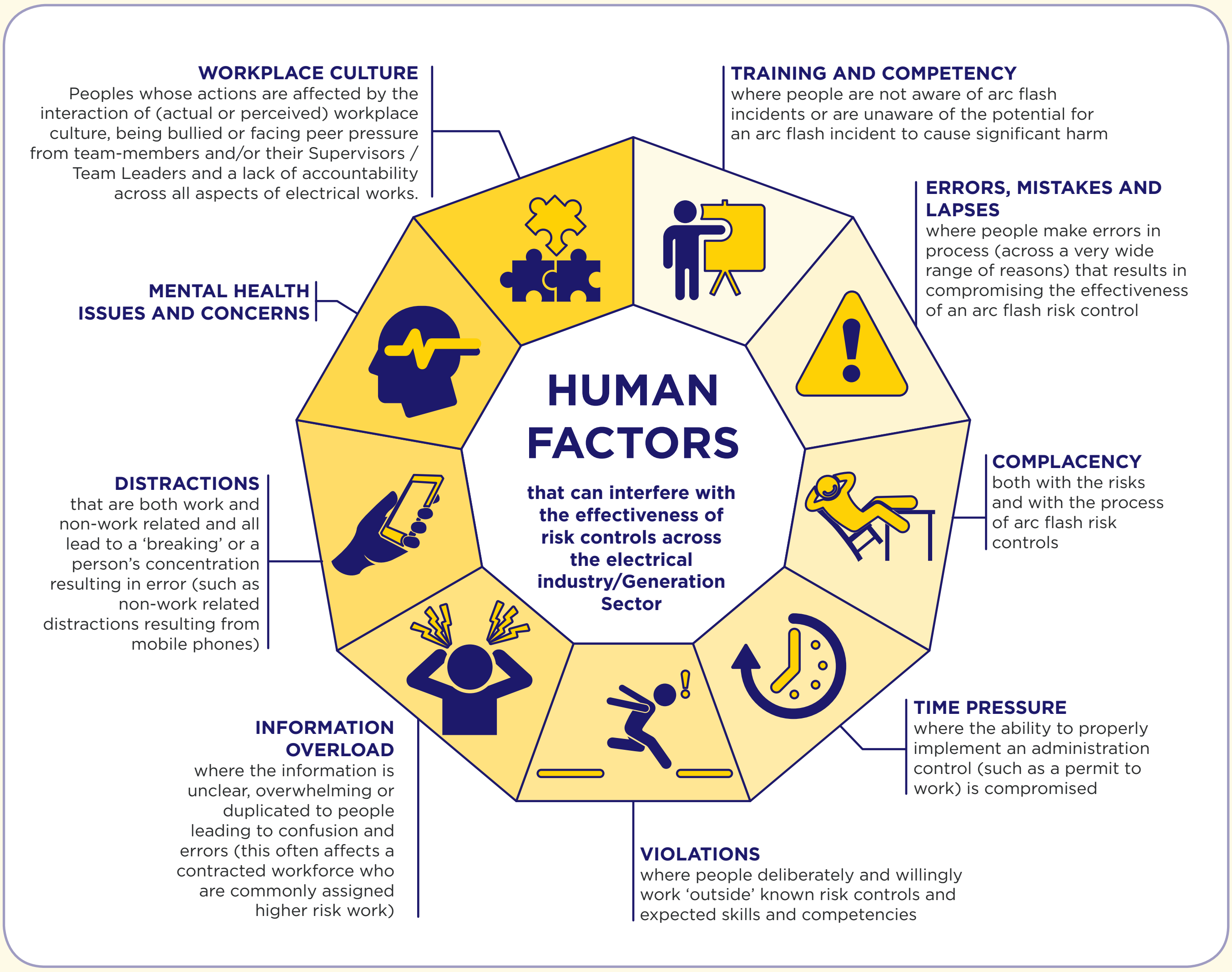


Diagram 5. Human factors

5.0 ELECTRICAL ARC FLASH HAZARD MANAGEMENT

5.1 OVERVIEW OF HAZARD MANAGEMENT PROCESS

When workers are required to work on or near electrical equipment, all reasonably practicable measures should be taken to protect workers from the harmful effects of electric arc flash hazards through hazard elimination and risk reduction.

To achieve this, the following steps should to be undertaken:

a. Understand the hazard
b. Identify assets or asset groups with arc flash hazard potential
c. Quantify the hazard (calculate the arc flash incident energy on each asset or asset group)
d. Assess the risk (using your organisation's risk management framework)
e. Develop and implement risk treatments using the hierarchy of controls
f. Validate control effectiveness
g. Monitor and review.

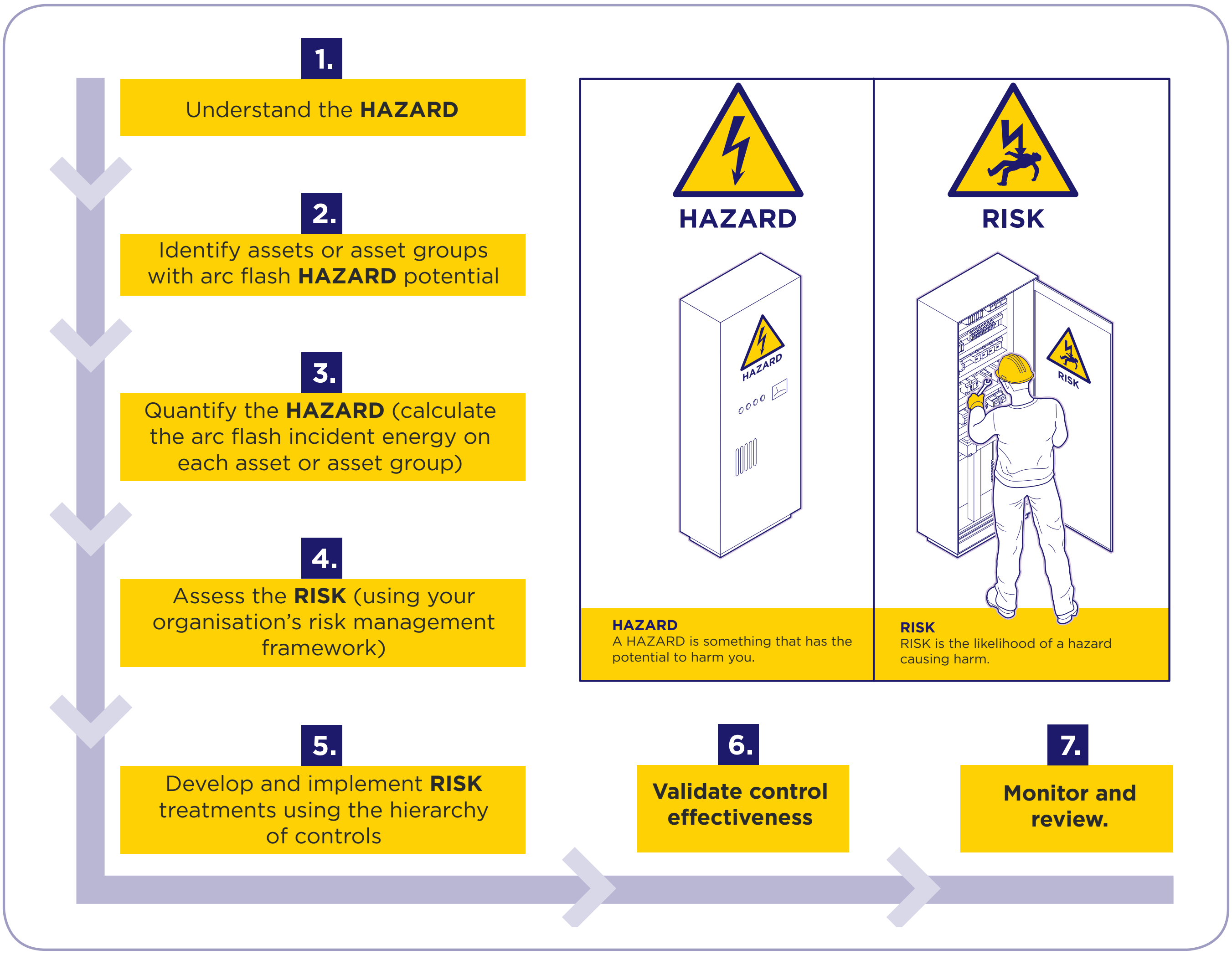


Diagram 6. Hazard management process

5.2 WHAT IS AN ARC FLASH?

An electrical arc fault is often referred to as an Arc Flash.

Arc faults arise when current flows through the air between phase conductors or between phase conductors and neutral or ground. Put simply, an arc fault could be described as an unexpected, violent, electrical short circuit in the air that produces an arc and associated by-products.

When arc faults occur, the resulting energy released may be enough to seriously burn or otherwise injure nearby persons, ignite flammable materials (including clothing), and cause significant damage to plant and equipment.

The term Arc Flash comes from an earlier understanding that the burns from an arc fault were similar to the flash burns from a welding arc. That is, the heat was transferred to the individual by the radiant heat and light (infrared – ultraviolet) from the arc.

Recent research has shown that, although the radiant energy from an electrical arc contributes to the energy received, the major hazard to an individual comes from the plasma ejected by an arc.

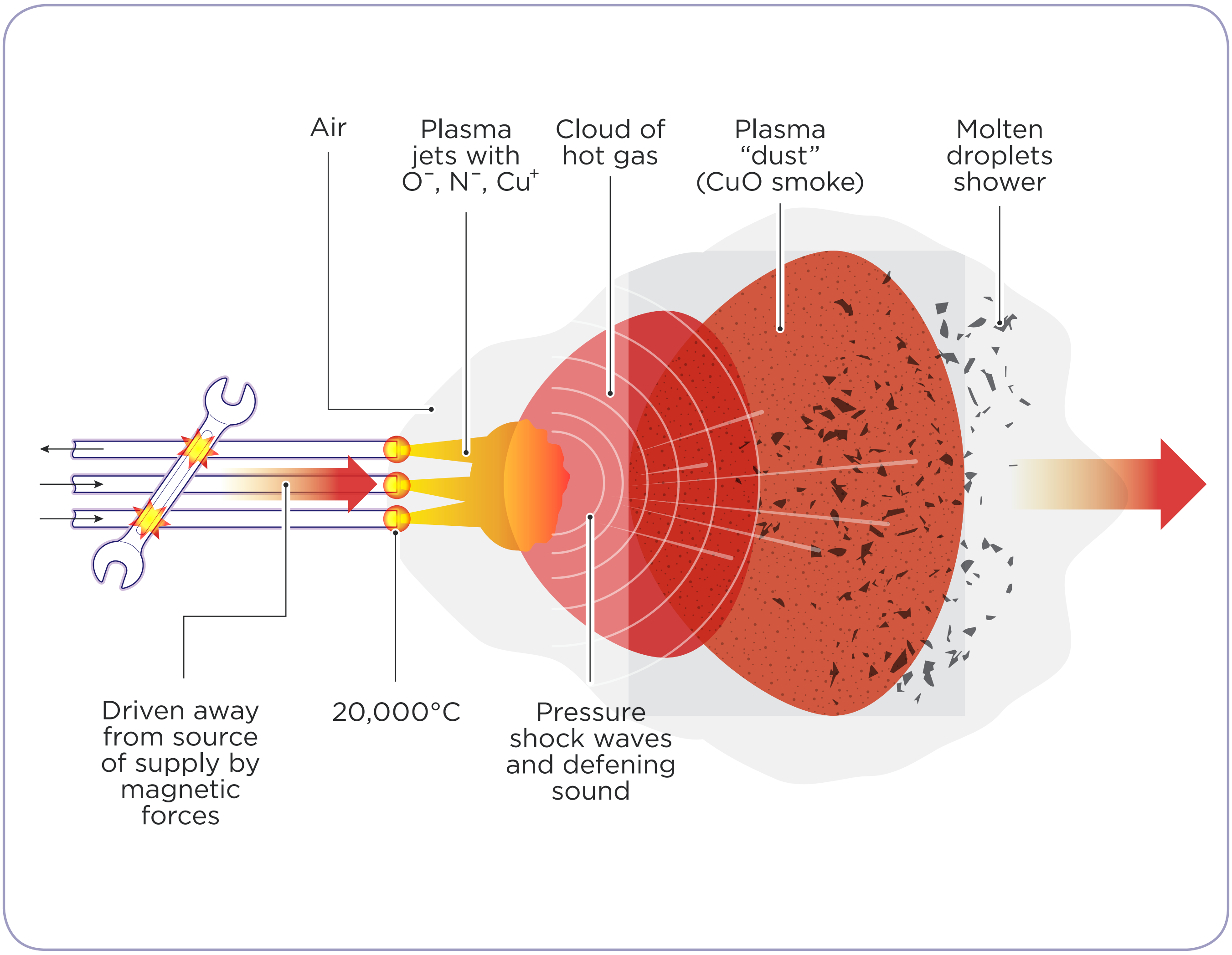


Diagram 7. What is an Arc-flash?

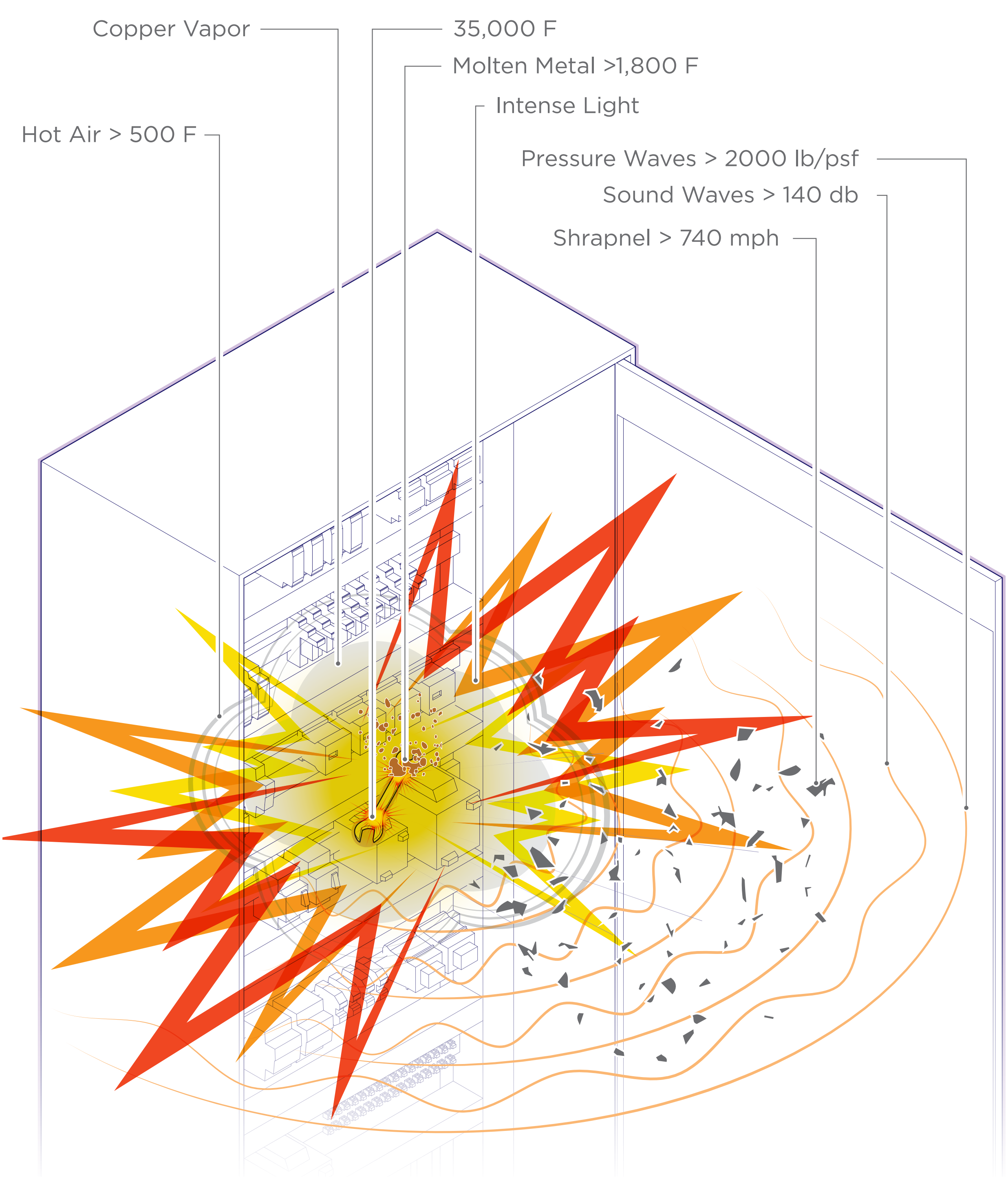


Diagram 8. Other components of an Arc-flash

5.3 WHAT IS ARC PLASMA?

Arc Plasma is the fourth (4^{th}) state of matter (solid, liquid, gas, plasma) and is probably best described as 'super-heated ionised gas'.

The arc plasma ejected by an electrical arc fault may be at temperatures more than 5000 degrees (C) and has sometimes been described as a "fireball or plasma ball" coming from an arcing fault.

Contact with this 5000-degree (C) plasma "fireball" may lead to serious burns.

Importantly though, such contact may also ignite non-arc rated clothing and other Personal Protective Equipment (PPE) with burning clothing and PPE known as significant contributors to the seriousness of injury outcomes.

Clothing and PPE often continue to burn and subsequently continue to impact even after the arc fault and contact with plasma have ceased.

5.4 OTHER PRODUCTS OF AN ARC FAULT

Along with the thermal effects of plasma and radiated heat/light, an arc fault may also produce the following:

> Molten metal droplet spray and metal vapour;
> Ejected debris;
> Pressure wave;
> Noise.

The arc flash will melt and vaporise conductors and other material, which the sudden transition from solid to vapour results in a pressure wave from the rapid expansion (for example copper expands 67,000 times in volume transitioning from solid to vapour).

The high pressures can easily exceed hundreds or even thousands of kilos per square meter and can result in knocking workers off ladders, rupturing eardrums and collapsing a person's lung. Material and molten metal are expelled away from the arc at speeds exceeding 1120 km/hr (700 mph) and are fast enough for shrapnel to completely penetrate the human body. The vaporised and molten metal presents a hazard from both contact and from the inhalation of hot and hazardous compounds.

Arcs that occur in enclosures can be focused, resulting in a higher-pressure rise directed towards an enclosure opening (such as is often the case when a panel door is open and at the point where a person is likely to be positioned).

5.5 WHEN AND WHERE DO ELECTRICAL FAULTS OCCUR?

Unintended and uncontrolled electrical arc faults may occur in several workplace locations and circumstances, and during a range of activities.

Any activity in the vicinity of energised conductors has the potential for arc flash, but arc flash most commonly happens when a person is working on an energised circuit or equipment (knowing it is energised or believing it is not). The risk increases by the degree of interaction with the energised equipment.

The diagram below indicates the increase in risk in the performance of tasks:

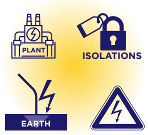
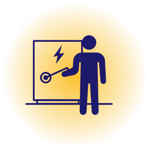
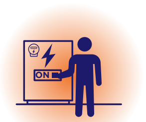
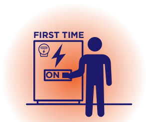
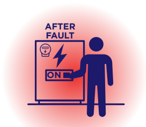
ACTIVITY	**Work on the equipment (isolated, proven de-energised and earthed)**	**Vicinity of equipment**	**Inspection (panel closed)**	**Operating equipment (panels closed)**	**Inspection (panel open)**	**Testing voltage, including proving de-energised**
RISK						
	Work on plant, with isolations locked and tagged, earths applied, barriers and signs	Person standing near electrcial equipment	Person standing in front of electrical panel, reading a meter on the front panel	Person operating equipment with operating handle	Person inspecting open panel, using IR thermometer	Person testing open panel, using multimete
						
	Workers in standard PPE (helmet, safety glasses, ankle to wrist hi visibility clothes, safety boots)	Workers in standard PPE (helmet, safety glasses, ankle to wrist hi visibility clothes, safety boots)	Workers in standard PPE (helmet, safety glasses, ankle to wrist hi visibility clothes, safety boots)	Workers in operating PPE (helmet and face shield, safety glasses, balaclava, ankle to wrist hi visibility clothes, insulated gloves with leather over gloves, safety boots)	Workers in live work PPE (helmet and face shield, safety glasses, balaclava, ankle to wrist hi visibility clothes, insulated gloves, safety boots) Safety observer with LV rescue kit	Workers in live work PPE (helmet and face shield, safety glasses, balaclava, ankle to wrist hi visibility clothes, insulated gloves, safety boots) Safety observer with LV rescue kit

Diagram 9. Increasing Arc Flash risk with work activity Table.

(NB: The PPE and Clothing suggested in this table is a guide only and should be regularly risk assessed based on the equipment design and construction, local business procedures, the actual Arc Flash Incident Energy Level of any of the pieces of equipment as well as the actual activity/work task to be performed).

Work on the equipment (isolated but not proven de-energised)	**Racking (panels closed)**	**Restoration**	**Commissioning**	**Racking (panel open)**	**Restoration after a fault or operation of equipment with possible defect**
Person removing component from open panel, using insulated screwdriver 	Person racking circuit breaker, panel closed, with racking handle 	Person switching electrical equipment on 	Person switching electrical equipment on for the first time 	Person racking circuit breaker, panel open with racking handle 	Person switching electrical equipment on after a fault 
Workers in live work PPE (helmet and face shield, safety glasses, balaclava, ankle to wrist hi visibility clothes, insulated gloves, safety boots) Safety observer with LV rescue kit	Workers in operating PPE (helmet and face shield, safety glasses, balaclava, ankle to wrist hi visibility clothes, insulated gloves with leather over gloves, safety boots)	Workers in operating PPE (arc flash suit)	Workers in operating PPE (helmet and face shield, safety glasses, balaclava, ankle to wrist high visibility clothes, insulated gloves with leather over gloves, safety boots)	Workers in operating PPE (helmet and face shield, safety glasses, balaclava, ankle to wrist hi visibility clothes, insulated gloves with leather over gloves, safety boots)	Workers in operating PPE (helmet and face shield, safety glasses, balaclava, ankle to wrist hi visibility clothes, insulated gloves with leather over gloves, safety boots)

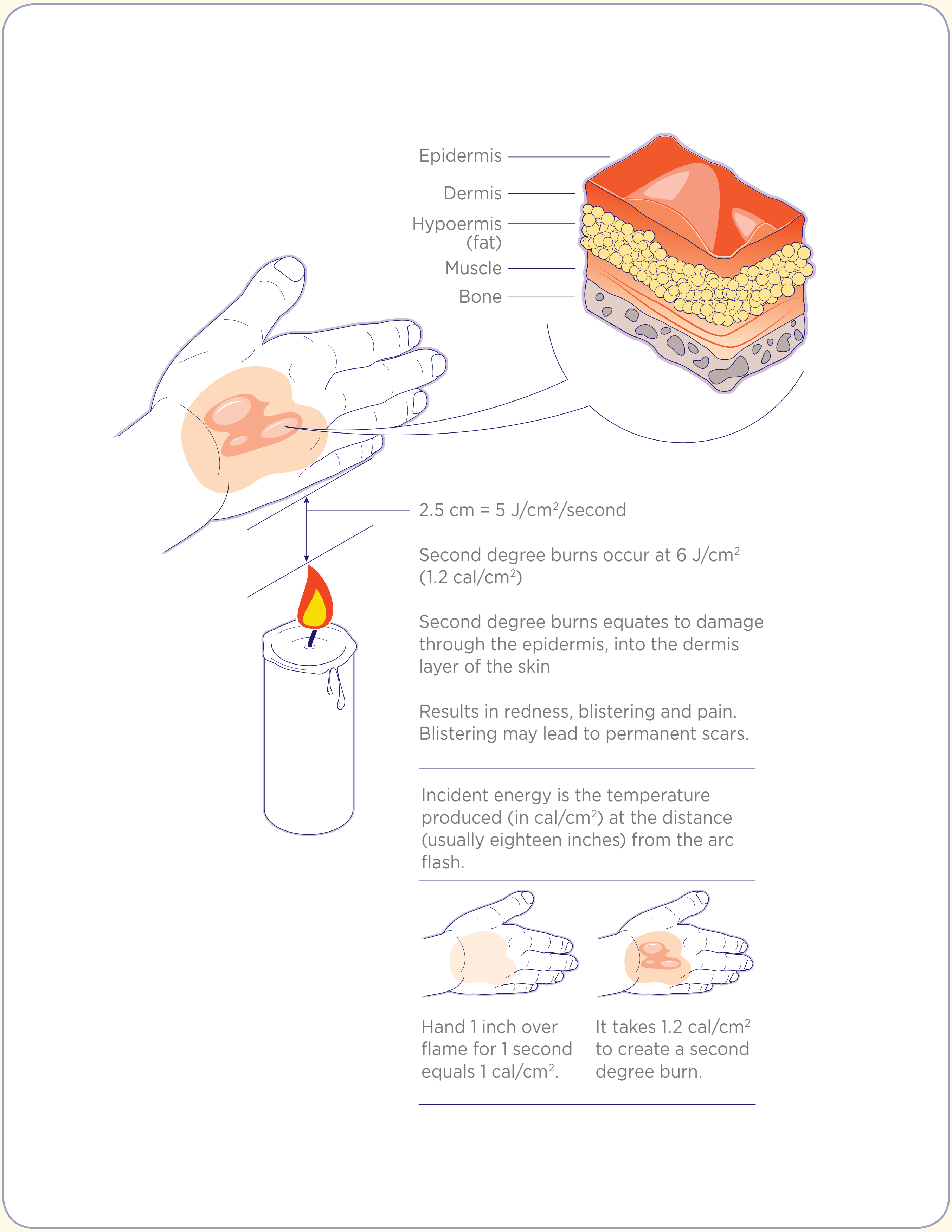


Diagram 10. Second degree burns

TABLE 1: INCREASING ARC FLASH RISKS WITH WORK ACTIVITY

5.6 INCIDENT ENERGY / HEAT FLUX

The amount of energy that strikes an individual during an arc fault is termed **incident energy** (sometimes referred to as **heat flux**) and is usually measured in Joules/cm^2 (or calories/cm^2).

The arc energy is the energy in the arc, but the incident energy is the energy that reaches an individual or surface at a distance from the arc during an arc fault. The duration of an arc fault is usually quite short and is primarily determined by the time it takes for over current protective devices to operate (i.e. open the circuit).

In general, the higher the fault current and/or the longer the protection clearing time, and/or and the shorter the distance from the arc, the greater the incident energy. Calculation of arc flash incident energy is covered in **Annex D: Arc Flash Incident Energy Calculation Methods.**

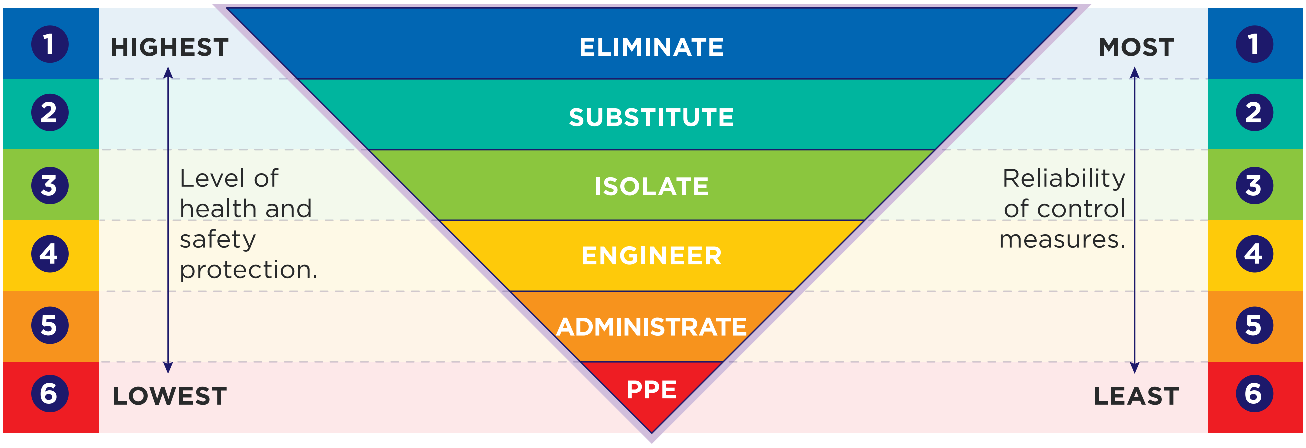
Second-degree burns (also called 'Partial Thickness Burns') are possible on unprotected skin from exposure to arc fault incident energies. The onset of a second-degree burn on unprotected skin is likely to occur at an exposure of 1.2 cal/cm2 (5 J/cm2) for one second.

Therefore, 5J/cm^2 (1.2cal/cm^2) is an important incident energy level threshold for arc fault hazard management.

5.7 RISK MITIGATION – HIERARCHY OF CONTROLS

The **model Work Health & Safety (WHS) Regulations** require duty holders to work through the Hierarchy of Controls when managing health and safety risks.

The ways of controlling risks are ranked from the highest level of protection and reliability to the lowest – details of arc flash risk control measures are included in **Annex A: Arc Flash Risk Assessment.**



1. Eliminate the hazard
2. Replace the hazard with something safer
3. Separate the hazard from people
4. Reduce the risk through engineering controls
5. Change/control the way people work
6. Protect the worker

Diagram 11. Arc flash control measures

5.8 EFFECTIVE IMPLEMENTATION OF ARC FLASH CONTROLS

With arc flash, where the hazard cannot be eliminated, it is often a combination of control measures used to mitigate the hazard. Whilst greater details are outlined in **Annex A: Arc Flash Risk Assessment**, this is typically:

> Elimination – elimination, where possible, is the most effective risk control / mitigation method.

> This means working on energised equipment when:

(a) it is necessary in the interests of health and safety that the electrical work is carried out on the equipment while the equipment is energised, or

Example: It may be necessary that life-saving equipment remain energised and operating while electrical work is carried out on the equipment.

(b) it is necessary that the electrical equipment to be worked on is energised in order for the work to be carried out properly, or

(c) it is necessary for the purposes of testing required under clause 155, or

(d) there is no reasonable alternative means of carrying out the work

> Substitution –Replacing the higher risk activity with a lower risk. Replacing a standard switchboard with one that has been designed and tested for arc-resistant construction

> Isolate – isolation of hazard which can be achieved by working on de-energised (and earthed) electrical equipment or using techniques like remote switching/ racking

> Engineering – such as arc resistant switchboards designed to contain and redirect the arc flash. Alternately, incorporating faster protection settings during maintenance work using remote rackable circuit breakers.

> Administration – such as permits to work, signs, barriers and similar processes which ensure consistent work methods that minimise risk;

> Administration – such as labelling;

> Personal Protective Equipment (PPE) and Clothing.

5.8.1 LABELLING

To clearly communicate the arc flash risk on electrical equipment, it is recommended that electrical equipment is properly labelled.

It is recommended that the Energy Industry considers all labels as needing to meet the requirements of Danger Signage (Danger signs communicate a hazard, condition or situation that is likely to be life threatening).

It is recommended that the Energy Industry considers all labels provide the critical risk information clearly, concisely and consistently. Whilst minimum size of labels cannot be recommended, it is a recommendation of this Guideline that labels are located so they are clearly visible, well placed and include all the information required in international arc flash documents and in a format consistent with Australian requirements. The details included in the labels are shown in the illustration below however as a minimum, it is recomended that all Arc Flash Hazard labels across the Australian Energy Industry include (as a minimum):

> Bus Name or Equipment Name;

> Bus Voltage Level;

> Activity to be performed;

> Incident Energy Level;

> Arc Flash Boundaries; and

> PPE Level Required for varying activity and switchboard status (for example door open / door closed).

> PPE – which protect people from the incident energy if all other controls fail and an arc flash occurs.

Whilst the effective implementation of arc flash controls in aged plants can be incredibly troublesome, some practical recommendations have been provided in **Annex A: Arc Flash Risk Assessment.**

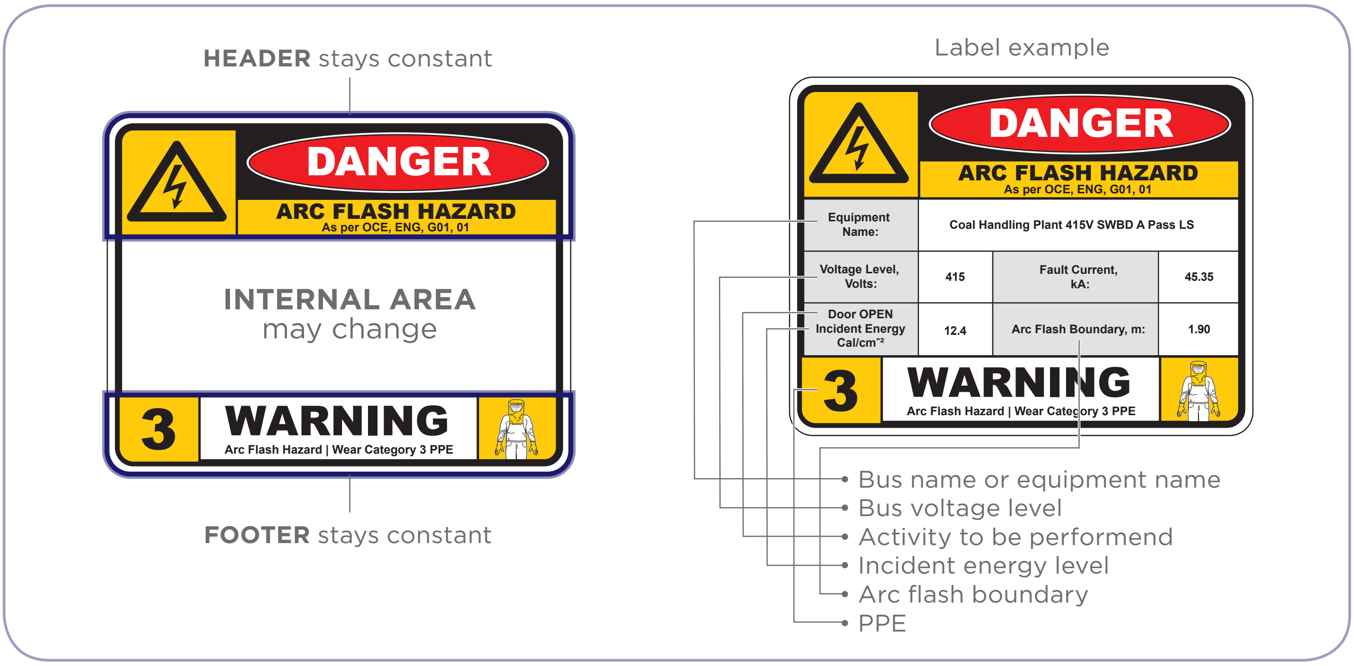


Diagram 12. Arc flash label design

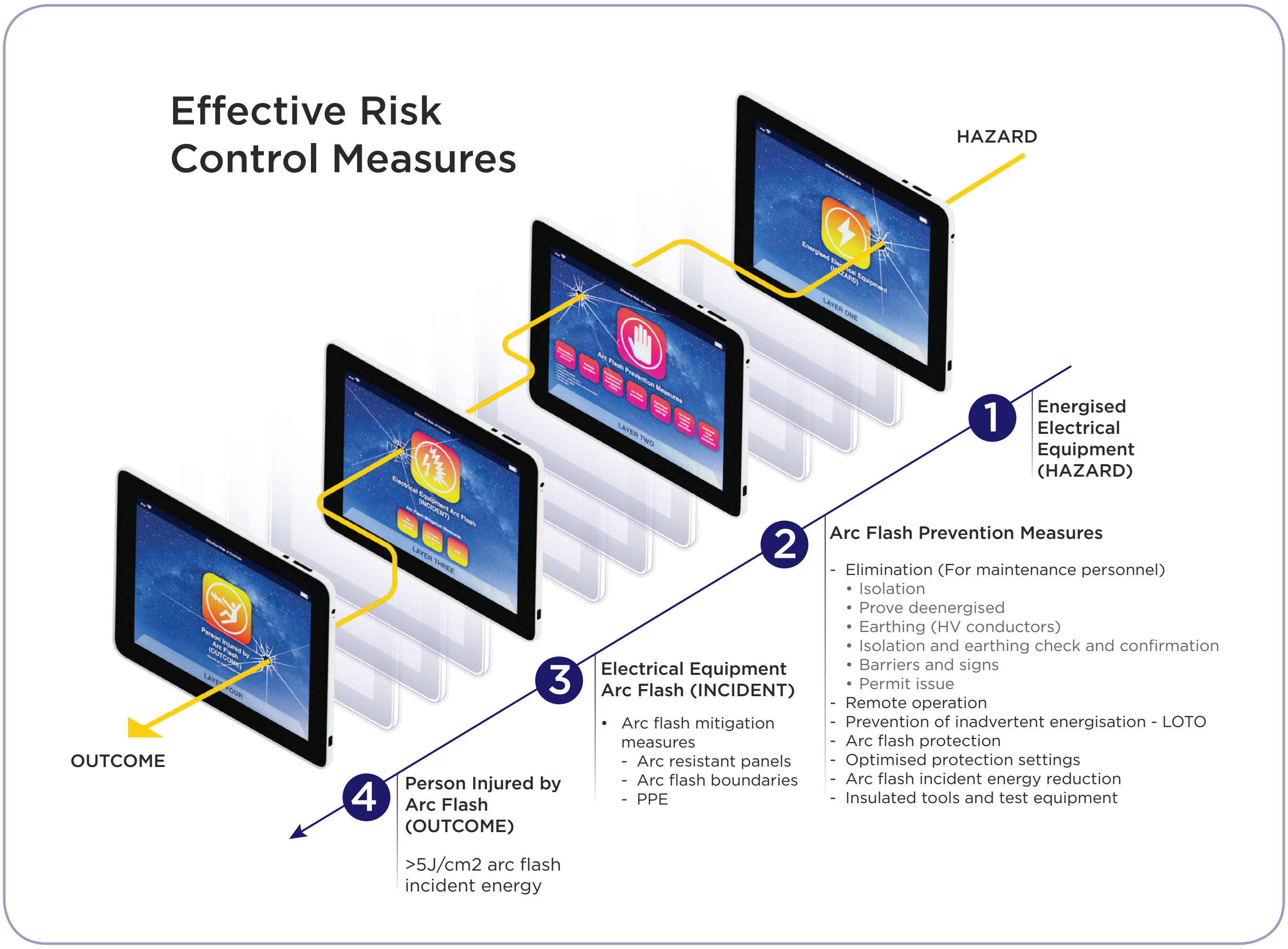


Diagram 13. Layering of controls

This table provides an example where typical steps required for electrical work (LV and HV) and what control measures are effective at that stage.

The table demonstrates that the preferred elimination of hazards is only possible after the de-energisation, isolation and prove deenergised, which still results in hazard to the operators of the equipment. The table should be considered as a guide and is advisory only.

It is not the intent of this guideline to set out detailed risk controls, and as such, risk controls should be developed, implemented and monitored and regularly reviewed by each Energy Industry organisation in accordance with the principles or risk control contained in this Guideline.

TABLE 2: TYPICAL ELECTRICAL WORKER ACTIVITIES AND SUGGESTED RISK CONTROLS

TASK	CONDITION OF BOARD: ENERGISED STATE	CONDITION OF BOARD: PANELS	LEVEL OF RISK* (*REFER TO DIAGRAM 11 - ARC-FLASH CONTROL MEASURES)	WHAT TO LOOK OUT FOR
Work scoped Work identified to be done	Energised	Closed	3	Correct understanding of the work Confirmation bias may exist
Work inspection Plant may require inspection to fully determine the scope and work instructions, or to correctly design the isolations.	Energised	Open	4 5 6	Plant is energised and is at risk of arc flash. The inspection must not place the persons inspecting at risk. If it does, it should be treated
Risk Assessment and Work instructions prepared Work instructions and risk assessments completed	Energised	Closed	3 5	Work instructions and risk assessments can be limited by the knowledge and experience of the persons creating them. Check and challenge to ensure all the work and risks are identified.
Isolations designed Isolations and earthing required making the work area safe need to be designed.	Energised	Closed	3	The design of the isolations determines the effectiveness of the Elimination control. Inaccuracy or lapses have a potential major impact. Should be checked by another person to ensure accuracy Checking drawings for accurate information Identifying all possible energised supplies
Approval of the work, risk assessment and isolation design as per company procedures	Energised	Closed	3	The approval process is to ensure the work scope, risk assessment and isolation design process have been completed correctly and thoroughly.
De-energisation (remote) Switching of plant by means that does not require the operator to stand in the arc flash boundary	Unknown	Closed	3 5	Ensure other personnel are not in the vicinity and at risk; Ensure remotely operated plant is confirmed to have operated correctly.
De-energisation (local) Switching of plant that require the operator to stand in the arc flash boundary	Unknown	Closed	4 5 6	Ensure only load breaking rated plant is used to break load currents; Operator should position themselves to stand to the side of plant where possible, to reduce the direct incident energy from and arc flash.
Isolations applied Application of isolations as per company procedures.	Unknown	Open	4 5 6	Locks and Tags best practice; Ensure 3 phase devices all phases operated correctly; Ensure correct isolations devices identified, operated correctly and confirmed in the correct state.

Prove circuits deenergised	Deenergised	Open	4	5	6	Include all circuits that workers may be exposed to. Prove the tester, before and after testing. If the isolations are not correct, the prove deenergised test may cause an arc flash.
Earths applied to HV conductors and where required	Deenergised	Open	4	5	6	If the conductor is energised, the earthing will cause an arc flash.
Permit issued/job briefed Work party correctly briefed on the safety precautions required for the work to be undertaken. If under a permit, the correct permit issue is adhered to.	Deenergised/ earthed	Open	1	5	6	Permit issue is the formal acknowledgement by the work party that they correctly understand the permit conditions and will adhere to all safety instructions. Last chance to confirm the safety precautions are correct and the work can be completed safely. Complacency and inattention at this step place the work party at risk.
Work party undertakes the work as per the work scope.	Deenergised/ earthed	Open	1	5	6	Ensure work party is either competent to perform the work, or adequately supervised. Beware of scope creep, which may result in work beyond what the risk assessment and isolation design allowed for.
Permit relinquished and cancelled Work party relinquishes permit and the operator cancels	Deenergised/ earthed	Open	1	5	6	Permit holder and operator should check and confirm the state of the plant, to ensure it is safe to reenergise. Left tools, earths or incorrectly replaced covers or fittings can result in arc flash upon reenergisation
Earths removed Removal of earths from conductors	Deenergised	Open	1	5	6	As soon as earths are removed, HV conductors are unsafe. All earths must be removed, as reenergisation on an earth will result in a short circuit and potential arc flash risk.
Isolations restored to allow plant to be energised	Unknown	Open	4	5	6	Ensure restoration of isolation will not inadvertently energise the plant as this can result in the isolation failing.
Reenergisation (remote) - Switching of plant by means that does not require the operator to stand in the arc flash boundary	Energised	Closed	3	5		Ensure other personnel are not in the vicinity and at risk; Ensure remotely operated plant is confirmed to have operated correctly.
Reenergisation (local) Switching of plant that require the operator to stand in the arc flash boundary	Energised	Closed	4	5	6	Ensure only load breaking rated plant is used to break load currents; Operator should position themselves to stand to the side of plant where possible, to reduce the direct incident energy from and arc flash.
Operational testing Plant may require checking and testing to ensure operating correctly	Energised	Open	4	5	6	Plant is energised.

Supporting information has been provided in several ‘informative’ annexes to assist with the minimum competency requirements of Energy Industry organisations’ as they progress their specific arc flash hazard management system.

The annexes provided are for information and guidance only.

6.0 DEMONSTRATION OF INDEPENDENT COMPETENCY IN PERFORMING THE FOLLOWING TASKS

Whilst definitions of electrical work (and electrical workers) differ across all Australian States and Territories, it is the intent of this guideline to recommend the minimum competency requirements for workers who are (or have the potential to be) exposed to the harmful effects of electric arc flash hazards.

It is recommended that the Energy Industry considers, as a minimum, the following:

TYPE OF WORKER	MINIMUM COMPETENCY REQUIREMENT	MINIMUM EDUCATIONAL REQUIREMENT
Electrical Engineers	> Arc Flash Risk Assessment > Arc Rated Clothing and Personal Protective Equipment (including the limitations of arc flash PPE and incorrect Arc Flash PPE) > Arc Flash Labelling > Arc Flash Incident Energy Calculation Methods (‘Theory’) > Calculating Incident Energy or Heat Flux (‘Practice’) > References > Definitions	> Registered and / or Australian recognised qualification in Electrical Engineering > Instruction, Supervision, Information or Training in Human Factors
Electricians	> Arc Flash Risk Assessment > Arc Rated Clothing and Personal Protective Equipment (including the limitations of arc flash PPE and incorrect Arc Flash PPE) > Arc Flash Labelling > References > Definitions	> Registered and / or Australian recognised Trade based Qualification > Instruction, Supervision, Information or Training in Human Factors
Maintenance	> Arc Flash Risk Assessment > Arc Rated Clothing and Personal Protective Equipment (including the limitations of arc flash PPE and incorrect Arc Flash PPE) > Arc Flash Labelling	> Registered and / or Australian recognised Maintenance Qualification > Specific and / or directly related industry experience > Instruction, Supervision, Information or Training in Human Factors

TYPE OF WORKER	MINIMUM COMPETENCY REQUIREMENT	MINIMUM EDUCATIONAL REQUIREMENT
Operators	> Arc Flash Risk Assessment > Arc Rated Clothing and Personal Protective Equipment (including the limitations of arc flash PPE and incorrect Arc Flash PPE) > Arc Flash Labelling	> Registered and / or Australian recognised Operator Qualification > Electrical Plant Specific Operator Training > Instruction, Supervision, Information or Training in Human Factors
Electrical Contractors	> Arc Flash Risk Assessment > Arc Rated Clothing and Personal Protective Equipment (including the limitations of arc flash PPE and incorrect Arc Flash PPE) > Arc Flash Labelling > References > Definitions	> Registered and / or Australian recognised Trade based Qualification > Instruction, Supervision, Information or Training in Human Factors
Health & Safety Practitioners / Professionals	> Electrical Arc Flash Hazards Management Guideline Checklist	> Registered and / or Australian recognised qualification in WHS (or related discipline) > Instruction, Supervision, Information or Training in Human Factors
Technical Trainers	> Arc Rated Clothing and Personal Protective Equipment (including the limitations of arc flash PPE and incorrect Arc Flash PPE) > Arc Flash Labelling > References > Definitions	> Registered and / or Australian recognised qualification in WHS (or related discipline) > Instruction, Supervision, Information or Training in Human Factors

7.0 ADDRESSING THE HUMAN FACTORS

Human factors play a significant role in how people organise, manage and conduct various activities and how they respond to various situations. In the context of electric arc flash, these human factors and consideration of 'vulnerable' people has gained considerable attention.

Increasingly there is growing awareness for consideration of the general effect of human factors and of the specific requirements of people deemed 'vulnerable' and currently working in the Energy Industry. The human factors involved in incidents / accidents around electrical arc flash incidents in the Energy Industry are:

> Workers being inexperienced or having never received formal training (or been deemed competent) in electrical arc flash hazards and the expected risk controls;
> Workers making unintentional errors because of performing familiar tasks out of habit or whilst on 'auto-pilot' or perhaps because they are complacent or have made a mistake;
> Workers making intentional errors or violating the procedures of safe work;
> The self-imposed or actual pressure and stress of insufficient time, high workloads and interruptions / distractions;
> Technical / other information overload (this includes when safe work procedures are ambiguous or confusing);
> When personal stress or mental health factors (such as relationship breakdown, death of a family member etc) are involved or are involved to a level that workers are not used to dealing with; and
> When the workplace contributes to an unsafe workplace culture.

The recommended actions for organisations to consider if human factors are or have the potential to interfere with the effectiveness of risk controls are outlined below. All suggested Human Factor risk controls have been provided are for information and guidance only and are still subject to a risk assessment per team, site or workplace.

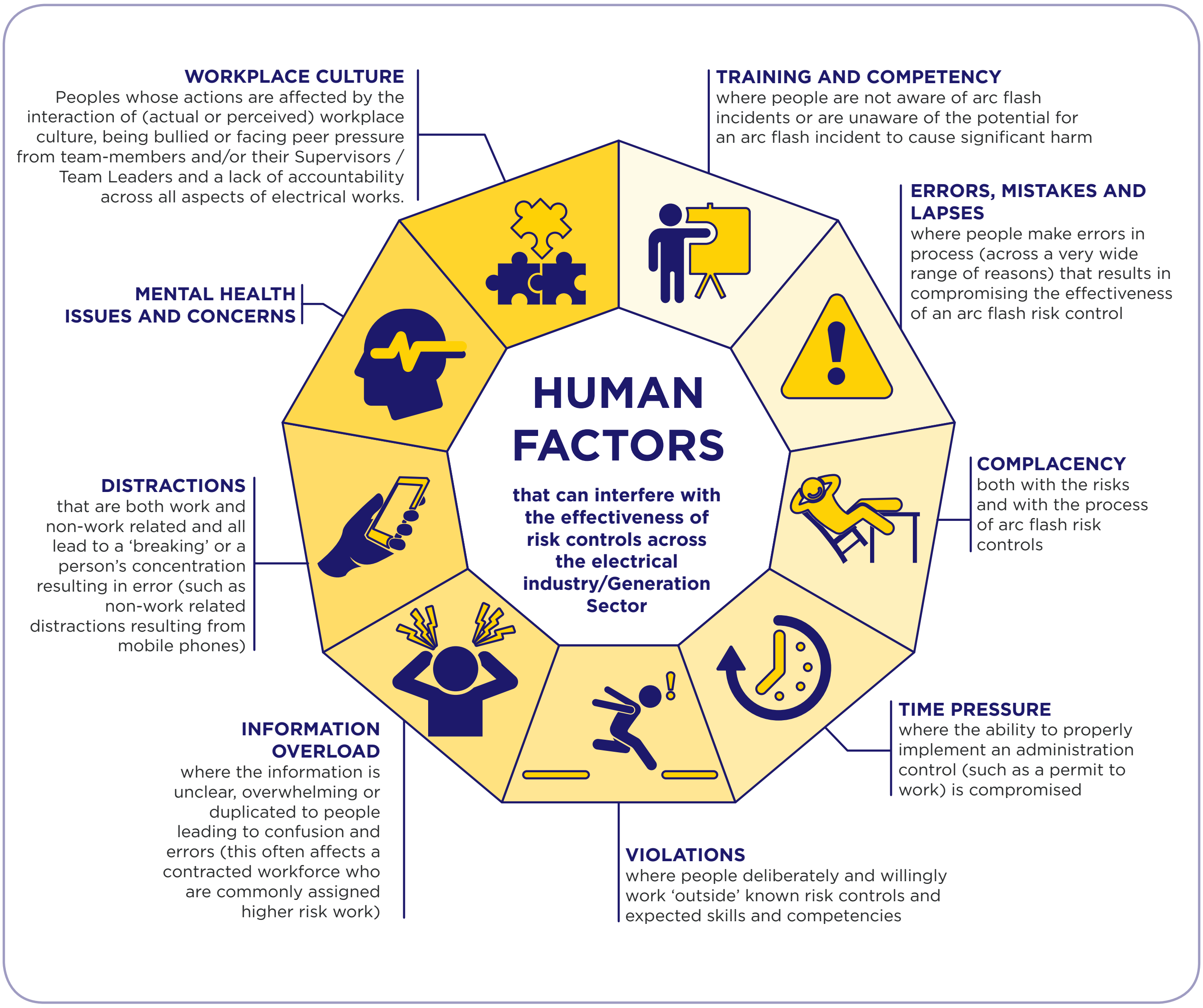


Diagram 14. Human factors

TABLE 3: TYPICAL HUMAN FACTOR ACTIVITIES AND SUGGESTED RISK CONTROLS

HUMAN FACTOR	CONSIDERATION OF HUMAN FACTOR RISK CONTROL
Training and Competency	> Commit to an implementation of the minimum competency requirements when working on / around electrical arc flash hazards > Instruction, Supervision, Information or Training in Human Factors > Appropriate worker selection and monitoring to the ongoing suitability of workers selected to perform relevant works
Errors, Mistakes and lapses	> Verification activities. Isolation, plant ID and activity required > Appropriate worker selection and monitoring to the ongoing suitability of workers selected to perform relevant works > Stop and think processess (Take 5) > Ongoing safety observation process (Behavioural based) > Management, Team Leader and Supervisor and Peer walkdowns Effective QA documentation – Switching or job instruction > Interlock and control – error tolerent equipment
Complacency	> Ensure levels and type of supervision matches the actual (or potential) of arc flash hazards and risk > Commit to arc flash awareness activities by way of alerts, training, refreshers, tool box talks, and lessons learned (post industry incidents and accidents).
Time Pressure	> Executive and Senior Management oversight > Proper planning and resourcing for activities > Higher risk activities emphasised in risk assessment > Management, Team Leader and Supervisor and Peer walkdowns
Violations	> Ensure levels and type of supervision matches the actual (or potential) of arc flash hazards and risk > Accountability process implement for all levels of business > Executive oversight of competing business drivers

HUMAN FACTOR	CONSIDERATION OF HUMAN FACTOR RISK CONTROL
Information Overload	> Simple english documentation and signage > Local signage > Removal of detail not required by person undertaking activity > Diligence towards the creation of simple software systems and processes toward Permit to Work Systems and other isolation tasks
Distractions	> Ensure levels and type of supervision matches the actual (or potential) of arc flash hazards and risk > Stop and think processess (Take 5) > Ongoing safety observation process (Behavioural based) > Management, Team Leader and Supervisor and Peer walkdowns
Mental Health issues and concerns	> Ensure levels and type of supervision matches the actual (or potential) of arc flash hazards and risk > Stop and think processess (Take 5) > Ongoing safety observation process (Behavioural based) > Management, Team Leader and Supervisor and Peer walkdowns > Employee Assistance Programs (EAP) and other Mental Health First Aid assistance in the event of worker disclosure of mental health issues and concerns
Workplace Culture and other organisational / team factors	> Cultural audit > Accountability process implement for all levels of business > Ensure levels and type of supervision matches the actual (or potential) of arc flash hazards and risk > Stop and think processess (Take 5) > Ongoing safety observation process (Behavioural based) > Management, Team Leader and Supervisor and Peer walkdowns

8.0 MANAGEMENT OF CHANGE

The effective management of change is especially important within the Energy Industry because it supports communication, teamwork and the effective coordination of activity toward the elimination or minimisation of risk of injury to persons from an electrical arc flash hazard.

Any organisations management of change method should be applied to any electrical arc flash hazard management program and in conjunction with **Annex F: Electrical Arc Flash Management Guideline Checklist.**

9.0 ANNEXES

Annex A: Arc Flash Risk Assessment

Annex B: Arc-Rated Clothing and Personal Protective Equipment

Annex C: Do’s and DON’T’s of Arc Flash Labelling

Annex D: Arc Flash Incident Energy Calculation Methods (‘Theory’)

Annex E: Calculating Incident Energy or Heat Flux (‘Practice’)

Annex F: Electrical Arc Flash Hazards Management Guideline Checklist

Annex G: References

Annex H: Definitions

ANNEX A: ARC FLASH RISK ASSESSMENT AND CONTROL

ASSESSING THE RISK OF ARC FLASH

The WHS Act and Regulations require persons who have a duty of care to ensure health and safety to 'manage risks.' This eliminates or minimises health and safety risks so far as is reasonably practicable.

Risk assessment involves considering what could happen if someone is exposed to a hazard and the likelihood of it happening.

As per Model Code of Practice - Managing Electrical Risks in the Workplace (published as approved code of practice under Section 274 of WHS Act), a risk assessment is to be prepared. Control/mitigation measures are to be put in place to reduce the level of risk so far as is reasonably practicable.

RISKS CAN ARISE FROM THE FOLLOWING:

- The properties of electricity (in the form of a hidden risk) as electrical currents are mostly invisible, have no smell or sound (noting that some equipment does emit a sound when energised such as Transformers and HV lines);
- Work environment such as wet weather, confined spaces and hazardous atmospheres;
- Competency of the individual carrying out the electrical work.

TO ASSESS THE RISK, CONSIDER:

- What is the potential impact of the hazard?
  - Severity of the electrical hazard such as direct contact causing electrocution, fire or explosion causing serious burns or death.
  - Number of persons exposed to the hazard
- Likelihood of the hazard causing harm
  - Likely, unlikely, possible or would it be a rare event
  - Frequency of exposure

OTHER FACTORS THAT MAY AFFECT CONSEQUENCES & LIKELIHOOD ARE:

- Equipment working conditions (wet condition, outdoors, confined space)
- Work practices (isolations, permits) and availability of work procedures to carry out electrical maintenance
- Experience, skill and capability of relevant workers.

WHS RISK MANAGEMENT REQUIREMENTS

For work on or near energised electrical equipment (including the isolation, testing for deenergised, and restoration of the equipment required for safe access), works must be assessed for risk.

As per Work Health & Safety Regulation 34 Duty to Identify Hazards requires a duty holder to identify of reasonably foreseeable hazards (including arc flash hazards).

WHS regulation 35 requires risk management to eliminate, and if not possible, to minimise risks "so far as is reasonably practicable".

As per Work Health & Safety Act Division 4 Section 157 electrical work on energised electrical equipment – when permitted, is not carried unless:

a. It is necessary to do carry out the work in the interests of health and safety. For example, it may be necessary that life-saving equipment remain energised and operating while electrical work is carried out;
b. It is necessary that the electrical equipment is energised in order for the work to be carried out properly;
c. It is necessary for the purposes of testing required under clause 155;
d. There is no reasonable alternative means of carrying out the work.

Work should be carried out in accordance of the requirements for energised work.

REQUIREMENTS FOR ENERGISED WORK:

1. A documented risk assessment;
2. Area clear of obstructions to allow for easy access and exit;
3. Point of supply clearly marked, labelled and capable of being operated quickly (with exceptions);
4. Following consultation with a person with management control of the workplace;
5. Inadvertent contact prevented;
6. Carried out by a competent person;
7. With tools, testing equipment and PPE suitable for the work, properly tested and maintained in good working order;
8. In accordance with a SWMS; and
9. With a safety observer, competent to implement control measures and rescue the worker if necessary (with the exception that not required if work identified there is no serious risk and consisting only of testing

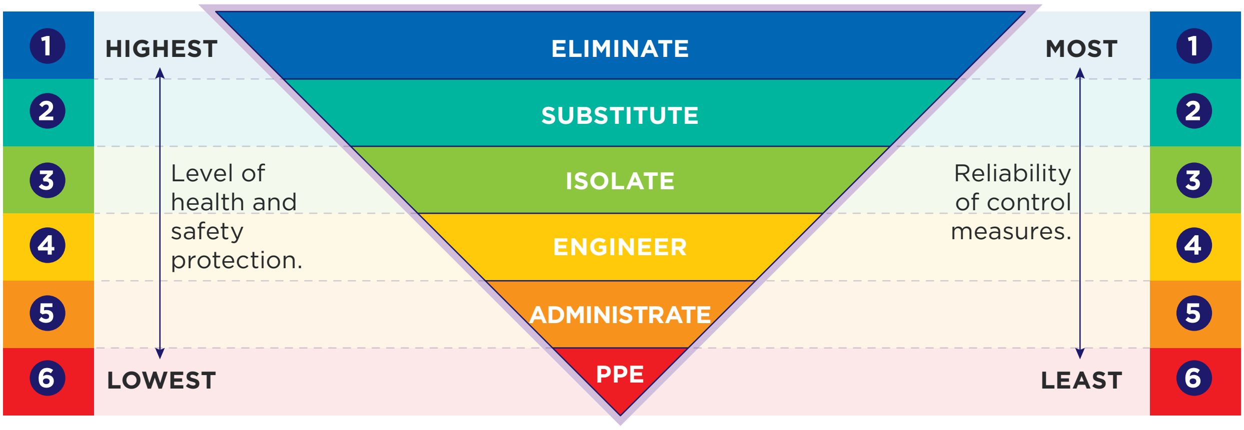
Until the arc flash hazard has been eliminated or isolated, personnel inside the arc flash limit should be using PPE appropriate for the energy level (cal/cm2).

Electrical equipment shall be treated as energised until it is isolated and proven deenergised.

CONTROLS FOR ARC FLASH TYPICALLY RELY TO THE FOLLOWING PRINCIPLES:

- Reduction of arc flash energy;
- Reduce the exposure of personnel to the arc flash;
- Protect people from the arc flash though application of the Hierarchy of Controls;
- Increase the commitment to experience, skills and capabilities of relevant workers.

HIERARCHY OF CONTROL



1. Eliminate the hazard
2. Replace the hazard with something safer
3. Separate the hazard from people
4. Reduce the risk through engineering controls
5. Change/control the way people work
6. Protect the worker

Diagram 15. Hierarchy of controls diagram to re-draw in new style

RISK CONTROL / MITIGATION – ELIMINATION

Elimination is the most effective risk control/ mitigation method. The elimination of arc flash risk requires that there is no exposure of personnel to energised electrical equipment, either by the physical separation for the energised equipment, or by the effective isolation (and earthed if high voltage) and proof that electrical conductors are deenergised.

Whilst the isolation and earthing of conductors eliminates the risk, the process to isolate, prove deenergised and earth conductors still has arc flash risk.

CONTROLS THAT MAY ELIMINATE THE ARC FLASH RISK ARE:

> Eliminate the need to be near energised electrical conductors – relocate the work.

> Isolate and earth conductors, so they are no longer energised.

RISK MITIGATION – SUBSTITUTION

Substitution requires a hazard to be replaced with a less dangerous hazard. With electrical equipment, there is little opportunity to substitute.

RISK MITIGATION – ISOLATION

Isolation of arc flash risk involves the separation of personnel from the energised electrical equipment and conductors. Isolation is most effective for personnel who do not need to operate or work on the electrical equipment.

Some controls that may isolate the arc flash risk are:

> Restrict proximity to energised electrical plant;

> Restrict switch rooms and substations to authorised personnel only;

> Use Arc Flash boundaries;

> Restrict access when switching or live work is undertaken;

> Use remote switching and racking equipment;

> Follow permit to work system and electrical safety procedures;

> Keep away from the arc flash boundary.

ARC FLASH BOUNDARIES

Arc Flash Boundaries are the distances from energised equipment that should be maintained to manage arc flash risk.

The boundaries are set around two key criteria:

> The distance for the standard levels of PPE to protect the person;

> The amount of energy a person in the working position will be exposed to during an arc flash.

The determination of the appropriate boundaries is by the reviewing **Annex D – Arc Flash Incident Energy Calculation Methods.**

The boundaries are defined as:

> Arc Flash boundary (outer boundary): The flash boundary is the farthest established boundary from the energy source. If an arc flash occurred, this boundary is where an employee would be exposed to a curable second-degree burn (1.2 cal/cm2).

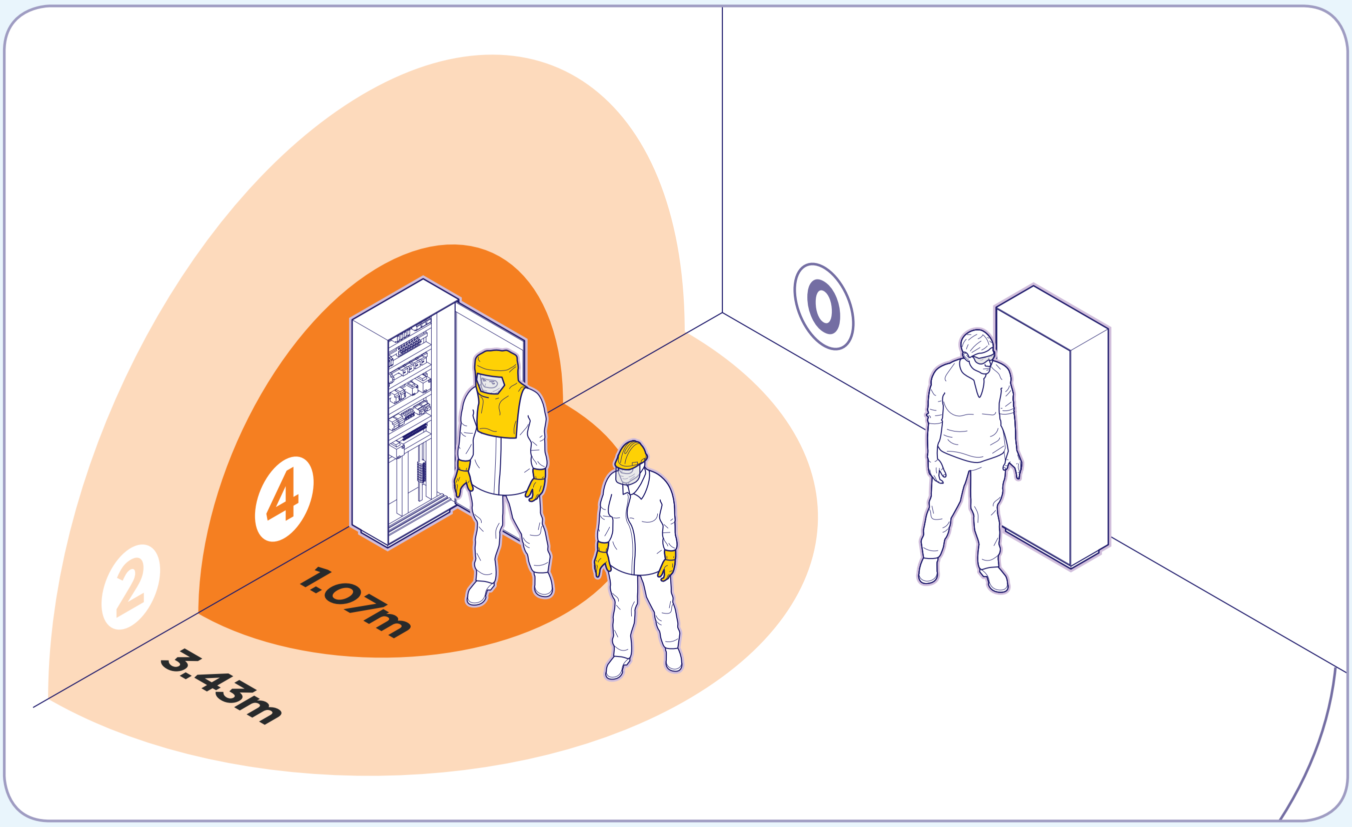


Diagram 16. 3D/Isometric to show boundary and people with PPE

RISK MITIGATION – ENGINEERING CONTROLS

Engineering Controls for reducing the risk from arc flash are:

- Availability of accurate and updated arc flash register and plant single line diagrams;
- Plant identification as per electrical drawings;
- Reduce the energy released in an arc flash, by reducing arc energy (fault current):
  - Configuration of boards (open bus-tie during maintenance)
  - Employ High Resistance Grounding for three phase circuits
  - Use current limiting reactors
- Reduce the energy released in an arc flash, by reducing arc duration (trip time):
  - Reduce protection settings (if practicable);
  - Reliable and faster switchgear/ protection devices;
  - Use Zone Selective Interlocking;
  - Implement a Bus Differential Scheme (Faster than ZSI);
  - Deploy Arc Flash Reduction Maintenance System;
  - Easy Egress.
- Reduce the probability of an arc flash occurring by:
  - Use of insulating tools;
  - Use of calibrated and tested test equipment.
- Contain or redirect the arc flash energy away from personnel by using:
  - arc resistant enclosures;
  - arc blast ducts;
  - remote operation of breakers and switches, including remote tracking devices.

Other recommended arc flash controls:

- New Plant (tips and pointers for manufacturers or suppliers):
  - Passive arc resistant design (segregated bus compartments, arc containment/diversion etc.)
    - Equipment not initially designed for arc resistance cannot be readily modified to be arc resistant. Essentially, arc resistant equipment must be designed, built and installed to be arc resistant;
  - Arc flash detection system;
  - IP2X compliant panels.
- Old Plant (tips and pointers for operations and maintenance personnel):
  - Inspect and make panels IP2X compliant;
  - Routine inspection, maintenance and testing;
  - Thermography (Infra-red scanning) of panels, thermal stickers;
  - Check integrity of panel fasteners/ locks;
  - Noise / PD monitoring;
  - Dust ingress protection (pressurised or air-conditioned switch rooms).

Engineering controls provide permanent reduction in arc flash risk, but these controls must be monitored and reviewed from time to time.

The arc flash register must be controlled, and any changes updated immediately. Drawings must be updated for plant changes and management of change process strictly followed.

Insulating tools degrade over time and must be replaced.

Testing gear must be within date while being used for electrical testing.

RISK MITIGATION – ADMINISTRATIVE CONTROLS

Administrative controls minimise the risk from arc flash by ensuring appropriate procedures are adhered to.

Examples of administrative controls used for arc flash are:

> Work/access permit system;
> Permit system for live and energised low voltage work;
> Risk assessments;
> Job Briefings;
> Arc flash labels.

RISK MITIGATION – PERSONAL PROTECTIVE EQUIPMENT (PPE)

PPE controls reduce the arc flash energy reaching the skin, in the event of an arc flash. The purpose of arc flash PPE is to reduce the energy reaching the skin below the 1.2 cal/cm2 limit.

Minimum PPE standards for access near energised electrical equipment are:

> Safety glasses;
> Safety boots;
> Ankle to wrist non-flammable clothing;
> Arc flash rated PPE;
> Insulated gloves for exposure to live low voltage;
> Insulated tools for exposure to live low voltage;
> In addition to the reduction of the arc flash energy, a risk that must be considered is the flammability of the PPE. A significant amount of injury from arc flash incidents occurs from the ignition of the clothing, which can occur with PPE that is not appropriately fire retardant.

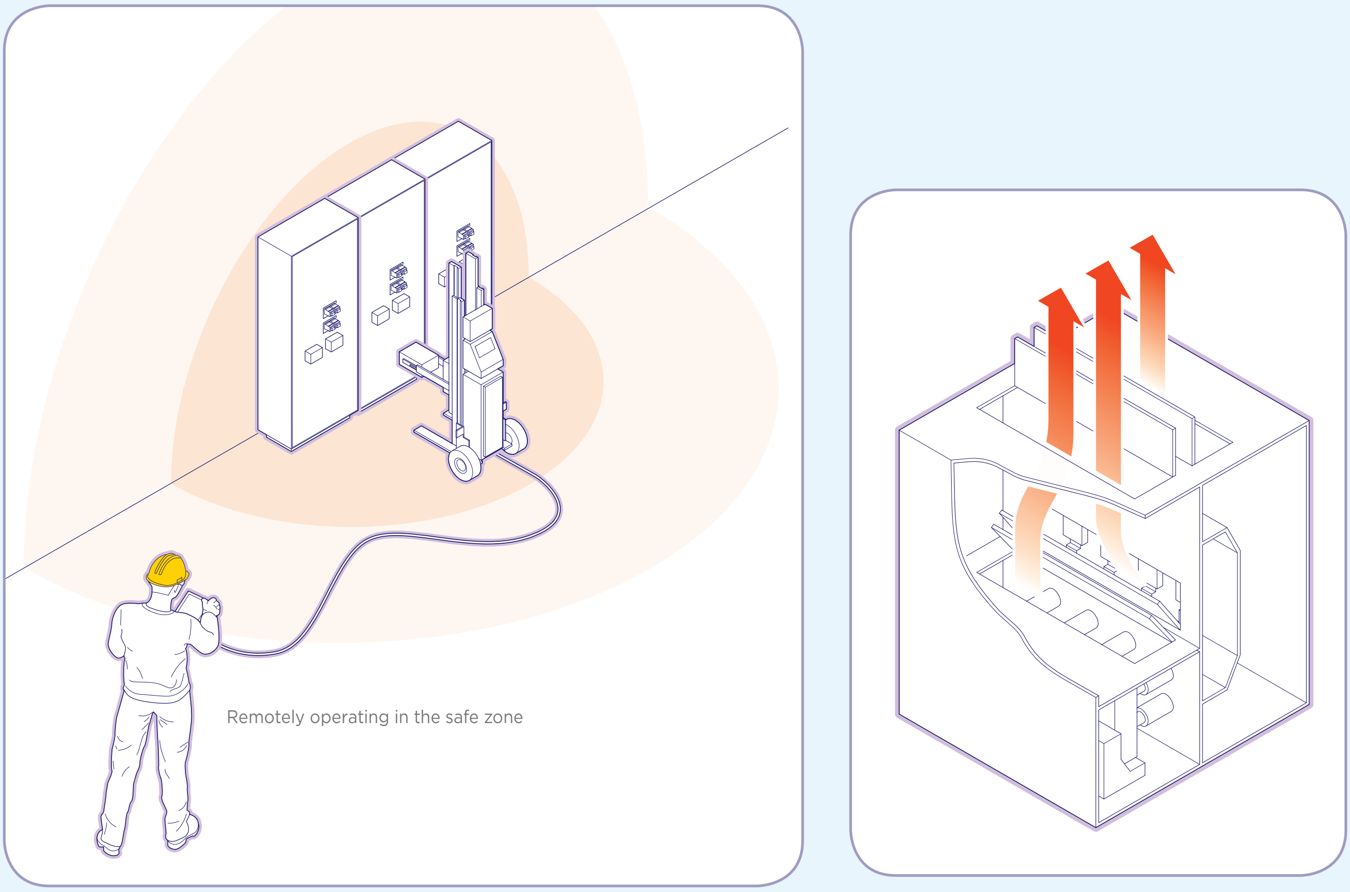


Diagram 17. Engineering controls

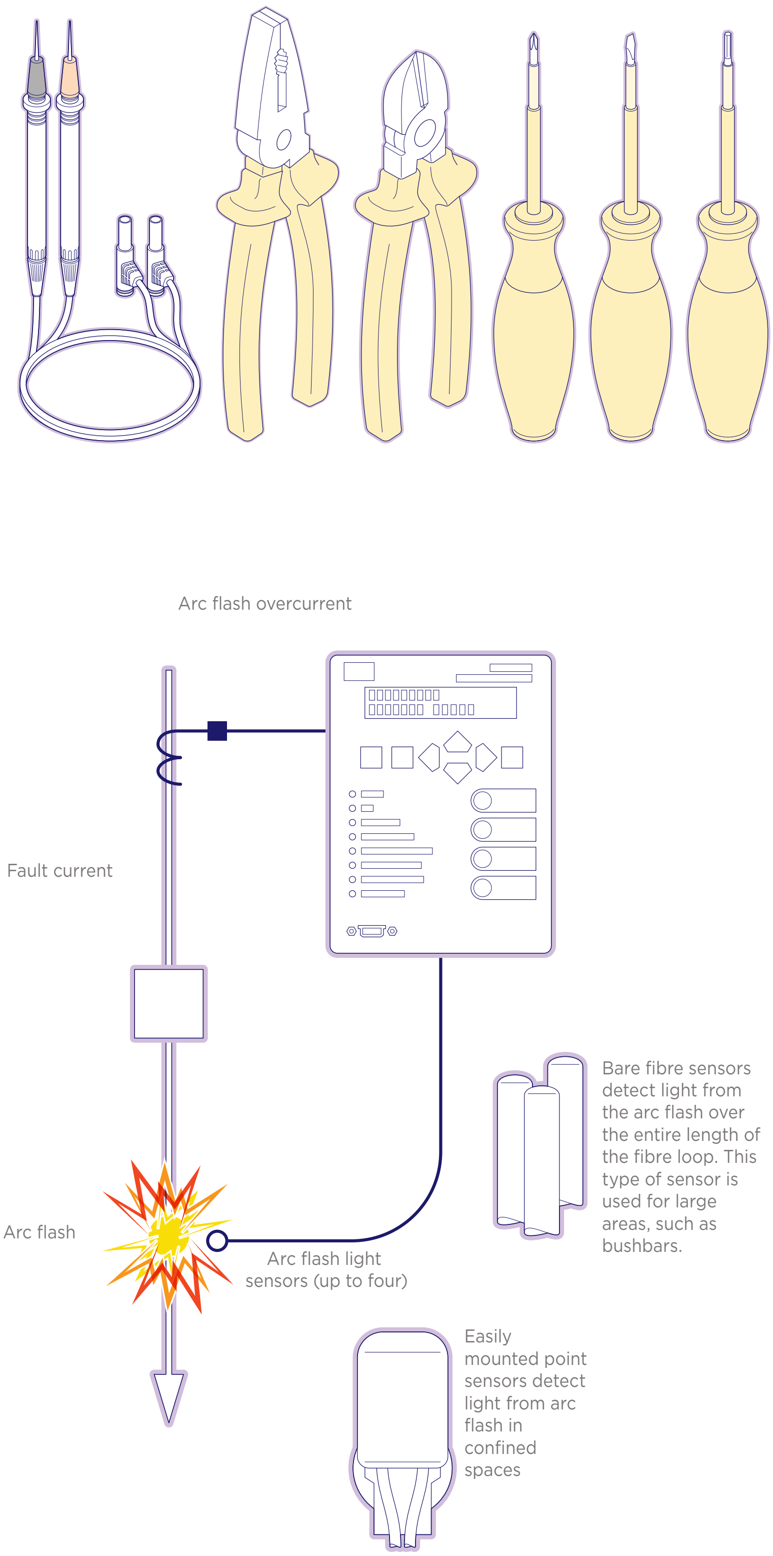


Diagram 17. Engineering controls

ANNEX B: ARC-RATED CLOTHING AND PERSONAL PROTECTIVE EQUIPMENT

ARC FLASH PERSONAL PROTECTIVE EQUIPMENT

In the case of arc flash hazard, the main purpose of Personal Protective Equipment is to reduce burn injury to worker to a level of curable burn.

Personal protective equipment may, or may not, provide adequate protection in the case of arc flash exposure.

It is important that workers understand the use, care, and limitations. Workers must not treat PPE as a substitute for common sense and safe work practices.

The most common and industry accepted PPE that protects the body from arc flash is arc-rated clothing. Arc-rated clothing is tested for performance under exposure to electric arc. This is different from flame-resistant clothing, though arc-rated clothing is also flame-resistant.

Some of the main considerations of PPE inside arc flash boundaries are:

> All employees within the arc flash boundary to wear arc flash PPE appropriate for the incident energy exposure (Note: this time is dependent on the task being performed so should be specific to the risk assessment requirements);

> PPE should cover all other clothing that can be ignited;

> PPE should not restrict visibility and movement;

> Non-conductive protective head wear is required when in contact with live parts or when there is a possibility of electrical explosion. The face, neck and chin must be protected;

> Eye protection is required;

> Hearing protection is required;

> Body protection is required using arc-rated clothing when the estimated incident energy at the body may cause a second degree (curable) burn (1.2 cal/cm2);

> Heavy-duty leather or arc-rated gloves are required to protect the hand;

> If incident energy exceeds 4 cal/cm2, heavy-duty boots are required to protect the feet.

0 cal/cm^2	4 cal/cm^2	8 cal/cm^2	25 cal/cm^2	40 cal/cm^2
PPE CATEGORY 0	**PPE CATEGORY 1**	**PPE CATEGORY 2**	**PPE CATEGORY 3**	**PPE CATEGORY 4** **HAZARD - Be aware of heat stress when wearing Cat 4 clothing**
• No protection	• Arc-rated long sleeve shirt • Arc-rated pants or overalls • Arc-rated face shield with hard hat • Safety glasses • Hearing protection • Leather & voltage rated gloves (as needed) • Leather work shoes	• Arc-rated long sleeve shirt • Arc-rated pants or overalls • Arc-rated face shield & balaclava or Arc flash suit with hard hat • Safety glasses • Hearing protection • Leather & voltage rated gloves (as needed) • Leather work shoes	• Arc-rated long sleeve jacket • Arc-rated pants • Arc-rated flash hood with hard hat • Safety glasses • Hearing protection • Leather & voltage rated gloves (as needed) • Leather work shoes	• Arc-rated long sleeve jacket • Arc-rated pants • Arc-rated flash hood with hard hat • Safety glasses • Hearing protection • Leather & voltage rated gloves (as needed) • Leather work shoes

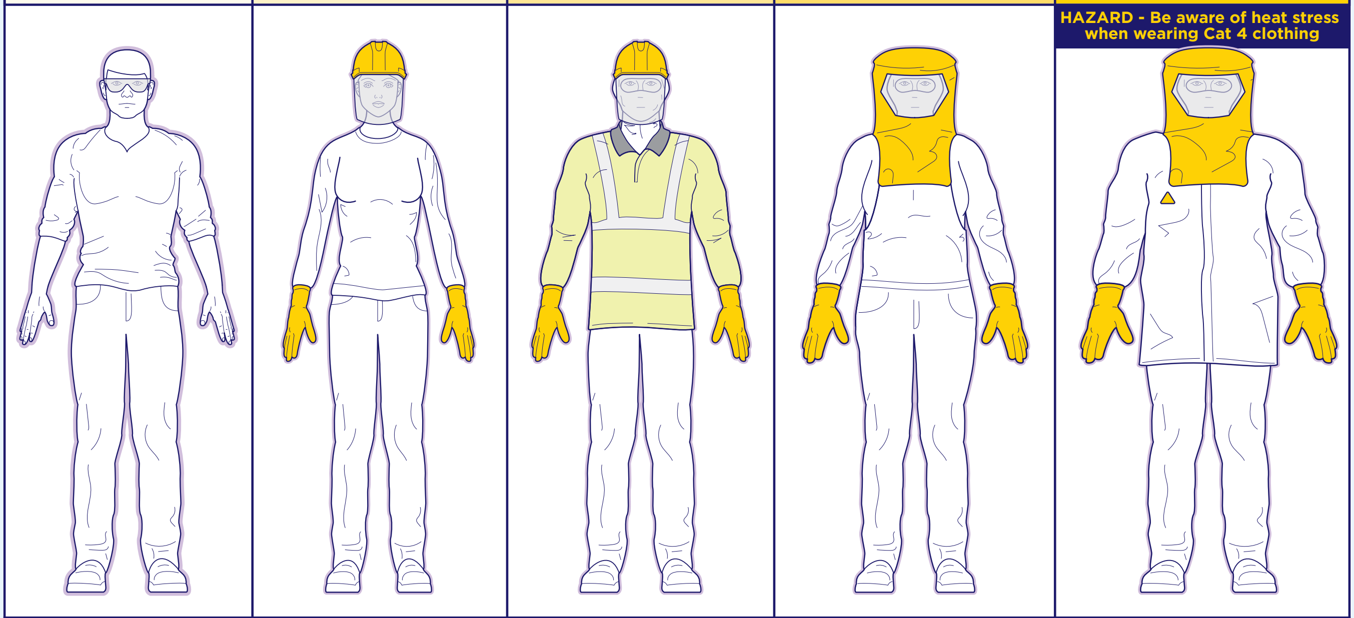


Diagram 18. PPE icons and their PPE levels

INCORRECT ARC FLASH PPE

Incorrect use of arc flash PPE will compromise its ability to reduce the incident energy that reaches the skin of the wearer. Common issues include exposure of skin, typically the hands, forearms and neck, and the wearing of fasteners or jewellery that will absorb heat in an arc flash, resulting in continuing burns.

Why?

- > Exposed skin is not protected and will burn under arc flash;
- > Synthetics and non-arc flash rated material at risk of melting and/or igniting under the extreme temperature, increasing the burn injuries;
- > Metal fasteners and jewellery heat up and continue to burn under the extreme temperatures;
- > Safety glasses (clear or tinted as appropriate) worn, even under face shields to protect the eyes. Face shields without side and chin protection can act as a scoop, directing the arc flash around the face;
- > Hearing protection (with in ear canal inserts) to minimise hearing loss from the arc blast.

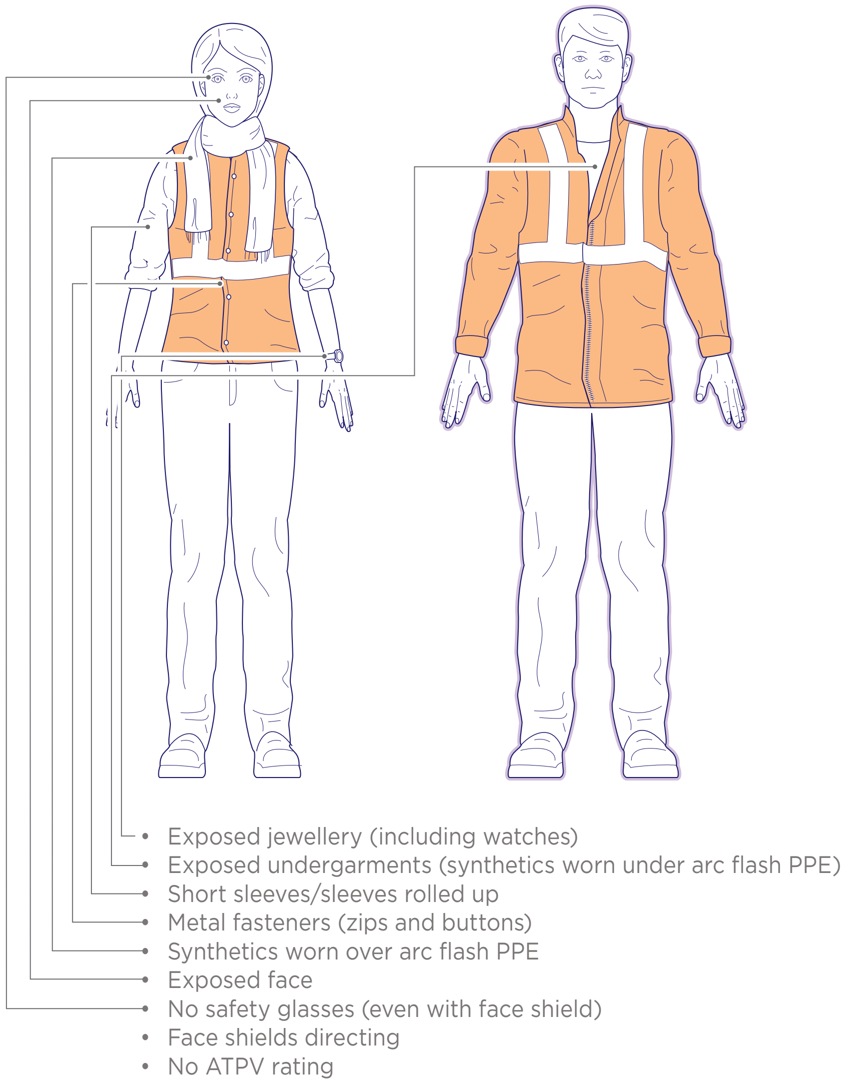


Diagram 19. Incorrect PPE

ANNEX C: DO'S AND DON'T'S OF ARC FLASH LABELLING

DO

> Label "worst" case energy or PPE category based on system configuration;

> Consider all possible modes of operation;

> Provide clear information on labels for people to use PPE and clothing;

> Label using only one colour (Red for Danger);

> Replace label based upon equipment nominal voltage. The working distance is 455mm for LV switchboards and 910mm for HV switchboards;

> Manage PPE categories or incident energy analysis using Permit to Work processes, stating increased distances based on work tasks and safety procedures;

> Label to warn of potential danger, not for the purpose of working on the equipment;

> Implement NFPA 70E Article 130.2 Work Permit requirements for all energised work even if a label is present.

DON'T

> Label each MCC bucket, breaker fuse cubicle or plug-in (busway);

> Use 'common sense' in your hazard labelling;

> Proceed with work if instructions and or PPE are unclear or unsuitable.

RECOMMEND PLACEMENT OF ARC FLASH LABELS

Switchboards and switchgear labelling are consolidated into 1-2 larger labels. This reduces the clutter and sign blindness on the switchboard and simplifies the information for the workers.

Worst case arc flash should be used for a switchboard, rather than labelling for each circuit.

It is recommended to place a label every 3-5 meters, and at incomers, bus ties (if applicable) or where there is significant change in incident energy and PPE requirement.

To be easily identified and read, it is recommended the bottom of the labels to be placed 1.5m from the ground.

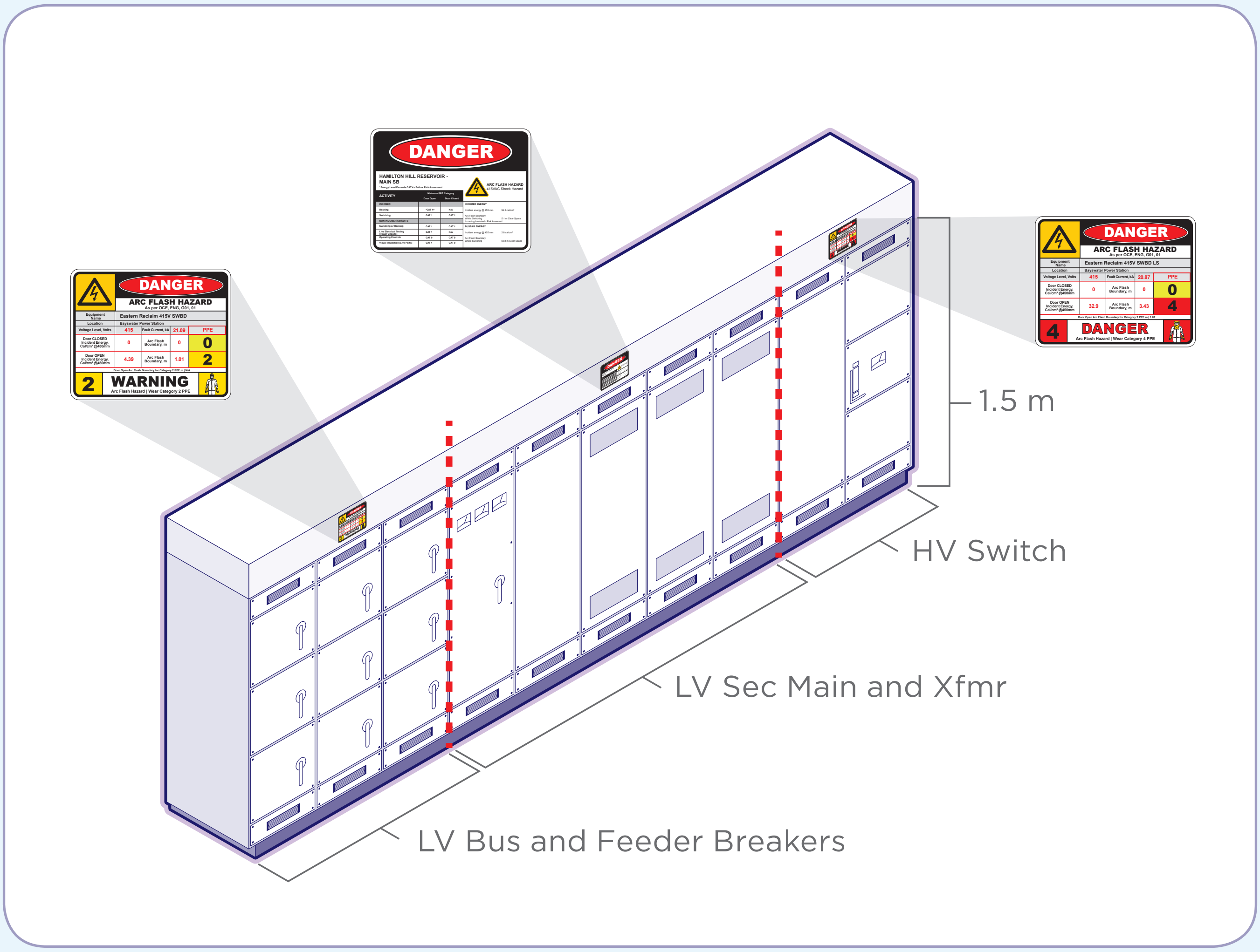


Diagram 20. Placement of arc flash labels

ANNEX D: ARC FLASH INCIDENT ENERGY CALCULATION METHODS ('THEORY')

Currently, there are several industry standards and guidelines and technical papers for the calculation of arc flash incident energy. However, IEEE 1584 Guide for Performing Arc-Flash Hazard Calculations (IEEE 1584) has been widely adopted by the industry as a "defacto" standard.

IEEE 1584-2018 has undergone major revision and incorporates research work done by major organisations and captures learning and feedback.

It is recommended that IEEE 1584 be used by sector organisation for calculation incident energy at working distance.

Other papers and standards that address this topic are:

> EESA Electrical Arcing Hazards - A paper by Dr. David Sweeting (Sweeting Consulting) and Professor Tony Stokes (Electrical Engineering University of Sydney) presented at the EESA Conference in Sydney on 12 August 2004;

> Arc Flash Hazard Standards – The Burning Question, Sesha Prasad paper to IDC Electrical Arc Flash Forum, Melbourne, April 2010;

> NFPA 70E Annex D1;

> CAN/ULC-S801-10 Standard on Electric Utility Workplace Electrical Safety for Generation, Transmission and Distribution;

> Canadian Standards Association Z462-08.

QUANTIFYING ARC FAULT HAZARD INCIDENT ENERGY

The purpose of an Arc Fault Hazard Assessment is to quantify the potential incident energy per unit area that an individual may be exposed to during an arc fault.

The arc fault hazard analysis should include a calculation of the estimated arc fault incident energy based on the available fault current, the duration of the arc (cycles), the voltage, and the distance from the arc to the worker and the nature of the enclosure.

In the absence of a calculated arc flash incident energy, NFPA 70E includes the Arc Flash PPE Category Method. However, the PPE category method of NFPA 70E should be used with caution as it defines PPE categories based on equipment types, protection devices and clearing times, etc. These may not be directly applicable to the installation in Australia and hence incident energy calculation method is considered more appropriate.

Incident energy is inversely proportional to the working distance squared (double the distance equals one-quarter the incident energy). It is directly proportional to the time duration of the arc and to the available bolted fault current (double the arc duration or fault current equals double the incident energy). It should be noted that time generally has a greater effect on the incident energy than the available bolted fault current.

When performing arc fault hazard assessments, consideration should be given to very low fault energy areas as well as very high. Low fault currents can result in very long clearing times and may give higher total incident energies than high fault currents with very fast clearing times.

The arc fault hazard analysis should also consider all possible network configurations, including temporary configurations.

When using any calculation, the assumptions behind the tool must be understood, including:

> Whether it is calculating for ‘open air’ or ‘arc in a box’;
> Single phase or multi-phase fault;
> Type of equipment and protection;
> Voltage limitations.

All calculations must cater for Australian electricity supply parameters and switchgear type, and all calculation methodologies must be used only under technically competent supervision.

Arc fault hazard assessments should be reviewed periodically, and as a minimum, when design changes intended to be permanent occur to electrical system parameters that affect the assessment (e.g. when changing protection settings, changing power transformer size, or power source configuration, etc.).

Refer to IEEE 1584 for the calculation methodology and input data/information required.

A fault study and protection grading study is required to provide short circuit current and protection clearing times besides many other parameters about system/equipment configuration.

Suggested steps that may be taken in Arc Flash Calculations are:

1. Ensure the single line diagram is correct;
2. Obtain the impedance and rating data necessary to perform fault studies;
3. Review the protection. Confirm settings and check that the grading is correct;
4. Perform fault studies;
5. Perform the calculations according to IEEE 1584.

HV SWITCHBOARDS

BAYSWATER POWER STATION - High Voltage Switchboards										
Bus Name	Bus (KV)	Bus Bolted Fault (KA)	Bus Arcing Fault (KA)	Trip/Delay Time (sec)	Breaker Opening Time/Tol (sec)	Arc Flash Boundary (mm)	Working Distance	Incident Energy (cal/cm2)	PPE Level	AF_FB@ IE2 Arc Flash Boundary per Cat 2 PPE (mm at 8 Cal/ cm2)
1 Unit 11KV Switch-board Section B	11.00	41.25	39.09	0.02	0.080	5843	910	7.3	Level 2	N/A
1 Unit 11KV Switchboard Section C LS	11.00	40.02	37.93	1.2	0.080	41593	910	49	DANGER-OUS!	5894

Diagram 21. HV switchboard table

LV SWITCHBOARDS

BAYSWATER POWER STATION - Low Voltage Switchboards										
Bus Name	Bus (KV)	Bus Bolted Fault (KA)	Bus Arcing Fault (KA)	Trip/Delay Time (sec)	Breaker Opening Time/Tol (sec)	Arc Flash Boundary (mm)	Working Distance	Incident Energy (cal/cm2)	PPE Level	AF_FB@ IE2 Arc Flash Boundary per Cat 2 PPE (mm at 8 Cal/ cm2)
1/2 Station 415V Switchboard A	0.415	40.75	15.94	0.957	0.080	4383	455	49	DANGER-OUS!	1376
2 Unit 415V SWBD B LS	0.415	46.37	20.85	0.2	0.080	1382	455	7.4	Level 2	N/A

Diagram 22. LV switchboard table

LV SWITCHBOARDS

In a single 11kV Switchboard, the arc flash level can range from Cat 2 level (7.29 Cal/cm2) to Dangerous level (49.2 Cal/cm2). Understanding of information written on the arc flash level and its placement is very important.

415V switchboards can have different incident energy levels (49.1 Cal/cm2 & 7.4 Cal/cm2) as per above examples. Identification of switchboards and arc flash labels accuracy plays a very important role.

The calculations in the previous examples are based on IEEE 1584. If we consider line of fire calculation according to NENS 09, the incident energy levels can be as high as 3 times as those calculated under IEEE 1584. If the switchboard door is open, the plasma jet/fireball is highly likely to be directed to the personnel standing in front of the panel. This risk must be considered.

RECOMMENDED METHODOLOGY

The recommended methodology based on the work of Dr. David Sweeting provides the best current assessment of the nature of electrical arc hazard behaviour in Australia for arc faults between parallel conductors.

If this methodology is not utilised, at least one of the following methodologies or recognised equivalents should be carefully used with due respect to their limitations:

> Calculations based on IEEE 1584 (i.e. in either the Spread sheet option or Software program option);

> Activity Tables in USA Standards NFPA 70E 2012 or NESC:2012.

Note: IEEE 1584 based methodology has consistently and significantly underestimated incident energies recorded for arc faults between parallel conductors during Australian testing due to arguably flawed assumptions underpinning the methodology.

The preferred NENS09 methodology best predicted actual Australian test outcomes that were consistently in the order of three times the IEEE 1584 predicted values. The IEEE 1584 based methodology, however, does reasonably predict radiant energy for opposing conductors as also demonstrated by the Ausgrid testing outcomes.

This discrepancy has been corrected in 2018 edition of IEEE 1584 as the required data involved enclosure design, bus configuration and various other parameters that were missing in 2002 edition.

ANNEX E: CALCULATING INCIDENT ENERGY OR HEAT FLUX ('PRACTICE')

IEEE 1584

One of the most common methods of estimating incident energy (or heat flux) is using the standard of the Institute of Electrical and Electronics Engineers (IEEE) 1584 – 2002 Guide for Performing Arc-Flash Hazard Calculations.

The incident energy/heat flux calculation formulae within IEEE 1584 have been developed using the data from a large number of laboratory tests.

However, the IEEE 1584 tests and calculations are based upon a radiant heat transfer model that may not accurately estimate incident energy in some situations.

According to the IEEE 1584 model, in the event of an arc fault, the arc emits energy (light in all spectrums – infrared, visible, ultraviolet, x-ray) that is transferred to an individual by radiation.

It is believed that the same incident energy is received at a given radius from the arc, in all directions.

The incident energy per unit area is understood to be a product of current, time and distance.

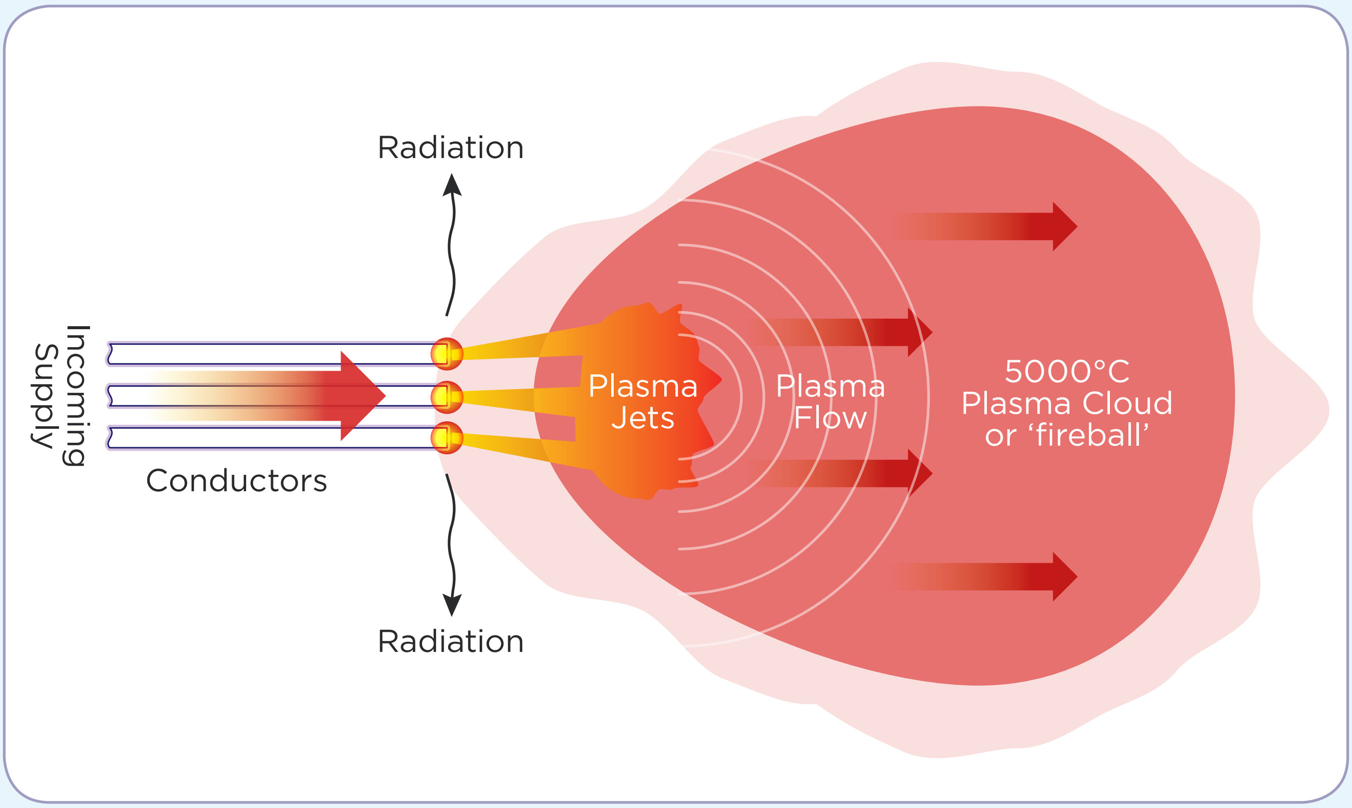


Diagram 24. NENS09 Model, ENA NENS 09 – 2014 National Guideline for the Selection, Use and Maintenance of Personal Protective Equipment for Electrical Arc Hazard

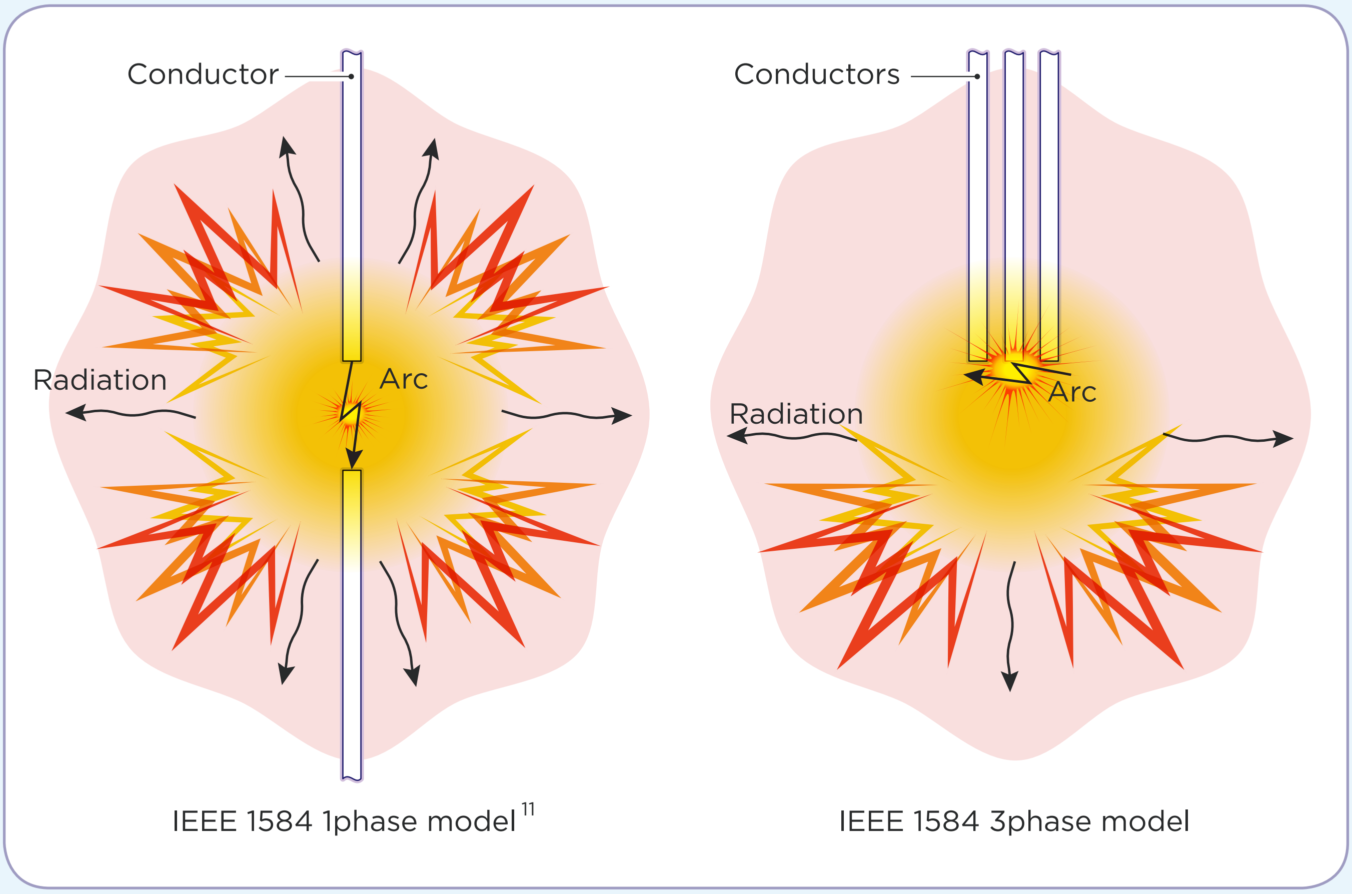


Diagram 23. IEEE 1584 1 and 3 phase models.

IEEE 1584 CALCULATIONS SUMMARY

1. Calculate the fault current
2. Calculate the arc current
3. Calculate the normalised incident energy
4. Calculate the incident energy (in Joules/cm2)
5. Calculate the boundary

NENS 09-2014

Arc Plasma

Another common methods of estimating incident energy (or heat flux) is the use of the standard of the Energy Networks Association (ENA) National Guideline for the Selection, Use and Maintenance of Personal Protection Equipment for Electrical Arc Hazards 09 - 201412Recent Australian research has shown that, although the radiant energy from an arc contributes to the energy received, the major hazard to an individual comes from the plasma* ejected by an arc.

*Plasma is the fourth (4th) state of matter (solid, liquid, gas, plasma) and is probably best described as "super-heated ionised gas".

ARC BEHAVIOUR – PARALLEL ELECTRODES

NENS 09-2014 formulae are based on a parallel electrode model, as most conductors in real-world situations are in parallel formation.

An arc between parallel electrodes will travel along the electrodes, moving away from the source, by motor effect.

At some conductor termination, the arc will develop into plasma jets emitted from the end of the electrodes. These plasma jets will create a cloud of plasma that will be at temperatures of at least 5000 deg C. (See diagram below).

It is contact with this plasma cloud that has the greatest potential to cause severe burns.

To the sides of the electrodes, radiant energy is emitted, like the IEEE 1584 model.

Figure 3 – NENS09 Model, ENA NENS 09 – 2014 National Guideline for the Selection, Use and Maintenance of Personal Protective Equipment for Electrical Arc Hazard

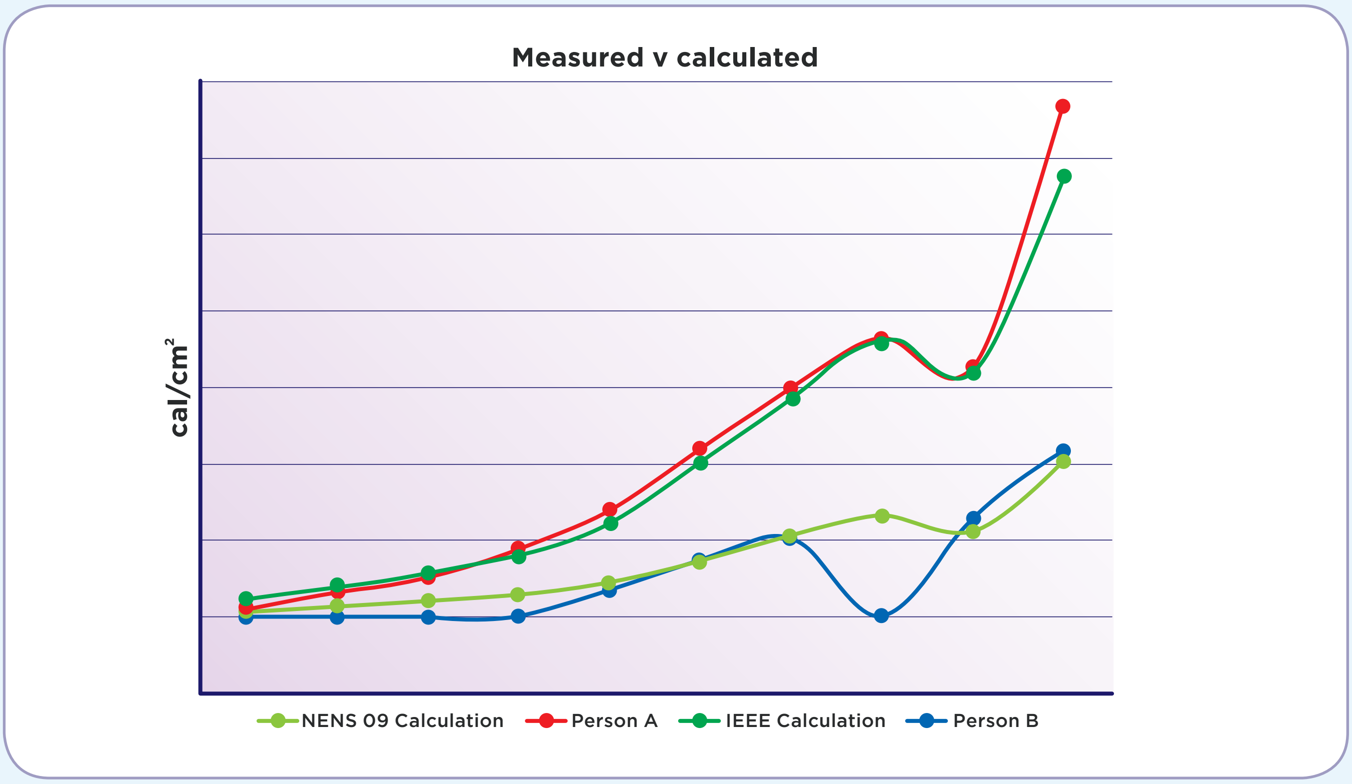


Diagram 26. Comparison of measured results against calculated values.

IEEE 1584 / NENS09-2014 COMPARISON

There is a dramatic difference between the incident energy levels associated with plasma cloud interface (e.g. as generated at the end of the electrodes) compared to the incident energy levels associated only with radiant exposure (e.g. to the side of the electrodes) as for Ausgrid actual testing outcomes in FY14 (see section A4 below).

For example, in the diagram below, in the event of an arc, Person 'A' will be subject to the plasma cloud and will receive three (3) times the energy received by Person 'B, who will be predominantly subjected to radiant energy.

The energy received by Person 'A' will be approximately the value calculated by the NENS09-2014 formulae at A5 below. This will be approximately three (3) times the IEEE 1584 calculated values.

The energy received by Person 'B' will be approximately 1/3 of the energy calculated by the formulae below. This will be approximately equal to the IEEE 1584 calculated values.

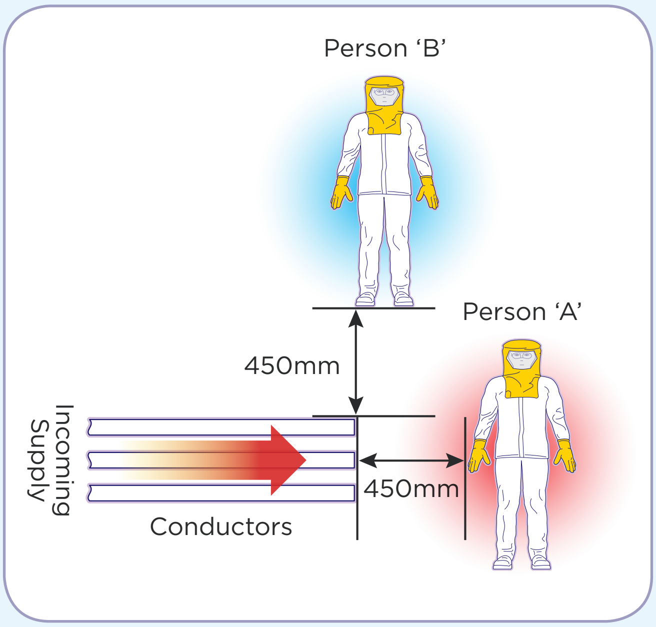


Diagram 25. Energy comparison by position.

Therefore, with an arc on parallel electrodes, the incident energy / heat flux is a product of current, time, distance and **direction.**

Unless you can be sure of the position of the individual in relation to the electrodes and the arc, the formulae at A5 below should be used to cover the "worst case" scenario.

AUSGRID FY14 LANE COVE TEST STATION ARC FAULT TESTING OUTCOMES

This following graph compares the measured and calculated incident energy for tests conducted under Test Series 8940 at the Lane Cove Test Station. Calorimeters measured the energy at the positions for Persons A and B in the diagram.

RECOMMENDED FORMULAE FOR DETERMINING INCIDENT ENERGIES FOR DIFFERENT FAULT CURRENTS AND / OR FAULT DURATIONS

The following formulae are based on a 50Hz ac supply.

Where:

t	= fault duration (seconds)
IE(cal/cm2)	= incident energy / heat flux (cal/cm2)
Irms	= prospective symmetrical RMS three phase fault current (Amps)
r	= distance from the arc (metres)3

Copper Electrodes

a. The formula used to calculate the single-phase incident energy (IE) values for copper electrodes is:

Incident Energy (cal/cm2) = 1.2667 x 10 -4 x t x Irms 1.12 / r2

b. This can be rearranged to calculate distance:

r = 0.011258 x t 0.5 x Irms 0.56 / IE 0.5

c. The formula used to calculate the three-phase incident energy values (IE) for copper electrodes is:

Incident Energy (cal/cm2) = 3.8 x 10 -4 x t x Irms 1.12 / r2

d. This can be rearranged to calculate distance:

r = 0.0195 x t 0.5 x Irms 0.56 / IE 0.5

Aluminium Electrodes

For aluminium electrodes the above formulae become:

e. Single phase faults:

Incident Energy (cal/cm2) = 1.4667 x 10 -4 x t x Irms 1.12 / r2

r = 0.0121 x t 0.5 x Irms 0.56 / IE 0.5

f. Three phase faults:

Incident Energy (cal/cm2) = 4.4 x 10 -4 x t x Irms 1.12 / r2

r = 0.021 x t 0.5 x Irms 0.56 / IE 0.5

Application Variations

The above formulae can be used for circumstances where different fault currents and/or different fault durations are anticipated.

The formulae for two-phase (only) faults can be determined by doubling the RHS of equations for single-phase incident energy in Paragraphs A4.1 and A4.2. These formulae can then be manipulated to derive the equations for distance.

Calories to Joules

Given arc-rated protective clothing / PPE globally is classified by ATPV in cal/cm2, the formulae above have been provided in calories rather than Joules.

> To convert from calories to Joules, multiply by 4.184.

> Joules = calories x 4.184

ANNEX F: ELECTRICAL ARC FLASH HAZARDS MANAGEMENT GUIDELINE CHECKLIST

The following Checklist has been provided to support Professionals and Practitioners that are developing or completing their system of work around the hazard of Electrical Arc Flash.

The Checklist is provided are for information and guidance only and all results should be reviewed / approved and subject to audit by qualified and competent Subject Matter Experts.

Arc Flash Guideline Requirement	Is it in place?	Is it working well?	Actions
Procedures for Electrical Arc Flash Hazard Management have been developed (or integrated into Electrical Safety) into the Organisations Management System.			
A program for managing change has been applied to Electrical Arc Flash Hazard Management procedures.			
Training in Electrical Arc Flash Hazard Management procedures (including Human Factors) have been implemented and workers required to perform electrical work have been deemed competent to perform all electrical work.			
Electrical Arc Flash Subject Matter Experts have effectively completed their Arc Flash Incident Energy Calculation Method and all risk control methods (including labelling) are implemented			
Electrical Arc Flash Subject Matter Experts and OHS Professionals (where available) collaborate and complete electrical safety risk assessments and all risk control methods are implemented			
Electrical Arc Flash Subject Matter Experts and OHS Professionals (where available) review Arc Flash PPE & Clothing and have registers in place for repair / replacement			
Electrical Arc Flash Hazard Management practices are subject to audit at scheduled regular intervals			
Electrical Arc Flash Hazard Management Procedures are reviewed on an annual basis by the Organisations Management System Professionals			

ANNEX G: REFERENCES

The documents below are referred to in these Guidelines and / or associated annexes:

AS/NZS 1336	Recommended practices for occupational eye protection
AS/NZS 1800	Selection, care and use of occupational safety helmets
AS/NZS 1906	Retro-reflective materials and devices for road traffic control purposes
AS/NZS 2210	Occupational protective footwear
AS/NZS 2210-1	Guide to selection, care and use
AS/NZS 2919	Industrial clothing
AS/NZS 4602	High visibility safety garments
AS 1319	Safety signs for the occupational environment
AS 4501-2	Occupational protective clothing – General requirements
AS 4501-1	Guidelines on the selection, use, care and maintenance of protective clothing
AS 1957	Textiles—Care labelling
AS 2001	Methods of test for textiles
AS 2001.5.4	Dimensional change—Domestic washing and drying procedures for textile testing (ISO 6330:2000, MOD)
AS 2225	Insulating gloves for electrical purposes
AS/NZS 4836:2011	Safe working on or near low-voltage electrical installations and equipment
	Work Health and Safety Regulation 2011.
ISO 139	Textiles - Standard atmospheres for conditioning and testing
ISO 6330	Textiles - Domestic washing and drying procedures for textile testing
ISO 3175-1	Textiles - Professional care, dry cleaning and wet cleaning of fabrics and garments - Part 1: Assessment of performance after cleaning and finishing
ISO 15025	Protective Clothing – Protection against heat and flame – Method of test for limited flame spread
ISO 6941	Burning behaviour – Measurement of flame spread properties of vertically orientated specimens
ISO 10047	Textiles - Determination of surface burning time of fabrics
ISO 14116	Protective clothing – Protection against heat and flame – limited flame spread materials, material assemblies and clothing
ASTM F1959 / F1959M - 06ae1	Standard Test Method for Determining the Arc Rating of Materials for Clothing
ASTM F1506-08	Standard Performance Specification for Flame Resistant Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards
ASTM D6413-08	Standard Test Method for Flame Resistance of Textiles (Vertical Test)
ASTM F496 - 08	Standard Specification for In-Service Care of Insulating Gloves and Sleeves

IEC 61482-1	Live working - Protective clothing against the thermal hazards of an electric arc - Part 1-1: Test methods - Method 1: Determination of the arc rating (ATPV or EBT50) of flame resistant materials for clothing
IEC 61482-2	Live working - Protective clothing against the thermal hazards of an electric arc - Part 2: Requirements
IEEE 1584	Guide for Performing Arc Flash Hazard Calculations
NFPA 70E	Standard for Electrical Safety in the Workplace (2018)
NESC:2012	National Electrical Safety Code
CAN/ULC-S801-10	Canadian Standards Association CAN/ULC-S801-10 Standard on Electric Utility Workplace Electrical Safety for Generation, Transmission and Distribution
CAN Z462-08	Canadian Standards Association Z462-08 Workplace electrical safety, Annex D
	Electricity Engineers' Association of New Zealand (EEA) Guide for the Management of Arc Flash Hazards, October 2011
	Arc Flash Hazard Standards – The Burning Question, Sesha Prasad paper to IDC Electrical Arc Flash Forum, Melbourne, April 2010. (Available at www.arcflash.com.au/documents/Arc_Flash_Hazard_Standards_The_Burning_Question_Sesha.pdf)
	EESA Electrical Arcing Hazards, A paper by Dr. David Sweeting (Sweeting Consulting) and Professor Tony Stokes (Electrical Engineering University of Sydney) presented at the EESA Conference in Sydney on 12 August 2004
	Arc-Flash PPE Research Update, Hugh Hoagland, pages 1179-1187; IEEE Transactions on Industry Applications, Vol. 49, No. 3, May / June 2013
	Practical approaches to mitigating arc flash exposure in Europe, Institute of Electrical and Electronics Engineers — May 28, 2013, Paper No. IS-20 presented at the 10th Petroleum and Chemical Industry Conference Europe Electrical and Instrumentation Applications
	ISSA Guideline for the selection of personal protective equipment when exposed to the thermal effects of an electric fault arc, 2nd Edition 2011
Australian Government Civil Aviation Safety Authority (CASA)	Safety Behaviours: Human Factors – Resource Guide for Engineers (2013). Humanfactors@casa.gov.au.

ANNEX H: DEFINITIONS

Approved

Having appropriate organisation endorsement for a specific function.

Arc Fault Protection Boundary

The arc fault protection boundary (within which arc-rated PPE is required) for systems 50 volts and greater shall be the distance at which the potential incident energy equals 5 J/cm2 (1.2 cal/cm2).

Arc Flash PPE category method

NFPA 70E categories defining levels of arc-rated protection required when performing tasks based on the arc flash PPE category method, in lieu of the incident energy analysis, with estimated incident energy exposures within an escalating set of incident energy ranges, as for the example table below (where IE = Incident Energy):

Arc flash PPE category

Min. Protective Clothing Rating	[cal/cm2]
0	AR not required (Non-melting or untreated natural fibre specified)
1	4
2	8
3	25
4	40

Arc Thermal Performance Value (ATPV)

In arc testing, the incident energy on a material or a multi-layer system of materials that results in a 50% probability that enough heat transfer through the tested specimen is predicted to cause the onset of a second-degree skin burn injury based on the Stoll curve, without break-open.

Note: ATPV is expressed in kW.s/m2 or Cal/cm2.

Base Garment

A garment which is considered as outer wear but may be worn in direct contact with the skin, e.g. shirts, trousers or coveralls, etc.

Break-open

In electrical arc fault testing, material response evidenced by the formation of one or more openings in the material which may allow flame to pass through the material (see also EBT).

The specimen is considered to exhibit break-open when any opening is at least 300 mm2 in area or at least 25 mm in any dimension. A single thread across the opening does not reduce the size of the hole for the purposes of the tests methods ASTM 1959 or IEC 61482.

A multi-layer specimen is considered to exhibit break-open when all layers show formation of one or more openings.

Calorie

The energy required to raise one gram of water by one degree Celsius at one atmosphere pressure. Second-degree burns occur at 1.2 calories per centimetre squared per second (cal/cm2/s).

Composite

The layer or layers that provide protection required (i.e. outer shell, thermal barrier and/or moisture barrier).

Conductor

A wire, cable, form of metal or any other material designed for carrying electric current.

Component assembly

The material combination found in a multi-layer garment arranged in the order of the finished garment construction and including any inner liner.

Coverall / Overall

Protective garment designed and configured to provide protection to the torso, arms, and legs, excluding the head, hands, and feet.

De-energised

Not connected to any source of electrical supply, but not necessarily isolated.

EBT (Break-open Threshold Energy)

The incident energy on a material or material system that results in a 50% probability of break-open

Electrical Arc Fault

An unplanned or unexpected explosion caused by the short circuiting or grounding of one or more energised electrical conductors.

Electrical apparatus

Any electrical equipment, including overhead lines and underground cables, the conductors of which are live or can be made live.

Electrical operating work

Work involving the operation of switching devices, links, fuses or other connections intended for ready removal or replacement, proving electrical conductors de-energised, earthing and/or short-circuiting, locking and/or tagging of electrical apparatus and erection of barriers and/or signs.

Electrode

Any conductive material which forms the anode or cathode of an electric arc.

Energised

Connected to a source of electrical supply.

Exposed conductor

An electrical conductor, approach to which is not prevented by a barrier of rigid material or by insulation that is adequate under a relevant Australian Standard specification or other for the voltage concerned.

Flame retardant

Having properties that suppress or delay the combustion or propagation of flame.

Garment

A single item of clothing which may consist of single or multiple layers.

Hardware

Non-fabric components of protective clothing including those made of metal or plastic material, e.g. fasteners, company logos, name badges, buttons.

Hazard Risk Category (HRC)

Previous versions of the NFPA 70E categories defining levels of arc-rated protection required when performing tasks with estimated incident energy exposures within an escalating set of incident energy ranges. This has been replaced with the Incident energy analysis method 130.5(G) or the

Arc flash PPE category method 130.7(C) (15).

Heat Flux

The thermal intensity of the arc that is incident by the amount of energy transmitted per unit area and per unit of time, measured in Joules per square centimetres per second (J/cm2/s) or calories per square centimetres per second (cal/cm2/s).

Hierarchy of controls

Measures taken to minimise risks to the lowest level reasonably practicable in the descending order of: Elimination, Substitution, Engineering Controls, Administrative Controls, and PPE.

High voltage (HV)

A nominal voltage exceeding 1,000V alternating current (ac) or exceeding 1,500V direct current (dc).

High voltage live work

Work performed on or near components of a line capable of being energised to high voltage without implementing the full protective practice of isolating, proving de-energised and earthing.

Heat attenuation factor (HAF)

In electric arc fault testing is the percent of the incident energy which is blocked by a material at an incident energy level equal to ATPV.

Incident Energy

The term incident energy (IE) is used to describe the thermal energy to which a worker is exposed in an arc fault incident.

It can be defined as the thermal energy generated during an electrical arc fault incident that is impressed on a surface at some specified distance from the source of an arc fault, usually measured in joules per square centimetre (J/cm2) or calories per square centimetre (cal/cm2).

Incident energy estimates for specific workplace exposures assume that the applicable overcurrent protective device has sensed, responded to, and ultimately cleared the arc fault within its published time-current curve.

Incident energy analysis method

The NFPA 70E details the Incident energy analysis method for the determination of PPE requirements. The incident energy exposure level is based on the working distance of the employee's face and chest areas from a prospective arc source for a specific task to be performed. Arc-rated clothing and other PPE shall be used by the employee based on the incident energy exposure associated with the specific task.

Innermost lining

The lining found on the innermost face of a component assembly.

Interface area

An area of the body not protected by a protective garment, helmet, gloves, footwear, or any other PPE; the area where the protective garments and the helmet, gloves, footwear, meet, i.e. the protective coat/helmet/SCBA face piece area, the protective coat/glove area, and the protective trouser/footwear area.

Interface component

Item or items designed to provide limited protection to interface areas.

Isolated

A conductor which is disconnected from all possible sources of electricity supply by means which will prevent the unintentional energising of the apparatus and which is assessed as a suitable step in the process of making safe for access purposes.

Live

A conductor which is energised or subject to hazardous induced or capacitive voltages.

Low voltage (LV)

A nominal voltage exceeding 50 V ac or 120 V ripple free dc but not exceeding 1,000V ac or 1,500 V dc.

Joule

The energy required to raise 0.239 grams of water by one degree Celsius at one atmosphere pressure, or the energy expended in one second by one ampere current against a resistance of one ohm.

1 Joule equals 0.239 calories, or, 1 calorie equals 4.184 Joules.

Manufacturer

The entity that assumes the liability and provides the warranty for the compliant product.

Material combination

A material produced from a series of separate layers, intimately combined prior to the garment manufacturing stage, e.g. a quilted fabric.

Melt

To change from solid to liquid form, or become consumed by action of heat.

Moisture barrier

A fabric or membrane used in a component assembly to enable the properties of the assembly to comply with the manufacturer's claims concerning hydrostatic pressure and water vapour permeability.

Multi-layer clothing assembly

A series of layers of garments arranged in the order as worn.

It may contain multi-layer materials, material combinations or separate layers of clothing materials in single layers.

Near / In Proximity / Close to

A situation where there is a reasonable possibility of a person either directly or through a conductor, coming within the relevant assessed electric arc hazard.

Outer material

The outermost material of which the protective clothing is made.

Outer shell

The outside facing portion of the composite with the exception of trim, hardware, reinforcing material, and wristlet material.

Overlap

Interface area which should be maintained, for example whilst performing stooping, reaching or turning movements.

Overhead line

Any aerial conductor or conductors with associated supports, insulators and other apparatus erected, or in the course of erection, for the purpose of conveyance of electrical energy.

Protective clothing

Protective garments, configured as a shirt and trousers or as a coverall which may or may not include a jacket, coat, hood, and / or gloves (etc.), and interface components that are designed to provide protection to the worker's body. For garments that are arc-rated, they shall be tested and marked with a ATPV value.

Protective garment

A single item of clothing which may consist of single or multiple layers (e.g. protective jacket / coat; protective shirt; protective trousers; or protective coverall / overall).

Protective trouser

A protective garment designed and configured to provide protection to lower torso and legs, excluding the feet.

Reasonably practicable

That which is, or was at a particular time, reasonably able to be done to ensure health and safety, considering and weighing up all relevant matters including:

1. The likelihood of the hazard or the risk concerned occurring;
2. The degree of harm that might result from the hazard or the risk;
3. What the person concerned knows, or ought reasonably to know, about the hazard or risk, and ways of eliminating or minimising the risk;
4. The availability and suitability of ways to eliminate or minimise the risk; and
5. After assessing the extent of the risk and the available ways of eliminating or minimising the risk, the cost associated with available ways of eliminating or minimising the risk, including whether the cost is grossly disproportionate to the risk.

Removable inner liner

An inner garment designed to be attached or to be worn separately under an outer garment in order to provide thermal insulation.

Safe approach distance

The minimum separation in air from an exposed conductor that shall be maintained by a person, or any object (other than insulated objects designed for contact with live conductors) held by or in contact with that person. These are detailed in ENA NENS 04 National Guidelines for Safe Approach Distances to Electrical Apparatus.

Second Degree Burns (may also referred to as Partial Thickness Burns)

A burn that affects the epidermis and the dermis, classified as superficial or deep according to the depth of injury.

The superficial type involves the epidermis and the papillary dermis and is characterized by pain, oedema, and the formation of blisters; it heals without scarring.

The deep type extends into the reticular dermis, is pale and anaesthetic, and results in scarring.

Substation

A switchyard, terminal station or a place where high-voltage is converted or transformed to a different voltage.

Switching / Protective Jacket

A protective garment (jacket) designed and configured to provide protection to upper torso and arms, excluding the hands and head.

Thermal barrier

That portion of the composite designed to provide thermal protection.

Thermal hazard

A hazard having sufficient heat energy to cause the onset of partial thickness burns.

Trim

Retro-reflective and fluorescent material attached to the outer shell for visibility enhancement retro-reflective materials enhance night-time visibility, and fluorescent materials improve daytime visibility.

Under garment

A garment which is worn under a basic garment.

Work

Any activity or process including installing maintaining, inspecting, operating and supervision, carried out on energised equipment or equipment which is capable of being energised.

Working Distance

The dimension between the possible arc point and the head of the body of the worker positioned in place to perform the assigned task.

Worker

Persons who may be exposed to electric hazards.