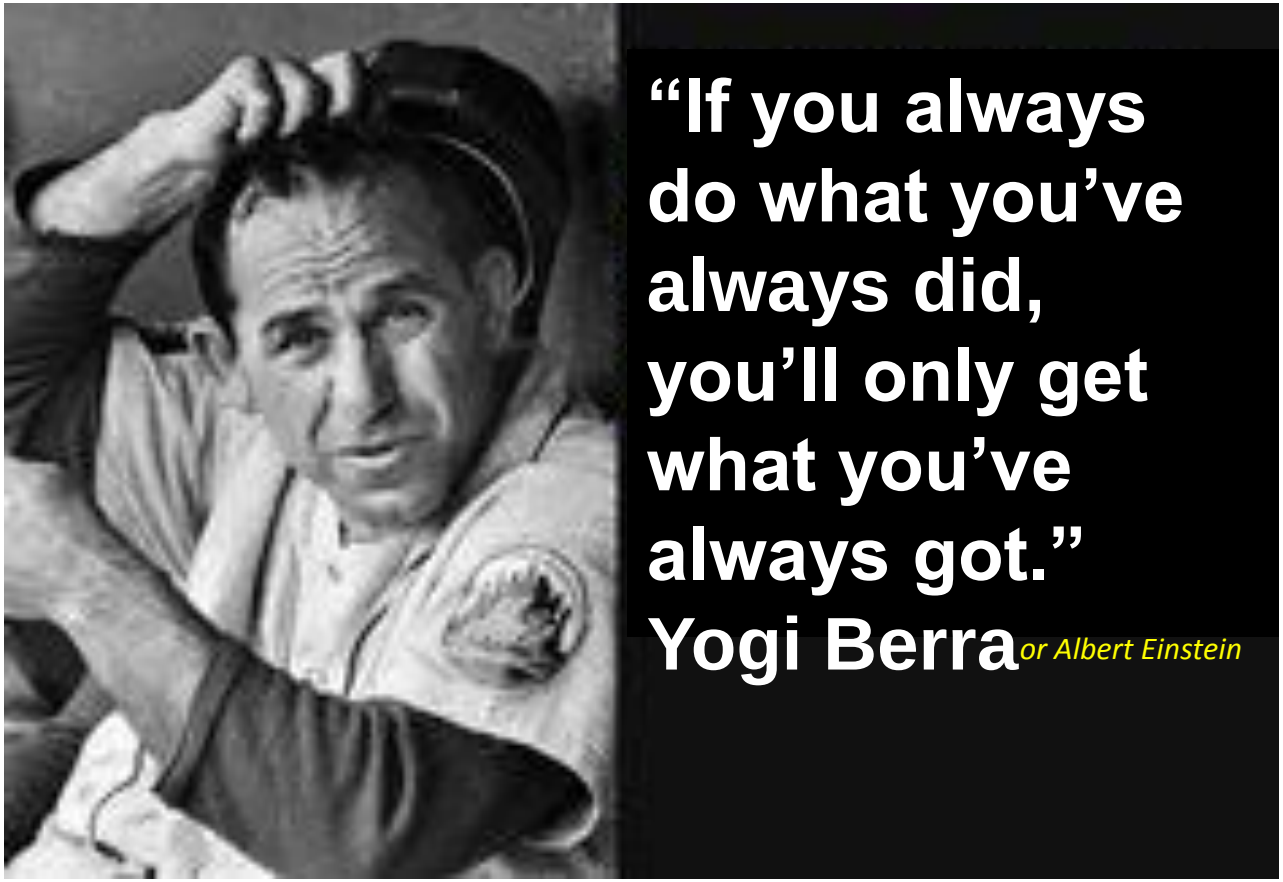
Scar Tissue

from the

Lessons We Learned

Arc Flash Incident and Hazard Mitigation & Management

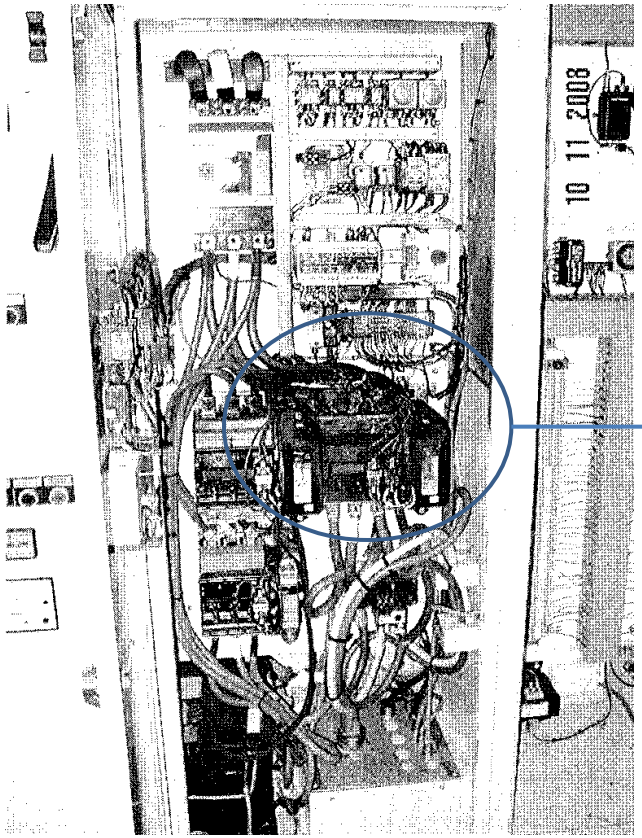
Robert Lewis, General Manger Operations South SunWater Limited


“If you always do what you’ve always did, you’ll only get what you’ve always got.”
Yogi Berra or Albert Einstein

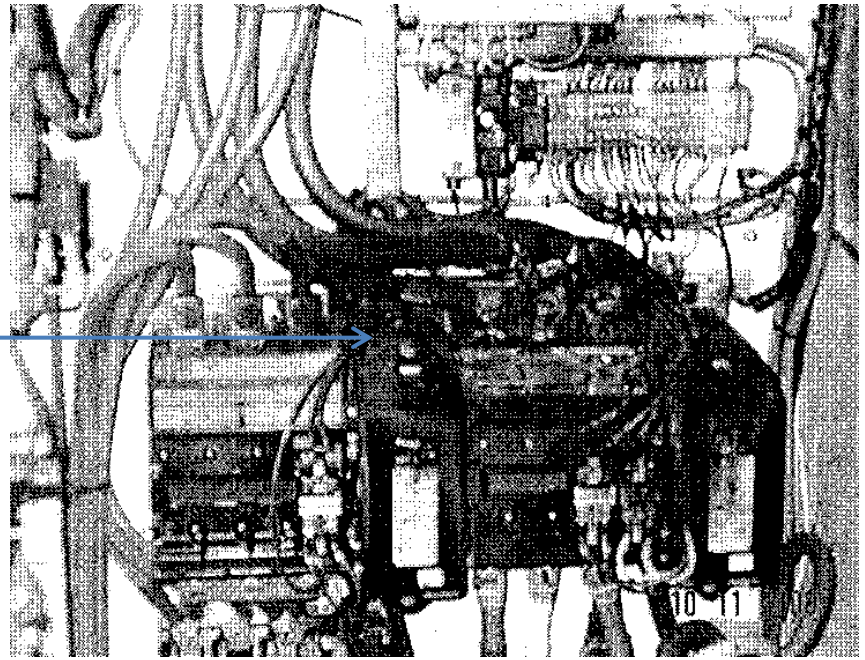
Incident 1 10/11/2008

- An electrician employed by SunWater received first and second degree burns (4-5% of body) to a hand and arm as a result of an electrical arc incident.
- A control fuse was accidentally dropped onto live terminations as it was being removed inside a motor starter panel.
- The task being performed was to test a motor protection relay.
- Power was turned off to open the switchboard (door interlocked mechanically to the isolator). Test equipment was then connected. Then with the door open, the isolator was turned on.
- The control fuse was required to be removed as part of the procedure.
- Incident investigation found deficiencies with the design, electrical maintenance procedures and work practices and supervision of the work.
- SunWater was fined a total of $38,419 (including costs) in legal proceedings brought by the Electrical Safety Office in relation to the incident. No action was taken against the Directors and Officers of SunWater.
- Electrician was working alone and was sent to perform the task alone.

Switchboard



Short circuit line side contactor

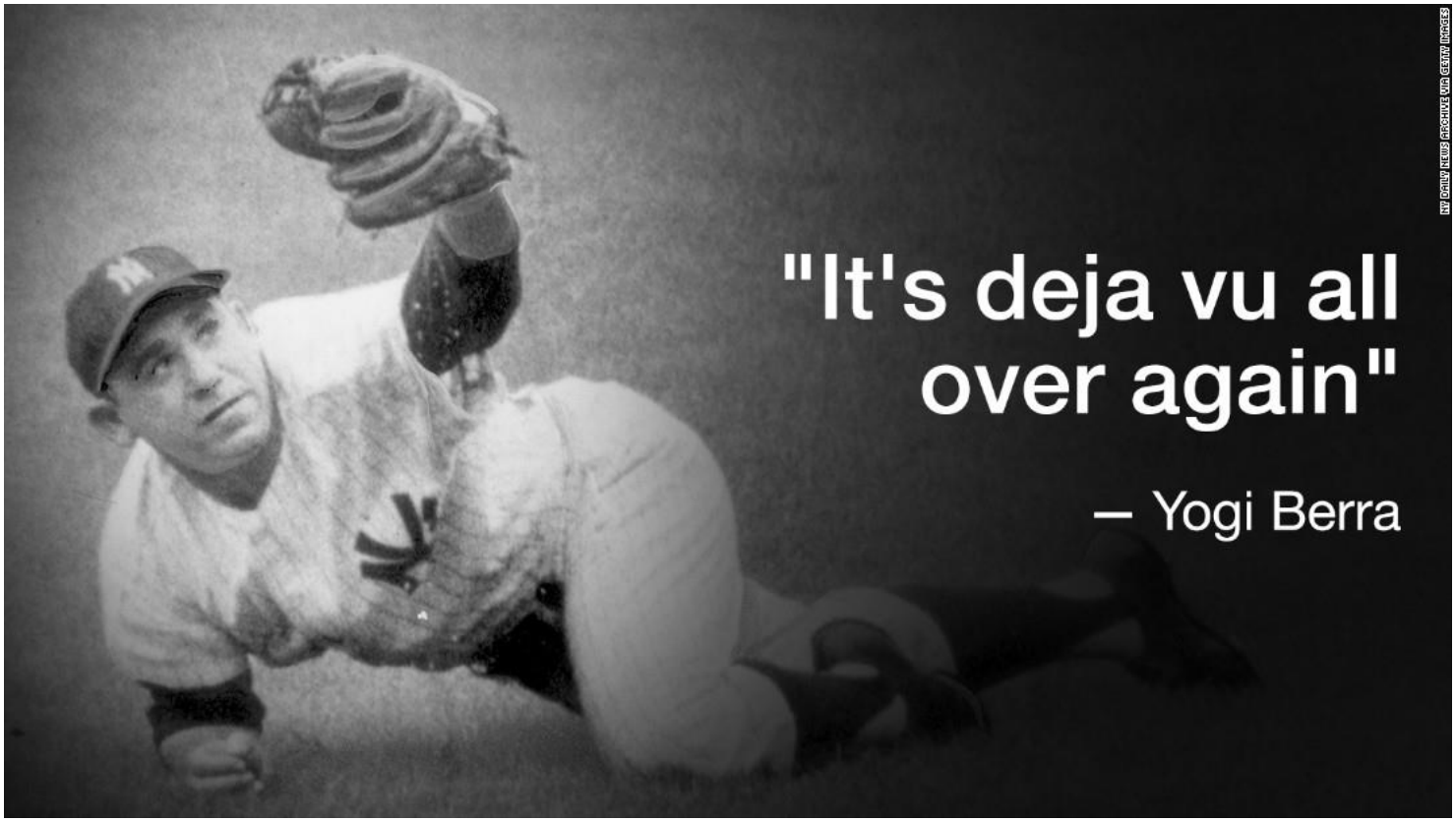


Response

- From memo written after the incident
  - *Warning signs are to be erected at all switchboards with an assessed safety score of major and above, until appropriate risk mitigation measures are in effect.*
  - *Appropriate work methods are to be developed and implemented for these switchboards until they are replaced or modified.*
  - *Switchboard replacements are to be scheduled in WMS.*
  - ***Sign-off of any modifications to switchboards must be completed by an electrical engineer in advance to any works.***
- External audit of a sample of switchboards across the business
- No acknowledgement, recognition of Arc Flash Hazard although discussion around high current risks as part of the incident analysis.

External Audit Results

- 20% sample - 80 Switchboards audited across 32 locations from Mareeba in the North to Goondiwindi in the South
  - High and Low Voltage Switchboards, Light and Power, Control Switchboards, Motor Control Centres
- Assessment to -
  - AS/NZS 3439.1:2002 Low-voltage switchgear and control gear assemblies
  - AS/NZS 3000:2007 Wiring Rules
  - AS/NZS 2067:2008 Substations and high voltage installations exceeding 1 kV a.c.
  - Queensland Electrical Safety Regulations 2002.
- Issues identified -
  - Aged assets greater than 30 years old
  - Significant number of assets installed in the 1980's – 20-30 yo
  - Lack of regular periodic preventative maintenance, inspections and testing, no thermal imaging
  - Absent markings in accordance with AS/NZS 3439.1:2002 Section 5.2
  - Access to live conductors - Switchboards not locked or do not require a key or tool to open
  - Access to live conductors on the line side of main isolators with interlocked main isolator off and door open
  - Lack of appropriate barriers, insulation or shrouding to provide a level of protection compliant with IP2X
  - Lack of a consistent approach to work practices and work instructions across the regions.
  - Lack of provision of lockout facilities - Lockable Isolators
  - Asbestos – 3 switchboards highly likely
- Recommendations included -
  - 7 immediate high risk corrective actions
  - 7 urgent replacements – 4 > 50yo, 1 >40yo < 50yo, 2 > 30 yo < 40 yo including Theodore PSTN
  - 15 other replacements over the short term – 5 years with remedial short term actions
  - Switchboards to be retained, and remedial actions to be undertaken on existing switchboard.


"It's deja vu all over again"
— Yogi Berra
NY DAILY NEWS ARCHIVE VIA GETTY IMAGES

Incident 2 –August 2012

- Monday 7:59AM an accident occurred at the Theodore Pump Station.
- An electrician employee of a contractor received serious burns to his left hand and left side of his face and neck as a result of an explosion caused by electrical energy.
  - An arc flash occurred a result of failure of the insulation of the switchboard.
  - Primary cause of the failure not identified.
- The accident happened on the first day of a planned shutdown of site work to replace switchboards.
- The works were Principal Contractor works as defined under the Queensland WHS Act.
  - Contract works included design construction, removing old switchboards including the main switchboard and light and power switchboard, installation and commission of the works.
  - Contractor was advised of the reasons for changing the switchboards.
  - Specific direction provided not to perform live electrical work aside from low risk test for dead and required testing for commissioning new equipment.
- Work was generated from the planned program of switchboard replacements from the external audit.
  - This audit report recommended replacement of the main switchboard based upon condition, age and safety concerns including asbestos.
  - Interim risk control measures including providing signage to direct employees to isolate the main switch before accessing the switchboard were implemented.
  - A corrective work order for interim controls was raised in 2010 but was not closed.
- Regulator attended the accident site same day and took statements from the contractors employees and the injured person the next day.
- No action taken against SunWater, not aware of any action being taken against the contractor or its employees by the regulator.

INCIDENT / ACCIDENT
Injury to Personnel or Equipment Damage

Unplanned Release of Hazardous Energy or Material
RELEASE OR EXCHANGE - TRANSFER OF ENERGY

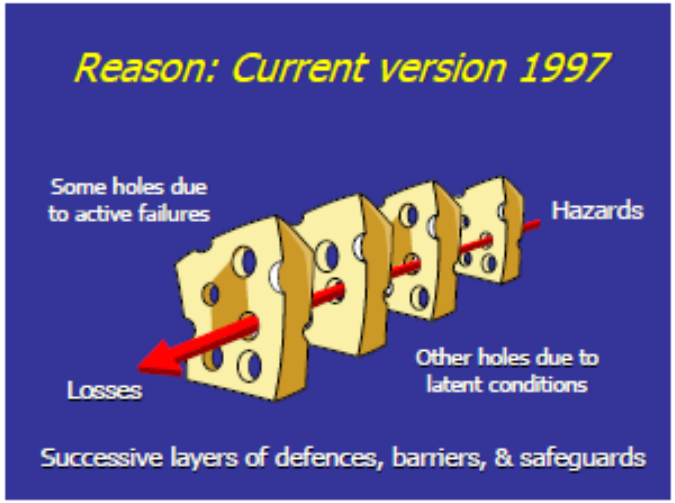
Direct Causes of Injury or Damage

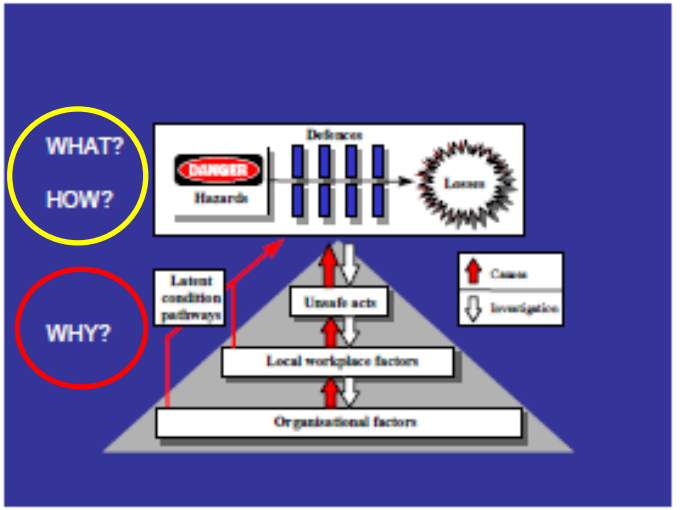
UNSAFE ACTS *And* **UNSAFE CONDITIONS**

Basic or Root Causes ORGANISATIONAL FACTORS

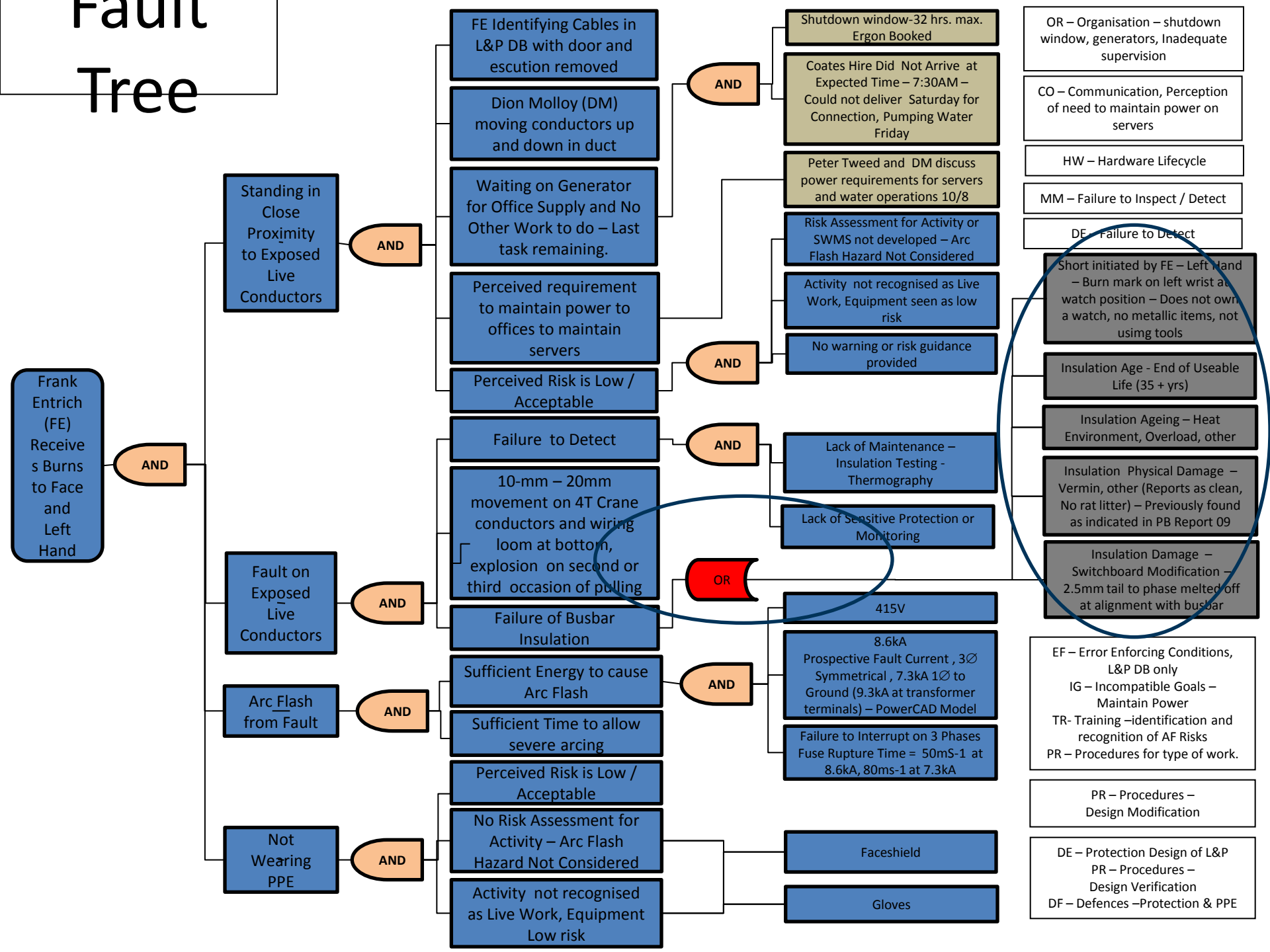
Safety Leadership & Organisational Culture, Change Management, Design, Training, Maintenance Management, Procedures, Communication etc,

Indirect Causes LATENT CONDITIONS & PATHWAYS



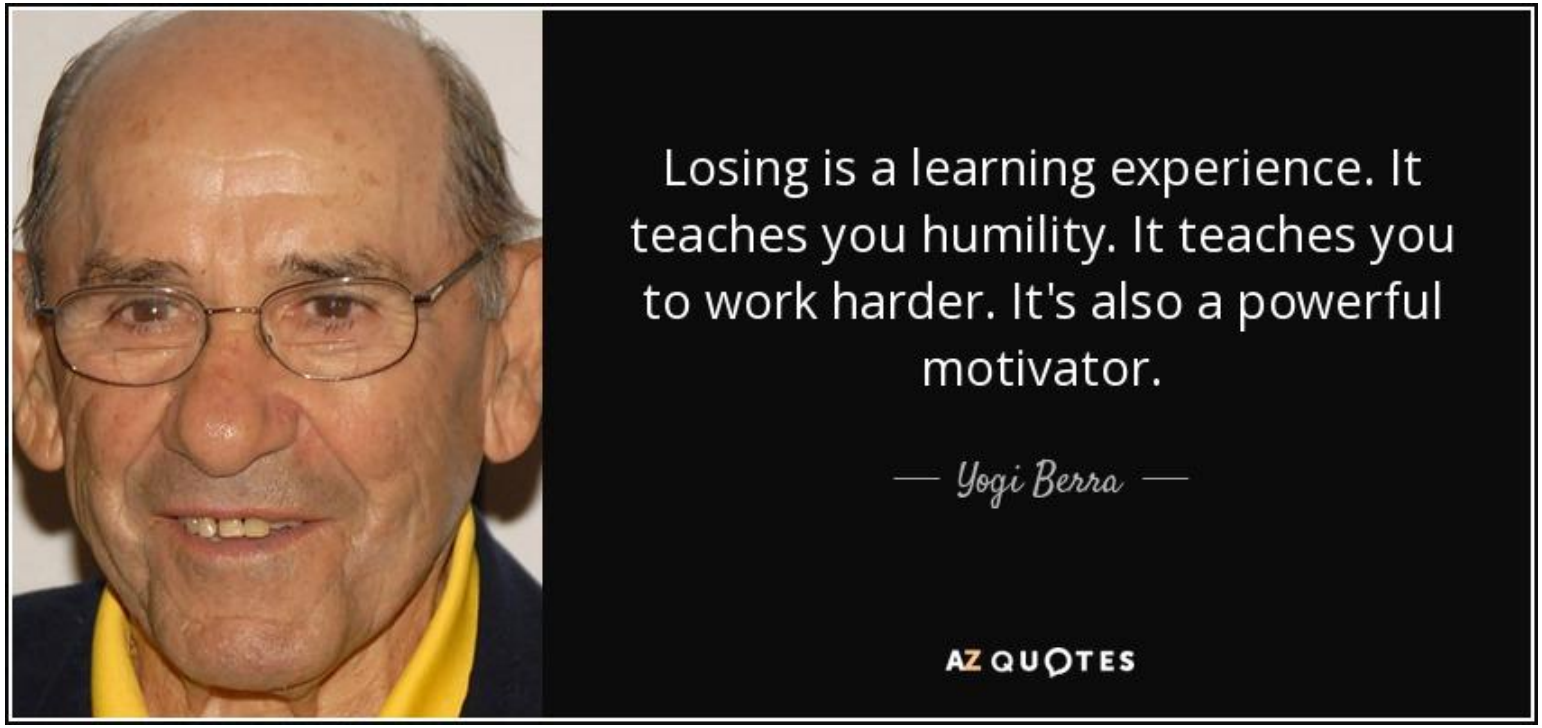


Fault Tree


Frank Entrich (FE) Receives Burns to Face and Left Hand
AND
Standing in Close Proximity to Exposed Live Conductors
AND
FE Identifying Cables in L&P DB with door and escution removed
Dion Molloy (DM) moving conductors up and down in duct
Waiting on Generator for Office Supply and No Other Work to do – Last task remaining.
AND
Shutdown window-32 hrs. max. Ergon Booked
Coates Hire Did Not Arrive at Expected Time – 7:30AM – Could not deliver Saturday for Connection, Pumping Water Friday
Perceived requirement to maintain power to offices to maintain servers
Peter Tweed and DM discuss power requirements for servers and water operations 10/8
Perceived Risk is Low / Acceptable
AND
Risk Assessment for Activity or SWMS not developed – Arc Flash Hazard Not Considered
Activity not recognised as Live Work, Equipment seen as low risk
No warning or risk guidance provided
Fault on Exposed Live Conductors
AND
Failure to Detect
AND
Lack of Maintenance – Insulation Testing - Thermography
Lack of Sensitive Protection or Monitoring
10-mm – 20mm movement on 4T Crane conductors and wiring loom at bottom, explosion on second or third occasion of pulling
OR
Short initiated by FE – Left Hand – Burn mark on left wrist at watch position – Does not own a watch, no metallic items, not usimg tools
Insulation Age - End of Useable Life (35 + yrs)
Insulation Ageing – Heat Environment, Overload, other
Insulation Physical Damage – Vermin, other (Reports as clean, No rat litter) – Previously found as indicated in PB Report 09
Insulation Damage – Switchboard Modification – 2.5mm tail to phase melted off at alignment with busbar
Failure of Busbar Insulation
415V
Arc Flash from Fault
AND
Sufficient Energy to cause Arc Flash
AND
8.6kA Prospective Fault Current , 3∅ Symmetrical , 7.3kA 1∅ to Ground (9.3kA at transformer terminals) – PowerCAD Model
Sufficient Time to allow severe arcing
Failure to Interrupt on 3 Phases Fuse Rupture Time = 50mS-1 at 8.6kA, 80ms-1 at 7.3kA
Not Wearing PPE
AND
Perceived Risk is Low / Acceptable
No Risk Assessment for Activity – Arc Flash Hazard Not Considered
Activity not recognised as Live Work, Equipment Low risk
Faceshield
Gloves
OR – Organisation – shutdown window, generators, Inadequate supervision
CO – Communication, Perception of need to maintain power on servers
HW – Hardware Lifecycle
MM – Failure to Inspect / Detect
DE – Failure to Detect
EF – Error Enforcing Conditions, L&P DB only
IG – Incompatible Goals – Maintain Power
TR- Training –identification and recognition of AF Risks
PR – Procedures for type of work.
PR – Procedures – Design Modification
DE – Protection Design of L&P
PR – Procedures – Design Verification
DF – Defences –Protection & PPE

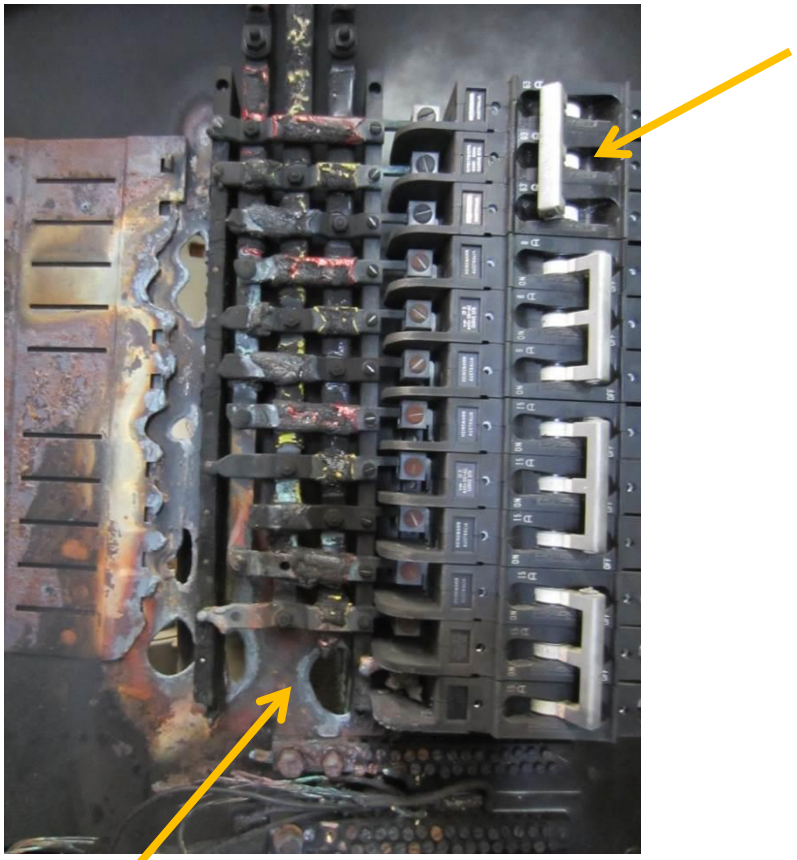
What Happened

- Plan was to remove power from the site that morning.
- Supply authority isolation booked for the site between 8:00AM and 10:00AM to remove site power.
- A generator to supply the workshops was due to be delivered by a hire company at 7:30AM. The generator did not arrive.
  - It was planned to connect this generator to the SunWater Workshop. Power to the SunWater servers was to be maintained by the UPS while the generator was being connected.
- The contract employees had completed all tasks required before switchboard removal except identifying the light and power circuit conductors.
- They were conscious of the tight window to change over the switchboards with Ergon booked the next day between 2:00PM – 3:00PM to restore site power.
- There was no other work to do. One contractor employee was sweeping the floor.
- The two others decided they could safely identify the circuit wiring in the DB panel with the switchboard escution panel removed and all circuit breakers turned off except the circuit breaker for the Workshop supply.
- DB Busbars and the single circuit outgoing Workshop circuit were energised.
  - All other circuit breakers were turned off.
- Multiple points on exposure live conductors were within easy and accessible reach of where the injured person who was standing in front of the switchboard.
  - Minimum 750mm clearance to wall in front of the switchboard.
- The second contractor employee crouched in front the panel immediately below the Main Isolator and pulled on wires going into the light and power distribution board so that they could be identified by their movement.
- On the second or third pull the explosion occurred.

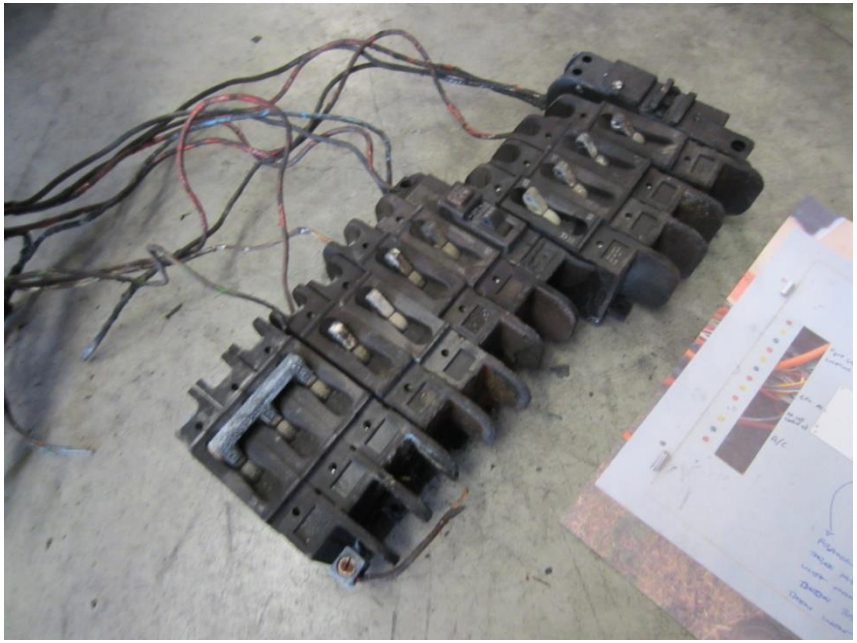

Losing is a learning experience. It teaches you humility. It teaches you to work harder. It's also a powerful motivator.
— Yogi Berra —
AZ QUOTES

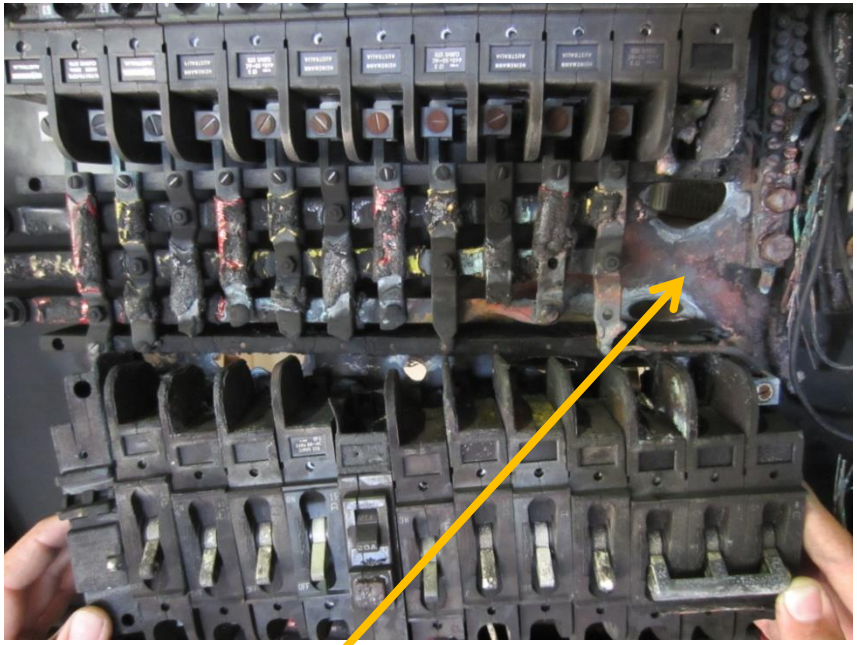
Switchboard Damage

DB cut into and recessed into the side of the MCC to allow 600mm clearance to wall.

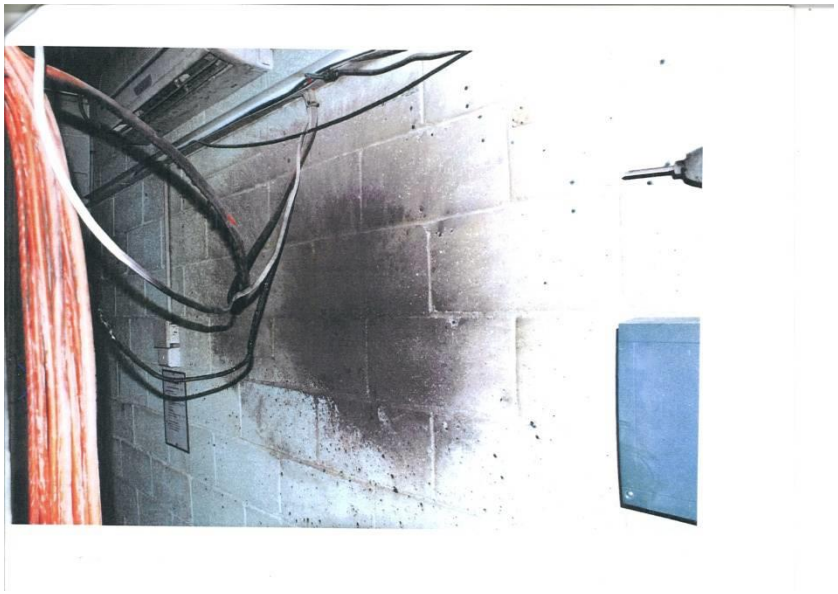


CB’s Reassembled in Position





Carbon on Rear Wall Paintwork



Pole top SA 500A HRC Fuses 2/3 Ruptured

CF Series CB

CF Series circuit breakers

4A to 100A STANDARD FORMS

INTERRUPTING CAPACITY 0.020A - 100A

6.0kA at 415V a.c. Sym.	(2, 3 pole)
6.0kA at 240V a.c. Sym.	(1 pole)
2.5kA at 660V a.c. Sym.	(3 pole)
10 kA at 48V d.c.	(1 pole)
5.0kA at 125V d.c.	(1 pole)
3.0kA at 250V d.c.	(2 pole)
1.5kA at 480V d.c.	(3 pole)

APPROVALS AND TESTS
Approved by Aust. Statutory Auth. N15765
Complies with AS 3111 and AS 2184
Lloyd's Approved

MAX. INSULATION VOLTAGE
600V a.c.; 480V d.c. Uimp 6kV

MAX. CABLE SIZE
Standard front connect tunnel terminal accommodates 50 mm^2

CAT. Nos. STANDARD FORMS (2)
i.e.: Cat. Nos. apply only for a.c. current ratings, standard (Curve 2) time delay and front connect tunnel terminal. All other forms should be priced per Special Form pricing.

Poles	1	2	3	4	6
H	149	149	149	149	149
W	26.1	52.2	78.3	104.4	156.6
D	67	67	67	67	67
kg	0.31	0.77	1.04	1.32	2.08

Typical DB

Type HMP for CF breakers

FEATURES

- Robust 1.6mm steel **multi-purpose** construction with baked polyester powder finish, Colour N12 'Pastel Grey' to AS 2700.
- 250A 20kA 0.2s HVB type tested busbar system.
- Optional door – removable L.H. hinged with concealed hinges and flush lockable catch. Can be converted to R.H. hinged.
- KO entries in top and bottom for 50 x 50; 75 x 50; 100 x 50 and 100 x 75 cable ducting.
- KO entries in rear – top and bottom.
- Increased depth (115 under esc.) and spare space for mounting ancillary devices.
- **IP40** Degree of Protection.

HMP36M100D

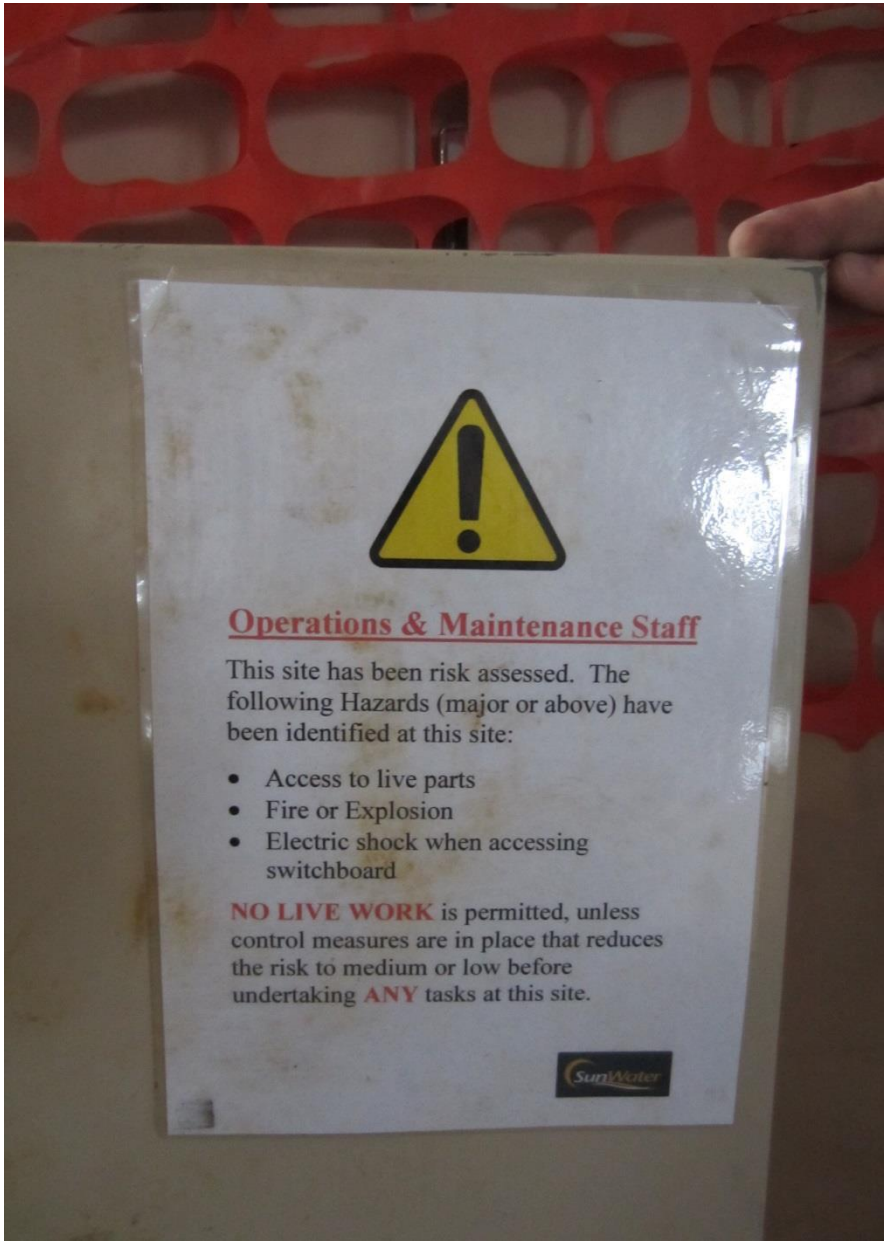
WITH 100A MAIN SWITCH TOP CENTRE (1) – without circuit breakers

Revelations

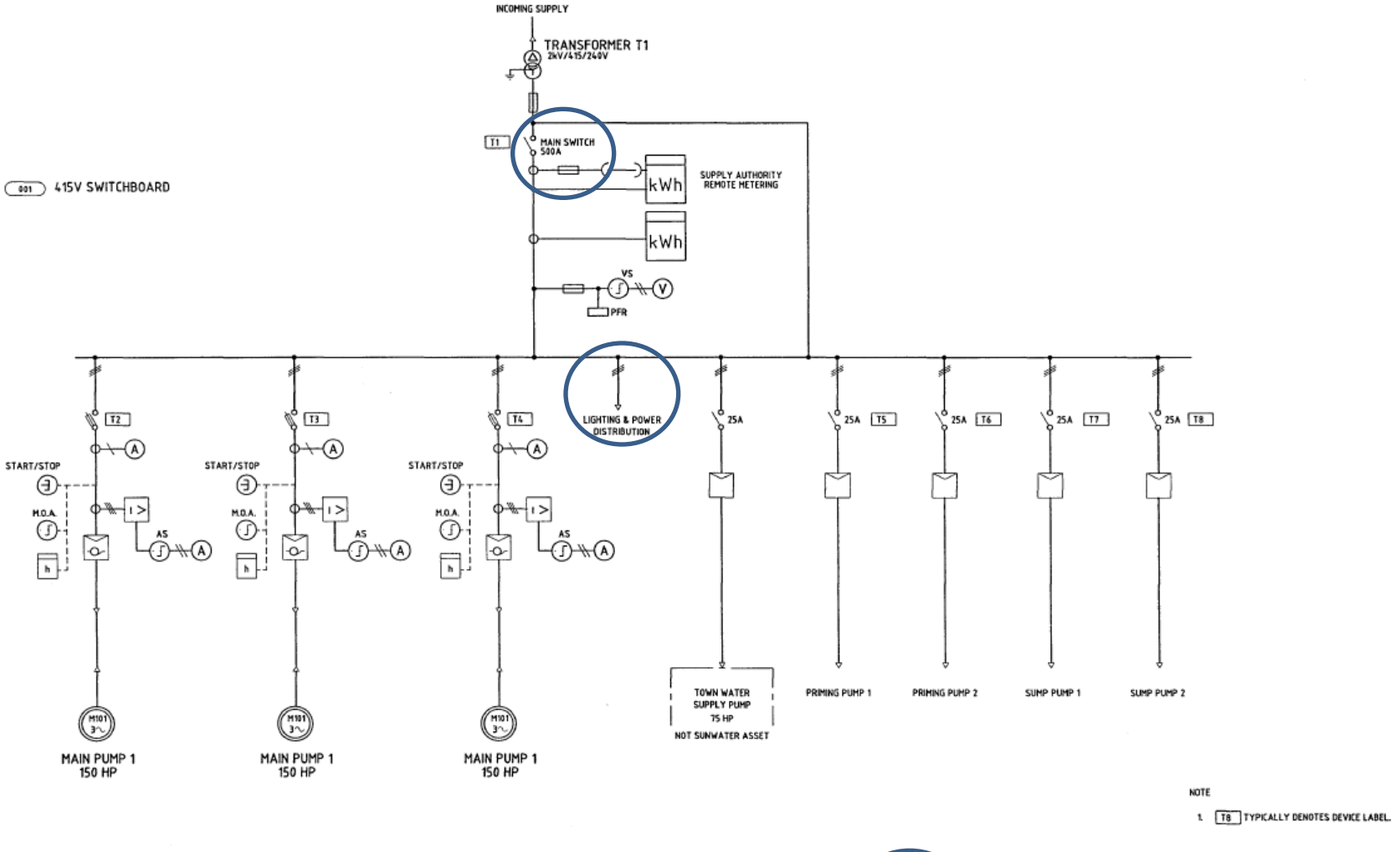
- Drawings dated 1974 but thought existed that the MCC may have come from somewhere else prior.
- Suitable electrical protection was not provided for the DB or the MCC Busbars.
- Inadequate systems and standards for modifying electrical installations were applied in the past. Design verified drawings issues 1996 and 2003 showing the DB as installed.
- Adequate maintenance inspection or insulation testing was not occurring considering age of asset.
- The original design was inadequate given no point of isolation for the DB aside from the MCC Main Switch, and the inadequate electrical protection for the DB and busbars.
- The external audit failed to identify the defect with regard to isolation and DB electrical protection.
- The electrical equipment was interim hazard labelled in accordance with the requirements of the external audit report.
- The contractor/contractors employees failed to:
  - Follow the direction of Sunwater not to perform live work
  - Identify and assess the risks associated with the work activity and implement adequate controls.
  - Identify the work being performed as live electrical work.
  - Prepare a risk assessment for the live work .

  Note: The contractors employees did not classify the work as live because they were not using tools or test equipment and did not have hands inside the switchboard.
  - Work in accordance with the contractors designated safe system of work.
  - Recognise, understand or assess the risks associated with high fault currents at the work site. The system of safe work did not provide for adequate identification of high fault current hazards or adequately define them. Arcing Hazard assessment not performed for asset or assessed by contractor.
  - Wear appropriate PPE for the hazard present at the worksite.

  Note: The employees were provided with safety faces shields and safety gloves by their employer but were not arc rated and not worn anyway. Clothing worn by the injured was polyester / cotton with three layers.


Operations & Maintenance Staff
This site has been risk assessed. The following Hazards (major or above) have been identified at this site:
• Access to live parts
• Fire or Explosion
• Electric shock when accessing switchboard
NO LIVE WORK is permitted, unless control measures are in place that reduces the risk to medium or low before undertaking ANY tasks at this site.
SunWater

Single Line Diagram

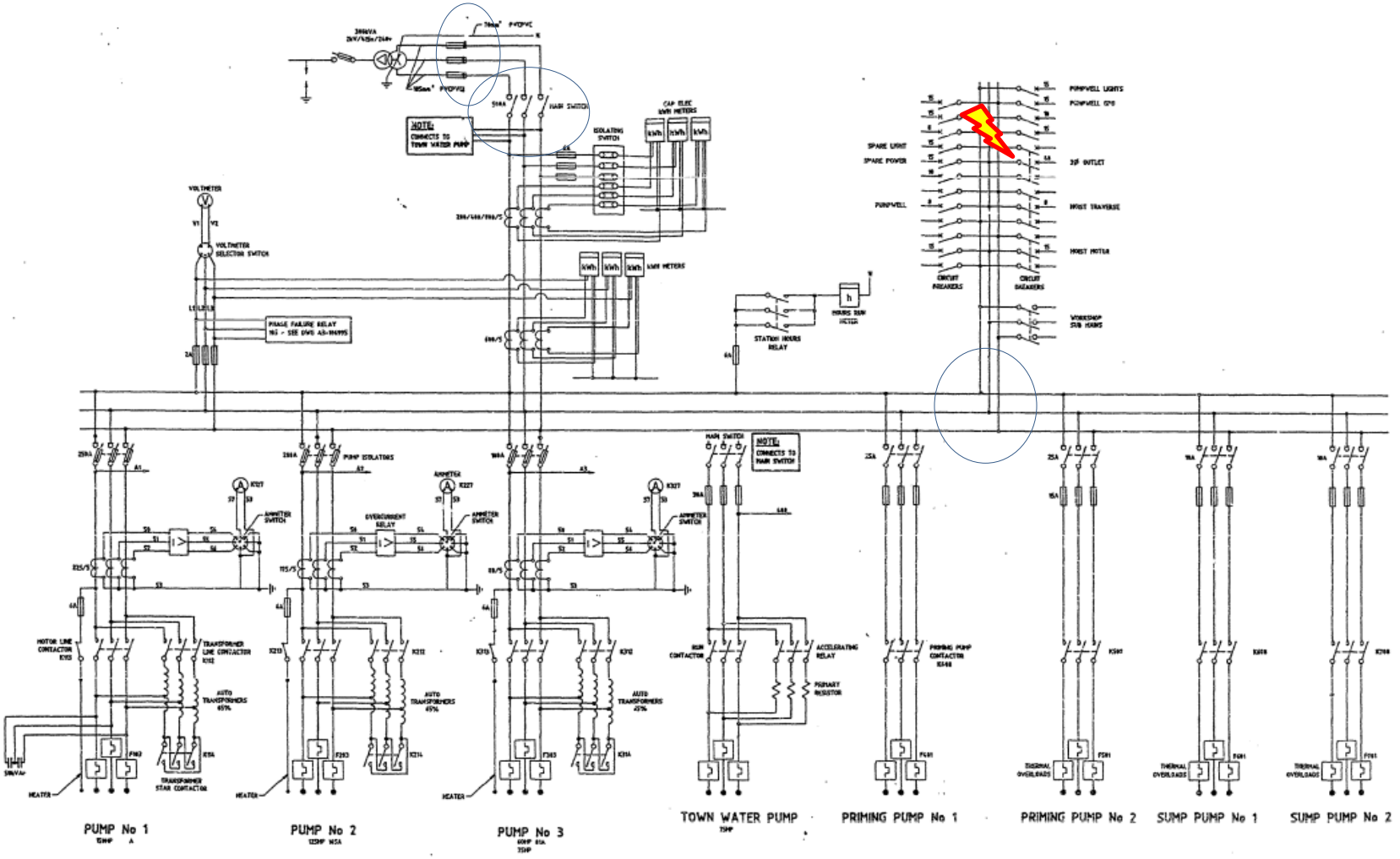


NOTE

1. T8 TYPICALLY DENOTES DEVICE LABEL.

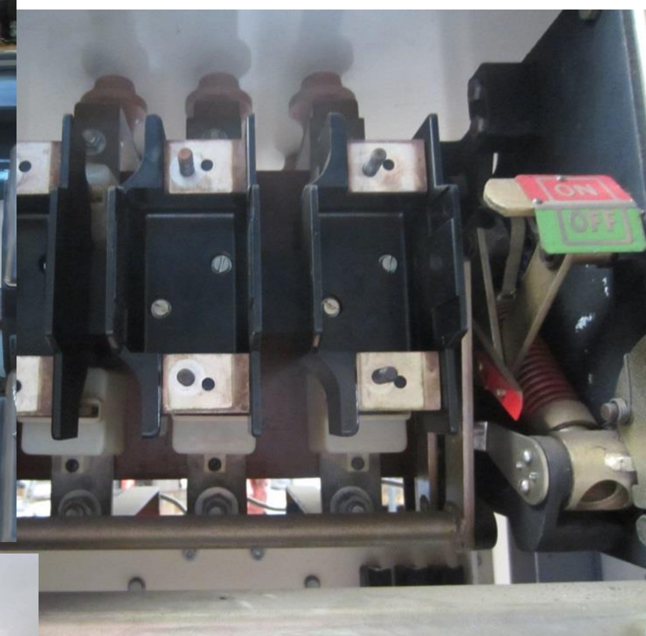
DRAWING GM / DESIGN	SunWater	DAWSON VALLEY IRRIGATION AREA	CONTRACT NUMBER
DRAFTING CHK / DESIGN CHK MJ		THEODORE PUMP STATION	DRAWING NUMBER 220623
APPROVED		SINGLE LINE DIAGRAM	DATE AUG 2003
CHIEF ENGINEER M&E			

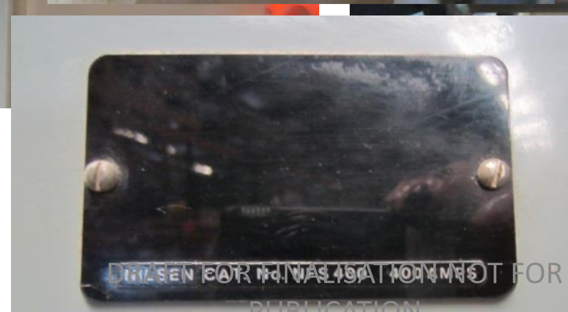
Power Schematic



Main Panel

Copper links installed in CFS Unit



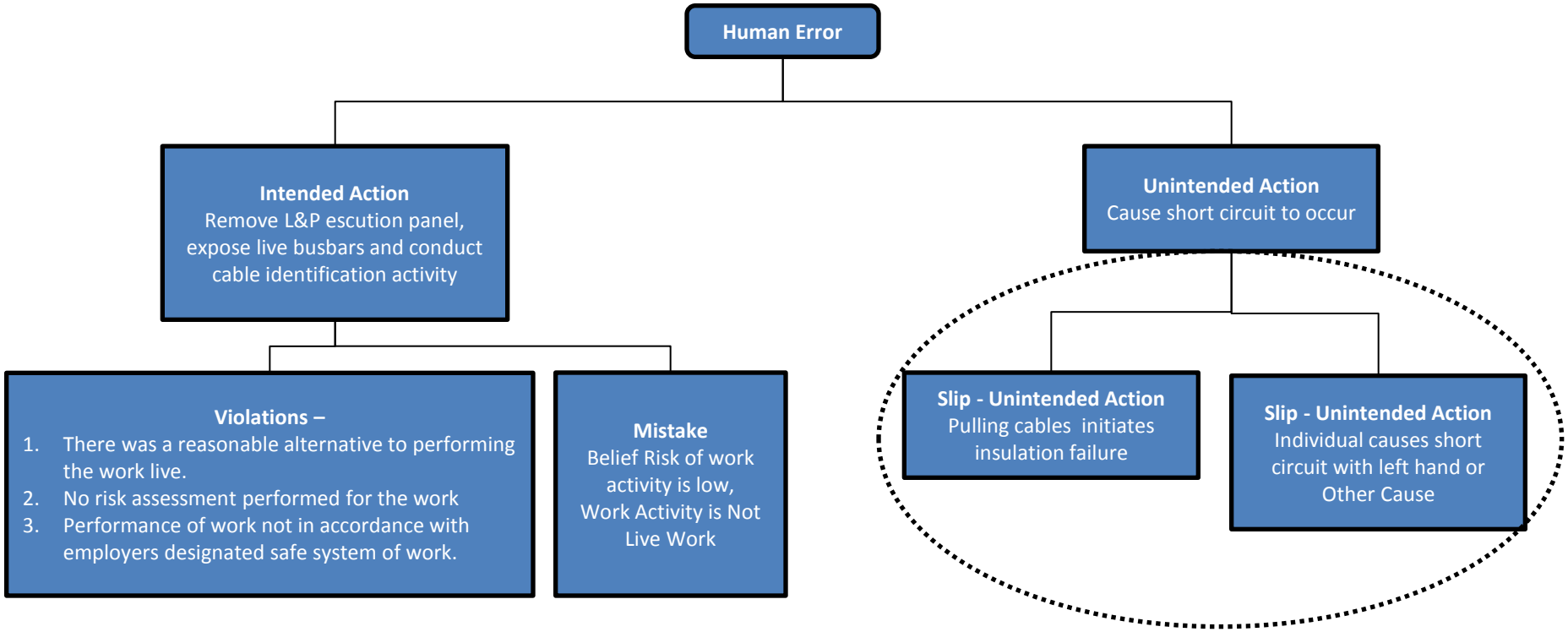


Damage to Clothing

Outer Layer

Second Layer

Inner Layer



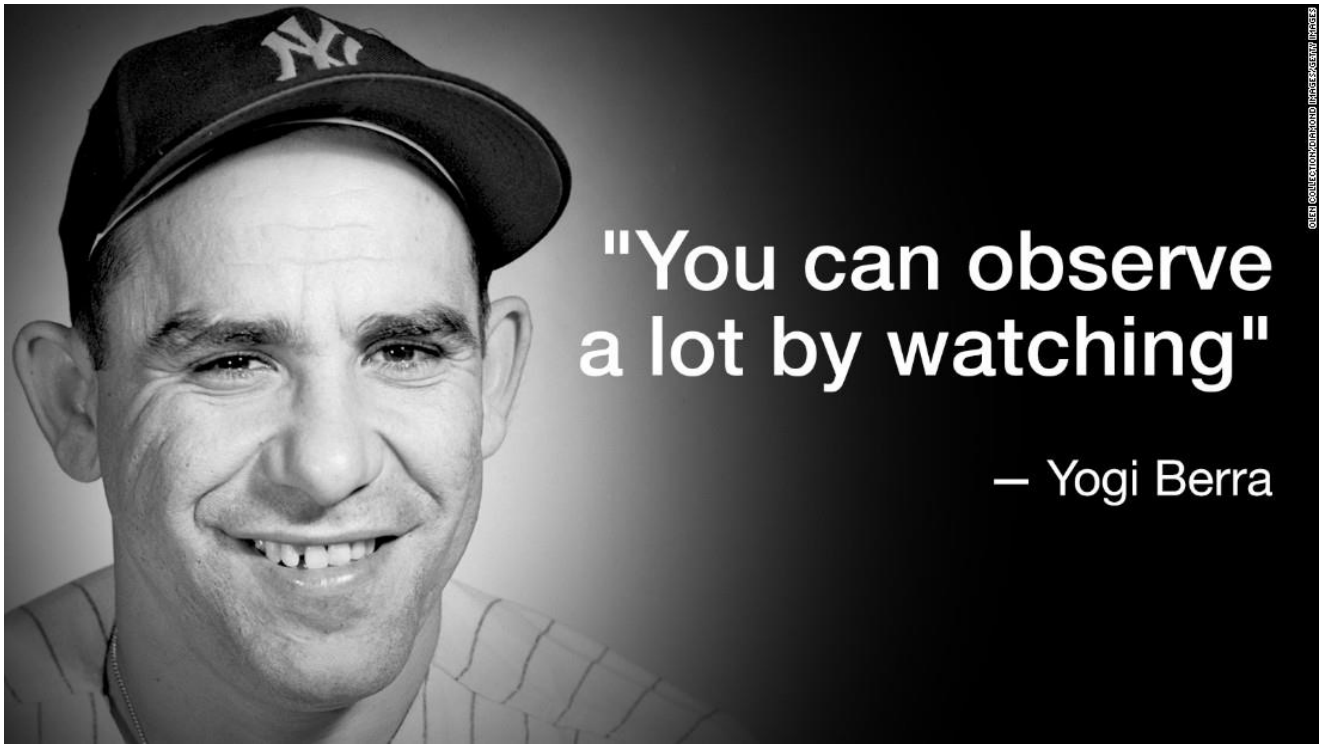
Fatality Formula

A Mistake + A Violation = A Fatality

Thankfully no permanent disabling injury, permanent scarring or disfigurement.

It is somewhat ironic that Ergon arrived at 8:10AM to perform the site isolation.

The simple act of waiting 10 minutes would have prevented the accident occurring.


"You can observe
a lot by watching"
— Yogi Berra
OLEN COLLECTION/DIAMOND IMAGES/GETTY IMAGES

Unsafe Physical Conditions – Latent Conditions

Design

- Lack of adequate electrical protection.
- No isolation point for the Distribution Board
- DB cut into and recessed into the side the MCC
- Original design and installation 1974 was entirely inadequate.

Change Management

- Subsequent drawing revisions 1996 and 2003 did not detect the issues - Drawings ***initialled*** in Design Box.

Asset & Maintenance Management

- No regular test and maintenance regime including thermography or insulation testing.
- Age of installation and insulation, particularly busbar separation – 35 years minimum.

Unsafe Acts - Decisions

- Task to be performed is not Live Work and low risk.
  - The act of standing or looking should be low risk, the introduction of another activity changes the risk profile
  - Did not follow safe work procedures (Not Live Work)
- Standing in close proximity to live electrical conductors without understanding or assessing the risks.
- Failure to adopt reasonable alternative
  - Failure to wait.
- Failure to wear appropriate PPE
  - Redundant control if de-energised, isolated and proved zero potential.

Simple Cheap Electrical Protection

As Shown

BUS-MSB

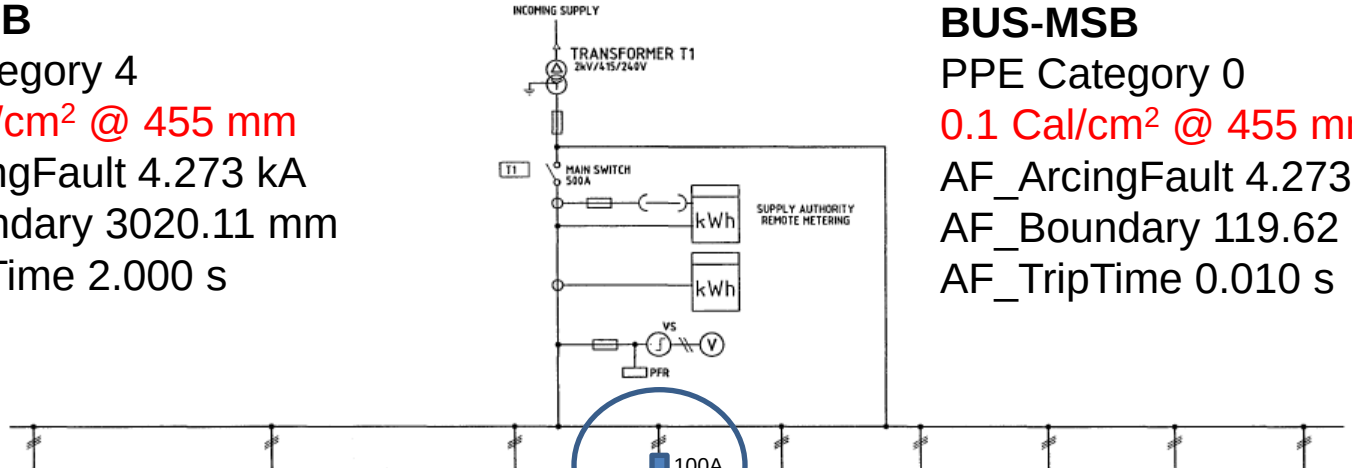
PPE Category 4

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

Fast Acting Electrical Protection

- Could have been 63A Fuses or CB installed
- Benefits of EL protection

Distance is your friend

- 1/d^2 e.g. Double Distance ¼ of the Incident Energy

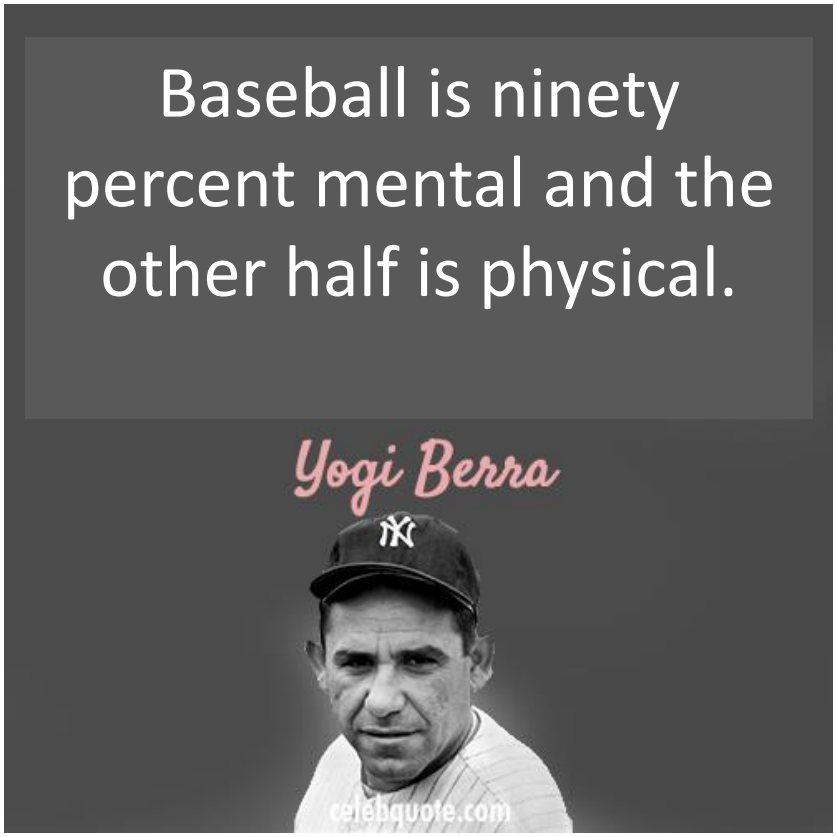
Assess for Actual Hazard

- Better to know what the actual hazard is

Standards and Management of Electrical Installation

Appropriate Safe Work Practices and PPE

Perhaps electrical safety should be ninety percent engineering and the other half safe work method or practice!




I NEVER SAID
MOST OF THE THINGS
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Yogi Berra
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celebquote.com