SunWater

MAKING WATER WORK

Development and Implementation of an Arc Flash Management Program

Arc Flash Hazard Management - Our Approach & Learnings

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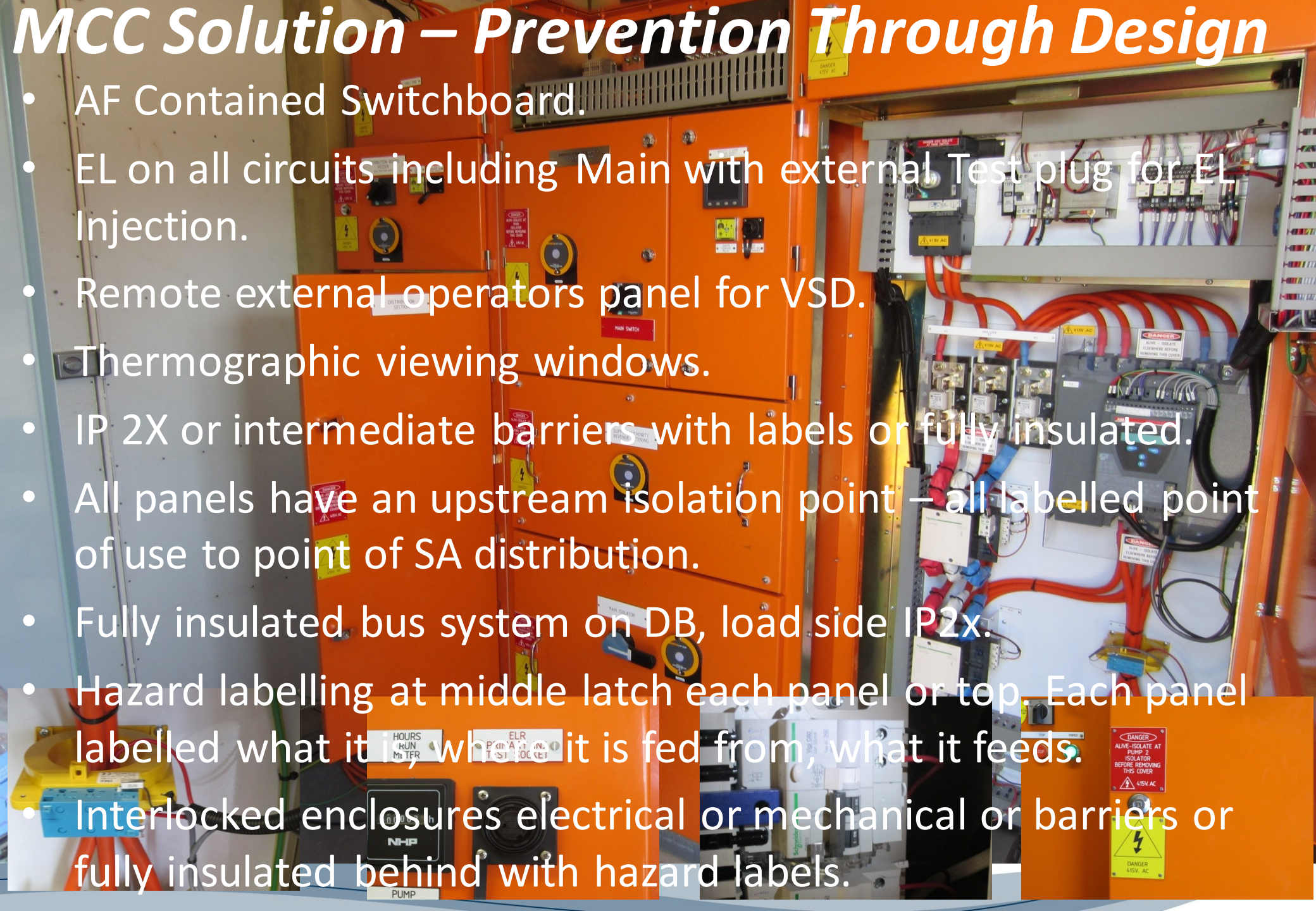
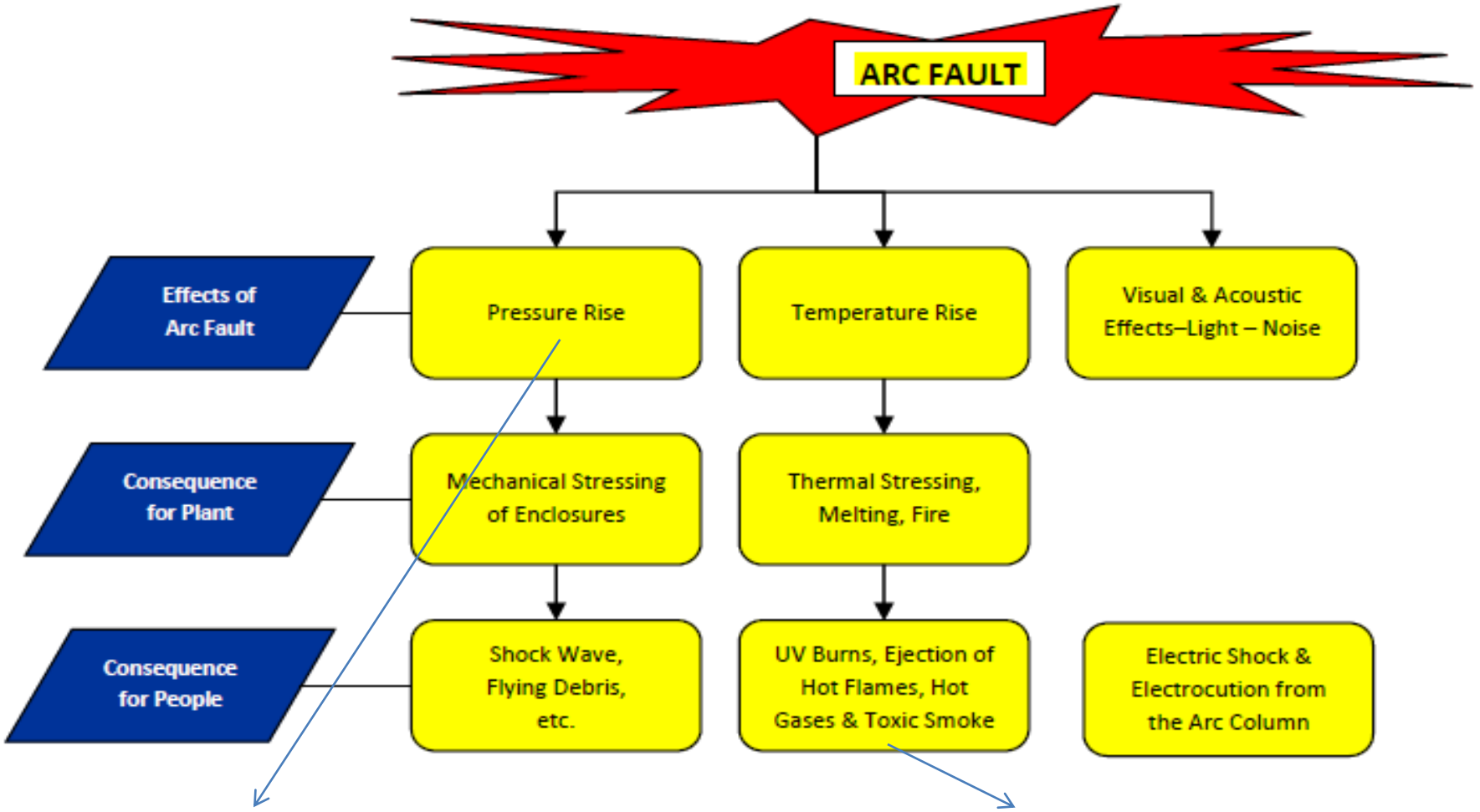
“If you come to a fork in the road you should take it.”
Yogi Berra

MCC Solution – Prevention Through Design



- AF Contained Switchboard.
- EL on all circuits including Main with external Test plug for EL Injection.
- Remote external operators panel for VSD.
- Thermographic viewing windows.
- IP 2X or intermediate barriers with labels or fully insulated.
- All panels have an upstream isolation point – all labelled point of use to point of SA distribution.
- Fully insulated bus system on DB, load side IP2x.
- Hazard labelling at middle latch each panel or top. Each panel labelled what it is, where it is fed from, what it feeds.
- Interlocked enclosures electrical or mechanical or barriers or fully insulated behind with hazard labels.

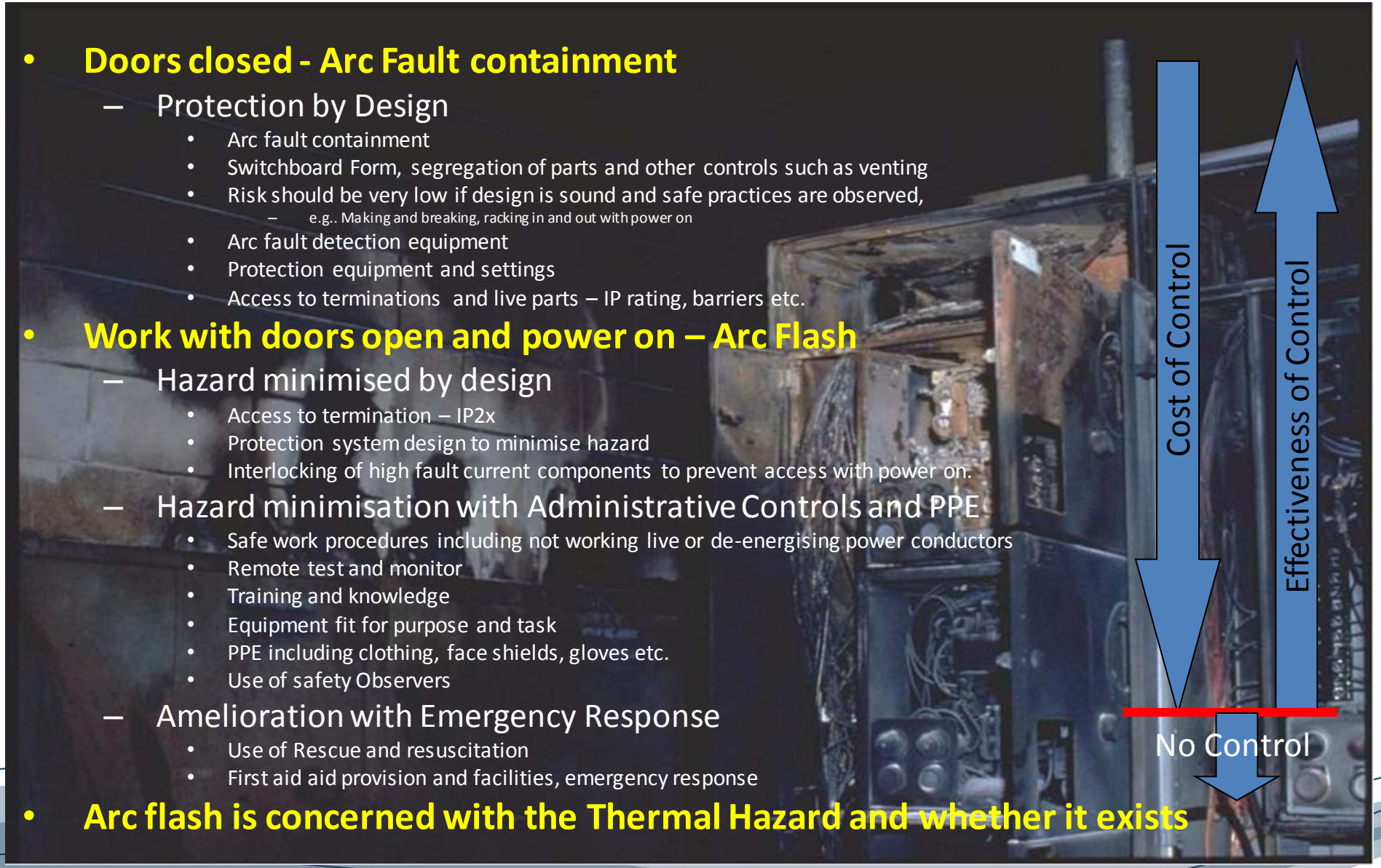


Arc Blast – Pressure Rise & Hazard

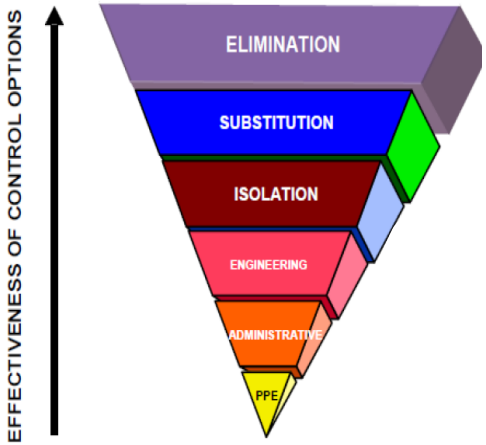
Arc Flash– Thermal Effects & Hazard

Considerations

- **Doors closed - Arc Fault containment**
  - Protection by Design
    - Arc fault containment
    - Switchboard Form, segregation of parts and other controls such as venting
    - Risk should be very low if design is sound and safe practices are observed,
      - e.g.. Making and breaking, racking in and out with power on
    - Arc fault detection equipment
    - Protection equipment and settings
    - Access to terminations and live parts – IP rating, barriers etc.
- **Work with doors open and power on – Arc Flash**
  - Hazard minimised by design
    - Access to termination – IP2x
    - Protection system design to minimise hazard
    - Interlocking of high fault current components to prevent access with power on.
  - Hazard minimisation with Administrative Controls and PPE
    - Safe work procedures including not working live or de-energising power conductors
    - Remote test and monitor
    - Training and knowledge
    - Equipment fit for purpose and task
    - PPE including clothing, face shields, gloves etc.
    - Use of safety Observers
  - Amelioration with Emergency Response
    - Use of Rescue and resuscitation
    - First aid aid provision and facilities, emergency response
- **Arc flash is concerned with the Thermal Hazard and whether it exists**

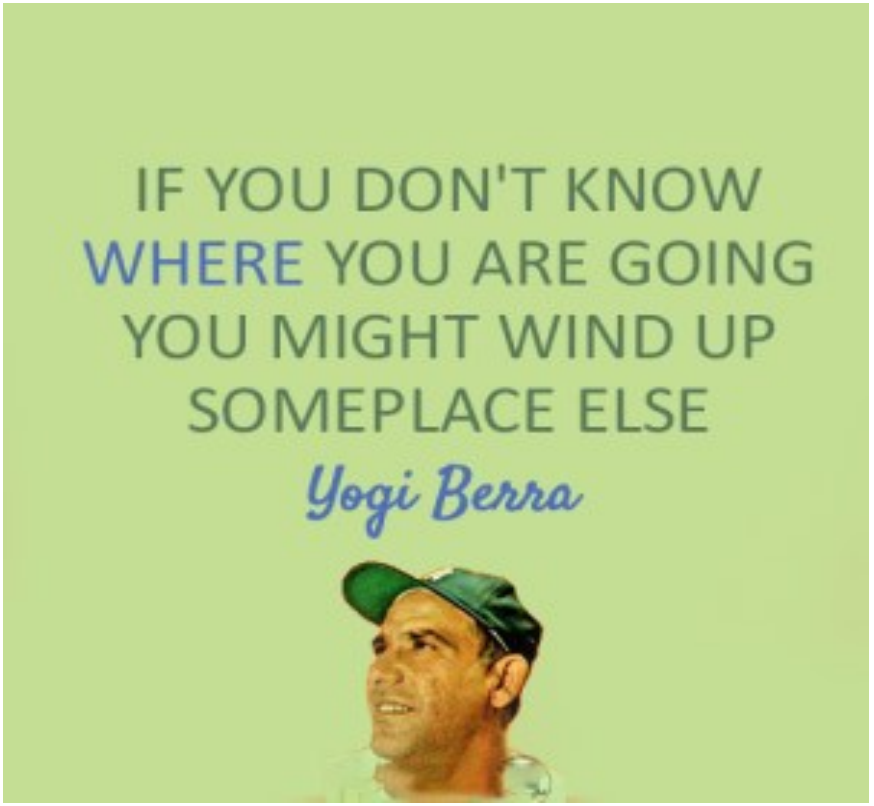


Hierarchy of Controls



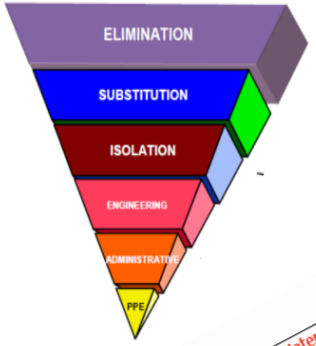
Elimination	De-energise at an upstream location, ie. No live parts inside the switchboard. Disconnect conductors form supply elsewhere before work on all conductors in and around the work area.
Substitution	Use high voltage apparatus to reduce the incident energy available noting this introduces other risks and issues. Use lower voltage systems however the power may not be available to do the work. Replace switchboards with arc fault contained equipment.
Engineering Controls	Use of certified Arc Resistant switchgear (fully insulated bus systems and IP2x terminations and Arc contained switchboards Limit Fault current by use of Current Limiting Breakers, Current Limiting Reactors and High Resistance Grounding Reduce fault clearing time without affecting system discrimination Reduce fault clearing time by installation of Arc Detection Relays and Sensors Remote Operation (Open/Close) and remote racking systems Use of appropriately rated test equipment Design and installation of electrical installations Proper maintenance regime Management of insulation life cycle considering ambient and environmental conditions Use of IR windows to preclude live thermography
Administrative Controls	Arc Flash analysis and installation of warning labels Arc Flash Management plan and training Live work procedures including testing Avoid live working where possible and use of safe work procedures Competency Assessment, Risk Assessment and Authorisation for work Assure maintenance performance Safe work observations and audit of safe work practices
PPE	Use of arc rated PPE appropriate for the task being performed

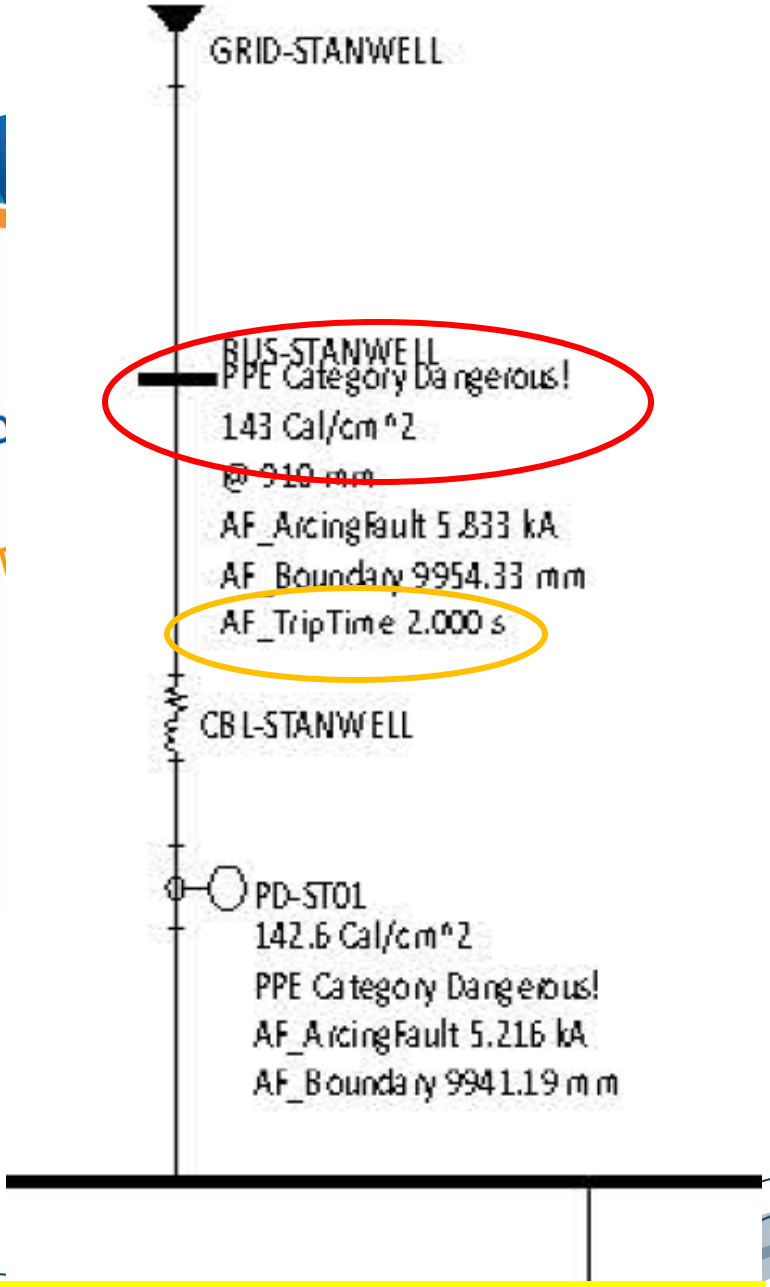
Table 1 – Hierarchy of Risk Controls for Arc Flash Hazard Management



You have to have a plan.

With some irony we were in the process of developing our program when we experienced our last incident.

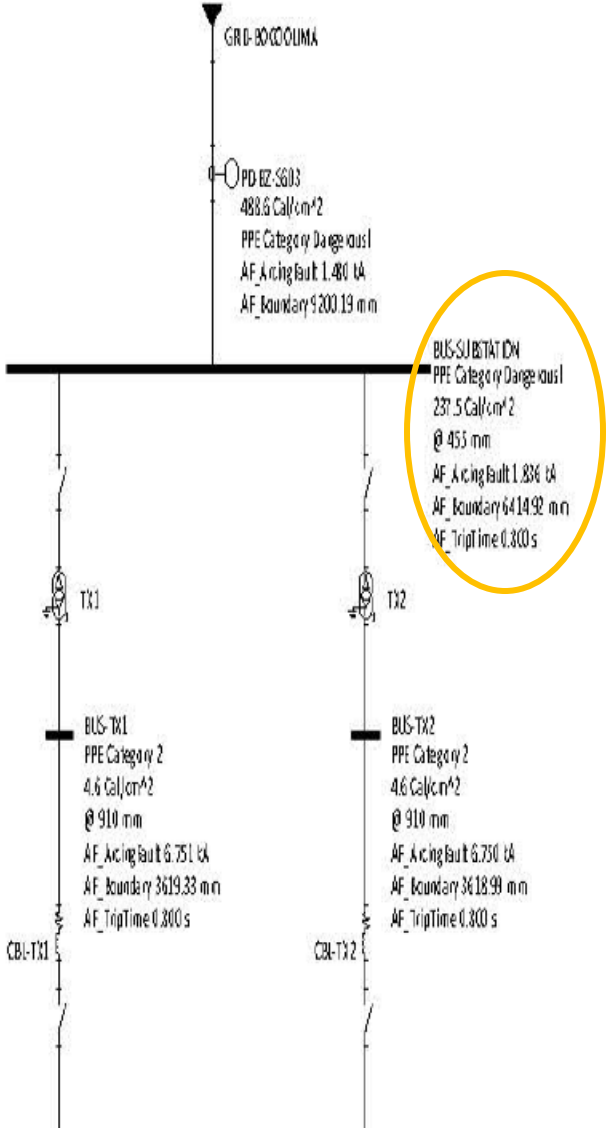


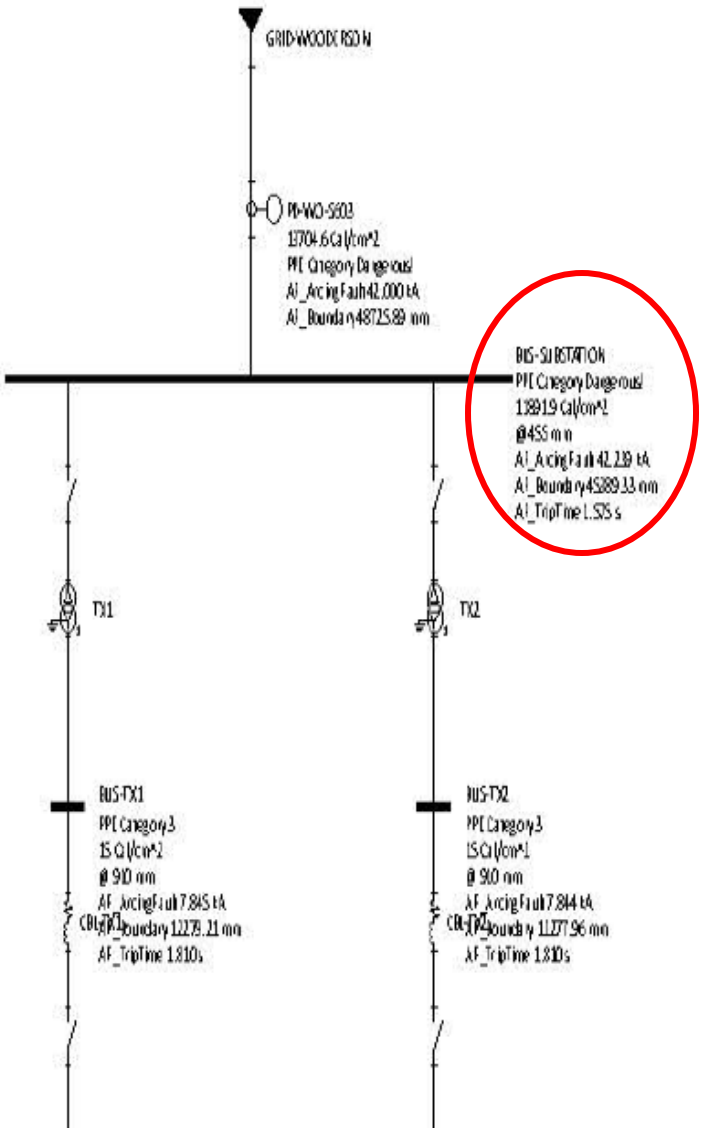


Handbook being developed for staff

Studies provide an opportunity to lower protection and redcue the incident energy.

Better to Know





SunWater Arc Flash Management Program

- SunWater committed to understanding, identifying and quantifying the hazards and implement a management program to control the risks.
- Identification and calculation of Incident Energy Exposure in Excess of 1.2 cal/cm^2.
  - Based on IEEE 1584 and Lee Equation.
  - Multiple Feed/Source, separate calculation for energy feeds by each source if tripping time > 2 sec.
  - Tripping location based on forms of segregation of switchboard.
  - Excludes 240V <150kVA cct's in immediate supply
- Define and determine the appropriate PPE and associated procedures required and label.
- Generalised Approach where analysis not done yet similar to
  - NFPA 70E – 2015 – AF Hazard Identification Table.
  - NFPA 70E – 2015 – Work Table for PPE

Multi Faceted Program of Controls

- Prevention through design or modification of electrical installations
- Prevention through asset management and maintenance
- Prevention through management of change
- An arc flash hazard assessment to be completed based on up-to-date and accurate data and analysis of arc fault hazards for each low voltage switchboard where potential for a significant release of incident energy exists (**Rating >240V 150kVA**).
- Arc flash hazard labelling corresponding to the flash hazard assessment to be placed on all electrical cabinets that are likely to require examination, adjustment, servicing or maintenance where a potential arc flash hazard exists.
- A process to be in place for updating the arc flash hazard analysis and labelling as changes and electrical upgrades occur that might affect the available short circuit current on the system.
- Safe work practices and PPE requirements to provide assurance for safe work on electrical switchboards.
- People potentially exposed to any arc flash hazard to be trained in the hazards associated with electrical arc flash and the application of selection, wearing and maintenance of appropriate clothing and arc flash personal protective equipment.
- A system is to be in place to verify the worker's ability to assess personal protective equipment requirements specific to electrical task hazards.
- Prohibition of live electrical work except for low risk testing procedures controlled by a risk assessment completed for the task or activity.

IEEE Std 1584-2002 (*Guide for Performing Arc-Flash Hazard Calculations*)

The current passage is through ionised air and the vapour of the arc terminal material, which has substantially higher resistance than the solid material. For low voltage circuits the arc length consumes a substantial proportion of the available current. This is why arcing faults are not a risk on lower voltage systems (<240V 150kVA). For high voltages, the arc lengths can be considerably greater, before the system impedance tries to regulate or limit the fault current.

It is very important for electrical safety to have up-to-date single-line diagrams available. Refer to IEEE Std 315-1975 and IEEE Std 315A-1986 plus IEEE Std C37.2-1996 for examples.

When the basic electrical system scheme is complete on the diagrams, add the data needed for the short-circuit study. The study must take into account all sources, including utilities, standby and power generators, and large motors—those 37 kW and larger that contribute energy to short circuits. [10] The diagrams must show all transformers, transmission lines, distribution circuits, electrical system grounding, current limiting reactors and other current limiting devices, voltage correction or stabilization capacitors, disconnect switches, switchgear, motor control centers (MCCs), panelboards/switchboards including protective devices, fused load interrupter switches including fuse types and sizes, feeders and branch circuits, as well as motors down to the 600 V or 400 V level, and transformers supplying instrument power and protective devices. Equipment below 240 V need not be considered unless it involves at least one 125 kVA or larger low-impedance transformer in its immediate power supply.

Design Considerations or Redesign

- Design of new electrical switchboards and replacement of existing installations to cater for arc fault containment and / or detection to manage equipment life cycle for more hazardous or high value situations.
- This will consider and include where appropriate provision of:
  - Arc detection equipment and relays in high risk or high value situations to ensure the fastest cut off time possible.
  - Emergency stop facilities outside all HV rooms and the provision of remote switching facilities for all high voltage and high capacity low voltage circuit breakers.
  - Equipment with protection settings adjustments to lower incident energy while work is performed or changing out fuses to lower rated devices with faster operating times while risk assessed testing work is performed on the power system
- Fast Acting Protection systems and Lower protection settings as far as possible to reduce incident energy

Simple Cheap Electrical Protection

As Shown

BUS-MSB

PPE Category 4

26.7 Cal/cm^2 @ 455 mm

AF_ArcingFault 4.273 kA

AF_Boundary 3020.11 mm

AF_TripTime 2.000 s

100A HRC Fuses Installed

BUS-MSB

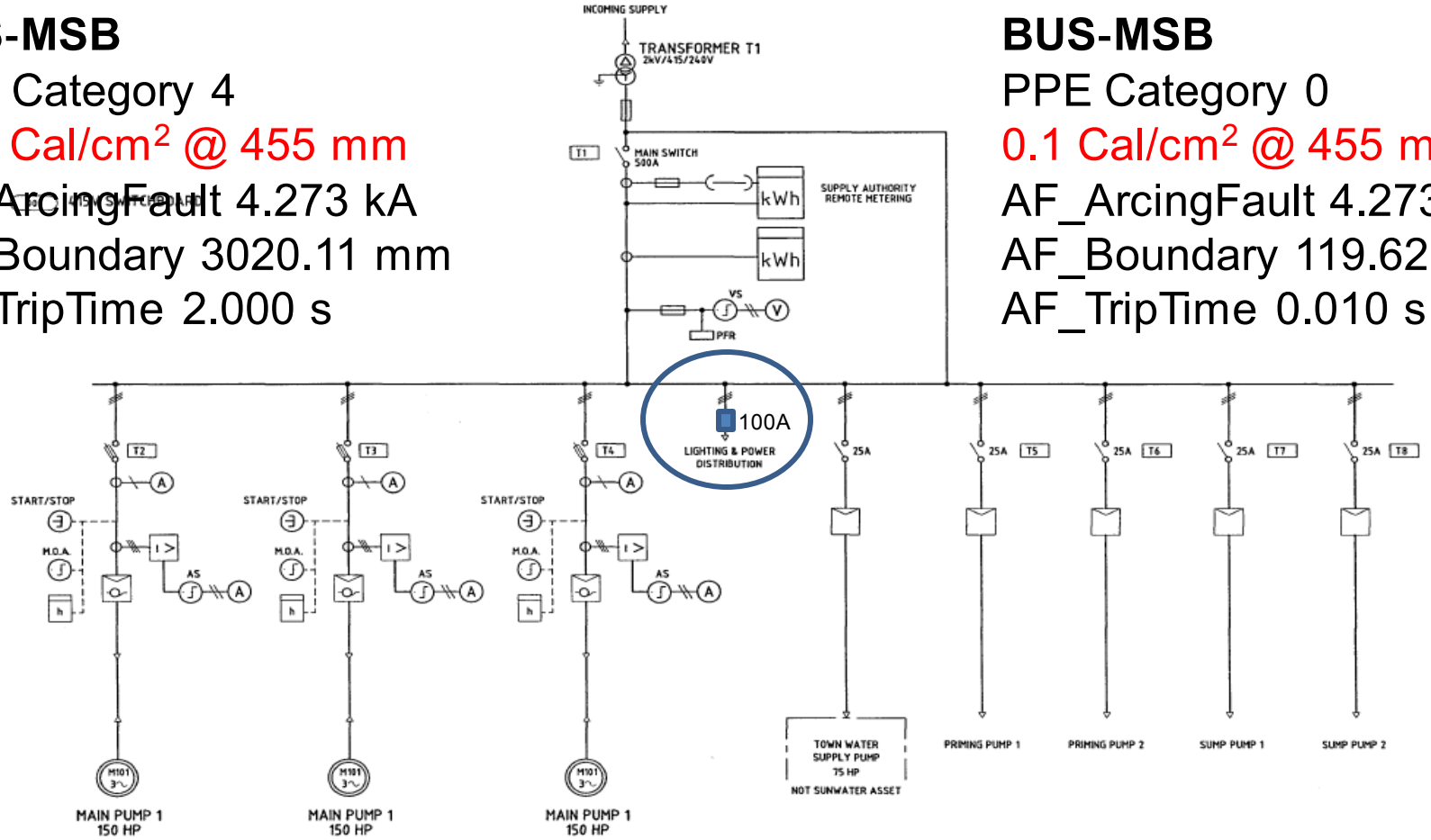
PPE Category 0

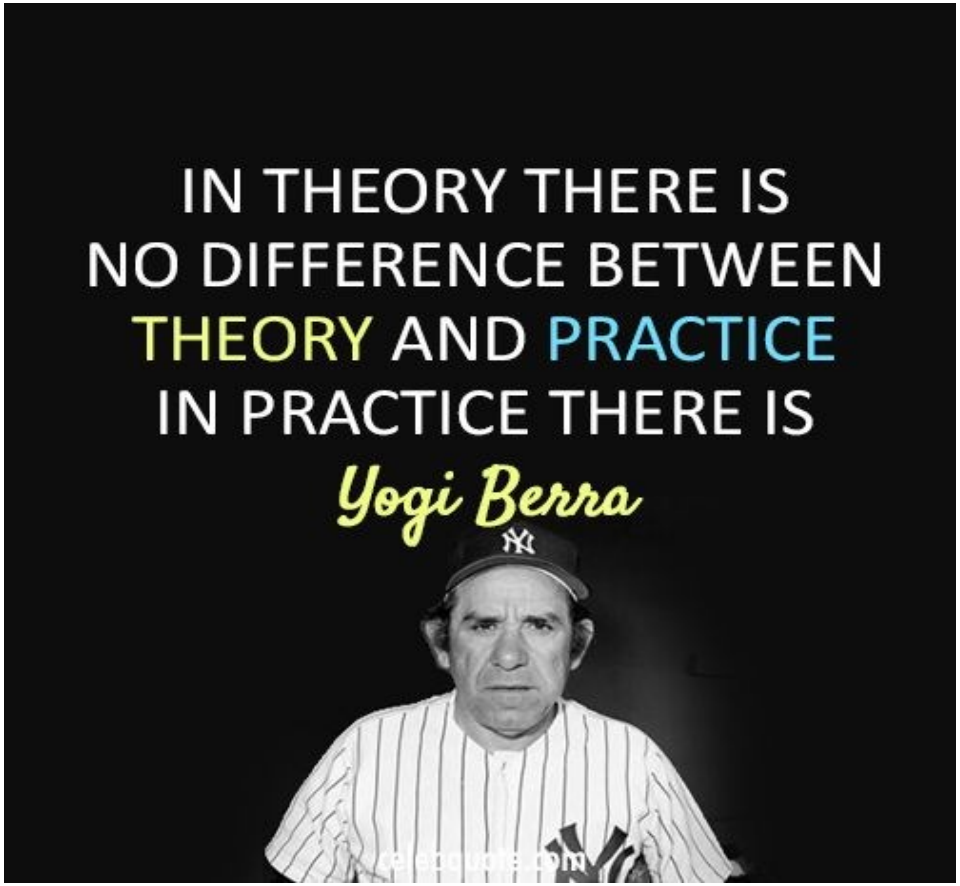
0.1 Cal/cm^2 @ 455 mm

AF_ArcingFault 4.273 kA

AF_Boundary 119.62 mm

AF_TripTime 0.010 s





If AFHA is a doors open assessment.

If the doors are closed in Theory is there no risk?

Risks associated with doors open / closed

There has been discussion around the risks posed to a person from walking or being in close proximity to electrical switchboards. J.C. Das cites the following statistics for all Arc Flash Incidents in the book Arc Flash Hazard Analysis and Mitigation:

1. When the worker or operator is working with the doors open 65%
2. When a person is not present and the equipment is not rated for arc containment 25%
3. When the worker or operator happens to be in front of the equipment and doors are closed 10%

The probability of a person being present outside a switchboard enclosure when an arc flash incident occurs is extremely low. The incidence of injury to a person from these events is much lower again.

It is the experience of the IEEE Technical Committee on Electrical Safety in the Work-places that normal operation of the enclosed electrical equipment, operating at 600V or less that has been properly designed, installed and maintained by qualified persons is not likely to expose a person to an electrical hazard. It is also of the opinion of the committee that there is little risk in performing normal operations of electrical equipment and devices such as opening and closing circuit breakers or starting and stopping equipment. The committee identifies higher risk activities where people interact with equipment in a manner that could cause an arc flash which includes racking of circuit breakers, withdrawing or inserting switchgear modules and MCC (Motor Control Centre) starter units. (Reference Arc flash Hazard analysis and Mitigation J.C.Das).

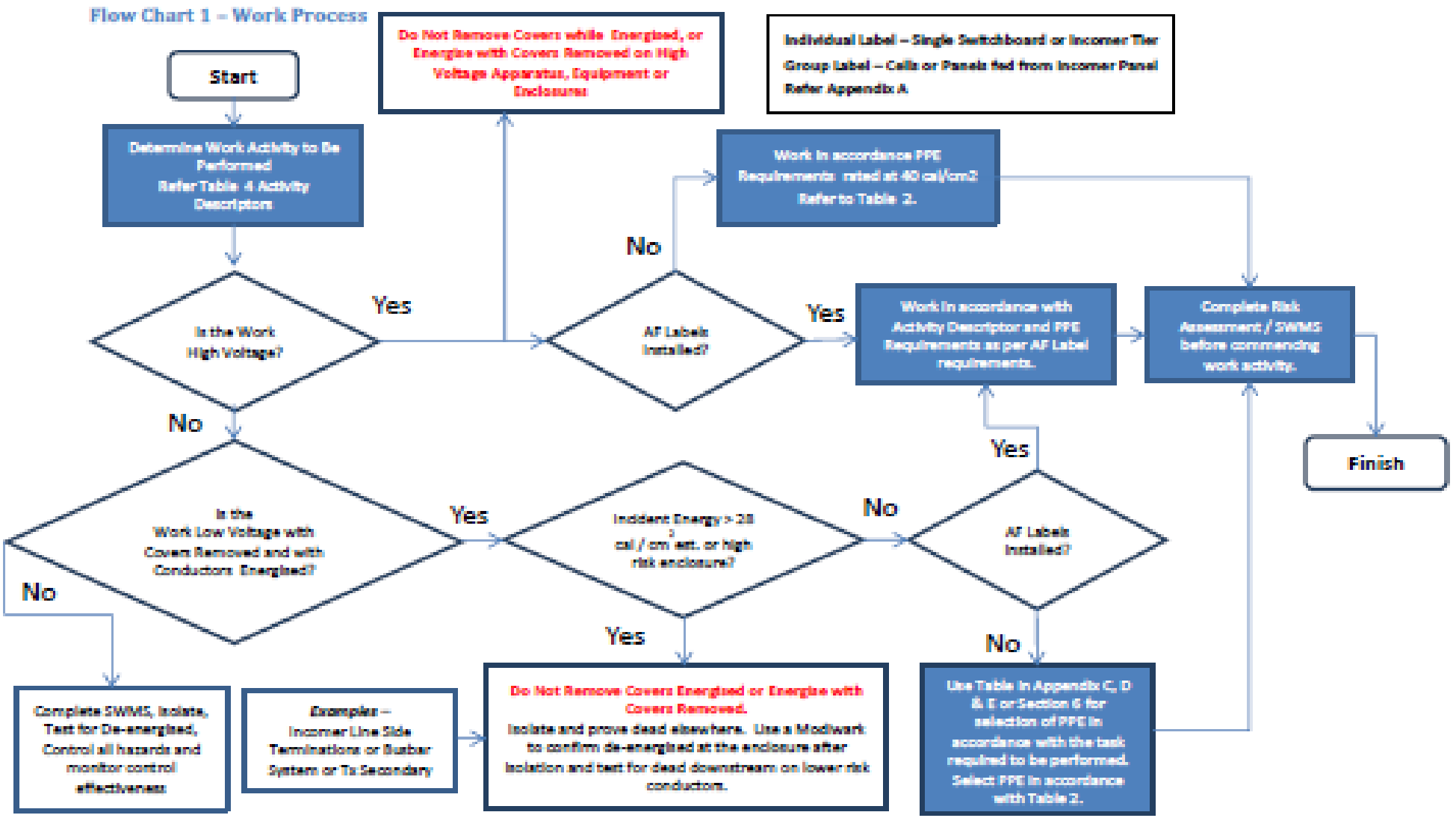
Defined a Table of Activity Types

Activity descriptors for work performed are shown in the table below. These Activity Categories are shown on AF labels along with PPE guidance for Doors Open and Door Closed situations with the equipment energised.

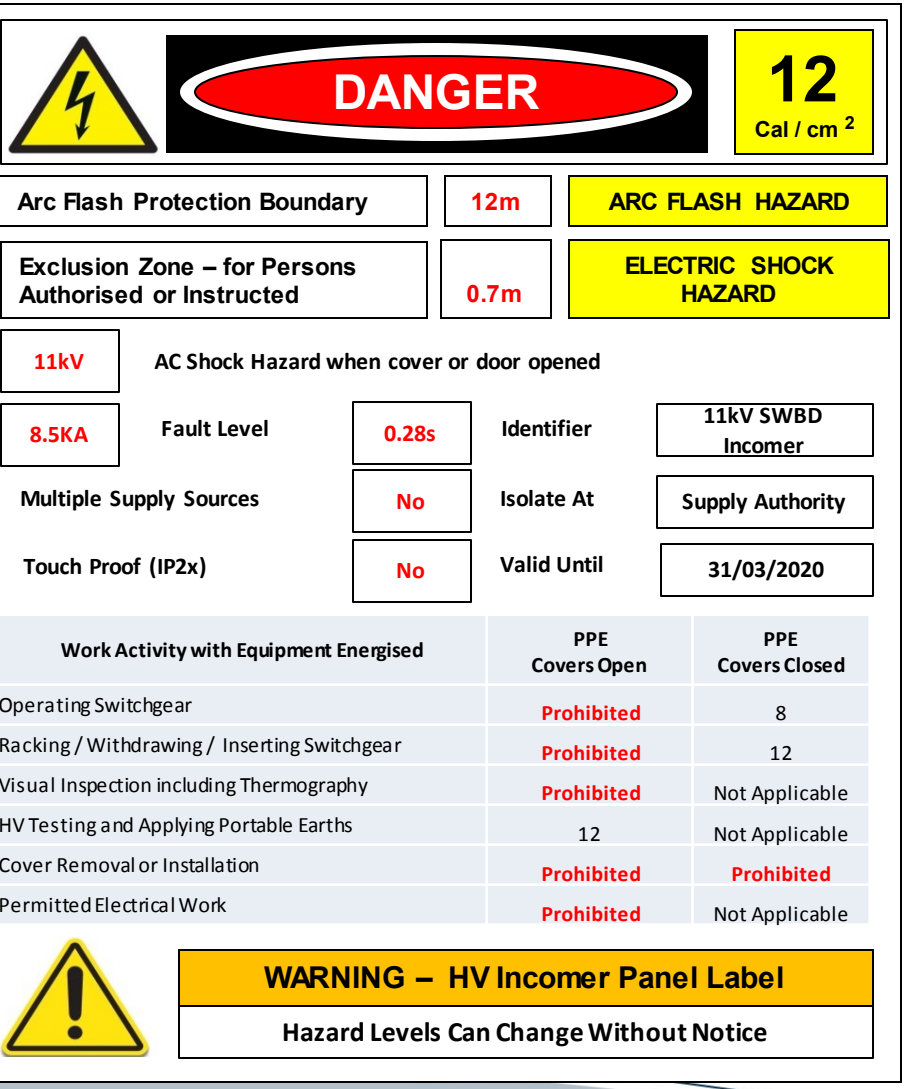
Switching	Changing state of functional unit i.e.: • Operating an isolator, fuse switch or circuit breaker. • Manual spring charging. • Operation of integral HV earthing mechanisms. • Fuse removal / insertion Excludes remote switching.
Racking	Disconnection of the functional unit from the bus via an integrated mechanism.
Visual Inspection	• Visual inspection is an activity that is undertaken following the opening or removal of panel doors/covers to expose energised equipment. • Visual inspection only permits activities to be completed whereby a person, tool, or component cannot enter the area 300mm from the front of the open panel containing the exposed energised equipment (e.g. looking, photography, thermography). • Performing work on electrical equipment includes testing (and testing for dead) but not visual inspection. • Arc flash requirements do not apply where the equipment is isolated and there is no live exposed equipment in the cubicle being worked on unless appropriately barricaded from contact by a tool, component, or person. • An example of an appropriate barricade would be an insulated blanket covering all live parts or permanent shrouding. Excludes high voltage unless the conductors are normally exposed, e.g. switchyard.
HV Testing and Portable Earthing (Enclosed HV Equipment) (Approved HV Test Equipment)	Phasing out. • Test for dead both direct contact (Taplin) or indirect (Modiwark). • Application of portable earths. • Insertion of test probes. Excludes the use of off-line test equipment (e.g. primary injection, ductor). For overhead exposed HV equipment (refer to 6.1).
Cover Removal	Does not include the removal of LV bus, LV transformer covers or high voltage covers which are all ***strictly prohibited***.
Electrical Work	Performing work on electrical equipment includes testing (and testing for dead) but not visual inspection. • Arc flash requirements do not apply where the equipment is isolated and there is no live exposed equipment in the cubicle being worked on unless appropriately barricaded from contact by a tool, component, or person. • An example of an appropriate barricade would be an insulated blanket covering all live parts or permanent shrouding.

Table 4 – Activity Descriptors for AF Labels

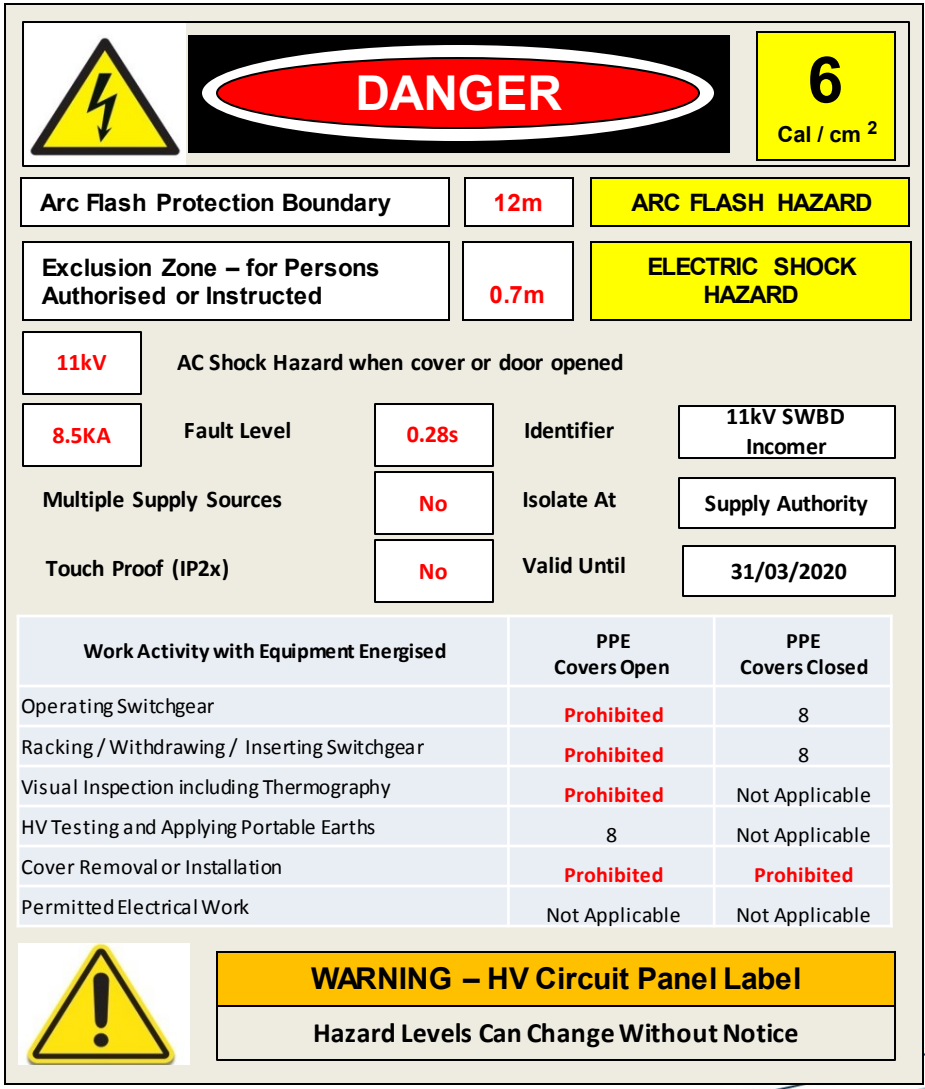
BASIC Workflow



High Voltage Incomer and Group Circuit Labels



Work Activity with Equipment Energised	PPE Covers Open	PPE Covers Closed
Operating Switchgear	Prohibited	8
Racking / Withdrawing / Inserting Switchgear	Prohibited	12
Visual Inspection including Thermography	Prohibited	Not Applicable
HV Testing and Applying Portable Earths	12	Not Applicable
Cover Removal or Installation	Prohibited	Prohibited
Permitted Electrical Work	Prohibited	Not Applicable

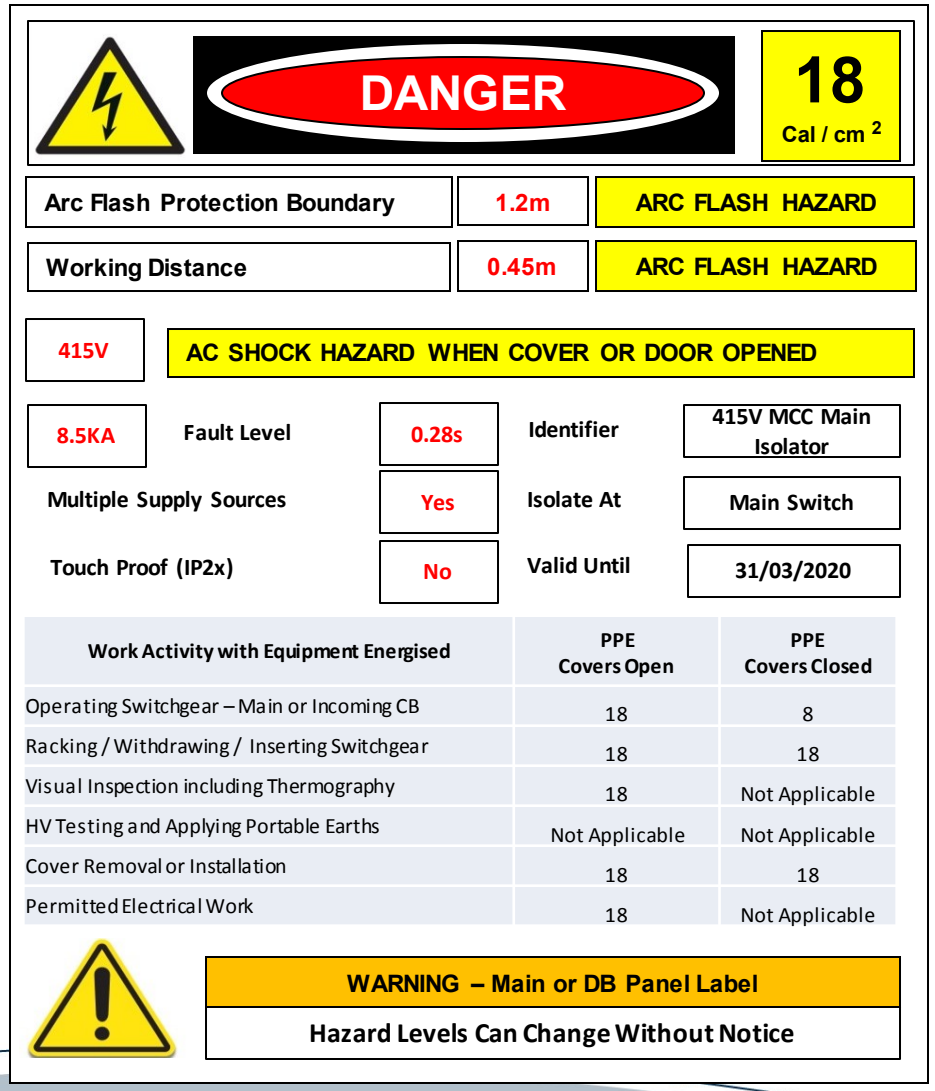


Work Activity with Equipment Energised	PPE Covers Open	PPE Covers Closed
Operating Switchgear	Prohibited	8
Racking / Withdrawing / Inserting Switchgear	Prohibited	8
Visual Inspection including Thermography	Prohibited	Not Applicable
HV Testing and Applying Portable Earths	8	Not Applicable
Cover Removal or Installation	Prohibited	Prohibited
Permitted Electrical Work	Not Applicable	Not Applicable

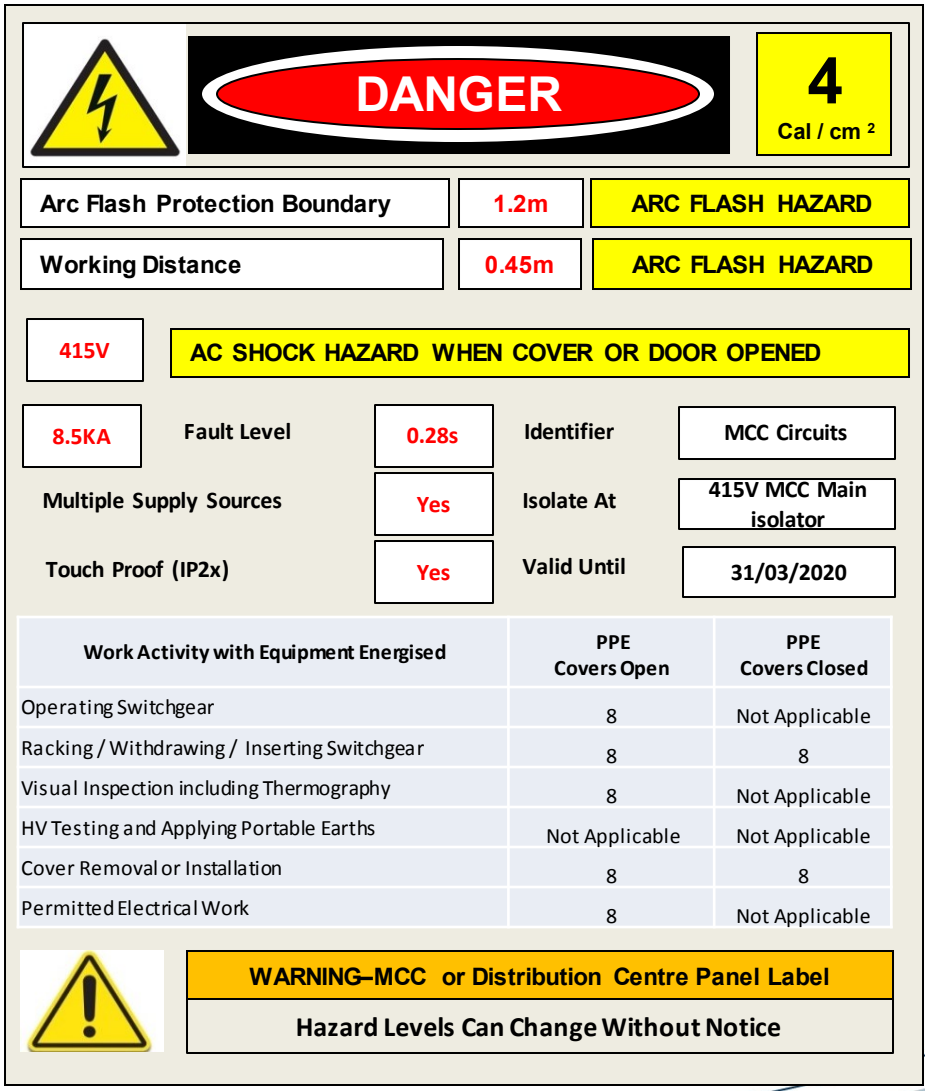
High voltage labels indicate the Exclusion Zone for HV Conductors as defined under the QESR

Group labels are to be installed to the right of Incomer Panel labels

Low Voltage Incomer and Group Circuit Labels



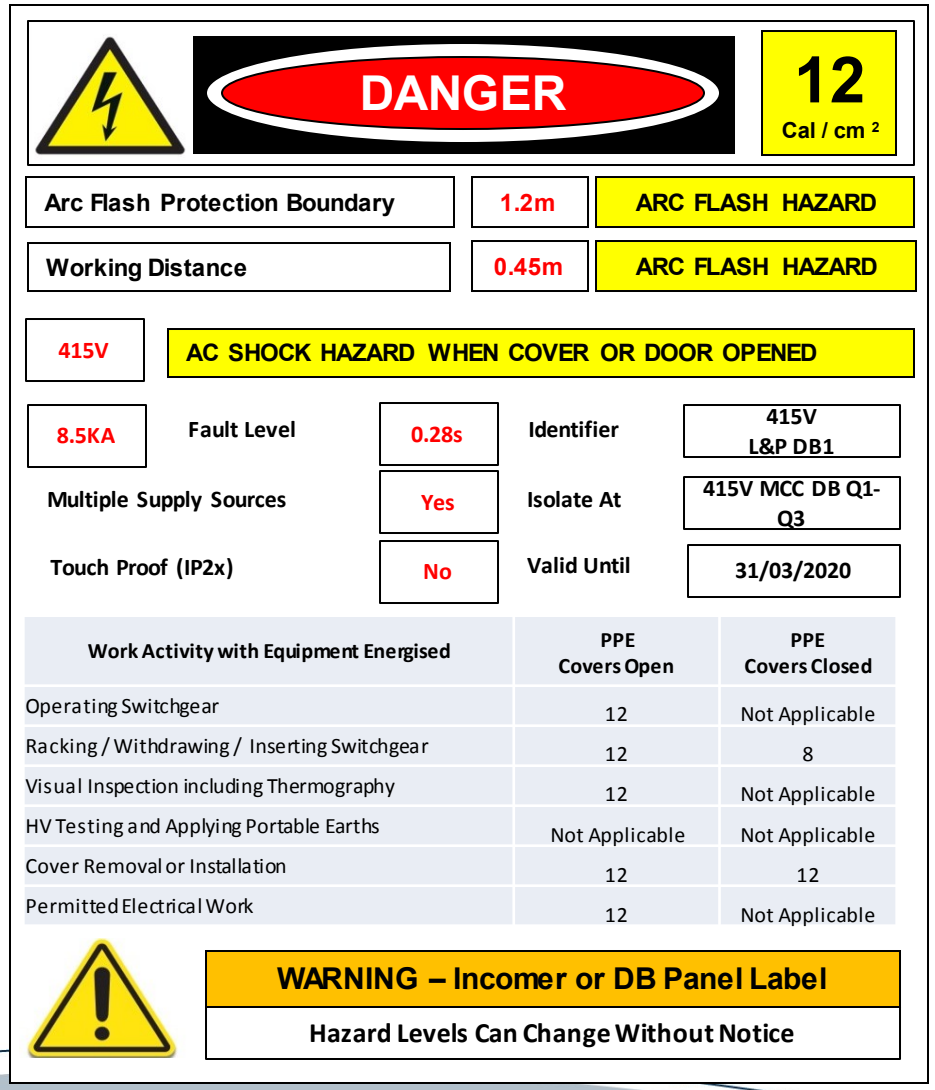
Work Activity with Equipment Energised	PPE Covers Open	PPE Covers Closed
Operating Switchgear – Main or Incoming CB	18	8
Racking / Withdrawing / Inserting Switchgear	18	18
Visual Inspection including Thermography	18	Not Applicable
HV Testing and Applying Portable Earths	Not Applicable	Not Applicable
Cover Removal or Installation	18	18
Permitted Electrical Work	18	Not Applicable

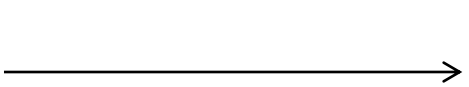


Work Activity with Equipment Energised	PPE Covers Open	PPE Covers Closed
Operating Switchgear	8	Not Applicable
Racking / Withdrawing / Inserting Switchgear	8	8
Visual Inspection including Thermography	8	Not Applicable
HV Testing and Applying Portable Earths	Not Applicable	Not Applicable
Cover Removal or Installation	8	8
Permitted Electrical Work	8	Not Applicable

Low voltage labels indicate the Working Distance for LV Conductors in accordance with NFP70E
Group labels are to be installed to the right of Incomer Panel labels

Low Voltage Distribution Board Labels





The cal / cm2 rating becomes red for anything ≥ 25

Low voltage labels indicate the Working Distance for LV Conductors in accordance with NFP70E

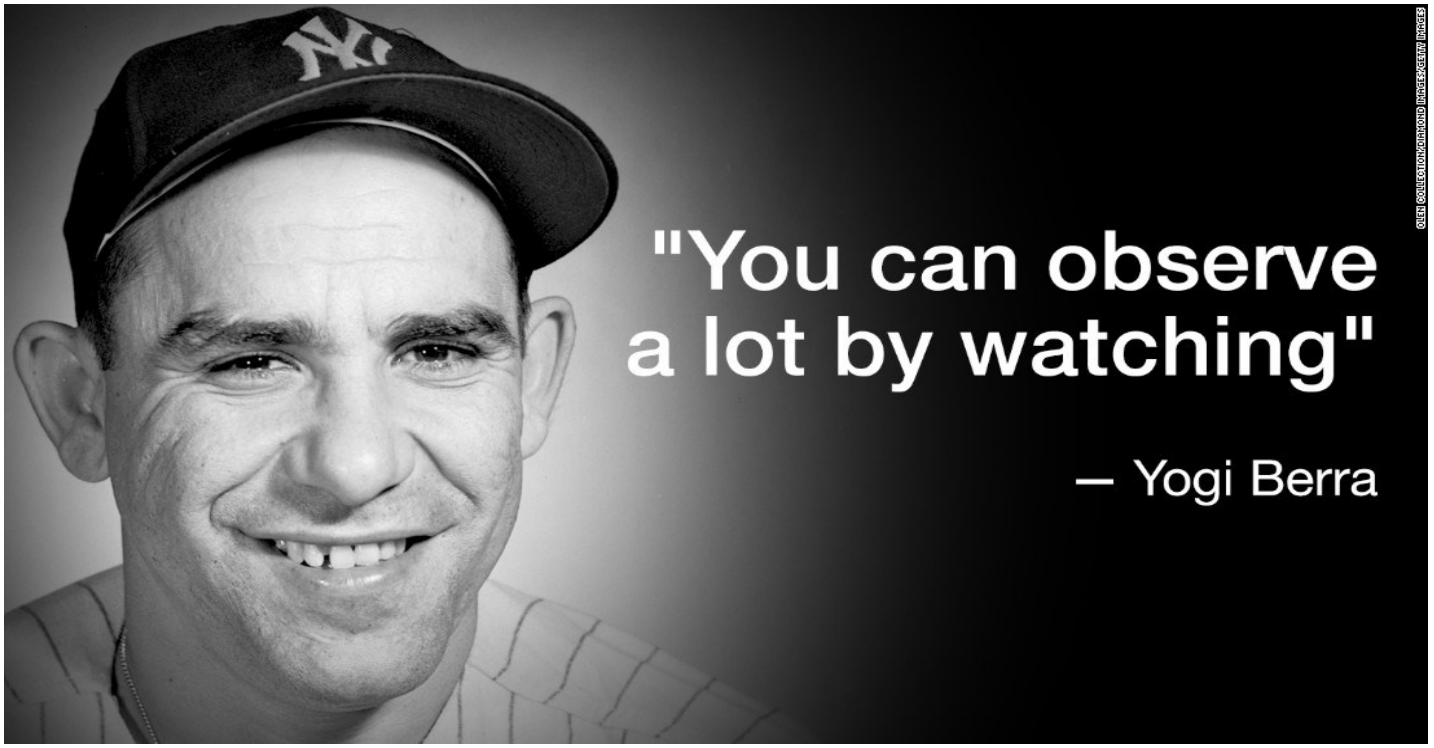
Low Voltage High Risk Zones

For all Category 4 415V location and transformer LV boxes, incomer cable zones or termination boxes

Key Challenges

- Staff need to learn a new language
  - Keep it simple Incident Energy, AF Boundary, Working Distance
  - Most staff get the thermal hazard but can not relate or forget about arc blast hazards.
- Clothing – 195gsm FR is much hotter than 185gsm heavy duty cotton workwear
- Can not layer clothing anymore unless it has been tested as a layered system
  - You waste a lot of time trying to satisfy everyone's perceived needs.
  - We run everyday workwear vented shirts 6.7 cal/cm2 and 8 pants, provide 12 cal/cm2 FR coverall and then provide 40 cal/c,m2 switching suits – Outer layer must satisfy the Incident Energy level.
- How to operate when Incident Energy is 140,000 cal/cm^2 and AF Boundary is 45m in a yard. TBV
- The need to link strategy through the hierarchy of control – Design, Asset management through maintenance through safe work practice and training and PPE etc.
- The time you need to invest to do something properly – V5 at rollout.
- Separate people where possible – Remote operations
- Reduce incident energy wherever practical - lower settings, AF detection relays, ….
- Good simple and reliable tables to reference for situations where analysis not done.

Safe Work and Critical Task Observations



The following standards have been referenced in the development of this document:

1. NFPA 70E: Standard for Electrical Safety in the Workplace 2015
2. AS/NZS3000:2007 Electrical Installations *known as* The Wiring Rules
3. Institute of Electrical and Electronics Engineers (IEEE) Standard 1584:2002 Guide for Performing Arc Flash Hazard Calculations
4. AS/NZS 4836:2011 Safe working on low-voltage electrical installations
5. Arc Flash Hazard Analysis And Mitigation J.C.Das IEEE Press C. 2012
6. ENA NENS 09-2014 National Guideline for the Selection, Use and Maintenance of Personal Protection Equipment for Electrical Arc Hazards

If you ask me anything I don’t know, I’m not going to answer.