Chris O'Riley
President and Chief Executive Officer
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June 22, 2023

David Morton
Chair and Chief Executive Officer
British Columbia Utilities Commission
Suite 410, 900 Howe Street
Vancouver, BC V6Z 2N3

Dear David Morton:

**RE: British Columbia Utilities Commission (BCUC or Commission)
British Columbia Hydro and Power Authority (BC Hydro)
Electrical Explosion Incident – Marine Building, Downtown Vancouver**

I am writing to provide the results of BC Hydro's investigation into the explosion and fire that occurred in one of BC Hydro's underground vaults (Vault No. 73) on the 300 block of Burrard Street in Vancouver at approximately 6:00 pm on February 24, 2023. Two members of the public were injured, and several businesses were damaged.

BC Hydro previously provided information to the Commission on this incident through confidential filings on March 14, March 29, and May 8 and has attached these documents to this filing for reference. The results of our investigation are being shared in this filing, which BC Hydro is making public. BC Hydro is also sharing the findings of our investigation with the public and with other electrical utilities.

Our investigation identified concerning gaps in our asset management practices for underground street vaults that contributed to this incident. I am deeply disappointed by these findings, and I sincerely apologize to the individuals and businesses that were injured or impacted because of these shortcomings, to those who live near our assets, and to our employees. The safety and reliability of our electricity system is critical, and I take responsibility, on behalf of BC Hydro, for the failures that occurred. This incident should never have happened.

Vault No. 73 was installed in 1975 and contained two oil-filed switches (commonly referred to as RAL Switches). During our investigation, we determined that serious risks had previously been identified with this equipment in the event of a failure. In 2016, one of BC Hydro's aging underground transformers failed and resulted in contaminated oil being released into a vault. BC Hydro responded by conducting an inventory of its remaining RAL switches and other equipment in its single and dual radial type underground street vaults. The report summarizing this work identified electrical equipment inside 14 vaults, including Vault No. 73, that was considered high risk, likely to be in poor condition and needing to be addressed either through continued inspections and maintenance or replacement. It stated that the consequence of not properly maintaining or replacing this equipment could include public or worker severe injury or death. It recommended replacing the RAL switches and transformers with modern equipment in five vaults, including the RAL Switches in Vault No. 73, as part of a system improvement project. It also recommended that the equipment in the remaining nine vaults be addressed through a combination of maintenance and replacements, as appropriate.[1]

The system improvement project proceeded with replacement of the equipment in five vaults, but the equipment in Vault No. 73 was removed from the project scope in favour of replacing the equipment in another vault on the system that was closer to the other four vaults, all of which were in the Gastown area of Vancouver. This revision to the scope of the system improvement project required inspection and maintenance to be continued on Vault No. 73 until the equipment replacement was completed.

In 2019, BC Hydro updated its plan to phase out all remaining RAL switches on the system. This plan included the removal of the RAL switches in all remaining vaults identified in the 2016 inventory. The removal of the oil filled switches in Vault No. 73 was most recently scheduled to be completed in late 2023.

Our investigation determined that the maintenance the revised plan relied upon was not carried out effectively as a result of gaps in our asset management practices. Our crews had difficulties performing the proper maintenance, despite their best efforts, because they did not have the proper information and instructions or the correct materials to complete the maintenance work.

As part of our investigation, BC Hydro retained Senez Consulting Ltd. to conduct a third-party investigation into the incident.[2] The investigation concluded that the only possible cause of the explosion was the accumulation of combustible gases caused by contaminated insulating oil inside an oil-filed load break switch in Vault No. 73. The contamination was caused by a leaking gasket in the lid of the switch. The gasket leak was caused using incompatible materials when the gasket was repaired and maintained over time. The gasket leak allowed corrosion to occur inside the switch housing, leading to deterioration in the insulating ability of the oil. This resulted in the partial discharge of electrical energy into the insulating oil, contaminating the oil and causing a build-up of combustible gases. The gases ignited and caused the explosion.

I want to be clear that our crews were doing the best they could with the materials, information, and instructions they received. The investigation determined that there was limited information and instructions on required visual inspections and when to replace a gasket, no defined replacement parts, and no end-of-life timing for the gaskets. This left field crews to use incompatible materials (pieces of Nebar gasket material and the use of silicone sealant) to repair the existing gasket when performing maintenance and inspections. If the gasket was found on inspection to be damaged, workers would cut

[1] This report is provided as Attachment 4.

[2] This report is provided as Attachment 1.

gasket material (Nebar) and add it to the lid. Silicone sealant was often added to create a better seal. This was identified as a contributing factor to the failure.

Senez Consulting Ltd. also found that BC Hydro's oil testing program was lacking; however, this was not identified as a contributing factor or cause of the incident. The investigation found that the program was not updated to reflect changes in industry standards, was limited in controls and tracking, and did not incorporate trending to identify patterns of oil degradation. This meant that monitoring the oil integrity relied upon operational diligence. A more thorough program may have identified issues with leaking seals in the lids of the switches over time.

I want to express how seriously we are taking this information. We should have recognized the difficulties our crews were facing as a result of not having the proper information and instructions or correct material, and we should have acted sooner to replace the vaults identified for replacement in 2016.

Public confidence in the safety of our electricity system is critical. Each year, we advance substantial investments to maintain and upgrade our equipment, including significant investments that have been made to upgrade infrastructure throughout downtown Vancouver, and every day, we make decisions to keep the public and our employees safe. Our employees understand the importance of disclosing and escalating asset management and safety concerns, and I have personally been involved in many cases where these types of concerns have been raised and properly addressed throughout my career at BC Hydro. The fact that this didn't happen in this case is deeply disappointing, and we will fully learn from the results of this investigation to prevent such circumstances from occurring again.

As a result of the findings of our investigation, we are taking several immediate actions:

- First, all remaining RAL Switches were removed from service as of April 1, 2023, and no longer present a risk. While this work was being completed, no BC Hydro worker was to be in the vicinity of energized RAL Switches unless those switches were de-energized;
- Second, a program review of distribution street-vault equipment has been initiated. The first phase of the review consists of a risk assessment with a targeted completion by August 31, 2023, and the initiation of mitigation plans with a targeted completion by September 30, 2023. The second phase consists of a review and update to BC Hydro's maintenance and replacement strategy for these assets, including recommendations for future work with a targeted completion by March 31, 2024; and
- Finally, BC Hydro will engage fully and transparently in any review that WorkSafeBC or the Commission undertake regarding this incident. While our investigation is ongoing, to inform the Commission's initial considerations on this matter, the following documents are attached to this letter:

- Attachment 1 provides the explosion and fire analysis reconstruction report from Senez Consulting Ltd;
- Attachment 2 provides a bulletin that was issued to BC Hydro staff and contractors following our investigation regarding the use of gaskets on oil-filled distribution electrical equipment in Distribution Street Vaults. This bulletin prohibits the use of unauthorized sealants and provides advice on how, when, and with what materials gaskets for oil filled street vault equipment will be replaced;
- Attachment 3 provides a notice issued to BC Hydro staff and contractors following our investigation regarding immediately escalating any difficulties following standards, procedures, or operating and maintenance manuals on distribution-related electrical equipment. The notice provides information and instructions on how to escalate these matters;
- Attachment 4 provides the 2016 Underground Vault Inventory that prioritized Vault No. 73 for replacement; and
- Attachment 5 provides copies of the March 14, March 29, and May 8 filings regarding this incident.

Yours sincerely,

Chris O'Riley
President and Chief Executive Officer
BC Hydro

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Enclosure

BC Hydro
Power smart

BC Hydro Electrical Explosion Incident – Marine Building, Downtown Vancouver

Attachment 1

Peter Senez Expert Investigation Report

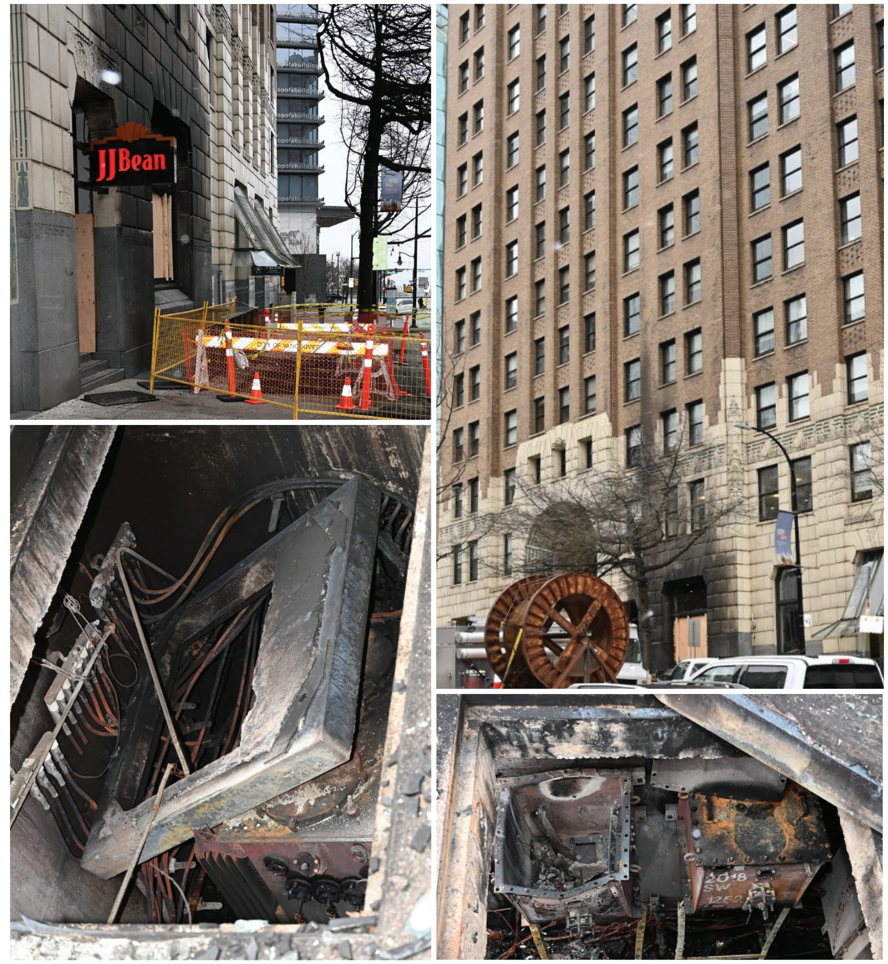
Attachment 1

PRIVILEGED AND CONFIDENTIAL – DEVELOPED IN PREPARATION FOR LITIGATION

SENEZ CO
FIRE SCIENCE & ENGINEERING

Explosion & Fire on Burrard Street at BCH V73

Explosion & Fire Analysis Reconstruction



Our File Number: 2300129
Date of Report: June 7, 2023
Revision: 0
Report #: 001
Date of Incident: February 24, 2023

Prepared for:
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BC Hydro Electrical Explosion Incident – Marine Building, Downtown Vancouver

Document Verification

Revision	Responsible Engineer	Internal Review Engineer	Comments
A	Peter Senez May 31 2023	Keith Calder May 31 2023	Draft for investigation team comment
0	Peter Senez June 6 2023	Keith Calder June 7 2023	Completed

Table of Contents

Table of Figures

Appendices

1.0 EXECUTIVE SUMMARY

On February 24, 2023, an explosion and fire occurred in downtown Vancouver outside 353 Burrard Street, inside an electrical vault. Senez Consulting Ltd. was retained by BC Hydro to conduct a third-party investigation into this incident. The electrical vault contained an oil filled transformer as well as two oil filled switches. The metal enclosure of the standby switch was observed to have the largest amount of deformation.

This report established that this incident was a result of contaminated insulating oil inside an oil filled switch. The key factors are summarized as follows:

- It was found that the only possible cause of the explosion would be a buildup of combustible gases inside Switch 2019.
- This combustible gas buildup was a result of partial discharges of electrical energy into the insulating oil. The discharge process releases energy into the oil, which causes the oil to break down and form combustible gases.
- For partial discharges to occur, the insulation ability of the insulating oil had deteriorated. Either over time, or with contamination, the oil broke down and lost its insulating properties.
- The contamination occurred due to a leaking gasket in the lid of the switch. This was caused by incompatible products and potential contamination of the seal, compromising the nitrogen pressurization, and etching the surface of the enamelled paint inside the switch.
- This allowed for corrosion to occur in the steel below the surface of the paint allowing particles of iron and iron-oxide to mix with the oil, leading to partial discharges and the accumulation of combustible gases in the tank, which ignited and caused the explosion and subsequent fire.
- A review of the BC Hydro Work Procedure identified the following gaps:
  - There was limited guidance on required visual inspections and when to replace a gasket, no defined replacement parts, and no end-of-life timing for the gaskets. This left field crews to find gasket repair solutions that were insufficient and involved incompatible materials (e.g., unknown Nebar and silicone). This was found to be a contributing factor leading to the failure.
  - An oil-testing program that was not updated to reflect changes in standards, was limited in controls and tracking, and not incorporating trending. Monitoring of oil integrity was therefore a function of operational diligence in the absence of a more robust program. A more thorough program may have identified gasket sealing issues had the details of the pressurized tanks been tracked, but a specific correlation to this Incident was not identified.

2.0 GENERAL

2.1 Incident Summary

1. An explosion and fire occurred in electrical Vault 0073 (V73) in front of 353 Burrard Street (the Marine Building) on February 24, 2023, shortly after 6 pm. The vault is part of the BC Hydro (BCH) distribution network supplying power to BCH customers in the downtown core.

2. Vancouver Fire & Rescue Services (VFRS) responded to the incident along with BCH and Fortis BC emergency crews. The VFRS report for Case#230009137 established the event to be "Accidental." VFRS was not involved in the follow-up investigation.

3. According to VFRS two members of the public were injured with burns to their hands and face. As of February 25, 2023, B.C. Emergency Health Services told CBC that the two patients were in stable condition, but no further details or information has been made available to BCH.

4. The explosion caused multiple glass windows to break, and the subsequent fire caused heat damage to the exterior façade of tenancies in the adjacent building. The affected tenants within the Marine Building include a JJBean coffee shop and the Tractor restaurant. The reported injuries related to pedestrians walking along the sidewalk when the explosion occurred. There were no reported injuries to any of the occupants in the Marine Building.

5. V73 contained two electrical feeders, two oil-filled switches, a fuse box, a transformer and corresponding cabling and connectors to supply power to the equipment and then distribute to BCH's end customers.

6. V73 is located under the sidewalk on the west side of Burrard Street outside the Marine Building. The location of V73 can be seen from Google Earth arial view in **Figure 1**, or street view in **Figure 2**. The vault is situated outside a coffee shop (JJBean), as well as the neighbouring restaurant (Tractor), both of which were affected by the incident.

7. The vault is approximately 8 ft below street level and has an approximate footprint area of 5 ft by 15 ft, covered by concrete sidewalk inserts approximately 5 in. thick and a metal utility hole cover. One of the concrete inserts included four metal grates embedded within to provide natural ventilation to the vault.

2.2 About this Report

8. Paragraphs are sequentially numbered, and headings are provided in this report for reference and have no meaning other than convenience for the reader.

2.3 Responsible Engineer for Report

9. I am Peter Senez, the responsible engineer for the content of this report, and a Professional Engineer with over 30 years of experience in fire engineering, fire science, and fire investigation. My experience includes being a firefighter, fire inspector, fire engineer and fire investigator. I have been practicing as a fire engineering consultant since 1993 and conducting forensic investigations since 1999, including numerous deflagration explosions and failures involving industrial and power equipment, as is relevant to this matter.

10. My first university degree is in mechanical engineering (with a specialization in Machine Design) from Concordia University (1993) in Montreal, and I subsequently completed a Master's degree in Fire Protection Engineering from the University of British Columbia. Currently, I am pursuing Ph.D. studies on a part-time basis studying fuel volatility and ventilation-limited fires at the University of Waterloo. There, I also instruct a course in Advanced Fire Investigation for Fire Engineers.

11. A copy of my resume is included in **Appendix A**.

2.4 Scope of Report

12. The scope of this report is to document the investigation of the cause of the explosion and fire that occurred on February 24, 2023 (collectively, the "Incident").

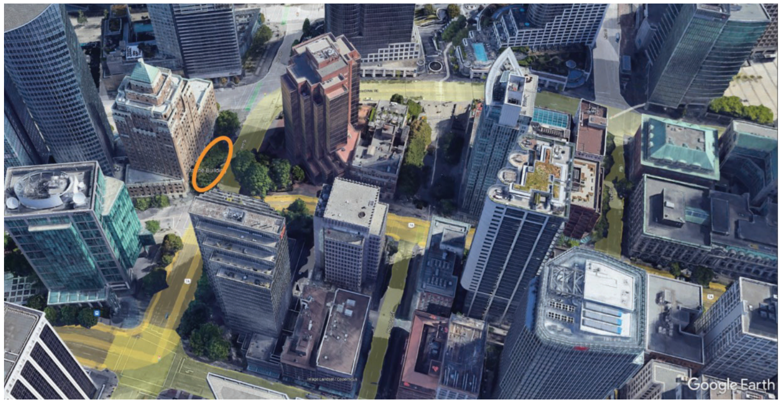

Figure 1: Google Earth image showing approximate location of V73 in orange circle.

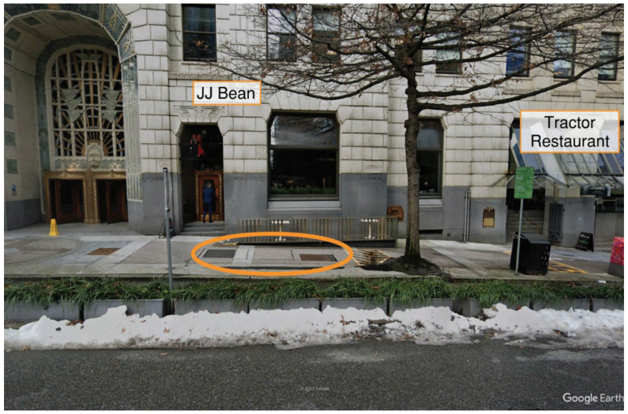

Figure 2: Google Earth Image showing the location of V73 in orange circle.

3.0 POST INCIDENT DATA GATHERING

3.1 General

13. BCH assembled a technical team to support data gathering for the incident. This included investigators from Senez Consulting Ltd. (SenezCo), Powertech, key engineers and technical staff from BCH, and field crews to support site activities. The team addressed immediate and ongoing site safety risks, gathered pertinent data from BCH sources, coordinated site crews to safely progress an investigation, secured evidence and completed necessary field activities.

14. SenezCo was initially contacted on February 25, 2023, and first attended the scene on February 25, 2023.

15. In addition to the documentation gathered by SenezCo, additional findings are documented in the following documents relative to this incident and prepared under separate cover:

- Investigation into Explosion of RAL Switch at BCH Vault 073, prepared by Stuart Chambers, Powertech Report ID PL_04215.39 (the "Powertech Report"), included as **Appendix B** to this report. This report includes additional testing and commentary forming part of the investigation including chemical, metallurgical and oil integrity analysis.
- BCH Engineering Report (the "BCH" Report), included as **Appendix C**, which describes the electrical configuration and system protection and includes oscillography of the circuits involved and the corresponding interpretation of the results. The oscillography is illustrated in **Figure 3**.

16. The force of the explosion raised the covers on V73. The 5 ft by 5 ft concrete sidewalk inserts had been lifted and displaced, as shown in **Figure 4**.

17. The grates located in the south concrete insert were lifted and displaced to the south, and the concrete insert had been lifted and fallen into the vault landing on top of the transformer. The north concrete insert was displaced up and to the north, resting diagonally from its original position, 7 ft - 10 ft.

18. The utility grate and opening were lifted and displaced to the northwest landing on the sidewalk and the storefront patio, shown in the top right corner of **Figure 4**.

19. The approximate layout of the electrical equipment in the vault, post event, is shown in **Figure 5.**

3.2 Relay and Sensor Data

20. Electrical relays and sensors connected to the circuits were able to record data up to the event. Switch 2018 and Switch 2019 were connected to Circuit CSQ 125F21 and CSQ 12F511 respectively.

21. The sensors recorded to an excessive of 8000 amps, for both circuits, at 6:06:22.4 pm and 6:06:23.6 pm for Circuit CSQ 125F21 and Circuit CSQ 125F11 respectively.

22. An electrical single line diagram for V73 is provided in **Figure 6**.

3.3 Pre-Incident Vault Condition

23. Photographic documentation on November 24, 2021 of V73 is available pre-fire in Street Vault Inspection Report, included in **Appendix D**.

24. 35 original digital photographs from the inspection were also obtained.

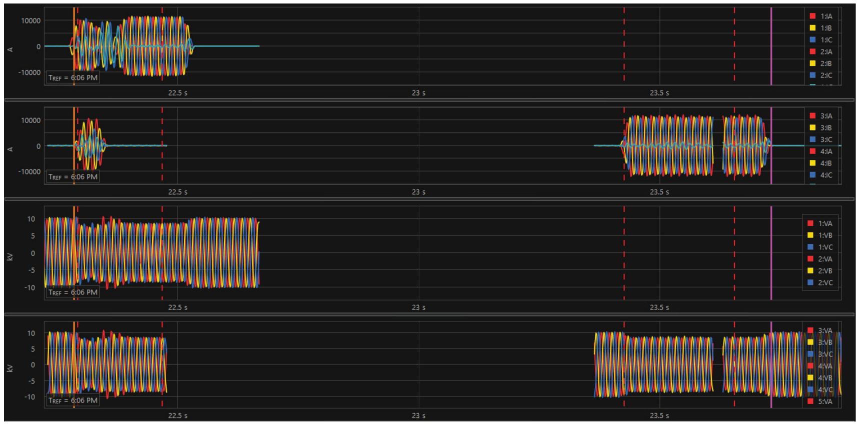

Figure 3: Oscillography of circuits connecting to V73.

Figure 4: Photo array showing vault debris displacement.

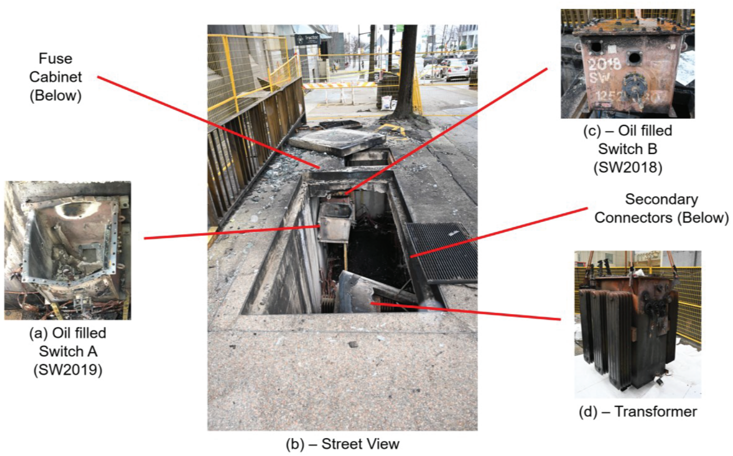

Figure 5: Vault V0073 Layout after the explosion.

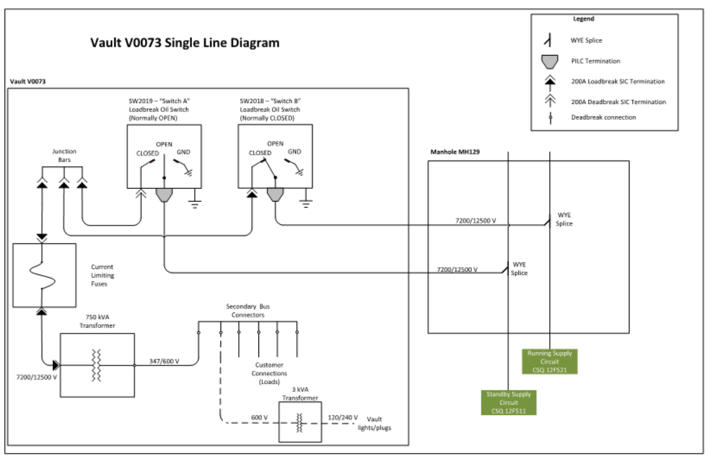

Figure 6: Vault V0073 Single Line Diagram.

3.4 Video of the Event

25. Video of the event was captured by a vehicle's rear-view camera and was posted onto a social media site Xiaohongshu by user @JZ. The vehicle was heading northbound on Burrard Street and drove past the location on Burrard Street, before stopping at the traffic light at West Cordova Street.

26. The video footage captures the initial explosions and flame looking backward from the vehicle. Still captures of the video illustrate the incident in **Figure 7**. The imaging captures the explosion, which occurred over approximately 2 seconds, before subsequently burning. No visible irregularities prior to the explosion are observable in the video. Time estimates are best estimates based on time in video image and frame counting.

27. The timestamp shown in the video footage aligns almost exactly with the time of the explosion recorded by BCH, at approximately 6:06:22 pm on February 24, 2023, assuming the time clocks on the different devices are aligned.

Figure 7: Still captures from video footage of explosion event.

3.5 Witness Documentation

28. The VFRS Report (Case 230009317, attached as **Appendix E**) on this incident states that two members of the public "were walking south in front of 353 Burrard when they heard and saw a large explosion. The witnesses stated that they did not see or hear anything that indicated an explosion was imminent".

29. An interview was conducted with a Cable Crew representative to "walk through" the process of inspecting and changing the oil in rotary switches. The interview occurred on May 5, 2023, at Powertech. Notes from the interview are attached in **Appendix F**.

3.6 Field and Evidence Reviews

30. Following the incident, two primary field investigations took place:

    a. An immediate post-incident response that included preliminary documentation, site survey, environmental containment and testing (February 25, 2023). V73 was secured by steel covers pending the investigation team establishing safety and environmental protocols for entry.

    b. An internal vault examination, documentation and preservation of evidence on February 28, 2023. Floor debris samples were secured from six locations by Powertech. Documentation and recovery of the transformer, switches, cables, junction bars and the fuse cabinet were completed by SenezCo and BCH and catalogued and secured by Powertech (February 28, 2023).

31. After the field reviews, the samples were analyzed inside Powertech labs. The list of laboratory examinations includes:

   a. Evidence examinations occurring inside Powertech Laboratory focused on the switch enclosures on March 24th, April 4th, and April 12th, and May 26th, 2023.

   b. Radiographic inspection of three fuses using an X-Ray on April 12, 2023.

   c. Radiographic inspection of the switch contacts and insulating bars from Switch 2019 using an X-Ray on April 24, 2023.

   d. Metallurgical analysis of the inside of the switch enclosures using Scanning Electron Microscopy/Energy Dispersive Spectroscopy on April 26, 2023.

   e. Infrared Spectroscopy (Fourier transform infrared) inspections onto a new and used gasket of similar age was conducted on April 27, 2023.

   f. A summary of laboratory testing findings is included in the Powertech Report. A list of evidence recovered for examination is included in **Appendix G**.

Attachment 1

4.0 FIELD & EQUIPMENT DAMAGE OBSERVATIONS

4.1 The Marine Building & Tenancies

32. The primary fire damage to the Marine Building was on the east façade, opposite V73. The main entrance to the building was set back from the street and no significant observations of explosion or fire damage were noted. V73 was located opposite of the east building façade that protruded beyond the remainder of the façade. Immediately to the north and south of the JJBean Café, the building façade stepped back.

33. The façade configuration meant that the predominant heat and fire damage was localized to a portion of the east façade of the building around the JJBean tenant space. Smoke damage was visible on the lower five storeys of the building façade, dominantly in front of the JJBean tenant and opposite V73 [**Figure 8** and **Figure 9**].

34. The glass windows and door of JJBean were broken from the Incident, as seen in **Figure 9**. This likely occurred in combination with the initial explosion and the subsequent heat exposure from the fire. The glass above the doorway to JJBean had one pane broken, but two remained intact.

35. Inside JJBean, there was heat damage along the interior walls and ceiling surrounding the damaged window [**Figure 10**]**,** and smoke damage throughout the space [**Figure 11**]. The automatic sprinklers were all intact at the time of the initial site inspection meaning the smoke and heat from the fire in the vault was insufficient to fuse the sprinkler heads and cause water to flow. This aligns with the absence of water patterns on the walls around the sprinkler heads suggesting no sprinkler heads had been replaced. A dominant smoke pattern was observed at the south end of the upper windowpane immediately opposite V73 [**Figure 10**].

36. Tractor, the neighbouring restaurant to the north, had a recessed entranceway with multiple glass panels and doors and a glass awning. A glass door and a window panel of the restaurant were broken, as shown in **Figure 12**. There was no evidence of significant heat and smoke damage within the restaurant. The glass awning (closer to the explosion) did not fail, and no sprinklers fused within the covered awning area or the restaurant.

Figure 8: Marine Building façade damage.

Figure 9: JJBean café east façade.

Figure 10: JJBean interior smoke extension dominant through south end of window.

Figure 11: JJBean interior looking north.

BC Hydro Electrical Explosion Incident – Marine Building, Downtown Vancouver

Figure 12: Images showing Tractor restaurant damage.

4.2 Vault Damage

37. The north wall of V73 was not structurally damaged and had limited soot deposition except in the northeast corner, below a small region of spalled concrete [**Figure 13**]. Similarly, the east wall at the north end had limited soot deposition.

38. Above, behind and below Switch 2019 (SW2019), there is a clean burn on the wall and ceiling centered and dominant in alignment with the switch. The demarcation decreases on the ceiling above Switch 2018 (SW2018) and is largely diminished above the fuse box [**Figure 14**]. Similarly, the hot region associated with the clean burn is dominantly below SW2019, extends north below SW2018, but does not extend below the fuse box, where the wall has greater soot staining [**Figure 18]**.

39. On the east wall, there is greater damage to the center opposite SW2019 extending south to the region of the vault between SW2019 and the transformer [**Figure 15**]. The red-phase cable connector block had melted to the floor along with the connecting cables. A portion of the yellow-phase connector block was also damaged and had fallen to the floor at the north end.

40. Although there was some minor spalling in the northeast corner, the greatest damage to the vault concrete enclosure was to the midsection where large portions of concrete had spalled, exposing the reinforcing bar [**Figure 16**].

41. The south wall and the south end of the east and west walls had considerable soot deposition [**Figure 17**]. Compared with the center portion of the vault, the region around the transformer had less heat damage than the midsection of the vault, and the transformer and corresponding equipment did not identify signs of failure; save for the damage from fire exposure.

42. The electrical cables were laying as bare conductors on the cable support brackets. Some of the cables at the south end behind the transformer still had portions of cable jacket remaining intact, but the vast majority of cables within the vault were exposed bare conductors, with no insulation or protective cover remaining. There were no signs of arcing, or overheating or fire patterns that align with a cable failure within the vault being the cause of the Incident.

43. Based on the above, the post-fire burning was dominant to the west-center of the vault, around and below SW2019 wholly, and SW2018 partially. This also aligns with the soot demarcation in the JJBean store where smoke dominantly entered the premises through the south end of the upper window and the area of hardness testing of SW2019 (as documented in the Powertech Report).

44. No abnormal substances or components were identified that are indicative of any penetration into the vault by foreign ignitable liquids, nor was there any indication of an intentional act such as vandalism or sabotage (see Powertech Report).

Figure 13: V73 north wall.

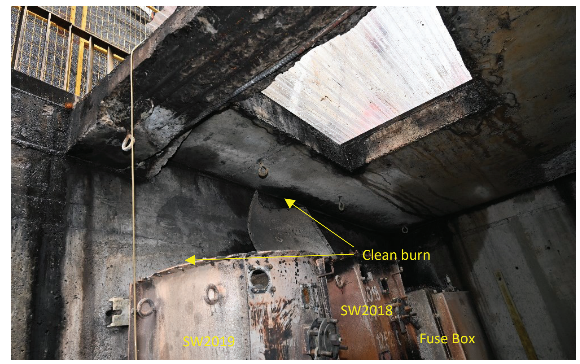

Figure 14: Ceiling on the west side at the north end of V73.

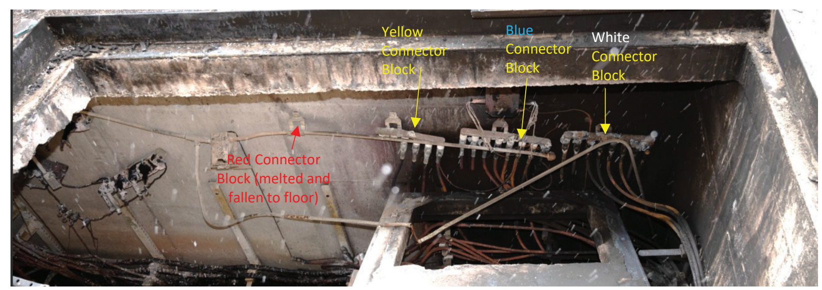

Figure 15: East wall at the south showing cable connector blocks for different phases, and missing red phase connector block.

Figure 16: Vault structural damage.

Figure 17: South end of V73.

Figure 18: West wall rotary switches and fuse box.

4.3 Transformer

45. The transformer had three insulated supply cables terminating on the front face of the housing (north side) connecting to the fuse cabinet. Four sets of four insulated distribution cables exited the transformer at the back (south side) and connected to the secondary bus connectors on the east wall.

46. Post-Incident, the cable conductors remained intact and connected to the transformer [**Figure 19**]. The three supply cables were no longer connected to the transformer and were on the ground in front of the transformer [**Figure 20**]. The paint on the transformer was heat damaged above the point of cable entry (yellow line superimposed on the figure). This aligns with the transformer being oil-filled above this line, meaning the oil remained in the transformer post-explosion prior to evaporating during the fire.

47. A heat demarcation at the top of the transformer was dominant towards the front on both sides (as indicated by the yellow arrows in **Figure 21**). The remainder of the sides of the transformer are marginally heat discoloured and smoke-stained. This aligns with the fire developing from the front (north) of the transformer.

48. The metal frame legs of the transformer were oxidized and corroded [**Figure 22**]. The right side of the base had the greatest damage, with the largest portion of the bar deteriorated, when compared to the other sides. This corrosion likely preceded the fire due to water infiltration into the vault. There was no indication of corrosion-related leaking of oil onto the floor of the vault either pre-Incident or post-Incident.

49. The transformer contained approximately 640L of insulating oil. BCH's environmental contractor recovered approximately 60L of the insulating oil (9 ppm PCB concentration). The remaining 580L of oil evaporated and combusted during the Incident.

50. The inside of the transformer had the majority of the components intact with limited heat damage [**Figure 23**]. Melted insulation from penetrations pooled down onto the electrical components.

51. In summary, there is no indication of electrical failure on the interior or exterior of the transformer. The physical damage to the transformer is therefore a consequence of the Incident.

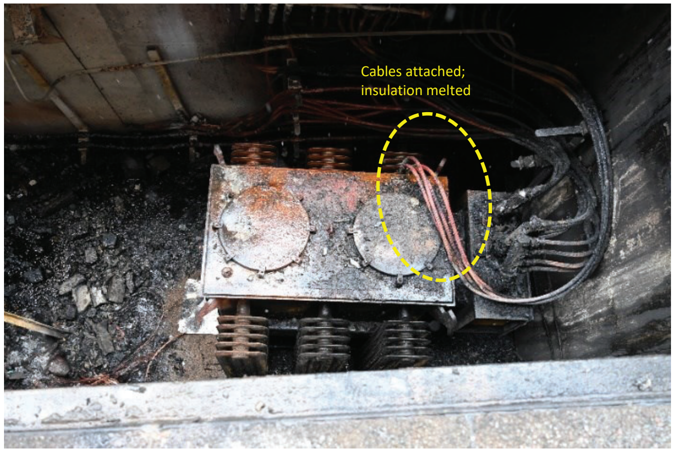

Figure 19: Transformer in the vault.

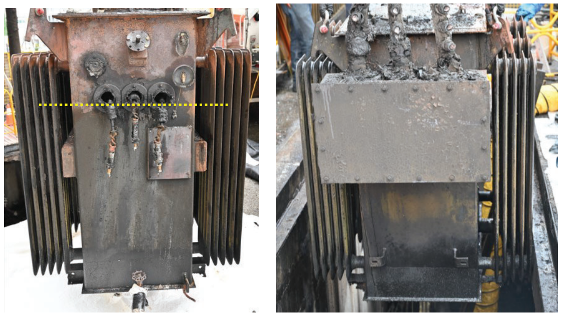

Figure 20: Transformer removed from vault: Left image - Front or north side; Right image - Back or south side.

Figure 21: Sides of transformer (a) Left - east side (b) Right - west side.

Figure 22: Transformer underside.

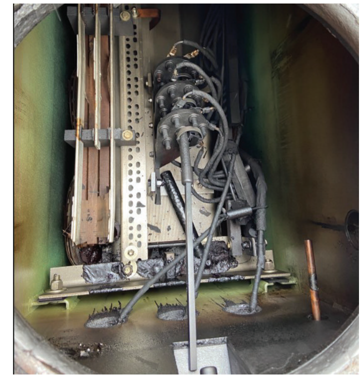

Figure 23: Transformer inside.

4.4 Fuse Cabinet

52. The current-limiting-fuse (CLF) cabinet was installed electrically between the switches and the transformer. The cables went from the switches to the east wall at the north end and then connected through the CLF before going to the transformer.

53. The CLF was installed on the west wall in the northwest corner of the cabinet [**Figure 24**]. The cabinet door had paint residue remaining with the dominant heat pattern to the south extending from the bottom on the exterior, and, on the interior, had paint peeling from the bottom left corner.

54. These patterns are consistent with thermal exposure from below and to the south of the cabinet, as depicted by the yellow lines and arrows in the figures. **Figure 25** depicts the front and back of the cabinet. The rust-like pattern on the back is likely due to being fastened to the wall and is unrelated to the Incident conditions. The remainder of the surface had soot staining on the paint, as did the right (north) side of the cabinet, which has less thermal exposure than the left side or front of the cabinet.

55. The elbow terminals connecting the top and bottom of the cabinet were not connected, as shown in **Figure 26**. Segments of cable remained on the bottom of the CLF cabinet, which had an aligning heat pattern at the front left corner to the patterns on the front and south sides of the unit.

56. Inside the CLF cabinet, all the components had fallen to the bottom. The fuses and connecting components were located in the debris at the bottom [**Figure 27**].

57. The fuses were measured and found not to have electrical continuity (meaning the fuses had fused). This is an expected consequence of the heat associated with the fire, and consequently, no conclusion can be drawn with the state of the fuses.

58. Further examination of the fuses was completed by Powertech (see **Appendix H**). No observations associated with the fuse damage or transformer damage are indicative to being causal with respect to the Incident, and all damage was as expected due to exposure from a fire or pre-existing conditions due to age.

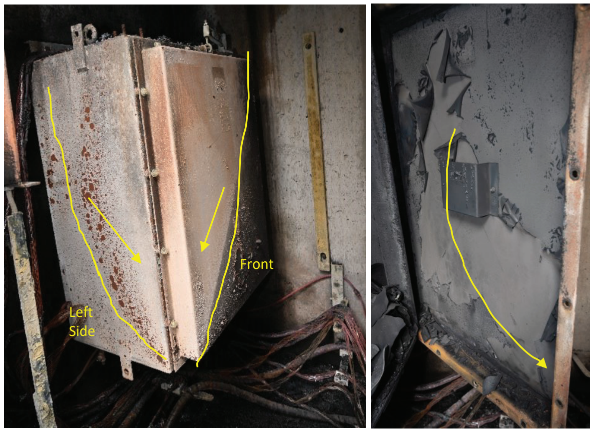

Figure 24: Front-left side of CLF (left); inside of cabinet door (right).

Figure 25: Front of CLF cabinet (left); back-right side of CLF cabinet (right).

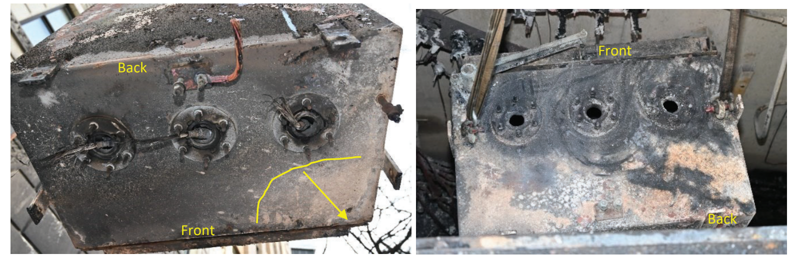

Figure 26: Bottom of CLF cabinet showing broken cables (left); top of CLF cabinet (right).

Figure 27: CLF cabinet inside (left); fuses and components found in debris at bottom (right).

4.5 Switch 2018 (SW2018)

59. Switch 2018 (SW2018) is the primary service switch for the vault (even numbers are normally electrically closed while odd numbers are normally open). SW2018 was found with its switch padlocked in the correct closed position as evidenced by the rectangular notch on the rotary dial on the outside (as opposed to notches with circular ends for padlocks). This position was confirmed when the lid of the switch was removed in follow-up examination [**Figure 28**].

60. The main supply cables enter through the paper-insulated lead-covered cable (PILC) termination which splits the phases of the cable and is fastened into three switch-blade assemblies composed of composite connector brackets that support a copper blade. The blades snap into contact forks on the service side when the rotary switch is closed, or to the ground side if it is desirable to ground the switch (not normally necessary) [**Figure 28** - right].

61. SW2018 contained approximately 120L of non-PCB insulating oil (Soltex 2288). No oil remained in the switch post-Incident. No significant deformation was observable on the structure of SW2018. The bolts securing the lid of SW2018 were fastened in the correct position and the switch remained anchored to the wall and on its supporting frame.

62. All external faces of SW2018 had paint residue and many of the original paint markings were still legible [**Figure 29**]. A smoke demarcation line was present on the left side and front emanating from an oil-fill line gage opening, as depicted by the yellow lines in **Figure 29** and **Figure 30**. This is indicative of combustion inside the switch, likely due to exposure from the fire.

63. The bottom of SW2018 was soot discoloured and did not have any cables remaining in place [**Figure 31** (a)], but the hold down clamps for the cable elbows were in place. All the cables were located along the ground under SW2018.

64. The PILC supplied the two switchboxes and terminated through the PILC connector to a larger precast termination, where the PILC cables were separated, and connected to the three phases of the switch terminals. The PILC supply cable connector was located under the switch [**Figure 32**]. The precast termination was melted away and partially still intact on the underside of the switch housing [**Figure 31** (b)]. This means that the PILC connection was in place at the time of the fire, which would have limited the dissipation of oil from the switch until the components on the underside of the switch melted in the fire.

65. In summary, the physical damage to SW2018 is consistent with fire exposure. No indications of failure were identified that are indicative of it being the cause of this Incident.

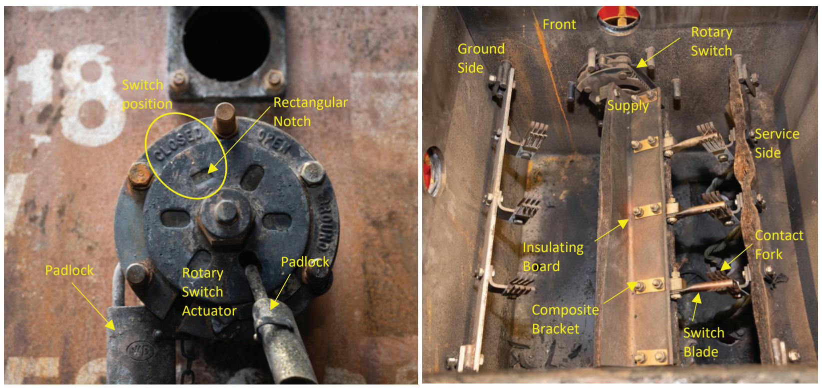

Figure 28: SW2018 position as found (left); and after the switch lid was removed (right).

Figure 29: SW2018 front and right-side view.

Figure 30: SW2018 back of housing - west side against the wall (left); left side and front (right).

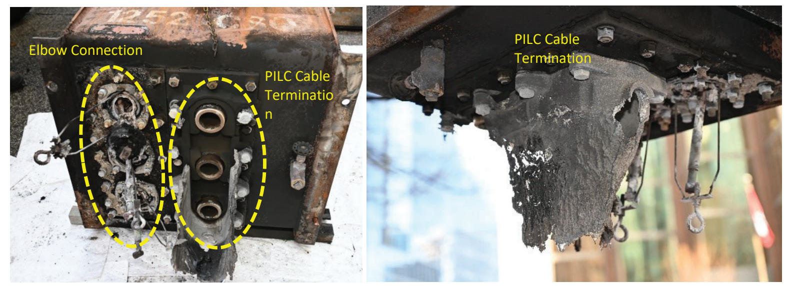

Figure 31: SW2018 external walls (a) front face; (b) bottom side.

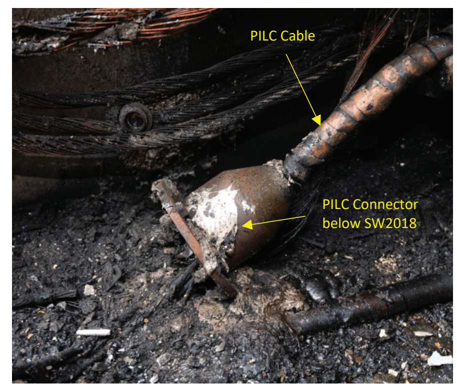

Figure 32: Partial housing for high-voltage alternative current cable terminal of Switch 2018.

4.6 Switch 2019 (SW2019) General Damage

66. SW2019 is a standby switch used when it is necessary to do work on the other circuit connected to SW2018. SW2019 is normally in the open position, meaning is not normally current-carrying. SW2019 was found padlocked in the open position, as evidenced by the rotary dial on the outside, and the position of the inner working of the rotary switch spring-loaded mechanism [**Figure 33**].

67. SW2019 originally contained approximately 120L (30 gal) of non-PCB mineral insulating oil (Soltex 2288). No oil remained in the switch post-Incident.

68. In general, SW2019 had the greatest physical damage, highest thermal exposure and greatest internal damage compared with any of the other major components within the vault. This damage was dominant on the right side and the right side of the front face, with paint residue remaining on the back and on the left side, with less so on the right side and on the front right side [**Figure 34**].

69. The housing of SW2019 was significantly deformed:

- The lid of SW2019 was previously secured with 32 fasteners around the perimeter of the enclosure. These were sheared and no longer in place, except for welded threaded pins along the back wall of the housing.
- The lid had been displaced and was located on top of SW2018 [**Figure 35**].
- The front of the lid was bent up by approximately 170 mm on the front and 90 mm on the left side [**Figure 36** and **Figure 37**]. The back of the lid was partially bent and the left side was more deformed than the right side.
- The front wall of the housing was bowed outwards in alignment with the bending of the lid (see the yellow arrow in **Figure 36**). Several fastener holes were deformed; one being split [**Figure 38**]. The paint surface was bubbled and scratch marks were evident on the left side and bottom [**Figure 34** - top right]. A photograph of the switch was taken in 2021 which shows the scratch marks pre-existed the Incident.
- The bottom of the housing was also bowed outwards [**Figure 39** - left], and the PILC termination and connectors were no longer in place, nor were the elbows or the exiting service cable [**Figure 39** - right].
- The PILC connector was still attached to its termination and was located on the ground below SW2019 [**Figure 40** - left]. The cables were severed at either end of the connector, but was otherwise intact and not thermally degraded [**Figure 40** - right] in a comparable manner to SW2018 where the connector was intact but the termination was melted away.

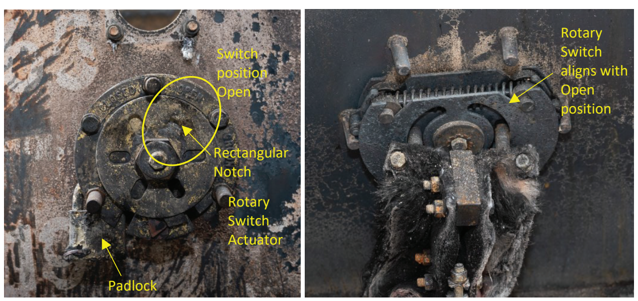

Figure 33: SW2019 showing switch position outside (left) and inside (right), as found post-Incident.

Figure 34: Images showing the perimeter faces of the SW2019 housing.

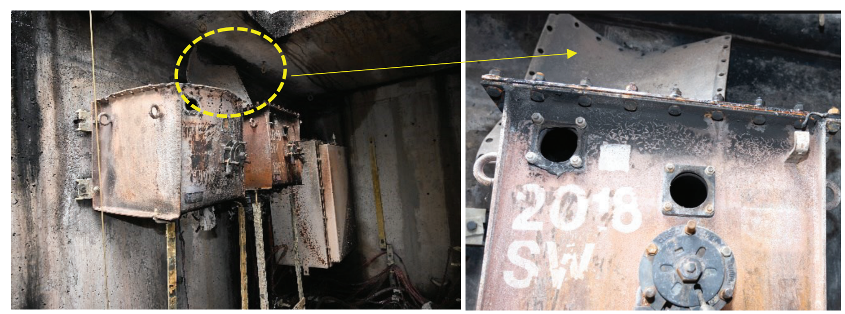

Figure 35: SW2019 lid on SW2018.

Figure 36: Lid of SW2019 in its original position (left); underside of the lid (right).

Figure 37: SW2019 lid deformation, observed during a laboratory examination.

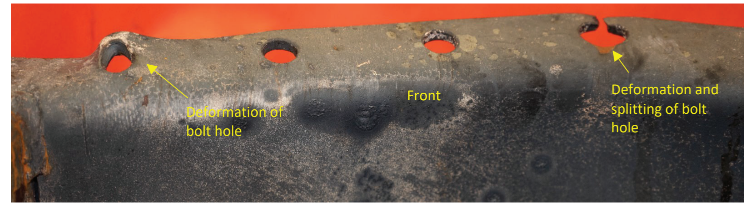

Figure 38: Deformation of bolt holes in front wall of SW2019.

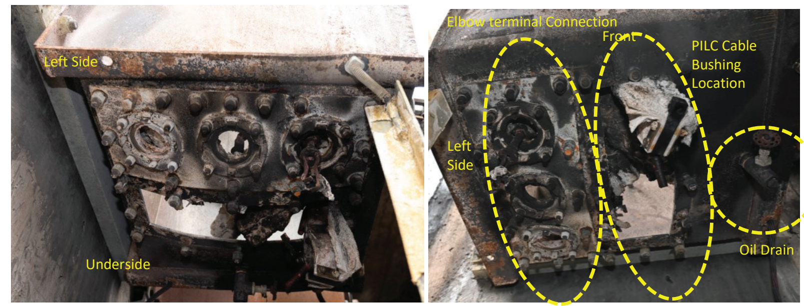

Figure 39: SW2019 underside of housing showing bowing (left), and absence of service connections (right).

Figure 40: SW2019 PILC Connector and Termination as found (left); in laboratory (right).

70. The deformation described above is consistent with an internal overpressure, and therefore explosion, from within SW2019. The sequence of the explosion is as follows:

- An internal electrical failure (discussed later) causes the build-up of flammable vapours and pressure until vapours reach an explosive concentration and ignite, creating an overpressure within the tank;
- The overpressure causes the simultaneous: (1) peeling of the lid in the front and then from the left to right bending the lid towards the back and then dislodging of the lid, possibly hitting the roof of the vault or the back wall before resting on top of SW2018; (2) dislodging of the service connections and PILC assembly at the bottom onto the floor; (3) draining of the remaining oil of the switch onto the PILC assembly and the floor.

- The combined vapour cloud explosion then propagated through the V73 enclosure causing displacement of the concrete inserts and utility covers and venting to the street, breaking nearby windows and creating a fireball.
- The oil that was drained from SW2019 then continued as a liquid fire at the bottom of the vault and within SW2019. This caused the damage to SW2018, and some combination of leaking and evaporation and combustion of oil from that switch, as well as the transformer which contributed to the sustained fire.

71. Internally, SW2019 had considerable damage and more damage than any other component.

4.7 SW2019 Internal Damage

72. Internally, the components of SW2019 were significantly damaged. Unlike other equipment in the vault, the internal workings of the switch were no longer fully intact and had damage from thermal exposure and electrical activity.

73. Within SW2019, the insulating board on the supply was detached from the back wall and had fallen to the right side, while the service side insulating board remained attached at the back of the switch box, but no longer attached at the front [**Figure 41**]. Pieces of concrete that had fallen from the ceiling of the vault due to thermal exposure were within the switch box (indicating this occurred after the explosion). The ground bar remained in place but there were no connecting forks remaining intact either on the ground bar or on the service-side insulating board assembly. Conversely, all three switch blades remained connected to the supply-side insulating board which was detached from the housing at the back.

74. Two switch components were recovered from within SW2019 prior to removal: one contact fork melted into an aluminum mass, and one elbow connector cable [**Figure 42**]. A full list of recovered items is included in **Appendix G**, as secured and maintained by Powertech.

75. Two other contact forks were located in the debris underneath SW2019 [**Figure 43**] along with the two other elbow connecting cables [**Figure 44**]. Two other additional forks were located in the debris immediately south of the switch frame [**Figure 43**].

76. The forks had varying degrees of damage. The ones labeled E10, G2, and R3 had melted aluminum on the surface and consequently, damage to these forks may be associated with alloying associated with the mixing of molten aluminum and copper. Forks E9 and R5 do not have melted aluminum. In the case of E9, optical analysis of the fork tips (included in Powertech Imaging in **Appendix I**) determined that minor parting arcs or partial discharges likely occurred from this fork. The greater mass loss and overall surface degradation of fork R5 corresponds with arcing occurring on this fork. The sixth fork was not located in the debris and may have been either vaporized by electrical arcing or thrown from the switch with other debris and not recovered.

77. The service side insulating board was frayed and had a dominant area of heating as evidenced by the white insulation at the back [**Figure 45**]. Similarly, the supply insulating board had greater fraying and also had dominant damage towards the back, as evidenced by the white discolouration of the fiberboard [**Figure 46**].

78. Examination of the blades attached to the supply insulating board identified further damage to the switch components that is consistent with arcing. Specifically, the blade ends had evidence of melting with greater melting on the two blades towards the back, but generally present on all three blades [**Figure 47**].

79. Arcing aligns with the presence of spatter on all four walls of the switch shown in **Figure 48** through **Figure 51**. Further chemical analysis, as documented in the Powertech Report, determined that the spatter contained carbon and aluminum as the predominant elements and iron, calcium and zinc as lesser present elements. This means that the arcing also involved components other than the blades and contact forks. These components would have normally all been present on components forming part of the insulating board assembly.

80. The presence of spatter on all four walls below the oil fill level indicates that arcing occurred after the oil spilled from the tank. Further, since there is no spatter on the lid of SW2019 [**Figure 52**], the arcing, and corresponding arc spatter occurred after the explosion. The physical deformation of the housing of SW2019 as a consequence of the exposure likely dislodged both of the supply and service insulating boards from their connecting pins, allowing both boards to free-pivot with the vibrations of the explosion allowing electrical arcing to occur between both copper and non-copper elements, which would otherwise not be possible. This is illustrated in **Figure 53**. The arcing occurrence after the explosion aligns well with the timing of the Oscillography discussed earlier in this report.

81. A corrosion pattern was observable on the inside surface of the switch on the right wall towards the front, as shown in **Figure 51**. The image shows a region where paint is no longer intact with a v-shaped corrosion mark descending to the bottom of the tank. Closer examination shows the corrosion inset beyond the surface of the tank. The corrosion mark aligns with a mark on the exterior right wall of the tank that is less prominent [**Figure 34**]. The nature of this corrosion can not be connected to the expected patterns from fire, and therefore Powertech was requested to conduct additional evaluation on the chemistry and metallurgy of the area. This is further addressed later in this report.

82. Insulating oils in switches limit the potential for transmission of electrical current. Oils degrade with time and/or can become contaminated, with moisture being one of many possible contaminants. For this reason, the switches are sealed and pressurized with nitrogen which both limits the oxygen environment within the head of the tank, but also limits the potential for air, and therefore moisture, to enter into the tank.

83. Based on the above, there is no evidence to suggest that a physical malfunction of the switches' internal operating components would have caused arcing leading to the explosion. However, the above analysis established that the probable cause of the explosion was contaminated oil allowing electricity to be dissipated into the oil through partial discharges (PD). In a PD, the oil absorbs the energy, but releases combustible gases into the head of the tank that are explosive in the correct operating environment. The potential for PD and contaminated oils is discussed at length in the Powertech Report and is not repeated here. The following sections discuss the further potential for contamination of the oil.

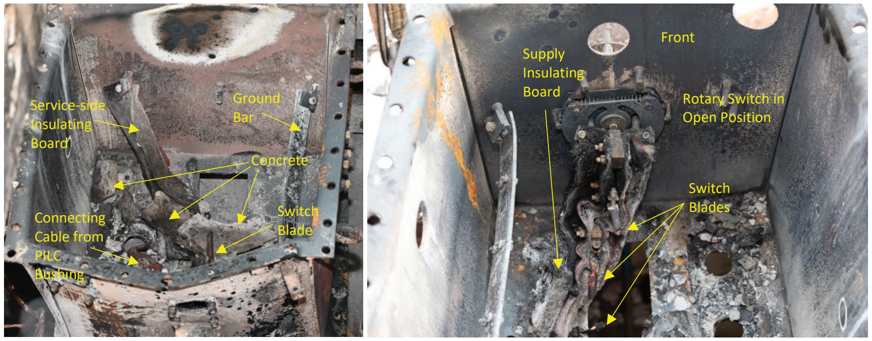

Figure 41: Interior of switch immediately post-incident (left); image of the front face of the switch box post-removal (right).

Attachment 1

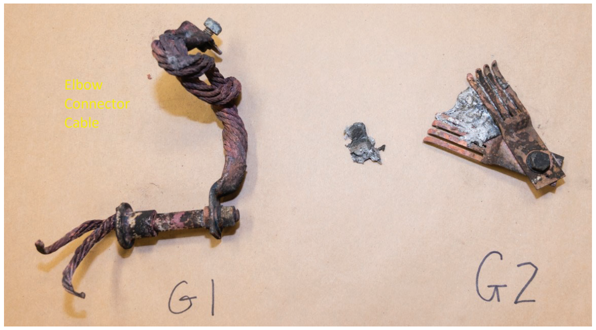

Figure 42: Switch components recovered from within the SW2019 housing.

Figure 43: Contact forks found in debris underneath switch (left two), and debris south of switch (right two).

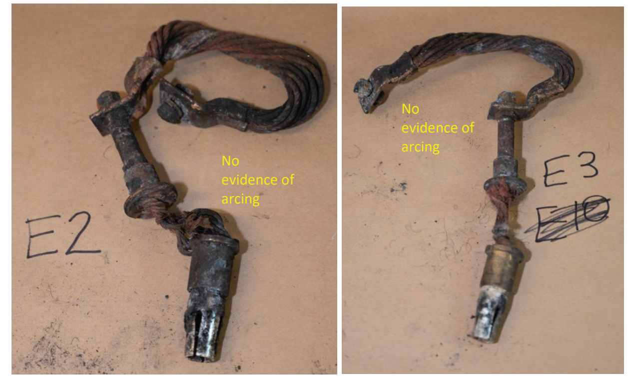

Figure 44: Elbow connector cables found in debris immediately below SW2019.

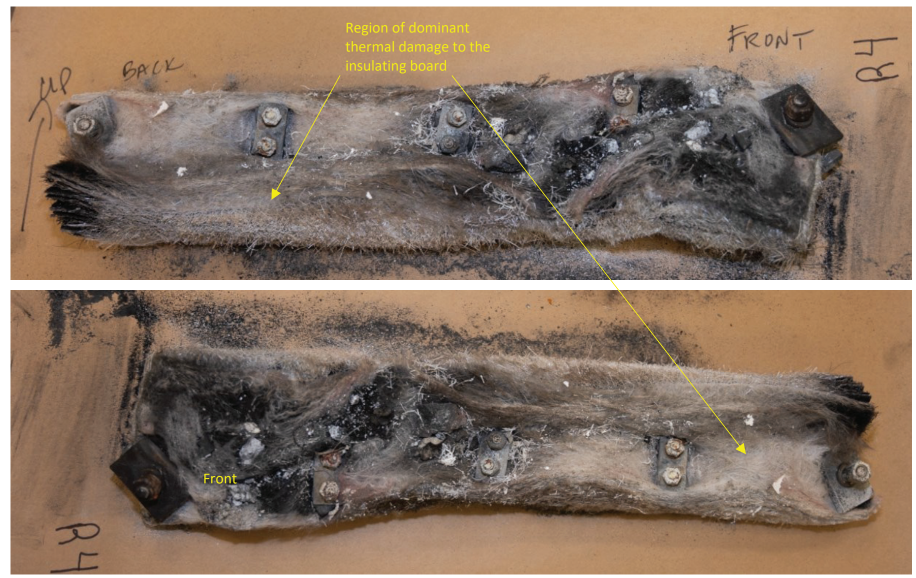

Figure 45: Images of insulating board on the service side of the switch, showing expansion of the fiberboard due to heat exposure.

BC Hydro Electrical Explosion Incident – Marine Building, Downtown Vancouver

Figure 46: Images showing different views of supply insulating board with remaining blades and greater damage to the board at the back of the switch.

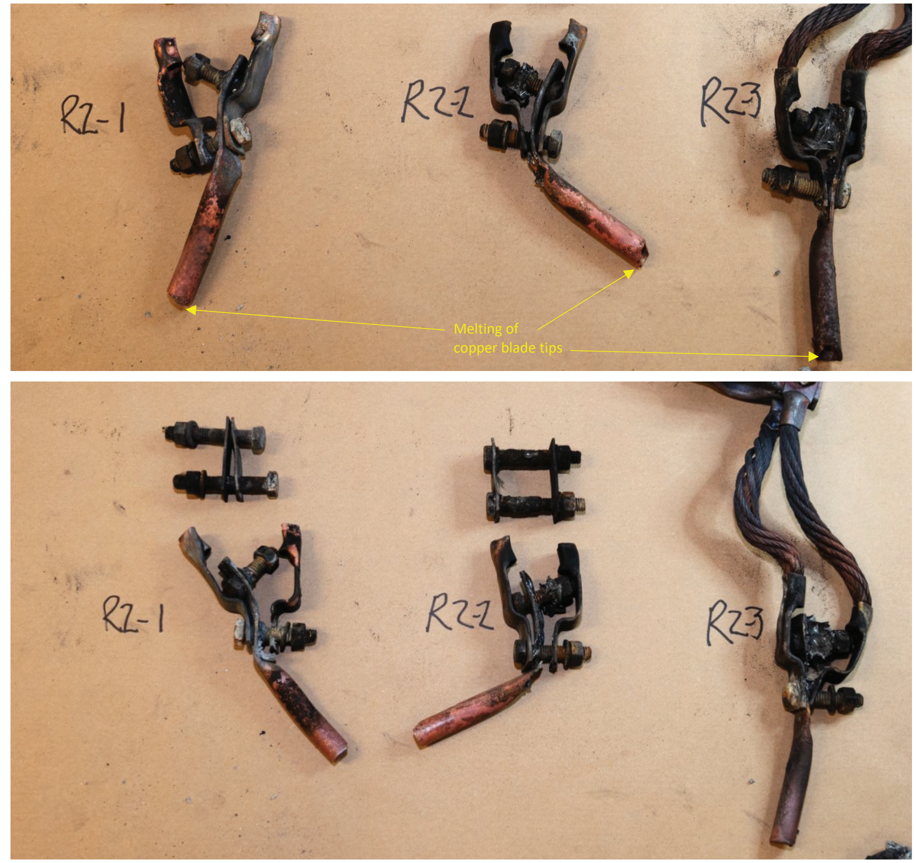

Figure 47: Blades from supply side of switch (two perspectives flipped 180 degrees).

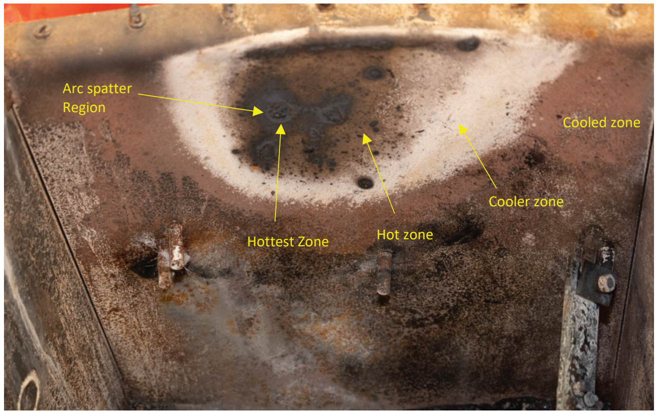

Figure 48: Arc spatter zone on interior back wall of SW2019.

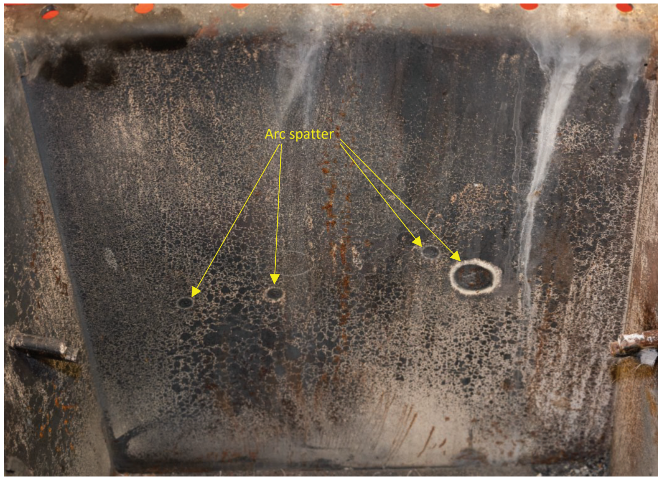

Figure 49: Arc spatter zone on interior left wall of SW2019.

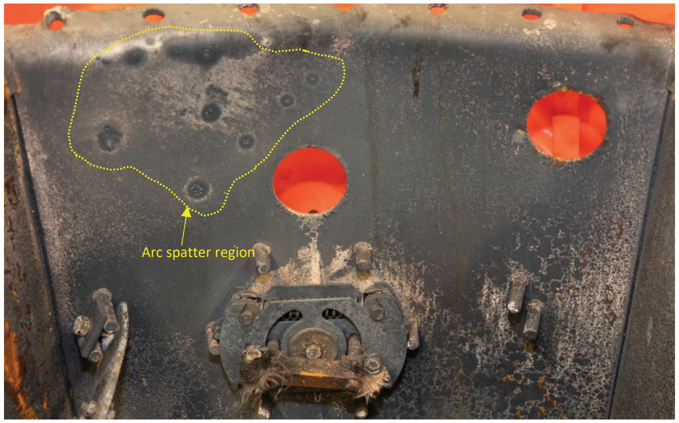

Figure 50: Arc spatter zone on interior front wall of SW2019.

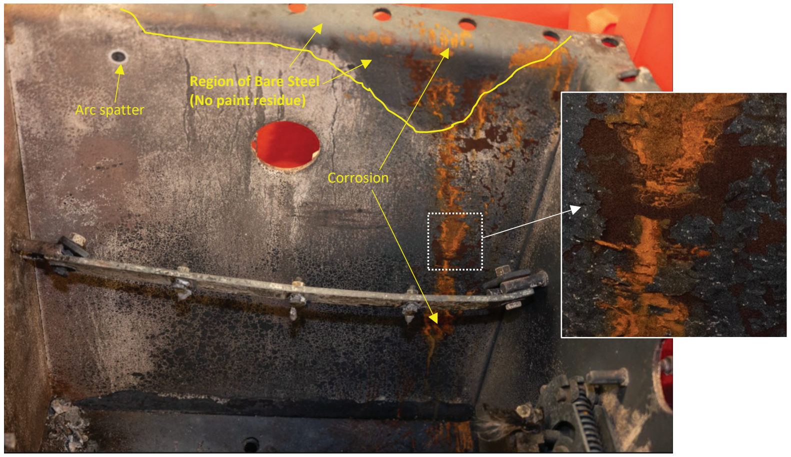

Figure 51: Arc spatter zone on interior right wall of SW2019 and corrosion region with blow-up inset.

Figure 52: Underside of the lid from SW2019.

Figure 53: Service insulating board assembly showing gap at left side (top); supply insulating board from SW2018 positioned in SW2019 showing gap due to deformation of the SW2019 housing.

Figure 54: Insulation for Switch Hinge Pins (a) Switch 2018 (Sample S5); (b) Switch 2019 (Sample R2).

5.0 OIL INTEGRITY REVIEW IN SW2019

84. Some degree of contamination/degradation of insulating oils is expected to occur through ordinary use of the equipment. As part of maintenance requirements on the vault, the oil filled components are to be externally inspected, and oil tests conducted annually. Every five years, the oil is to be changed, and the switch is to be internally cleaned and inspected. This requirement is documented in a BCH document titled "Maintaining Oil Switches" released on September 21, 2015. The document is attached in **Appendix J**.

85. After the event, an interview was conducted with a Journeyman in regard to BCH's method of changing oil in rotary switches. Notes from the interview are attached in **Appendix F**.

86. Information for this section comes from the following operational logs:

- Switching Operations Log SW2018 and SW2019 (**Appendix K**)
- V73 SAM Maintenance Logs (**Appendix L**)
- Oil Quality Historical Report SKM_C308_ID23041211020 (**Appendix M**)
- V0073 RAL Switch Oil Results (2000-2009) (**Appendix N**)

5.1 Maintenance Procedures

87. The switches are pressurized with nitrogen to limit the potential oxygen atmosphere within the top of the tank above the oil line and limit the potential for the infiltration of air, and corresponding airborne contaminants such as moisture. This reduces the potential for degradation of the oil from external sources.

88. Normal degradation of the oil occurs due to switching operations, which can create short-duration arcs at the blade/contact forks when the switch is opened or closed. This is normal and can result in some surface degradation/melting of the copper connection elements and can release particulate into the oil as well as degrade the oil's insulating capacity. Other miscellaneous particulate can also develop from partial discharges, or normal wear and tear on the equipment.

89. A walk-through of the Five-Year Work Procedure with a Cable Crew member is summarized as follows:

- The pressure is assessed at the start by opening the top port to listen for hissing and therefore the presence of pressurized nitrogen. An experiential estimate is that about half the time the switches are found without nitrogen.
- The oil is drained out of the switch from the drain port on the bottom of the switch.
- The bolts are removed, and then the seal of the lid is broken by two crew, each pulling one side until the seal releases.
- The internal components are then examined for wear and tear, alignment and general function of the switch.
- The enclosure is flushed with 50L-60L of clean oil; after the oil is drained, lint-free towels are used to remove all the flushing oil.
- The lid is cleaned and if the gasket is damaged sections of gasket material (trade name - Nebar) are cut and replaced/added to the lid. Silicon may also be added to create a better seal. If hissing was not noted at the start of the procedure, then additional care is taken to improve the seal on the tank with Nebar and applying silicone.
- The bolts are then fastened to seal the lid, and then the switch is filled with dry nitrogen at five psi, and held for five or more minutes to check for leaks. If leaks are found the lid seal is resealed, until no leaks are found.
- The nitrogen is then removed, and the new oil is added from the drain spigot until the fill line is reached in the window. The headspace is then filled with nitrogen at five psi.

90. The procedures described above generally align with BCH procedure, except as follows:

- "Maintaining Oil Switches" procedure, except for Item 5 on the Replace the Lid and Pressurize which requires that Snoop be used to check of nitrogen leaks:

> 5 Check the switch for leaks using Snoop.
>
> a) Squirt Snoop over all the joint areas on the outside of the switch using plenty of solution.
>
> b) Watch for bubbles that would indicate a nitrogen leak. If bubbles appear, tighten all the bolts around that joint and recheck. If bubbles continue, all gaskets and joint faces will have to be checked for particles of dirt and parts replaced. Re-pressurize the tank and re-check

- Both BCH Service and the technician state that the headspace pressure at the end of the process is to be between 3 psi and 5 psi. The original equipment manual directs maintenance to fill the enclosure approximately 80% by volume with oil, and then fill the remaining headspace with nitrogen pressurized to 0.5 psi, as per the excerpt below.

> To avoid trapping moisture laden air in the space above the oil, purge this space with dry nitrogen for approximately one minute. The space may be left filled with nitrogen at a slight positive pressure (approx. ½ lb. per square inch) to serve as an indicator of tightness of the tank.

- The use of silicon as a sealant is not described as an option in the procedure. Our understanding is that any commercially available room-temperature-vulcanizing silicone (RTV Silicone) would be used to supplement the Nebar.

91. In general, the BCH procedure with respect to gasket inspection and replacement provides limited direction to support field operations doing maintenance:

- Under the heading "Remove the Oil," there is an indication to "lif[t] the lid carefully so not to damage the tank gasket, as it remains in place on the tank."
- No further guidance is provided on inspecting the gasket.
- Under the heading "Replace the Lid and Pressurize," there is an indication to "Ensure the gasket is in place."
- Attached to the BCH procedure is the manufacturer's literature that recommended as part of the internal inspection to "Check gaskets for cracks and flexibility," and to "Replace all lids with new gaskets where required.
- In order to obtain a proper seal, the gasket should be cut as a single piece in a rectilinear shape with pre-punched bolt holes. In practice, crews were patching the gasket with sections of Nebar and supplementing with RTV Silicone, neither of which was tested for compatibility with the switch components.
- Further, there was no part number or gasket replacement part to order from BCH Stores, leaving it necessary for the crews to "field-fix" any gasket leaks.

92. As outlined in the Powertech Report, the method of resealing the lid of the switch presented the following risks, which increase the likelihood of a poor seal and the creation of acids or contaminants that are incompatible:

- Inadequate seals due to joints and overlaps of Nebar material;

- Incompatibility of the silicone with the cork contained in the Nebar and with the nitrogen;
- RTV silicones are not typically used for pressurized applications which can create leaks before curing;
- Inconsistent application of silicone can cause excess product to squish out the side and down the wall of the tank.

93. Accordingly, the limited specificity of the gasket inspection in the maintenance procedure increased the likelihood of leaking gaskets. The absence of nitrogen in the field-estimated 50% of the switches, which is not reported on as part of the procedure or contained within any field notes examined, did not afford any early warning of potential inadequate methods of sealing the lids on the switches.

5.2 Dielectric Breakdown Voltage and Oil Testing Program

94. The integrity of the insulating oil is tested by measuring the dielectric strength of the oil. IEEE defines dielectric breakdown voltage of insulating oil as a measure of its ability to withstand voltage stress without failure.

95. Powertech measures the dielectric strength of the oil as the minimum voltage in which electricity can arc across the oil, when two conductors are placed 2 mm apart in accordance with ASTM D1816, “Standard Test Method for Dielectric Breakdown voltage of Insulating Liquids Using VDE Electrodes.”

96. The test serves primarily to indicate the presence of electrically conducted contaminants in the oil, such as water, dirt, moist cellulose fibers or particulate matter. A failed test does not indicate the likelihood of an explosion; however, it can be a result of one of the following:

- Enclosure leak,
- Overuse of Switch, or
- Damage or Wear of internal components (pressboard insulation, paint).

97. The criteria defined by BCH in the Maintaining Oil Switches Work Procedure specifies that, during the five-year maintenance:

- The oil from the degasser hose (off of the truck providing the oil) be tested and if the oil is less than 22 kV then do not refill the switch.
- If the oil tests at 22 kV or above, then obtain a sample for the laboratory.

98. In practice, however, the following inaccuracies exist with respect to the implementation of this standard:

- The use of 22 kV is inconsistent with the manufacturer’s specifications for new oil within the Work Procedure which, as reproduced below, is 30 kV.

> **2.8 OIL FILLING**
> Use any clean, dry inhibited or uninhibited oil that is regularly used in circuit breakers or transformers. The oil should test 30,000 volts in standard test cup with 1/10 inch gap.

- No oil sample is taken on the five-year maintenance cycle and sent to the laboratory. The dielectric voltage is recorded on the service tag and applied to the equipment.

99. The above is further complicated by a transition of the test methods and standards for new and used oil samples. The original manufacturer’s literature was predicated on the test method in ASTM D-877, which, although it still exists, now references the ASTM D-1816 for new oils as the preferred method. The difference is in the shape of the electrodes being used and the separation distance between the electrodes (2 mm in D1816 as opposed to 2.5 mm in D877). The BCH Work Procedure (dated September 21, 2015) references ASTM D-1816 as the test method for oil shipped for testing, and Powertech was performing the testing using a 2 mm separation distance in accordance with ASTM D-1816.

100. Establishing the context for the differences in testing can be established by reviewing the IEEE Std C57.106 – 2006, “Guide for Acceptance and Maintenance of Insulating Oil in Equipment” The suggested criteria identified in the guide for acceptability under the ASTM D-1816 test method would have been 27 kV for in-service oils instead of 22 kV, and 35 kV for new oils being put into service. These are used as a benchmark for the purposes of this report, but our review suggests additional investigation is warranted into the most appropriate criteria for BCH given the change in test method.

101. Applying the practice identified in the IEEE Guide, and applying a consistent methodology in its application, the five-year maintenance tests off the degasser truck for installation of new oil going into a rotary switch would be expected to test at 35 kV (and not 22 kV as per the BCH Work Procedure), and in-service oils being sent to the lab for testing should be switched out if it is below 27 kV (and not 22 kV as per the BCH maintenance standard).

102. With respect to the Incident, the service tag for SW2019 was captured in a photograph on November 24, 2021 and shows an oil test of 35 kV completed in March 2021 [**Figure 55**], which aligns with the new test method and IEEE Guide.

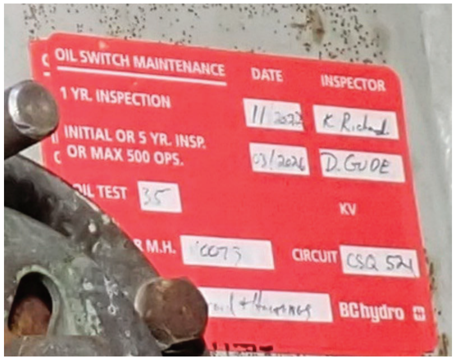

Figure 55: 5-year Oil Switch inspection tag on SW2019 taken from Street Vault Inspection November 24, 2021.

103. However, confirming oil history for SW2019 was a more complicated matter.

- In the Switching Operations Log, request 8-00180223 comments that SW2019 failed an oil insulation test and required 5-year maintenance. This request is dated for November 2014, and comes two months after a test dated September 2014 in the Oil Quality Analysis showed a measured dielectric strength of 21 kV, below the 22 kV limit in the equipment manual.
- The Switching Operations log then shows an entry approximately 12 months later with an attached comment, “outage required to allow maintenance oil change of switch 2019 in V73”.
- This aligns with the BCH manual test limit. No clear guidelines were made regarding the time to change after a failed test.
- There is conflicting information regarding the timeline when the oil inside SW2019 was changed, and the accuracy of the measurements taken.

104. Oil change history shown in the *V73 SAM Maintenance Logs RDL* (see **Appendix L**).

- March 31, 2021
- April 12, 2013

105. Oil change history shown in *Switching Operations Log SW2019 CSQ 12F511 UCF65 - CROW Client Outage Requests_20230428_085432.xlsx*
   - March 19-29, 2021
   - November 18, 2015- January 15, 2016
   - July 3-10, 2012
   - March 23-30, 2006

106. The two maintenance logs also show dates in which oil tests were conducted; these dates also conflict. An Oil Quality Historical Report for SW2019 was also provided (see **Appendix M**) and shows dates in which the oil was taken from SW2019. The dates in the Oil Quality Historical Report align more closely with the dates in the Switching Operations Log rather than the V73 SAM maintenance Logs. It is unclear if one or both reports are correct, but there is further conflicting information between the years 2000 - 2009 (see **Appendix N**).

107. Historical data for dielectric strength in the Oil Quality Historical Report was charted in **Figure 56**, along with the oil change history, assuming the dielectric strength for new oil is 60 kV as suggested by C57.106-2006 for new circuit breaker insulating oil after being energized. (Data from the Maintenance logs from 2009 shows multiple data points at 60 kV, after an oil change, which supports the idea that the new uncontaminated oil after being energized has a dielectric strength of 60 kV as suggested in the Guide.)

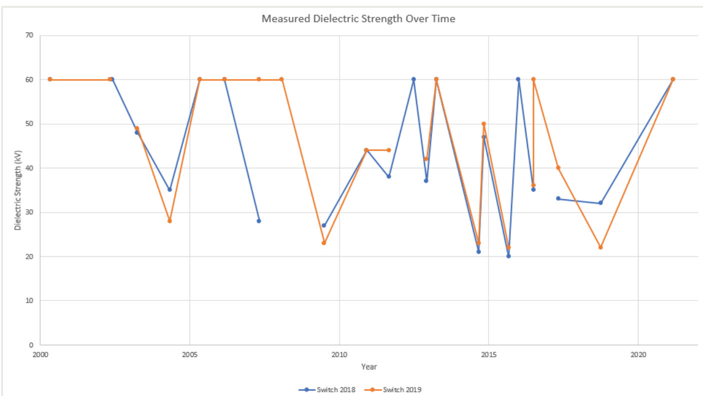

Figure 56: Measured Oil Dielectric Strength.

108. In the above graph, all the data points at 60 kV were assumed based on oil change dates based on the Switching Operations Log. Discrepancies between data sources limit the potential to draw any conclusions regarding contamination with high certainty, however; the rate of degradation of oil quality and the low-point of the oil quality suggests a potential for greater than expected oil degradation.

109. The expected shape of the graph is that the dielectric strength is at 60 kV after an oil change, and then decays.

110. There are varying, conflicting accounts of when the annual and five-year maintenance was conducted. Across all the documents, the most recent entry says that V73 (both switches included) was inspected on March 31, 2022 (Item ID: 179345-9), and November 15, 2021 (Item ID:177832-9). This information came from the SAM Maintenance Logs for V73.

111. There are multiple entries in the SAM log that indicate the oils inside SW2019 and SW2018 were sampled for the lab, and a field test was conducted. On the Oil Quality Historical Report, the last entry for either SW2019 or B is October 2018; after that, there is no data.

112. There are known discrepancies between the reports and information from the Cable Crew information. The annual inspection template (in the SAM log) asks if the gaskets, insulators, connections are okay, a field check of oil breakdown and an oil sample taken to the lab. The Technician insight is that a visual inspection is completed, but they don't inspect for a good seal, don't field check oil, and that oil sampling was stopped for a few years starting 2020/2021.

113. A sample of oil was taken from both SW2019 and SW2018 in March 2022, and was analyzed after the incident. The oil quality report is attached as **Appendix O**. The report showed that the measured value of the dielectric strength was 30 kV and 34 kV for SW2019 and SW2018 respectively. There was also a comment that noted 'Particles' for both samples. The oil samples also had over 18 ppm of water.

114. Considerably greater discussion is provided on oil properties and test methods in the Powertech Report.

115. From our review, there is likely an opportunity for modernization of the test procedure to better reflect modern standards for oil storage, sampling, testing and monitoring. It was unclear having to pull data from multiple systems that failed lab findings would result in a work-order to change, and it was unclear where in BCH responsibility rested for the oil testing program. There is also likely a need to coordinate when testing occurs given the standards now assume a performance of oil integrity after the equipment is energized, which is not addressed in any of the documentation reviewed.

116. Nevertheless, it is difficult to conclude as to the relevance of the oil quality integrity one way or another with respect to this Incident. On one hand there appears to be a pattern of degraded oil occurring in SW2018 and SW2019 with very low readings well below reference documentation in relatively short periods. On the other hand, there seems to be inconsistency in methods of taking samples in the field, an absence of modernization of methods to meet more current guides and test methods, gaps in the capture of all of the oil test data (field versus laboratory), no sampling of oil from the switch at the laboratory after the oil is changed, no follow-up oil sample after the equipment is energized, and unobservable controls in monitoring and oversight of the oil test program. There is no clear indication to suggest this Incident could have been predicted had a more robust oil-testing program been in place. On the balance, therefore, the oil testing program is not considered a contributing factor to this Incident.

6.0 EXPLOSION CAUSATION & CONTRIBUTING FACTORS

117. Based on the above, it is clear that the explosion occurred first, and the fire developed subsequently after. There is no fire scenario within the vault that is likely to lead to a switch explosion. This eliminates the cabling, fuse box, SW2018, and transformer as causing the explosion and fire. The unique overpressure damage and subsequent fire damage align with the explosion originating from SW2019.

118. Examination of the components of SW2019 confirmed that significant electrical arcing occurred causing spatter onto the walls of the switch, but not on the lid which was dislodged in the explosion. The occurrence of arcing aligns with the physical deformation of the switch housing, which dislodged the two insulating board assemblies from one end of their connections with the walls of the housing. This in turn allowed the electrical and fork contacts to move relatively free-form and arc to each other spattering molten debris on the walls. The physical damage aligns with the oscillography and the timing of the vehicle camera capturing the explosion and combined, it can be concluded that the significant electrical arcing within the switch is consequently related to the explosion and not a root cause.

119. Further, no indications on any of the individual components of SW2019 were suggestive of malalignment, pre-event physical damage, improper installation of any of the cables, or significant physical damage to the switch that would cause a failure.

120. In reviewing the pre-test procedure with the vacuum truck and the method of cleaning the switch during the five-year maintenance, no parameters were identified that would cause reason to suspect a contaminant infiltration during the procedure, and the service tag indicates the dielectric strength was appropriate.

121. In reviewing the 5-year work procedure of the gasket sealing the switch lid it was found the procedure lacked specific direction on inspection, did not have a mandatory gasket change-out period defined, and suitable parts were not identified or available. This opened the door to “field-fix” solutions to adequately seal the lid of the switch, using untested materials that were likely were not compatible with the installed equipment.

122. A region of corrosion was observed on the inside and outside of the right wall of SW2019. These rust regions align with three bolt openings near the front on the flange of the switch housing, on the front right side [**Figure 51**]. These patterns are not consistent with damage from fire exposure, nor the missing region of enameled paint along the flange, shown in **Figure 58**.

123. The extent to which the corrosion was further explored through additional metallurgical and chemical analysis is documented in the Powertech Report. Key findings are:

- Corrosion scrapings from the inside of the tank were found to have two forms of iron oxide, magnetite and hematite, as well as trace amounts of other compounds;
- The presence of magnetite is indicative of the corrosion being present pre-explosion and formation in an oxygen-reduced environment (i.e., when still pressurized with nitrogen).
- The presence of hematite indicates the corrosion occurred in a non-oxygen reduced environment, meaning the tank had lost its nitrogen seal over an extended period of time (weeks/months).
- Iron-oxide (rust) particles are highly conductive and will remain suspended in oil, and lead to a significant breakdown in dielectric strength of the oil (only a few ppm of iron-oxide leads to a greater than 10 kV drop in dielectric breakdown strength).
- Corrosion/rust residue from other areas within the switch housing were more spotted and closer to the surface, indicating it likely developed after the explosion and fire.

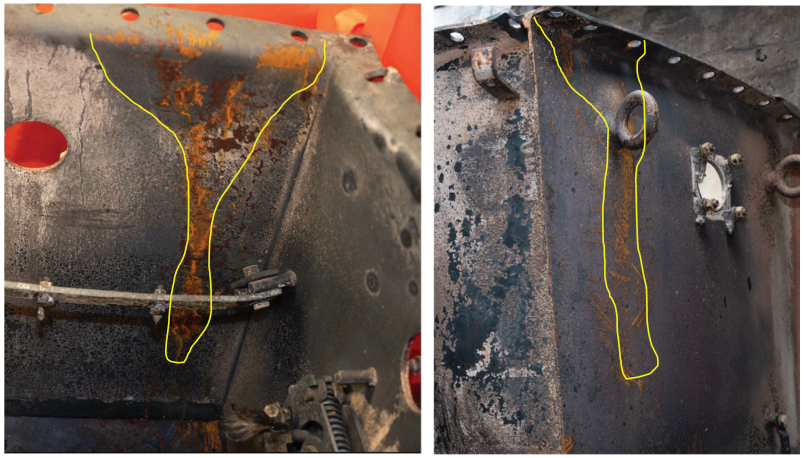

Figure 57: Corrosion region on inside and outside of the switch housing aligning with three bolt openings.

124. Further chemical analysis was also completed in a region of the right wall of SW2019 that visually did not appear to have any enamelled coating (paint) remaining, an observation that is inconsistent with exposure from the Incident events. The Powertech Report confirms that:

- The paint used on the inside walls of the tank was determined to be epoxy-based enamel from FT-IR analysis.
- The referenced region was free of any coatings or deposits meaning there was an absence of any paint in this region.
- Acetic acid from silicone could cause cracks in the paint, the paint lifting, or minor electrolytic corrosion as well as react with the Nebar seal causing a seal failure, water to leak into the tank, the paint to lift, and initiate the corrosion process.
- Collection of degraded enamel just outside the no-paint region had a different spectral pattern than other paint areas in the tank indicating a chemical degradation by more than just thermal exposure from the fire.

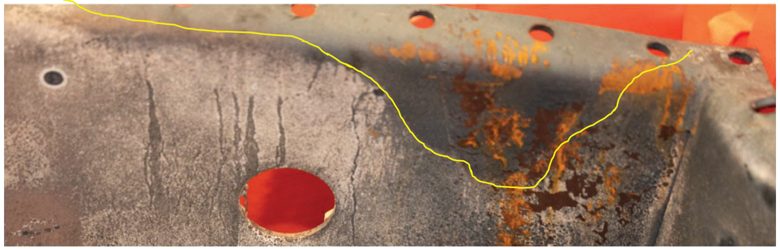

Figure 58: Region where no epoxy-enameled paint remained post-Incident.

7.0 SUMMARY AND CONCLUSIONS

125. The following summarizes the findings of the investigation:

<u>General</u>

a. The explosion and fire primarily involved BCH infrastructure and equipment. Two people were injured from the explosion. The glass doors and windows of the JJBean were broken, and the coffee shop had smoke and heat damage from the subsequent fire in V73. The adjacent Tractor restaurant had broken glass. The building façade had smoke damage up to five-storeys in height.

b. No abnormal substances or components were identified in the search or the subsequent lab testing that are indicative of any penetration into the vault by foreign ignitable liquids, nor was there any indication of an intentional act such as vandalism or sabotage.

c. The combined physical damage and subsequent chemical analysis support the cause of the explosion due to contaminant leaking into SW2019 allowing partial discharges to occur, which in turn created an explosive quantity of gases which were then ignited.

d. A chemical reaction between silicone and Nebar was the probable mechanism to damage the rim seal on the lid of the tank. This was visually evident due to the absence of paint remaining on the inside surface of the tank at that location and confirmed through chemical analysis.

e. The absence of enamelled paint on the right wall and presence of corrosion was indicative of a leak around three bolt penetrations, allowing the nitrogen to dissipate and air/moisture to penetrate.

f. The combination of acetic acid and/or moisture-initiated corrosion on the wall of the tank caused flaking and allowed iron and iron-oxide particles to free-float within the tank. Iron-oxide flakes are known at low concentrations to significantly degrade the oil and provide a mechanism of partial discharges.

<u>Potential Operational Considerations</u>

g. In general, the BCH procedure with respect to gasket inspection and replacement provided limited direction to support field operations doing maintenance. Specifically, there was no guidance on what to look for in determining whether there is contamination or failure of the gaskets, there was no defined maximum life of the gaskets, and there were no replacement parts available for crews to replace the gaskets with an appropriately fitted and compatible part.

h. This left crews to “field-fix” any failed gaskets which required cutting and bunching strips of Nebar that may or may not have been compatible and using commercially available RTV silicone which is not compatible with Nebar or the operating environment.

i. Gathering information from oil tests required information from multiple different sources, including Switching Operation Logs, V73 SAM Maintenance Log, Oil Quality Historical Report, RAL2009 (draft). It was found that the oil test program was misaligned with changes in industry standards, lacked documentation and centralized monitoring, and no trending had been completed that would have identified a pattern of oil degradation.

j. However, it was also not possible to connect oil-degradation patterns to this Incident, which is more likely to have occurred between maintenance cycle times and may not have been identified even if a more robust oil monitoring program was in place. Although there were indications of oil degradation in the testing, it was not unique to SW2019. This is more likely attributed to other factors.

k. The testing of oil at the 5-year oil change in SW2019 was found to meet industry norms. The after-Incident recovered oil sample from the 1-year check in March 2022 was also above industry norms (see Powertech Report). Therefore, it is likely that significant degradation leading to the explosion occurred only after these tests were performed, and therefore would not have been identified even if the oil had been tested in March 2022.

l. A more enhanced monitoring program could have included tracking of whether switches remained pressurized with nitrogen at the time of the five-year maintenance. This could have identified issues with leaking seals in the lids of the switches.

126. In conclusion, the failure occurred due to a leaking gasket in the lid of SW2019 caused by incompatible products and contamination, compromising the nitrogen seal and etching the surface of the enamelled paint. This allowed for corrosion to occur in the steel wall of the tank below the surface of the paint, which in turn allowed flakes of iron-oxide to mix with the oil, leading to partial discharges and the accumulation of combustible gases in the tank which ignited and caused the explosion.

Appendix A: CV of Peter Senez

Attachment 1

SENEZ CONSULTING LTD — FIRE SCIENCE & ENGINEERING

Peter L. Senez, M.Eng., P.Eng.

About

Peter Senez is a professional engineer with 25 years of experience in fire safety, fire protection engineering and fire investigation. He is well practiced in complex building and fire code design matters and has worked extensively as a forensic engineer relative to origin, cause, equipment failure and fire spread. In addition to forensic work, Peter is actively involved in fire and life safety aspects of construction projects across the country. Peter is currently doing research at the University of Waterloo on fire dynamics in residential fires. This includes response of smoke detectors and considerations for tenability and human response in residential fires. This research project was initiated in 2015 and is expected to complete in 2022.

Peter is also Chair of the SFPE Scientific and Education Foundation which provides oversight on research in fire engineering through the Society of Fire Protection Engineers.

Contact:
psenez@senezco.com

P: 604-449-1688
M: 604-315-9060

Education:

PhD Candidate – Mechanical Engineering (Fire), University of Waterloo, expected completion 2022

Master of Engineering – Fire Protection Engineering, University of British Columbia, May 1997

Bachelor of Engineering – Mechanical Engineering – Design, Concordia University, May 1993

Professional Engineering Licensing:

Alberta
British Columbia
Manitoba
Ontario
Saskatchewan

Work Experience Overview

2019-Present – Principal and President of Senez Consulting

2015-2018 – Executive Vice President, Jensen Hughes. Led the expansion of Canadian Operations from coast to coast and expanded service lines in industrial, nuclear and forensics vertical markets. Subsequently led the expansion of the global forensic services practice with a multidisciplinary team, including opening an office in London, UK, and expanding service lines into new markets. Responsible for sector strategic direction, planning, interview and integration of acquired firms, as well as leading large and complex design and forensic engineering projects.

2003-2015 – CEO & President, Sereca Consulting. As one of the three founding partners of the company, led the expansion of the organization from infancy to the largest Canadian specialty fire and forensic engineering firm. Routinely involved in design, build, operate and maintain projects and infrastructure projects. Responsible for global strategy of the organization and led the expansion of the firm into Singapore, Calgary, and Toronto through a combination of organic growth and acquisitions. The company was sold to Jensen Hughes in 2015.

Other Past Postings

Senior Forensic Engineer, Fire Group, MacInnis Engineering Associates, Vancouver, BC, 1999-2003

Fire Protection Engineer, Locke MacKinnon Domingo Gibson & Associates, Vancouver, BC, 1993-1999

Fire Protection/Mechanical Consultant, Public Works Canada – Architectural & Engineering Services, Vancouver, BC, July-September 1993

www.senezco.com

Professional Affiliations:

Society of Fire Protection Engineers

National Fire Protection Association

International Association of Fire Safety Science

Current & Recent Technology Advancement & Research:

Full-scale burn series in 2 storey house studying ignition, fuel volatility, ventilation.

University of Waterloo series of full-scale burns studying flame spread, heat release rates, fire patterns and furniture constructs in ventilation-limited fires.

Fire dynamics of fires for forensic applications with and without fire patterns and differences in fire patterns.

Risk of large-loss fires in residential homes due to upholstered furniture.

Risk of ignition fire development in commuter trains.

Effects of tunnel ventilation and heat release rate of fires.

Computer fire modelling in design and forensic applications.

Sergeant/Fire Inspector and Fire Fighter, Town of Otterburn Park, Otterburn, QC, 1988-1993

Select Publications

Repeatability of Underventilated Compartment Fire Testing with Complex Fuel Packages, Senez, P., Mulherin, P., Weckman, E., Proceedings of the 15th International Fire and Materials Conference, February 6-8, 2017

Case Study and Computational Modelling of the Impact of Fire Retardant on Fire Spread for Metal Building Insulation, Senez, P., Milford, A., Calder, K., Fire Technology, November 2016, Volume 52, Issue 6, pp. 1983-2003

The key modes of fire spread in wood-framed apartment buildings – a Canadian perspective, World Conference in Timber Engineering, Calder, K. and Senez, P., 2016

Influence of moisture and organic content on cigarette ignition of potting soil samples, Robbins, A., Bodnar, M., Lejeune, M., Senez, P., Fire & Materials Conference, San Francisco, USA, February 2015

The Risk Basis for the Height and Area Limits in US and Canadian Buildings Codes, Calder, K., McPhee, R., and Senez, P., SFPE 10th International Conference on Performance Based Codes and Fire Safety Design Methods, November 2014

Computational Analysis of Ignition Source Characteristics on Fire Development in Rapid Transit Vehicles, Milford, A., Senez, P., Calder, K., Coles, A., Proceedings of the Third International Conference on Fire in Vehicles Berlin, Germany, October 2014

Electronic Data Available for Fire Investigation, Lejeune, M., Senez, P., International Symposium on Fire Investigation, University of Maryland, Baltimore, September 2014

The Risk Basis for Height and Area Limits in North American Building Codes, Calder, K., Senez, P. and McPhee, R., World Conference in Timber Engineering, August 2014

Computation Study of Tunnel Ventilation Effects on Fire Development in Rapid Transit Vehicles, Milford, A., Calder, K., Senez, P., Coles, A., Proceedings of the 6th International Symposium on Tunnel Safety and Security, Marseille, France, March 2014

Fire Loss Statistical Considerations in Relating Failure and Building Damage to the Building Code Objectives, Senez, P., Calder, K., and Li, H., 13th International Interflam Conference, London, UK, June 2013

Experimental and Simulated Analysis of Room Fire Theory for Forensic Applications, Senez, P., Calder, K., Proceedings of the 9th International Fire and Materials Conference, San Francisco, CA, February 2005

BC Hydro Electrical Explosion Incident – Marine Building, Downtown Vancouver

Appendix B: Powertech Report

Powertech

Report ID: IR-04215.39
Revision: 0 Issued: 2023-06-06
Privileged and Confidential

Investigation into Explosion of Switch at BCH Vault 073

Privileged and Confidential – Developed in Preparation for Litigation

Investigation Report #: IR-04215.39

Project #: PL-04215.39

Report Date: June 06, 2023

Prepared for:

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Senior Manager, Legal Services
BC Hydro
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The Power of Trust. **The Future of Energy.**

INVESTIGATION REPORT

Prepared by: Stuart Chambers, PhD, PChem, MCIC
Technical Specialist/Subject Matter Expert
Technical Specialist/Consultant – SDChambers Consulting
PChem Number: 2015397

PROFESSIONAL
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K. W. CHENG
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2023-06-06

Approved by: Powertech's Permit to Practice No:1002531
Kevin Cheng, P. Eng.
Sr. Engineer, T&D Asset Management
Powertech Labs

Date of Issue: June 6, 2023

TABLE OF CONTENTS

Contents

LIST OF FIGURES

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1 BACKGROUND

On Friday, February 24, 2023 shortly after 6pm, an explosion at BC Hydro Vault 073 in downtown Vancouver occurred (Figure 1).

A sustained fire was also observed inside the vault, after the initial explosion. Once the burning in the vault was completed, it was observed that a transformer, two switches, a fuse box, and cables all located from inside Vault 073 were damaged from the fire. It could also be observed, from the street, that the switch 2019 had no lid on top and appeared void of oil and most internal components. Later in the evening, metal plates were placed on the street openings to isolate the contents of the vault. The area was then fenced off and with security personnel posted for the night.

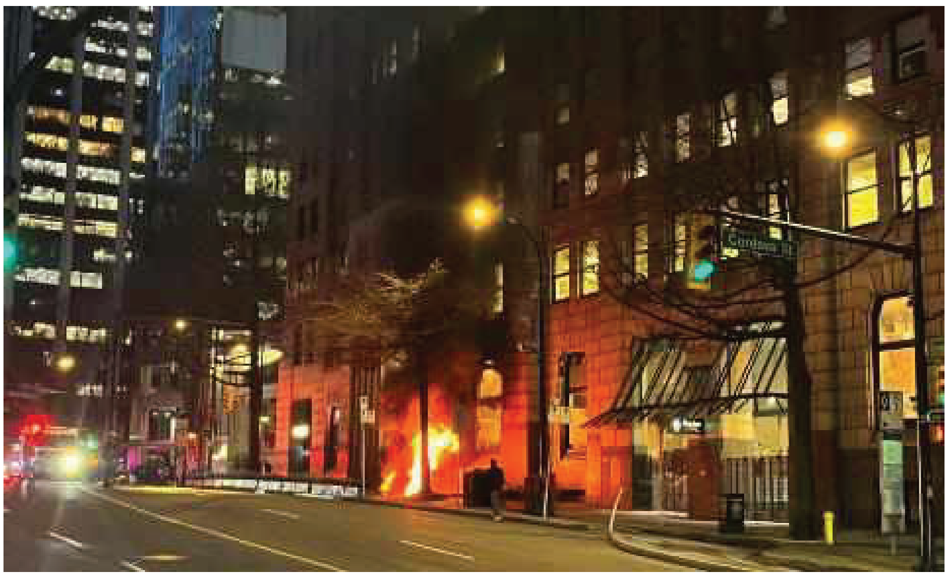


Figure 1. Photo of fire emanating from Vault 073 on February 24, 2023

The following day, Powertech personnel, BC Hydro personnel, an independent fire investigator, city maintenance personnel and others returned to Vault 073 in the afternoon (February 25) to perform a more thorough visual examination of the vault from street level. As a result, on February 28, personnel returned to the site of Vault 073 to collect samples and remove large pieces from the vault for further examination and analysis at Powertech Labs. Switches from other vaults (Vault 007 and Vault 055) were later supplied by BC Hydro to act as comparative systems.

2 INSPECTION OF SWITCHES AND SAMPLES COLLECTED FROM VAULT 073

2.1 Visual Inspection of Switches

2.1.1 Switch 2019 (auxiliary switch - heavily damaged from Vault 073)

The tank of switch 2019 (the origin of the explosion) had a deformed body, bowing out at the middle predominantly at the front and back (Figure 2). As a result, when trying to operate the switch mechanism (that was locked in the open position when received), the mechanism would move until coming in contact with the bowed wall. From the rigid movement of the switch that could be achieved when unlocked, it is not suspected that the switching mechanism had malfunctioned prior to the explosion.

The lid from the switch was collected as a separated sample item (was not attached to the switch during sample collection), and all the bolts that were used to hold down the lid were not present, with the exception of the back row, which was composed of threaded pins that were part of the tank. Additionally, it was observed that the metal on the bolt holes on the front centre and front right were deformed. The second to last bolt hole on the front right was both bent and appeared twisted at the edge facing the front (Figure 3). Figure 4 presents a photo of the lid from switch 2019.

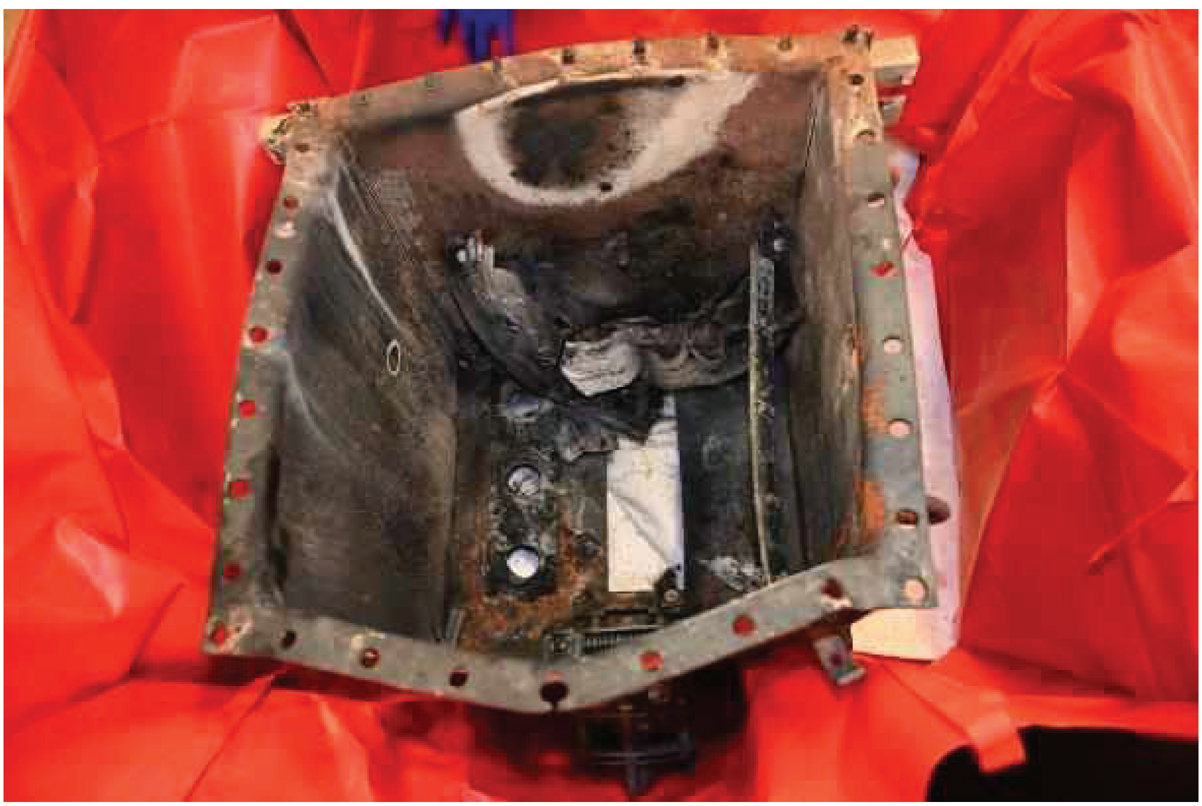


Figure 2. Top down view into switch 2019 (as received)

Figure 3. Close up of bolt holes on front right of switch 2019 (view from inside of tank)

Figure 4. Bent lid from switch 2019

At the back of the switch 2019 tank, a large, dark, discoloured patch with a white ring was observed (Figure 5). A similar small, dark patch with a white ring was also observed approximately halfway up on the left inside the tank. In both cases, small metallic-appearing deposits were in the middle of the dark patches/rings. These observations are consistent with a hot material contacting the wall, transferring heat outwards, damaging the paint on the inside of the tank in a radial fashion.

Figure 5. Close up of white rings on inside of the switch 2019 tank

At the front of the right side of the tank, a distinguishing path of orange discolouration and material flaking was observed from the top edge of the tank to approximately one-quarter from the bottom of the tank (Figure 6). Additionally, localized spotted sections of orange-brown flecks along the back edge to the right back corner of the switch 2019 tank, as well as the back left corner itself also showed signs of orange-brown discolouration. The ground bar, some of contacts (showing various degrees of damage), and the switching mechanism remained inside the tank of switch 2019, along with was carbonized pieces (charcoal) of material, soot and dirt, as received at Powertech.

Figure 6. Close up photos of orange-brown areas inside of switch 2019 tank

Upon retrieval of switch 2019 and corresponding recovered components from the vault, the PILC termination that is found bolted to the bottom of a non-damaged switch was intact and on the ground of the vault, below the switch 2019 housing. The damage to the top of the PILC termination, the broken insulators, is consistent with the termination dropping and rebounding off the ground (Figure 7).

Figure 7. PILC termination from switch 2019

2.1.2 Switch 2018 (active switch from Vault 073)

The lid on top of switch 2018 required all the securing nuts to be loosened and removed with wrenches to be able to remove the lid. Although subject to the fire, transport, etc. all nuts required some force to unscrew, and could not be removed with bare hands. Even with the nuts were engaged, a small gap could be observed between the lid and the top edges of the tank (the sealing edges supporting where the gasket would be). Upon removing the lid, small sections of black solid were present around the bolt holes in some areas, indicating the presence of a solid gasket material once being present (i.e., before the fire).

When fully removing the lid of switch 2018, the internal components were discoloured by carbon particles/soot from the vault fire, but were intact, showing minimal signs of physical damage (Figure 8).

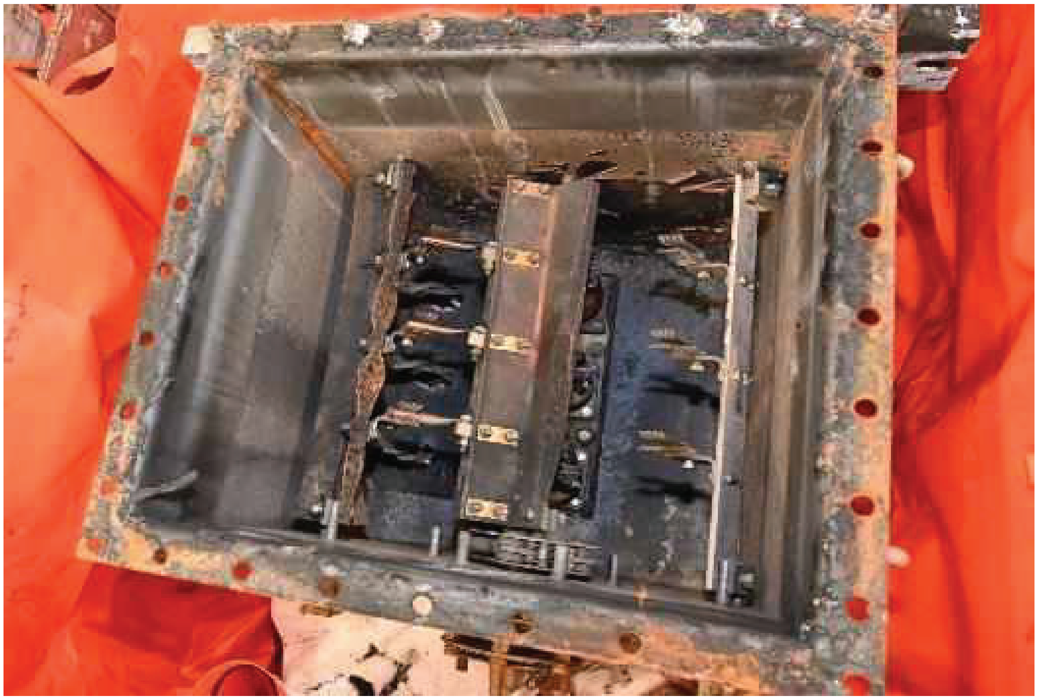


Figure 8. Top down view into switch 2018 (as received)

As received, switch 2018 was locked with a pad lock in the closed position. Cutting the lock and manually activating the switching mechanisms from closed to open, open to ground, and vice versa, the spring-loaded mechanism would “snap” into the blades into the set position instantaneously. Additionally, the switching mechanism was tight (i.e., minimal “play”/”slop” in the blades), producing only a few millimetres of sway if the switching mechanism rod was manually shaken. Even with heat and smoke damage, the switching mechanism of switch 2018 appeared fully functional and had not malfunctioned before the explosion in the vault.

Similar to the inside of the tank of switch 2019, the back left corner of the switch 2019 tank showed some orange-brown residue on the edge and down the inner corner wall, as well as along the front edge of the tank. However, unlike switch 2019, the orange-brown residue was more superficial (i.e., not as deep into the metal). Additionally, in all observations, the orange-brown residue in switch 2018 was not a continuously connected path from the edge of the tank down the side of the inner walls (Figure 9).

Figure 9. Close up of orange-brown residue on walls of switch 2018

On the back wall of switch 2018, a thin, top peeling layer was observed. Analysis of the layer identified it as a degraded epoxy-based base layer (i.e., organic; carbon-based) that was the coating for the inside of the switch tank. A fully intact, non-degraded white coating sample from another switch from another vault (vault 055, switch 1595) was also analyzed and was identified as an epoxy-based enamel. This supports that switch 2018 (and switch 2019) contained an epoxy-based enamel coating in the tank. Epoxy-based enamel paints typically have a degradation range of 200-350^{o}C. By the top coating inside the tank of switch 2018 chipping and peeling (and not being present in places at all), it indicates that the inside of the tank of switch 2018 did also experienced temperatures in excess of 200^{o}C. Additionally, by the coating not being present at the bottom of the tank, not being present on most of the walls, and appearing degraded propagating from the bottom to the top, indicates the predominant heat source originated from the bottom of switch 2018. Since the PILC termination and cables entering the tank melted under the switch (Figure 10), it provided an opening for the oil from inside the switch to leak out and propagate the fire in the vault.

Figure 10. Underside of switch 2018 (in field)

In addition to the missing and degraded paint inside the switch 2018 tank, the fibreglass contact bar on the left side of the switch was discoloured and expanded in sections (Figure 11), and the gasket beneath the lid had carbonized, being completely consumed in sections (Figure 12). These observations also indicate that the inner components of the tank where exposed to high temperatures (>200^{o}C) for a prolonged period of time.

Figure 11. Insulating bar from switch 2018 showing expansion due to be being exposed to high external heat

Figure 12. Close up of a region of carbonized and damaged gasket of switch 2018

2.2 Metallurgical Analysis of Metallic-Appearing Materials

2.2.1 Metallic-like splatter on tank walls, selected blades, and contacts

In several locations on the walls of switch 2019, metallic-like globule splatters were observed (Figure 13). In order to determine the composition of the metallic-like globule splatters on the walls of switch 2019, the residues were collected by using specialized silica-carbide abrasive discs and rubbed against the bulbous deposits.

Figure 13. Selected photos of metallic-like splatter on the tank walls of switch 2019

The silica-carbide discs were then analyzed by scanning electron microscopy equipped with an energy-dispersive x-ray spectroscopy (SEM-EDS) to determine which elements were present in the deposits. Almost all samples collected from the metallic-like globule splatters contained carbon and aluminum as the predominant elements; iron, calcium, and zinc as lesser present elements; and sulphur and magnesium as trace elements. Silicon and oxygen could not be analyzed for as they were part of the composition of the collection disc. Copper was not observed by the SEM-EDS analysis in any of the globules.

To try to determine the source of the metallic-like globule splatters, SEM-EDS analysis of two contacts from switch 2019 were performed (Figure 14). The bulk of the blades were determined to be almost exclusively copper, with minor amounts of aluminum, tin, and zinc on their surfaces. However, at the connection point of the blade to the switching device, the o-rings and bolts were observed to have similar presence of aluminum and copper, with minor amounts of iron, magnesium, and tin.

Figure 14. Blade assemblies analyzed from switch 2019

On the surface of the bulk of the blades were darker regions (Figure 15). When analyzed by SEM-EDS for their elemental composition, it showed the dark material to contain copper, but aluminum, tin, calcium, and carbon were the predominant elements. Zinc was also present in minor amounts. When scraped with a blade or abrasive disc, the black region would be removed, exposing a copper surface. This indicates the aluminum on the actual blades was a result of a deposition and not an intrinsic part of the blades.

Figure 15. Dark side/section of switch 2019 blade analyzed

In additional to analyzing the blades for elemental composition in switch 2019, two selected contacts were analyzed. As shown in Figure 16, both contacts showed damage.

Figure 16. Selected contacts analyzed by SEM-EDS for elemental analysis
Left: Bare Contact; Right: Contact with metallic mass at the end

The bare contact showed the bulk material of the blade to be copper. Lesser amounts of aluminum, carbon, chlorine and cobalt were also observed in the blade material sample. Meanwhile, the large globular mass enveloping the prongs of one of the contacts was identified as being almost exclusively aluminum, with minor amounts of carbon, chlorine, magnesium, tin, and zinc. Copper was observed in sub-trace concentrations in the large globular mass. These observations indicate that the aluminum observed on the walls of the tank were not from the blades or contacts of the switch, but instead from an alternate source.

2.2.2 Orange-brown residues (metal oxide appearing residues)

For the analysis of the orange-brown residues, based on the composition of the tank and colours observed, iron oxide (rust) was thought to be the source of the residue. However, the chemical form of the rust can provide insight into whether the rust was generated in an oxygen-starved environment (i.e., in oil under nitrogen), if the rust was generated with abundant oxygen (i.e., a leak into the system), or a possible combination of both scenarios.

To provide insight in the form of rust, a sample of the residue was collected from the defined section of deterioration at the right front wall of switch 2019 by physically scraping it, and the sample was analyzed by x-ray diffraction analysis (XRD). The XRD pattern of the rust sample, along with a reference analysis pattern of magnetite and hematite (forms of iron oxide) are provided in Figure 17 and Figure 18.

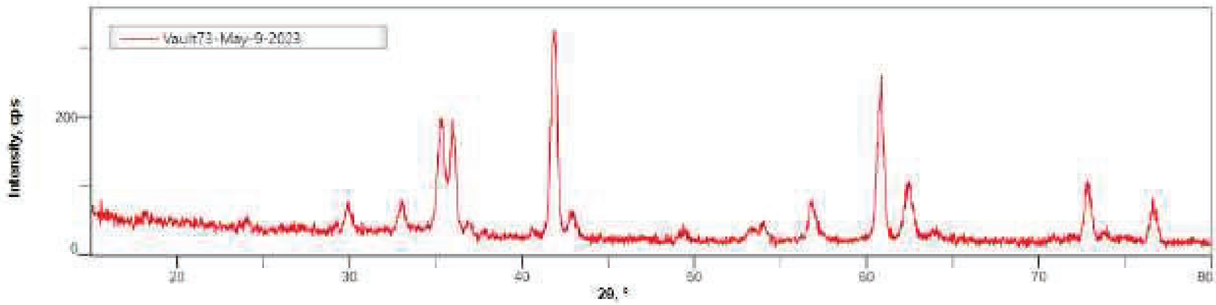


Figure 17. XRD pattern of the collected rust sample from switch 2019

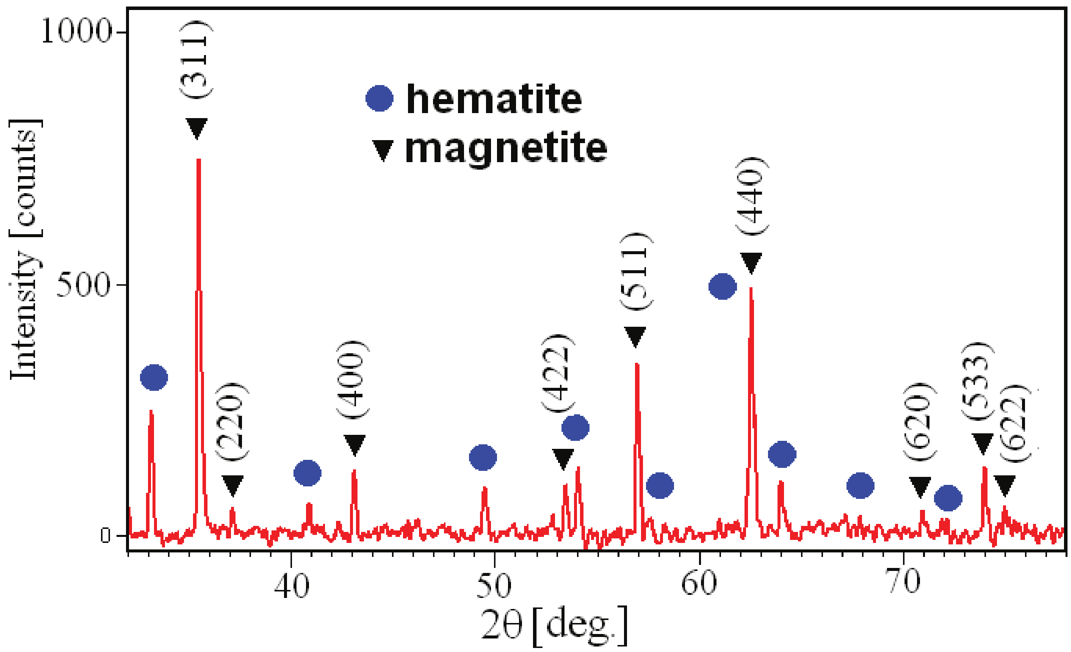


Figure 18. Reference XRD patterns for hematite and magnetite

When compared to the reference libraries and XRD patterns for hematite and magnetite, the sample was observed to contain both forms of iron oxide, as well as trace amounts of other compounds. The presence of magnetite indicates the formation of some of the sample under an oxygen-starved environment (i.e., under nitrogen blanket, moisture trapped under a surface by the wall).[1-5]

With the observation of magnetite, and knowing that the formation of magnetite is also slow compared to hematite, it indicates moisture was in contact with the steel for several weeks or longer. This signifies that the rust observed at the right front of the tank had been present in the system before the explosion, and not a result of being exposed to damage and water after the explosion. This finding is also supported by the observations of the investigative personnel, who saw rust at the same location inside the tank when on-site, the day after the explosion. By hematite also being observed in a significant amount, with flaking and channelling by the right front corner, this suggests rust formation also occurred in a non-oxygen reduced environment. If the switch tank eventually lost its seal, releasing the nitrogen and allowing air and moisture to get in, hematite would also form.

2.3 Switch Rim Hardness

To explore the possibility that the metal of the rim of switch 2019 may have been compromised before the explosion in vault 073, hardness measurements around the rims of switch 2018 and switch 2019 were performed. Using a portable Leeb Hardness tester, multiple points around the rim of each switch was tested three times and the average value was reported for a testing point (Figure 19).

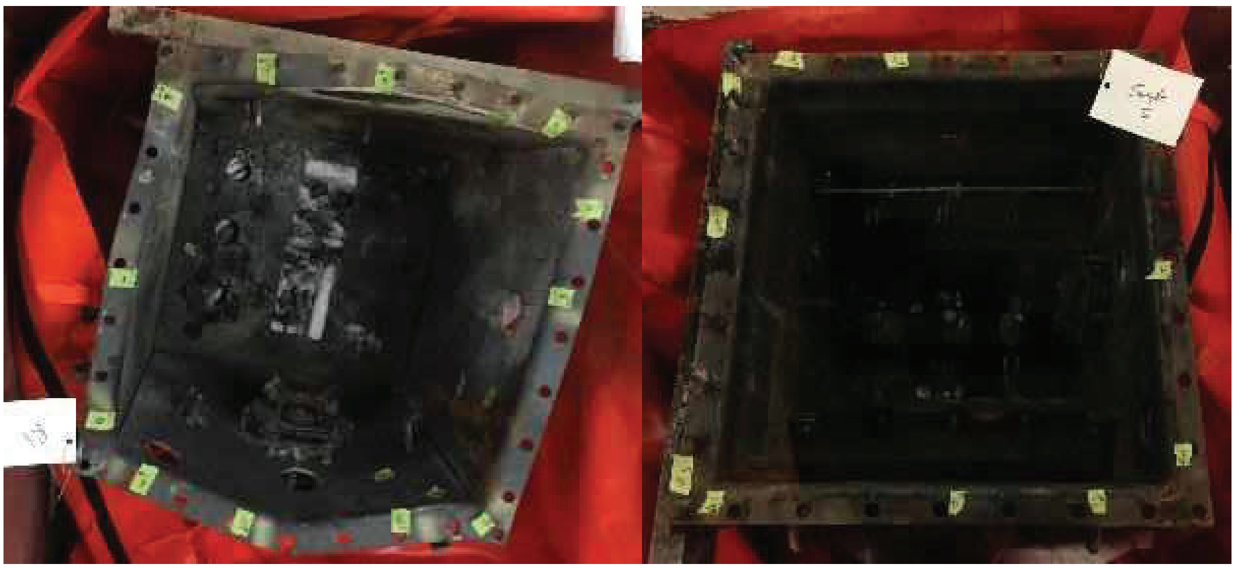


Figure 19. Locations on Switch 2019 and Switch 2018 subjected to Leeb hardness testing

The Leeb hardness test is of the dynamic or rebound type, which primarily depends both on the plastic and on the elastic properties of the material being tested. The results obtained are indicative of the material strength, and dependent on the heat treatment of the material tested. The Leeb hardness test is a superficial determination only measuring the condition of the surface contacted. The results generated at that location do not represent the part at any other surface location, and yield no information about the material at subsurface locations. The precision of a Leeb hardness tested is +/- 5, with acceptable range for steels typically being +/- 20 units (or ranges of 40 units).

The average values observed for within the typical ranges (343 to 383). Switch 2019 had many readings of less than 300, showing softer areas near the back and side of the switch closest to the transformer. However, these readings may have been due to softening from the deforming and heating of the metal from the explosion and resulting fire. The data for the hardness of the rims of the two switches did not indicate a potential issue with the hardness of the metal before the explosion.

2.4 Oil Used in Switches and Historical Oil Property Analysis

The oil that was used in the switches was Soltex 2288 (or Electrofill 2288) produced by Soltex Inc. The mineral oil is a type I, naphthenic-based mineral oil with the composition as presented in Table 1.

Table 1. Composition of Soltex 2288 Mineral Oil

Compound	Percent Composition
Hydrotreated light naphthenic petroleum distillates	50-80
Hydrotreated light paraffinic petroleum distillates	20-50
Solvent-refined light naphthenic petroleum distillates	0-5
Solvent-refined heavy naphthenic petroleum distillates	0-5
2,6-di-tert-butyl-p-cresol (oxidation inhibitor)	< 0.1

Although not specifically defined (due to being a trade secret), Soltex 2288 can contain a lower amount of paraffinic content compared to historic and other modern type I insulating naphthenic-based mineral oils (the dominant oil type). Although this is typically considered a beneficial trait in modern electrical equipment, this can be detrimental to older equipment components that are not always as compatible with such oils. As a result, older seals and paints used with low or high paraffinic content oil may degrade quicker than with insulating mineral oils that are more balanced. The potential effects of interaction, such as softening or filler extraction, will not be sudden, but will occur over longer periods of time (i.e., weeks, months, or years).

Soltex 2288 is also a type I insulating oil, indicating that it should only be used on equipment where normal oxidation resistance is required (i.e., sealed or blanketed units). In free-breathing equipment or equipment where the presence of oxygen would be highly detrimental to the operation/health of the equipment, type II insulating oil is recommended for use. For the switches in vault 073, if air entered the tank through a leak, the oil would have a limited resilience to oxidation (i.e., higher possibility of degradation product formation) with prolonged time.

The dielectric breakdown voltages of the oil in the vault 073 switches from 2009 to 2022 (the last year samples were provided to Powertech for analysis) are provided in Table 2.

Table 2. Historical Dielectric Breakdown Voltage

Date	Dielectric Breakdown Voltage (KV) ASTM 1816 (2 mm)		Water (ppm)	
	Switch 2018	Switch 2019	Switch 2018	Switch 2019
March 2022	34	30	19	18
Oct 23, 2018	32	22	20	21
May 29, 2017	33	40	13	16
July 1, 2016	35	36	28	28
Sept 29, 2015	20	22	-	-
Nov 27, 2014	-	50	-	15
Oct 18, 2014	47	-	14	-
Sept 11, 2014	23	21	-	-
Dec 05, 2012	37	42	-	-
July 17, 2012	-	44	-	-
Sept 13, 2011	38	30	-	-
Dec 28, 2010	44	44	-	-
July 24 2009	27	23	-	-

Note: - indicates no test performed

In several instances of the analyzed oil sample, the dielectric breakdown value was near or less than 40 kV (2 mm gap), which is the lower limit for in service equipment (< 69 kV) as per IEEE C57.106-2015. With the exception of in 2010 and the second measurements of both switches taken in 2014, all measurements were close to or lower than 40 kV. As part of BCH procedure, the oil is field tested from the drying unit before being introduced into the switches. Based on international electrical oil standards (IEEE, IEC), new oil for use in electrical equipment should be no less than 35 kV as received from a manufacturer and more than 45 kV prior to energization. By all the dielectric breakdown values of the oil samples being lower than 45 kV, with the exception of the second readings in 2014, it is indicative that the oil was degraded and/or became contaminated after filling. In September 2014, the dielectric breakdown of the oil was very low on both switches (22 +/- 1 kV). The increase in dielectric breakdown strength in the next readings of both systems can be contributed to the switches undergoing an oil change after September 2014 and then being tested only 1 or 2 months later (likely not enough time for degradation and/or contamination of the oil from an item such as a leak).

Water first started to be recorded for the switch oil in 2014. Mineral oils should contain as little water as possible when introduced into electrical equipment, with less than 10 ppm water being the industry standard. The work procedure for the switches required the use of oil directly from the mobile oil-conditioning unit. The oil-conditioning system (max. 400 L) processes the oil by heating, circulating, and reducing vacuum on the oil for at least a few hours before use. However, no moisture test is performed by crews prior to introducing oil into the switches or just after filling the switches. As moisture increases, the dielectric breakdown of oil decreases. As the units do not contain paper (which produces water with degradation), the moisture observed in the switches is from either from when the oil was first introduced into the switch, or as a result of moisture and air leaking into the switches. In a sealed system, the moisture should not change, or change by less than 5 ppm if paper is present, over the course of a year. By observing large differences in the oil water content each year tested, and water contents being higher than 10 ppm, this is suggestive that a break of the seal, allowing water, air and other environmental gases in was present into the switches for several years. These elevated concentrations could be in part due to inconsistent sampling methods used, but observing an overall elevated concentration of water through many samples suggests a more significant issue than simply sampling.

2.5 Gaskets Used in Systems

2.5.1 Gasket Material

Using a comparable switch from vault 055 (switch 1595; similar design – same vintage, similar oil volume, the same components and operating mechanism, slight difference in internal bus), a composite gasket was used as the top seal. The material used was a combination of natural cork and a rubber. As confirmed by BC Hydro crews, the gasket material in the switches were only visually inspected for significant cracking, deformation, or other damage, once every 5 years, as per the BCH maintenance standard (BC Hydro Distribution Maintenance Standard ES-64-C-03.01). If no significant deficiencies were visually observed during the maintenance, and a positive pressure was thought to be observed by the field personnel at the start of the maintenance (observed by a short, audible “hissing” noise), the gaskets were not touched by field personnel.

The gasket material used on the switches has a trade name of Nebar (confirmed by BCH field maintenance personnel). Nebar is composed of a rubber chosen for an application, bonded to cork. The material is formed into a flat sheet and cut into the required gasket shape to seal flat surfaces against fluid leakage (Figure 20).

The gaskets in the switches were not always single pieces of Nebar with holes punched out for the bolts. Instead, the gaskets were composed of four separate strips (one for each side of the tank) of the Nebar, with holes punched to allow the bolts to go through. Nebar materials are for use at temperatures less than 100°C (and no more than 120°C). Additionally, Nebar materials should only be used at low internal system pressures (5 bar; 60 PSI or below). Depending on the type of fluid contained in the equipment, various grades of Nebar can be used. However, no Nebar material should be used for sealing highly acidic or highly alkaline fluids, or for fluids that are slightly acidic or alkaline for extended periods of time (months or years), as the non-neutral pH will degrade the cork. To specify a Nebar for a particular application, it is always recommended to contact the manufacturer of the Nebar gaskets to determine which type and if any Nebar material is appropriate for the application.

Figure 20. Photo of some types of Nebar sheets

By Nebar utilizing natural cork as part of its composition, it needs to stay in contact with a liquid to keep it moist and free of shrinking, cracking, and losing elasticity. On the vault side of the gaskets, the vaults are typically humid. However, during summer months of lower precipitation, or winter months of higher precipitation, the humidity of the vaults can fluctuate. In either case, the change in humidity can cause swelling or shrinking of exposed Nebar, both cork and rubber (Figure 21). By the gaskets in the switches being composed of 4 separate pieces, by shrinking or swelling there is the increased risk of leaks forming at the interfaces of two sides. For example, if the gaskets shrunk or dried out at the interface of two sides, the seal could be lost. Similarly, if the gasket overlapped or significantly swelled at a corner, gaps could be formed to break the seal and cause a leak, or the material itself may start to mechanically crumble. Even if gasket was one piece, similar effects could be observed.

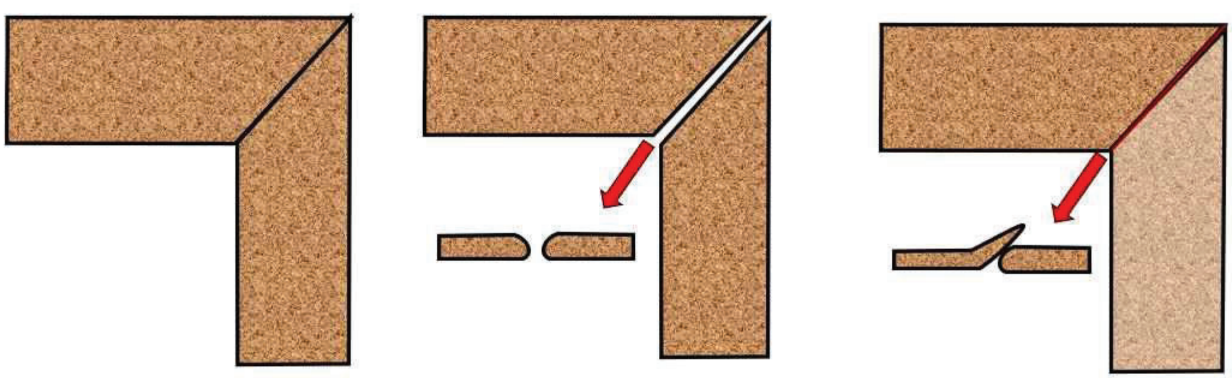


Figure 21. Depictions of effects of shrinking or swelling of gasket material
Left: A good corner interface of a gasket; Middle: Effect of shrinking; Right: Effect of swelling

Once the cork and/or rubber have deteriorated, they are compromised and do not self-repair. Additionally, if the vault becomes warmer from outdoor climate temperature, or from increased loading of the transformer also contained in the vault, the water in a vault can start to react with the Nebar (given high enough temperature and/or exposure time), causing degradation. At some point of deterioration, the Nebar will form microcracks, voids, etc. Some of these defects will not become apparent until the gasket is physically disturbed (i.e., opening the lid or vibrations are experienced), or when a change in pressure is experienced (i.e., quick release of nitrogen headspace, overfill of nitrogen, generation of gases from switch). As a result, the defects can be missed with just performing a visual inspection. Additionally, the leaks generated may be slow, taking hours or days to register a detectable reading on an analogue gauge. The ability to detect possible leaks is also made challenging by using a traditional low precision gauge. Additionally, as part of the 5-year maintenance procedure, the system is pressurized and depressurized by nitrogen before filling with oil. Although this provides a sealing check, it also creates additional stresses on the seal that could create a small, undetectable leak, when subsequently filled with oil.

In cases were the gaskets were observed to have visible degradation and/or did not appear to have a positive pressure at the start of the 5-year switch maintenance procedure, two potential correction paths were taken by field staff: 1) new pieces of Nebar were cut from new bulk material at BCH stores, to replace only the sides that looked damaged; 2) room temperature vulcanized (RTV) silicone rubber was applied in excess (all over the old gasket without removal, or in locations of suspected leakage)

In the case of applying new Nebar, or if not initially machined properly, if the holes of the Nebar were not cut to be flush with the edge of each bolt, then there would be less material available to seal the system than with a properly cut gasket (Figure 22). With less sealing material present in areas, the potential for microcracks or voids to form and create slow leaks is increased. If the holes were cut too small or not cut exactly in line with the bolts, the Nebar sealing material could become bent, cracked, folded, and/or torn, creating a location of stress and allowing for an increased possibility of a leakage forming.

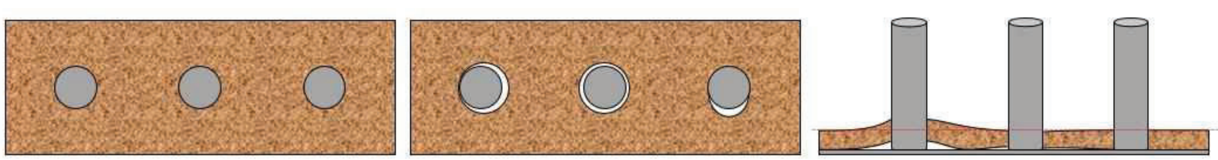


Figure 22. Diagram of possible holes made for gasket material
Left: Good bolt interface; Middle: Too big of holes; Right: Gasket hole made too small

2.5.2 Nebar Gasket and Chemical Compatibility

2.5.2.1 RTV Silicone

In the case where RTV silicone was applied due to a leak being detected or thought to be highly likely, excess silicone was placed directly only and around the untouched gasket before the lid was placed back on at the end of the 5-year switch maintenance procedure. In some cases, more RTV silicone rubber was applied along the edges of the seal and around the nuts and bolts holding the lid. Importantly, the RTV silicon used on the switches did not have a list of specifications or where from an approved list of products. With so many variations of RTV silicones (i.e., manufacture, application type, cure time, etc.) a large range of chemical and sealing results for the switches could occur due to wide range of possible variables.

RTV silicones are composed of silicone monomers and polymers, fillers, as well as catalysts. Depending on environmental conditions and composition of RTV silicone, silicon-oxygen bonds will be formed, but also, a variety of different chemical side chains and morphologies can be created. Importantly, the amount of water and the temperature in the surrounding environment can cause the physical structure, as well as the types and amounts of different chemical groups, to be different in applied solidified RTV silicone from the same bulk tube. For their typical use, RTV silicones are used as a water-repelling barrier in household or light commercial applications. For one-part RTV silicones (i.e., from a single tube), moisture in the atmosphere is used to cure applied material from the outside towards the center. The time to cure will decrease with an increase in temperature, humidity, and surface area to volume ratio. In a vault, likely with higher humidity and lower temperatures than the typical household environment of application, this will likely lead to inconsistent curing, as well as physical and chemical properties. Additionally, by the RTV silicone being placed with unmeasured, and possible inconsistent thickness between two solid surfaces, spanning several centimeters in width, air gaps and gradients of moisture can be produced (Figure 23). Although some RTV silicones may be tack-free in a little as 30 minutes with certain fillers added, the material is not solidified and chemically stable. By introducing dry nitrogen for a pressure/lead test and mineral oil, the silicon will not be fully cured and/or react with the oil, leading to detrimental properties such as cracks, bubbles, not bonding to the solid surfaces, not ever fully curing, etc.

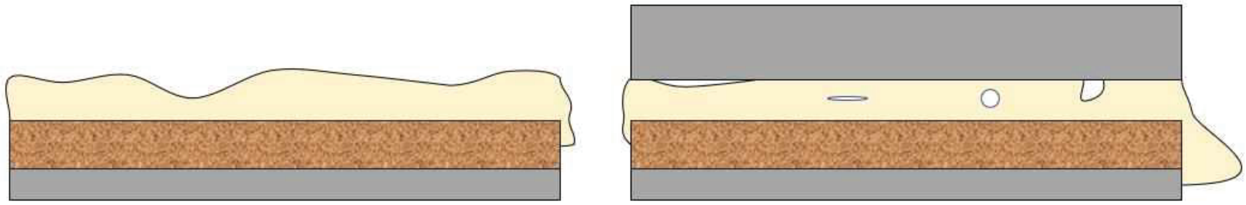


Figure 23. Sketch of uneven RTV application to switch at lid

Left: Uneven RTV silicon application to gasket;
Right: Possible holes/channels formed when lid placed on

Tack-free times of most RTV silicones are normally on the order 30 to 120 minutes and full cure times being many hours or days. To help reduce the curing time of many RTV silicones, acetic acid is added. Depending on how high in concentration the acetic acid is included in the RTV silicone, it can heavily influence the cure times by a couple of hours, requiring 12 to 72 hours for a full cure. As mentioned previously, acidic molecules are detrimental to cork – causing it to degrade and weaken (section 2.5.1). If RTV silicon that contained acetic acid was used on or around the Nebar gasket, it would promote a region of leaking or damage to the cork in the gasket. Additionally, depending on the type of rubber component contained in the gasket, it may not have good compatibility with the acetic acid, and may not bond well with the silicone. If an RTV silicone was used that were “quick-cure”, a higher amount of acetic acid would be contained and a greater probability of causing damage to the gasket, or even degrading the coatings and metals of the switch.

Independent of the gasket type used, it should be noted that most home, commercial, and industrial applications of self-curing RTV silicones are not intended for pressurized applications. Instead, they are to simply act as a water barrier in stationary applications (i.e., bathtubs, flashing on houses, windows, holes in siding or decking, etc.). The reason for this is RTV silicones do not typically have a roughening or etching agent that allow for good adhesion of the silicon to different surfaces. This is why applied silicones are relatively easy to remove with a flat rigid edged tool such as a putty knife or piece of plastic when needing replacement every 5 to 15 years. As a result, when pressurized with nitrogen, there is the potential that the silicon could release from smooth surfaces to create small channels for leaks to form. If the nitrogen is applied before fully curing, micro cracks could be formed and go unnoticed right from application. Alternatively, if the oil volatizes or gases are generated in the tank from different processes, the pressure could also increase, promoting release of the silicone from the different surfaces. Even when cured, the structural morphology of the silicone may not be as strong as if left to cure with no backpressure, allowing for the possibility of voids and leaks occurring as the silicone is left on the active unit.

2.5.2.2 Insulating fluid/Mineral Oil and Chemicals

Depending on the type of Nebar used, or even if it was a different material, the gasket may have some incompatibility with the oil that was used in the switch. Although the insulating oil used in the switch for at least the last 3 years was naphthenic-based, it was highly refined to have more naphthenic content than many naphthenic-based insulating oils used in the 20th century. Although, having more naphthenic component is typically seen as a superior product with modern equipment, new oils are not always compatible in the long term with historical sealing and coating materials. An example of this is new ester-based insulating fluids which are seen and safety to handle and more environmentally friendly than mineral oils, but can only be used with certain coatings and gaskets to last for longer than a few months in a transformer. The reason being is many new insulating oils and lubricants are similar in chemical composition to the both historic polymers and/or fillers which can promote dissolving, swelling, and leaching materials into the insulating fluids.

Since the mid-2000's, many equipment manufacturers have recommended the use of high-nitrile containing (20% or greater) or Viton gaskets to provide chemical compatibility with the insulating fluids used. With the gaskets in the switches not having been changed since installation (since the 1970's), not only will the gaskets have degraded with prolonged use, but they could have also deteriorated to create small channels, voids, small particles, etc. with being introduced to the Soltex 2288 that was used. For any insulating fluid-gasket combination to be used in electrical equipment, it is always recommended to test the compatibility (through testing such as ASTM D3455-11(2019) "Standard Test Methods for Compatibility of Construction Material with Electrical Insulating Oil of Petroleum Origin" or the BC Hydro Generation Standard 02.00.MTCE.08 Revision #1.

During the collection of the samples from Vault 073, it was observed that an open grate was initially present over approximately 1/3 of the vault, and the lid cover (not liquid tight) at street level was present above and in front of the switches. As a result, there is the possibility that several non-purposefully placed chemicals could have been present in the vault that originated from the streets above. A wide variety of compounds can have a wide range of properties. With possible exposure during its more than 40 years of service, it is possible that the seals, valves, ports, bolts, etc. may have been exposed to chemicals from the street, which may have contributed to degradation of the switch components, promoting small leaks into and out of the switch.

2.6 Contaminants and Their Effects on Dielectric Insulation

Electrical insulating fluids are fluids that have the desired properties of being electrically insulating as well as being stable at high temperatures. In addition to the electrical insulation properties, which stop arcing and other electrical discharges, the insulating fluids are also used to dissipate any heat generated in the equipment.

As mentioned in section 2.4, the oil used in the switches of Vault 073 was a naphthenic-based type I insulating oil (Soltex 2288). Type I oil is used in equipment where normal oxidation resistance is required. This description typically refers to equipment that is fully sealed and/or blanketed, where the system should be naturally oxygen starved (significantly less than 20,000 ppm). The reason for this is naphthenic-based oil oxidize and degrade more rapidly and to a greater extent from electrical discharges than paraffin oil. Type one oils have a lower amount of oxidation inhibitor added than Type II oils. As a result, the potential for oxygen inclusion has to be low otherwise the oxidation inhibitor would be used up relatively quickly, leaving the oil itself to react and degrade the oxygen. If a leak into the switch occurred, the oil would oxidize quicker than other more inhibited oil.

Importantly, the degradation products of naphthenic oil are more soluble than the by-products of paraffin oil. As a result, many of the naphthenic-based degradation products are suspended or dissolved back into the oil. This can be both beneficial and detrimental. If a contaminant and/or degradation product is introduced into a section of the electrical equipment, the insulating oil can dilute or re-distribute the contaminant to other portions of the fluid. Depending on the nature of the contaminant and/or degradation product, it can impact the electrical insulating properties of the oil.

Mineral oil-based insulating liquids, for all intents and purposes, are essentially non-polar and hydrophobic (water “fearing”). When the oil becomes oxidized, the incorporation of oxygen into the oil molecules adds polarity and makes the oxidized molecules less hydrophobic. The more polar a molecule is, the less it will mix with bulk, non-polar mineral oil. This repulsion of molecules disrupts the interactions of the insulating mineral oil molecules, and decreases the electrical insulating ability of the oil. In addition to disrupting the interactions of the insulating molecules, a molecule that is more polar is more electrically conductive. As a result, the inclusion of more polar molecules, reduces the electrical insulating ability of the oil two ways. For these reasons, the oxygen content (which can oxidize the mineral oil when heated or subjected to electrical discharge) should be as low as possible in electrical equipment. This is the reason many new pieces of equipment have a sealing bladder, are nitrogen blanketed, or are completely sealed.

With this said, water is one of the most abundant and common polar compounds in many environments. Thus, its inclusion in insulating oil is highly undesirable. The presence of water in insulating oil has been shown to have a strong relationship to the degradation of its electrical properties. Being highly polar, water does not mix well with mineral oil, typically allowing only a few parts-per-million to be dissolved. As a result, the water can generate small, suspended droplets that can hydrate small particles, disrupting the insulating bond interactions of the oil, react with the oil, and in extreme cases, coat sections of solid surfaces to make them conductive. By being in direct contact, water can oxidize the mineral oil molecules and create conductive, polar compounds including oxides and organic acids.[6,7] Additionally, water that comes in contact with glues, paints and rubbers in a switch can become oxidized, breaking down the materials into conductive molecules that can be introduced into the oil. In the case of iron, and subsequently steels, water in direct contact with iron can result in iron oxide (rust) particles, which are highly conductive and remain suspended in the oil. In general, the greater the number and the larger the size of suspended particles in mineral oil, the greater the decrease in breakdown voltage from the base oil. In the case of iron particles (rust, steel, or iron), only a few parts-per-million (> 3 ppm) are required before a large drop (> 10 kV) in dielectric breakdown can be observed.

2.7 Mineral oil and Silicone

As discussed, electrical insulating oil is non-polar, while the RTV silicone that may have been used on the switches is polar. Due to the difference in polarity between the two substances, the bulk silicone would not readily mix or suspend in the mineral oil of the switches. If RTV silicon was introduced by some means to the inside the tank of the switch, the silicone would likely sink to the bottom of the tank or be pressed to and run down the walls of the tank, as it would be pushed away from the bulk oil. Also, like water, a small amount of the silicone could be suspended in very small particles into the mineral oil, reducing the electrical insulating ability of the oil.

When the silicone would be curing (not-fully solidified), small particles of the fillers and small portions of the silicon monomers could non-specifically diffuse into the oil. Although not a lot of such particles would diffuse into the bulk oil, they could provide small points of reduced dielectric or increased ionization. A similar scenario could occur after the silicone cured and started to wear with time. The amount of wear of the silicone would be dependent on the temperature, swelling and shrinking of the material, interaction with other contaminants (such as acids), degradation from water and oxygen, and exposure to mechanical stresses, as well as magnetic and electric fields. This is in addition to what degradation products could from the interaction (i.e., long-term compatibility) of the oil itself with the silicone.

In the case of if RTV silicone was used that had any acetic acid contained, three potentially significant issues inside the switch could occur:

1) The acetic acid could slightly mix and/or react with the mineral oil, reducing the dielectric
2) The acetic acid could detrimentally react with the gasket (Nebar), allowing for a leak to be generated and the oxygen free atmosphere to be compromised
3) The acetic acid could etch the paint and metallic sides of the tank (iron/steel), producing iron and iron oxide particles that could diffuse into the oil

Of the three scenarios, the acetic acid mixing into the bulk mineral oil has the lowest likelihood of resulting in significant damage, as the free acetic acid would be the most prevalent when the silicon was first applied, and should react or precipitate with the oil within a few hours. However, the degradation to the gasket material is highly likely and was discussed in greater detail before. The acetic acid degrading the paint and rusting the metal is of potentially the largest consequence.

By the rust not just being superficial, flaking from the walls, and being in a defined path at the right front of the tank of switch 2019, it indicates exposure to a detrimental chemical to the tank surface for a prolonged period of time.

The bulk silicone with polar fillers and additives would be pressed against the side of the switch tank if dripping from the edge of the tank by the lid. Although the silicone itself would be the main component exposed to the oil, the acetic acid and other polar compounds would be directed and in contact with the tank wall. The paint used on the inside walls of the tank was determined to be epoxy-based enamel from FT-IR analysis. Although epoxy-based enamels are considered rugged, they are still subject to chipping and cracking from mechanical movement, and pinholes can develop from chemical wear/leaching with time. The lid of switch 2019 is heavy and removed every 5 years for full maintenance. When placing the lid back on after maintenance, the lid could scrape the edge of the tank (Figure 24). This would act as an entry point for oxygen, water, and chemicals (such as acetic acid if silicone was applied). By the enamel being rugged and somewhat chemically resistant, the chemicals could enter through the top edge openings and damage the steel along the wall.

Figure 24. Damage at edge of tank right front

Additionally, as discussed previously, one-part RTV silicones use moisture in order to cure. Although initially low (part-per-million levels), the moisture in the oil and on the walls of the tank could be drawn to the silicone and concentrate at the wall (Figure 25). Acetic acid would significantly enhance the degradation of any coating (including enamels); however, the heat generated by the silicone curing and localized high moisture content with other conductive filler components could cause cracks in the paint, the paint lifting, or minor electrolytic corrosion. In turn, the tank iron could be exposed, and small iron and oxidized iron (rust) particles could diffuse into the bulk oil of the tank. This would reduce the dielectric of the oil or generate locations of reduced insulation, promoting electrical potential, oxidation, and other detrimental events in the oil.

Figure 25. Depiction of silicon on tank wall for switch
Red: Area of application and possible overflow of silicon on tank edge and upper wall
Yellow: Possible drip channel of silicone or path of water, oxygen, etc. at wall

Analysis of the upper edge on the right side of the tank of switch 2019 (red section of Figure 25) for traces of an enamel coating, another organic coating, and silicon was performed. Samples of possible organic materials were collected both by collection with a specialized abrasive disc and chemical extraction in sections of the defined area. Analysis by FT-IR did not show the detectable presence of organic materials. This indicates that region was free of coatings or deposits as visual observation suggested. By comparison, areas on the side of the tank that had white residues/deposits were identified as having the presence of organic material (identified as a degraded enamel coating). These analyses indicate this area of the tank had a compromised coating in the identified region of Figure 25. As the other regions of the top of the tank did not have the same appearance (i.e., free of white and deepened rust), it indicates that the coating was degraded by not just the fire. Instead it is suggestive that the breakdown of the coating had undergone a chemical degradation. Collecting a surface sample from below the bare section (slightly white) and analyzing by

FT-IR indicated the presence of degraded enamel, which contained weak signals associated with oxygen bonds. This spectral pattern was unlike other parts of the tank that were by areas of heat marks. This also suggests that the coating in this region was degraded by more than just heat.

Observing orange-brown deposits in other areas of switch 2019 and switch 2018, the residues were more spotted and closer to the surface. This spotted appearance of rust residue suggests that the rust may have developed after the explosion, damaging the top-most surface of the steel, exposing iron that could react with moisture.

2.8 Thermal Degradation, Partial Discharge (PD), and Arcing

There are three main categories of events that can occur in electrical equipment that are detrimental to the dielectric insulating capability of oils (Figure 26):

1) Thermal
2) Partial Discharge
3) Arcing

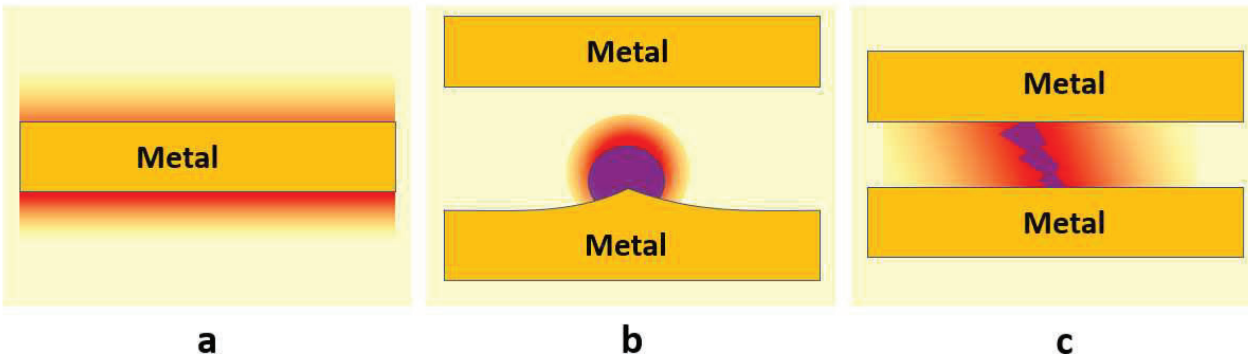


Figure 26. Depiction of heat detrimental events in electrical equipment
a) Hot conductor in contact with insulating fluid
b) Partial discharge between two conductive materials in insulating fluid
c) Electrical arcing between two conductive surfaces in insulating fluid
Purple = region of ionization

Thermal events in electrical equipment are defined as when the temperature of a region exceeds the ratings of the material. For example, more than approximately 90^{o}C is detrimental for many mineral oils. PD is a localized electrical discharge that only partially bridges the insulation between conductors. PD occurs whenever there is a stressed region due to some impurity/cavity inside the insulation or when there is a protrusion. The stressed regions are formed around sharp edges or protrusions around the conductor. Arcing occurs when the potential of the insulating medium is exceeded, resulting in the electrical breakdown of a medium (i.e., mineral oil) that produces an electrical discharge.

Although the categories of events are generally separated by the amount of energy they impart to the surroundings (i.e., insulating fluid), they are not mutually exclusive. For example, an arc releases a significant amount of electrical energy in the surroundings, but also generates a substantial amount of heat (> 1000^{o}C) in the immediate area. Alternatively, PD may generate conductive metal, metal oxides, and oxidized oil compounds and particles. As these items are generated and diffuse away from the point of PD, they can create a conductive path to generate an arc. In addition to solid and soluble decomposition products, PD also predominantly generates hydrogen and methane, and lesser amounts of ethane and ethylene when in mineral oil. If the discharge energy is increased from the source, moving towards arcing, acetylene is produced, with increasing production of hydrogen, methane, ethane and ethylene. Additional information about gas generation with electrical events will be discussed in section 3.

Assuming the oil is exposed to each event for the same amount of time, arcing produces the greatest number and amounts of degradation products. However, PD is usually not present for a short time span compared to fault arcing, which is complete in seconds. Instead, PD can last for minutes, hours, or even days depending on the conditions. This can generate a significant amount of suspended particles, sludge, and oxidized degradation products.

It was reported by switch field personnel that as part of the procedure, all surfaces of the switches are drained, flushed with new oil, and wiped down with lint free wipes to remove deposits and small particles that adhere to the surfaces. The particles can sometimes be observed through the site glass of the switches if a bright light is shined through an opened port or site glass. The particles typically cannot be seen without lights due to the particles being so fine and the oil not allowing much light inside the vault. If not observed through a site glass or port, when the oil is drained from a switch, a fine coating of black particles will be visible. The appearance of the deposited layer can be described as similar to dust on a cabinet surface that has not been cleaned for several weeks, but black instead of grey. These particles could be part of the reason that the dielectric of oil from previous years was as low as observed through lab testing (Table 3).

Particle Size (µm)	**Particle Count (ASTM D6786)**				
	Vault 0007 - Switch 2018 (2021-10-20)	**Vault 0007 - Switch 2018 (2021-10-20)**	**Vault 0007 - Switch 374M (2023-03-20)**	**Vault 0055 - Switch 4018 (2023-03-20)**	**Vault 0055 - Switch 4028 (2023-03-20)**
>4	1808	1956	1618	332	335
>6	552	656	508	24	93
>10	62	108	100	6	51
>14	15	35	38	N/D	20
>21	2	9	8	N/D	N/D

Table 3. Particle counts from oil samples of different vault switches
Note: N/D = not detected

Both the switches from vault 0055 had particle counts which are similar to new oil from a manufacture barrel after filtering. In contrast, oil samples from switches 2018 and 2019 from 2021, and an oil sample from switch 374M from vault 0007 had an elevated number of particles. With switch 2019 being an auxiliary switch and switch 2018 not being a high use switch (less than 10 operations between 2021 and 2023) and having maintenance with an oil change in March 2022, these particle counts are higher than would be anticipated. Performing a metals analysis of the 2021 oil samples of both vault 073 switches, showed no detectable concentrations of dissolved copper, iron, silicon, or aluminum. This indicates at the time of sampling, a significant number of particles were present, but were not metals based. This does not mean that metallic particles or dissolved metallic compounds were not generated after October 2021, but at the time of sampling the metals compounds were not at observable concentrations. Also, the particles that were present in the October 2021 samples may have been somewhat conductive to reduce the dielectric breakdown voltage of the oil.

Some particles will naturally be generated in the switches with every switching operation from open to ground, open to closed, and vice versa. Each operation of the switch is completing the electrical circuit inside the switch. As the blades on the actuated portion of the switch come close to the stationary contacts of the switch, an arc will be generated between the two points. Once in contact with each other, the circuit is complete, and arcing is stopped. As the switching operation should occur almost instantaneously, a minimal, but non-zero number of particles and decomposition products will be produced. If for some reason the blades do not make completed contact with the contacts, the possibility of small discharges or PD are possible at and around the resting point of the blades (Figure 27).

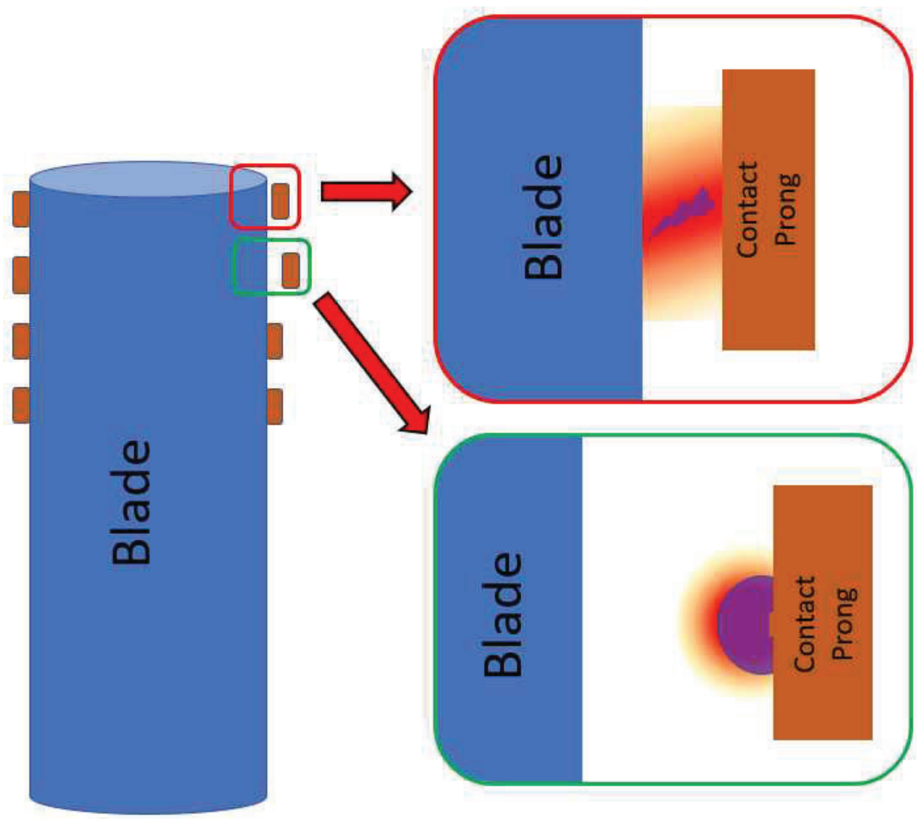


Figure 27. Diagram on the generation of PD or arcing at contact blades in switches Top: arcing; Bottom: PD

In the open position, the switches should be electrically isolated by the mineral oil as the potential between the blade tips and other components should be significantly less than the oil. However, if water, oxygen and/or other contaminants entered the switches or generated conductive degradation products, they could have compromised the dielectric of the oil. Although the dielectric breakdown of the oil would occur, the potential for a full flashover is unlikely based on the results of the dielectric breakdown tests from previous years.

2.9 Soil samples collected from the floor of Vault 073

On February 28, before any equipment or components were removed from vault 073, soil samples were collected from 6 locations on the vault floor (Figure 28).

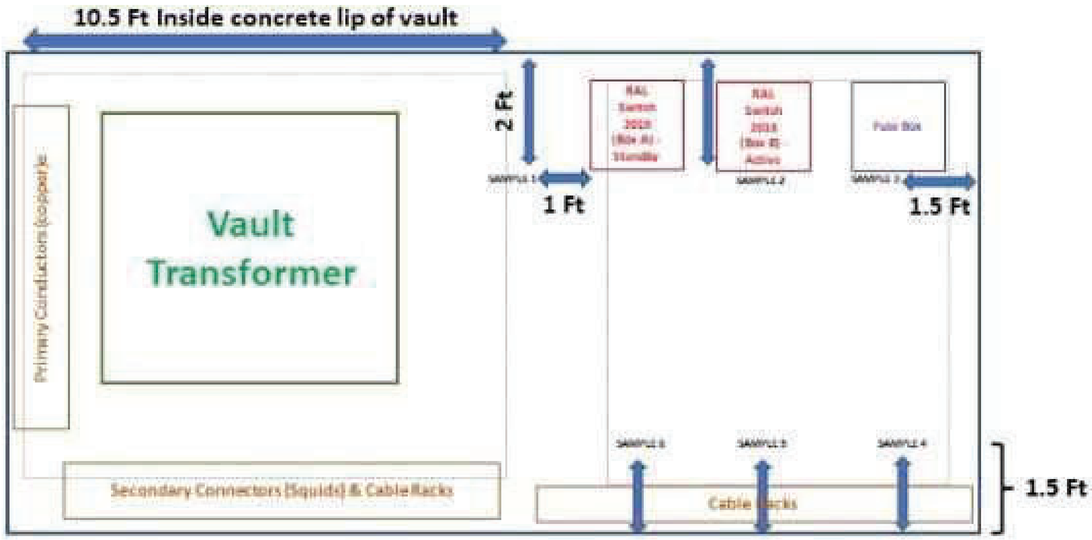


Figure 28. Schematic of vault and locations of soil sample collected
Dotted lines indicate openings to street (Not to scale)

The chemicals from the soil samples (comprise mainly of degraded oil and water) were collected by two methods:

1) Collecting and analyzing the free fluid at the bottom of the sample jars used for the samples
2) Adding a hexanes solvent to extract compounds adsorbed to the soil components, followed by collecting the hexane solvent for analysis

Independent of the method used to collect the chemicals from the soil samples; the chemicals were analyzed by gas chromatography-mass spectroscopy (GC-MS) using different analytical columns and temperature methods to observe different volatile compounds.

In all the free liquids collected from the soil samples, none showed detectable amounts of accelerants or other abnormal fluids that are not typically found in an underground vault. The free liquid collected from the soil sample from below switch 2019 showed no or minimal amounts of volatile compounds, likely due to being fully consumed by the vault fire. However, the free liquid samples collected from soil samples 5 and 6 (in-front of the switches) had clear signals of compounds such as benzene, toluene, propene, and 1,3-butadiene. Lab experiments have shown that subjecting naphthenic-based insulating mineral oil to arcing or PD at a copper surface will create these compounds.[8] By these compounds being present, this indicates that electrical discharge activity did occur at some point inside switch 2019. To this, the activity likely occurred for some time to allow for such material compounds to be observed in soil residues at measurable concentrations after the fire.

3 PROPOSED MECHANISM OF FAILURE

From the analysis of the different components and samples collected from inside the vault, it appears that electrical discharge was present for intermittent and/or prolonged periods of time. If switch 2019 was an isolated, closed system with a nitrogen blanket, while not optimal, the system would not pose a high safety risk. However, if air was to enter the system, an explosive system filled with fuel (i.e., mineral oil) would be generated.

The two switches (2018 and 2019) were in a dual-radial arrangement. Switch 2018 was the primary switch (i.e., in the closed position), while switch 2019 was the auxiliary switch (i.e., in the open position). By being in a dual-radial arrangement, even though switch 2019 is not load carrying, it would still have electric potential contained within the switch. Figure 29 presents a diagram of the setup of the switch in vault 073.

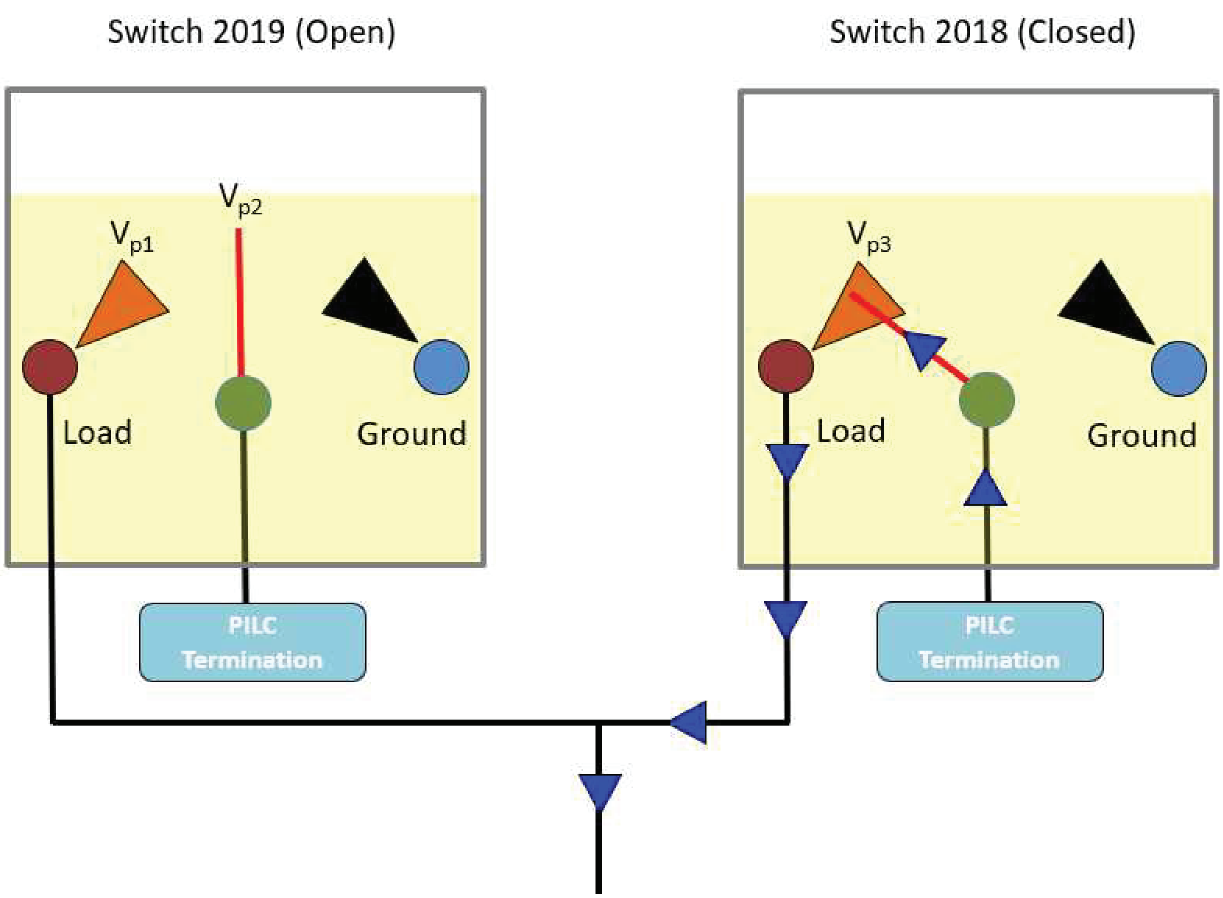


Figure 29. Arrangement of switches in vault 073 (Blue arrows indicate current flow)

Although switch 2019 does not have current flow, it does have potential at both the load (contacts, V_{p1}) and source (blades, V_{p2}) when in the central position of the switch. Electrical discharge does not happen at the end of the central switch contacts due to the insulating characteristics of the oil. However, if the oil becomes contaminated due to a leak of water and/or air into the system, the dielectric would be reduced. From the observation of the tank of switch 2019 and analysis of the rust, it appears that the integrity of the tank seal had been compromised for some time. This is supported by the historical dielectric breakdown values of the oil being poor every year of testing, and the water concentrations of both switch 2018 and switch 2019 being higher than 10 ppm for all the years they were analyzed. Additionally, switch 2019 may have received an application of silicone sealant after maintenance in 2018. However, when field crews perform such a procedure, it is not documented on the switches. A partial reason for this was the switches were set to be decommissioned before the end of the next 5-year maintenance cycle. The rust pattern on the right front side of switch 2019 is suggestive of an ingress path of moisture for a prolonged period of time, and/or a chemical such as silicone could have run down the side of the inner wall of the tank. If RTV silicone was applied, there is a high probably that acetic acid (an additive in most RTV silicones) was also introduced inside the switch. The presence of acetic acid presents three issues:

1) it will degrade the rubber and cork that is used in the Nebar seals (which would have already aged more than 40 years in service) to allow for ingress of water, oxygen and possibly other contaminants;

2) the acetic acid would degrade the oil and reduce the dielectric of the oil;

3) the acetic acid at the wall (either due to hydrophobic repulsion to the oil, or trapped under RTV silicone at the switch wall) caused rust and small paint particles to enter the oil, also reducing the dielectric.

As described in section 2.5, dissolved iron or suspended iron particles can be as little as a few part-per-million in the oil to reduce the dielectric of naphthenic mineral oil to only a few kilovolts. In the case of less conductive particles than metals or dissolved compounds more polar than the oil (i.e., carbon particles, generated organic acids, etc.), if present in a region of potential in the oil, their presence can reduce the dielectric insulating ability in the area.

Although the distances between the conductive components in the auxiliary switch may have been far enough away not to cause PD and arcing with new oil. As degradation produces build up dielectric is reduced from the contamination, and the system becomes set up to allow PD (Figure 30). If the dielectric is reduced enough, an arc will be produced. Depending on the dielectric between the blades and contacts themselves, the blades and the tank walls, the blades and the air, the blades and wall of the tank, etc. they all have the ability to generate PD. PD does create conductive particles in mineral oil and degradation products, but it also generates several combustible gases such as hydrogen and methane. When a system is closed and free of oxygen, even though combustible gases as generated, they will not ignite even when subjected to an electrical discharge or heat, since oxygen is required to burn. However, if the switch had leaks into the tank (as was indicated from the presence of the rust) oxygen would enter the system. Depending on the size of the leak and the amount of time allowed to leak, an explosive mixture could be produced. Depending on the diffusion and dispersion of the degradation products and conductive particles, there can be regions or pathways of reduced dielectric breakdown. When the dielectric pathway becomes enough of a conductor, a point of electrical discharge can be extended and, in an extreme case, an arc can be generated.

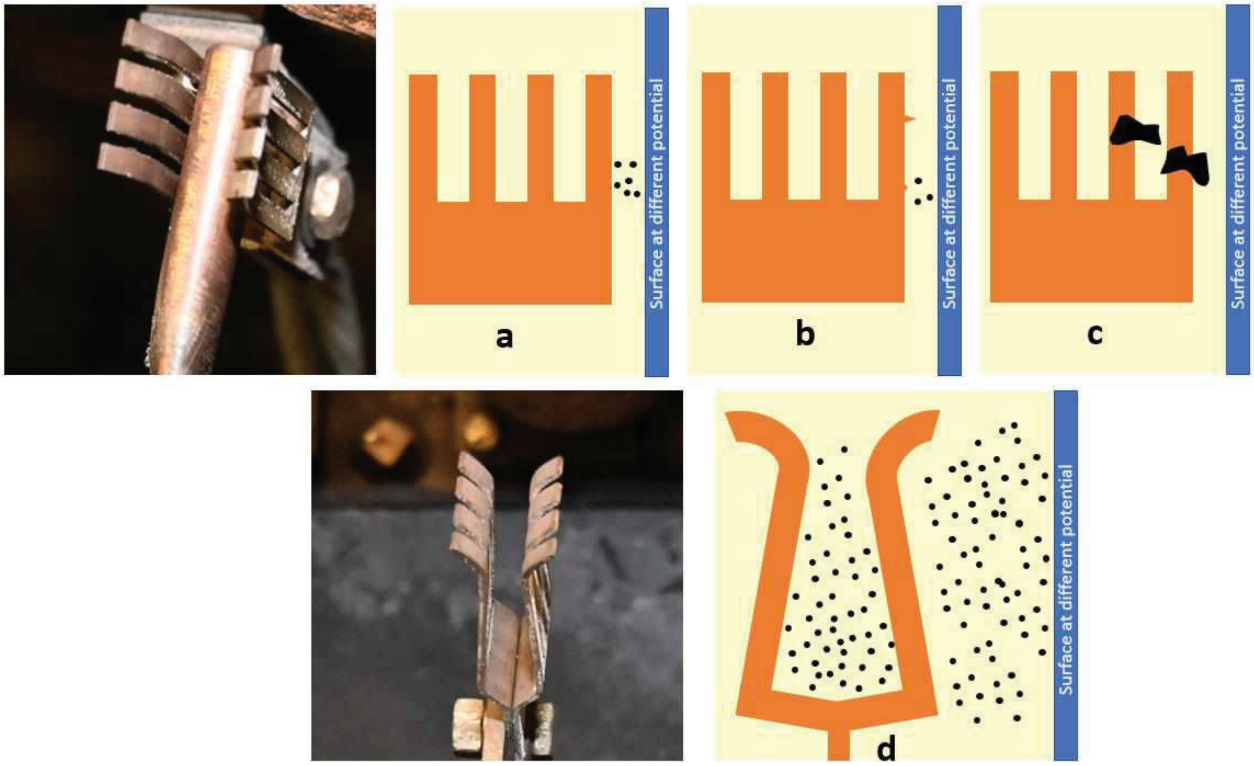


Figure 30. Sketches of scenarios that would lead to PD or arcing at contacts (not to scale)
a) Higher density of conductive materials between contacts and another surface
b) Burr or burr and conductive materials between contacts and another surface
c) Larger debris laying across surface of contacts and extending towards another surface
d) High concentration of particles between different potentials of forks and another surface

Using optical microscopy to have a closer look at the copper blades of switch 2019, the ends show signs of PD by the tips not being uniform and missing material, but still having a smooth edge (Figure 31). This surface observation is consistent with PD, which occurs at sharp points or edges of metals. The amount of material lost from the end of the blades indicates the PD was present for a significant amount of time. The loss observed on some of the contacts in switch 2019 is indicative of PD, but also arcing (Figure 32).

With PD of the copper blades and contacts, small pieces of copper and copper degradation products would also be introduced into the oil in the switch. Just like iron, copper heavily reduces the dielectric of mineral oil, but at 2 to 3-fold.

Figure 31. Microscope photos of two different example tips of copper blades from switch 2019

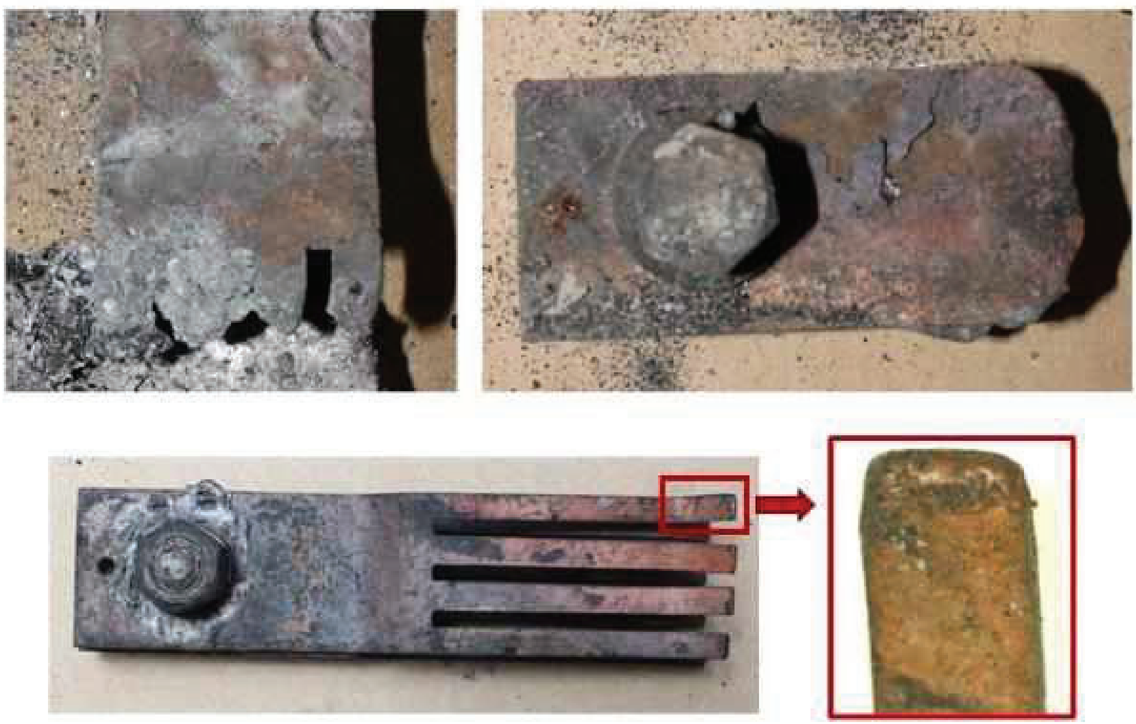


Figure 32. Photos of two different example forks of from switch 2019

With air and moisture able to enter the switch, PD was active for repeated and/or extended periods of time in switch 2019. The PD developed due to a reduced dielectric of the oil from the contamination of items such as water, oil oxidation products, small conductive particles (iron, iron oxides, and copper), dissolved metal complexes, etc. As PD occurred, more oil degradation products and metals would have suspended or been dissolved in the oil. Some products generated with each PD event in oil are combustible gases (such as hydrogen and methane). Eventually the combustible gases built up to a high enough concentration and were ignited from the PD itself, or as a result of the oil becoming so compromised that an arc was generated and ignited the combustible gases in the switch.

4 REFERENCES

1. Jones, Denny A. "Principles and prevention of *Corrosion"* Vol 2 (1996); Ishikawa, T., Kondo, Y., Yasukawa, A. and Kandori, K., 1998.

2. Ishikawa, T., Kondo, Y., Yasukawa, A., & Kandori, K. (1998). Formation of magnetite in the presence of ferric oxyhydroxides. *Corrosion science*, 40(7), 1239-1251.

3. Vereda, F., de Vicente, J., & Hidalgo-Álvarez, R. (2007). Influence of a magnetic field on the formation of magnetite particles via two precipitation methods. *Langmuir*, *23*(7), 3581-3589.

4. Frietsch, R. (1967). *The relationship between magnetite and hematite in the iron ores of the Kiruna type and some other iron ore types*. Sveriges Geologiska Undersökning

5. Lagoeiro, L. E. (1998). Transformation of magnetite to hematite and its influence on the dissolution of iron oxide minerals. *Journal of Metamorphic Geology*, *16*(3), 415-423.

6. Prakoso, M. H. (2015). Effects of water content on dielectric properties of mineral transformer oil. *International Journal of Electrical and Computer Engineering*, *9*(10), 1142-1146.

7. Sai, R. S., Rafi, J., Farook, S., Kumar, N. M. G., Parthasarathy, M., & Bakkiyaraj, R. A. (2020). Degradation studies of electrical, physical and chemical properties of aged transformer oil. *Journal of Physics: Conference Series*, 1706(1), set 012056., 1-11.

8. Chambers, S. D., Trivedi, V. & Kato, D (2018) *Enhanced Diagnostics and Condition Assessment of LTCs*. CEATI report No. T173700-30/122, 1-45.

Appendix C: BCH Engineering Report

DISTRIBUTION STANDARDS
BC Hydro
Power smart

Inter-Office Memo

File Number: 1613.7.5-005
Date: May 31, 2023

To: Ed Mah, Tead Lead, Distribution Asset Sustainment Maintenance

From: Grant Ringham, Specialist Engineer, Distribution Standards

cc: Tom Huitika, Senior Engineer, Distribution Asset Sustainment Maintenance

EGBC Permit to Practice: 1002449
PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA
G. A. RINGHAM # 37382
2023-06-06

Subject: Vault V0073 - Protection Operation Details

On February 24, 2023 at approximately 6pm there were protection operations on the circuits that feed V0073, which experienced a significant event at this time. These notes provide a detailed summary of those protection operations.

Circuits CSQ 12F511 and CSQ 12F521 are fed from the Cathedral Square Substation in downtown Vancouver. Both circuits feed V0073 with CSQ 12F521 acting as the running circuit and CSQ 12F511 acting as the standby circuit. This means that, under normal conditions, the switch fed by the running circuit is closed and feeding power while the switch fed by the standby circuit is open and not feeding power. Both circuits are energized and ready to be operated. In V0073 the running switch is SW2018 and the standby switch is SW2019.

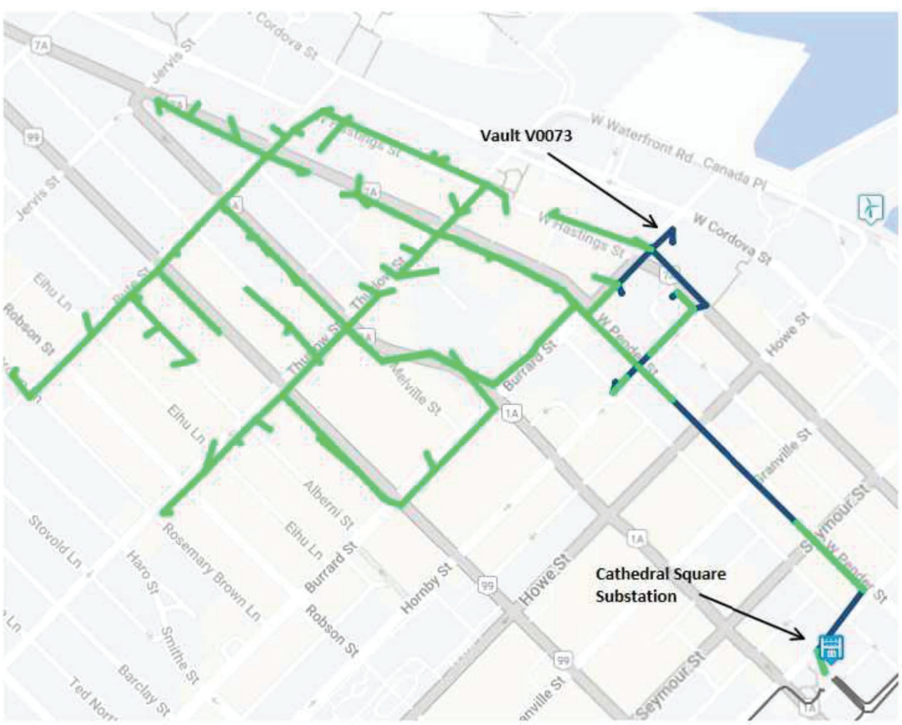


Figure 1 - Circuit Map

The protection relays, sensors, and circuit breakers involved in the protection operation are all housed in the substation. The summary details included below are gathered from the protective relay event logs, sequence of event records, and oscillography. The recorded sequence of events is as follows:

Time stamp	CSQ 12F511 - Standby Feeding SW2019	CSQ 12F521 - Running Feeding SW2018
18:06:22.285	Three-phase fault detected	
18:06:22.293		Three-phase fault detected
	These faults are effectively simultaneous - Within error of GPS time propagation and sampling error	
18:06:22.351	The three-phase fault detected on CSQ 12F511 continues	Approximately 3.5 cycles after fault detection, the three-phase fault detected on CSQ 12F521 ends. The protection did not operate due to the short fault duration (trip time not reached).
18:06:22.460	Approximately 10.75 cycles after the three-phase fault detected on CSQ 12F511 started, the protection operated on a time-over-current element (51P1T). The breaker operated at 18:06:22.535 (breaker clearing time approximately 4.5 cycles). Fault current = 8384A.	
18:06:23.427		Approximately 1s after the initial fault on CSQ 12F521 ended and approximately 0.9s after the fault on CSQ 12F511 was cleared, a new three-phase fault is detected on CSQ 12F521
18:06:23.656		Approximately 13.75 cycles after the new three-phase fault detected on CSQ 12F521 started, the protection operated on a time-over-current element (51P1T). The breaker operated at 18:06:23.731 (breaker clearing time approximately 4.5 cycles). Fault current = 8636A.
End of sequence - Total elapsed time approximately 1.4s		

Event Data Discussion:

1) This is a significant fault event for the BC Hydro distribution system.
2) The faults initiated effectively instantaneously:
    a. There are very few locations in the vault that this could happen without significant precursors such as smoke or fire caused by a cable fault
    b. The most likely location is at SW2019 where the switch blades are energized by CSQ 12F511 and the switch contacts are energized by CSQ 12F521.
3) The event initiated with phase-to-phase arcing in both circuits on phases A and B, eventually propagating to phase C.
    a. The phase taping colours seen in inspection photos (A-phase red, B-phase yellow, C-phase blue) showing phases ABC from the wall outwards. Therefore, significant faulting would likely have occurred in the back portion of the switch where those phases are located.
4) Something significant must have happened for the faulting of CSQ 12F521 to suddenly stop without protection operation. Underground arcing faults such as this do not tend to self extinguish.
    a. The PILC termination for this circuit was found fundamentally intact on the floor beneath SW2019
    b. The faulting on CSQ 12F511 was also significantly disturbed at the time that CSQ 12F521 stopped
    c. The time delay before the fault re-ignites is significant in terms of protection operation time periods

Oscillography:

CSQ 12F511 Current

CSQ 12F521 Current

CSQ 12F511 Voltage

CSQ 12F521 Voltage

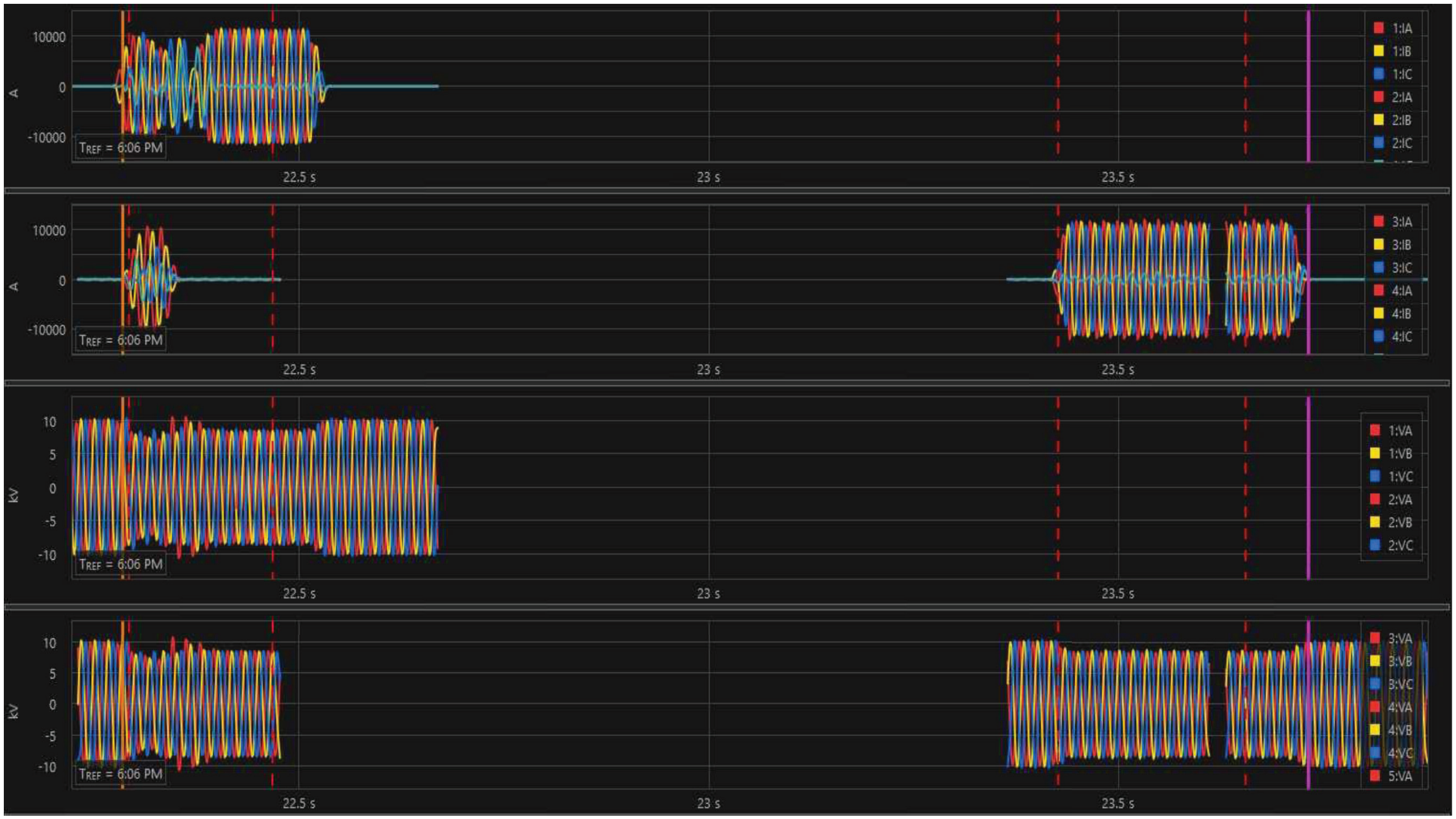


Figure 2 - Event Oscillography

Single Line Diagram:

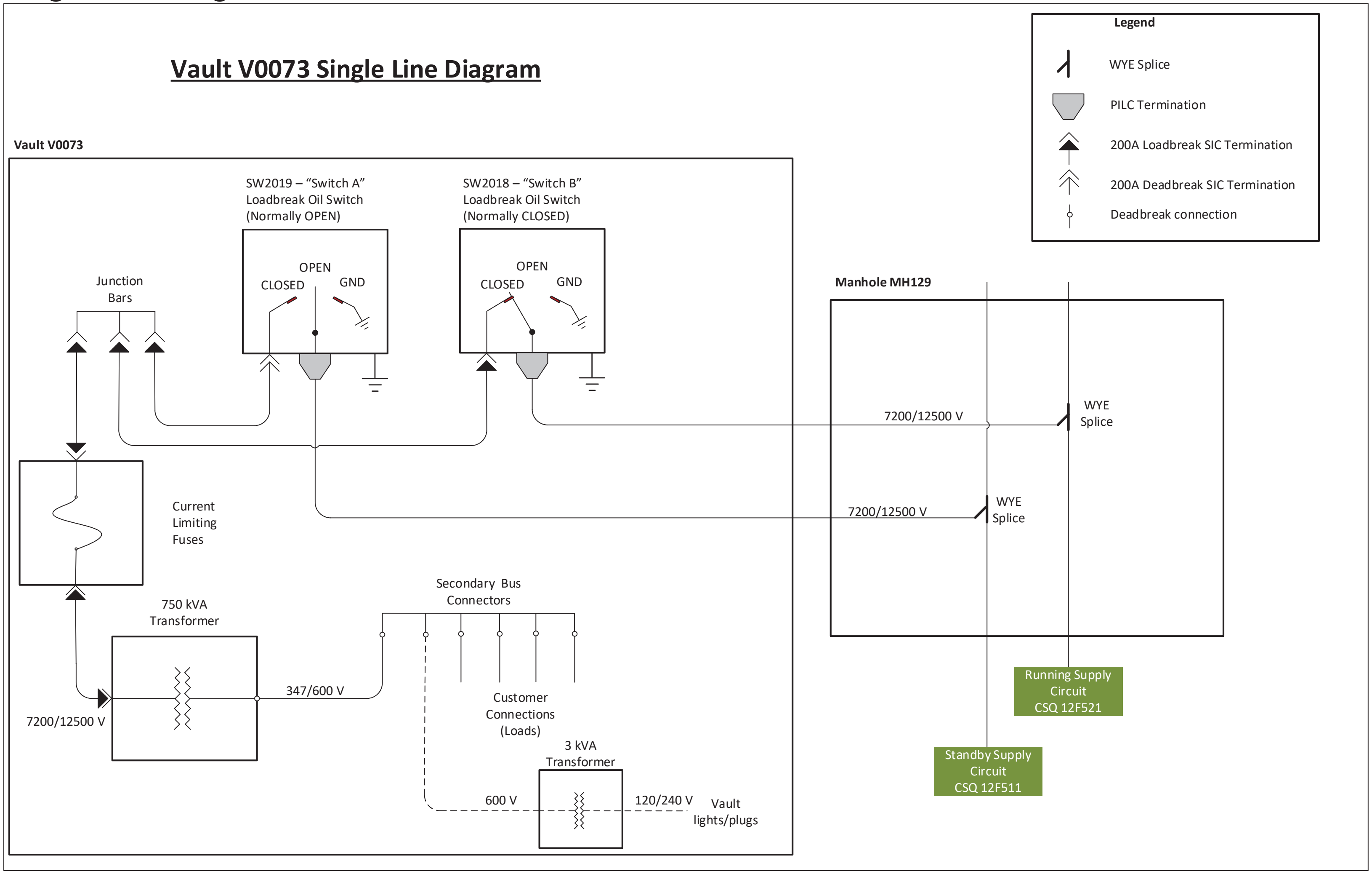


Figure 3 - V0073 Single Line Diagram

Appendix D: Street Vault Inspection Report

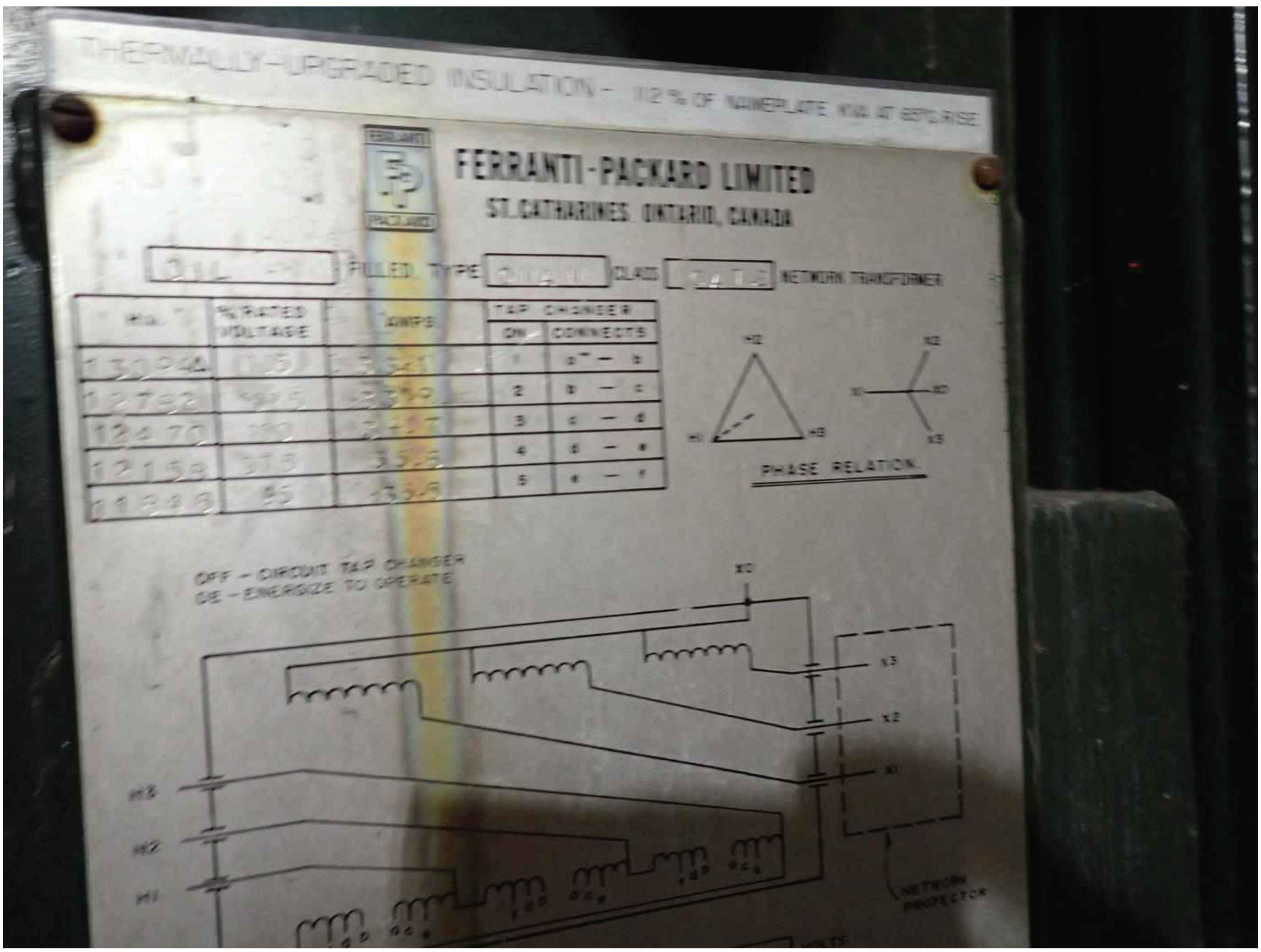
Allteck
A Quanta Services Company

CONTRACTOR: ALLTECK

Vault	V0073
District:	VAN
Address:	355 Burrard St
Date Assessed:	Nov 24, 2021
WO	M176575

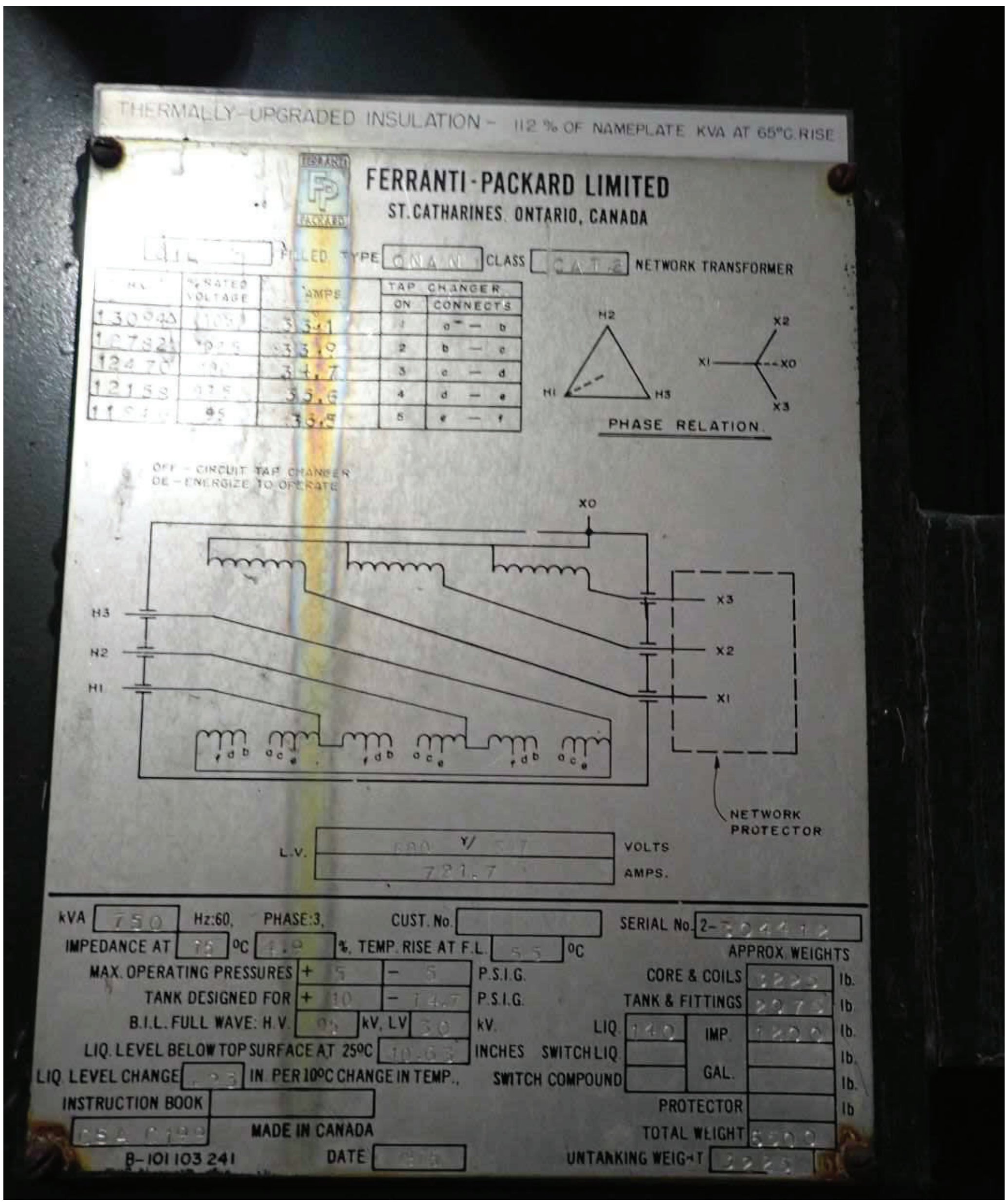
CONTRACTOR: ALLTECK

Vault	V0073
District:	VAN
Address:	355 Burrard St
Date Assessed:	Nov 24, 2021
WO	M176575



CONTRACTOR: ALLTECK

Vault	V0073
District:	VAN
Address:	355 Burrard St
Date Assessed:	Nov 24, 2021
WO	M176575



CONTRACTOR: ALLTECK

Vault	V0073
District:	VAN
Address:	355 Burrard St
Date Assessed:	Nov 24, 2021
WO	M176575

Allteck
A Quanta Services Company

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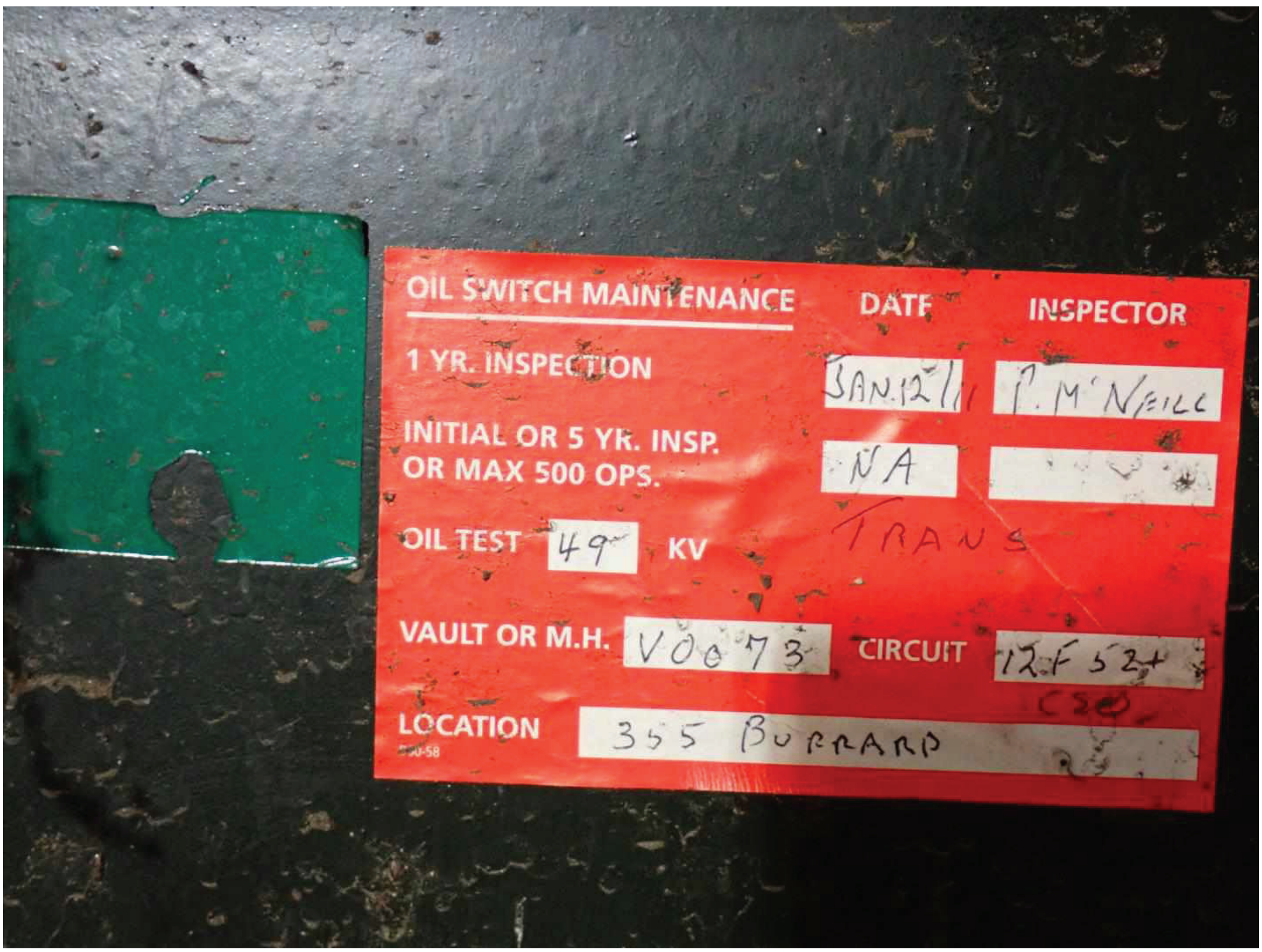

Alltteck
A Quanta Services Company

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CONTRACTOR: ALLTECK

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Address:	355 Burrard St
Date Assessed:	Nov 24, 2021
WO	M176575

CONTRACTOR: ALLTECK

Vault	V0073
District:	VAN
Address:	355 Burrard St
Date Assessed:	Nov 24, 2021
WO	M176575

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Vault	V0073
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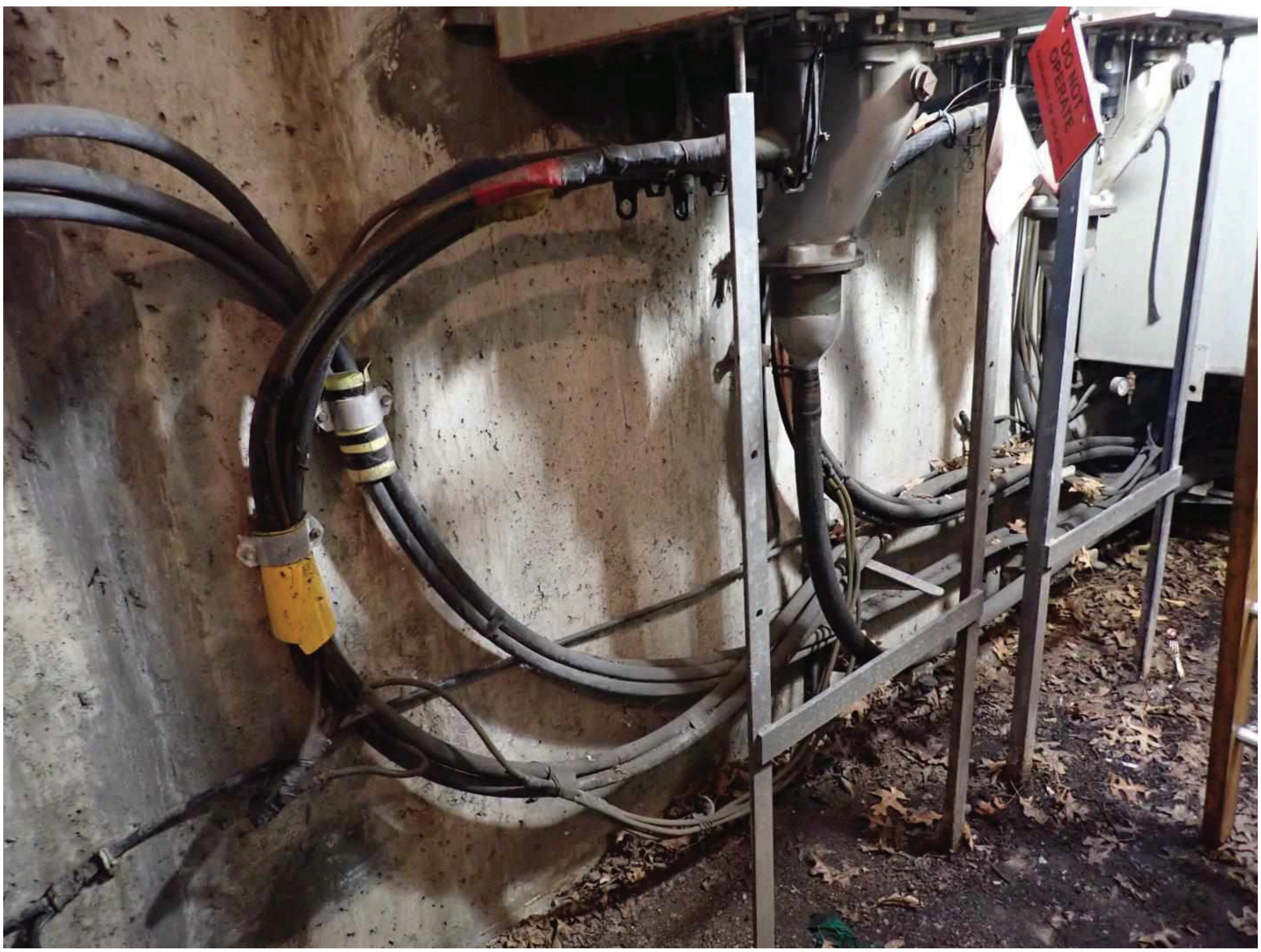
Date Assessed:	Nov 24, 2021
WO	M176575



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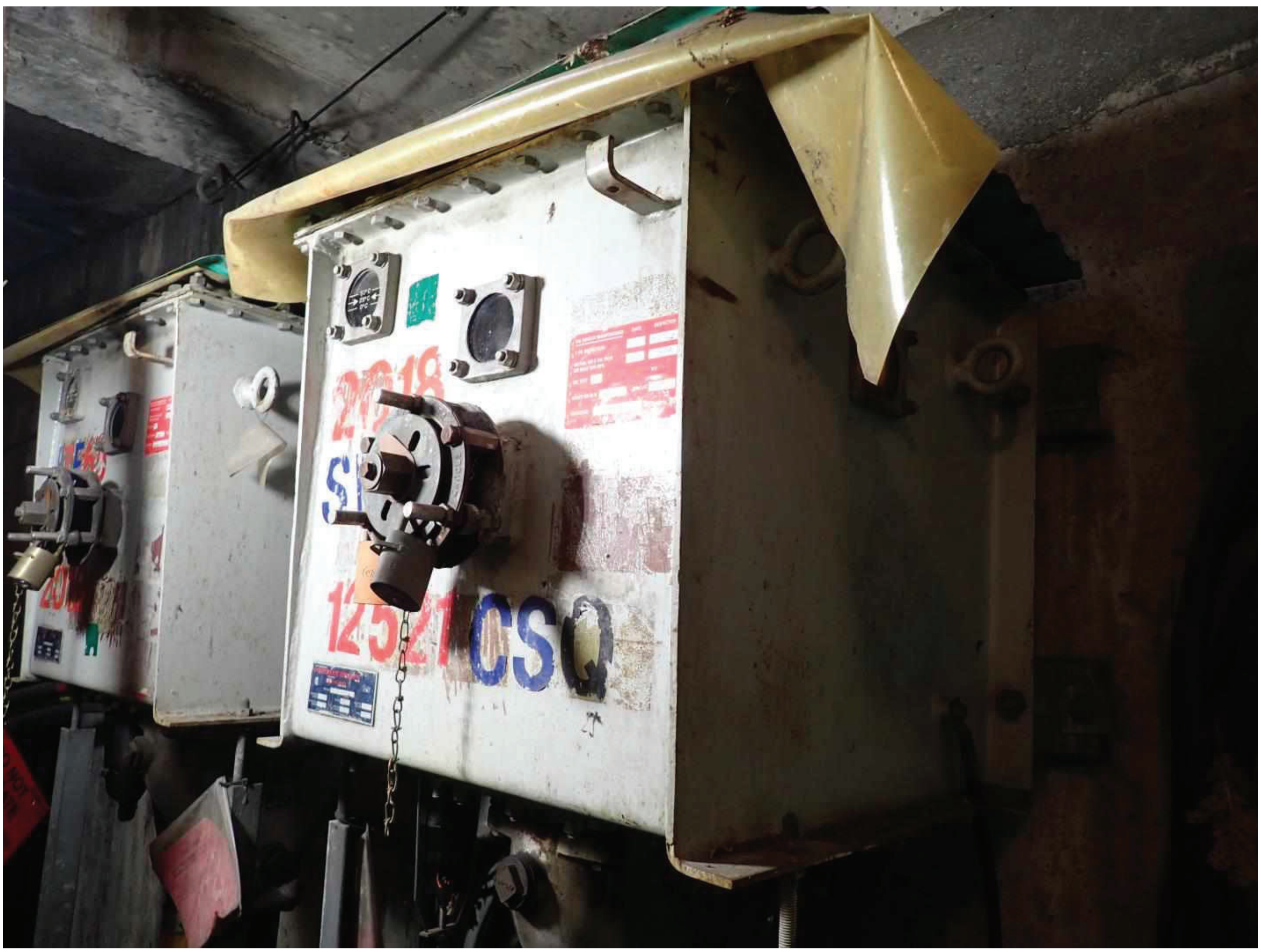
District:	VAN
Address:	355 Burrard St
Date Assessed:	Nov 24, 2021
WO	M176575

CONTRACTOR: ALLTECK

Vault	V0073
District:	VAN
Address:	355 Burrard St
Date Assessed:	Nov 24, 2021
WO	M176575

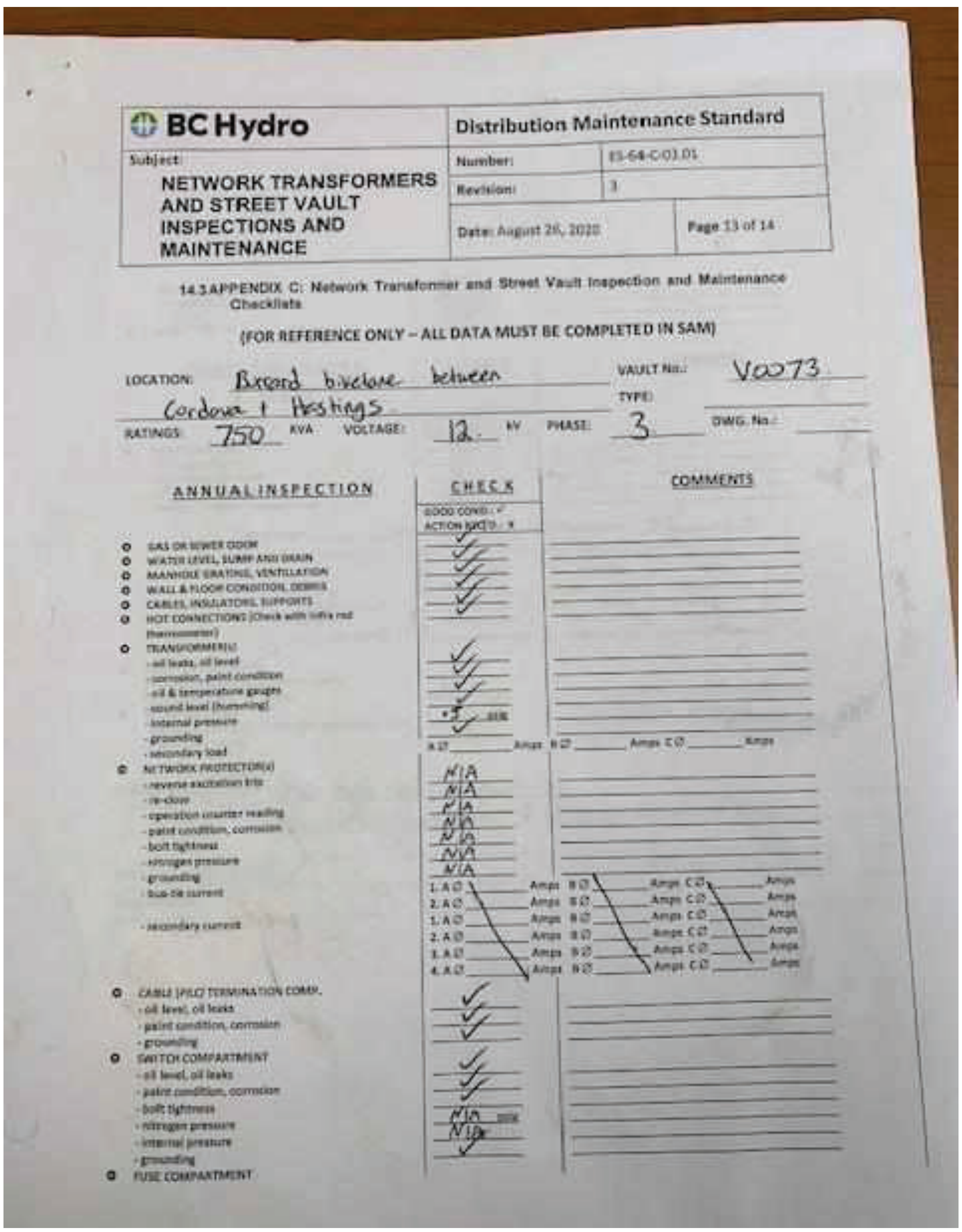


CONTRACTOR: ALLTECK

Vault	V0073
District:	VAN
Address:	355 Burrard St
Date Assessed:	Nov 24, 2021
WO	M176575

CONTRACTOR: ALLTECK

Vault	V0073
District:	VAN
Address:	355 Burrard St
Date Assessed:	Nov 24, 2021
WO	M176575



BC Hydro

Distribution Maintenance Standard

Subject: NETWORK TRANSFORMERS AND STREET VAULT INSPECTIONS AND MAINTENANCE

Number: ES-64-C-01.01

Revision: 3

Date: August 26, 2020

Page 13 of 14

14.3 APPENDIX C: Network Transformer and Street Vault Inspection and Maintenance Checklists

(FOR REFERENCE ONLY – ALL DATA MUST BE COMPLETED IN SAM)

LOCATION: Bxrrard bikelane between Cordova + Hastings

VAULT No.: V0073

TYPE:

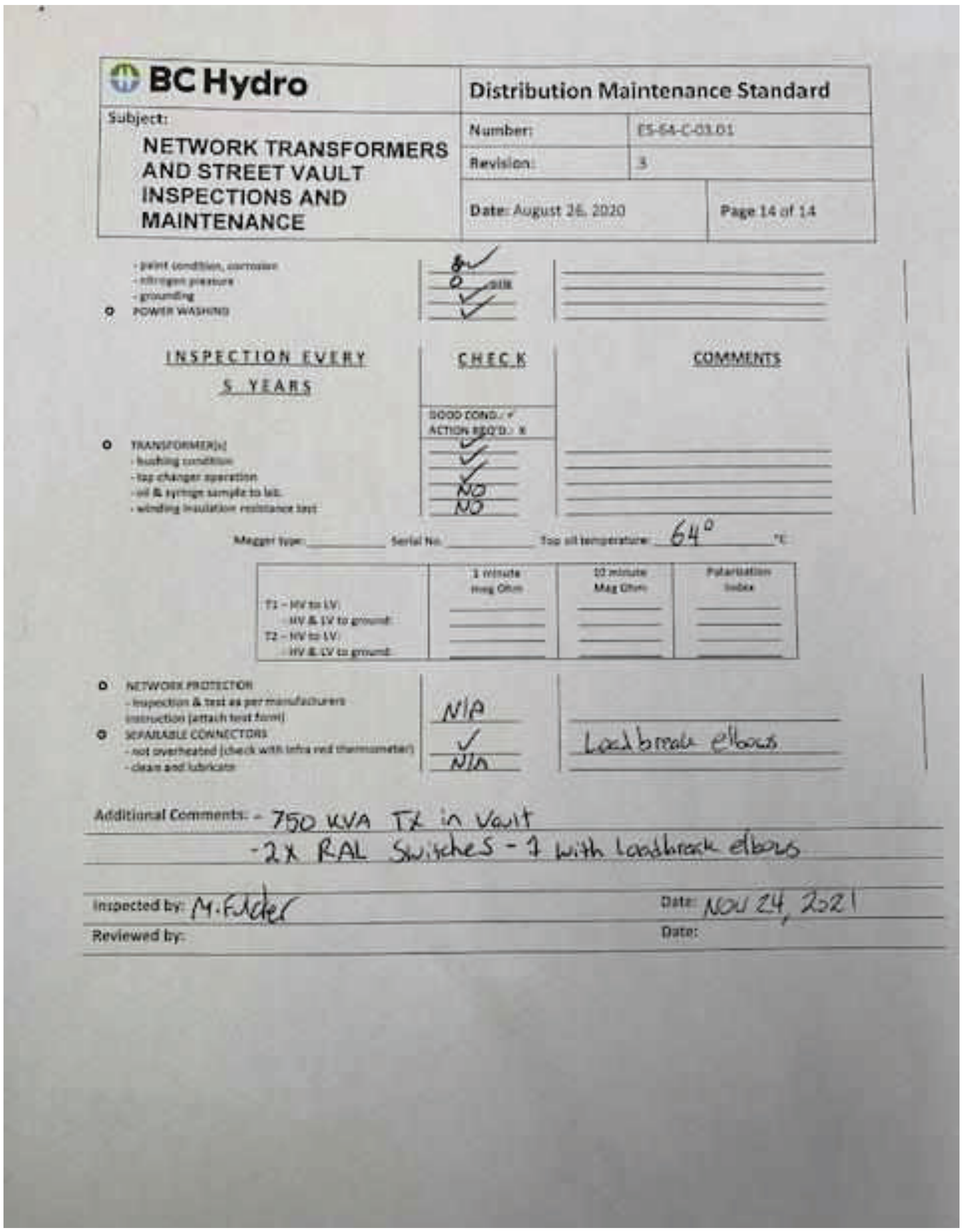
RATINGS: 750 KVA VOLTAGE: 12 kV PHASE: 3 DWG. No.:

ANNUAL INSPECTION	CHECK (GOOD COND.: ✓ ACTION REQ'D: ✗)	COMMENTS
GAS OR SEWER ODOR	✓	
WATER LEVEL, SUMP AND DRAIN	✓	
MANHOLE GRATING, VENTILATION	✓	
WALL & FLOOR CONDITION, DEBRIS	✓	
CABLES, INSULATORS, SUPPORTS	✓	
HOT CONNECTIONS (Check with infra red thermometer)	✓	
TRANSFORMER(s)		
- oil leaks, oil level	✓	
- corrosion, paint condition	✓	
- oil & temperature gauges	✓	
- sound level (humming)	✓	
- internal pressure	✓	
- grounding	✓	
- secondary load	A Ø ____ Amps B Ø ____ Amps C Ø ____ Amps	
NETWORK PROTECTOR(s)		
- reverse excitation trip	N/A	
- re-close	N/A	
- operation counter reading	N/A	
- paint condition, corrosion	N/A	
- bolt tightness	N/A	
- nitrogen pressure	N/A	
- grounding	N/A	
- bus-tie current	1. A Ø ____ Amps B Ø ____ Amps C Ø ____ Amps 2. A Ø ____ Amps B Ø ____ Amps C Ø ____ Amps	
- secondary current	1. A Ø ____ Amps B Ø ____ Amps C Ø ____ Amps 2. A Ø ____ Amps B Ø ____ Amps C Ø ____ Amps 3. A Ø ____ Amps B Ø ____ Amps C Ø ____ Amps 4. A Ø ____ Amps B Ø ____ Amps C Ø ____ Amps	
CABLE (PILC) TERMINATION COMP.		
- oil level, oil leaks	✓	
- paint condition, corrosion	✓	
- grounding	✓	
SWITCH COMPARTMENT		
- oil level, oil leaks	✓	
- paint condition, corrosion	✓	
- bolt tightness	✓	
- nitrogen pressure	N/A	
- internal pressure	N/A	
- grounding	✓	
FUSE COMPARTMENT		

Alltech — A Quanta Services Company

CONTRACTOR: ALLTECK

Vault	V0073
District:	VAN
Address:	355 Burrard St
Date Assessed:	Nov 24, 2021
WO	M176575



BC Hydro

Distribution Maintenance Standard

Subject: NETWORK TRANSFORMERS AND STREET VAULT INSPECTIONS AND MAINTENANCE

Number:	ES-54-C-03.01
Revision:	3
Date: August 26, 2020	Page 14 of 14

	Check	Comments
- paint condition, corrosion	✓	
- nitrogen pressure	0 psi	
- grounding	✓	
o POWER WASHING	✓	

INSPECTION EVERY 5 YEARS	CHECK (GOOD COND.: ✓ ACTION REQ'D.: X)	COMMENTS
o TRANSFORMER(s)	✓	
- bushing condition	✓	
- tap changer operation	✓	
- oil & syringe sample to lab	NO	
- winding insulation resistance test	NO	

Megger type: ______ Serial No. ______ Top oil temperature: 64° °C

	1 minute Meg Ohm	10 minute Meg Ohm	Polarization Index
T1 – HV to LV:			
- HV & LV to ground:			
T2 – HV to LV:			
- HV & LV to ground:			

o NETWORK PROTECTOR - inspection & test as per manufacturers instruction (attach test form)	N/A	
o SEPARABLE CONNECTORS - not overheated (check with infra red thermometer)	✓	Loadbreak elbows
- clean and lubricate	N/A	

Additional Comments: - 750 KVA TX in Vault
-2X RAL Switches - 1 with Loadbreak elbows

Inspected by: M. Felder Date: NOV 24, 2021

Reviewed by: Date:

Appendix E: VFRS Report
Case 230009317

Vancouver Fire and Rescue Services

Incident Report

Case # **230009137** **CAD Event #** *E230550292* **CAD Type** SMOKE OR FIRE CONFINED TO UNDERGROUND VAULT

Insurance Adjuster
Claim Number
Policy Num

External Remarks

Title LAFC 2809

INC#23-0009137
VPD INC#23-31511
353 Burrard St
February 24, 2023
1807hrs

VANINV73 responded to 353 Burrard St for a structure fire and reported explosion in an underground electrical vault. AC Nichols, BC Burden and Captain Ferris of Engine8 were on side with a second alarm assignment. The fire occurred under the sidewalk outside of 353 Burrard St.

Witness 1: s.22(1) [redacted]
Witness 2: s.22(1) [redacted]
Chief Engineer of 355 Burrard: Sam Xian s.22(1) [redacted]
BC Hydro Sub Foreman/Powerline Tech: Harrison Parker 250-701-3497
Building Operation Manager 355 Burrard: Paul Fernandez s.22(1) [redacted]
VPD PC 3096

Crews stated that they arrived and found a large fire burning from an underground vault. The fire was occurring outside of JJ Bean coffee shop at 353 Burrard.

The two witnesses stated that they were walking south in front of 353 Burrard when they heard and saw a large explosion occur. The witnesses stated that they did not see or hear anything that indicated an explosion was imminent. Both witnesses sustained 2nd degree burns to there hands and face. Both were treated and sent to Vancouver General Hospital for treatment. Both witnesses were released from hospital.

Area of origin was in the underground electrical vault. In this area was found large pieces of dislodged concrete, shattered glass, a shattered manhole cover and the charred remains of electrical distribution equipment.

Vancouver Fire and Rescue Services

Incident Report

Case # **230009137** **CAD Event #** *E230550292* **CAD Type** SMOKE OR FIRE CONFINED TO UNDERGROUND VAULT

Based on the evidence at the scene this fire was ACCIDENTAL. According to BC Hydro Sub Foreman/Powerline Technician Harrison Parker, there is probable cause to support that a 1200 Volt Primary Switch within the underground vault sustained an electrical short. This electrical short caused an explosion and a subsequent fire. 355 and 335 Burrard sustained damage from the explosion. 353 Burrard damage included smashed windows in the storefront and a sprinkler activation. 355 Burarrd also sustained smashed windows in the entry and smoke damage on the exterior of the building. 335 also sustained smashed windows.

Scene left in care of BC Burden.

LAFC 2809

Michael Heslop

CAD/Dispatch Notes

LocationComments

20230224180723PS ** LOI search completed at 02/24/23 18:07:23 911002161 icad94prodcomm1
20230224180738PS LOTS OF SMOKE CAME FROM UNDER GROUND 911002161 ecfd04
20230224180741PS FIRE ALARMS GOING OFF 911002161 ecfd04
20230224180743PS End of Duplicate Event data 911001995 ecfd05
20230224180756PS ** Event Type changed from EXP1 to VAULT at: 02/24/23 18:07:56 911002758 ecfd03
20230224180756PS ** >>>> by: 911002758 on terminal: ecfd03 911002758 ecfd03
20230224180756PS ** Event Priority changed from 4 to 1 at: 02/24/23 18:07:56 VAF 911002758 ecfd03
20230224180756PS ** >>>> by: 911002758 on terminal: ecfd03 VAF 911002758 ecfd03
20230224180757PS GAS EXPLOSION ? CAME FROM UNDERATH 911002161 ecfd04
20230224180759PS T: 6VA 911002758 ecfd03
20230224180759PS ** Cross Referenced to Event # B230550184 at: 02/24/23 18:07:59 0 icad94prodcomm1
20230224180759PS ** >>>> by: 0 on terminal: icad94prodcomm1 0 icad94prodcomm1
20230224180804PS ** Case number 230009137 has been assigned to event E230550292 911002758 ecfd03
20230224180804PS ** >>>> by: 911002758 on terminal: ecfd03 911002758 ecfd03
20230224180804PS ** Recommended unit VAS07 for requirement SQUAD3 (2.5 min) ** Recommended unit VAL07 for requirement LADDE

Vancouver Fire and Rescue Services

Incident Report

Case # **230009137** **CAD Event #** *E230550292* **CAD Type** SMOKE OR FIRE CONFINED TO UNDERGROUND VAULT

R (2.5 min) ** Recommended unit VAE08 for requirement ENGINE (2.6 min) ** Recommended unit VAP06 for requirement ENGINE (2.9 min) ** Recommended unit VAR08 for requirement RESCUE2-Standalone (2.1 min) ** Recommended unit VAB1 for requirement BATTALION C HIEF (4.2 min) VAF 911002758 ecfd03
20230224180815PS HEARD LOUD BANG FIRE BALL FROM THE GROUND 911001995 ecfd05
20230224180825PS End of Duplicate Event data 911002161 ecfd04
20230224180838PS End of Duplicate Event data 911002161 ecfd04
20230224180851PS End of Duplicate Event data 911001995 ecfd05
20230224180852PS BCAS: YELLOW 911002758 ecfd03
20230224180852PS BCAS Event Number: E230122033 911002758 ecfd03
20230224180852PS AA: BC1171 LTE VANCOUVER - W HASTINGS/BURRARD (WATERFRONT) , 999 HASTINGS ST VAN PH s.22(1) [redacted] || 911002758 ecfd03
20230224180852PS ** Cross Referenced to Event # B230550185 at: 02/24/23 18:08:15 911002758 ecfd03
20230224180852PS ** >>>> by: 0 on terminal: icad94prodcomm1 911002758 ecfd03
20230224180852PS ** LOI search completed at 02/24/23 18:08:15 911002758 ecfd03
20230224180852PS ** BCEHS Critical Location Information for B230550185 Changed from '' to 'A/F JOEY BENTALL' 911002758 ecfd03
20230224180852PS Age unknown, Gender unknown, Consciousness unknown, Breathing status unknown. Unknown number of patients invol ved. | Chief Complaint: explosion top building | KQ: A structure is still burning. | KQ: It's not known if everyone is safe and out of danger. | KQ: They were involved in an explosion/blast. | KQ: This happened now (less than 6hrs ago). | KQ: It's not known if they are responding normally (completely alert). | KQ: It's not known if they have difficulty breathing. | KQ: It's not known if they have difficulty speaking between breaths. | K Q: The extent of their burns or injuries is not known. 911002758 ecfd03
20230224180852PS End of Duplicate Event data 911002758 ecfd03
20230224180852PS ** Cross Referenced to Event # E230550293 at: 02/24/23 18:08:52 911002758 ecfd03
20230224180853PS ** >>>> by: 911002758 on terminal: ecfd03 911002758 ecfd03
20230224180854PS End of Duplicate Event data 911001562 ecfd01
20230224180858PS End of Duplicate Event data 911002161 ecfd04
20230224180905PS PER EHS CALL, POSSIBLY BURRARD/W PENDER 911002758 ecfd03
20230224180905PS End of Duplicate Event data 911001995 ecfd05
20230224180916PS End of Duplicate Event data 911001562 ecfd01
20230224180917PS End of Duplicate Event data 911002161 ecfd04
20230224180943PS End of Duplicate Event data 911001995 ecfd05
20230224180945PS End of Duplicate Event data 911002161 ecfd04
20230224180959PS HANG UP FROM THE Q s.22(1) [redacted] - SAID EXPLOSION AND HUNG UP 911002161 ecfd04
20230224181018PS End of Duplicate Event data 911001995 ecfd05
20230224181031PS End of Duplicate Event data 911001995 ecfd05
20230224181035PS VAE08 -- MSG RCD 911002758 ecfd03

Vancouver Fire and Rescue Services

Incident Report

Case # **230009137** **CAD Event #** *E230550292* **CAD Type** SMOKE OR FIRE CONFINED TO UNDERGROUND VAULT

20230224181040PS VAAC01 ADV 911001562 ecfd01
20230224181043PS MARINE BUILDING THERE IS FIRE 911002161 ecfd04
20230224181049PS FIRE BALL 2 STORIES TALL .. 911001995 ecfd05
20230224181102PS FIRE ON SIDEWALK.. 911001995 ecfd05
20230224181117PS End of Duplicate Event data 911002161 ecfd04
20230224181122PS BURRARD/W HASTING A/F JOEY BENTHAL EXPLOSION SEEN? NOTHING ABOUT SPECIFIC PATIENTS AT THIS TIME PER EHS JUST HAVE CALLERS CALLING IN THE EVENT GENERALLY 911002475 ecfd06
20230224181136PS VAE08 -- MSG RCD 911002758 ecfd03
20230224181142PS End of Duplicate Event data 911001995 ecfd05
20230224181149PS ANOTEHR HANG UP FROM THE Q - EXPLOSION ATHE A/L 911002161 ecfd04
20230224181152PS VAE08 -- SEEING BLK SMOKE..TRYING TO FIND LOCATION 911002758 ecfd03
20230224181158PS End of Duplicate Event data 911002161 ecfd04
20230224181212PS End of Duplicate Event data 911002161 ecfd04
20230224181214PS VAB1 -- COPIES ALL UPDATE 911002758 ecfd03
20230224181233PS End of Duplicate Event data 911001995 ecfd05
20230224181251PS End of Duplicate Event data 911001562 ecfd01
20230224181251PS CALLING HYDRO 911002475 ecfd06
20230224181307PS s.22(1) [redacted] - HANG UP FROM Q - EXPLOSION 911002161 ecfd04
20230224181311PS End of Duplicate Event data 911002161 ecfd04
20230224181316PS End of Duplicate Event data 911001562 ecfd01
20230224181320PS End of Duplicate Event data 911001995 ecfd05
20230224181345PS End of Duplicate Event data 911001995 ecfd05
20230224181348PS s.22(1) [redacted] .. AT THE RESTAURAT - 1001 W CORDOVA - TRANSFERRING TO BCAS 911002161 ecfd04
20230224181358PS 355 BURRARD ALARMS.,.. TYCO.. s.22(1) [redacted] 911001995 ecfd05
20230224181404PS BCAS: RED 911002758 ecfd03
20230224181404PS BCAS Event Number: E230122045 911002758 ecfd03
20230224181404PS Age unknown, Gender unknown, Consciousness unknown, Breathing status unknown. 911002758 ecfd03
20230224181404PS | Chief Complaint: Explosion - Multiple patients hit by glass 911002758 ecfd03
20230224181404PS | KQ: They were involved in an explosion/blast. 911002758 ecfd03
20230224181404PS ** Cross Referenced to Event # B230550188 at: 02/24/23 18:13:55 911002758 ecfd03
20230224181404PS ** >>>> by: 0 on terminal: icad94prodcomm1 911002758 ecfd03
20230224181404PS ** LOI search completed at 02/24/23 18:13:55 911002758 ecfd03
20230224181404PS End of Duplicate Event data 911002758 ecfd03
20230224181404PS ** Cross Referenced to Event # E230550296 at: 02/24/23 18:14:04 911002758 ecfd03

Vancouver Fire and Rescue Services

Incident Report

Case # **230009137** **CAD Event #** *E230550292* **CAD Type** SMOKE OR FIRE CONFINED TO UNDERGROUND VAULT

20230224181404PS ** >>>> by: 911002758 on terminal: ecfd03 911002758 ecfd03
20230224181434PS HYDRO ADVD WILL BE THERE IN APPROX 30 MINS 911002475 ecfd06
20230224181442PS PT IS IN THE WASHROOM AT 1001 W CORDOVA 911002161 ecfd04
20230224181451PS VAB1 -- OS..REPORTING EXPLOSION AT 355 BURRARD..DMG TO BUILDING..SECOND ALARM..ENSURE HYDRO IS RESPONDING 911002758 ecfd03
20230224181515PS ** BCEHS Critical Location Information for B230550185 Changed from '' to 'A/F JOEY BENTALL' 911000001 icad94prod comm2
20230224181523PS VAB1 -- COPY 911002758 ecfd03
20230224181528PS ** Alarm level updated to 1 VAF 911002758 ecfd03
20230224181529PS ** Alarm level updated to 2 VAF 911002758 ecfd03
20230224181538PS ** Recommended unit VAS04 for requirement SQUAD3 (5.8 min) ** Recommended unit VAAIR18 for requirement AIR (9.6 min) ** Recommended unit VAINV75 for requirement FIRE INVESTIGATOR (4.2 min) ** Recommended unit VAB3 for requirement BATT ALION CHIEF (9.6 min) ** Recommended unit VARU18 for requirement REHAB SUPPORT UNIT (9.6 min) ** Recommended unit VAE06 for requirement ENGINE (2.9 min) ** Recommended unit VAE02 for requirement ENGINE (3.0 min) ** Recommended unit VAAC01 for requirem ent ON DUTY ASSISTANT CHIEF (4.2 min) ** No recommendation for requirement DUTY VAF 911002758 ecfd03
20230224181654PS s.22(1) [redacted] CALLED BACK .. AND CALLING ABOUT EXPLOSION 911001995 ecfd05
20230224181704PS VAB1 -- STAGING AT BURRARD/W HASTINGS 911002758 ecfd03
20230224181725PS CALLING FIRE INV 911002475 ecfd06
20230224181758PS INV75 ADVD AND ATTENDING 911002475 ecfd06
20230224181817PS MARINE BLDG.. 355 BURRARD... PEOPLE STUCK HIGHER FLS UNABLE TO GET OUT 911001995 ecfd05
20230224181949PS VAB1 -- JUST ARRIVING OS..APPEARS BUILDING IS JUST AN EXPOSURE..WILL HAVE AN UPDATE TO FOLLOW 911002758 ecfd03
20230224182107PS FILL-IN VAE03 X #4,,,,,VAE01 X #6,,,,,VAL15 #7 911001562 ecfd01
20230224182222PS EHS ADVD TO SEND STANDBY CAR AS WELL FOR CREWS 911002475 ecfd06
20230224182258PS VAB1 -- CMD REP 2 PTS AT 1001 CORDOVA..NEED 2 BCAS UNITS..LCAERATIONS AND FACIAL BURNS..ANY INF O TO WHERE PEOPLE ON UPPER FLOORS ARE LOCATED? 911002758 ecfd03
20230224182412PS VAB1 -- COPY..PP STATING UPPER FLOORS..WILL ADVVISE 911002758 ecfd03
20230224182429PS VPD ADVISING PEOPLE ON UPPER FLS UNABLE TO LEAVE .. THEY WILL CALL WITH FURTHER INFO.. ADVISE LOTS OF POLICE O/S AS WELL 911001995 ecfd05
20230224182456PS BCAS ADV TO ATTEND 1001 W CORDOVA X 2 - FACIAL LACERATIONS 911001562 ecfd01
20230224182540PS Alarm Timer Extended: 0 VAF 911002758 ecfd03
20230224182817PS RMS COMMAND ASSUMED 911002758 ecfd03
20230224183918PS VAB1 -- ANY FURTHER INFO FROM VPD ABOUT PERSONS ON UPPER FLOORS? 911002758 ecfd03
20230224183948PS CALLING VPD 911002059 ecfd01
20230224184149PS VPD - HAS NO FURTHER UPDATES ON - @ 18:19 - REPORT OF PPL ON 7 TH & 8TH FLR 911002059 ecfd01

Vancouver Fire and Rescue Services

Incident Report

Case # **230009137** **CAD Event #** *E230550292* **CAD Type** SMOKE OR FIRE CONFINED TO UNDERGROUND VAULT

20230224184403PS ***COMMAND*** VAF 911002758 ecfd03
20230224184429PS VAB1 -- COPY..PERSONS ON 7TH AND 8TH FLOORS 911002758 ecfd03
20230224184434PS VPD - MARINE BLDG - UK HOW MANY PPL ARE TRAPPED - 355 BURRARD ST - BLDG IN QUESTION - HAVE MANAGER FOR FLR 7 & 8 -UK HOW MANY PPL - GENERAL MANAGER IS ONS - JUST WAITING FOR AN UPDATE - 911002059 ecfd01
20230224184437PS Alarm Timer Extended: 0 VAF 911002758 ecfd03
20230224184712PS VAB1 -- COPY THAT 911002758 ecfd03
20230224184755PS Alarm Timer Extended: 0 VAF 911002758 ecfd03
20230224184851PS CHF FRY CALLING TO BE UPDATED.. GAVE DETAILS TO HER .. 911001995 ecfd05
20230224185213PS Alarm Timer Extended: 0 VAF 911002471 ecfd07
20230224191816PS VAB1 -- HYDRO ETA 911002471 ecfd07
20230224191930PS Tracker AutoARER ER-to-OS VAF 0 icad94prodcomm2
20230224192105PS HYDRO ETA - WITHIN 45 MIN 911002059 ecfd01
20230224192317PS PER EHS... WH 911003801 ecfd09
20230224192352PS PER EHS* ASKING WHAT ALARM LEVEL AND PT.. ADVD OF PTS TRAPPED IN BLDG AND ALARM 2 911003801 ecfd09
20230224192359PS *PT DETAILS 911003801 ecfd09
20230224195232PS VAB1 -- HYDRO ETA 911002471 ecfd07
20230224195248PS CALLING HYDRO 911001995 ecfd05
20230224195505PS HYDRO IS SAYING 2030HRS 911002059 ecfd01
20230224202305PS VAB1 -- PR FOR TRACTOR RESTUARANT....ADDY 335 BURRARD 911002471 ecfd07
20230224202440PS VAB1 -- SIGNIFICANT DAMAGE TO THE RESTAURANT 911002471 ecfd07
20230224203257PS PER VPD... TRACTOR MARINE.. s.22(1) [redacted] ... s.22(1) [redacted] ... PR FOR 335 BURRARD 911003801 ecfd09
20230224205555PS CALLED PR - WILL CALL BACK WITH AN ETA 911002059 ecfd01
20230224205915PS TRACTOR PR ETA 10-15 MIN 911001942 ecfd02
20230224210252PS VAE08 -- L08 TO COME AND RELIEVE US... 911002471 ecfd07
20230224210659PS VAE08 -- P06 ER TO RELIEVE 911002471 ecfd07
20230224212813PS VAE08 -- P06 NOW CMD.. 911002471 ecfd07
20230224215924PS VAB1 -- CLRING - LICO P06 - P6 IN CMD 911002059 ecfd01
20230224223200PS VAP06 -- CLRING - HYDRO IS SHUT OFF THE POWER AND POWER TO BLDG IS SAFE TO BE ON - LICO MANAGER 911002059 ecfd01

CAD Note

SIDEWALK BLEW UP ...STAGING BURRARD/W HASTINGS

End of Report for Case#: 230009137

Appendix F: Cable Crew Interview Notes, May 5, 2023

May 5, 2023

Cable Crew Rep. - Discussion Notes

INTERVIEW OF:
Cable Crew Rep.

IN ATTENDANCE

BC Hydro
Grant Ringham
Ryan Laing

Powertech
Weili Kang
Stu Chambers
(external consultant)

Senez Consulting
Peter Senez

NOTES BY
Peter Senez

LOCATION
Powertech, Surrey, BC

DATE/TIME
May 5 2023, 9:30 – 11:45 am

The following are meeting notes from discussions with cable crew representative on May 5th, 2023, who provided general background information on BC Hydro's method of changing oil in rotary switches. The Rep. has been with BC Hydro since 2008 and has considerable experience changing the oil in these types of switches. The BC Hydro investigation team for the explosion that occurred in Vault 73 on February 24, 2023 is appreciative of Cable Crew Rep's assistance in the investigation.

Square brackets denote clarifications or input by interviewers.

GENERAL

Jobs involving oil changes in equipment are required to be planned in order to minimize impacts of the work. An outage is submitted and approved in advance, usually providing about a week-window for completion to give flexibility on when the job can occur. Changing the oil in a switch usually takes about 1 day. Weather is a factor; there is an increased risk of oil contamination on bad weather days. If they have to do the work due to urgency, then the crew would gear up better with tents and other equipment to protect the vault and reduce the contamination risk. Optimally, the work is scheduled in summer months when the weather is drier.

On the day the work is to be completed, an SPG is pulled. The crew will start loading the needed gear. The oil is already on a dedicated truck with a "degassing unit" on it. The truck has a tank with a heater inside and a pumping unit. It is kept under a vacuum, measured using "Torr" units [a measure of pressure]. The truck maintains the vacuum 24/7 [which limits potential for air contamination of the oil]. Trucks are connected to shore power. The truck tank has close to 2 barrels of oil, approximately 400L. The truck is used for oil-filled transmission cables and RAL switches.

There are two types of oil which come from Stores. Soltex 2288 is the product that has been used for a long time, at least since 2008.

Prior to the work, one of the crew will make sure the truck is full. If not full, then they fill it. However, this is done at least a day in advance of the work. Transmission [BC Hydro Transmission Cables Dept] owns the truck but it is used by Cables [BC Hydro Distribution Cables Dept]. The oil comes from Stores and therefore crews not familiar with any QA/QC for oil when it is received [additional information could be obtained through purchasing].

Oil is stored in a warehouse. The barrels come sealed. To fill the truck, they break the seal, then use a bung wrench to open the hole on the top of tank. Once opened, the barrel is open to the atmosphere. To transfer the oil into the tank on the truck, a suction tool that connects to a hose which connects to the pump on the Degassing Unit, is inserted into the barrel. The barrel is emptied in about 3 minutes into the truck tank. There are no valves on the hose itself, and it sits in the open atmosphere when not in use. The suction tube is a big, long copper rod that goes almost to the bottom of the barrel. Once the barrel is near-empty, air is pulled into the tube and therefore into the tank on the truck. The machine is set to degassify, at least overnight, which removes any air from the tank and therefore the oil. The Torr meter is used to check the vacuum level [0.05 Torr].

INITIAL SITE ATTENDANCE

When the oil in the truck reaches a satisfactory vacuum level on the Torr meter, then the truck is taken to site on the day work is to be completed on the RAL switch. Usual procedures then follow, a Tailboard safety briefing is completed where they go over what the scope of work is, whether it is a 1-year or 5-year check on the Switch. They do a confined space checklist, assign roles, dedicate someone enter the vault, someone running the truck and safety team. Next step is to install a gas detector and do confined space checks. MH permits are also on adjacent circuits to further isolate the switch.

Only one switch's oil is changed at a time. The second switch remains energized to supply power to the customer and therefore it isn't touched during the procedure. Usually one circuit of all switches is done under one permit, and then do another permit for the other set of switches. These are usually done within the same year of each other although there are occasional situations where they can't do that. Most of the training has been field-based from others under apprenticeship along with 5 year maintenance program. There is also the BCH maintenance procedure and manufacturer's maintenance information.

VAULT ENTRY & SAFETY CHECKS

Once safety steps are in place the manhole lid is opened, the vault is entered, the location is confirmed by checking the stamp on collar. One individual is going to do the safety checks, visual on transformer, Fliring (an IR camera) the elbows. A vault general condition assessment is completed which includes a visual evaluation for safety and integrity. Visual checks are performed on both RAL switches to observe for oil leaks. On the transformer, the radiator fins are checked, as well as around the base of the transformer to see if it's sweating oil out. Transformers are energized when doing the work.

Examples of issues that can arise are severe rusting from the outside, checking the decals and nameplates. Looking at the bottom of the pothead / feeder portion of the switch, and checking the URD elbows to make sure they're seated properly. You can tell if it's not seated by a collar inspection. Other examples of issues include hot elbows, if the elbow has a temperature of 3 degrees hotter than the cable it's connected to. Other problems, elbows on the bottom are load-break. Haven't seen too many problems with elbows on top [Referring to the elbows on the fuse cabinet.]. A bale is a restraining clamp for dead-break elbows and a missing bale can be the reason the elbow is not sitting properly.

Once a visual assessment is complete and there are no issues, the following steps are taken:

- Confirm that the isolation is correct in the vault.
- Outside of the switch - verify that switch is open.
  (Even numbered switches are the running circuit, odd numbered switches are the standby)
- Don't expect to see an SPG tag on the switch if doing the 5-year maintenance.
- Expect cable PLT technicians to have disconnected the XLPE cables to the switch, to make sure confirm the SPG tag is on the junction bar on the opposite wall where the cables are isolated [stood-off and parked].

- Will then leave the Vault, and will ground the components, with hot stick and remove DVI [Digital Voltage Indicator], and can then install a ground. Looks like an elbow, yellow in colour.
- [Backnote] - before going into the Vault and just after the tailboard, will go to separate location to ground the PILC feeder to the Vault.
- After grounded feeder cable, and URD cable connections, now re-enter the vault, from outside check with Modiwark [No contact voltage meter] sensing on the windows of the RAL switch. Never experienced problems with this voltage being present but good additional check to make sure the switch is de-energized. Also checks the meter with adjacent energized switch to make sure Modiwark is working.
- Now the locks are removed on the switching mechanism and a switching handle is installed. This is installed in a manner that allows the switch to be grounded.
- Leave the vault and operate the switch into the ground positioned from above.
- Re-enter the vault and remove the handle.

SWITCH PREPARATORY WORKS

Work can now begin to change the oil on the switch:

- The switch is raised so a ladder is used to access.
- Remove any covering that is used to keep debris off the switch.
- Open the port and listen for any hissing which shows there's still nitrogen, and then close it right away again if there is. Screw on cap. If you don't hear hissing right away, then you continue opening the cap until loose and then if no hissing then close. This finding is not recorded. It's probably 50/50 on whether there is evidence of escaping gas, and therefore the nitrogen is still present within the tank. This informs whether the seal is sufficient. If no hissing, will do a fairly thorough silicon job to better seal the lid later in the procedure. Room Temperature Vulcanizing silicon is used as an additional measure, generally available commercial silicones are used [as available in any hardware store].
- [Typical approach for cleaning the lid] Complete a thorough, brush-off of debris on top of switch with broom, then clean top of lid with shop vacuum, then wipe down. In years past Isopropanol was used and now Spray Nine is used to remove dust and debris.
- [Draining the oil] Open the top port back up (where pressure check was done) and leave open to atmosphere. Get small portable 120 V pumping unit, attach it to the hose connection on the front of the unit, turn the pump on. Uses ~1.5 inch hose. Oil is drained out, going up from switch to pump and into empty oil barrel.
- [Opening the Lid of Switch] Remove all the bolts on the top to remove lid, collect all the bolts in a bucket, bolts are frequently dropped and often replaced.
- [Lifting the lid] - two welded handles on the top are pulled to break seal, two-person job, one from top with a hook and one in the vault, each pull a handle until the lid is free and then top-side work pulls lid out of Vault. Topside worker cleans lid while inside worker cleans switch. When lid is removed, the silicon comes off quite easily.
- Modiwark is going to be used again just as a final check before hand contact.

SWITCH MAINTENANCE

- Next, switch maintenance is completed:
  - Switch is in a ground position. Look at other set of contacts attached to the URD cable. Visual inspection, whether they are bent, pitted, signs of arcing, eyeball and hand check. (Lights are in as part of manhole procedure - lights suspended above and therefore good visibility inside the switch). Check walls for paint on inside. Have never seen failed paint on the walls, only on the lid in the center.
  - Never observed need for full retrofit due to internal damage. Switch components normally intact and not in need of repair.
  - The contacts are cleaned, if pitting and arcing then a more thorough cleaning. Cleaning done using aluminum oxide sandpaper 120 grit, if needed, and scouring pads.
  - If seeing a little carbonization on the contacts, sanding and wiping with either sandpaper or scouring pads (BCH stock item - 6 x 8 squares). Similar [conditions found] for Active and Standby [switch] contacts, similar number of switch operations.
  - Checking tension on the internal bolts - torque settings, verifying the tension.
  - General condition of red fiberboard, making sure there are no cracks, or nothing is off, while also cleaning the components.
  - On the fiberboard loose grit contained in the oil remaining on the fiberboard. What looks like soot is wiped clean.
- Next, the switch is operated (there is a spring disengaging mechanism on the switch so oil doesn't shoot up). Ground to open first. Then clean ground. Looking at whole mechanism, looking at braids that attach the switch blades below, checking for broken strands, should have some slack). Likely just copper braided cables that connect. Never seen any issues with this.
- Also looking at rocker mechanism, will then close the switch, first without the spring action to make sure the contacts are aligning (always seem to be true), general assessment of the switch functionality. Will then operate under tension to make sure everything is working. Cycling the switch open-to-close to ground a few times to make sure everything is functioning.
- Will then move over to the ground bar, doesn't get used much (switch normally left open or closed). Never see arcing or pitting on the ground bars. Check bolts.
- Oil hose from the Degassing Unit brought in while extracting oil. Will thoroughly hose it off with fresh oil all components of switch, while extracting to remove any remaining residue within the switch.
- 50 - 60L of oil used to flush the switch. Bottoms are flat so some oil pools in bottom. Wipe down the insulators with wipealls and use wipeall to push all debris into the drain, giving all components a wipe (uses a lot of wipealls), until towel is clean when wiped and doesn't have oil residue.
- No lint wipealls are used. BCH product.
- Leave switch in open position, once everything is clean and good.

NEW OIL ADDED AND RETURN OF SWITCH TO SERVICE READY

Crew outside has cleaned the lid.

- Now going to put the lid back on.
  - Visual observation of the gasket is completed. If there was gas during initial inspection, then likely not adding silicone to the gasket.
  - If there are sections of gasket missing then additional gasket is added. There is no one-piece gasket to replace in equipment. Sections of Nebar [rubber gasket material] are cut to replace any missing components of the lid gasket, and silicon is added to provide additional seal.
  - If there was no nitrogen, then apply silicone sealant. Will do sealant on the flange the lid adheres to and then put the lid on top.
  - Swing lid in place with plug replaced, put lid down. Doesn't recall exact torque but will first install bolts snug and then torque wrench, doing criss-cross fastening pattern.
  - Remove the oil pump and close bottom spigot and close that valve.
  - Fill with Nitrogen gas using the Schrader valve. Use a nitrogen cylinder (dry nitrogen) (Linde). Fill switch tank with about 5lbs of pressure with Nitrogen, and then determine if pressure holds. Wait at least 5 minutes or longer depending on other activities. If it's holding, no further action required and if not holding then redo the gasket and lid until it does.
  - Then empties the nitrogen out.
  - Ready to fill - will attach the same oil hose, will attach to spigot where the drain is from. Check Torr rating, and will begin filling the switch.
  - Now filling, every 2 or 3 minutes, the plug is cracked to release over pressure. Fill until it reaches fill line in glass. Then close the spigot; and then reinstall the stopper in the plug in the bottom.
  - Then pressurize with nitrogen to 5 PSI.
  - Most pertinent information recorded on red sticker, not usually stuck directly on the tank, stickers are laminated and wired to frame in visible location.
  - Several checks to make sure the switch is left in the open position, then locked back in. (Done by more than one crew person so redundant checks are completed).
- Hipotronic tester [Hipotronics TC/DE test cell] for oil quality directly from the unit (usually done by Topside Crew), fill a small cup, slowly builds voltage up, and then hold that rating, and then record that which then goes on the red sticker on the outside of the switch. (No additional recording of oil quality).
- No oil sample of used oil is part of 5-year process
- End procedure includes removing the grounds, truck is returned. Return the SPG and then the circuit is ready to be energized gain.

OTHER GENERAL & 1 YEAR PROCEDURE

1 year procedure:

- No grounding required, no SPG, will do both switches.
- Verify the oil is visible in the site glass and clean, not cloudy etc.
- If okay, then going to bottom of spigot and remove 1L of oil, sticker on the bottom where it came from, which switch, and do the same thing.
- Some pull oil right away, some throw away a bit and then fill.
- Do a general visual through the windows and on the switch.

- Never has occurred where the oil was too low. Switches hold about 30 gal oil. Removing 1 liter is not a big deal.
- Never any issues with valves. Even if it did leak, there is also a stopper. Never had any issues with the spigot valve.

Since 2020/2021 sampling was stopped for a few years.

Never did Field oil sampling in 1 year, just the lab sample.

Biggest concern with 5-year maintenance was the lead up to isolating the switch. Gaps in procedure for isolating, and crew would show up and find the elbows hot. Since 2014, would go do maintenance with experienced crew. 5-year procedure is a variance in the isolation procedure. Easy to get complacent.

Never observed any concerns, uses the safe work method [SafeHub 312] procedure and not manufacturer's procedure as primary method.

END

Appendix G: Sample Logging

Items to do: *Take pictures of both sides; Take pictures of any interesting visuals; Collect wipes if wet; Collect foreign debirs (or items handing off) if larger*

Bag	# of items	Sub-items	Sample Description	General Description	More Detailed on Description	Any pieces/items collected	What was the item	Date of picture and sample collection in the lab
A	1	A1	RAL Switch on North side of Vault, around RAL Switches	large metal lid with two handles on top		No	N/A	March 7th 2023
B part 1	7	B part 1 - 1	Fuse 1 (insulator and bus accessories)	large metal piece with a ceramic end		Yes	light grey deposits	March 7th 2023
		B part 1 - 2		long cylindrical metal piece		No	N/A	
		B part 1 - 3		large, broken ceramic piece		No	N/A	
		B part 1 - 4		medium, broken ceramic piece		No	N/A	
		B part 1 - 5		smaller, broken ceramic piece A		No	N/A	
		B part 1 - 6		smaller, broken ceramic piece B		No	N/A	
		B part 1 - 7		plastic/polyester like curly fibers		No	N/A	
B part 2	5	B part 2 - 1	Fuse 1	smaller ceramic-like piece A		No	N/A	March 7th 2023
		B part 2 - 2		black, plastic/polyester like curly fibers A		No	N/A	
		B part 2 - 3		black, plastic/polyester like curly fibers B		No	N/A	
		B part 2 - 4		smaller ceramic-like piece B		No	N/A	
		B part 2 - 5		smaller cylinderical metal piece		No	N/A	
C	7	C1	Fuse 2	large metal piece with a ceramic end		No	N/A	March 7th 2023
		C2		long cylindrical metal piece		No	N/A	
		C3		large, broken ceramic piece		No	N/A	
		C4		medium, broken ceramic piece A		No	N/A	
		C5		medium, broken ceramic piece B		No	N/A	
		C6		plastic/polyester like curly fibers		Yes	curly fibers; black and white in colour	
		C7		multiple smaller black pieces/debris		No	N/A	
D	13	D1	Fuse 3	large metal piece with a ceramic end		No	N/A	March 7th 2023
		D2		long cylindrical metal piece		No	N/A	
		D3		large, broken ceramic piece		No	N/A	
		D4		medium, broken ceramic piece A		No	N/A	
		D5		medium, broken ceramic piece B		No	N/A	
		D6		medium, broken ceramic piece C		No	N/A	
		D7		medium, broken ceramic piece D		No	N/A	
		D8		medium, broken ceramic piece E		No	N/A	
		D9		medium, broken ceramic piece F		No	N/A	
		D10		medium, broken ceramic piece G		No	N/A	
		D11		medium, broken ceramic piece H		No	N/A	
		D12		smaller, broken ceramic piece		No	N/A	
		D13		plastic/polyester like curly fibers		No	N/A	
E	10	E1	Components under RAL Switch (Standby, Box A)	metallic piece capped at one end and wires on the other end	uncertain crimped wire	No	N/A	March 7th 2023 AND March 13th 2023
		E2		metallic piece with twisted copper wires at another end A	Braid connection to switching mechanism	No	N/A	
		E3		metallic piece with twisted copper wires at another end B	Braid connection to switching mechanism	No	N/A	
		E4		small metallic piece that has a circular base and an arch like frame on top		No	N/A	
		E5		hollow, metallic cylindrical pin-like structure A	Termination rods	No	N/A	
		E6		hollow, metallic cylindrical pin-like structure B	Termination rods	No	N/A	
		E7		hollow, metallic cylindrical pin-like structure C	Termination rods	No	N/A	

		E8		metallic bolt with a square plate around it	Wall insert and bolt	Yes	black scrapings from surface	
		E9		two four-pronged metallic plates attached at the base with a metallic nut and bolt LARGE	Switch contact	No	N/A	
		E10		two four-pronged metallic plates attached at the base with a metallic nut and bolt SMALL	Switch contact	No	N/A	
F	1	F1	PILC Termination (Standby, Box A)	PILC from RAL switch Box A		Yes (4 samples)	1st: Oily tar from pothead and from inside surface of the bag; 2nd: Melted aluminum piece from pothead's surface (dry side); 3rd: wipe from side with no words on it; 4th wipe from side with words on it	March 7th 2023 AND March 13th 2023
G	2	G1	Switch Components Switch Interior *no note on which Switch*	twisted metallic wires caped with a nut and bold on one end	Braid connection to switching mechanism	No	N/A	March 7th 2023
		G2		two four-pronged metallic plates attached at the base with a metallic nut and bolt; melted aluminum(?) metal is stuck between the two sets of prongs	Switch contact	No	N/A	
H	1	H1	Junction Bar - Left	Junction bar - LEFT; metallic structure with three metal cylindrical 'tubes' coming out from the top; a number of metallic (copper?) wires attached to the structure		Yes	Black coloured debris	March 7th 2023
I	4	I1	Junction Bar - Right	Junction Bar - RIGHT; metallic structure with three metal cylindrical 'tubes' coming out from the top; on one end there is a metalllic wire that has been cut		Yes	Black and white coloured debris pieces	March 7th 2023
		I2		metallic structure with two metallic 'tubes' coming out from the top of a very small base;		No	N/A	
		I3		hollow, metallic, cylindrical pin-like structure		No	N/A	
		I4		metallic structure that was attached to the opposite end of the Junction Bar; has a screw and nut to help keep it in place but it came off while taking pictures		No	N/A	
J	3	J1	Junction Bar - Centre	Junction Bar - CENTER; metallic structure with two metal cylindrical 'tubes' coming out from the top; one of the 'tubes' looks to have fallen out but came with the rest of the sample		Yes	Grey-ish white debris	March 8th 2023
		J2		hollow, metallic, cylindrical pin-like structure		No	N/A	
		J3		small metallic piece that has short plastic fibers coming out at one end; looks like a small paint bursh		No	N/A	
K	3	K1	Secondary Connector (Squid) 1	Secondary connector (Squid) 1; metallic base (made of aluminum?) with 6 metallic (copper?) wires coming off of each 'port'; they are held together via nuts and bolts		No	N/A	March 8th 2023
		K2		one bundle of wires that broke off from the base with melted metal where the wires come into contact with the base		No	N/A	
		K3		one bundle of wires that broke off from the base with melted metal where the wires come into contact with the base		No	N/A	
L	20	L1		Secondary connector (Squid) 2; metallic base (made of aluminum?); it is broken and only has three 'ports'; black in colour		No	N/A	
		L2		metallic base (made of aluminum?); broken piece and only has one 'port'; black in colour A		No	N/A	

		L3		metallic base (made of aluminum?); broken piece and only has one 'port'; black in colour B	No	N/A	
		L4		metallic base (made of aluminum?); broken piece and only has one 'port'; black in colour C	No	N/A	
		L5		metallic base (made of aluminum?); broken piece and only has one 'port'; black in colour D	No	N/A	
		L6		metallic base (made of aluminum?); broken piece and only has one 'port'; black in colour E	No	N/A	
		L7		melted piece of broken aluminum(?); black in colour A	No	N/A	
		L8		melted piece of broken aluminum(?); black in colour B	No	N/A	
		L9		bundle of copper wires cut at one end and 'capped' together at the other end and held together via two nuts and bolts A	No	N/A	
		L10		bundle of copper wires cut at one end and 'capped' together at the other end and held together via two nuts and bolts - A	No	N/A	
		L11	Secondary Connector (Squid) 2	bundle of copper wires cut at one end and 'capped' together at the other end and held together via two nuts and bolts - B	No	N/A	March 8th 2023
		L12		bundle of copper wires cut at one end and 'capped' together at the other end and held together via two nuts and bolts - C	No	N/A	
		L13		bundle of copper wires cut at one end and 'capped' together at the other end and held together via two nuts and bolts - D	No	N/A	
		L14		bundle of copper wires cut at one end and 'capped' together at the other end and held together via two nuts and bolts - E	No	N/A	
		L15		bundle of copper wires cut at one end and 'capped' together at the other end and held together via two nuts and bolts - F	No	N/A	
		L16		bundle of copper wires cut at one end and 'capped' together at the other end and held together via two nuts and bolts - G	No	N/A	
		L17		bundle of copper wires cut at one end and 'capped' together at the other end and held together via two nuts and bolts; has a bit of melted metal at this end - H	No	N/A	
		L18		bundle of copper wires cut at one end and 'capped' together at the other end and held together via two nuts and bolts; has a piece of the metallic base attached at this end - I	No	N/A	
		L19		nut and bolt A	No	N/A	
		L20		nut and bolt B	No	N/A	
M	1	M1	PILC Termination (Active, Box B)	number of wires wrapped around each other with lots of greasy black debris in between; was too heavy and was only took pictures from the top down not bottom up	Yes (2 samples)	1st: thin layer wrapped around cable (could be metallic); 2nd: Black debris taken from in between cable bundle	March 8th 2023
N	4	N1		long bundle of copper and aluminum cable wires wrapped around each other - A	No	N/A	
		N2	"B" Switch, elbow termination	long bundle of copper and aluminum cable wires wrapped around each other - B	Yes	brittle copper wire pieces	March 8th 2023
		N3		long bundle of copper and aluminum cable wires wrapped around each other - C	No	N/A	
		N4		broken off pieces of copper wires from bundle B	No	N/A	

O	25	O1	Components under RAL Switch (Standby, Box A)	metallic-like cylindrical piece; black in colour - A		No	N/A	March 8th 2023 AND March 13th 2023
		O2		metallic-like cylindrical piece; black in colour - B		No	N/A	
		O3		metallic-like cylindrical piece; black in colour - C		No	N/A	
		O4		metallic-like cylindrical piece; black in colour - D		No	N/A	
		O5		metallic-like cylindrical piece; black in colour - E		No	N/A	
		O6		metallic-like cylindrical piece; black in colour - F		No	N/A	
		O7		metallic-like cylindrical piece; black in colour - G		No	N/A	
		O8		metallic-like cylindrical piece; black in colour - H		No	N/A	
		O9		metallic-like cylindrical piece; black in colour - I; looks like a wishbone		No	N/A	
		O10		melted metal A		No	N/A	
		O10		melted metal B		No	N/A	
		O10		melted metal C		No	N/A	
		O10		melted metal D		No	N/A	
		O10		melted metal E		No	N/A	
		O10		melted metal F		No	N/A	
		O10		melted metal G		No	N/A	
		O10		metled metal H				
		O10		melted metal I				
		O11		longer piece of metal; looks like part of a large bolt		No	N/A	
		O12		one nut		No	N/A	
		O13		looks like the top half of a bolt		No	N/A	
		O14		Nut and threaded rod				
		O15		larger piece of melted metal		No	N/A	
		O16		piece of thick glass		No	N/A	
		O17		medium sized metal piece		No	N/A	
		O18		large curved possibly pot metal piece		Yes	Wipe sample of black surface residue	
		O19		smaller possibly concrete piece		No	N/A	
		O20		small rock		No	N/A	
P	1	P1	RAL Switch (Standby, Box A) Termination	bundle of copper and aluminum cables wrapped around each other; small pieces of melted aluminum present amongst wires		Yes	melted cable insulation	March 8th 2023 AND March 13th 2023
Q	3	Q1	Components under RAL Switch (Active, Box B)	piece of ceramic		Yes	took a cotton cheese cloth and took a wipe sample of the black sludge on the surface	March 8th 2023
		Q2		screw cap(?) A		No	N/A	
		Q3		screw cap(?) B		No	N/A	
UNKNOWN	1	UNKNOWN 1	Was not on the list	corner of the maintenance hole lid		No	N/A	March 8th 2023
R		R1	Failed RAL Switch (left side) - #2019	Enclosure				
		R2		Rotary switch assembly incoming	Sub divided to focus on "knives" (bars) R2_1, R2_2, R2_3. (see photos for clarification)	no		
		R3		Four pronged metal plates with blob of metal	Switch contact			
		R4		Rotary switch assembly outgoing				
		R5		End of Four pronged metal fork with no prongs	Switch contact (with no prongs)			
		R6		Groundbar (right side) when facing straight on				
		R7		FTIR samples Taken	R7_1 - R7_11	Yes	Surface Samples	April 12th 2023
S	2	S1		Gasket from top front middle of switch				
		S2		Gasket from top middle left corner of switch				
		S3		Front switch holder bolt				

		S4	Failed RAL Switch (right side - active) - #2018	Back Switch holder bolt				
		S5		?				
		S6		Metal Chips from back wall				
		S7		Possible bottom Gasket				
		S8		Bottom Gasket bushing side				
		S9		Possible bottom Gasket				
T			RAL Switch - from a vault ("still good")	Just opened up - not doing anything with switch since it's so different				
U			RAL Switch #1594	Switch taken out of service from another vault (V055)				
V	3	V	RAL Switch #1595	Switch taken out of service from another vault (V055)				
		V1		Top front left gasket sample		yes	Gasket sample	April 12 2023
		V2		Top right side gasket sample		yes	Gasket sample	April 12 2023
		V3		Bottom Gasket		yes	Gasket sample	April 12 2023

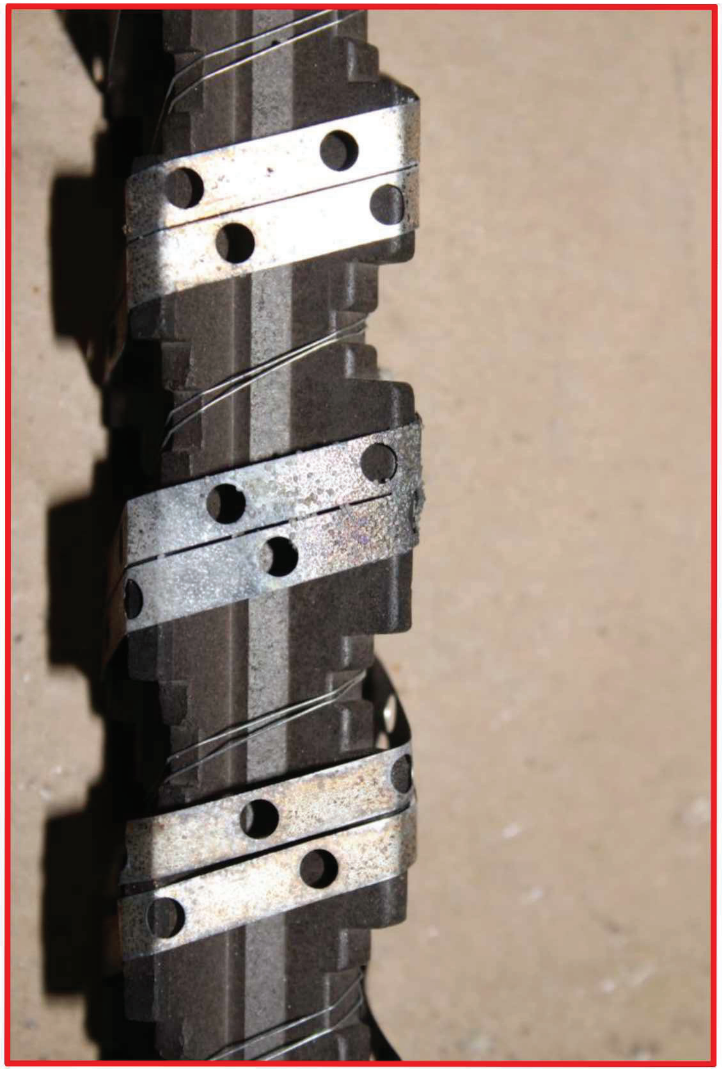
Appendix H: Powertech Fuse Examination

Dismantled Fuses from Switch 2019

Observations:

- Fuses were filled with sand.
- Outer shell was a wrap of several layers of (metal?) fiber mesh.
- Sample C - Fuse two had the most visible damage. The outer case was hardened on one end and frayed on the other. Inner beam was broken into several pieces.
- All fuses appear to have some rust on the inside.

Sample B – Fuse 1



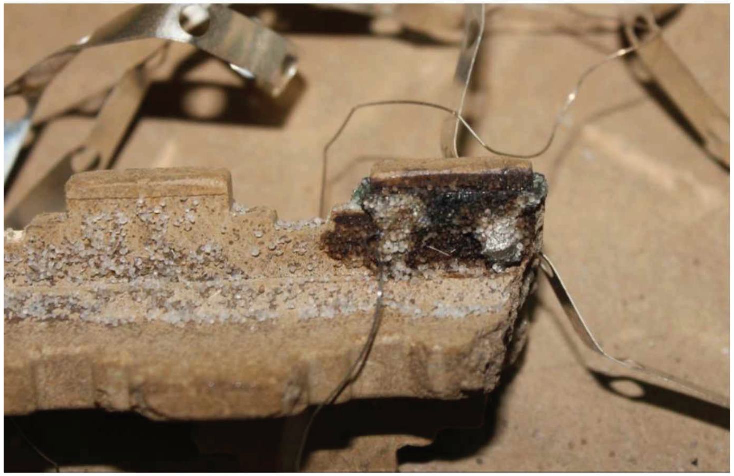
Sample B – Fuse 1

Sample B – Fuse 1

Sample C – Fuse 2

Sample C – Fuse 2

Sample C – Fuse 2



Sample D – Fuse 3

Sample D – Fuse 3

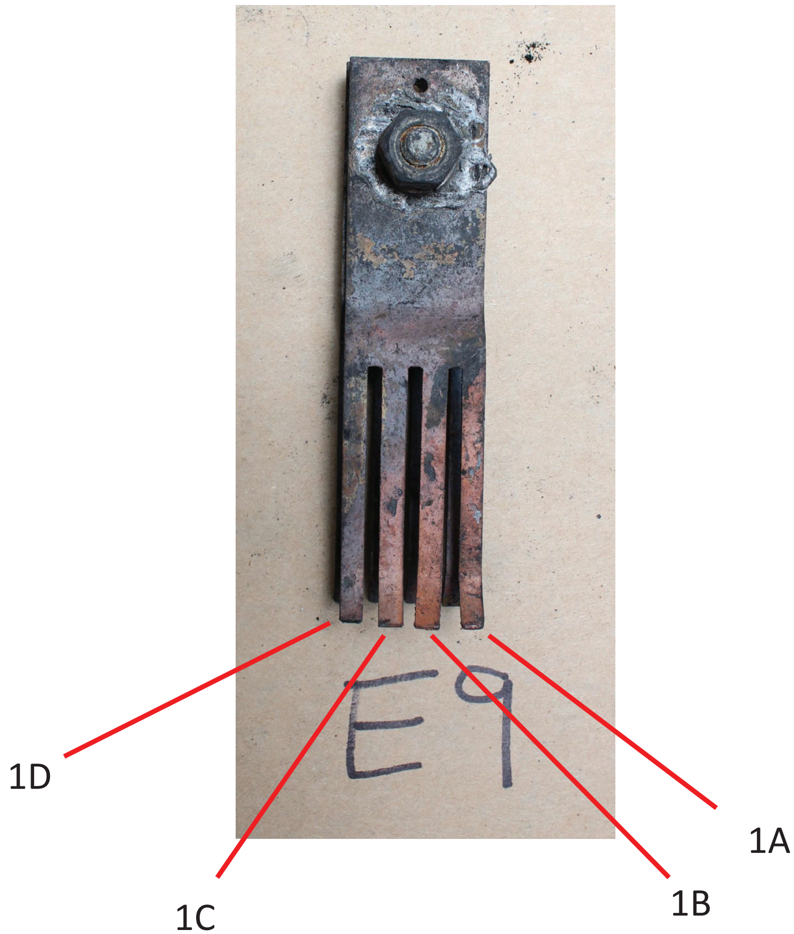
Appendix I: Powertech Imaging

Vault 73 Investigation

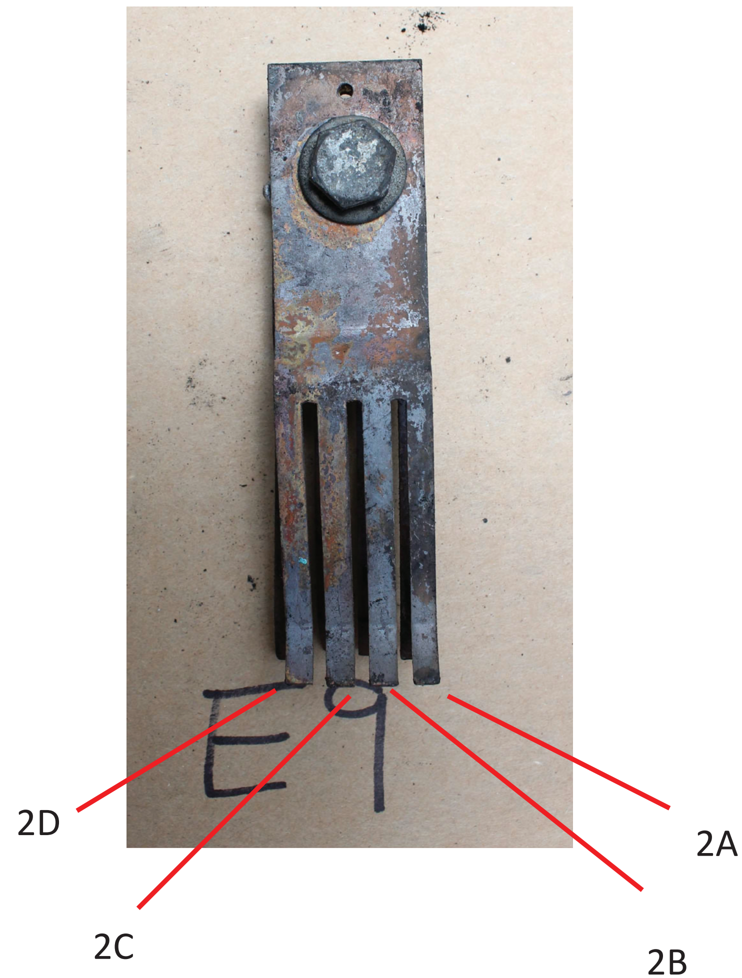
Contacts Microscope Photos

March 29 2023

E9 Nut Side (Side 1)



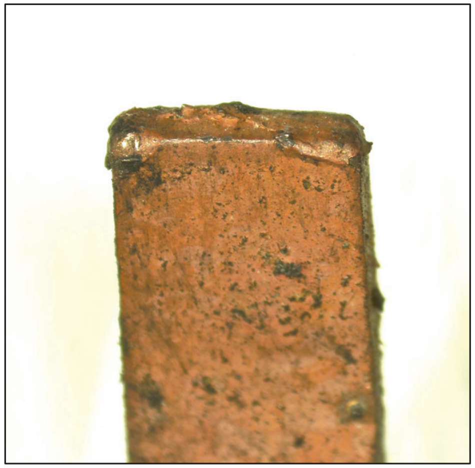
E9 Bolt Side (Side 2)



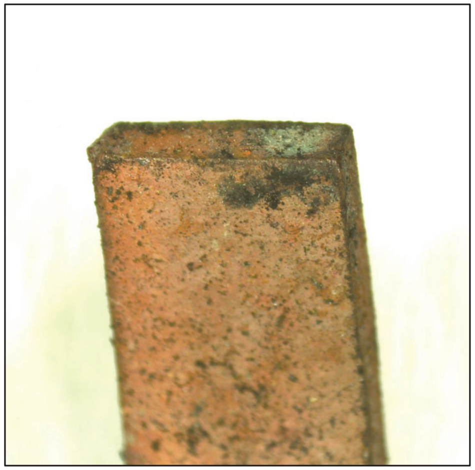
E9 Nut Side
Outside

1A Outside

1B Outside



1C Outside

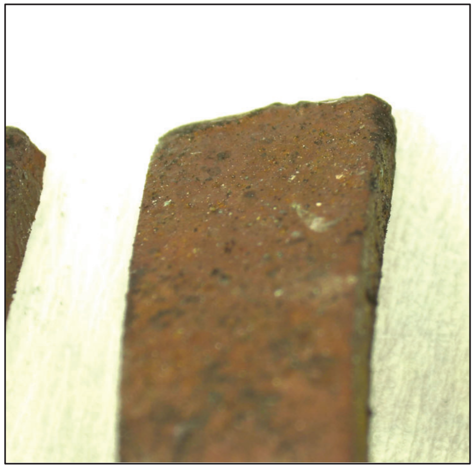


1D Outside

E9 Nut Side
Inside

1A Inside

1B Inside



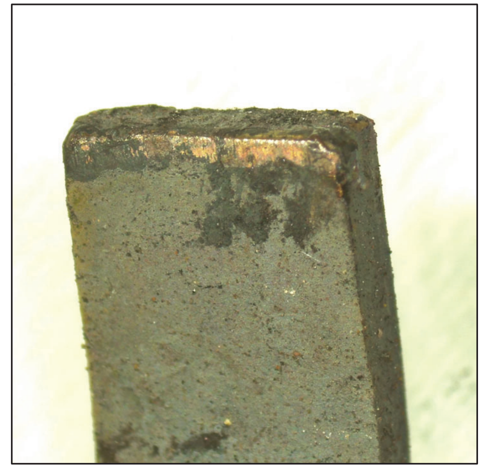
1C Inside

1D Inside

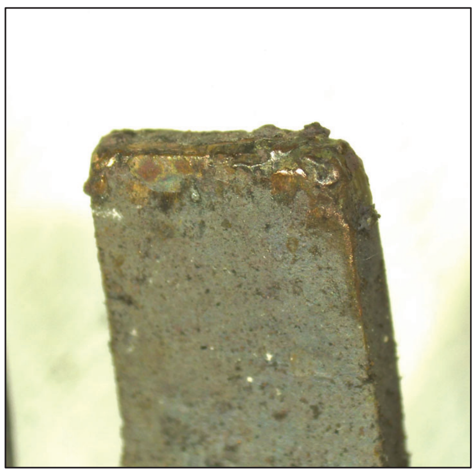
E9 Bolt Side
Outside

2A Outside

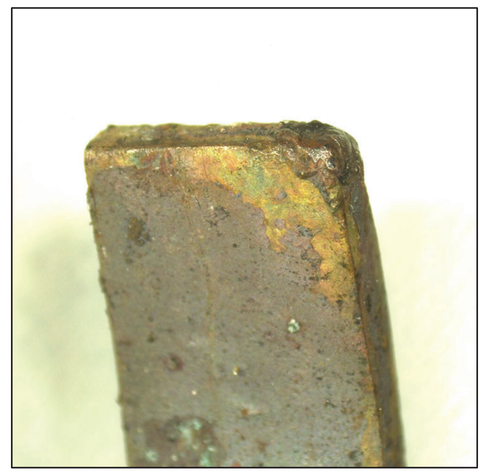
2B Outside



2C Outside

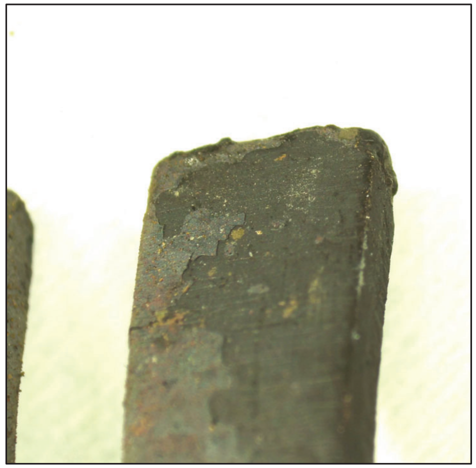


2D Outside

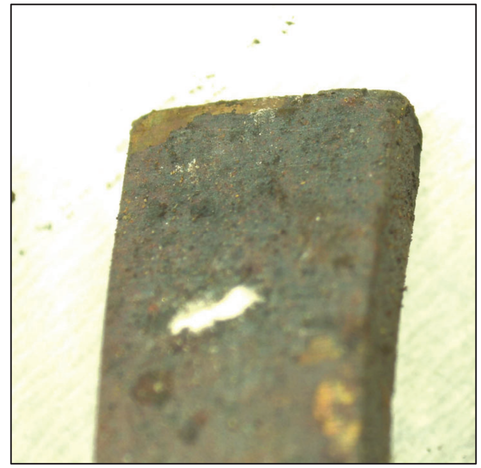


E9 Bolt Side
Inside

2A Inside

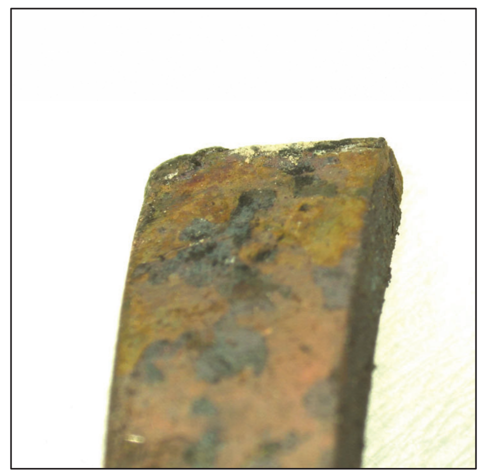


2B Inside

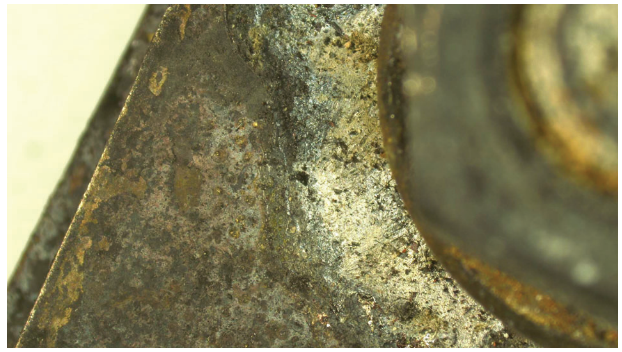


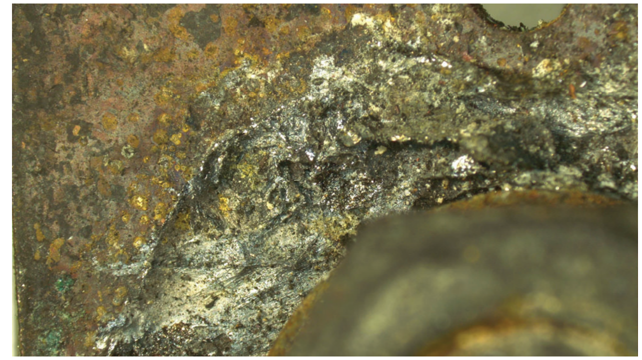
2C Inside

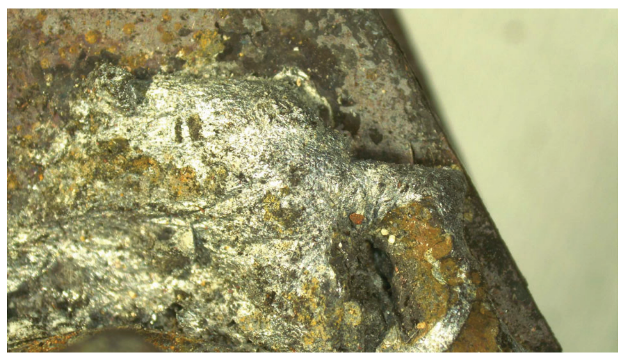
2D Inside

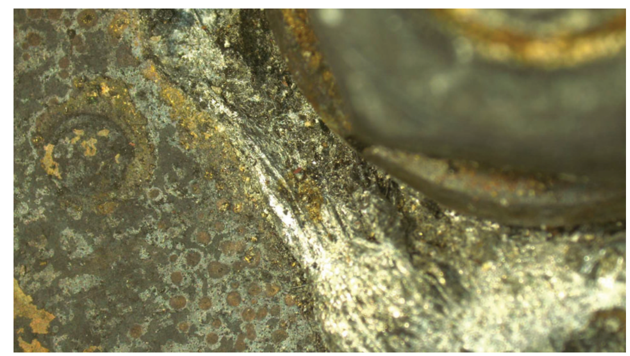


E9 Damage around Nut

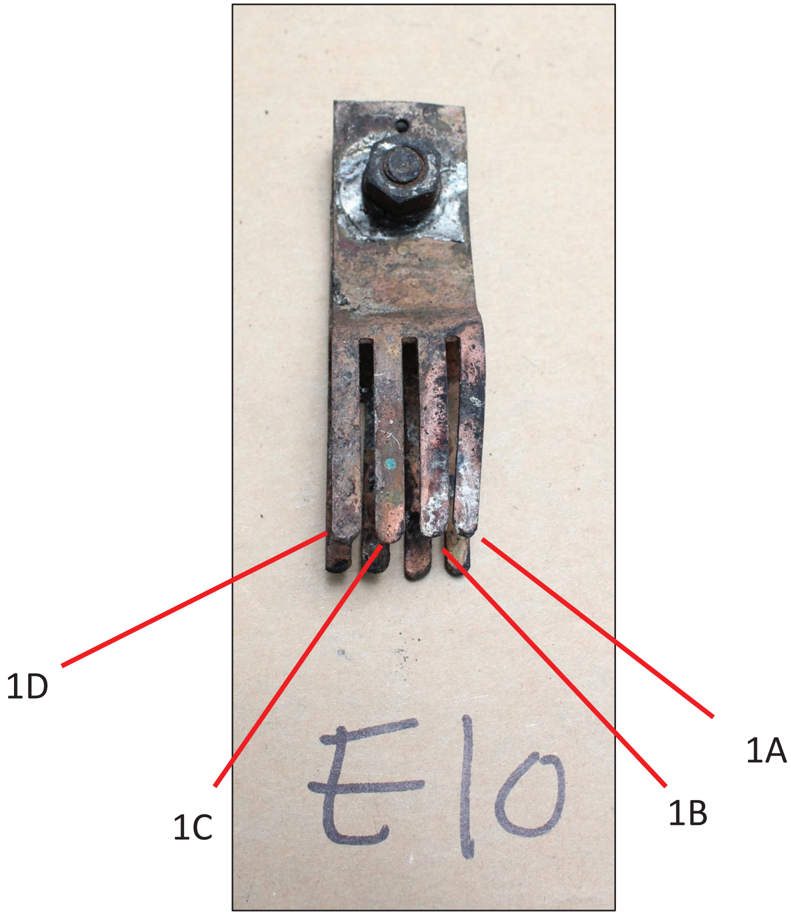




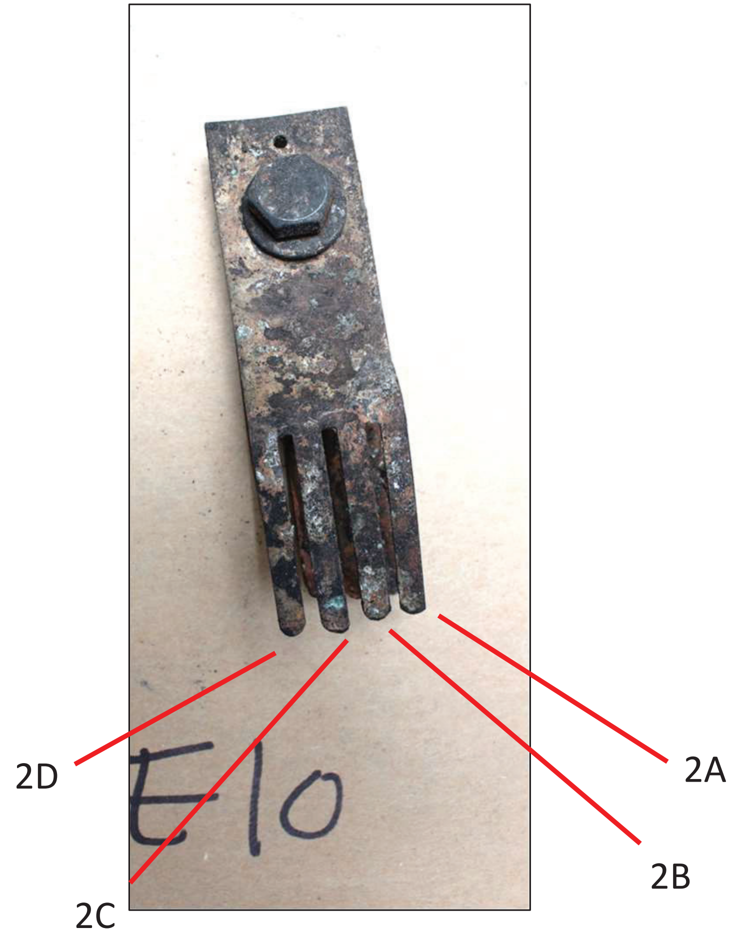




E10 Nut Side (Side 1)

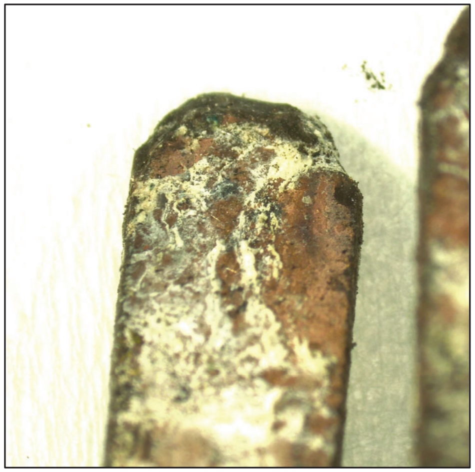


E10 Bolt Side (Side 2)



E10 Nut Side
Outside

1A Outside



1B Outside

1C Outside

1D Outside

E10 Nut Side
Inside

1A Inside

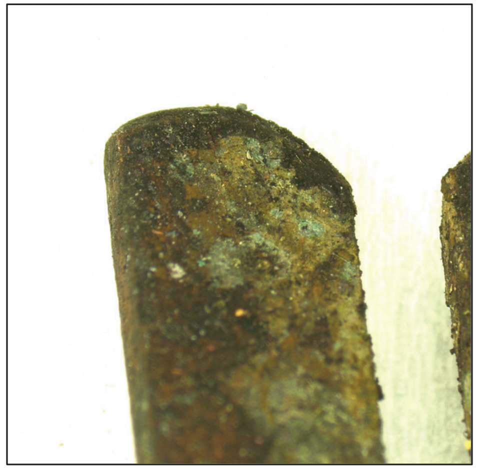
1B Inside

1C Inside

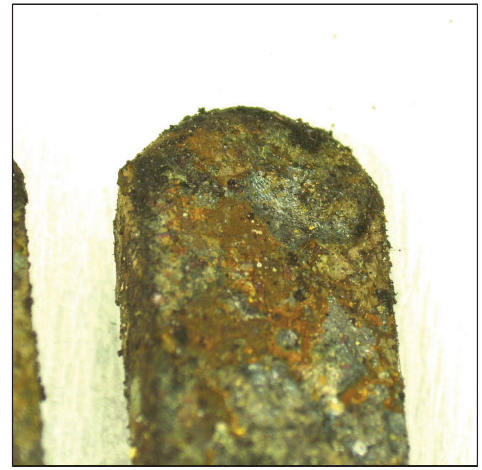
1D Inside

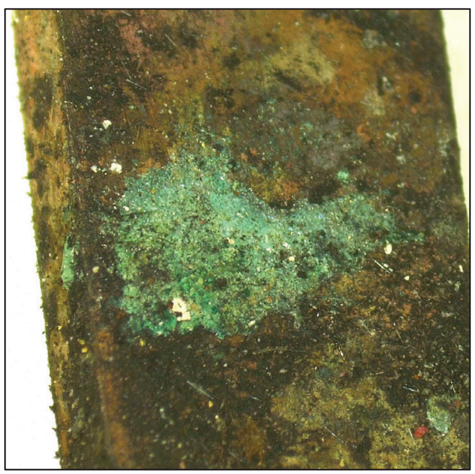
E10 Bolt Side
Outside

2A Outside



2B Outside





2C Outside

2D Outside

E10 Bolt Side
Inside

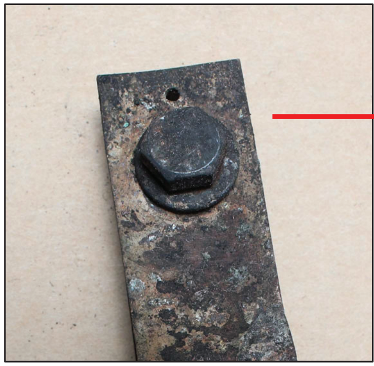
2A Inside

2B Inside

2C Inside

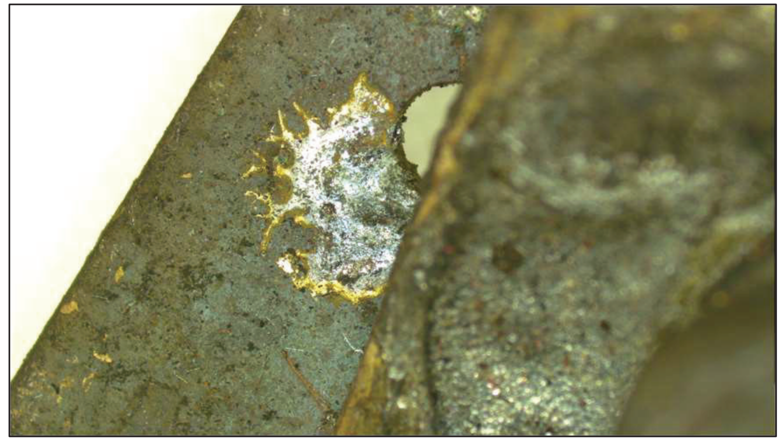
2D Inside

E10
Around Nut

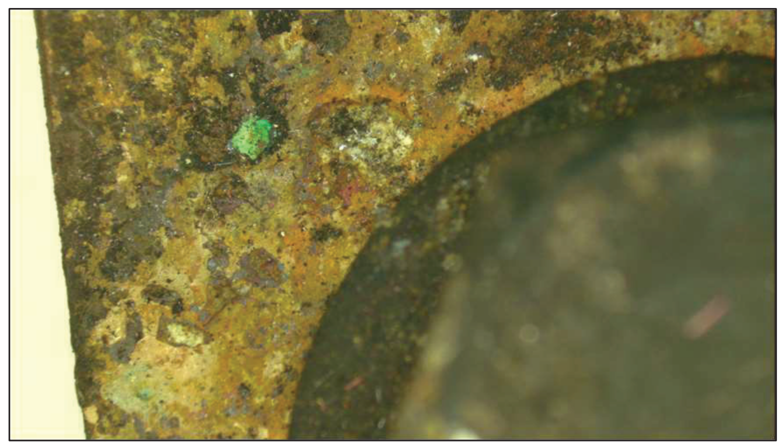


E10
Around Bolt

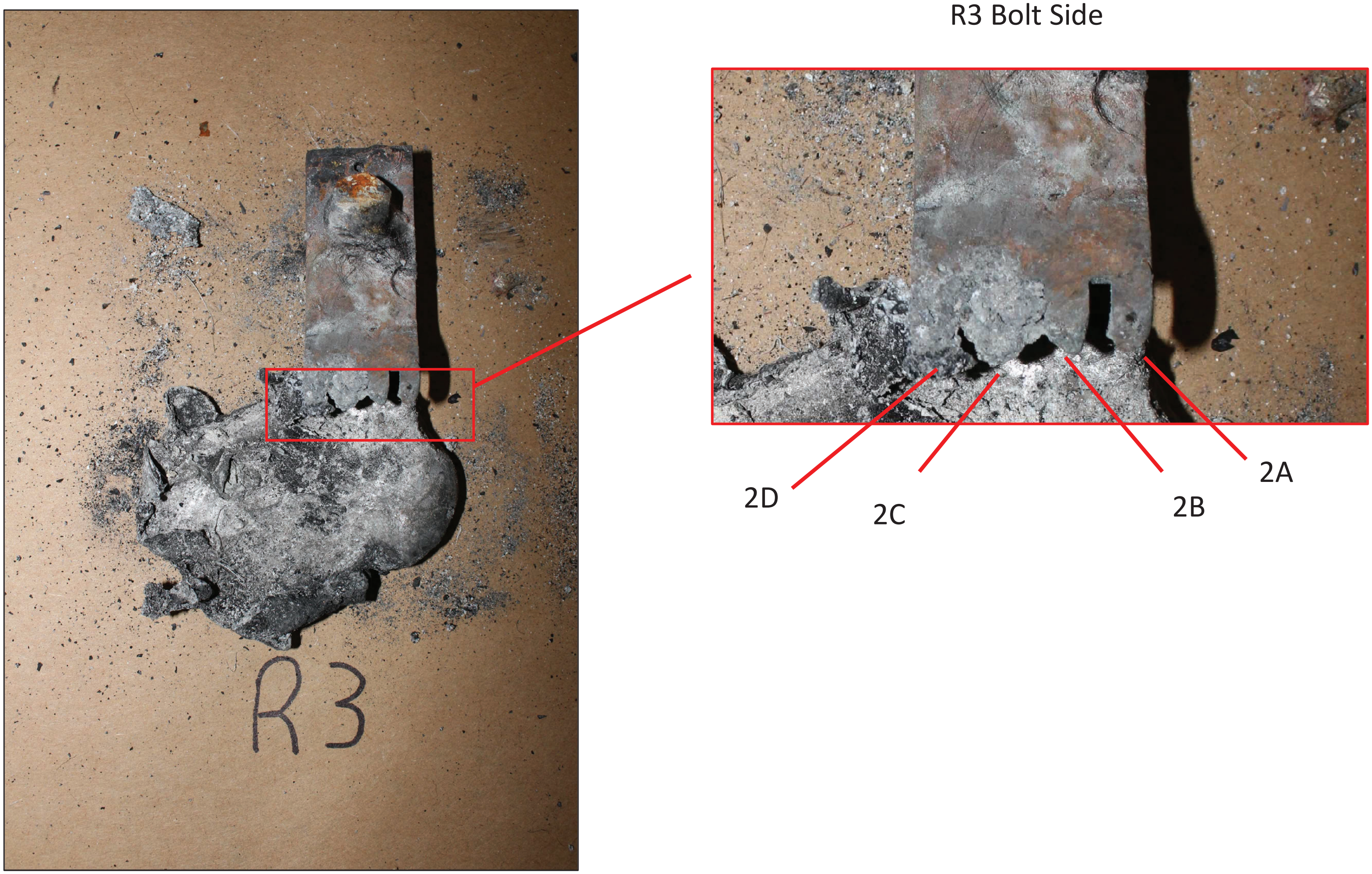
E10 Bolt Side (inside)



E10 Bolt Side (Outside)



R3 Bolt Side



R3 Bolt Side
Outside

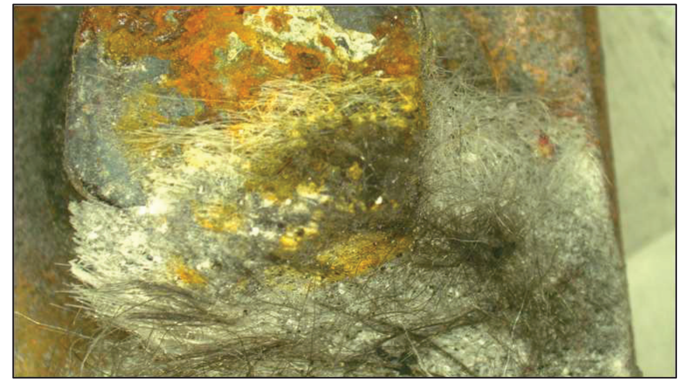
2A Outside

2B Outside

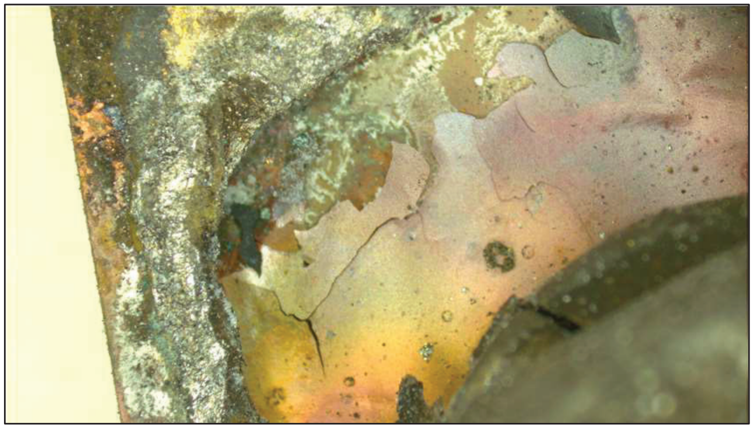
2C Outside

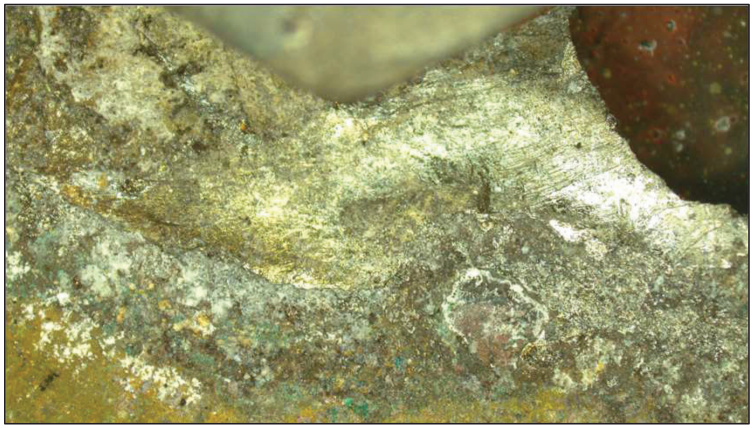
2D Outside

R3 by Bolt

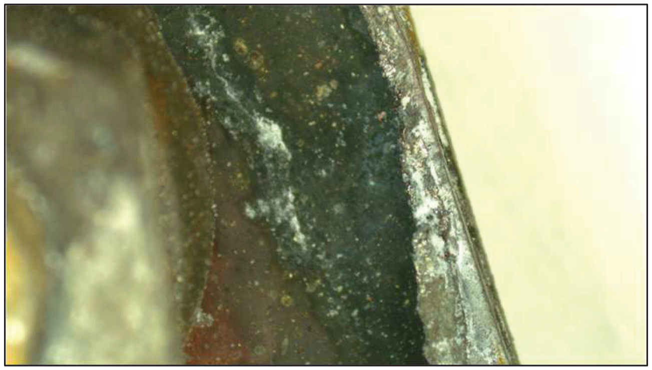


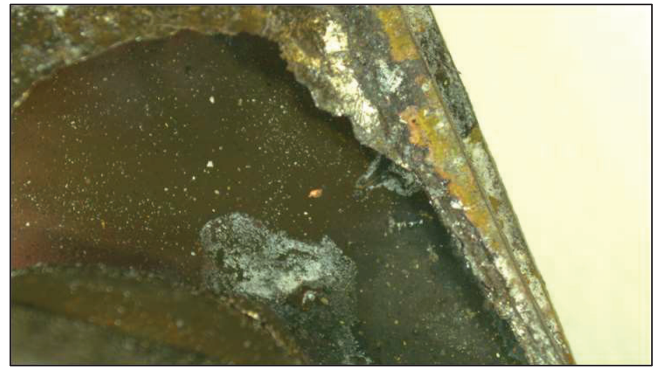
R3 Around Nut



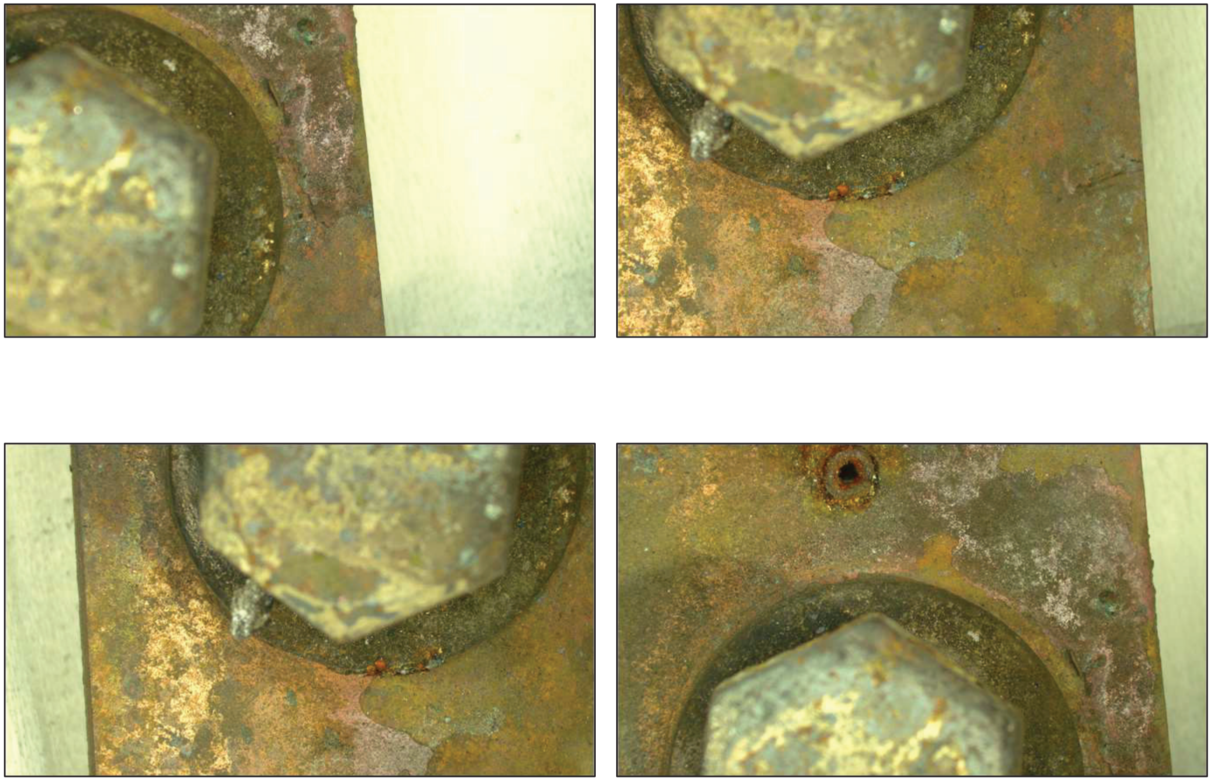


R3 Around nut
Continued





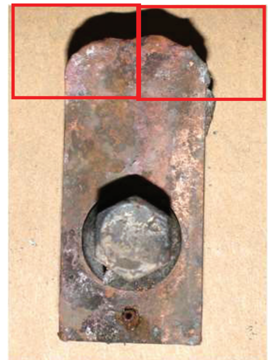
R5 Around Bolt



R5 Around Nut

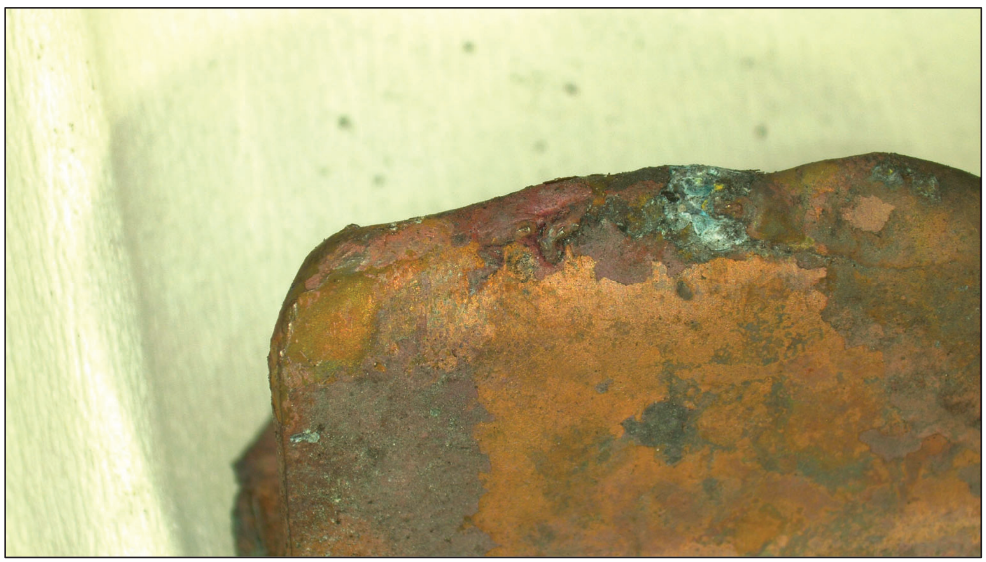


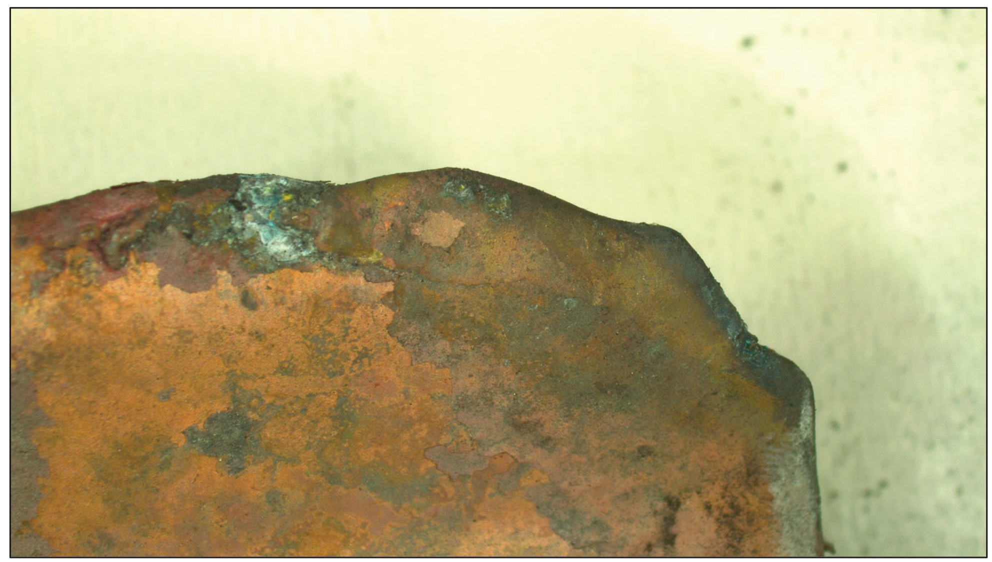


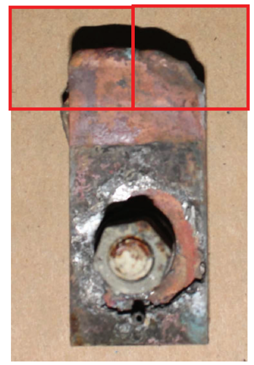


R5 Nut Side Outside 1A/ 1B

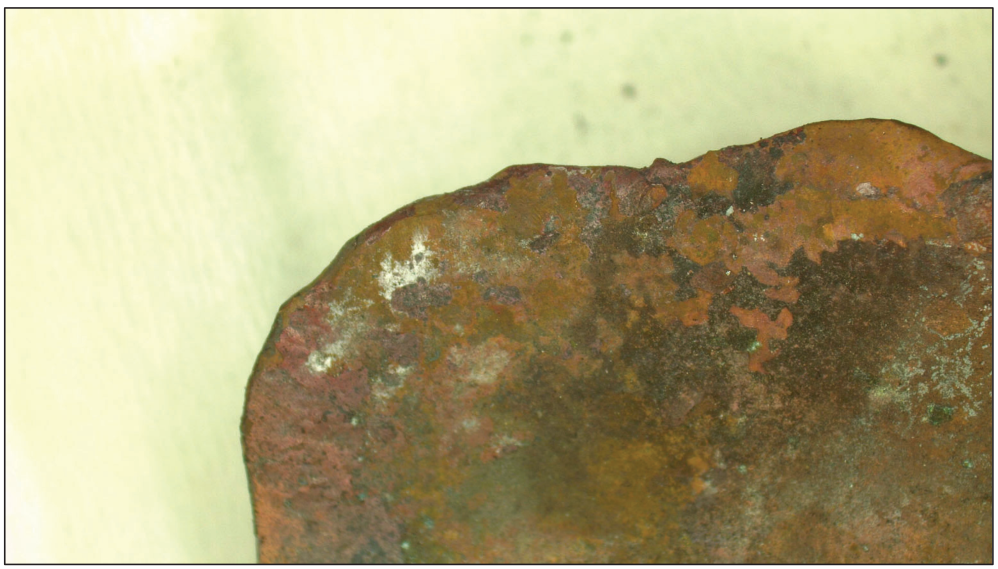
R5 Nut Side Outside 1C/ 1D



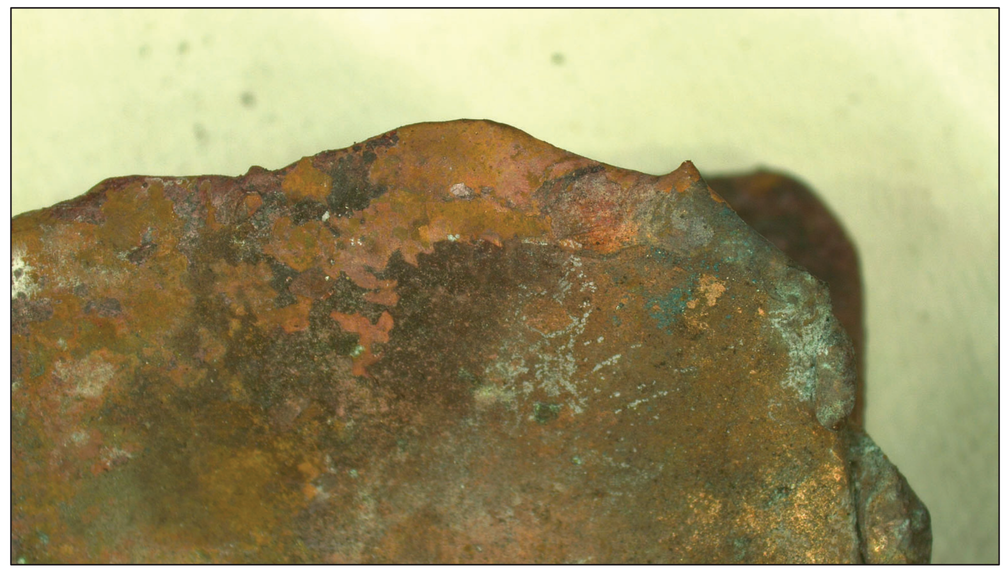




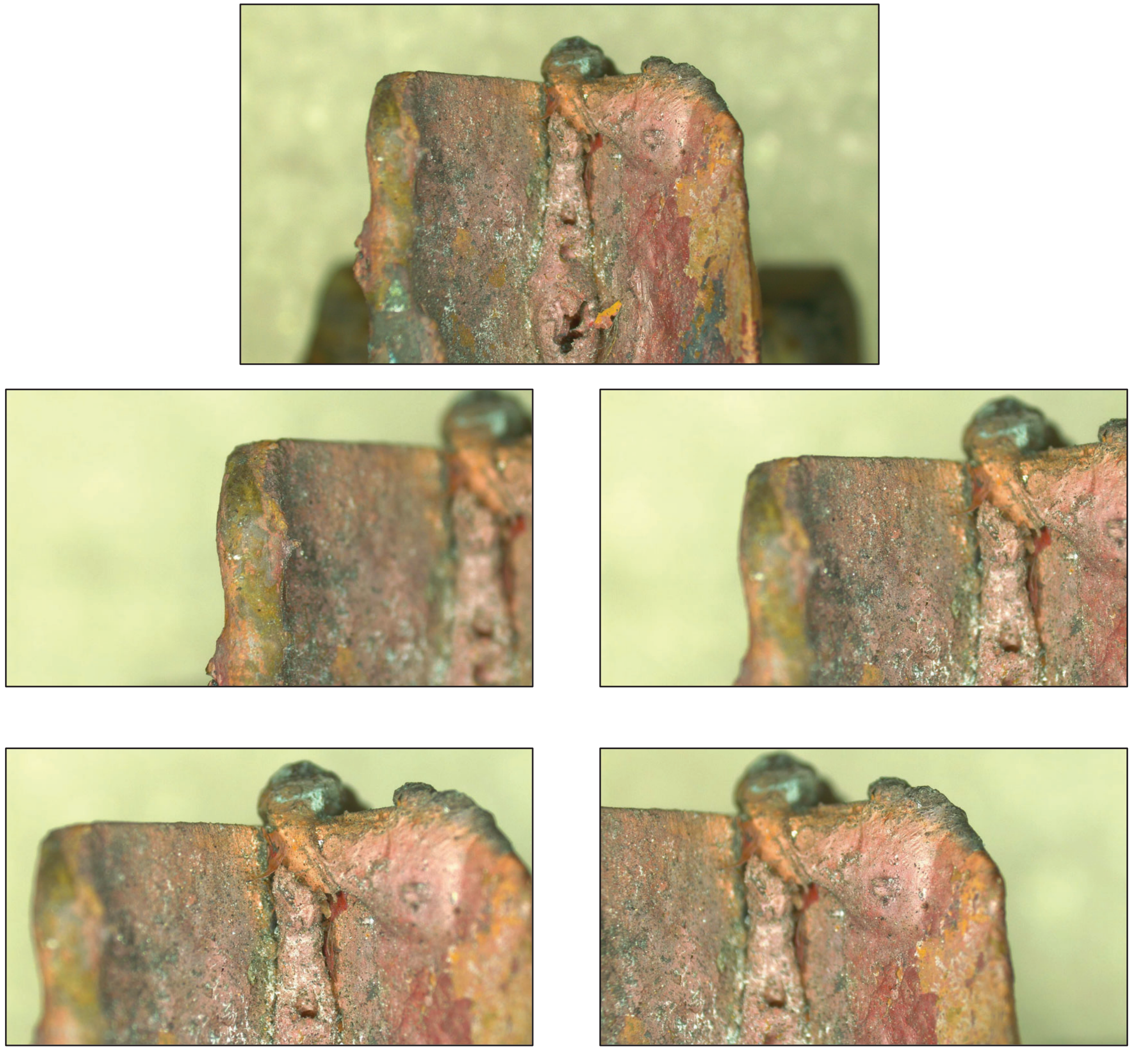
R5 Bolt Side Outside 2A/ 2B



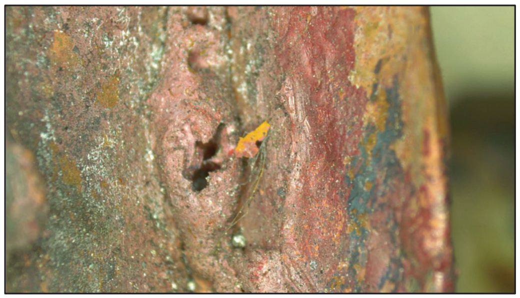
R5 Bolt Side Outside 2C/ 2D



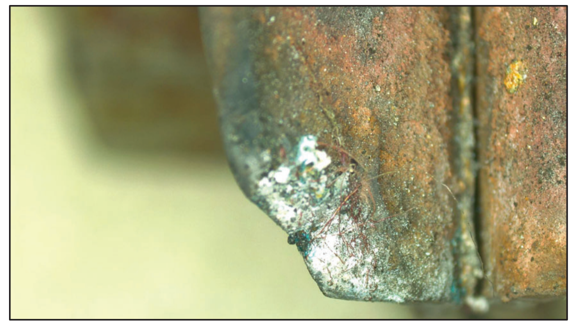
R5 Inside

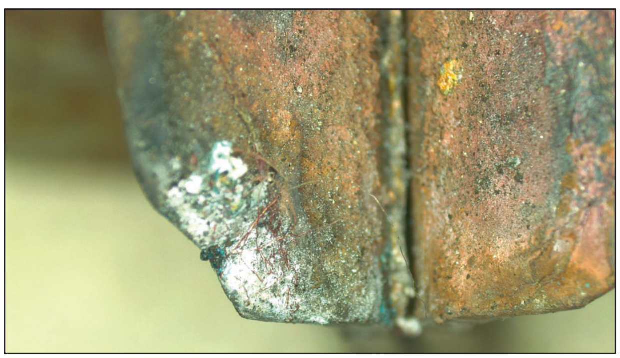


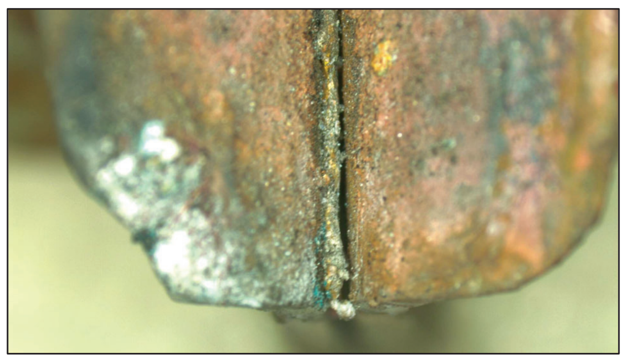
R5 Inside



R5 Inside







G2 Nut Side (Side 1)

1D

1C

1B

1A

G2 Bolt Side (Side 2)

2D

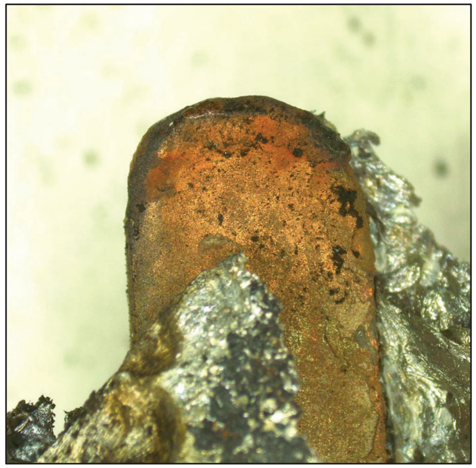
2C

2B

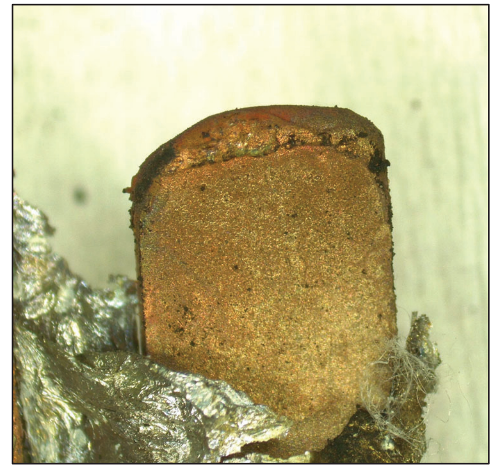
2A

G2 Nut Side
Outside

1A Outside



1B Outside



1C Outside

1D Outside

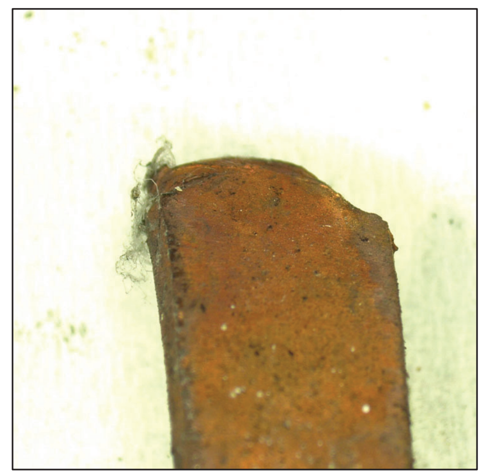
G2 Nut Side
Inside

1A Inside

1B Inside

1C Inside

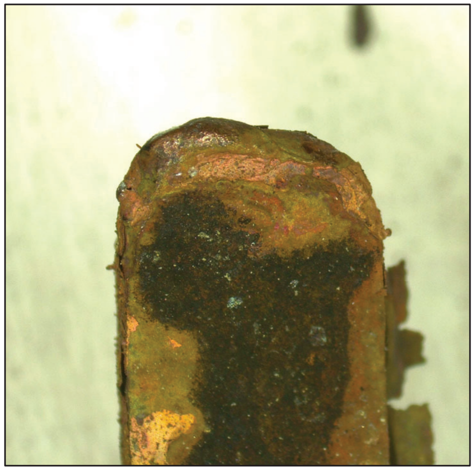
1D Inside



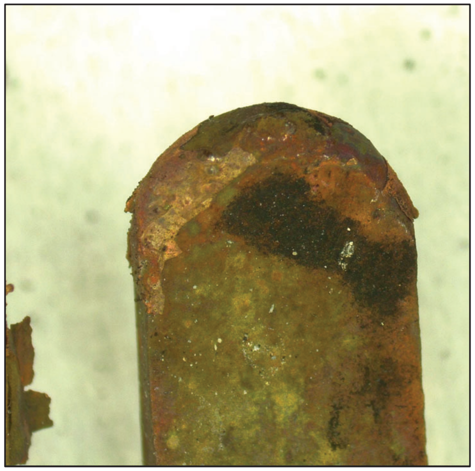
G2 Bolt Side
Outside

2A Outside

2B Outside



2C Outside

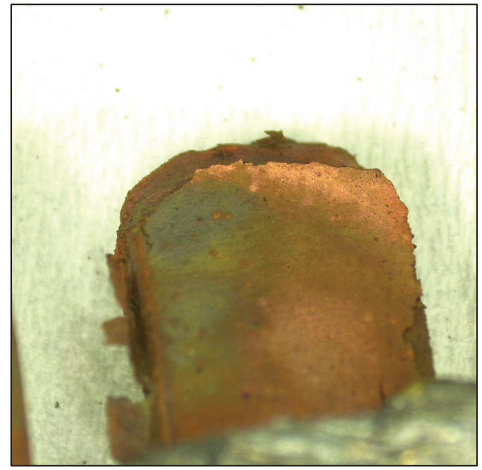


2D Outside

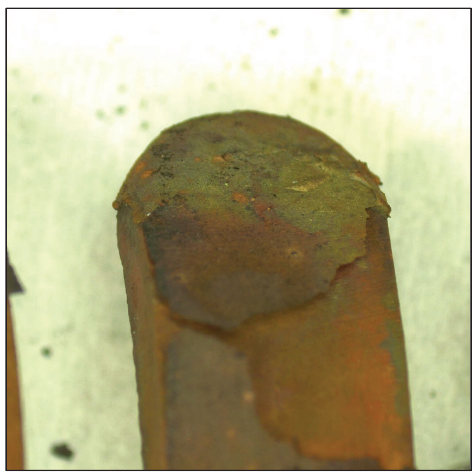
G2 Bolt Side
Inside

2A Inside

2B Inside

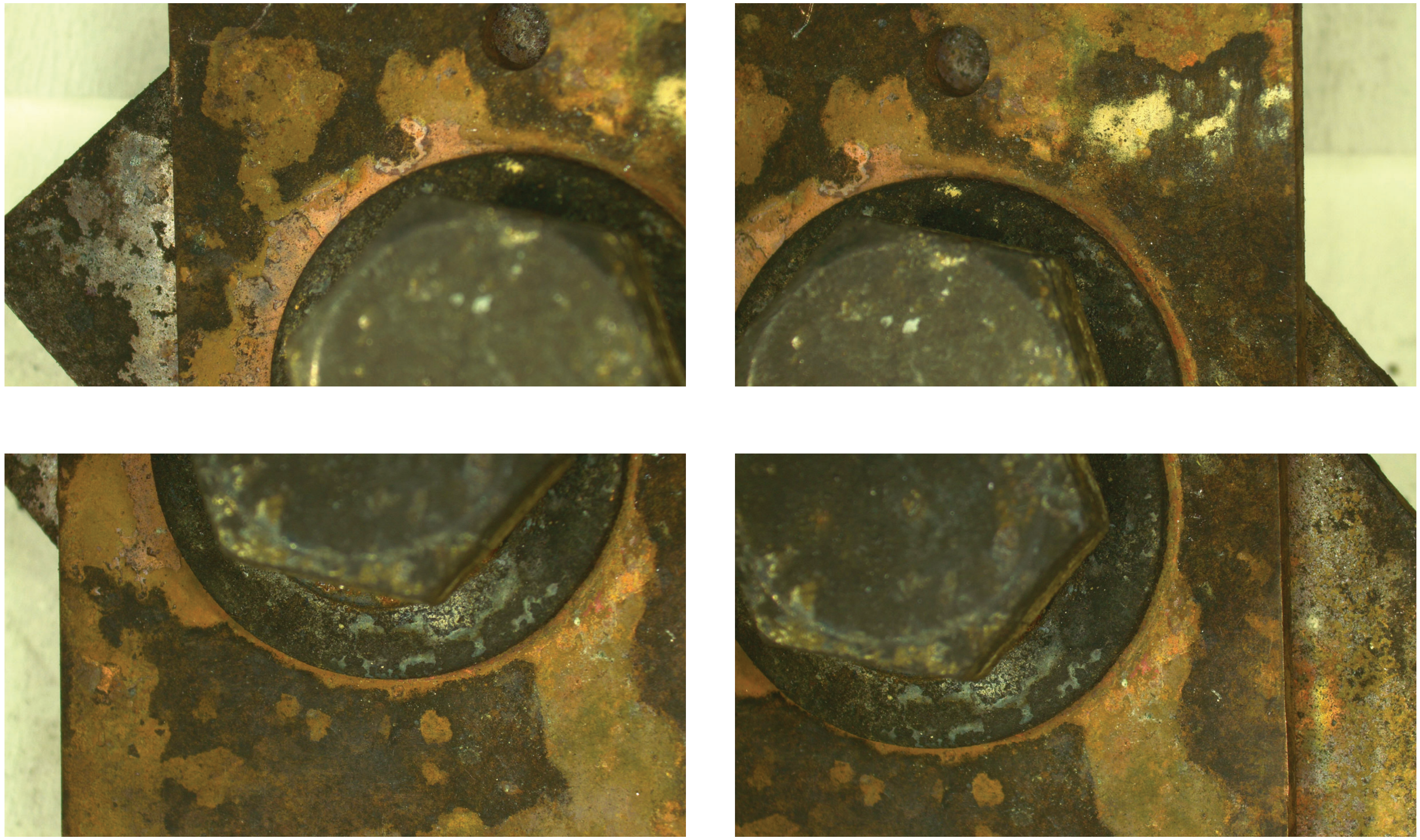


2C Inside

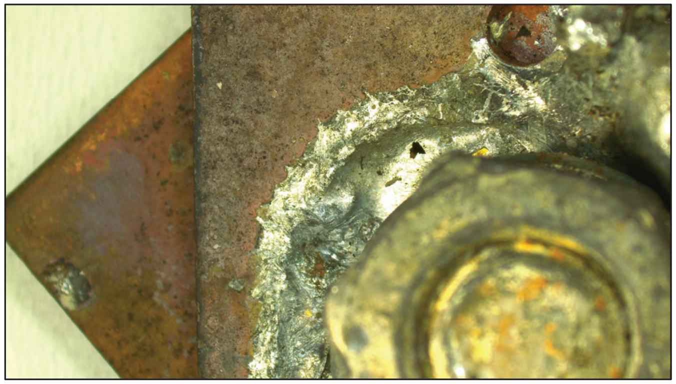


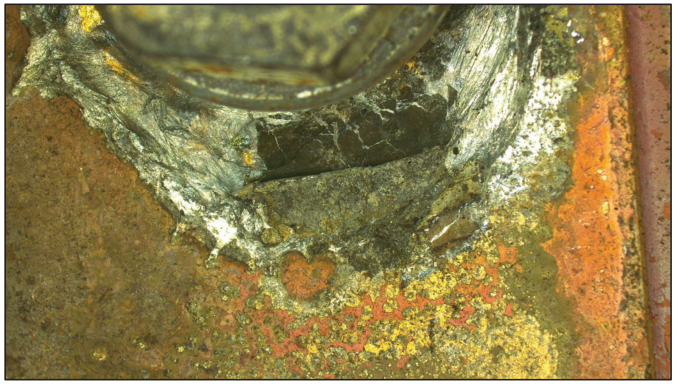
2D Inside

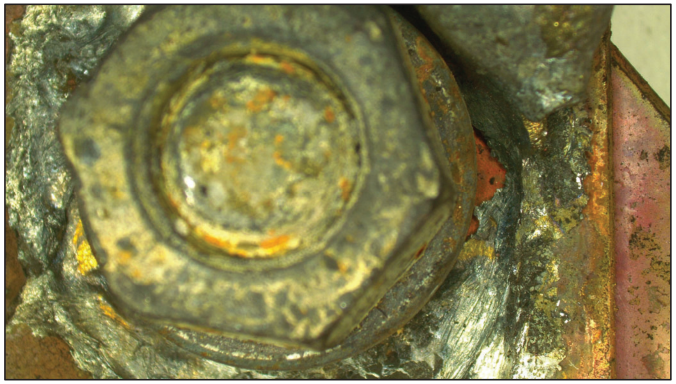
G2 Around Bolt



G2 Around Nut







Appendix J: Maintaining Oil Switches

MAINTAINING OIL SWITCHES

Prepared By:	Checked by:	Approved by:	Date:
Work Methods	K. McCormick, Trades Training Instructor	B. Spalteholz, Work Methods Manager	September 21, 2015
Revision Rationale: **September 2015 -** Updates to document format and confirmed content. Updated formatting October 2015. **July 2010** – Initial release, material from Apprenticeship manual			

Introduction

Oil switches are used mainly as a sectionalizing device to break down a circuit into smaller, more manageable sections. If there is a fault on a part of the circuit, that section has to be isolated by using the switches. A section can also be isolated if maintenance is required.

Some of the switches used by BC Hydro are manufactured by G & W Electric Company. They are either RA, RA20 or RA40. The RA means rocker arm and the number (if present) refers to the different load break ratings.

An external inspection and oil test must be done once every 12 months. Every 5 years the oil must be changed and the interior of the switch inspected and adjusted, if needed.

Equipment and Materials

Equipment and materials used to maintain oil switches:

Equipment/Material	Purpose
Aluminum oxide cloth	Clean any arc erosion off of the contacts
Degassed oil	Refill the switch tank
Dry Nitrogen	
Approved voltage detector	Confirm switch is de-energized
Heat gun or equivalent	Check for hot spots at the XLPE elbows
Hipotronics TC/DE test cell	Test the oil from the degasser truck prior to refilling the switch tank
Inspection label	States inspection date and the insulation level of the oil in kV
Confined space Entry meters and equipment	Perform confined spaces entry procedures
Oil pump and hoses	Remove the old oil from the switch tank and put it in waste barrels
Sample labels	Identify the oil sample that is sent to the lab for testing
Sampling container	Collect the oil sample.
Snoop solution	Soapy solution used to detect leaks
Torque wrench	
Traffic control (as needed)	
Waste barrels and containers	Collect the oil to be discarded

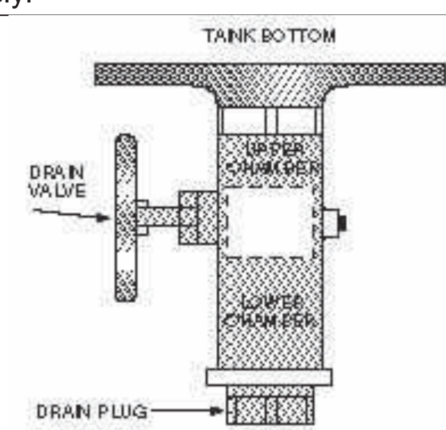
Yearly Maintenance Inspection

The yearly inspection includes an external inspection of the switch and the taking of an oil sample. This is done with the switch still energized and in operation. An SPG is not required since the apparatus will not be operated during this inspection. An inspection form must be completed during the inspection.

The yearly external inspection and oil test consist of the following:

Perform Entry Procedures	• Follow confined space entry and manhole entry work procedures prior to entry.
Inspect Exterior of the Switch	• A visual inspection is made to check for oil leaks. If a leak is found, record it on the inspection form. If the leak is substantial (e.g., puddle or continuous drip), report it immediately to a supervisor, they will determine whether to continue or discontinue the inspection. • A visual inspection is also made to check for rust or corrosion. If either is found, they must be touched up with paint.
Check for Proper Torque	The nuts and bolts on the following items must be checked for tightness: • Switch lid • Viewing window • Oil gauge • Cable entrance • Operator handle • Top filler plug In the manufacturers instructions for the switch (Appendix A), there is a table that gives the proper torque required for each item. Use a torque wrench to ensure the correct tightness is obtained.
Check XLPE Elbow	• When XLPE elbows are present, they must be checked for hot spots using a handheld infrared thermometer or equivalent. • Check Manhole Entry Procedure for cutoff values for temperature.

Check Visibility of Contacts	• Look through the viewing windows (portholes) in the switch and check the visibility of the contacts. If they cannot be seen, it means the oil is dirty and must be changed. Stop this inspection and report this to your supervisor and they will make arrangements to have it changed. • Record any problems noticed including; contacts out of alignment, broken contacts and burnt contacts. **Do not operate the levers (operator handles) when checking the contacts.**
Check Oil Level	• Check the oil level by looking at the oil level gauge on the switch. If the oil is visible in the gauge but low, make note of that on the inspection form. If the oil is not visible in the gauge then notify your supervisor immediately. Arrangements will be made to have the switch de-energized to investigate the problem and add oil to the switch. The inspection stops in this case.
Inspect and Sample Oil	• An oil sample can be safely taken from the energized switch provided that oil is showing in the oil level gauge. **If oil is not visible in the oil gauge, do not take a sample.** The switch must not be re-filled when it is energized. **If the oil is colder than the surrounding air, do not take the sample, as condensation will form on the surface of the oil.** • Care must be used when taking an oil sample to avoid contaminating it with moisture and dirt • Sample must be taken quickly and sealed immediately. • Sampling must occur quickly as exposure to air and moisture can affect the test results. • Sample should not be exposed to ultraviolet rays (sun) so cover or box it immediately.



Sample Oil Inspection

STEP	TASK
1	Ensure a positive pressure exists in the switch by attaching a nitrogen cylinder to the tank. Pressurize between 3 and 5 psi.
2	Clean the area around the drain valve (plug). This valve is located at the bottom of the tank and it is used tor sampling the oil. Remove the plug from the valve and let the oil, located in the lower valve chamber, run into waste containers.
3	Open the valve slightly and run off a minimum amount of oil to waste to flush the valve.
5	Put the sampling container under the valve, slowly open the valve (to avoid air bubbles) and half-fill the container with oil.
6	Inspect the sample for signs of water, carbon, sludge or emulsion and record your observations on the inspection form. Abnormal oil conditions, such as excessive free water and carbon, must be reported immediately to the supervisor.
7	Dump the oil in the container into a waste container.
8	Take the oil sample to be tested by a laboratory. Fill the container with oil and seal immediately.
9	Replace the plug in the valve and hand tighten.
10	Open the valve slightly (crack it) to fill the lower chamber with oil. Let oil seep out around the plug.
11	Tighten the plug with a wrench until seepage around the plug ceases.
12	Close the valve. Filling the lower chamber of the valve with oil prevents dirt and moisture from entering. The figure below shows the drain valve with upper and lower chambers filled with oil.
13	Label the oil sample. The samples must be correctly identified since they will be sent to a laboratory for testing. The lab performs an oil test in accordance with ASTM Standard D-1816. If the oil tests below 22k, it is rejected and the oil in the switch must be changed as soon as possible. A switch cannot be operated with oil that tests below 22kV. The lab will issue an inspection label if the oil test is acceptable.

Five Year Maintenance Inspection

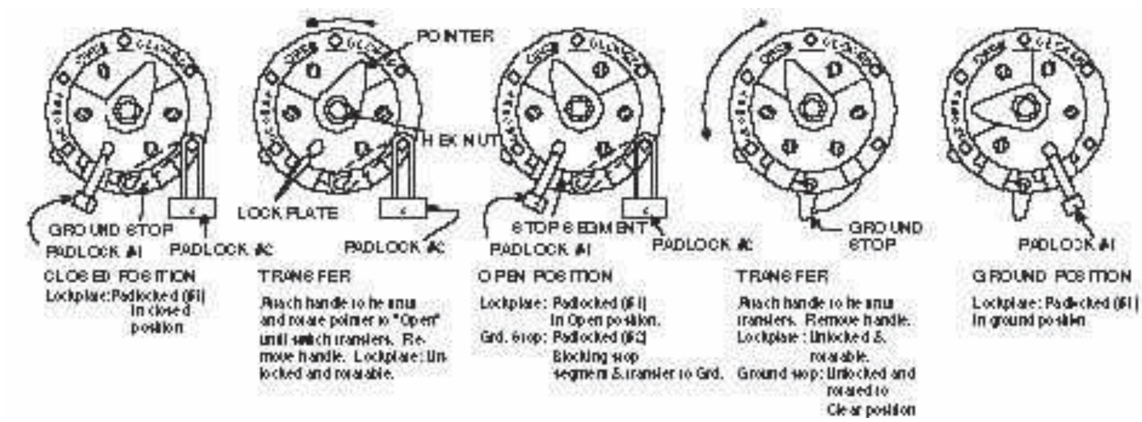
Once every five years the switch must be internally inspected and the oil changed.

The five year internal inspection and oil change consists of the following:

Obtain SPG and Apply Grounding	• Before any work can be done for the five year inspection, a safety protection guarantee must be taken. • Grounds must be applied to all cables entering switch. For information on this procedure refer to grounding procedures.
Prepare Job Site and Set Up Equipment	• Set up traffic control as required. • Position the degasser truck close to the manhole/vault for the switchgear. • Place the oil waste barrels side by side. The oil pump is placed close to the manhole/vault. • Before entering the manhole or vault, follow work procedure on Manhole Entry.
Visual Check	• Perform a visual check of the switch and switch joints for oil leaks. If any leaks are found, make a note of them and check these areas during the maintenance of the switch. • Repair the leaks when the switch drained.

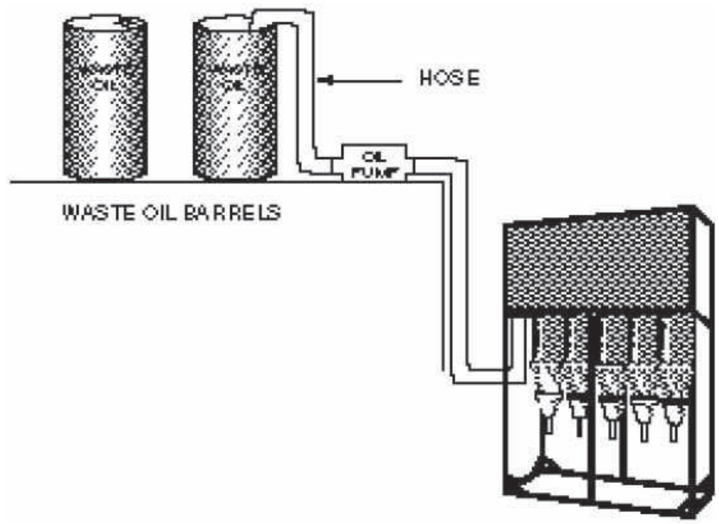
Prepare Switch for Oil Removal

STEP	TASK
1	Ensure the switch is de-energzied. Check for potential by holding a potential indicator (Modiwark) closed to the viewing window, pointing directly at the window. • If potential is indicated, the switch is not de-energized. Contact supervisor • If no potential is indicated then continue preparing the switch for oil removal.
2	Make a note of the position of the operators as they must be returned to their original position at the end of the job.
3	Take operators out of operation. If operators have a ground position, rotate them to this position from above the manhole. If there is no ground position, then rotate them to the open position, this takes them out of the circuit.

4	Using the handle, rotate the operator to the desired position. Move the handle smoothly without interruption to the next position. Most operators will click and stop when the next position is reached.
5	Lock the operator in the ground position (or open, if ground is not present). Always refer to the manufacturer's instructions for the correct operation of the operators.
	
6	Switch is now ready for oil removal.

Remove the Oil

STEP	TASK
1	Before removing the oil, the lid must be taken off of the switch to allow for viewing during the removal process.
2	To remove lid: • Clean the lid to remove all loose dust and dirt. • Remove all the lid bolts. • Life the lid carefully so not to damage the tank gasket, as it remains in place on the tank. • Lower the lid and place (with the bolts) in a safe location. Do not lay it flat on the ground (undersurface facing down) to keep clean and not contaminate the oil when lid is replaced.
3	With the lid off, the oil removal equipment can be set up as shown in the figure.



- Connect two hoses to the pump. Run one from the pump to a waste barrel and the other run from the pump to the switch tank.

  The hose at the switch tank is attached to the drain valve located on the bottom of the switch.
- Plug the pump into the electrical outlet on the degasser truck.
- Switch on the pump and remove all the oil from the switch. The pump may need to be stopped after the first barrel is full.
- Transfer the hose from the full waste barrel to the other empty one.
- Turn pump on and remove the remaining oil.

4	After all the oil has been pumped out, leave the pump and hoses in place as they will be needed later on in the maintenance process. The interior of the switch can be checked.

Check and Adjust Interior Parts

	**Throughout the maintenance procedure you must refer to the manufacturer's instructions (installation instructions) for the switch being working on. There are specifications given for such things as torque on bolts and alignment of contacts.**

The G & W Instructions that you will be dealing with are:

- GWI 503-2 (Type RA Oil Switches)
- GWI 520-3 (RA20 Oil Switches)
- GWI 521-2 (RA40 Oil Switches)

Copies of these instructions are available from the cable department.

Checking and Adjusting Interior Switch Parts

STEP	TASK
1	Check contacts for arc erosion, spring tension and deformed parts or loose screws. Tighten loose screws or bolts to specifications. Clean off any arc erosion using an aluminum oxide cloth. If any parts are deformed, replace them. If the contact springs cannot be adjusted to hold the switch blade or contact securely, replace them
2	Check rocker arm for lose bolts. Mechanism and rocker arm must be firmly connected. Check contact alignment and engagement.
3	Move each operating mechanism through its sequence of operation by pushing in on the internal latches (see manufacturer's instructions). Do this several times to ensure the mechanism operates freely and completely without binding or interference. If any binding occurs, adjust to the manufacturer's specifications. Refer to the manufacturer's instructions.
4	Tighten all bolts to specifications.
5	Check all porcelains for cracking and chipping. If any porcelains are chipped or cracked, replace them.
6	After checking and adjusting the interior parts to specifications, the next step is to flush out the switch tank.

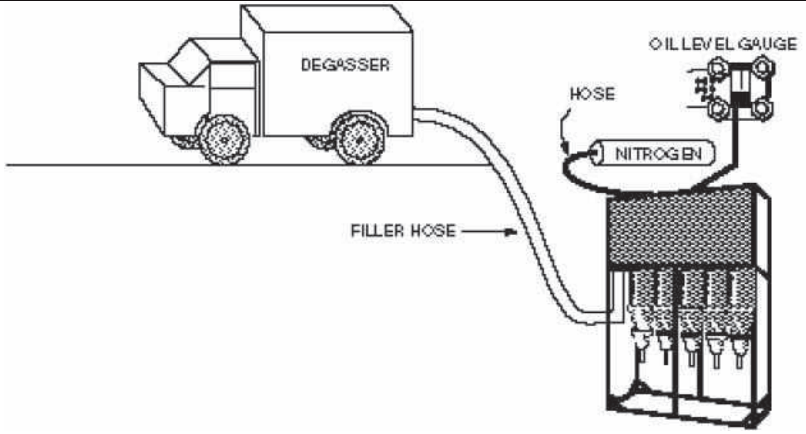
Flush the Switch

STEP	TASK

1	The switch tank is flushed out using degassed oil from the degasser truck to remove any dirt or particles.
2	The degasser truck must be close enough so that the filling hose from the degasser truck reaches the switch.
3	Use the hose to flush down all the interior parts of the switch including the walls and bottom of the tank.
4	To remove the flushing oil, use the pump set up previously. Pump the flushing oil into a waste barrel.
5	Ensure that all the sludge is removed from the bottom of the tank.
6	Once flushing is complete, close the drain valve and remove the waste oil hose.
7	Replace it with the hose from the degasser.
8	Ensure all connections are tight.

Replace the Lid and Pressurize

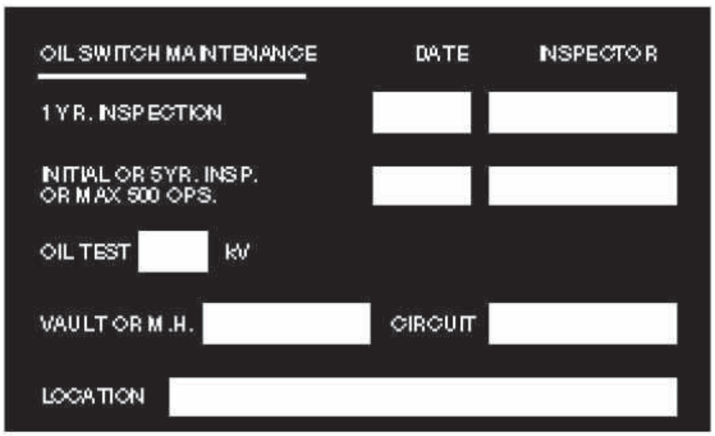
STEP	TASK
1	Replace the lid ensuring not to knock any dirt or dust into the switch.
2	Ensure the gasket is in place.
3	Replace the bolts and tighten to specifications.
4	Once the lid is secure, purge the switch interior with nitrogen to remove the air. a) Attach a nitrogen cylinder to the pressure valve on top of the bank. b) Open valve on the nitrogen cylinder to 5 psi and leave it open for 2 to 3 minutes, then open the vent plug in the tank lid to release the pressure. c) Close the vent plug and pressurize the tank to 5 psi and verify pressure valve to ensure pressure.

	
5	Check the switch for leaks using Snoop. a) Squirt Snoop over all the joint areas on the outside of the switch using plenty of solution. b) Watch for bubbles that would indicate a nitrogen leak. If bubbles appear, tighten all the bolts around that joint and recheck. If bubbles continue, all gaskets and joint faces will have to be checked for particles of dirt and parts replaced. Re-pressurize the tank and re-check
6	Once all the leaks are eliminated then the oil can be tested, a sample taken and, if it tests good, the tank can be refilled with the degassed oil.
7	**Sample oil:** Take oil sample directly from the degasser hose. If the oil tests lower than 22kV, repeat the test. If it is still below 22kV then do not refill the switch. Notify the supervisor that there is a problem with the degasser truck equipment. If oil tests at 22kV or above, obtain a sample for the laboratory using the procedures explained previously and begins to refill the switch tank.
8	**Refill with oil:** The tank is now refilled with degassed oil from the bottom. Oil is added until it appears in the centre of the oil level gauge, proving approximately 20% of unfilled space above the oil. This space is needed to allow for oil expansion during higher temperatures and remains filled with nitrogen at 3-5 psi. With the tank filled with oil to the proper level and pressurized, the nitrogen hose is removed. The cap is placed on the pressure valve.
9	**Return Switch and Circuit to normal:** Switch operators are returned to their original position and the security locks are replaced. • Remove any grounds that were applied. • The switch maintenance is now complete and it can be returned to service.

Apply Inspection Label

Oil samples are sent to the lab to be tested. The insulation capacity of the oil is checked. The oil must be able to insulate at 22kV. The lowest oil kV that the switch can be operated at is 22kV. Below 22kV, the oil must be changed.

Once the oil is tested and is determined to be acceptable, an inspection label is issued. A cable splicer is usually instructed to apply the label to the appropriate switch. It is placed over the old label.



These inspection labels are good for one year. If, at any time, you are at a switch and notice the expiry date is a month or less away, notify your supervisor. If the decal has expired do not operate the switch. Notify your supervisor of your findings. Arrangements will be made to have the oil sampled ant tested.

Appendix A: Manufacturer's Instructions

G&W	INSTALLATION INSTRUCTIONS RA20 OIL SWITCHES	GWI 520-3 Page 1 July 1972

PART I — INTRODUCTION

1.1 GENERAL

G&W RA-20 switches are dsigned, manufactured and tested to current ASA, EEI, and NEMA standards.
These switches are completely assembled, adjusted, tested and sealed at the factory.
The information and instructions included herein are an aid to the proper installation of the units.

1.2 SHIPMENT INSPECTION

Uncrate and remove the packing and switch lid as soon as possible after receiving the switch.
Examine the equipment carefully for any damage that may have occurred in transit. If any damage is found, a claim should be filed at once with the transportation company.

1.3 STORAGE

Switches that will not be set up immediately for service must be prepared and stored in a suitable location. After the shipment inspection is completed, check the switch interior for indications of moisture. If moisture has been or is present in the switch, dry it out thoroughly. Long time exposure to moisture will effect the mechanical and electrical characteristics of the rocker arm and insulating stringers. Replace if necessary. Replace the lid bolts and tighten evenly around the gasketed joint.
Pressurize the switch to 3 psig with dry nitrogen or fill with insulating oil.

PART II — INSTALLATION PROCEDURE

Before the switch is operated the following procedure is recommended:

2.1 INTERNAL INSPECTION

Remove the switch lid.
Examine the interior for moisture, dirt or other foreign matter entry which could impair optimum switching performance.
Examine switch for damage.
Check all fastenings and tighten as necessary.
The following is a guide to internal tank bolts and shows approximate torque values:

Isulated Supports 3/8-16 HHCS	20 FT-LB.
Spring Operator Connection to Operator Shaft 5/16-18 HHCS	20 FT-LB.
Spring Operator Connection to Rocker Arm 5/16-18 HHCS	20 FT-LB.
Front and Rear Rocker Arm Clamp Connections 5/16-18 HHCS	20 FT-LB.

Clean and dry out the switch if necessary to prevent foreign matter from contaminating the insulating oil.

2.2 CHECK CONTACT ALIGNMENT

Although all contacts are properly aligned before switches leave the factory, it is possible that fastenings may have become loose during shipment or storage. Therefore, before the switch is operated, contact alignment should be checked and stationary contacts adjusted for correct blade entry and engagement. (See Fig. 1) Follow the procedure outlined below:

a. Remove any padlocks holding the switch in position.

b. Remove the operating handle from the operator hex nut.

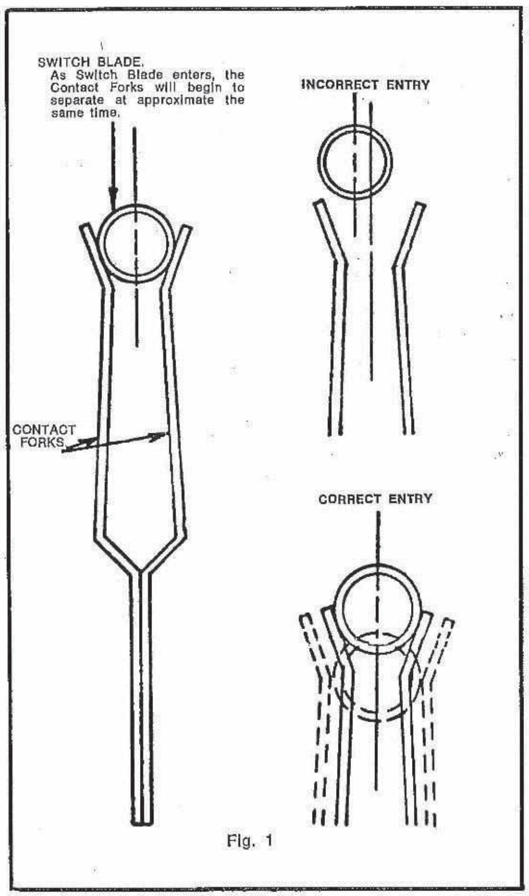


Fig. 1

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c. Over-ride the snap-action operator mechanism.
Each switching way of an RA-20 Switch has a quick-make, quick-break operator.
The operator is equipped with two rollers which act as position stops when engaged with the weld studs on the tank wall. An interference fit exists between the rollers and the weld studs. (Fig. 2) When normally operated by means of the external handle, this interference allows the mechanism springs to compress and snap the rocker arm into position.
Over-riding the mechanism is accomplished by pressing the appropriate roller inward by hand and rotating the operator past the weld studs. (Fig. 3) One roller will interfere with each direction of rotation.

d. Once the operator is disengaged from the weld studs, rotate the rocker arm to a position where the switch blades are just beginning engagement with the stationary contacts forks. (Fig. 4)

e. Rotate the rocker arm toward the stationary contacts and check for even blade entry into the contact forks. Refer to Figure 4.

f. Rotate the rocker arm into the stationary contacts (operator rollers engaged with the weld studs). (Fig. 5) Check proper contact engagement for all switch ways in the closed positions. Figure 6 shows the correct penetration and method of measuring.

g. If engagement is not within the tolerance specified, or blade entry is uneven, follow the Contact Adjustment Instruction.

2.3 CONTACT ADJUSTMENT

If allignment is required proceed as follows:

a. Place switch in the closed position. Adjust all contacts with the rocker arm blades engaged and the operator rollers rotated onto the weld studs.

b. Loosen the ⅜"-16 x 1½" long hex head cap screws at each end of the contact insulating angles. Refer to Figure 2. **CAUTION: DO NOT** operate switch when assembly is loose.

Fig. 2

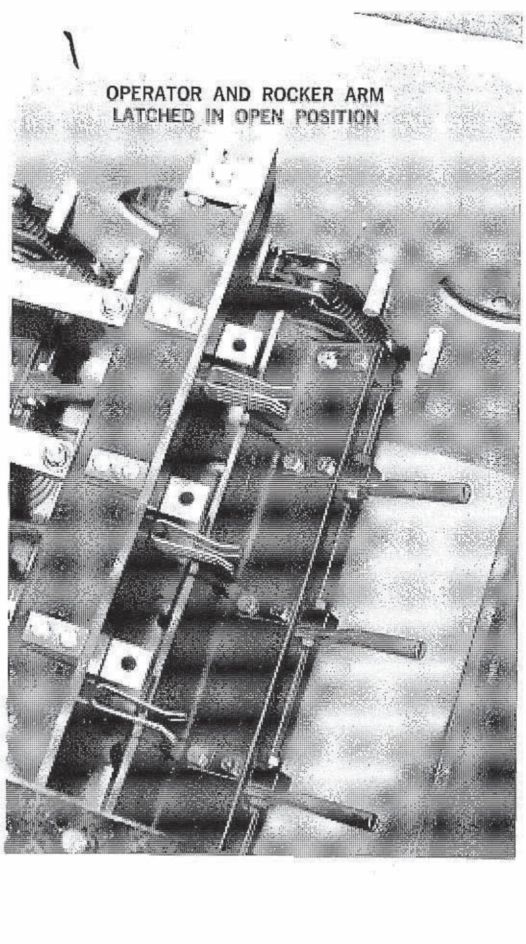
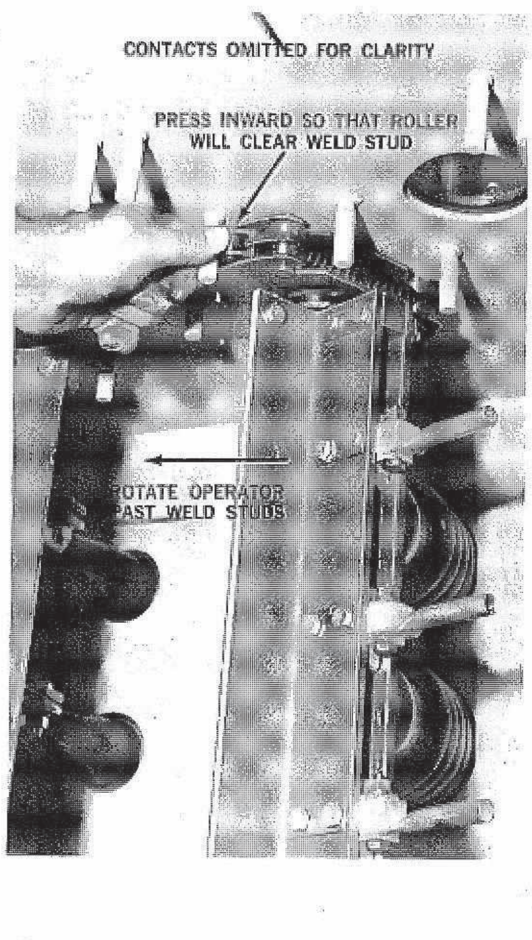


Fig. 3



c. The three phase contact assembly may now be moved:
   1. Toward the rocker arm blades to allow more engagement.
   2. Away from the rocker arm blades to allow less engagement.
   3. Adjust so that the rocker arm blades penetrate the contact forks as shown in Fig. 6.

d. With the stringer loose, even contact entry will automatically self align and further adjustment should not be necessary.

e. Retighten the contact mounting bolts.

f. Check that proper alignment has been attained by repeating steps "e" and "f" in Section 2.2

g. After all contacts have been aligned and tightened, actuate each operating lever several times to make sure the mechanism operates freely and completely without binding or interference. Operation Instructions are given in Section 2.6.

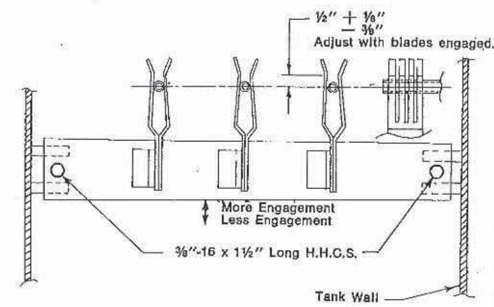


Fig. 6

Fig. 4

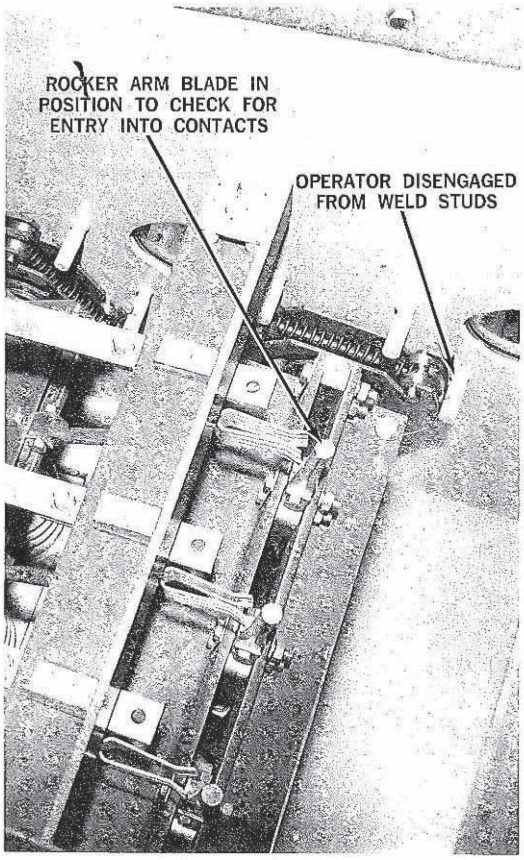
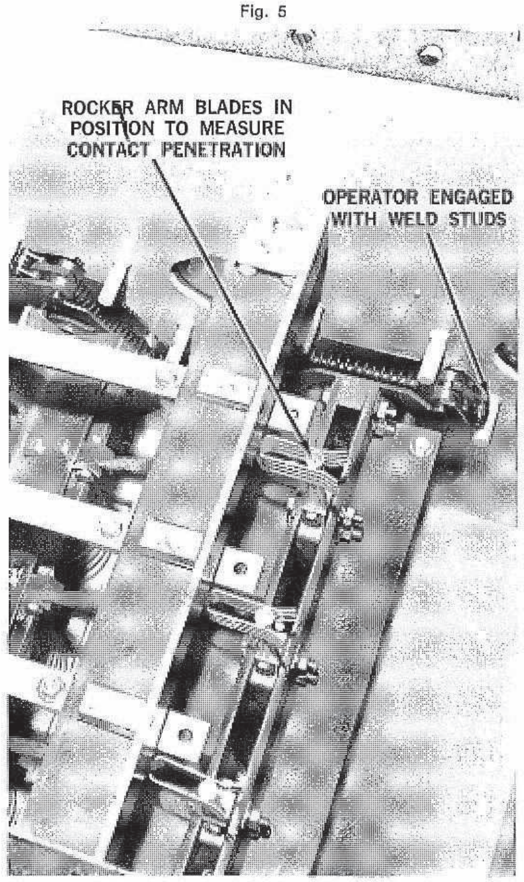


Fig. 5



2.4 TERMINATE CABLES

Follow separate instructions on cable installation.

Check contact wire rope connections to the cable terminations and tighten if necessary, using the following guide:

Lug Connection to Rocker Arm Blades 5/16"-18 HHCS	20 FT-LB.
Clamp Connection to Cablehead or ESNA 3/8"-16 HHCS	20 FT-LB.
Size 2 or 3 Slip-On Lug Connection 5/16"-18 HHCS	15 FT-LB.
Size 1 Slip-On Lug Connection 3/8"-16 HHCS	20 FT-LB.

2.5 EXTERNAL INSPECTION

Replace the lid and tighten the lid bolts down evenly around the gasket joint. DO NOT APPLY ANY ADHESIVE COMPOUND OR OIL TO THE GASKET SURFACE. Pressurize the switch to 3 psig with dry nitrogen for 15 minutes or fill with air to same pressure. Check for leaks by applying soapy water to all joints and watch for leaks indicated by soap bubbles. Tighten joints as necessary to seal the switch using the following bolt check:

Side Plate Entrance Nuts — 1/2"-13	25 FT-LB.
Lid Bolts and Nuts — 1/2"-13	25 FT-LB.
Viewing Windows and Oil Gage Nuts — 3/8"-16	15 FT-LB.
Shaft Housing Bolts — 1/2"-13	25 FT-LB.
1/4" Straight Pipe Plug	3 FT-LB.
1" Straight Pipe Plug	12 FT-LB.

2.6 OPERATION OF THE MULTI-POSITION OPERATOR — WITH ONE PIECE HANDLE

a. The multi-position operator works with a removable handle which fits onto the hex nut of the operating shaft.

b. The multi-position operator travels 60° per operation. The operating handle must travel the full 60° before the spring mechanism inside the switch tank will unlatch. At that point the rocker arm moves rapidly from one position to the next. Therefore, the handle can be moved slowly, if desired, throughout the entire handle travel pattern required for switching.
As a safety measure, handle stops prevent the performance of successive, same direction operations without first removing the handle and repositioning it to the initial position.

c. The operating handle is rotated in the same direction as the desired rotation of the switch rocker arm. This provides a natural operating sequence and should avoid confusion. In the "at rest" position the operator pointer is in the same direction as the switch rocker arm.

d. The external operators are equipped with provisions for padlocking in all positions. Figures 7 thru 14 show padlocking methods for standard two and three position operators. Figures 7 thru 9 illustrate the two position operator showing padlocking provisions.

e. Three position operator with Ground stop and padlocking provisions is shown in Figures 10 thru 14. Operators having a ground position are equipped with a ground stop. Figures 10 thru 14 show the function of this stop.

f. When keylocking is provided, figures 15 thru 17 show the operation of this lock.

g. For rope operation, a pully arrangement may be needed to keep the rope in the same plane as the front of the switch and also to properly use the available handle arc zone. Position the handle on the operator and secure it with a bolt and large washer pattern. Fasten the rope to the eye in the handle and train the rope to the desired operating location. Pull the rope until the switch operates. Since the multi-position operator "snaps" or transfers suddenly at the end of travel of the operating handle, this should be felt on the rope. For this reason it is best if the rope is pulled SLOWLY.

OPERATION OF THE TWO-POSITION OPERATOR

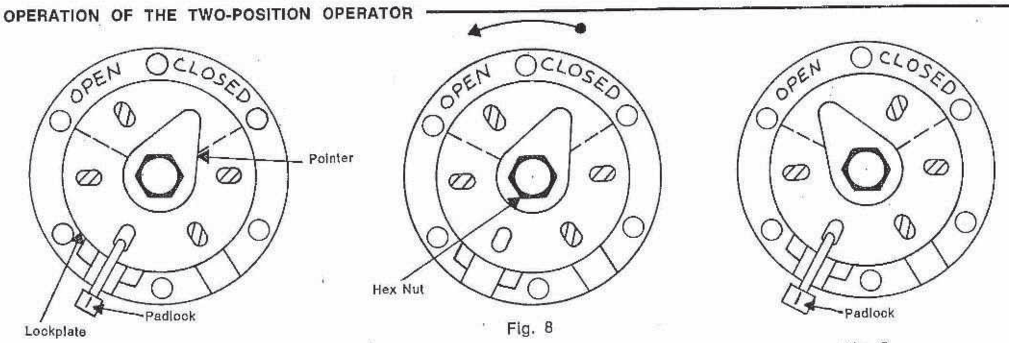


Fig. 7
CLOSED POSITION
Lockplate: Padlocked (#1) in Closed position

Fig. 8
TRANSFER
Attach handle to hex nut and rotate pointer to "Open" until switch transfers. Remove handle.
Lockplate: Unlocked and rotatable.

Fig. 9
OPEN POSITION
Lockplate: Padlocked (#1) in Open position.

OPERATION OF THE THREE-POSITION OPERATOR

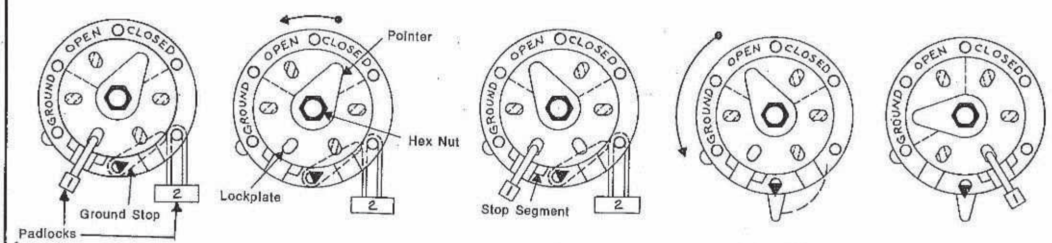


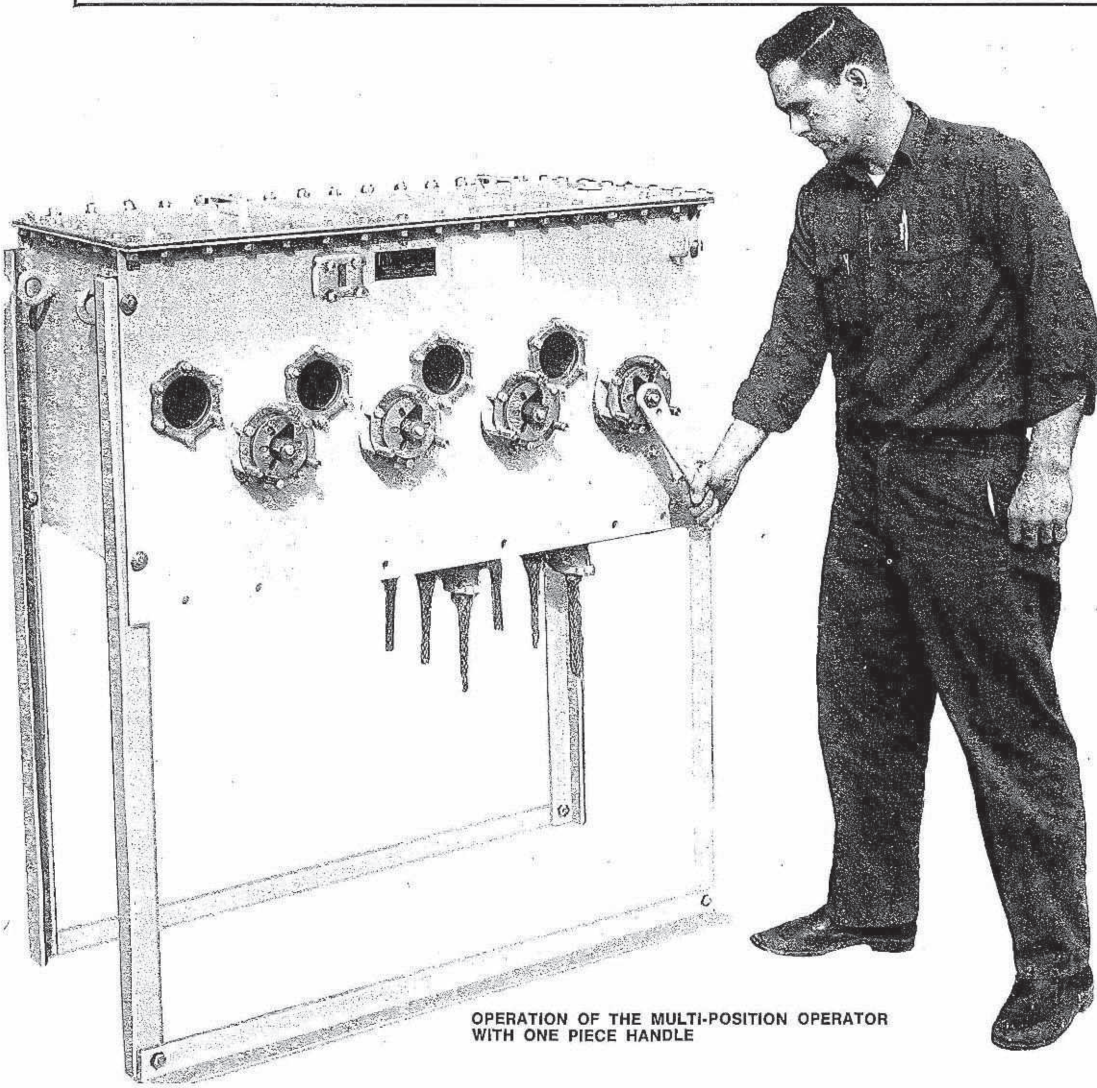
Fig. 10
CLOSED POSITION
Lockplate: Padlocked (#1) in Closed position

Fig. 11
TRANSFER
Attach handle to hex nut and rotate pointer to "Open" until switch transfers. Remove handle. Lockplate: Unlocked and rotatable.

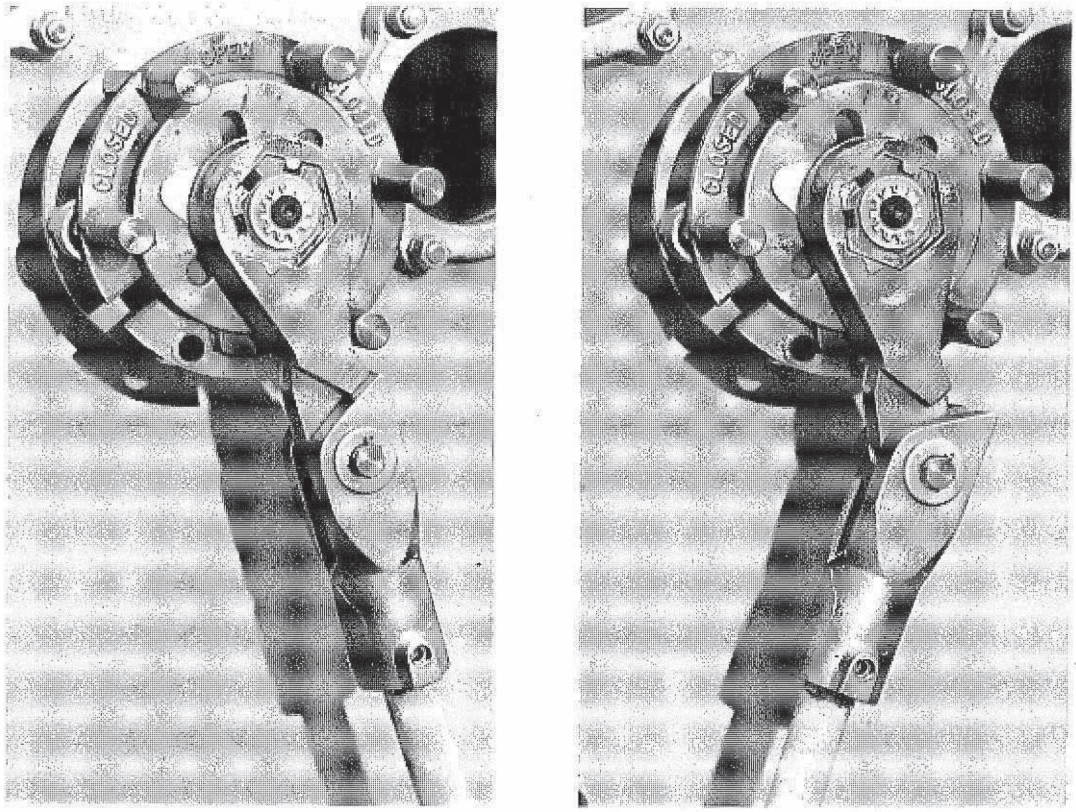
Fig. 12
OPEN POSITION
Lockplate: Padlocked (#1) in Open position.
Grd. Stop: Padlocked (#2) Blocking stop segment & transfer to Grd.

Fig. 13
TRANSFER
Attach handle to hex nut and rotate until switch transfers. Remove handle.
Lockplate: Unlocked & rotatable.
Ground Stop: Unlocked and rotated to Clear position

Fig. 14
GROUND POSITION
Lockplate: Padlocked (#1) in ground position



OPERATION OF THE MULTI-POSITION OPERATOR WITH ONE PIECE HANDLE



OPERATION OF THE MULTI-POSITION OPERATOR —
WITH NON-REVERSIBLE HANDLE

2.7 OPERATION OF THE MULTI-POSITION OPERATOR — WITH NON-REVERSIBLE HANDLE

To operate the switch, mount the handle on the hex nut so that the handle is rigid in the direction of operation. It will collapse and not operate the switch in the opposite direction. Handle stops prevent the performance of successive, same direction operations without first removing the handle and repositioning it to the initial position. The handle will operate in only one direction. Therefore, it is not possible to immediately reverse switch operation because the handle will collapse and must be removed and remounted to reverse direction.

1. All other operational instructions apply as outlined in section 2.6 on OPERATION OF THE MULTI-POSITION OPERATOR — WITH ONE PIECE HANDLE.

2.8 OIL FILLING

Use any clean, dry inhibited or uninhibited oil that is regularly used in circuit breakers or transformers. The oil should test 30,000 volts in standard test cup with 1/10 inch gap.

The oil level gauge on the switch tank is calibrated for filling temperature variations. Three levels are marked — 0°C, 25°C and 50°C and are also marked in 1/8 inch steps to facilitate filling to intermediate temperatures. With the switch filled to the proper level, the air space above the oil is sufficient to allow for expansion and contraction due to temperature changes.

To avoid trapping moisture laden air in the space above the oil, purge this space with dry nitrogen for approximately one minute. The space may be left filled with nitrogen at a slight positive pressure (approx. ½ lb. per square inch) to serve as an indicator of tightness of the tank.

2.9 OPERATIONAL CHECK

Actuate each operating lever through its sequence of operation several times to make sure the mechanism operates freely and completely without binding or interference.

Check the shaft oil seal to make sure there is no leakage.

2.10 ENERGIZATION

The switch is ready to be energized and operated within its ratings.

PART III —
MAINTENANCE RECOMMENDATIONS FOR RA-20 SWITCHES

3.1 OIL MAINTENANCE

The dielectric strength and interrupting characteristics of load break switches are controlled by the quality and condition of the oil. These switches utilize a plain break operation where the oil is the total interrupting medium. It is important that regularly scheduled maintenance programs be established for sampling and testing the switch oil.

Rating oil life is difficult and dependent upon the following:

1. Volume of oil.
2. Amount of chemical deterioration caused by load break interruptions.
3. Physical contamination due to moisture and sludging.

To assure reliable service, it is recommended that the oil in all switches be checked at least once a year or at shorter intervals when load break operations approach the maximum number as given in the chart below:

Service Voltage (Nominal) Volts	Transformer Excitation Current	Load Break Current 300 Amp
600 to 23,000	500	500

For additional information on the acceptance and maintenance of insulating oil consult ANSI C59.131-1971/1EEE Std. 64-1969.

Switches should be filled with any clean, dry inhibited or uninhibited oil that is regularly used in circuit breakers or transformers. The oil should test 30,000 volts minimum in a standard test cup with 1/10 inch gap. Oil, sampled from switches in service, should be reconditioned if tests show less than 22KV.

3.2 SWITCH MAINTENANCE

A. External Inspection

1. Check oil level in switch.
2. Take oil sample and test as recommended under oil maintenance.
3. Check outside of switch for any evidence of leaking oil.
4. Check all nuts and bolts for tightness on handle, oil seal, cable entrances and lids.
5. Inspect exterior of switch for evidence of rusting or corrosion. Touch-up paint as reqiured.

B. Internal Inspection

NOTE: Mechanism operated switches are assigned a close into fault rating. Design tests have shown that after fault closing, contacts without any attention will carry full rated current without exceeding a 50°C rise. However, it is recommended that contact maintenance be performed when fault closing near the maximum switch ratings are experienced.

CAUTION: Internal access requires that the switch be deenergized. Provisions should be made to carry the load thru an alternate source. Afterwards, remove the lid, drain the oil from the switch and proceed with inspection of all internal parts as follows:

1. Check contacts for arc erosion, spring tension, deformed parts or loose screws.
2. Check rocker arm for loose bolts. Mechanism and rocker arm should be firmly connected. Check contact alignment and engagement. Actuate each operating handle through its sequence of operation several times to make sure the mechanism operates freely and completely without binding or interference.
3. Check gaskets for cracks and flexibility.
4. Check all porcelains for cracking and chipping.
5. Inspect all mechanical & electrical connections that they are tight.
6. Clean any sludge from insulators, bottom of tank, or any other location.
7. Flush and clean the switch interior with oil and drain.
8. Replace all lids with new gaskets where required.
9. Refill wtih clean oil.

OPERATION OF 3 POSITION OPERATOR WITH KEYLOCK AND PADLOCK

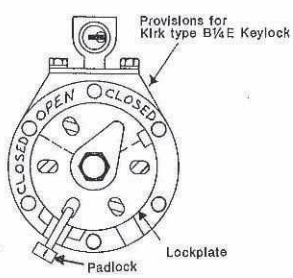


Fig. 15

CLOSED POSITION
Lockplate: Padlocked (#1) in Closed position.
Keylock: Bolt withdrawn & key held.

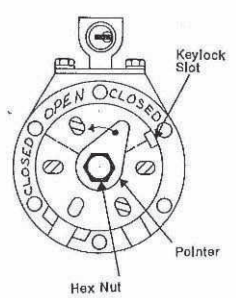


Fig. 16

TRANSFER
Attach handle to hex nut and rotate pointer to "Open" until switch transfers. Remove handle.
Lockplate: Unlocked & rotatable.

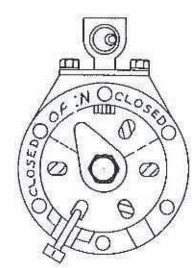


Fig. 17

OPEN.POSITION
Lockplate: Padlocked (#1) in "Open" position.
Keylock: Bolt extended—key removable.

LIABILITY CLAUSE

The information in this sheet is based on data which we believe to be reliable and it is presented in good faith but without guarantee since the conditions and methods of use of our products are beyond our control. We urge that the prospective user determine the suitability of our products and recommendations before putting them to use, and the user assumes all risks and liability whatsoever in connection therewith. Our sole obligation shall be to replace such quantity of our product proved to be defective in material or workmanship for a period of one year from date of shipment and we shall not be liable for any injury, loss or damage, direct or consequential, arising out of the use or inability to use the product. Suggestion for uses of our product are not to be considered recommendations that they be used in violation of any patents.

If our product be sold by any intermediate purchaser, such intermediate purchaser shall inform the ultimate user of these conditions.

G&W

G&W	INSTALLATION INSTRUCTIONS RA40 OIL SWITCHES	GWI 521-2 Page 1 July 1972

PART I — INTRODUCTION

1.1 GENERAL

G&W RA-40 switches are designed, manufactured and tested to current ASA, EEI, and NEMA standards.
These switches are completely assembled, adjusted, tested and sealed at the factory.
The information and instructions included herein are an aid to the proper installation of the units.

1.2 SHIPMENT INSPECTION

Uncrate and remove the packing and switch lid as soon as possible after receiving the switch.
Examine the equipment carefully for any damage that may have occurred in transit. If any damage is found, a claim should be filed at once with the transportation company.

1.3 STORAGE

Switches that will not be set up immediately for service must be prepared and stored in a suitable location. After the shipment inspection is completed, check the switch interior for indications of moisture. If moisture has been or is present in the switch, dry it out thoroughly. Long time exposure to moisture will effect the mechanical and electrical characteristics of the rocker arm and insulating stringers. Replace if necessary. Replace the lid bolts and tighten evenly around the gasketed joint.
Pressurize the switch to 3 psig with dry nitrogen or fill with insulating oil.

PART II — INSTALLATION PROCEDURE

Before the switch is operated the following procedure is recommended:

2.1 INTERNAL INSPECTION

Remove the switch lid.
Examine the interior for moisture, dirt or other foreign matter entry which could impair optimum switching performance.
Examine switch for damage.
Check all fastenings and tighten as necessary.
The following is a guide to internal tank bolts and shows approximate torque values:

Stringer Supports 1/2"-13 HHCS	35 FT-LB.
Contacts and Insulators 5/16"-18 HHCS	15 FT-LB.
Spring Operator Connection to Operator Shaft 5/16"-18 Allenhead Screw	20 FT-LB.
Spring Operator Connection to Rocker Arm 1/2"-13 HHCS	35 FT-LB.
Front and Rear Rocker Arm Connections to Wood Laminate Clamping Strips 3/8"-16 HHCS	20 FT-LB.

Clean and dry all porcelain insulators if moist or dirty. Clean and dry out the switch if necessary to prevent foreign matter from contaminating the insulating oil.

2.2 CHECK CONTACT ALIGNMENT

Although all contacts are properly aligned before switches leave the factory, it is possible that fastenings may have become loose during shipment or storage. Therefore, before the switch is operated, contact alignment should be checked and stationary contacts adjusted for correct blade entry and engagement (see Fig. 1). Follow the procedure outlined below:

a. Remove any padlocks holding the switch in position.

b. Remove the operating handle from the operator hex nut.

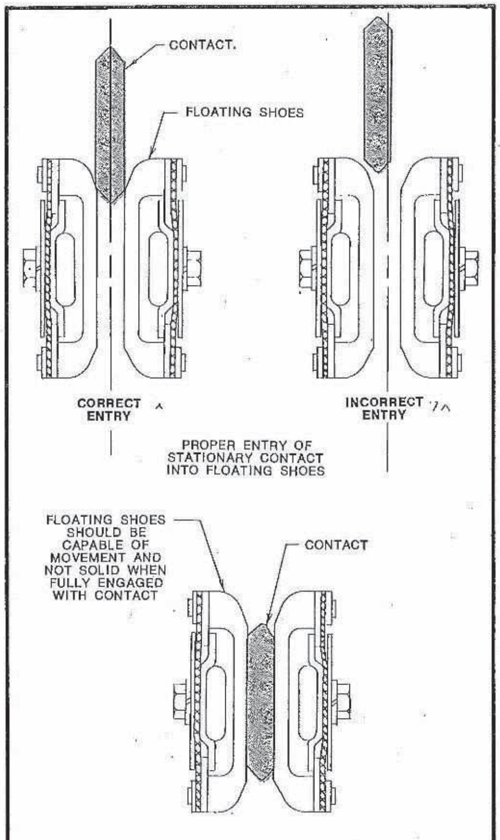


Fig. 1

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c. Over-ride the snap-action operator mechanism.
Each switching way of an RA-40 Switch has a quick-make, quick-break operator.

The operator is equipped with four rollers which act as position stops when engaged with the weld studs on the tank wall. An interference fit exists between the rollers and the weld studs. (Fig. 2) When normally operated by means of the external handle, this interference allows the mechanism springs to compress and snap the rocker arm into position.

Over-riding the mechanism is accomplished by pressing the appropriate rollers inward by hand and rotating the operator past the weld studs. (Fig. 3) Two rollers will interfere with each direction of rotation.

d. Once the operator is disengaged from the weld studs, rotate the rocker arm to a position where the floating contact shoes are just beginning engagement with the stationary contacts (Refer to Fig. 2.).

e. Rotate the rocker arm toward the stationary contacts and check for even floating shoe entry.

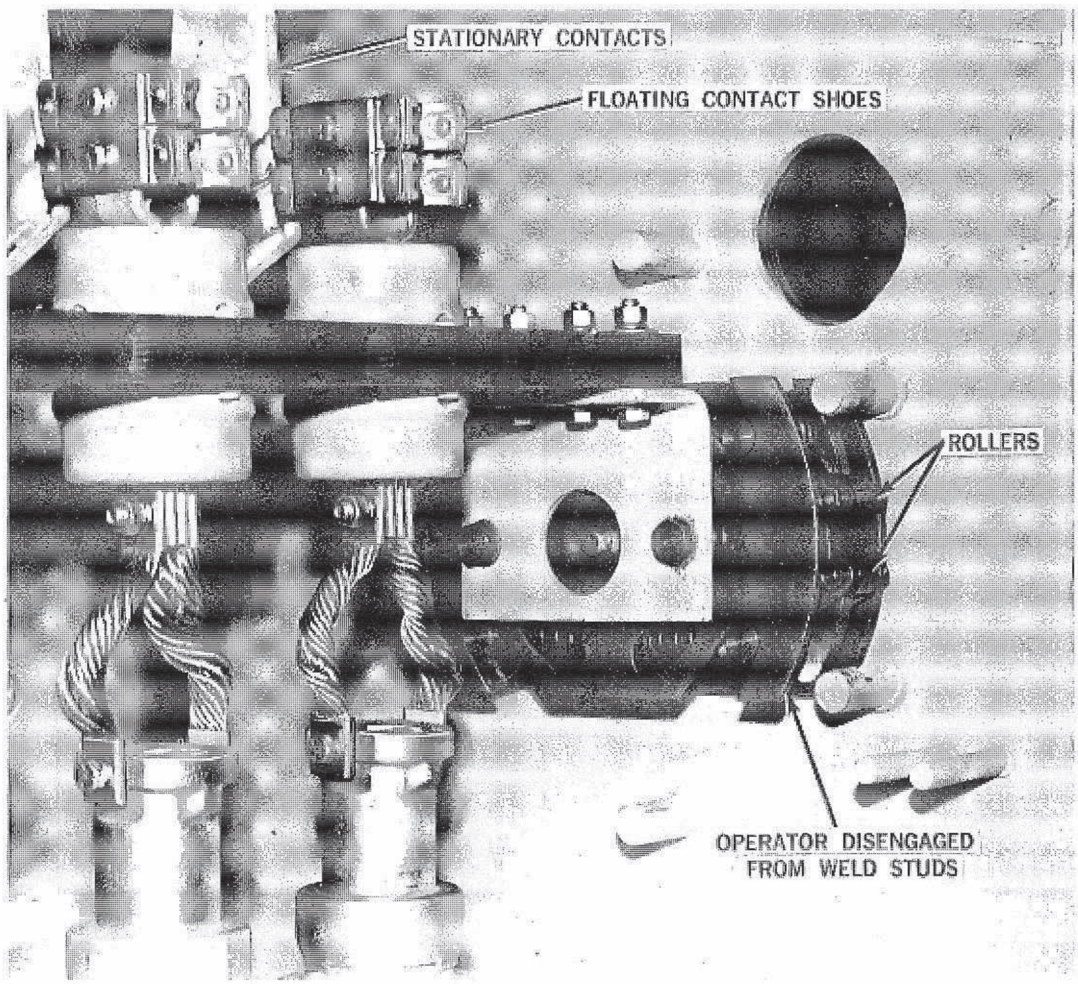
f. Rotate the rocker arm onto the stationary contacts. Check each floating shoe for pressure against the contact by pressing the shoes away from the contact. The shoes on each side of the contact should have movement.

2.3 CONTACT ADJUSTMENT

If alignment is required proceed as follows:

a. Rotate the operator and switch links toward the contacts

Fig. 2

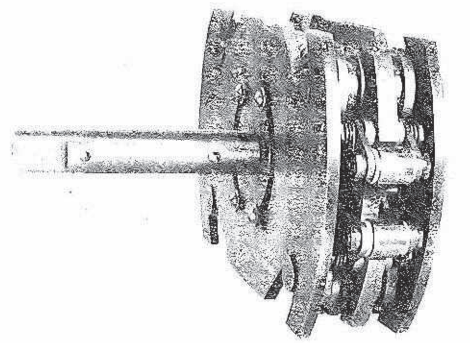


to be aligned and into the fully closed position. The operator rollers should be engaged with the weld studs.

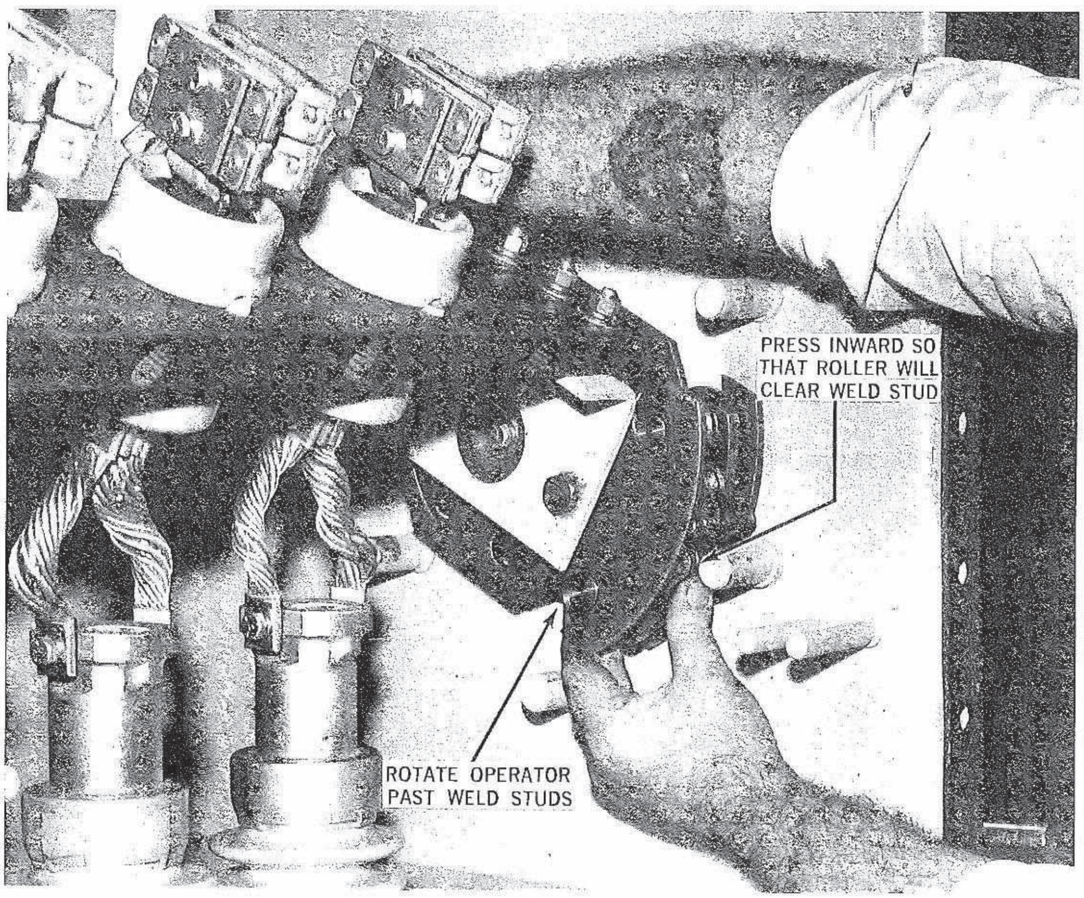
b. Loosen the 5/16"-18 HHCS holding the stationary contact to the standoff insulator. The loose contact will self-align with the floating shoes. Retighten the HHCS. CAUTION: Do not operate the switch with the stationary contacts loose.

c. Check that proper alignment has been attained by repeating steps e and f.

After all contacts have been aligned and tightened, actuate each operating lever several times to make sure the mechanism operates freely and completely without binding or interference. Operation Instructions are given in Section 2.6.



Each switching way of the load break oil switch is equipped with a quick-make, quick-break, manually controlled mechanism.



2.4 TERMINATE CABLES

Follow separate instructions on cable installation. Check contact braid connections to the cable terminations and tighten if necessary, using the following guide:

Braid Connection to Switching Links 3/8-16 HHCS	20 FT-LB.
Clamp Connections to Cablehead or Esna 3/8-16 HHCS	20 FT-LB.
Size 2 or 3 Slip-On Braid Connection 5/16-18 HHCS	15 FT-LB.
Size 1 Slop-On Braid Connection 3/8-16 HHCS	20 FT-LB.

2.5 EXTERNAL INSPECTION

Replace the lid and tighten the lid bolts down evenly around the gasket joint. DO NOT APPLY ANY ADHESIVE COMPOUND OR OIL TO THE GASKET SURFACE. Pressurize the switch to 3 psig with dry nitrogen for 15 minutes or fill with air to same pressure. Check for leaks by applying soapy water to all joints and watch for leaks indicated by soap bubbles. Tighten joints as necessary to seal the switch using the following bolt check:

Side Plate Entrance Nuts 1/2"-13	25 FT-LB.
Lid Bolts and Nuts 1/2"-13	25 FT-LB.
Viewing Windows and Oil Gage Nuts 3/8"-16	15 FT-LB.
Shaft Housing Bolts 1/2"-13	25 FT-LB.
1/4" Straight Pipe Plug	3 FT-IB.
1" Straight Pipe Plug	12 FT-LB.

2.6 OPERATION OF THE MULTI-POSITION OPERATOR — WITH ONE PIECE HANDLE

a. The multi-position operator works with a removable handle which fits onto the hex nut of the operating shaft.

b. The multi-position operator travels 60° per operation. The operating handle must travel the full 60° before the spring mechanism inside the switch tank will unlatch. At that point the rocker arm moves rapidly from one position to the next. Therefore, the handle can be moved slowly, if desired, throughout the entire handle travel pattern required for switching.
As a safety measure, handle stops prevent the performance of successive, same direction operations without first removing the handle and repositioning it to the initial position.

c. The operating handle is rotated in the same direction as the desired rotation of the switch rocker arm. This provides a natural operating sequence and should avoid confusion. In the "at rest" position the operator pointer is in the same direction as the switch rocker arm.

d. The external operators are equipped with provisions for padlocking in all positions. Figures 4 thru 11 show padlocking methods for standard two and three position operators. Figures 4 thru 6 illustrate the two position operator showing padlocking provisions.

e. Three position operator with Ground stop and padlocking provisions is shown in Figures 7 thru 11. Operators having a ground position are equipped with a ground stop. Figures 7 thru 11 show the function of this stop.

f. When key interlocking is provided, figures 12 thru 14 show the operation of this lock.

g. For rope operation, a pulley arrangement may be needed to keep the rope in the same plane as the front of the switch and also to properly use the available handle arc zone. Position the handle on the operator and secure it with a bolt and large pattern washer. Fasten the rope to the eye in the handle and train the rope to the desired operating location. Pull the rope until the switch operates. Since the multi-position operator "snaps" or transfers suddenly at the end of travel of the operating handle, this should be felt on the rope. For this reason it is best if the rope is pulled SLOWLY.

OPERATION OF THE TWO-POSITION OPERATOR

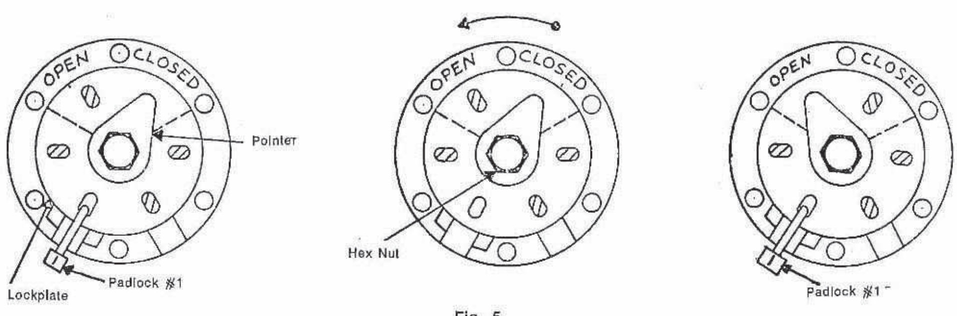
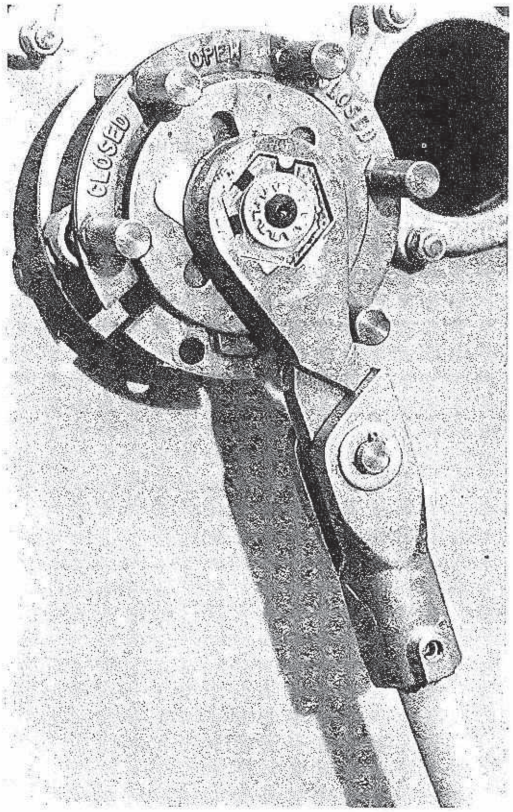
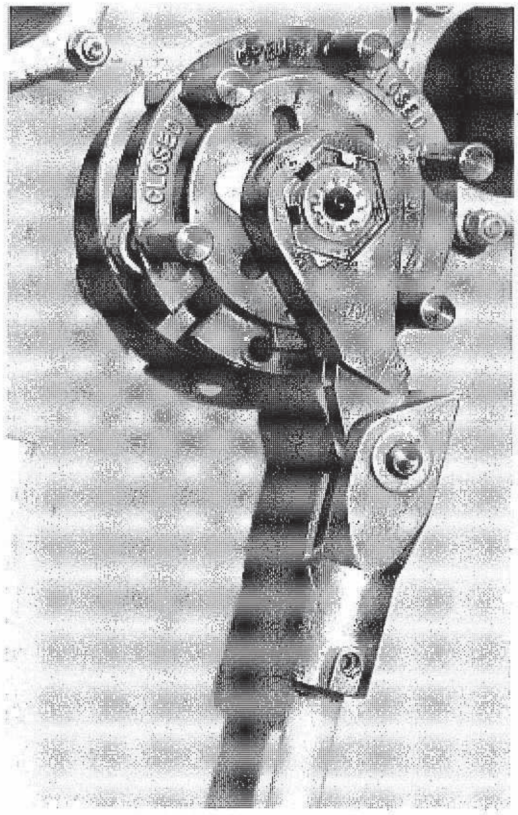


Fig. 4
CLOSED POSITION
Lockplate: Padlocked (#1) in Closed position

Fig. 5
TRANSFER
Attach handle to hex nut and rotate pointer to "Open" until switch transfers. Remove handle.
Lockplate: Unlocked and rotatable.

Fig. 6
OPEN POSITION
Lockplate: Padlocked (#1) in Open position.





OPERATION OF THE MULTI-POSITION OPERATOR — WITH NON-REVERSIBLE HANDLE

2.7 OPERATION OF THE MULTI-POSITION OPERATOR — WITH NON-REVERSIBLE HANDLE

To operate the switch, mount the handle on the hex nut so that the handle is rigid in the direction of operation. It will collapse and not operate the switch in the opposite direction. Handle stops prevent the performance of successive same direction operations without first removing the handle and repositioning it to the initial position.

The handle will operate in only one direction. Therefore, it is not possible to immediately reverse switch operation because the handle will collapse. The handle must be removed and remounted to reverse direction.

1. All other operational instructions apply as outlined in section 2.6 on OPERATION OF THE MULTI-POSITION OPERATOR—WITH ONE PIECE HANDLE.

2.8 OIL FILLING

Use any clean, dry inhibited or uninhibited oil that is regularly used in circuit breakers or transformers. The oil should test 30,000 volts in standard test cup with 1/10 inch gap. The oil level gauge on the switch tank is calibrated for filling temperature variations. Three levels are marked — 0°C, 25°C and 50°C are also marked in 1/8 inch steps to facilitate filling to intermediate temperatures. With the switch filled to the proper level, the air space above the oil is sufficient to allow for expansion and contraction due to temperature changes.

To avoid trapping moisture laden air in the space above the oil, purge this space with dry nitrogen for approximately one minute. The space may be left filled with nitrogen at a slight positive pressure (approx. ½ lb. per square inch) to serve as an indicator of tightness of the tank.

2.9 OPERATIONAL CHECK

Actuate each operating lever through its sequence of operation several times to make sure the mechanism operates freely and completely without binding or interference.

Check the shaft oil seal to make sure there is no leakage.

2.10 ENERGIZATION

The switch is ready to be energized and operated within its ratings.

PART III — MAINTENANCE RECOMMENDATIONS FOR RA-40 SWITCHES

3.1 OIL MAINTENANCE

The dielectric strength and interrupting characteristics of load break switches are controlled by the quality and condition of the oil. These switches utilize a plain break operation where the oil is the total interrupting medium. It is important that regularly scheduled maintenance programs be established for sampling and testing the switch oil.

Rating oil life is difficult and dependent upon the following:

1. Volume of oil.
2. Amount of chemical deterioration caused by load break interruptions.
3. Physical contamination due to moisture and sludging.

To assure reliable service, it is recommended that the oil in all switches be checked at least once a year or at shorter intervals when load break operations approach the maximum number as given in the chart below:

Service Voltage (Nominal) Volts	Transformer Excitation Current	Load Break Current 300 Amp	Load Break Current 400 Amp	Load Break Current 600 Amp
600 to 34,500	500	500	500	500

For additional information on the acceptance and maintenance of insulating oil consult ANSI C59.131-1971/1EEE Std. 64-1969.

Switches should be filled with any clean, dry inhibited or uninhibited oil that is regularly used in circuit breakers or transformers. The oil should test 30,000 volts minimum in a standard test cup with 1/10 inch gap. Oil, sampled from switches in service, should be reconditioned if tests show less than 22KV.

3.2 SWITCH MAINTENANCE

A. External Inspection

1. Check oil level in switch.
2. Take oil sample and test as recommended under oil maintenance.
3. Check outside of switch for any evidence of leaking oil.
4. Check all nuts and bolts for tightness on handle, oil seal, cable entrances and lids.
5. Inspect exterior of switch for evidence of rusting or corrosion. Touch-up paint as reqiured.

B. Internal Inspection

NOTE: Mechanism operated switches are assigned a close into fault rating. Design tests have shown that after fault closing, contacts without any attention will carry full rated current without exceeding a 50°C rise. However, it is recommended that contact maintenance be performed when fault closing near the maximum switch ratings are experienced.

CAUTION: Internal access requires that the switch be deenergized. Provisions should be made to carry the load thru an alternate source. Afterwards, remove the lid, drain the oil from the switch and proceed with inspection of all internal parts as follows:

1. Check contacts for arc erosion, spring tension, deformed parts or loose screws.
2. Check rocker arm for loose bolts. Mechanism and rocker arm should be firmly connected. Check contact alignment and engagement. Actuate each operating handle through its sequence of operation several times to make sure the mechanism operates freely and completely without binding or interference.
3. Check gaskets for cracks and flexibility.
4. Check all porcelains for cracking and chipping.
5. Inspect all mechanical & electrical connections that they are tight.
6. Clean any sludge from insulators, bottom of tank, or any other location.
7. Flush and clean the switch interior with oil and drain.
8. Replace all lids with new gaskets where required.
9. Refill wtih clean oil.

OPERATION OF THE 3 POSITION OPERATOR WITH KEYLOCK AND PADLOCK

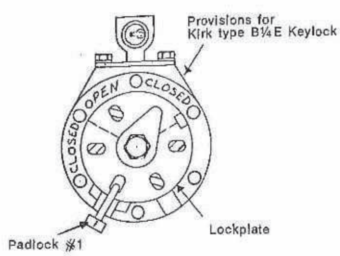


Fig. 12

CLOSED POSITION
Lockplate: Padlocked (#1) in Closed position.
Keylock: Bolt withdrawn & key held.

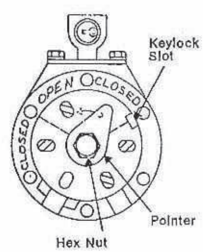


Fig. 13

TRANSFER
Attach handle to hex nut and rotate pointer to "Open" until switch transfers. Remove handle.
Lockplate: Unlocked & rotatable.

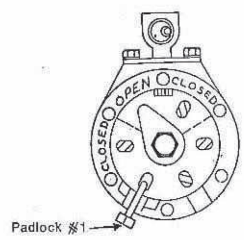


Fig. 14

OPEN POSITION
Lockplate: Padlocked (#1) in "Open" position.
Keylock: Bolt extended—key removable.

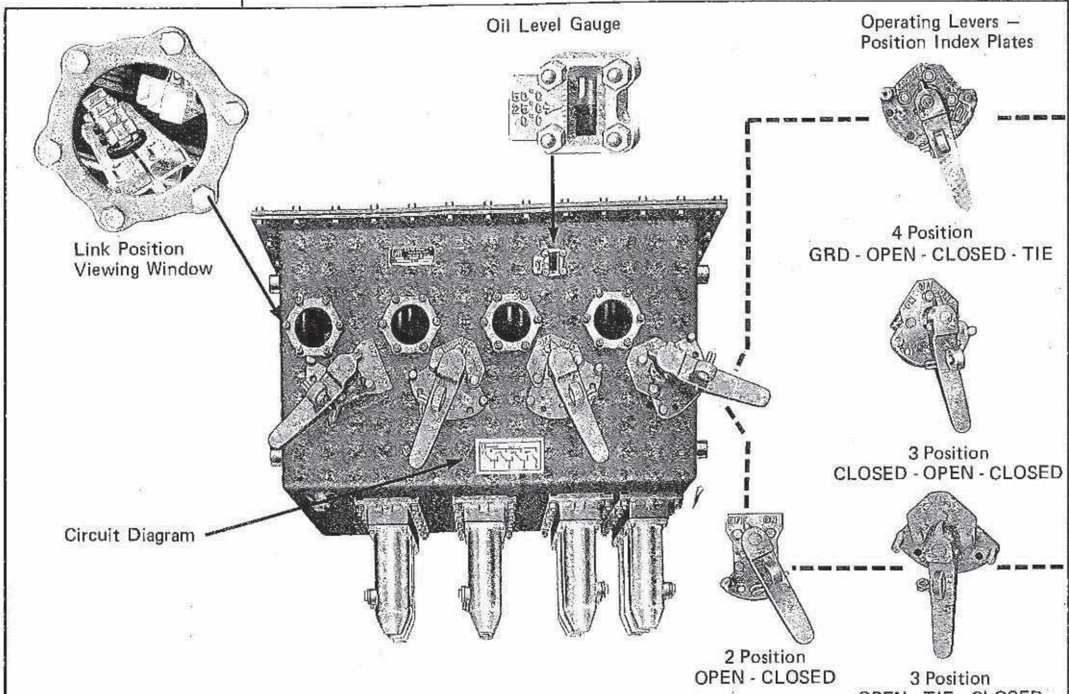
LIABILITY CLAUSE

The information in this sheet is based on data which we believe to be reliable and it is presented in good faith but without guarantee since the conditions and methods of use of our products are beyond our control. We urge that the prospective user determine the suitability of our products and recommendations before putting them to use, and the user assumes all risks and liability whatsoever in connection therewith. Our sole obligation shall be to replace such quantity of our product proved to be defective in material or workmanship for a period of one year from date of shipment and we shall not be liable for any injury, loss or damage, direct or consequential, arising out of the use or inability to use the product. Suggestion for uses of our product are not to be considered recommendations that they be used in violation of any patents.

If our product be sold by any intermediate purchaser, such intermediate purchaser shall inform the ultimate user of these conditions.

G&W

G&W	INSTALLATION INSTRUCTIONS TYPE "RA" OIL SWITCHES	GWI-503-2 Page 1 January 1973



PART I — INTRODUCTION

1.1 GENERAL

G&W RA switches are designed, manufactured and tested to current ANSI, IEEE, and NEMA standards.
These switches are completely assembled, adjusted, tested and sealed at the factory.
The information and instructions included herein are an aid to the proper installation of the units.

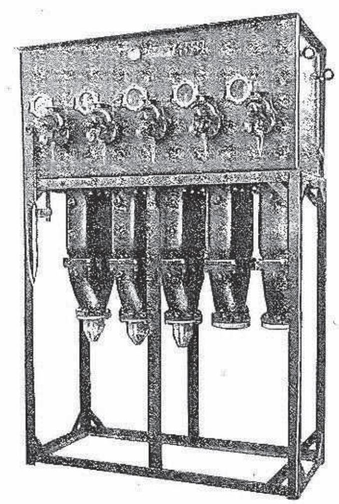
1.2 SHIPMENT INSPECTION

Uncrate and remove the packing and switch lid as soon as possible after receiving the switch.
Examine the equipment carefully for any damage that may have occurred in transit. If any damage is found, a claim should be filed at once with the transportation company.

1.3 STORAGE

Switches that will not be set up immediately for service must be prepared and stored in a suitable location. After the shipment inspection is completed, check the switch interior for indications of moisture. If moisture has been or is present in the switch, dry it out thoroughly. Long time exposure to moisture will effect the mechanical and electrical characteristics of the rocker arm and insulating stringers. Replace if necessary. Replace the lid bolts and tighten evenly around the gasketed joint. Pressurize the switch to 3 psig with dry nitrogen or fill with insulating oil.

Multi-Way Device — more than one switching link may be housed in a single enclosure for switching multi circuits.



NEW SHEET
Supersedes Bulletin DB-D
Dated May 1962

G&W ELECTRIC SPECIALTY CO.
BLUE ISLAND, ILLINOIS

PART II – INSTALLATION PROCEDURE

Before the switch is operated the following procedure is recommended:

2.1 INTERNAL INSPECTION

Remove the switch lid.
Examine the interior for moisture, dirt or other foreign matter entry which could impair optimum switching performance.
Examine switch for damage.
Check all fastenings and tighten as necessary.
The following is a guide to internal tank bolts and shows approximate torque values:

Stringer Supports 1/2"-13 HHCS	35 FT-LBS.
Contacts and Insulators 5/16"-18 HHCS	15 FT-LBS.
Front and Rear Rocker Arm Connections to Wood Laminate Clamping Strips 3/8" HHCS	20 FT-LBS.

Clean and dry all porcelain insulators if moist or dirty. Clean and dry out the switch if necessary to prevent foreign matter from contaminating the insulating oil.

2.2 CONTACT ALIGNMENT

Although all contacts are properly aligned before switches leave the factory, it is possible that fastenings may have become loose during shipment, storage or cable installation. Contact alignment should be checked. If necessary, stationary and pivot contacts should be adjusted for correct blade entry and engagement. Follow the procedure outlined below:

a. Check floating shoes for proper engagement with pivot contacts. (See Fig. 1A) The contact system is properly aligned if the floating shoes are capable of movement and not solid against the pivot contact.

b. Remove any padlocks holding the operating handle in place and rotate the rocker arm toward the stationary contacts. Check for even floating shoe entry. (See Fig. 1B)

c. Rotate the rocker arm onto the stationary contacts and check floating shoes for proper engagement. Follow same procedure as outlined in Paragraph "a" above.

2.3 CONTACT ADJUSTMENT

If alignment is required proceed as follows:

a. Any discrepencies in pivot contact engagement must be corrected first. Accomplish this by setting the centers of the pivot contacts on the bushing plate with those established by the rocker arm floating shoes. Referring to Fig. 2 check the middle porcelain by using a square laid on the mounting plate. The contacts should be parallel with the vertical blade of the square. The center of the middle contact should align with the center of the bushing plate. If it does not, tighten the two bolts on the left or right of the center porcelain clamps to tip the porcelain in the desired direction. Adjust the outer porcelains in the same manner to obtain the required spacing between stationary contacts, dimension C in Fig. 2.

If after the above corrections have been made, the floating shoes are still tight against the same side of all three pivot contacts, then loosen the bushing plate fasteners and shift the entire cablehead unit in the direction required. Further adjustments can be made by loosening the end bolts in the rocker arm and shifting this assembly.

b. The alignment of contacts on cableheads other than the pivot (See Fig. 4, item B or C) essentially follows the same procedure as outlined above. However, the lateral location of rocker arm assembly should not be shifted because that would disturb the adjustment already established for the pivot contacts.

c. Stationary contacts supported by insulating stringers (See Fig. 4, Item D or E) are adjusted by first rotating the rocker arm into a fully engaged position with the contacts to be aligned. Loosening the 5/16"-18 HHCS holding the stationary contact to the standoff insulator, the loose contact will self-align with the floating shoes. Retighten the HHCS.

CONTACT ALIGNMENT

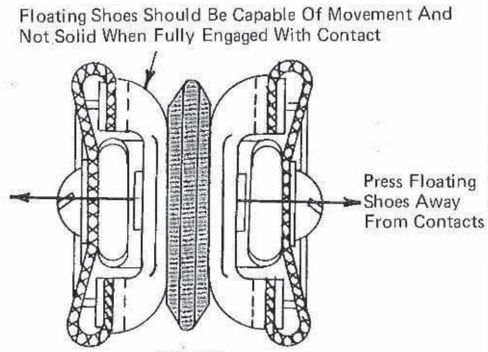


FIG. 1A
Proper Engagement

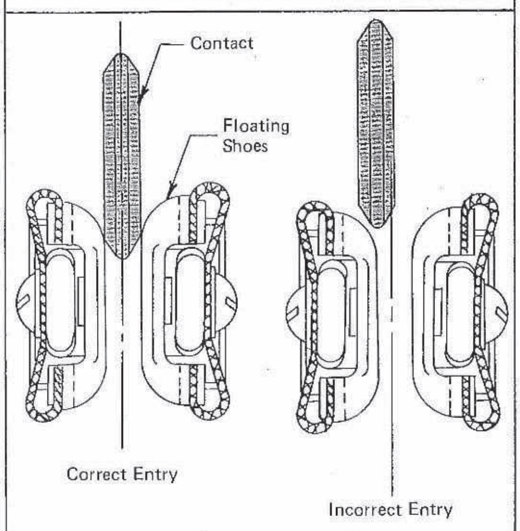


FIG. 1B

After all contacts have been aligned and tightened, actuate each operating lever several times to make sure proper adjustments have been made and the rocker arm operates without binding or interference. Operating insturctions are given in Section 2.6.

2.4 TERMINATE CABLES

Follow separate instructions on cable installation. Check contact connections to the cable terminations and tighten if necessary, using the following guide:

Pivot Contacts 3/8"-16 HHCS	20 FT-LBS.
Cable Entrance Hoodnuts	12 FT-LBS.

NOTE: Cable installation may disturb contact alignment, especially if the entrance was removed during installation. Recheck alignment and make corrections if required.

2.5 EXTERNAL INSPECTION

Replace the lid and tighten the lid bolts down evenly around the gasket joint. DO NOT APPLY ANY ADHESIVE COMPOUND OR OIL TO THE GASKET SURFACE. Pressurize the switch to 3 psig with dry nitrogen for 15 minutes or fill with air to same pressure. Check for leaks by applying soapy water to all joints and watch for leaks indicated by soap bubbles. Tighten joints as necessary to seal the switch using the following bolt check:

Side Plate Entrance Nuts 1/2"-13	25 FT-LBS.
Lid Bolts and Nuts 1/2"-13	25 FT-LBS.
Viewing Windows and Oil Gage Nuts 3/8"-16	15 FT-LBS.
Shaft Housing Bolts 1/2"-13	25 FT-LBS.
1/4" Straight Pipe Plug	3 FT-LBS.
1" Straight Pipe Plug	12 FT-LBS.

ADJUSTMENTS AND PARTS LOCATIONS

"C" Dimension

KV Rating	Inches
7.5	4
15	5-3/8
23	6-1/2
34.5	10

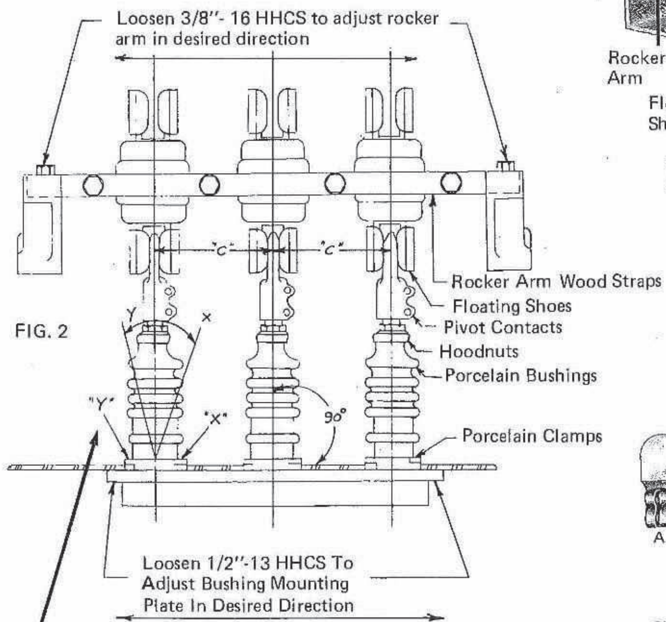


FIG. 2

Adjust pivot contacts to "C" dimension by tightening 3/8"-16 HHCS marked "X" and "Y" to tilt the porcelain bushing in the desired X or Y direction.

Internal view RA Switch

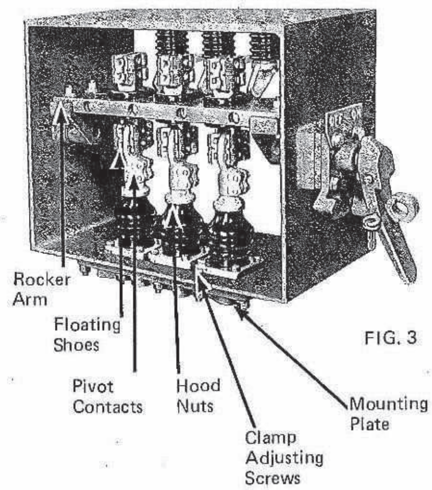
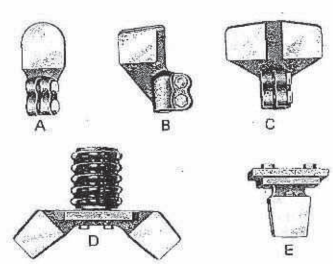


FIG. 3

FIG. 4

STATIONARY CONTACTS



Typical standard contacts. Pivot contacts (A) are rounded on top. Other contacts have straight beveled edges and are sloped for proper engagement of floating contacts. A, B & C clamp onto hoodnuts of cablehead porcelains.

2.6 OPERATION INSTRUCTIONS

a. RA switches are equipped with a manual operating handle. Travel is 45 degrees per operation. The operating handle is rotated in the same direction as the desired rotation of the switch rocker arm. This provides a natural operating sequence and should avoid confusion.

b. Standard features as provided on a 3-position handle are shown in Fig. 5. Operating handles have a spring loaded position pin which is forced into the holes provided in the index plate. Padlocking eye bolts are located in the side of the operating lever. One is permanently attached, the other must be withdrawn to disengage the position pin, permitting handle operation.

The plate has bosses for stopping the lever at its extremities. For an intermediate stop, pull out the position pin and move the lever very slightly allowing the end of the position pin to rest on the index plate and slip into the next hole as the handle is operated. To pass by a midposition stop, pull out the position pin and use the padlocking eyebolt to hold it out.

c. A three position operating handle with a ground stop and keylock provisions is shown in Fig. 6. Ground stops are included on all operators with a ground position. These stops have padlocking provisions in the blocking position.

d. Proper operation of the RA switch is not complicated but the ease of operation may permit tickling the contacts which is undesirable. The correct operating procedure is as follows:

1. Determine the direction in which the switch is to be thrown.
2. Remove all padlocks and unlock all keylocks.
3. Hold the operating lever firmly in one hand and release the spring loaded position pin with the other.
4. Edge the handle about 1/4 to 1/2 inch until the position pin is held open by the index plate.
5. Move the handle quickly and POSITIVELY to the next position where it will be stopped by the action of the spring loaded pin dropping into the next hole.

CAUTION: Once the throw has been started, there should be no hesitation on the part of the operator to complete the operation. Movement of the contacts for only a short distance or slow switching action is undesirable and in general the quicker the contacts are separated, the sooner the arc is extinguished lessening the deterioration effects on the oil.

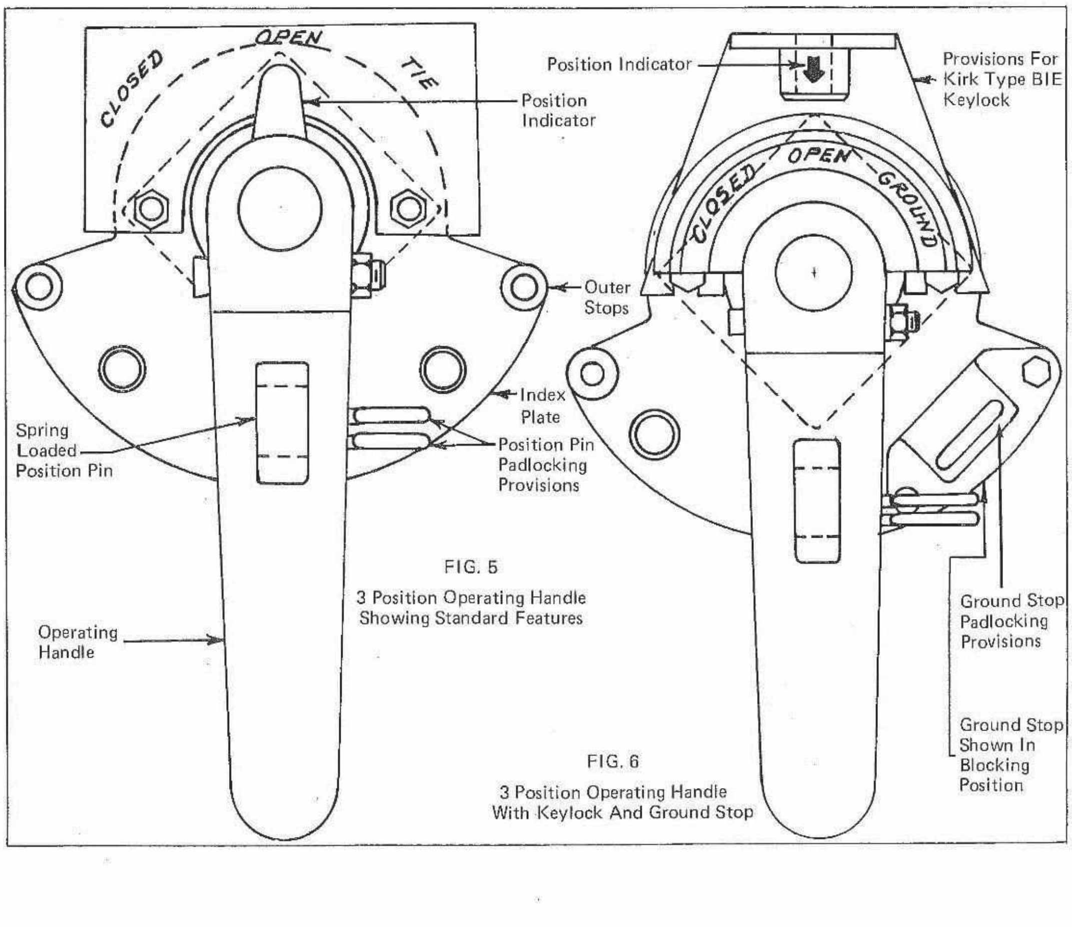


FIG. 5
3 Position Operating Handle Showing Standard Features

FIG. 6
3 Position Operating Handle With Keylock And Ground Stop

2.7 OIL FILLING

Use any clean, dry inhibited or uninhibited oil conforming to ASTM D1040-69 that is regularly used in circuit breakers or transformers. The oil should test 30,000 volts in standard test cup with 1/10 inch gap. The oil level gauge on the switch tank is calibrated for filling temperature variations. Three levels are marked – 0° C, 25° C and 50° C are also marked in 1/8 inch steps to facilitate filling to intermediate temperatures. With the switch filled to the proper level, the air space above the oil is sufficient to allow for expansion and contraction due to temperature changes.

To avoid trapping moisture laden air in the space above the oil, purge this space with dry nitrogen for approximately one minute. The space may be left filled with nitrogen at a slight positive pressure (approx. 1/2 lb. per square inch) to serve as an indicator of tightness of the tank.

2.8 OPERATION CHECK

Actuate each operating lever through its sequence of operation several times to make sure the rocker arms operate freely and completely without binding or interference. Check the shaft oil seal to make sure there is no leakage.

2.9 ENERGIZATION

The switch is ready to be energized and operated within its ratings.

PART III – MAINTENANCE RECOMMENDATIONS FOR RA SWITCHES

3.1 OIL MAINTENANCE

The dielectric strength and interrupting characteristics of load break switches are controlled by the quality and condition of the oil. These switches utilize a plain break operation where the oil is the total interrupting medium. It is important that regularly scheduled maintenance programs be established for sampling and testing the switch oil.

Rating oil life is difficult and dependent upon the following:

1. Volume of oil.
2. Amount of chemical deterioration caused by load break interruptions.
3. Physical contamination due to moisture and sludging.

To assure reliable service, it is recommended that the oil in all switches be checked at least once a year or at shorter intervals when load break operations approach the maximum number as given in the chart below:

Service Voltage (Nominal) Volts	Transformer Excitation Current	Load Break Current 100 AMP.	Load Break Current 200 AMP.	Load Break Current 400 AMP.
600 to 34,500	500	500	500	500

For additional information on the acceptance and maintenance of insulating oil consult ANSI C59.131-1971/1EEE Std. 64-1969.

Switches should be filled with any clean, dry inhibited or uninhibited oil that is regularly used in circuit breakers or transformers. The oil should test 30,000 volts minimum in a standard test cup with 1/10 inch gap. Oil, samples from switches in service, should be reconditioned if tests show less than 22 KV.

3.2 SWITCH MAINTENANCE

a. External inspection

1. Check oil level in switch.
2. Take oil sample and test as recommended under oil maintenance.
3. Check outside of switch for any evidence of leaking oil.
4. Check all nuts and bolts for tightness on handle, oil seal, cable entrances and lids.
5. Inspect exterior of switch for evidence of rusting or corrosion. Touch-up paint as required.

b. Internal Inspection

CAUTION: Internal access requires that the switch be deenergized. Provisions should be made to carry the load thru an alternate source. Afterwards, remove the lid, drain the oil from the switch and proceed with inspection of all internal parts as follows:

1. Check contacts for arc erosion, spring tension, deformed parts or loose screws.
2. Check rocker arm for loose bolts. Operating handle and rocker arm should be firmly connected. Check contact entry and engagement. Actuate each operating handle through its sequence of operation several times to make sure the rocker arm operates freely and completely without binding or interference.
3. Check gaskets for cracks and flexibility.
4. Check all porcelains for cracking and chipping.
5. Inspect all mechanical and electrical connections that they are tight.
6. Clean any sludge from insulators, bottom of tank, or any other location.
7. Flush and clean the switch interior with oil and drain.
8. Replace all lids with new gaskets where required.
9. Refill with clean oil.

Manufactured in Canada by

POWERLITE DEVICES LIMITED

Halifax - Montreal - Ottawa - Toronto
London - Winnipeg - Calgary - Vancouver

LIABILITY CLAUSE

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If our product be sold by any intermediate purchaser, such intermediate purchaser shall inform the ultimate user of these conditions.

G&W

Appendix K: Switching Operations Log SW2018 and SW2019

Request # Rev. # Type Charge #	Outage Request Status	Required Approvals	Equip. Requested / Major Equipment Impacted	Permits	Outage Start/ Permit Start	Outage Complete/ Permit Complete	Duration Cont./Daily	Switching Notifications	Requested By/ Reason/Priority	Flag 10
2-00001839 Rev. #9 Planned	Completed 2004/11/27	LMC: Approved	CSQ 12F521 Feeder Cable OOS		2004/11/25 08:00:00	2004/11/27 16:00:00	3 Days Continuous	Sent Bleko, Marinko	Bessant, Kim A. CUST VAULT MTCE @ C2561	
2-00003542 Rev. #6 Planned	Completed 2005/06/22	LMC: Approved	CSQ 12F521 Feeder Cable OOS		2005/06/17 08:00:00	2005/06/22 16:00:00	6 Days Continuous	Sent Bleko, Marinko	Groves, Randy C. CUST VAULT MTCE @ C1250 STANDBY UC7F65	
1-00024103 Rev. #7 Planned 1101080P0037849104	Completed 2005/07/15	LMC: Approved	CSQ 12F521 Feeder Cable OOS		2005/07/13 08:00:00	2005/07/15 16:00:00	3 Days Continuous		Sinosich, Frank M. LIPA AND METALURGICAL TESTS IN STATION ON THE FEEDER (STBY UC7F65)	
2-00017379 Rev. #6 Planned SW - DRM - 19VAN	Completed 2006/09/11	LMC: Approved	CSQ 12F521 Feeder Cable OOS		2006/09/07 08:00:00	2006/09/11 16:00:00	5 Days Continuous	Sent Bleko, Marinko Sent Line Dept, Vancouver	Threlkeld, Ian R. CUST VLT MTCE AT C1078	
1-00039437 Rev. #9 Planned P00519267-02	Completed 2006/10/04	LMC: Approved	CSQ 12F414 Feeder Cable OOS CSQ 12F521 Feeder Cable OOS		2006/09/25 08:00:00	2006/10/04 16:00:00	10 Days Continuous	Not Sent Bleko, Marinko Not Sent Line Dept, Vancouver	Kerr, Kristopher EXTEND 12F113 CSQ FOR CUTOVER OF VAULT C2561 FROM 12F521 CSQ,REMOVE RISERS PA#VAN 13687 WO#P00519267-02	
2-00023885 Rev. #5 Planned SW - DRM - 19VAN	Completed 2007/04/23	LMC: Approved	CSQ 12F521 Feeder Cable OOS		2007/04/20 08:00:00	2007/04/23 16:00:00	4 Days Continuous	Sent Bleko, Marinko Sent Line Dept, Vancouver	Threlkeld, Ian R. CUST VLT MTCE AT C0016	
1-00055718 Rev. #7 Planned P00203738-19	Completed 2008/02/28	LMC: Approved	CSQ 12F521 Feeder Cable OOS		2008/02/26 08:00:00	2008/02/28 16:00:00	3 Days Continuous	Sent Bleko, Marinko Sent Line Dept, Vancouver	Dukeshire, Devin RAL SW MAINTENACE IN VAULT#73 SW#2018 @ 355 BURRARD	
2-00035467 Rev. #6 Planned SW - DRM - 19VAN	Completed 2008/05/02	LMC: Approved	CSQ 12F521 Feeder Cable OOS		2008/04/29 08:00:00	2008/04/30 16:00:00	2 Days Continuous	Sent Bleko, Marinko Sent Line Dept, Vancouver	Threlkeld, Ian R. CUST VLT MTCE AT C1261	
2-00033731 Rev. #9 Planned S W- DRM - 19VAN	Completed 2008/06/30	LMC: Approved	CSQ 12F521 Feeder Cable OOS		2008/06/26 08:00:00	2008/06/30 16:00:00	5 Days Continuous	Sent Bleko, Marinko Sent Line Dept, Vancouver	Groves, Randy C. CUST VLT MTCE AT C1250	
3-00002982 Rev. #6 Planned SW-DRM-19VAN	Completed 2008/10/06	LM: Approved	CSQ 12F521 Feeder Cable OOS		2008/10/03 08:00:00	2008/10/06 16:00:00	4 Days Continuous	Sent Bleko, Marinko Sent Line Dept, Vancouver	Groves, Randy C. CUST VAULT MTCE @ C1078	
1-00079596 Rev. #7 Planned SW-DRM-19VAN	Completed 2009/07/28	LM: Approved	CSQ 12F521 Feeder Cable OOS		2009/07/24 08:00:00	2009/07/28 14:00:00	5 Days Continuous	Sent Bleko, Marinko Sent Line Dept, Vancouver	Groves, Randy C. CUST VAULT MTCE @C1250 CONTACT: CAMERON HITE @MAGNA 604-944-6697 Requested for start time change from 8:00 to 17:00. Please confirm a.s.a.p.	
1-00079551 Rev. #7 Planned 00784340-01	Completed 2009/08/10	LM: Approved	CSQ 12F521 Feeder Cable OOS		2009/07/28 14:00:00	2009/08/10 16:00:00	14 Days Continuous	Sent Bleko, Marinko Sent Line Dept, Vancouver	MONTGOMERY, JOHN A. 2010 Olympic defect repairs	
1-00096024 Rev. #8 Planned SW-DRM-19VAN	Completed 2010/08/23	Area: Approved	CSQ 12F521 Feeder Cable OOS		2010/08/20 08:00:00	2010/08/23 14:00:00	4 Days Continuous	Sent Bleko, Marinko Sent Line Dept, Vancouver	Groves, Randy C. CUST VAULT MTCE @C0016 - 900 W. HASTINGS ST - CONTACT: RICK @604-778-3706 ****PLEASE APPROVE ASAP*****	
1-00096688 Rev. #5 Planned SW-DRM-19VAN	Completed 2010/08/25	Area: Approved	CSQ 12F521 Feeder Cable OOS		2010/08/23 14:00:00	2010/08/25 16:00:00	3 Days Continuous	Sent Line Dept, Vancouver	Groves, Randy C. CUST VAULT MTCE @C1261 - 510 BURRARD ST CONTACT: CRAIG LAWSON @PROCON 604-329-3915 PLEASE APPROVE ASAP	
1-00097324 Rev. #7 Planned TZ04840280	Completed 2010/09/09	Area: Approved	CSQ 12F521 Feeder Cable OOS		2010/09/07 08:00:00	2010/09/10 16:00:00	4 Days Continuous	Sent Bleko, Marinko Sent Line Dept, Vancouver	Morency, Harold E. Update 12F521 PN, 12CB521 and 12D3521 controls. Then Trip test all.	

1-00100524 Rev. #6 Planned P00948045T05	Completed 2010/12/20	Area: Approved	CSQ 12F521 Feeder Cable OOS	2010/12/09 08:00:00	2010/12/20 16:00:00	12 Days Continuous	Sent Bleko, Marinko Sent Line Dept, Vancouver	MONTGOMERY, JOHN A. P.A. VAN 35245 - To relocate on e section of cable between Mh. 989 and Mh. 4939
1-00100395 Rev. #9 Planned sw-drm-19van	Completed 2011/03/02	Area: Approved	CSQ 12F521 Feeder Cable OOS	2011/02/25 08:00:00	2011/03/03 14:00:00	7 Days Continuous	Sent Bleko, Marinko Sent Line Dept, Vancouver	Groves, Randy C. Cust vault mtce @ C1078. 999 W Hastings St, Vancouver. Contact: MAGNA, Cameron Hite (604) 944-6697.
1-00103399 Rev. #7 Planned sw-drm-19van	Completed 2011/03/07	Area: Approved	CSQ 12F521 Feeder Cable OOS	2011/03/03 14:00:00	2011/03/07 16:00:00	5 Days Continuous	Sent Bleko, Marinko Sent Line Dept, Vancouver	Groves, Randy C. Cust vault mtce @ C1250. 400 Burrard St. Contact: MAGNA, Cameron Hite, 604-944-6697.
2-00064925 Rev. #6 Planned SW-DRM-19VAN	Completed 2011/08/22	Area: Approved	CSQ 12F521 Feeder Cable OOS	2011/08/19 08:00:00	2011/08/22 16:00:00	4 Days Continuous	Sent Bleko, Marinko Sent Line Dept, Vancouver	Groves, Randy C. CUST VAULT MTCE @C1261 - 510 BURRARD ST CONTACT: CRAIG LAWSON 604-329-3915 @ POR-CON
8-00090489 Rev. #12 Planned TY0142 2190	Completed 2012/05/17	Area: Approved	CSQ 12CB525 OOS CSQ 12F525 Feeder Cable OOS CSQ 12CB521 OOS CSQ 12F521 Feeder Cable OOS CSQ 12B53 OOS	2012/05/01 08:00:00	2012/05/17 16:00:00	17 Days Continuous	Sent Bleko, Marinko Sent Line Dept, Vancouver	Buccini, Keith V. See attached document for description of Stages. To Install & Test New Circuit Breakers CSQ 12CB521 & 12CB525 Tom Connauton : Cell 780 - 937-8175 : Office 780 - 447-4766 ABB Site Manager / Site Safety Coordinator
8-00097050 Rev. #8 Planned SW-DRM-19VAN	Completed 2012/08/21	Area: Approved	CSQ 12F521 Feeder Cable OOS	2012/08/17 08:00:00	2012/08/21 16:07:00	5 Days Continuous	Sent Line Dept, Vancouver Sent Bleko, Marinko	Groves, Randy C. CUST VAULT MTCE @ C1261 (running circuit) - 510 Burrard St. contact; Craig Lawson @ Pro-Con 604-329-3915.
8-00141928 Rev. #6 Planned 1228674	Completed 2013/11/13	Area: Approved	CSQ 12F521 Feeder Cable OOS	2013/11/07 08:00:00	2013/11/13 18:05:52	7 Days Continuous	Sent Line Dept, Vancouver Sent Karpinski, Bogdan	MONTGOMERY, JOHN A. Powertech LIPA testing cables. Rokstad holding permit.
8-00134952 Rev. #8 Planned SW-DRM-19VAN	Completed 2013/11/18	Area: Approved	CSQ 12F521 Feeder Cable OOS	2013/11/14 14:00:00	2013/11/18 15:48:45	5 Days Continuous	Sent Line Dept, Vancouver Sent Dual Radial Vault, Vancouver Sent Karpinski, Bogdan	Smith, Christopher CD. CUST VAULT MTCE @C1261 - 510 BURRARD ST CONTACT: CRAIG LAWSON @PRO-CON 604-329-3915
8-00156501 Rev. #13 Planned SW-DRM-19VAN	Completed 2014/05/20	Area: Approved	CSQ 12F521 Feeder Cable OOS	2014/05/16 08:00:00	2014/05/20 14:44:11	5 Days Continuous	Sent Line Dept, Vancouver Sent Karpinski, Bogdan Sent Kinnunen, Arnie (Aarno)	Smith, Christopher CD. CUST VAULT MTCE @C0016 - 900 WEST HASTINGS ST CONTACT: JAMES THEKKAKARA 604-688-7900 @GE CANADA
8-00145816 Rev. #6 Planned SW-DRM-19VAN	Completed 2014/06/23	Area: Approved	CSQ 12F521 Feeder Cable OOS	2014/06/20 08:00:00	2014/06/23 12:10:31	4 Days Continuous	Sent Line Dept, Vancouver Sent Karpinski, Bogdan Sent Kinnunen, Arnie (Aarno)	Smith, Christopher CD. CUST VAULT MTCW @C1078 999 WEST HASTINGS ST CONTACT: JOSH KONKIN 604-202-4538 @ PACIFIC POWERTECH
8-00148828 Rev. #7 Planned SW-DRM-19VAN	Completed 2014/06/30	Area: Approved	CSQ 12F521 Feeder Cable OOS	2014/06/23 14:00:00	2014/06/30 14:42:43	8 Days Continuous	Sent Kinnunen, Arnie (Aarno) Sent Karpinski, Bogdan Sent Line Dept, Vancouver	Smith, Christopher CD. CUST VAULT MTCE @C1250 - 400 BURRARD ST CONTACT: CAMERON 604-944-6697 @ PACIFIC POWERTECH
8-00179196 Rev. #9 Planned 1237531-01	Completed 2014/11/25	Area: Approved	CSQ 12F521 Feeder Cable OOS	2014/11/17 09:00:00	2014/11/25 15:09:00	9 Days Continuous	Sent Karpinski, Bogdan Sent Line Dept, Vancouver Accepted Bleko, Marinko	Horwell, Adrian K. 1. To perform maintenance on RAL switch 2018 in V0073. 2. To repair leaking pothead in customer vault C1250. 3. Repair Hot-Spot on C phase load side elbow at 'J bar'. NOTE: Special entry procedures required for V0073

8-00244498 Rev. #5 Planned n/a	Completed 2016/07/04	Area: Approved	CSQ 12F521 Feeder Cable OOS	T&W	2016/06/28 08:00:00	2016/07/04 14:30:09	6.27 Days Continuous	Sent Smith, Christopher CD. Sent Line Dept, Vancouver Sent Dual Radial Vault, Vancouver Sent TAGSETH, CATHY . Sent Karpinski, Bogdan	Calder, David change oil in switch 2018 in v0073 and replace hot elbow and cable between jbar and switch 2018 also in v0073.
8-00272479 Rev. #7 Planned SW-DRM-19VAN	Completed 2017/03/02	Area: Approved	CSQ 12F521 Feeder Cable OOS	GOI	2017/02/24 08:00:00	2017/03/02 14:36:43	6.28 Days Continuous	Sent Line Dept, Vancouver Sent Electricians, Horne Payne	Christensen, Cathy J. CUST VAULT MTCE @C1261 - 510 BURRARD ST - CONTACT: CRAIG LAWSON 604-329-3915 @ PRO-CON
8-00283773 Rev. #4 Planned W01051654-11	Completed 2017/07/15	Area: Approved	CSQ 12F521 Feeder Cable OOS	GOI	2017/07/13 20:00:00	2017/07/15 10:55:11	1.62 Days Continuous	Sent Line Dept, Vancouver Not Sent Electricians, Horne Payne	Smith, Christopher CD. CUST VAULT MTCE @ C0016 900 W. Hastings St, Van - contact Lawren Thompson @ Exell Power, cell 778-868-8765
8-00279188 Rev. #11 Planned SW-DRM-19VAN	Completed 2017/08/03	Area: Approved	CSQ 12F521 Feeder Cable OOS	GOI	2017/07/15 14:30:00	2017/08/03 15:47:51	19.05 Days Continuous	Sent Line Dept, Vancouver Not Sent Electricians, Horne Payne	Christensen, Cathy J. CUST VAULT MAINT @ C1250 @ 400 BURRARD CONTACT: CRAIG LAWSON 604-329-3915 OUTAGE TO C1078 TO OCCUR AT 1800
8-00329955 Rev. #5 Planned n/a	Completed 2018/06/20	Area: Approved	CSQ 12F521 Feeder Cable OOS	GOI	2018/06/15 08:00:00	2018/06/20 13:10:33	5.22 Days Continuous	Sent Line Dept, Vancouver Not Sent Electricians, Horne Payne	Canaday, Shannon VAULT MAINTENANCE IN C1078 - 999 West Hastings - CUSTOM WINDOW
8-00434617 Rev. #12 Planned W01051654-11	Completed 2020/03/03	Area: Approved	CSQ 12F521 Feeder Cable OOS	GOI	2020/02/28 08:00:00	2020/03/03 12:24:53	4.18 Days Continuous	Sent Line Dept, Vancouver Sent Electricians, Horne Payne	Smith, Christopher CD. Customer vault maintenance @ C1261 - 510 Burrard Street, Vancouver. Contact Todd Nordin of Wismer & Rawlings Electric Ltd. at 604-209-0915.
8-00419729 Rev. #18 Planned W01051654-11	Completed 2020/07/17	Area: Approved	CSQ 12F521 Feeder Cable OOS	GOI	2020/07/15 08:00:00	2020/07/17 09:25:00	2.06 Days Continuous	Sent Line Dept, Vancouver Sent Electricians, Horne Payne	Smith, Christopher CD. Customer maintenance @ C0016, 900 W Hastings, Van. Contact Lawren Thompson 778.868.8765 (Exell Power)
8-00438924 Rev. #12 Planned W01051654-11	Completed 2020/07/21	Area: Approved	CSQ 12F521 Feeder Cable OOS	GOI	2020/07/17 14:30:00	2020/07/21 15:55:32	4.06 Days Continuous	Sent Line Dept, Vancouver Sent Electricians, Horne Payne	Smith, Christopher CD. Customer vault maintenance @ C1250 - 400 Burrard Street, Vancouver. Contact Len Albertson of Resa Power Service at 604 209 7461.
8-00535959 Rev. #17 Planned W01051654-11	Completed 2021/02/09	Area: Approved	CSQ 12F521 Feeder Cable OOS	GOI	2021/02/05 08:00:00	2021/02/09 13:35:53	4.23 Days Continuous	Sent Line Dept, Vancouver Sent Electricians, Horne Payne	Smith, Christopher CD. CUSTOM WINDOW customer vault repair @ C0016 - 900 W Hastings Street, Vancouver. Contact Lawren Thompson of Exell Power Services Ltd at 778-868-8765.
8-00563725 Rev. #14 Planned M169270-01	Completed 2021/04/06	Area: Approved	CSQ 12F521 Feeder Cable OOS	T&W	2021/03/29 08:00:00	2021/04/06 17:31:51	8.4 Days Continuous	Sent Line Dept, Vancouver Sent Electricians, Horne Payne	Wardrop, Kevin J. 5 year RAL switch maintenance on sw 2018 @V0073 Scheduler Notes:No customer outage required for this outage as the switch can be isolated from the Load break elbows on the common junction bar coming from 2019 . CSQ 12F521 should be de-energized prior to crews opening V0073 load break elbows Special Entry procedures required for switching in V0073
8-00460711 Rev. #15 Planned SW-DRM-19VAN	Completed 2021/07/22	Area: Approved	CSQ 12F521 Feeder Cable OOS	GOI	2021/07/15 08:00:00	2021/07/22 20:28:54	7.52 Days Continuous	Sent Line Dept, Vancouver Sent Electricians, Horne Payne	Villanueva-Acabal, Michelle Customer Vault Maintenance@C1078 - 999 W. Hastings. Contact Pacific Powertech Inc. Kane Hite 604 328 4489

8-00627437 Rev. #14 Planned w01051654 11	Completed 2021/09/28	Area: Approved	CSQ 12F521 Feeder Cable OOS	GOI	2021/09/24 08:00:00	2021/09/28 18:38:30	4.44 Days Continuous	Sent Line Dept, Vancouver Sent Electricians, Horne Payne	Smith, Christopher CD. CUSTOM Customer Vault maintenance @C1078 999 W Hastings Vancouver contact Kane Hite 604328 4489 of Pacific Powertech
8-00693813 Rev. #18 Planned w01051654 11	Completed 2022/07/23	Area: Approved	CSQ 12F521 Feeder Cable OOS	GOI	2022/07/14 08:00:00	2022/07/21 13:55:53	7.25 Days Continuous	Sent Line Dept, Vancouver Sent Electricians, Horne Payne	Smith, Christopher CD. Customer Vault Mtce @C1261 (running circuit)510 Burrard St Vancouver. Contact Demy Ciarniello 604 816 0359 of WRE.
8-00808061 Rev. #13 Planned 2163197-02	Completed 2023/02/10	Area: Approved	CSQ 12F521 Feeder Cable OOS CSQ 12F511 UC7F65 OOS	T&W	2023/02/10 08:00:00	2023/02/10 15:16:50	7.28 Hours Continuous	Sent Line Dept, Vancouver	SCHMIDT, CRAIG T. Work on secondary side of transformer in V0073
8-00789415 Rev. #2 Planned W01051654-11	Approved 2022/11/21	Area: Approved	CSQ 12F521 Feeder Cable OOS	GOI	2023/07/14 08:00:00	2023/07/17 16:00:00	3.33 Days Continuous	Not Sent Line Dept, Vancouver Not Sent Electricians, Horne Payne	CONNELL, JESSE L. Customer vault maintenance @ C0016 - 900 West Hastings Street, Vancouver. Contact Lawren Thompson of Exell Power Services Ltd at 604-514-9472.
8-00833123 Rev. #2 Planned W01051654-11	Approved 2023/03/22	Area: Approved	CSQ 12F521 Feeder Cable OOS	GOI	2023/07/15 14:30:00	2023/07/17 16:00:00	2.06 Days Continuous	Not Sent Dual Radial Vault, Vancouver Not Sent Line Dept, Vancouver Not Sent Electricians, Horne Payne	CONNELL, JESSE L. Customer vault maintenance @ C1250 - 400 Burrard Street, Vancouver. Contact Len Albertson of RESA Canada Inc at 604-209-7461.

Request # Rev. # Type Charge #	Outage Request Status	Required Approvals	Equip. Requested / Major Equipment Impacted	Permits	Outage Start/ Permit Start	Outage Complete/ Permit Complete	Duration Cont./Daily	Switching Notifications	Requested By/ Reason/Priority
2-00000727 Rev. #6 Planned	Completed 2003/12/01	LMC: Approved	CSQ 12F511 UC7F65 OOS		2003/11/28 08:00:00	2003/12/01 16:00:00	4 Days Continuous		Hollins, Christopher W. CUST VAULT MTCE @ C2561
2-00001844 Rev. #14 Planned	Completed 2004/11/01	LMC: Approved	CSQ 12F511 UC7F65 OOS		2004/10/29 08:00:00	2004/11/01 16:00:00	4 Days Continuous		Bessant, Kim A. CUST VAULT MTCE C0027
2-00002373 Rev. #6 Planned	Completed 2005/04/09	LMC: Approved	CSQ 12F511 UC7F65 OOS		2005/04/08 08:00:00	2005/04/09 08:00:00	24 Hours Continuous		Hollins, Christopher W. CUST VLT MTCE @ C0276
2-00002375 Rev. #8 Planned	Completed 2005/04/11	LMC: Approved	CSQ 12F511 UC7F65 OOS		2005/04/09 08:00:00	2005/04/11 16:00:00	3 Days Continuous		Hollins, Christopher W. CUST VLT MTCE @ C0190
2-00002452 Rev. #8 Planned	Completed 2005/04/21	LMC: Approved	CSQ 12F511 UC7F65 OOS		2005/04/21 12:00:00	2005/04/21 16:00:00	4 Hours Continuous		Groves, Randy C. to facilate tests in vault UC7F65 in vault C0016 - the vault cabinet door cannot be safely removed while energized DUAL RADIAL
2-00003932 Rev. #6 Planned SW-DRM-19VAN	Completed 2005/06/13	LMC: Approved	CSQ 12F511 UC7F65 OOS		2005/06/09 08:00:00	2005/06/13 16:00:00	5 Days Continuous	Sent Line Dept, Vancouver	Groves, Randy C. CUST VAULT MTCE @ C2524
2-00003544 Rev. #5 Planned SW-DRM-19VAN	Completed 2005/06/27	LMC: Approved	CSQ 12F511 UC7F65 OOS		2005/06/24 08:00:00	2005/06/27 16:00:00	4 Days Continuous		Groves, Randy C. CUST VAULT MTCE @ C1250
2-00009095 Rev. #8 Planned SW - DRM - 19VAN	Completed 2005/11/07	LMC: Approved	CSQ 12F511 UC7F65 OOS		2005/11/04 08:00:00	2005/11/08 14:00:00	5 Days Continuous	Not Sent Line Dept, Vancouver	Threlkeld, Ian R. CUST VLT MTCE C0016
2-00009244 Rev. #11 Planned SW - DRM - 19VAN	Completed 2005/11/09	LMC: Approved	CSQ 12F511 UC7F65 OOS		2005/11/08 14:00:00	2005/11/10 16:00:00	3 Days Continuous	Not Sent Line Dept, Vancouver	Threlkeld, Ian R. CUST VLT MTCE C1250
2-00011048 Rev. #5 Planned SW-DRM-19VAN	Completed 2006/02/13	LMC: Approved	CSQ 12F511 UC7F65 OOS		2006/02/10 08:00:00	2006/02/13 16:00:00	4 Days Continuous	Sent Line Dept, Vancouver	LM2, Outage Scheduler CUST VLT MTCE @ C1261
2-00011531 Rev. #6 Planned SW - DRM - 19VAN	Completed 2006/03/02	LMC: Approved	CSQ 12F511 UC7F65 OOS		2006/02/28 08:00:00	2006/03/02 16:00:00	3 Days Continuous	Not Sent Line Dept, Vancouver	Threlkeld, Ian R. CUST VLT MTCE C0352
1-00032761 Rev. #6 Planned 1101084 RB 19	Completed 2006/03/23	LMC: Approved	CSQ 12F511 UC7F65 OOS		2006/03/20 09:00:00	2006/03/23 16:00:00	4 Days Continuous	Sent Austrom, Rick K. Sent Groves, Randy C. Sent Line Dept, Vancouver	Radziwon, Adam DOING 5 YEAR MAINTNANCE ON RAWL SW#2019 IN VAULT#73.
2-00012836 Rev. #5 Planned SW-DRM-19VAN	Completed 2006/05/08	LMC: Approved	CSQ 12F511 UC7F65 OOS		2006/05/05 08:00:00	2006/05/08 16:00:00	4 Days Continuous	Sent Line Dept, Vancouver	LM2, Outage Scheduler CUST VLT MTCE @ C0351
2-00017382 Rev. #5 Planned SW - DRM - 19VAN	Completed 2006/09/05	LMC: Approved	CSQ 12F511 UC7F65 OOS		2006/09/01 08:00:00	2006/09/05 16:00:00	5 Days Continuous	Sent Line Dept, Vancouver	Threlkeld, Ian R. CUST VLT MTCE AT C1078
1-00040088 Rev. #15 Planned P00519267-02	Completed 2006/10/27	LMC: Approved	CSQ 12F111 Feeder Cable OOS CSQ 12F511 UC7F65 OOS		2006/10/20 08:00:00	2006/10/27 16:00:00	8 Days Continuous	Not Sent Bleko, Marinko Not Sent Line Dept, Vancouver	Krienke, Colin K. EXTEND 12F111 CSQ FOR CUTOVER OF VAULT C2561 FROM UC7F65, REMOVE RISERS PA#VAN 13698 WO#P00519267-02

2-00027205 Rev. #7 Planned SW - DRM - 19VAN	Completed 2007/07/17	LMC: Approved	CSQ 12F511 UC7F65 OOS	2007/07/12 08:00:00	2007/07/17 16:00:00	6 Days Continuous	Sent Line Dept, Vancouver	Threlkeld, Ian R. CUST VLT MTCE AT C0027 LINEMAN TO SWITCH IN MH 2435 ENERGIZED
2-00028812 Rev. #5 Planned SW-DRM-19VAN	Completed 2007/10/23	LMC: Approved	CSQ 12F511 UC7F65 OOS	2007/10/19 08:00:00	2007/10/23 16:00:00	5 Days Continuous	Sent Line Dept, Vancouver	LM2, Outage Scheduler CUST VLT MTCE AT C1261
2-00032038 Rev. #6 Planned SW - DRM - 19VAN	Completed 2008/02/21	LMC: Approved	CSQ 12F511 UC7F65 OOS	2008/02/20 08:00:00	2008/02/21 14:00:00	30 Hours Continuous	Sent Line Dept, Vancouver	Threlkeld, Ian R. CUST VLT MTCE AT C0276
2-00032037 Rev. #6 Planned SW - DRM - 19VAN	Completed 2008/02/22	LMC: Approved	CSQ 12F511 UC7F65 OOS	2008/02/21 14:00:00	2008/02/22 16:00:00	26 Hours Continuous	Sent Line Dept, Vancouver	Threlkeld, Ian R. CUST VLT MTCE AT C0190
2-00036396 Rev. #6 Planned SW - DRM - 19VAN	Completed 2008/07/07	LMC: Approved	CSQ 12F511 UC7F65 OOS	2008/07/04 08:00:00	2008/07/07 16:00:00	4 Days Continuous	Sent Line Dept, Vancouver	Groves, Randy C. CUST VLT MTCE AT C1250
3-00002421 Rev. #8 Planned SW-DRM-19VAN	Completed 2008/08/13	LM: Approved	CSQ 12F511 UC7F65 OOS	2008/08/08 08:00:00	2008/08/13 16:00:00	6 Days Continuous	Not Sent Line Dept, Vancouver	Groves, Randy C. Vault mtce in C-1250
3-00002988 Rev. #7 Planned SW-DRM-19VAN	Completed 2008/10/01	LM: Approved	CSQ 12F511 UC7F65 OOS	2008/09/25 08:00:00	2008/10/01 16:00:00	7 Days Continuous	Not Sent Line Dept, Vancouver	Groves, Randy C. CUST VAULT MTCE @ C1078
3-00003727 Rev. #5 Planned DR SW DRM 19VAN	Completed 2008/11/11	LM: Approved	CSQ 12F511 UC7F65 OOS	2008/11/07 08:00:00	2008/11/10 16:00:00	4 Days Continuous	Sent Line Dept, Vancouver	Groves, Randy C. Vault mtce in C-0016
1-00072251 Rev. #6 Planned SW-DRM-19VAN	Completed 2009/05/26	LM: Approved	CSQ 12F511 UC7F65 OOS	2009/05/22 08:00:00	2009/05/26 16:00:00	5 Days Continuous	Not Sent Line Dept, Vancouver	Groves, Randy C. CUST VAULT MTCE @C0190 CONTACT: CRAIG LAWSON @PROCON 604-329-3915
1-00075718 Rev. #6 Planned SW-DRM-19VAN	Completed 2009/10/31	LM: Approved	CSQ 12F511 UC7F65 OOS	2009/10/29 08:00:00	2009/10/31 16:00:00	3 Days Continuous	Sent Line Dept, Vancouver	Groves, Randy C. CUST VAULT MTCE @C0027 CONTACT: JIM LOEHR @WISMER&RAWLINGS 604-468-5578
1-00080159 Rev. #7 Planned SW-DRM-19VAN	Completed 2009/11/07	LM: Approved	CSQ 12F511 UC7F65 OOS	2009/11/06 08:00:00	2009/11/08 14:00:00	3 Days Continuous	Sent Line Dept, Vancouver	Groves, Randy C. CUST VAULT MAINT @ C0351. CONTACT CRAIG LAWSON @ PRO-CON, 604-329-3915
1-00084701 Rev. #4 Planned SW-DRM-19VAN	Completed 2009/11/03	LM: Approved	CSQ 12F511 UC7F65 OOS	2009/11/08 14:00:00	2009/11/09 14:00:00	24 Hours Continuous	Sent Line Dept, Vancouver	Groves, Randy C. CUST VAULT MAINT @ C0352. CONTACT SCOTT WELTON @ EXELL POWER, 604.315.9953
1-00080249 Rev. #7 Planned SW-DRM-19VAN	Completed 2009/11/10	LM: Approved	CSQ 12F511 UC7F65 OOS	2009/11/09 14:00:00	2009/11/12 16:00:00	4 Days Continuous	Sent Line Dept, Vancouver	Groves, Randy C. CUST VAULT MAINT @ C2524. CONTACT CRAIG LAWSON @ PRO-CON, 604-329-3915
1-00085828 Rev. #5 Planned SW-DRM-19VAN	Completed 2009/12/10	LM: Approved	CSQ 12F511 UC7F65 OOS	2009/12/09 08:00:00	2009/12/10 16:00:00	2 Days Continuous	Sent Line Dept, Vancouver	Groves, Randy C. CUST VAULT MTCE @C0352 CONTACT: SCOTT WELTON @EXELL 604-315-9953
1-00091229 Rev. #6 Planned SW-DRM-19VAN	Completed 2010/04/12	Area: Approved	CSQ 12F511 UC7F65 OOS	2010/04/09 08:00:00	2010/04/12 16:00:00	4 Days Continuous	Sent Line Dept, Vancouver	Groves, Randy C. CUST VAULT MTCE @C1078 - 999 W HASTINGS ST CONTACT: ELMIR JASAREVIC @MAGNA 604-999-2043
1-00096235 Rev. #11 Planned n/a	Completed 2010/09/30	Area: Approved	CSQ 12F511 Feeder Cable OOS CSQ 12F511 UC7F64 OOS CSQ 12F511 UC7F65 OOS CSQ 12F511 UC7F66 OOS CSQ 12F511 UC7F67 OOS	2010/09/21 08:00:00	2010/09/29 16:00:00	9 Days Continuous	Sent Bleko, Marinko Sent Line Dept, Vancouver	MONTGOMERY, JOHN A. PA VAN 33035 R2 - To replace Ral switch in MH 2435 with new VSWB 71201

1-00099431 Rev. #5 Planned P00948045T04	Completed 2010/11/04	Area: Approved	CSQ 12F511 UC7F65 OOS	2010/10/27 08:00:00	2010/11/05 16:00:00	10 Days Continuous	Sent Line Dept, Vancouver	MONTGOMERY, JOHN A. PA VAN 35299 - To re&re cable between Mh. 2424 and Mh. 4939 (new)
1-00105004 Rev. #5 Planned 910745	Completed 2011/03/12	Area: Approved	CSQ 12F511 UC7F65 OOS CSQ 12F521 OOS	2011/03/12 08:00:00	2011/03/12 16:00:00	8 Hours Continuous		Groves, Randy C. Repair hot elbow on B-phase J-bar in V73
1-00103552 Rev. #5 Planned sw-drm-19van	Completed 2011/04/10	Area: Approved	CSQ 12F511 UC7F65 OOS	2011/04/08 08:00:00	2011/04/10 14:00:00	3 Days Continuous	Sent Line Dept, Vancouver	Groves, Randy C. Cust vault mtce @ C1250. 400 Burrard St. Contact: MAGNA, Cameron Hite 604-944-6697.
1-00102240 Rev. #7 Planned sw-drm-19van	Completed 2011/04/12	Area: Approved	CSQ 12F511 UC7F65 OOS	2011/04/10 14:00:00	2011/04/12 16:00:00	3 Days Continuous	Sent Line Dept, Vancouver	Groves, Randy C. Cust vault mtce @ C0276. 355 Burrard St. Contact: PRO-CON, Craig Lawson (604) 329-3915.
2-00064924 Rev. #7 Planned SW-DRM-19VAN	Completed 2011/08/08	Area: Approved	CSQ 12F511 UC7F65 OOS	2011/08/05 08:00:00	2011/08/08 16:00:00	4 Days Continuous	Sent Line Dept, Vancouver	Groves, Randy C. CUST VAULT MTCE @C1261 - 510 BURRARD ST CONTACT: CRAIG LAWSON 604-329-3915 @PRO-CON
8-00073323 Rev. #6 Planned SW-DRM-19VAN	Completed 2012/01/31	Area: Approved	CSQ 12F511 UC7F65 OOS	2012/01/26 08:00:00	2012/01/31 16:00:00	6 Days Continuous	Sent Line Dept, Vancouver	Groves, Randy C. CUST VAULT MTCE @ C0027 - 501 BURRARD ST (BENTALL TOWER 1 & 2) CONTACT: NATHAN WARD @604-468-5587 FROM WISMER & RAWLINGS
8-00086249 Rev. #5 Planned SW-DRM-19VAN	Completed 2012/04/10	Area: Approved	CSQ 12F511 UC7F65 OOS	2012/04/05 08:00:00	2012/04/10 16:00:00	6 Days Continuous	Sent Line Dept, Vancouver	Groves, Randy C. CUST VAULT MTCE @ C190 - 1055 2. HASTINGS ST - contact: Craig Lawson @ Pro-Con 604-329-3915
8-00096485 Rev. #7 Planned W01148460T01	Completed 2012/07/10	Area: Approved	CSQ 12F511 UC7F65 OOS	2012/07/03 08:00:00	2012/07/10 14:23:38	8 Days Continuous	Sent Groves, Randy C. Sent Line Dept, Vancouver	PIILO, JASON . MAINTENANCE ON RAL SWITCH IN V0073 - SW 2019.
8-00094062 Rev. #7 Planned SW-DRM-19VAN	Completed 2012/07/31	Area: Approved	CSQ 12F511 UC7F65 OOS	2012/07/26 08:00:00	2012/07/31 16:00:00	6 Days Continuous	Sent Line Dept, Vancouver	Groves, Randy C. CUST VAULT MTCE @ C1261 (standby circuit) - 510 Burrard St., contact: Craig Lawson @ Pro-Con 604-329-3915.
8-00103475 Rev. #8 Planned SW-DRM-19VAN	Completed 2013/01/14	Area: Approved	CSQ 12F511 UC7F65 OOS	2012/12/14 08:00:00	2013/01/14 12:05:19	32 Days Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. CUST VAULT MTCE @ C0016 STANDBY CIRCUIT (Non-Compliant) - 900 W. Hastings St. contact: James Thekkakara @ GE Canada 604-788-3531
8-00116321 Rev. #8 Planned SW-DRM-19VAN	Completed 2013/03/12	Area: Approved	CSQ 12F511 UC7F65 OOS	2013/03/08 08:00:00	2013/03/12 12:00:57	5 Days Continuous	Sent Dual Radial Vault, Vancouver Sent Line Dept, Vancouver Sent Karpinski, Bogdan	Smith, Christopher CD. CUST VAULT MTCE @C2524 - 401 BURRARD ST CONTACT: CRAIG LAWSON @PRO-CON 604-329-3915
8-00119768 Rev. #8 Planned SW-DRM-19VAN	Completed 2013/03/18	Area: Approved	CSQ 12F511 UC7F65 OOS	2013/03/12 14:00:00	2013/03/18 00:43:00	6 Days Continuous	Sent Dual Radial Vault, Vancouver Sent Line Dept, Vancouver	Smith, Christopher CD. CUST VAULT MTCE @C0352 1070 WEST PENDER ST CONTACT: CRAIG LAWSON @PRO-CON 604-329-3915
8-00117485 Rev. #9 Planned SW-DRM-19VAN	Completed 2013/03/18	Area: Approved	CSQ 12F511 UC7F65 OOS	2013/03/18 00:15:00	2013/03/18 02:36:00	2.4 Hours Continuous	Sent Dual Radial Vault, Vancouver Sent Line Dept, Vancouver	Smith, Christopher CD. CUST VAULT MTCE @C0351 - 1050 WEST PENDER ST CONTACT: CRAIG LAWSON @PRO-CON 604-329-3915
8-00126078 Rev. #5 Planned sw-drm-19van	Completed 2013/09/17	Area: Approved	CSQ 12F511 UC7F65 OOS	2013/09/13 08:00:00	2013/09/17 11:48:50	5 Days Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. CUST VAULT MTCE @ C1078 - 999 W. HASTINGS ST, VANCOUVER - CONTACT: Josh Konkin @ Pacific Power 604-202-4538
8-00149904 Rev. #6 Planned SW-DRM-19VAN	Completed 2014/02/17	Area: Approved	CSQ 12F511 UC7F65 OOS	2014/02/14 08:00:00	2014/02/17 13:13:06	4 Days Continuous	Sent Line Dept, Vancouver	Son, Malsoon S. Repair work in @C0190 (not vault mtce) - GUINNESS TOWER 1055 WEST HASTINGS ST CONTACT: CRAIG LAWSON 604-329-3915 OR LEN ALBERTSON 604-209-7431@PRO-CON

8-00163221 Rev. #6 Planned SW-DRM-19VAN	Completed 2014/07/29	Area: Approved	CSQ 12F511 UC7F65 OOS		2014/07/25 08:00:00	2014/07/29 12:38:49	5 Days Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. CUST VAULT MTCE @C0276 - 355 BURRARD ST @ THE MARINE BUILDING CONTACT: CRAIG LAWSON 604-329-3915 @PRO-CON NOTE: VSWB 71201 requires special procedures for entry due to confined space (unless it can be de-energized)
8-00148832 Rev. #8 Planned SW-DRM-19VAN	Completed 2014/08/05	Area: Approved	CSQ 12F511 UC7F65 OOS		2014/07/29 14:00:00	2014/08/05 17:23:47	8 Days Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. CUST VAULT MTCE @C1250 - 400 BURRARD ST CONTACT: CAMERON 604-944-6697 @PACIFIC POWERTECH NOTE: VSWB 71201 requires special procedures for entry due to confined space (unless it can be de-energized)
8-00180223 Rev. #6 Planned WO # 1366949-01	Completed 2014/11/28	Area: Approved	CSQ 12F511 UC7F65 OOS		2014/11/25 08:00:00	2014/11/28 11:54:36	4 Days Continuous	Sent Line Dept, Vancouver	BARTLE, CHRIS L. Switch 2019 failed oil insulation test, requires 5 year maintenance. Also, hot load-break elbow to be replaced during maintenance.
8-00175435 Rev. #5 Planned SW-DRM-19VAN	Completed 2014/12/09	Area: Approved	CSQ 12F511 UC7F65 OOS		2014/12/05 08:00:00	2014/12/09 17:50:29	5 Days Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. CUST VAULT MTCE @C0027 - BENTALL TOWER 1 & 2 501 BURRARD ST CONTACT: NATHAN 604-468-5587 @WISMER & RAWLINGS
8-00206602 Rev. #5 Planned SW-DRM-19VAN	Completed 2015/08/18	Area: Approved	CSQ 12F511 UC7F65 OOS		2015/08/14 08:00:00	2015/08/18 16:25:14	4.35 Days Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. CUST VAULT MTCE @C0190 - 1055 WEST HASTINGS CONTACT: CRAIG LAWSON 604-329-3915 @PRO-CON
8-00217960 Rev. #6 Planned SW-DRM-19VAN	Completed 2015/10/29	Area: Approved	CSQ 12F511 UC7F65 OOS		2015/10/26 08:00:00	2015/10/29 11:00:00	3.13 Days Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. CUST VAULT MTCE @C0352 - 1070 WEST PENDER ST CONTACT: CRAIG LAWSON 604-329-3915 @PRO-CON
8-00206914 Rev. #5 Planned SW-DRM-19VAN	Completed 2015/11/12	Area: Approved	CSQ 12F511 UC7F65 OOS		2015/11/10 08:00:00	2015/11/12 12:22:14	2.18 Days Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. CUST VAULT MTCE @C1261 - 510 BURRARD ST CONTACT: CRAIG LAWSON 604-329-3915 @PRO-CON NOTE: Special entry procedures req'd for access to V0073.
8-00219992 Rev. #9 Planned mo82522	Completed 2016/01/15	Area: Approved	CSQ 12F511 UC7F65 OOS		2015/11/18 08:00:00	2016/01/15 15:56:28	58.33 Days Continuous	Sent Line Dept, Vancouver	Calder, David outage required to allow maintenance oil change of switch 2019 in vault 73.
8-00222596 Rev. #6 Planned SW-DRM-19VAN	Completed 2016/01/26	Area: Approved	CSQ 12F511 UC7F65 OOS		2016/01/22 08:00:00	2016/01/26 17:40:44	4.4 Days Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. CUST VAULT MTCE @C1261 - 510 BURRARD ST - CONTACT: CRAIG LAWSON 604-329-3915@PRO-CON
8-00239871 Rev. #8 Planned SW-DRM-19VAN	Completed 2016/08/17	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2016/08/12 08:00:00	2016/08/17 15:18:10	5.3 Days Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. CUST VAULT MTCE @C2524 - 401 BURRARD ST CONTACT: CRAIG LAWSON 604-329-3915@PRO-CON
8-00257753 Rev. #4 Planned SW-DRM-19VAN	Completed 2016/11/11	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2016/11/10 08:00:00	2016/11/11 08:02:00	24.03 Hours Continuous	Sent Line Dept, Vancouver	Christensen, Cathy J. CUST VAULT MAINT @ C0351 AT 1050 WEST PENDER CONTACT: CRAIG LAWSON 604-329-3915 @ PRO-CON
8-00255942 Rev. #6 Planned W01051654-11	Completed 2016/11/14	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2016/11/11 14:30:00	2016/11/14 17:34:32	3.13 Days Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. CUST VAULT MTCE @ C0027, 501 Burrard St, Van – contact Nathan Ward 604-468-5587 @ Wismer & Rawlings Electric Ltd.
8-00274504 Rev. #6 Planned n/a	Completed 2017/02/24	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2017/02/23 08:00:00	2017/02/24 14:43:33	30.73 Hours Continuous	Sent Line Dept, Vancouver	Carey, Daniel E. Customer Vault Maintenance - C0016 - 900 West Hastings. Contact Lawren Thompson 778 868 8765 @ Excel Power Services See Scheduler's notes
8-00283366 Rev. #3 Planned w01051654-11	Cancelled 2020/08/02	Area: Approved	CSQ 12F511 UC7F65 OOS	T&W	2017/05/04 08:00:00	2017/05/08 14:30:00	2.33 Days Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. Customer installing fiber optics cable in close proximity to pothead UC 7F65 in C0016
8-00276920 Rev. #5 Planned SW-DRM-19VAN	Completed 2017/05/10	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2017/05/08 14:30:00	2017/05/10 16:31:32	2.08 Days Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. For vault maintenance @ C0352, 1070 West Pender St. Van., Bentall Kennedy, contact Darren Boeur 604.813.2917 Accurate Power

8-00288502 Rev. #4 Planned n/a	Completed 2017/08/12	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2017/08/11 08:00:00	2017/08/12 13:49:26	29.82 Hours Continuous	Sent Line Dept, Vancouver	Canaday, Shannon Customer Vault Miantnenace @ C1078 - 999 West Hastings. Contact Josh Konkin @ 604 202 4538 Pacific Powertech (duration of outage: 5 hours)
8-00293933 Rev. #4 Planned SW-RDM-19VAN	Completed 2017/08/13	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2017/08/12 14:30:00	2017/08/13 09:46:46	19.28 Hours Continuous	Sent Line Dept, Vancouver	Christensen, Cathy J. CUST MAINT @C0276 AT 355 BURRARD CONTACT CRAIG LAWSON @ 604-817-2104 @ RESA POWER
8-00279192 Rev. #6 Planned SW-DRM-19VAN	Completed 2017/08/14	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2017/08/13 08:30:00	2017/08/14 13:21:48	28.86 Hours Continuous	Sent Line Dept, Vancouver	Christensen, Cathy J. CUST VAULT MAINT @ C1250 @ 400 BURRARD CONTACT: CRAIG LAWSON 604-329-3915
8-00334953 Rev. #6 Planned W01051654-11	Completed 2018/11/10	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2018/11/09 08:00:00	2018/11/10 09:32:30	25.54 Hours Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. Customer vault maintenance @ C0027 - 501 Burrard St., Van (Bentall Tower 1 &2) Contact Deny Ciarniello of Wismer & Rawlings Electric Ltd at 604-816-0359
8-00341457 Rev. #4 Planned SW-DRM-19VAN	Completed 2018/11/13	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2018/11/10 14:30:00	2018/11/13 15:31:00	3.04 Days Continuous	Sent Line Dept, Vancouver Not Sent Electricians, Horne Payne	Christensen, Cathy J. CUST MNTNC @ C0190 AT 1055 WEST HASTINGS CONTACT CRAIG LAWSON 604-817-2104 @ RESA
8-00357910 Rev. #7 Planned 1817227-02	Completed 2019/01/07	Area: Approved	CSQ 12F511 UC7F65 OOS	T&W	2019/01/02 08:00:00	2019/01/07 13:58:02	5.25 Days Continuous	Sent Line Dept, Vancouver	MONTGOMERY, JOHN A. PA VAN 81535 R1 - Remove standby circuit from MH 1401 to C0352 SW 2031 AFTER PERMIT ISSUED FVO SCHEDULING TO ISSUE NEW DRSC
8-00379286 Rev. #4 Planned W01051654-11	Completed 2019/05/07	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2019/05/03 08:00:00	2019/05/07 17:34:48	4.4 Days Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. Customer vault maintenance @ C1261 510 Burrard St, Van. Contact Graham Moore of Wismer & Rawlings Electric Ltd at 604 816 2110
8-00385352 Rev. #4 Planned W01051654-11	Completed 2019/08/21	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2019/08/16 08:00:00	2019/08/21 16:23:49	5.35 Days Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. Customer vault maintenance @ C2524 401 Burrard St., Vancouver. Contact Dave Henderson of Exell Power Services Ltd. at 604 315 5889.
8-00419740 Rev. #9 Planned W01051654-11	Completed 2020/05/01	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2020/04/30 08:00:00	2020/05/01 14:35:08	30.59 Hours Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. Customer maintenance @ C0016, 900 W Hastings, Van. Contact Lawren Thompson 778.868.8765
8-00442989 Rev. #12 Planned W01051654-11	Completed 2020/05/11	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2020/05/01 14:30:00	2020/05/11 14:58:38	10.02 Days Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. Customer vault maintenance @ C0351 - 1050 West Pender Street, Vancouver. Contact Len Albertson of Resa Power Service at 604-209-7461.
8-00450834 Rev. #10 Planned W01051654-11	Completed 2020/08/15	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2020/08/12 08:00:00	2020/08/15 11:58:34	3.17 Days Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. Customer vault maintenance @ C0276 - 355 Burrard Street, Vancouver. Contact Filip Ljubichich of Exell Power Services Ltd at 778-957-3687.
8-00438927 Rev. #13 Planned W01051654-11	Completed 2020/08/21	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2020/08/15 14:30:00	2020/08/21 18:30:37	6.17 Days Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. Customer vault maintenance @ C1250 - 400 Burrard Street, Vancouver. Contact Len Albertson of Resa Power Service at 604 209 7461.
8-00487668 Rev. #17 Planned w01051654-11	Completed 2020/11/10	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2020/11/05 08:00:00	2020/11/10 13:34:29	5.23 Days Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. CUST VAULT MNTCE @ C0027 - BENTALL TOWER 1&2 - 501 BURRARD STREET WISMER AND RAWLINGS ELECTRIC LTD CONTACT TODD NORDIN @ 604-209-0915
8-00518509 Rev. #6 Forced	Completed 2020/11/27	Area: n/a	CSQ 12F511 OOS CSQ 12F511 Feeder Cable OOS CSQ 12F511 UC7F64 OOS CSQ 12F511 UC7F65 OOS CSQ 12F511 UC7F66 OOS CSQ 12F511 UC7F67 OOS	T&W	2020/11/19 23:33:00	2020/11/27 15:34:17	7.67 Days Continuous		Captein, Patrick PS. Circuit tripped carrying CSQ 12F514 for GOI maintenance job, CSQ 12F514 picked up load, ORF #8-487674 (LD7-516820) Electrician confirmed A-B-C phase fault up to 8200 fault amps on 12F511.
8-00526364 Rev. #3 Forced	Completed 2020/12/13	Area: n/a	CSQ 12F511 OOS CSQ 12F523 OOS CSQ 12F511 Feeder Cable OOS CSQ 12F511 UC7F64 OOS CSQ 12F511 UC7F65 OOS CSQ 12F511 UC7F66 OOS CSQ 12F511 UC7F67 OOS	T&W	2020/12/13 00:12:21	2020/12/13 04:48:18	4.6 Hours Continuous		MacKenzie, Charlie W. CSQ 12CB511 kicked out. CSQ 12511 normally a no load standby circuit, but currently carrying all of CSQ 12F523 via dual radial. CSQ 12F523 currently isolated in station to accommodate a GOI scheduled for Dec. 13, 2020 @ 2300. Electrician called out to restore CSQ 12F523 in station. PLT's called out to inspect/transfer all vaults from standby CCT (CSQ 12F511) to running circuit (CSQ 12F523)

8-00460707 Rev. #17 Planned SW-DRM-19VAN	Completed 2021/02/04	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2021/01/26 08:00:00	2021/02/04 16:38:14	9.36 Days Continuous	Sent Line Dept, Vancouver	Villanueva-Acabal, Michelle Customer Vault Maintenance@ C1078 - 999 W. Hastings. Contact Pacific Powertech Inc. Kane Hite 604 328 4489
8-00559480 Rev. #12 Planned m169270-01	Completed 2021/03/29	Area: Approved	CSQ 12F511 UC7F65 OOS	T&W	2021/03/19 08:00:00	2021/03/29 11:39:27	10.15 Days Continuous	Sent Line Dept, Vancouver	Wardrop, Kevin J. 5 year RAL switch maintenance Scheduler Notes:No customer outage required for this outage as the switch can be isolated from the Load break elbows on the common junction bar coming from 2018 . CSQ 12F511 UC7F65 should be de-energized prior to crews opening V0073 load break elbows C0354 - Notified March 16, 2021
8-00495690 Rev. #19 Planned W01051654-11	Completed 2021/05/05	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2021/04/30 08:00:00	2021/05/05 17:08:05	5.38 Days Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. Customer vault maintenance @ C0190 - Guinness Tower - 1055 W Hastings St. Vancouver. Contact Filip Ljubichich of Exell Power Services Ltd at 778-957-3687.
8-00575749 Rev. #14 Planned W01051654-11	Completed 2021/08/25	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2021/08/11 08:00:00	2021/08/25 19:41:39	14.49 Days Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. Customer vault maintenance @ C1261 - 510 Burrard Street, Vancouver. Contact Deny Ciarniello of Wismer & Rawlings Electric Ltd at 604-816-0359.
8-00705435 Rev. #15 Planned W01051654-11	Completed 2022/08/22	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2022/08/09 08:00:00	2022/08/22 14:07:34	13.26 Days Continuous	Sent Line Dept, Vancouver	Smith, Christopher CD. Customer vault maintenance @ C2524 - 401 Burrard Street, Vancouver. Contact Lawren Thompson of Exell Power Services Ltd at 778-868-8765.
8-00746774 Rev. #5 Planned W01051654-11	Cancelled 2022/10/27	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2022/11/02 08:00:00	2022/11/07 16:00:00	5.38 Days Continuous	Sent Line Dept, Vancouver	CONNELL, JESSE L. Customer vault maintenance @ C0027 - 501 Burrard Street, Vancouver - Bentall Tower 1 & 2. Contact Deny Ciarniello of Wismer & Rawlings Electric Ltd at 604-816-0359.
8-00770619 Rev. #18 Planned W01051654-11	Completed 2022/11/28	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2022/11/18 08:00:00	2022/11/28 16:17:51	10.35 Days Continuous	Sent Line Dept, Vancouver	CONNELL, JESSE L. CUSTOM WINDOW customer vault maintenance @ C0027 - 501 Burrard Street, Vancouver - Bentall Tower 1 & 2. Contact Deny Ciarniello of Wismer & Rawlings Electric Ltd at 604-816-0359.
8-00808061 Rev. #13 Planned 2163197-02	Completed 2023/02/10	Area: Approved	CSQ 12F521 Feeder Cable OOS CSQ 12F511 UC7F65 OOS	T&W	2023/02/10 08:00:00	2023/02/10 15:16:50	7.28 Hours Continuous	Sent Line Dept, Vancouver	SCHMIDT, CRAIG T. Work on secondary side of transformer in V0073
8-00823375 Rev. #5 Forced	Completed 2023/02/25	Area: n/a	CSQ 12F511 OOS CSQ 12F511 UC7F65 OOS	T&W	2023/02/24 18:06:24	2023/02/25 22:52:57	28.78 Hours Continuous		Patton, Kirsten M.
8-00823372 Rev. #15 Forced	Implemented 2023/02/25	Area: n/a	CSQ 12F521 OOS CSQ 12F511 UC7F65 OOS CSQ 12F511 OOS	T&W	2023/02/24 18:06:27	2023/02/25 12:54:00	18.79 Hours Continuous		Patton, Kirsten M. Restoration center reports customer saw fireball erupt from manhole at Burrard and Cordova St.
8-00789420 Rev. #3 Planned W01051654-11	Approved 2022/11/21	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2023/08/11 08:00:00	2023/08/12 14:30:00	30.5 Hours Continuous	Not Sent Line Dept, Vancouver	CONNELL, JESSE L. Customer vault maintenance @ C0016 - 900 West Hastings Street, Vancouver. Contact Lawren Thompson of Exell Power Services Ltd at 604-514-9472.
8-00811358 Rev. #5 Planned W01051654-11	Approved 2023/01/26	Area: Approved	CSQ 12F511 UC7F65 OOS	GOI	2023/08/12 14:30:00	2023/08/14 16:00:00	2.06 Days Continuous	Not Sent Line Dept, Vancouver	CONNELL, JESSE L. Customer vault maintenance @ C0190 - 1055 W Hastings Street, Vancouver. Contact Kane Hite from Pacific Powertech Inc @ 604-328-4489
8-00844785 Rev. #1 Planned W01051654-11	Submitted 2023/04/26	Area: Pending	CSQ 12F511 UC7F65 OOS	GOI	2023/08/13 23:00:00	2023/08/14 03:00:00	4 Hours Continuous		CONNELL, JESSE L. Customer vault maintenance @ C0351 - 1050 West Pender Street, Vancouver. Contact Len Albertson of RESA Canada Inc at 604-209-7461.

Appendix L: Vault 0073 SAM Maintenance Logs

BCH Fiscal	Completed/Last Updated Date	Asset Type	Asset ID	Item	Status	Item ID	Plain Description (Ryan)
F22	31-03-2022	Vault	V0073	Task	Field Complete	179345-9	RB-RAL Inspection (Oil Sampled, not Tested).
F22	24-11-2021	Vault	V0073	Task	Field Complete	176575-1	SI-Street Vault Inspection (Visual, no issues).
F22	15-11-2021	Vault	V0073	Task	Field Complete	177832-9	**RB-RAL Inspection (Oil Sampled, Tested?).**
F21	31-03-2021	Vault	V0073	Task	Field Complete	169270-1	**RB-RAL Inspection (Oil Changed).**
F21	22-01-2021	Vault	V0073	Task	Field Complete	151664-4	RB-RAL Inspection (No Oil Sample).
F20	28-02-2020	Vault	V0073	Task	Cancelled	139267-12	F20 RB RAL Inspection Cancelled (No Oil Sample - Unit was being removed from system).
F20	28-02-2020	Vault	V0073	Task	Cancelled	151669-22	F20 SI Street Vault Inspection Cancelled (Vault was being removed/repurposed as part of RAL Removal).
F19	29-01-2019	Vault	V0073	Task	No Action Required	118740-9	F19 RB RAL Inspection Cancelled (No Oil Sample - Unit was being removed from system).
F18	20-07-2017	Vault	V0073	Task	Field Complete	105288-25	SI-Street Vault Inspection (Visual, no issues).
F18	20-07-2017	Vault	V0073	Public Safety Inspection	Field Complete	437414546	Automatic Public Safety Inspection Record due to worker entry.
F18	19-07-2017	Vault	V0073	Task	Field Complete	105287-25	**RB-RAL Inspection (Oil Sampled, Tested?).**
F18	19-07-2017	Vault	V0073	Public Safety Inspection	Field Complete	437414543	Automatic Public Safety Inspection Record due to worker entry.
F17	29-12-2016	Vault	V0073	Public Safety Inspection Archive	Field Complete	394550507	Automatic Public Safety Inspection Record due to worker entry.
F17	29-12-2016	Vault	V0073	Public Safety Inspection Archive	Field Complete	663813825	Automatic Public Safety Inspection Record due to worker entry.
F17	29-12-2016	Vault	V0073	Action Request	Field Complete	394550537	AR Completed for hot elbow replaced on Switch 2018 (not the one that failed).
F17	30-09-2016	Vault	V0073	Task	Field Complete	92707-23	**RB-RAL Inspection (Oil Sampled, Tested?).**
F17	30-09-2016	Vault	V0073	Public Safety Inspection Archive	Field Complete	394550504	Automatic Public Safety Inspection Record due to worker entry.
F16	10-02-2016	Vault	V0073	Task	Field Complete	81660-55	SI-Street Vault Inspection (Visual, no issues).
F16	26-01-2016	Vault	V0073	Task	Cancelled	82522-3	F16 RB Job Cancelled
F15	11-09-2014	Vault	V0073	Task	Field Complete	64227-27	**RB-RAL Inspection (Oil Sampled, Tested?).**
F15	09-08-2014	Vault	V0073	Task	Field Complete	53984-21	SI-Street Vault Inspection (Visual, no issues).
F15	09-08-2014	Vault	V0073	Public Safety Inspection Archive	Field Complete	253269616	Automatic Public Safety Inspection Record due to worker entry.
F14	12-04-2013	Vault	V0073	Task	Field Complete	42745-29	**RB-RAL Inspection (Oil Changed, sample taken).**
F13	11-04-2012	Vault	V0073	Task	Cancelled	50992-585	F13 Cancelled Inspection of PCB data related to the Tx in the Vault.
F12	03-02-2012	Vault	V0073	Task	Field Complete	48061-44	SI-Street Vault Inspection (Regular SI + 2012 Asbestos Survey of UG Assets).
F12	03-02-2012	Vault	V0073	Public Safety Inspection Archive	Field Complete	171215947	Automatic Public Safety Inspection Record due to worker entry.
F04	15-04-2003	Vault	V0073	Task	Field Complete	34685-10	Data Correction packaged as an SI in SAM - not field work.

Appendix M: Oil Quality Historical Report

Powertech
A subsidiary of BC Hydro

Lower Mainland Transmission
Company Code: LMT

RAL Switches - Dual Radial Vaults
Station Code: RAL Sws
Attention:
Phone:
Fax:

Equipment Details: V073/355 Burrard (Sw2018 - 12F522CSQ - M) [PWT/4855]

Equipment Details: Others

Oil Quality Historical Report

Port ID	Date	KV D877	KV 1816 .08	KV 1816 .04	Neut Num. (mg KOH/gm)	IFT (dynes/cm)	Color (units)	Inhib Content (%w/w)	PF 100C (%)	PF 25C (%)	Water (ppm w/w)	PCB 1242 (ppm w/w)	PCB 1254 (ppm w/w)	PCB 1260 (ppm w/w)
Main Oil Tank (V073/355 Burrard: TNK)														
M	23 Oct 2018	–	32	–	–	–	–	–	–	–	20	–	–	–
M	29 May 2017	–	33	–	–	–	–	–	–	–	13	–	–	–
M	01 Jul 2016	–	35	–	–	–	–	–	–	–	28	–	–	–
OP	29 Sep 2015	–	20	–	–	–	–	–	0.10	–	–	–	–	–
M	18 Oct 2014	–	47	–	–	–	–	–	–	–	14	–	–	–
M	11 Sep 2014	–	23	–	–	–	–	–	–	–	–	–	–	–
OP	05 Dec 2012	–	37	24	–	–	–	–	–	–	–	–	–	–
OP	13 Sep 2011	–	38	28	–	–	–	–	–	–	–	–	–	–
OP	28 Dec 2010	–	44	–	–	–	–	–	–	–	–	–	–	–
OP	24 Jul 2009	–	27	–	–	–	–	–	–	–	–	–	–	–

Powertech
A subsidiary of BC Hydro

Lower Mainland Transmission
Company Code: LMT

RAL Switches - Dual Radial Vaults
Station Code: RAL Sws
Attention:
Phone:
Fax:

Equipment Details: V073/355 Burrard (Sw2019 - M) [PWT/4857]

Equipment Details: Others

Oil Quality Historical Report

Port ID	Date	KV D877	KV 1816 .08	KV 1816 .04	Neut Num. (mg KOH/gm)	IFT (dynes/cm)	Color (units)	Inhib Content (%w/w)	PF 100C (%)	PF 25C (%)	Water (ppm w/w)	PCB 1242 (ppm w/w)	PCB 1254 (ppm w/w)	PCB 1260 (ppm w/w)
Main Oil Tank (V073/355 Burrard: TNK)														
M	23 Oct 2018	–	22	–	–	–	–	–	–	–	21	–	–	–
M	29 May 2017	–	40	–	–	–	–	–	–	–	16	–	–	–
M	01 Jul 2016	–	36	–	–	–	–	–	–	–	28	–	–	–
OP	29 Sep 2015	–	22	–	–	–	–	–	0.30	–	–	–	–	–
M	27 Nov 2014	–	50	–	–	–	–	–	–	–	15	–	–	–
M	11 Sep 2014	–	21	–	–	–	–	–	–	–	–	–	–	–
OP	05 Dec 2012	–	42	27	–	–	–	–	–	–	–	–	–	–
OP	17 Jul 2012	–	30	14	–	–	–	–	–	–	–	–	–	–
OP	13 Sep 2011	–	44	23	–	–	–	–	–	–	–	–	–	–
OP	28 Dec 2010	–	44	–	–	–	–	–	–	–	–	–	–	–
OP	24 Jul 2009	–	23	–	–	–	–	–	–	–	–	–	–	–

Appendix N: V0073 RAL Switch Oil Results (2000-2009)

Attachment 1

RAL SWITCHES - DUAL RADIAL VAULTS

									2005		
Circuit	Vault #	MH#	Switch #	Location	5 Year	Date Oil Changed	5 Year Mtce Date	NEW STICKER Date	Date Tested	Lab Sample Number	Lab Test kV
12.525CSQ	V37		SW 2082	Melville & Bute	2001			2006 FEB	2005.02.24	05-0009-01	54
UC7F66	V37		SW 2087	Melville & Bute	2000		2000.03.01	2005 MAR	2005.02.24	05-0009-02	44
12.92MU-1	V55		SW 1594	Gore & Keefer	2002		2000.03.02	2005 MAR	2005.02.24	05-0009-03	44
UC8F9	V55		SW 1595	Gore & Keefer	2000		2000.02.29	2005 MAR	2005.02.24	05-0009-04	49
12.91MU-1	V58		SW1684	221 Carrall St	2003	2003.07.09	2004 OCT	2009 OCT	2005.02.24	05-0009-06	50
UC8F10	V58		SW1685	221 Carrall St	2003	2003.07.02			2005.02.24	05-0009-07	25
12.88DGR	V62	2400	SW 1860	Seymour S. of Georgia	2004			2009	2005.02.24	05-0009-09	52
12.622 CSQ	V64		SW 1734	559 Georgia	2001		2001 JAN	2006 JAN	2005.02.24	05-0009-11	34
12.611CSQ	V64		SW 1735	559 Georgia	2003	2004.06.08	2003.07.07	2008 JUL	2005.02.24	05-0009-10	41
12.91MU-1	V67		SW 1702	345 Water St	2004	2002.04.28	2004 APR	2009 APR	2005.02.24	05-0009-13	53
UC8F10	V67		SW 1703	345 Water St	2004		2004 APR	2009 APR	2005.02.24	05-0009-14	56
12.91MU-1	V68		SW 1698	199 Water St	2003	2003.07.09	2003.07.09	2008 JUL	2005.02.24	05-0009-16	53
UC8F10	V68		SW 1699	199 Water St	2003	2003.07.09	2004 APR	2009 APR	2005.02.24	05-0009-17	59
12.91MU-1	V69		SW 1696	151 Water St	2004	2002.04.28			2005.02.24	05-0009-19	60
UC8F10	V69		SW 1697	151 Water St	2004				2005.02.24	05-0009-20	33
12.91MUR	V70		SW 1692	134 Abbott St	2004	2002.04.28			2005.02.24	05-0009-22	50
UC8F10	V70		SW 1693	134 Abbott St	2004				2005.02.24	05-0009-23	52
12.91MU-1	V71		SW 1688	55 Water St	2003	2003.07.09	2003.07.09	2008 JUL	2005.02.24	05-0009-25	52
UC8F10	V71		SW 1689	55 Water St	2003	2003.07.02			2005.02.24	05-0009-26	50
12.521CSQ	V73		SW 2018	355 Burrard	2000	2002.05.15	2000.03.02	2005 MAR	2005.02.24	05-0009-28	36
UC7F65	V73		SW 2019	355 Burrard	2000	2002.06.06	2000.02.25	2005 MAR	2005.02.24	05-0009-29	51
12.78MUR	V78		SW 1578	Main & Terminal	2001				2005.02.24	05-0009-31	60
UC8F-12	V78		SW 1579	Main & Terminal	2003	2003.07.03	2004 MAY	2009 MAY	2005.02.24	05-0009-32	46
12.611CSQ	V79		SW 1609	602 Dunsmuir	2001			2006 JAN	2005.02.24	05-0009-34	54
12.621CSQ	V79		SW 1608	602 Dunsmuir	2001			2006 JAN	2005.02.24	05-0009-35	55
UC6E2	V914		SW 5194	Stanley Park	2002	2004.06.08	2002	2007	2005.02.24	05-0009-37	34
UC6E3	V914		SW 5193	Stanley Park	2002		2002	2007	2005.02.24	05-0009-38	42
12.53 DGR	V967		SW 2126	Burrard & Georgia	2003	2002.04.02	2004 SEP	2009 SEP	2005.02.24	05-0009-39	43
12.57Q MU-1		2366	SW 1680	Cordova & Main	2003	2003.07.15	2003.07.15	2008 JUL	2005.02.24	05-0009-40	56
12.511CSQ	V2435		SW 2133	555 Burrard	2004		2004	2009	2005.02.24	05-0009-41	36

Circuit	Vault #	Switch #	Location	5 Year Maintenance	Date Tested	Lab Sample Number	Lab Test Kv (2003)	Date Tested	Lab Sample Number	Lab Test Kv (2004)
12.57Q MU-1	MH2366	SW 1680	Cordova & Main	2003 ✓	May 01/03	03-0038-04	38	May 06/04	04-0023-09	29
12.91 MU-1	V58	SW1684	221 Carrall St	2003 ✓	Jul. 09/03	03-0049-01	41 37	May 06/04	04-0023-15	33
UC8F10	V58	SW1685	221 Carrall St	2003 ✓	Jul. 02/03	03-0049-02	32 22	May 06/04	04-0023-02	37
12.91 MU-1	V67	SW 1702	345 Water St	2004 ✓	May 01/03	03-0038-05	43	May 06/04	04-0023-03	30
UC8F10	V67	SW 1703	345 Water St	2004 ✓	May 01/03	03-0038-13	27	May 06/04	04-0023-13	27
12.91 MU-1	V68	SW 1698	199 Water St	2003 ✓	May 01/03 Jul. 09/03	03-0038-06 03-0049-04	39 36	May 06/04	04-0023-07	38
UC8F10	V68	SW 1699	199 Water St	2003 ✓	May 01/03 Jul. 03/03	03-0038-14 03-0049-05	42 41	May 06/04	04-0023-04	50
12.91 MU-1	V69	SW 1696	151 Water St	2004 ✓	May 01/03	03-0038-07	60	May 06/04	04-0023-08	34
UC8F10	V69	SW 1697	151 Water St	2004 ✓	Apr. 30/03	03-0038-15	33	May 06/04	04-0023-04	25
12.911 MUR	V70	SW 1692	134 Abbott St	2004 ✓	May 01/03	03-0038-08	54	Dec 22/04 May 06/04	 04-0023-04	36 39
UC8F10	V70	SW 1633	134 Abbott St	2004 ✓	Apr. 30/03	03-0038-03	41	May 06/04	04-0023-06	41
12.91 MU-1	V71	SW 1688	55 Water St	2003 ✓	Jul. 09/03	03-0049-06	35	May 06/04	04-0023-11	31
UC8F10	V71	SW 1689	55 Water St	2003 ✓	Jul. 02/03	03-0049-07	23	Dec 22/04 May 06/04	 04-0023-10	29 36
12.02 MU-1	V55	SW 1594	Gore & Keefer	2002 ✓			28	May 07/04	04-0024-16	21
UC8F9	V55	SW 1595	Gore & Keefer	2000 ✓			35	May 07/04	04-0024-15	24
12.622 CSQ	V64	SW 1734	559 Georgia	2001 ✓			42	Dec 22/04 May 07/04	 04-0024-02	60 35
12.611 CSQ	V64	SW 1735	559 Georgia	2003 ✓	Jul. 07/04	03-0049-03	44 36			
12.78 MUR	V78	SW 1578	Main & Terminal	2001 ✓			42	May 07/04	04-0024-14	19
UC8F-12	V78	SW 1579	Main & Terminal	2003 ✓	Jul. 09/03	03-0049-08	31	May 07/04	04-0024-10	26
12.53 DGR	V967	SW 2126	Burrard & Georgia	2003 ✓	May 01/03	03-0038-02	28	May 07/04	04-0024-03	24
12.88 DGR	V62 MH #2400	SW 1860	Georgia & Seymour	2004 ✓	May 01/03	03-0038-03	35	May 07/04	04-0024-09	20
12.511 CSQ	V2435	SW 2133	555 Burrard	2004 ✓	May 01/03	03-0038-01	38	May 07/04	04-0024-07	23
12.525 CSQ	V37	SW 2082	Melville & Bute	2001 ✓	May 01/03	03-0038-09	37	May 07/04	04-0024-18	21
UC7F66	V37	SW 2087	Melville & Bute	2000 ✓	May 01/03	03-0038-12	25	May 07/04	04-0024-06	28
12.521 CSQ	V73	SW 2018	355 Burrard	2000 ✓			48	May 07/04	04-0024-04	35
UC7F65	V73	SW 2019	355 Burrard	2000 ✓			49	May 07/04	04-0024-17	28
UC6E2	V914	SW 5194	Stanley Park	2002 ✓			36	May 06/04	04-0023-14	19
UC6E3	V914	SW 5193	Stanley Park	2002 ✓			33	May 06/04 May 07/04	04-0023-01 04-0024-04	43 30
12.611 CSQ	V79	SW 1609	602 Dunsmuir	2001 ✓	May 01/03	03-0038-10	46	May 07/04	04-0024-08	32
12.621 CSQ	V79	SW 1608	602 Dunsmuir	2001 ✓	May 01/03	03-0038-11	44	May 06/04	04-0024-01	26

12.91 MU-1

Dual Radial RAL Switches 2004

RAL SWITCHES - DUAL RADIAL VAULTS

Circuit	Vault #	MH#	Switch #	Location	5 Year	Oil Changed	Date Tested	Test kV	Comments
12.525CSQ	V37		SW 2082	Melville & Bute	2001		May 01/03	37	Tagged
UC7F66	V37		SW 2087	Melville & Bute	2000		May 01/03	25	Tagged
12.02 MU-1	V55		SW 1594	Gore & Keefer	2002		Apr 14/03	28	Tagged
UC8F9	V55		SW 1595	Gore & Keefer	2000		Apr 14/03	35	Tagged
12.91 MU-1	V58		SW1684	221 Carrall St	2003	Jul 09/03	Apr 14/03	41	Tagged
UC8F10	V58		SW1685	221 Carrall St	2003	Jul 02/03	Apr 14/03	32	Tagged
12.88DGR	V62	2400	SW 1860	Georgia & Seymour	2004		May 01/03	35	Tagged
12.622 CSQ	V64		SW 1734	559 Georgia	2001		Apr 24/03	42	Tagged
12.611 CSQ	V64		SW 1735	559 Georgia	2003	Apr 11/02, Jul 07/03	Apr 24/03	44	Tagged
12.91 MU-1	V67		SW 1702	345 Water St	2004	Apr 28/02	May 01/03	43	Tagged
UC8F10	V67		SW 1703	345 Water St	2004		May 01/03	27	Tagged
12.91 MU-1	V68		SW 1698	199 Water St	2003	Jul 09/03	May 01/03	39	Tagged
UC8F10	V68		SW 1699	199 Water St	2003	Jul 03/03	May 01/03	42	Tagged
12.91 MU-1	V69		SW 1696	151 Water St	2004	Apr 28/02	May 01/03	60	Tagged
UC8F10	V69		SW 1697	151 Water St	2004		Apr 30/03	33	Tagged
12.911 MUR	V70		SW 1692	134 Abbott St	2004	Apr 28/02	Apr 30/03	54	Tagged
UC8F10	V70		SW 1693	134 Abbott St	2004		Apr 30/03	41	Tagged
12.91 MU-1	V71		SW 1688	55 Water St	2003	Jul 09/03	**May 08/03**		Tagged
UC8F10	V71		SW 1689	55 Water St	2003	Jul 02/03	**May 08/03**		Tagged
12.521CSQ	V73		SW 2018	355 Burrard	2000	May 15/02	Apr 15/03	48	Tagged
UC7F65	V73		SW 2019	355 Burrard	2000	Jun 6/02	Apr 15/03	49	Tagged
12.78 MU-1	V78		SW 1578	Main & Terminal	2001		Apr24/03	42	Tagged
UC8F-12	V78		SW 1579	Main & Terminal	2003	Jul 03/03	**May 08/03**		Tagged
12.611CSQ	V79		SW 1609	602 Dunsmuir	2001		May 01/03	46	Tagged
12.621CSQ	V79		SW 1608	602 Dunsmuir	2001		May 01/03	44	Tagged
UC6E2	V914		SW 5194	Stanley Park	2002		Apr 14/03	36	Tagged
UC6E3	V914		SW 5193	Stanley Park	2002		Apr 14/03	33	Tagged
12.53DGR	V967		SW 2126	Burrard & Georgia	2003	Apr 3/02	May 06/03	28	Tagged
12.57Q MU-1		2366	SW 1680	Cordova & Main	2003	Jul 15/03	May 01/03	38	Tagged
12.511CSQ	V2435		SW 2133	555 Burrard	2004		May 01/03	38	Tagged

copy col. to "ALL"

[pink] - KEEP UPDATE [orange] - OMIT NOTES: V0028: NOT ON SHEET ? ALONG WITH OTHERS

#	New Circuit# (2007)	Vault #	MH#	Switch #	Location	DONE OR DUE 5 Year	DONE OR DUE 5 Year	2009 ANNUAL INSPECT. 5 Year	2009 LAB TEST PASS OR FAIL Maintenance(2007/2008)	New Lab KV Sample (2008)	New Lab Sample Number (2008)	New Lab Date Tested (2008)	New Lab KV Sample (2007)	New Lab Sample Number (2007)	New Lab Date Tested (2007)	Lab Sample Number (2007)	Lab Test kV (2007)
1	12F86DGR UC6F-33?	V7		SW 3168	Gilford St. and N. of Comox St.		?										
2	UC8F17	V8		SW2259?	lane N. of Union west of jackson		?									07-0528-01	20
3	UC8F18	V8		V8-M												07-0461-01	31
4	UC6F-27	V16		O/S?	Beach Ave on Bute		O/S?									REMOVE	
5	UC6F12	V17		?	Lane N. Burnaby @ Cardero	NO SAMPLE TAKEN - IN - OPERABLE											
6	UC6F-25126	V19		SW1989	Cardero St. S. of Harwood											07-0309-01	35
7	UC6F-37	V21		?	Lane N. of Pendrell @ Gilford		?										
8	UC6E-19	V22		?	Lane N. of Barclay on Chilco		?									07-0198-05	52
9	UC6F7	V23		SW1989	Apt. 1100 Harwood St. E of Bute St.		?									07-0309-02	31
10	12F86DGR UC6F19	V34		SW3164	Lane S of Comox St. & Chilco St.		?									07-0198-07	34
11	12F63DGR	V35		SW3583	Thurlow s. of pacific												
12	UC8F3	V35		SW3585	Thurlow s. of pacific												
13	12.525CSQ	V37		SW 2082	Melville & Bute	2001	2006									07-0198-09	61
14	UC7F66 (12.511)	V37		SW 2087	Melville & Bute	2000	2010									07-0198-10	28
15	UC6E17	V40			Lane S. of Robson between chilco & guilford											07-0198-13	29
16	UC6F-30	V49			Broughton St. lane N. of Beach Ave.											07-0309-03	26
17	12.92MU-1	V55		SW 1594	Gore & Keefer	2002	2007	2013	Done								
18	UC8F9 12F52 MUR-1	V55		SW 1595	Gore & Keefer	2000	+										
19	12.215 CSQ	V58		SW1684	221 Carrall St	2003	2008	2013	Done	60	07-1512-02	Jan 13/08	60	07-0481-01	May/07/29	07-0032-01	30
20	UC7F145 (12.211 CSQ)	V58		SW1685	221 Carrall St	2008	2008	2013	Done	56		Nov/11/07				07-0032-02	28
21	12.88DGR	V62	2400	SW 1860	Seymour S. of	2004	2009									07-0035-01	33
22	12.622 CSQ	V64		SW 1734	559 Georgia	2001	2006									07-0035-02	60
23	12.611CSQ	V64		SW 1735	559 Georgia	2003	2008									07-0035-03	48
24	12.215CSQ	V67		SW 1702	345 Water St	2004	2009	2013	Done				48	07-0481-02	May/07/29	07-0032-03	27
25	UC7145 (12.211 CSQ)	V67		SW 1703	345 Water St	2004	2009	2013	Done							07-0032-04	26
26	12.215CSQ	V68		SW 1698	199 Water St	2003	2008	2013								07-0035-04	47
27	UC7145 (12.211 CSQ)	V68		SW 1699	199 Water St	2003	2008	2013	Done	60	07-1512-03	Nov 07/07				07-0035-05	48
28	12.215CSQ	V69		SW 1696	151 Water St	2004	2009	2013	Done	56	07-1512-04	Nov 07/07	60	07-0481-03	May/07/29	07-0032-05	32
29	UC7145 (12.211 CSQ)	V69		SW 1697	151 Water St	2004	2009	2013	Done							07-0032-06	16
30	12.215CSQ	V70		SW 1692	134 Abbott St	2004	2009	2013	Done				60	07-0481-04	May/07/29	07-0032-07	17
31	UC7145 (12.211 CSQ)	V70		SW 1693	134 Abbott St	2004	2009	2013	Done	60	07-1512-05	Nov 08/07				07-0032-08	22
32	12.215CSQ	V71		SW 1688	55 Water St	2003	2008	2013	Done				60	07-0481-05	May/07/29	07-0032-09	22
33	UC7145 (12.211 CSQ)	V71		SW 1689	55 Water St	2003	2008	2013	Done							07-0032-10	22
34	12.521 CSQ	V73		SW 2018	355 Burrard	2000	2005	2013	Done							07-0035-06	25
35	UC7F65 (12.511)	V73		SW 2019	355 Burrard	2000	2005									07-0035-07	60
36	12.78MUR	V78		SW 1578	Main & Terminal	2001	2006	2013	Done				50	07-1131-01	Sep/07/06	07-0035-08	22
37	UC8F-12	V78		SW 1579	Main & Terminal	2003	2008									07-0035-09	46
38	12.611CSQ	V79		SW 1609	602 Dunsmuir	2001	2006									07-0035-11	45
39	12.621CSQ	V79		SW 1608	602 Dunsmuir	2001	2006									07-0035-10	43
40	UC6E2	V914		SW 5194	Stanley Park	2002	2007	2013	Done								
41	UC6E3	V914		SW 5193	Stanley Park	2002	2007	2013	Done								

2009

2366 SW1680

d	Lab Sample Number (2006)	Lab Test kV (2006)	Lab Date Tested (2006)	Date Oil Changed (2006)	Date Tested	Lab Sample Number	Lab Test kV (2005)	Date Tested	Lab Sample Number	Lab Test kV (2004)	Date Tested	2004 Oil Change	Lab Test Date	Lab Sample Number	Lab Test kV (2003)
	06-0034-26	47	March 20/06		2005.02.24	05-0009-01	54	May 07/04	04-0024-18	21	May 01/03			03-0038-09	37
	06-0034-31 06-0034-30	60(post 5 year maint.) 30(pre 5 year maint.)	March 20/06 March 20/06		2005.02.24	05-0009-02	44	May 07/04	04-0024-06	28	May 01/03			03-0038-12	25
	06-0034-04	45	March 19/06		2005.02.24	05-0009-03	44	May 07/04	04-0024-16	21			2003.04.24	03-0035-06	28
	06-0034-19 06-0034-32	44 60	March 16/06 March 23/06		2005.02.24	05-0009-04	49	May 07/04	04-0024-15	24					35
	06-0034-05	51	March 16/06		2005.02.24	05-0009-06	50	May 06/04	04-0023-15	33			2003.04.24	03-0035-05	41
	06-0034-20	25	March 16/06		2005.02.24	05-0009-07	25	May 06/04	04-0023-02	37	Jul. 02/03			03-0049-02	32 22
	06-0034-03	44	March 19/06					May 07/04	04-0024-09	20	May 01/03			03-0038-03	35
	06-0034-12	49	March 19/06		2005.02.24	05-0009-11	34	Dec 22/04		60					42
	06-0034-11	43	March 19/06		2005.02.24	05-0009-10	41					2004.06.08			44
	06-0034-06	46	March 16/06		2005.02.24	05-0009-13	53	May 06/04	04-0023-03	30	May 01/03			03-0038-05	43
	06-0034-21	25	March 19/06		2005.02.24	05-0009-14	56	May 06/04	04-0023-13	27	May 01/03			03-0038-13	27
	06-0034-07	46	March 19/06		2005.02.24	05-0009-16	53	May 06/04	04-0023-07	38	May 01/03			03-0038-06	39
	06-0034-15	43	March 19/06		2005.02.24	05-0009-17	59	May 06/04	04-0023-04	50	May 01/03 Jul. 03/03			03-0038-14 03-0049-05	42 41
	06-0034-08 06-0034-23	53 58	March 19/06 June 16/05		2005.02.24	05-0009-19	60	May 06/04	04-0023-08	34	May 01/03			03-0038-07	60
	06-0034-16	29	March 19/06		2005.02.24	05-0009-20	33	May 06/04	04-0023-04	25	Apr. 30/03			03-0038-15	33
	06-0034-09	55	March 19/06		2005.02.24	05-0009-22	50	Dec 22/04		36	May 01/03			03-0038-08	54
	06-0034-17	43	March 19/06		2005.02.24	05-0009-23	52	May 06/04	04-0023-06	41	Apr. 30/03			03-0038-03	41
	06-0034-09	49	March 19/06		2005.02.24	05-0009-25	52	May 06/04	04-0023-11	31	Jul. 09/03			03-0049-06	35
	06-0034-18	29	March 19/06		2005.02.24	05-0009-26	50	Dec 22/04 May 06/04	04-0023-10	29 36	Jul. 02/03			03-0049-07	23
					2005.02.24	05-0009-28	36	May 07/04	04-0024-04	35					48
	06-0034-29	60	March 20/06		2005.02.24	05-0009-29	51	May 07/04	04-0024-17	28					49
	06-0034-02	58	March 19/06		2005.02.24	05-0009-31	60	May 07/04	04-0024-14	19			2003.04.24	03-0035-04	42
	06-0034-22	44	March 19/06		2005.02.24	05-0009-32	46	May 07/04	04-0024-10	26	Jul. 09/03			03-0049-08	31
0	06-0035-03 06-0035-04	30old oil 60new oil	March 28/06 March28/06	March 22/06	2005.02.24	05-0009-34	54	May 07/04	04-0024-08	32	May 01/03			03-0038-10	46
0	06-0034-14	35	March 19/06		2005.02.24	05-0009-35	55	May 06/04	04-0024-01	26	May 01/03			03-0038-11	44
	06-0034-13	44	March 19/06		2005.02.24	05-0009-37	34	May 06/04	04-0023-14	19		2004.06.08			36
					2005.02.24	05-0009-38	42	May 06/04	04-0023-01	43					33

mple ber	Lab Test kV (2004)	Date Tested	2004 Oil Change	Lab Test Date	Lab Sample Number	Lab Test kV (2003)
4-18	21	May 01/03			03-0038-09	37
4-06	28	May 01/03			03-0038-12	25
4-16	21			2003.04.24	03-0035-06	28
4-15	24					35
3-15	33			2003.04.24	03-0035-05	41
3-02	37	Jul. 02/03			03-0049-02	32 22
4-09	20	May 01/03			03-0038-03	35
	60					42
			2004.06.08			44
3-03	30	May 01/03			03-0038-05	43
3-13	27	May 01/03			03-0038-13	27
3-07	38	May 01/03			03-0038-06	39
3-04	50	May 01/03 Jul. 03/03			03-0038-14 03-0049-05	42 41
3-08	34	May 01/03			03-0038-07	60
3-04	25	Apr. 30/03			03-0038-15	33
	36	May 01/03			03-0038-08	54
3-06	41	Apr. 30/03			03-0038-03	41
3-11	31	Jul. 09/03			03-0049-06	35
3-10	29 36	Jul. 02/03			03-0049-07	23
4-04	35					48
4-17	28					49
4-14	19			2003.04.24	03-0035-04	42
4-10	26	Jul. 09/03			03-0049-08	31
4-08	32	May 01/03			03-0038-10	46
4-01	26	May 01/03			03-0038-11	44
3-14	19		2004.06.08			36
3-01	43					33

Appendix O: Oil Quality Report

Powertech
A subsidiary of BC Hydro

POWERTECH LABS INC.

12388-88th Avenue, Chemistry Department., Surrey, British Columbia, Canada, V3W 7R7
Phone: 604 590 7500 Fax: 604 590 7455

Management system is registered to ISO9001 and ISO14001

Oil Quality Worksheet

Lower Mainland Transmission **Station:** RAL Switches - Dual Radial Vaults	**Attention:** Chris Wong **Phone:** 604 839 1038 **Fax:** **CC:**	**Station Code:** RAL Sws **Project:** OP-20210427-13366-01 VaultTX Proj **Ref. Number:** Project **Report:** OQB 2023-0597 - Rev 0 **Report Date:** 15 May 2023

Sample Information			**Notes**
Designation	V073/355 Burrard	V073/355 Burrard	
(Type ID) Equipment	(OTH): Sw2018 -	(OTH): Sw2019-M	
MFR/Serial	PWT / 4855	PWT / 4857	
Component Type	Main Oil Tank	Main Oil Tank	
Component	V073/355 Burrard: TNK	V073/355 Burrard: TNK	
Sample Reason/Port	N / Main Tank	N / Main Tank	
Sample Date	20 Oct 2021	20 Oct 2021	
Comments			
Lab Sample No.	23-0597-01	23-0597-02	
Work Order / Ref.			
Top Oil Temp (°C)			
Results ASTM			
kV Breakdown			
(2.5mm gap): D877			D877
(2mm gap): D1816	✔ 34	✔ 30	D1816
(1mm gap): D1816			D1816
Neut. Number.			
(mg KOH/g): D664			D664
IFT at 25°C			
(dynes / cm): D971			D971
Colour (units) D1500	✔ 0.0	✔ 0.0	D1500
Inhibitor content			
(%w/w): D2668			D2668
Power Factor			
100°C (%): D924			D924
25°C (%): D924			D924
Water (w/w) D1533	✔ 18.9359	✔ 18.3066	D1533
DC Resistivity			
100°C ($10^{12}\Omega\cdot$cm): D924			D924
25°C ($10^{12}\Omega\cdot$cm): D924			D924
Comments	Particles	Particles,	
PCB (ppm w/w)			
Aroclor 1242: D4059			D4059
Aroclor 1254: D4059			D4059
Aroclor 1260: D4059			D4059
Total PCB			Total

Due to Lack of sample Oil from DBV Poured back into Bottle for Both Samples

Rush!

ICP weighed out
Samples given to Tribology May 15

Remarks:
Asset Management
Investigation project of downtown SW vault V073 explosion.

Rev: 0 -

Approved By:
Job Title:
Signed:

BC Hydro
Power smart

BC Hydro Electrical Explosion Incident – Marine Building, Downtown Vancouver

Attachment 2

Distribution Maintenance Bulletin

BC Hydro	Distribution Maintenance Bulletin		
Subject: **Managing Gaskets on Distribution Street Vault Equipment**	**Number:**	2023-002	
	Prepared:	Thomas R Huitika	Initials TH
	Reviewed:	Stuart D Chambers	Initials SDC
	Issued/Approved:	Ed J Mah	Initials
	Revision:	0	
	Date: June 13, 2023	**Page** 1 of 2	

PURPOSE:

This bulletin applies to all oil filled equipment with gaskets located in distribution street vaults (network and non-network) throughout the province.

Instructions are provided to address gasket replacement during routine maintenance.

BACKGROUND:

A recent investigation on a failed oil filled medium voltage switch (RAL), indicated incompatibility between the insulating mineral oil and RTV silicone sealant used for repair, on the leaking gasket. Additives in the RTV silicone, and the silicon itself, can adversely react with the oil, equipment housing, and the associated seal. This can negatively affect the bulk oil quality, which then may result in partial discharges, the generation of significant amounts of combustible gases, and a potential equipment failure.

Related equipment of particular concern are the 16 spot network transformers in Vancouver and Victoria and the 95 secondary network transformers in Victoria, that all are 37 years or older. Each of these transformers has a cable termination and a medium voltage switch compartment sealed with gaskets. Each compartment uses a cork-based sealing gasket, secured with a bolted steel plate. Some of the gaskets may be approaching end-of-life, which means they may be drying out, shrinking, and could be susceptible to leaks.

BC Hydro	**Distribution Maintenance Bulletin**		
Subject: **Managing Gaskets on Distribution Street Vault Equipment**	**Number:**	2023-002	
	Revision:	0	
	Date: June 15, 2023		**Page** 2 of 2

DIRECTIVE:

Immediately stop applying any type of sealant, such as RTV silicone, on street vault installed oil filled equipment gaskets.

Custom made mineral oil compatible gaskets for network equipment are presently being investigated by the Maintenance Program Engineer specifically for spot network and secondary network transformers. A cork-based gasket approved by the Maintenance Program Engineer is to be used as an interim measure.

1) Install new gaskets during scheduled maintenance, regardless of condition.
2) If a leak is discovered after new gasket install:
    a. Create an Action Request with the location and condition of the equipment.
    b. Notify the Maintenance Program Engineer immediately of the leak.

        Email: thomas.huitika@bchydro.com

        Mobile: 250-213-5751
    c. Options for sealing or taking the equipment out of service will then be investigated with the Maintenance Program Engineer.
3) For any other non-network street vault installed, oil filled equipment:
    a. Do not replace the gasket if an oil leak is occurring on a transformer housing.
    b. Create an Action Request with the location and condition.
    c. Notify the Maintenance Program Engineer.
    d. If the equipment is to be taken out of service, the new replacement is to be identical to the existing equipment that is to be removed.

BC Hydro	**Distribution Maintenance Bulletin**	
Subject: **Managing Gaskets on Distribution Street Vault Equipment**	**Number:**	2023-002
	Revision:	0
	Date: June 15, 2023	**Page** 2 of 2

REVISION NOTES:

Revision	Date	Revision Description
0	June 15, 2023	Original Issue

Thomas R Huitika, P.Eng.
Underground Feeder System
Program Engineer

BC Hydro
Power smart

BC Hydro Electrical Explosion Incident – Marine Building, Downtown Vancouver

Attachment 3

Notice to Staff and Contractors

The Notice below was sent to BC Hydro staff and contractors who work on distribution infrastructure or supports distribution work.

Effective two-way communication is an essential barrier in preventing incidents. We all have a role to play to ensure that our written work instructions are clear, concise and applicable to the work and that the work is being done in adherence to the requirements of the written instructions.

For the owners of written instructions (including but not limited to construction standards and equipment advisories, maintenance standards and bulletins, work procedures, operation and maintenance manuals, operating and switching orders, etc.), we need to ensure that the instructions can be followed by field crews. And if issues are found with the instructions, we need to work together to find a safe and effective solution.

A reminder about the roles we all have to play and the resources available to you:

Owners of written instructions:

- Ensure specific direction and order of steps required to complete a task are included to a level appropriate for the risks and complexity of the work.
- When contacted by someone who needs clarity on instructions, be supportive and ensure direction is provided in a timely manner.
- Ensure instructions are reviewed periodically to address gaps, avoid ambiguity and are updated for clarity if they can't be applied in the field as written.

All workers working on distribution system:

- Remember that all written instructions must be followed as prescribed. This includes detailed direction (the steps to take and the order in which to take them) and the specific materials required to complete the task.
- If you can't follow the instructions as they're written, you must stop the work and seek clarifications by doing one of the following:

  For BC Hydro employees:

  - Contact your manager or crew lead, call the Safety Hotline, use the Safety Stop process, call your Safety Advocate, or contact the owner of the written instructions for support (for example, if there's an issue with a Distribution Maintenance Standard, the responsible Maintenance Program Engineer should be contacted).

  For contractors (working on distribution assets and following BCH procedures):

  - Contact your BC Hydro contract representative(s) who can support you in seeking clarification.

If you see an issue with a distribution asset in the field:

- Use a SAM Action Request to report damage and defects on equipment.

- Use a SAM repair or replacement Action Request to report unsafe non-standard and temporary installations, but please attach photos and comments in SAM showing and describing the issue in detail.
- Use SAM Data Corrections to fix map discrepancies, report new/missing assets and correct read-only Asset Data fields.

Our written instructions are an important part of ensuring we can all work safely. Thanks to all of you for your support and commitment to ensure that they're complete and effective.

BC Hydro Electrical Explosion Incident – Marine Building, Downtown Vancouver

Attachment 4

2016 Underground Vault Inventory

BC Hydro
Power smart

Distribution Line Strategy and Standards

July 2016 | Underground Vault Inventory

Revision: R3

A Strategy to Manage Safety Risks Associated with Underground Equipment in Street Vaults

Issued: July 2016

[redacted]

Table of Contents

List of Figures

Acronyms and Abbreviations

CLF	Current Limiting Fuse
GRA	A G&W type oil switch. Similar to RAL but with grounded switch position
MV	Medium Voltage (12 kV or 25 kV)
PILC	Paper Insulated Lead Cover (feeder cable)
RAL type	Switch category including RAL, GRA, and GRAM
RAL	A G&W type oil switch. The RAL switch is a 3 way, loop through and tap switch
XLPE	Cross-link Polyethylene (feeder cable)

This report could not have been completed without the contributions of the following:

[redacted]

Cover photo: Corroded Oil fused cut outs in Vault 49

1. EXECUTIVE SUMMARY

This project was undertaken to collect information and evaluate public and worker safety risk caused by street vaults containing aging oil filled switches and other associated aging assets in the vaults. The information is used to develop a holistic strategy to deal with these aging assets. A database was created that includes a spectrum of information for both risk analysis and maintenance on vaults and manholes throughout the province which were believed to contain oil switches. This database includes several other risk type equipment including oil fused cut outs, cable transition splices, and transformers.

The undertaking found that there are five primary vault configurations. The majority of oil filled equipment is found in two of these configurations; single radial feed to transformer through a switch, and dual radial feed to transformer through one or two switches. 14 vaults in Vancouver are considered very high risk with equipment likely to be in very poor condition as per Appendix A. Consequences of this high risk equipment could include public or worker severe injury or death. Public deaths and injuries as a result of underground oil filled equipment have previously occurred in North America. In BC Hydro a worker was seriously injured while maintaining aging underground oil filled switching equipment in December 2009.

Recommendations have been made to address risks:

Immediate term (F17 and F18) it is recommended that:

- Verify the database information in the field, repeat the risk prioritization method for new information, and update SAM/DAD.
- Install overhead current limiting fuses (CFLs) to protect three phase underground oil filled equipment in single radial and OH fed street vaults. While, the best safety informed solution requires a CLF installed for all oil filled equipment, given the space constraint in dual radial vaults fed by UG supply, continued close monitoring of UG fed dual radial vaults with immediate action on those which become poor condition can be a practical safety informed solution.
- Replace and upgrade the five dual radial street vaults (V58, V67, V69, V70, and V73). To align with System Planning's recommendation to upgrade to an open loop configuration with dual ratio submersible transformers with built-in CLFs.
- Repair, maintain and implement the recommendations for the remaining 9 units as outlined in appendix A.
- Investigate suitable replacements for RAL, VacPac, and non-vista SF6 switches, as well as oil fused cutouts.
- Sample all oil filled switches to determine if PCB contaminated and assess condition and action.
- Develop oil sampling procedure for transformers.

Mid-term (F19 to F20), it is recommended that:

- Sample transformer oil using the procedure developed in F17 and F18 to determine if PCB contamination is greater than 50 ppm.
- The remaining oil filled switches and transformers that are identified to be in fair condition are maintained, repaired, or replaced with suitable alternative (if feasible) to align with the strategy for downtown redevelopment project.
- Continued close monitoring of dual radial vaults without CLF and immediate action on poor and fair condition
- Investigate to improve tracking and record keeping for oil test.
- Fix sumps to prevent standing water causing corrosion issues.

Long Term (F21 and beyond):

- Replace all remaining non-oil filled three phase switch (e.g SF6, VacPac) with vista or suitable alternative aligning with downtown redevelopment strategy.
- Replace all remaining oil filled switches by December 31, 2025.
- Replace transformers with PCB contamination greater than 50 ppm by December 31, 2025.

Strategic opportunities include:

- Since the oil fused cutouts were installed around 50 years ago, it is likely that they contain PCBs and thus should be removed from service as opportunities arise. BC Hydro must meet a deadline of no PCBs greater than 50 ppm by December 31, 2025.
- There is an opportunity to proactively address WSBC regulation 9.4 by investigating non-oil type transformers for confined spaces.
- When installing new equipment into existing vault, the civil structures must be assessed to ensure its suitability for the life of the new equipment and to ensure that the condition and the size of the structures can accommodate the new equipment.

2. INTRODUCTION

A request was made by Asset Investment Management to review the safety risk associated with RAL switches and other underground infrastructure and to develop a strategy to address these aging assets. This request was triggered by BC Hydro (BCH) Incident #24760, a failure of an aging underground transformer which resulted in contaminated oil being released into the vault. Street vaults generally house a step down transformer downstream of an isolation point to provide energy to customers. The isolation point is typically one or both of oil fused cutouts and a three phase switch (often RAL or similar). Street vaults are akin to large through type manholes, with two larger top openings to allow the placement of equipment.

This report details the safety review, which includes the creation of an inventory of assets, a qualitative risk analysis, and a set of recommendations, such as installation of current limiting fuses (CLFs), repair and replacement of equipment, etc., to reduce risks associated with these underground assets.

3. SCOPE

In scope:

- Vault inventory containing aging oil filled switches
  - V#### series vaults in the City of Vancouver
  - Manholes and Vaults anywhere in BC which field crews or engineers believed may contain a switch
  - Locations where Distribution Analysis and Design (DAD) software indicates internal switch = 'RAL'
- Analysis of Risks associated with the above which directly have immediate effect on human life
- High level risk mitigation recommendations

Not in scope:

- Business and Cost analysis of alternatives
- Properties risks (for instance, risk of over voltage to customers due to lack of three phase switch feeding transformer)
- Environmental risk associated with existing or replacement equipment
- Detailed review of work procedures associated with working in and around these underground vaults/equipment

4. METHODOLGY

The first step to the safety review was to gather relevant information on the oil filled switches and other equipment in the underground infrastructure to understand what devices are in the field, in what configurations, and for what purpose.

The database was built as a desktop exercise only. Through the construction of the database, additional at risk equipment was identified. This database was then used to prioritize vault risk based on hazards associated with oil filled equipment using a qualitative risk analysis. Finally recommendations were made as to a risk mitigation approach.

This section describes the methods used for the risk analysis including assumptions, and vault information compilation.

4.1. Risk Evaluation

Risk analysis was done by a qualitative approach using the best available desktop information. In order to perform this analysis, it was necessary to understand:

- The hazards associated with the equipment and configuration
- The scenarios, associated with those hazards, which present safety risk
- The validity of those hazard scenarios
- Potential mitigation controls for these hazards, including examining the factors which escalate the risk

This lead to risk evaluation and recommended actions based on:

- Type of equipment
- Condition of equipment
- Protection scheme of equipment (i.e. presence of CLF)
- Maintenance of equipment
- Location of equipment

Several assumptions were made in this risk evaluation:

1. Likelihood of a risk event
    a. Poorly maintained equipment has a higher chance of failure
    b. Poor condition equipment has a higher chance of failure
    c. Well maintained equipment with no signs of reduced condition (rust, leaks) is unlikely to fail regardless of age
    d. Without a CLF, oil filled equipment failure is more likely to create a severe consequence event which could be fatal
2. Public exposure to a vault can be estimated by its general area
3. Even with a CLF, failed oil filled equipment may still create a hazardous event, however it is expected to be less severe
4. New submersible equipment is in good condition therefore standing water is not an escalating factor

4.2. Vault Information Compilation

The investigation was carried out as a desktop review only. Except where explicitly noted no field checks were performed.

Data was collected on each vault through desktop exercise to capture both information pertaining to risk as well as that which will be beneficial for maintenance, operation, and design. This included gathering information on

- The location of the vault
- The feed to the vault including circuit, protection, cable type, duct material and size
- The equipment in the vault, the condition of the equipment, how it has been maintained, and how it is configured
- The condition of the vault, including sump pumps and asbestos inventory
- The crew's comments about the vault and equipment

This information was gathered from multiple records, including drawings, inspection reports, photos, and subject matter experts. Detailed information on sources and how conflicts between sources were resolved is shown in Appendix B.

5. VAULT INFORMATION RESULTS

This section explains what was found to be in the field, how the technology progressed, and where vaults are located.

5.1. Street Vault and Equipment Configuration Information

Configuration of these vaults varied and could be divided into five typical configurations. This section describes the typical equipment and the five categories. Information is then presented on the progression of technology and locations of street vaults in Vancouver.

- Cutouts (aka Oil Fuse Cutout)
  - G&W oil filled device designed to provide isolation and overcurrent protection which is often not recognized by crews. These are likely to contain PCBs. These have never been maintained. In some cases these may be gang operated but this is not clear. This equipment is from the 1960's and has no spare parts or replacements available.
- Three phase switch
  - Provides isolation, as well as three phase switching capability which prevents single phasing transformers protecting customers from over voltage due to ferroresonance
  - Several types include:
    - RAL type oil filled switches
      - RAL – A switch (shown Figure 3 and Figure 4) is an oil filled switch which allows two sources to be either off, or tied together temporarily for switching purposes, or fed to the output. Generally used in single radial vaults, this switch has PILC connections, and cannot be maintained without a prolonged outage.
      - GRA – are from the same family (GRAM) of oil filled switches from G&W as the RAL, where the tie position is replaced by a grounded position. Generally used in dual radial vaults, PILC in, XLPE out. GRA switches (shown Figure 7 and Figure 8)
    - Vacuum type, typically VacPac, with no operating procedures, remote operational capability, or spare parts
    - SF6 (non-vista) type, either single or dual radial, with no operating procedures, remote operational capability, or spare parts
    - Vista (housed outside of vault), open loop
- Transformer , oil filled device provides voltage step down
- Cable Transition Splices (Cable Transition Modules) transition to/from XLPE/PILC cable

- Junction Bars are an XLPE insulated equipment that allows the connection of multiple cables. These allow connections to be switched around for open loop, and are used to connect the transformer to switches in dual radial vaults.
- Network protector, a device common in Victoria, used in two spot network vaults in Vancouver
- Sump Pumps keep vaults dry

RAL type switches are currently slated for replacement. These switches are approaching end of life, and present operational challenges.

The following table describes typical configurations of the equipment mentioned above and shows the approximate number of each configuration found within the BC Hydro system

Table 1 - Vault Configuration

Configuration	Description	Approximate Count
1	Direct feed to transformer without 3 phase switch in vault, includes recently installed vista fed transformer vaults	42
2	Single radial, including switching capability and a transformer. Typically this uses RAL switches	19 (16 with oil filled switch)
3	Dual radial, including switching capability and a transformer. Often uses oil filled GRA switches, some SF6 and Vacuum	21 (14 with oil filled switch)
4	Open Loop with J-Bar. Only transformer contains oil.	4
5	Network, Vaults 13 and 38. Only transformer contains oil.	2

Configuration 1 – Single Radial direct feed to the submersible transformer

Isolation device oil fused cut outs

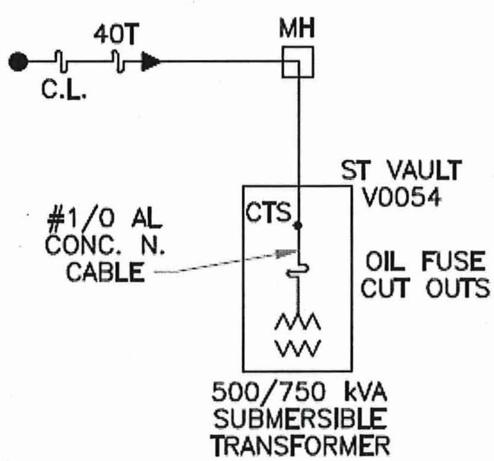

Figure 1 - Single radial one line without switch

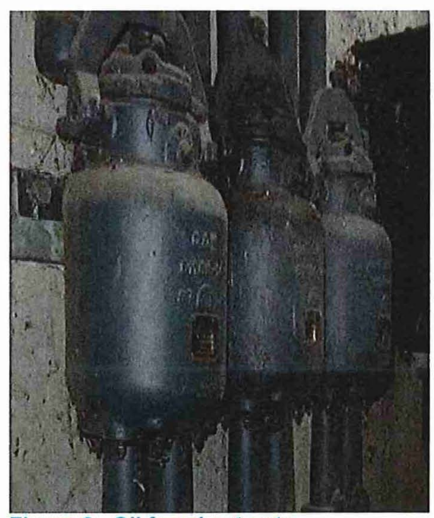

Figure 2 - Oil fused cut outs

Configuration 2 – Single Radial with 3 phase isolation switch

Typical isolation switches ; RAL switch, VacPac switch, JB

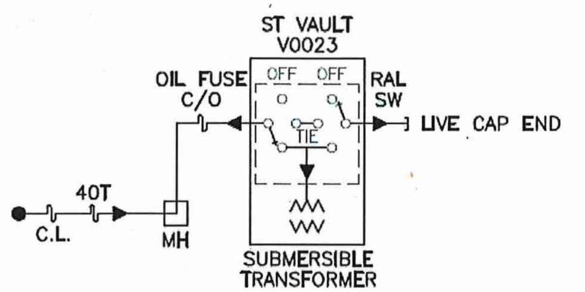

Figure 3 - Single Radial one line with RAL

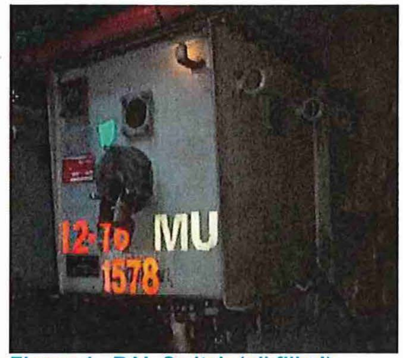

Figure 4 - RAL Switch (oil filled)

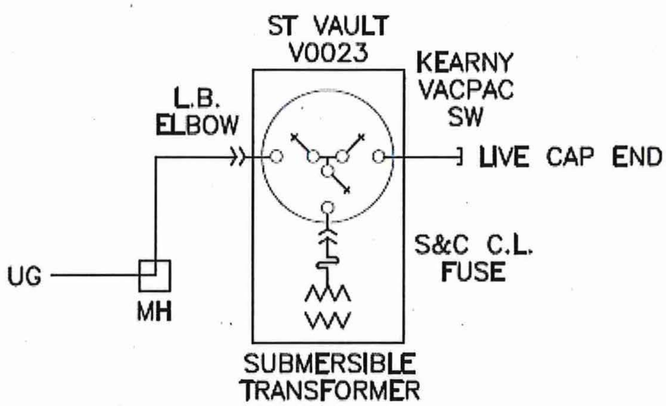

Figure 5 - Single Radial one line with VacPac Switch

Figure 6 - VacPac Switch

Configuration 3 – Dual Radial with 3 phase isolation switch

Typical isolation switches: SF6 switch, Vacuum switch, GRA switch, SVRAM33 switch

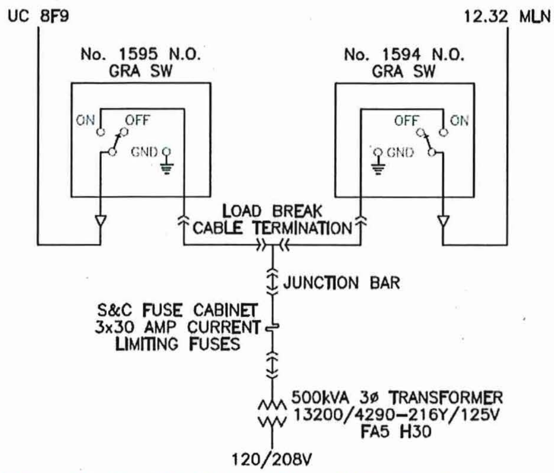

Figure 7 - Dual Radial one line with GRA switch

Figure 8 - GRA switch (oil filled)

Configuration 4 – Open Loop (Street vaults 1,2 ,10,24)

Isolation device is junction bars

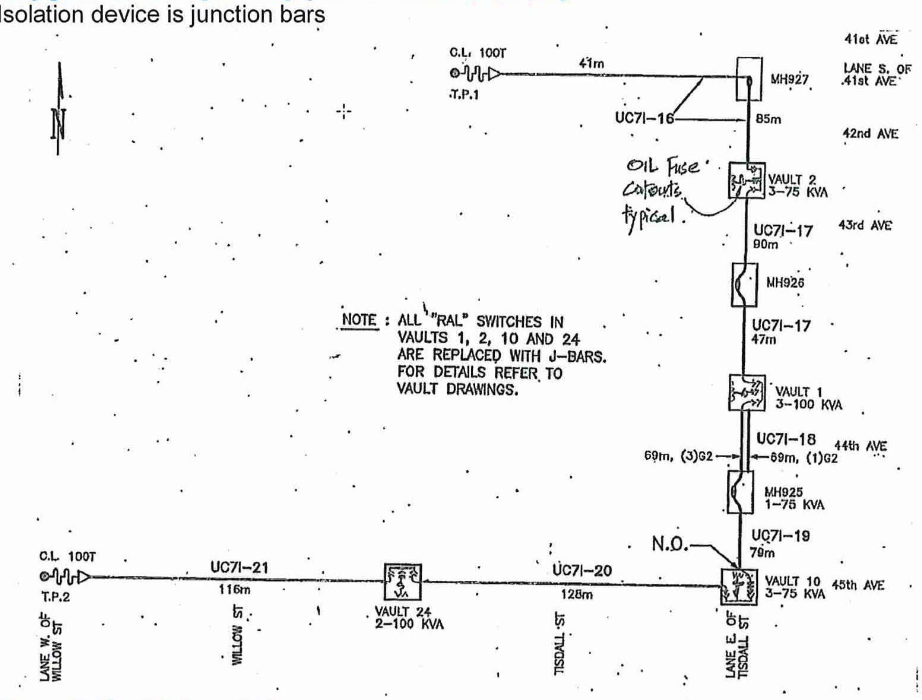

Figure 9 - Open loop one line

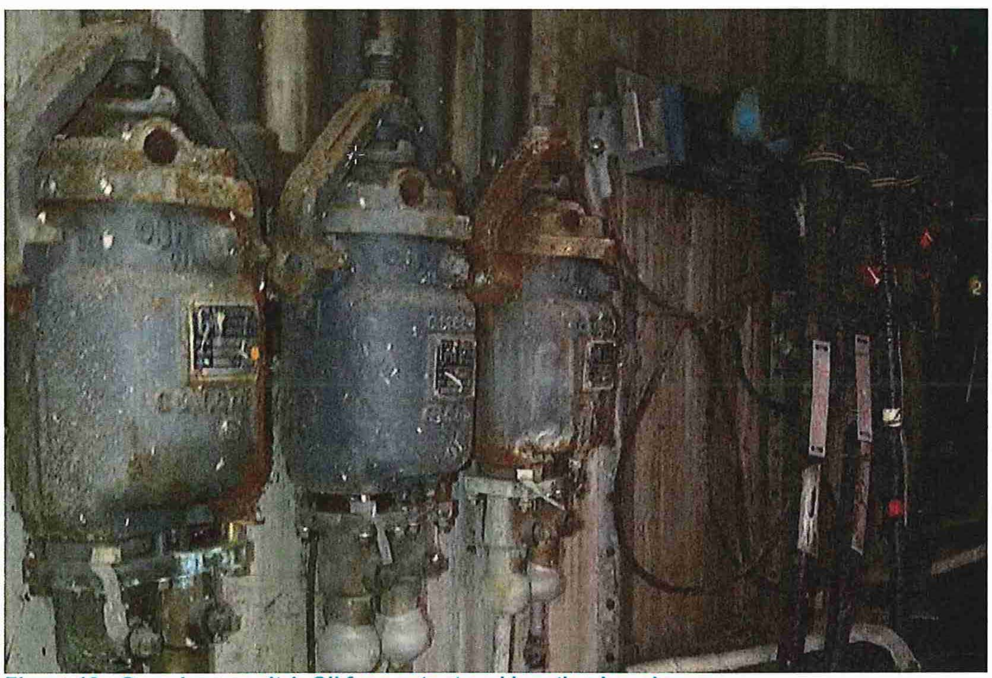

Figure 10 - Open loop vault 1, Oil fuse cutout and junction bar shown

Configuration 5 – Spot Network (Street vaults 13,38)

Isolation device is network protector

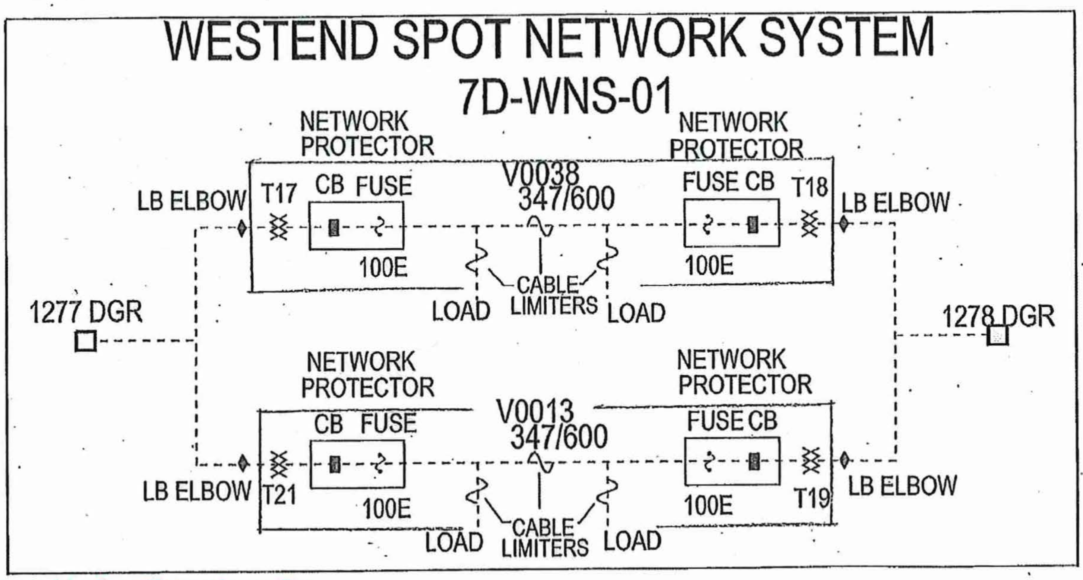

Figure 11 - Spot Network one line

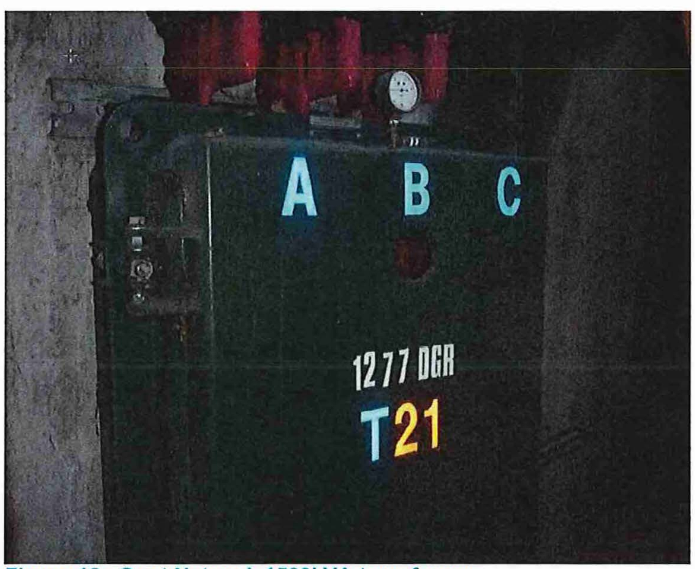

Figure 12 - Spot Network 1500kVA transformer

5.2. Technology progression

Figure 13 - Technology Chronology

Early vaults are generally single radial feeds, later including RAL switches. Typically these vaults are fed from an overhead dip designed with a current limiting fuse and feed into the vault through underground oil fused cutouts.

The next era was of GRA switches and began the age of dual radial vaults fed with both primary and standby circuits. These are most commonly underground fed, and have current limiting fuses within the vault between the GRA switches and the transformer.
Vac Pac switches were installed in the mid 1990's, mostly in Kamloops. SF6 switches were then installed through to the end of the 1990's, many of which as part of the Gastown redevelopment project.

Starting in 2012-2013 Vista switches began to be used to feed transformer vaults as part of the H-Frame elimination program.

Historically vaults were built with Transite or Black Fiber ducts. Transite and Black Fiber ducts typically contain asbestos. BC Hydro stopped using Transite ducts in 1975.

5.3. Installation Locations

The majority of vaults can be found in Vancouver (shown in Figure 14). Kamloops has 6 manholes which were believed to contain switches. Of these, 2 are empty (MH 18 and 20) and 4 contain VacPac switches (MH69, MH71, MH72, MH73) and are currently slated for replacement by system planning. VacPac switches do not present immediate public safety risk, but are identified as priority 7.
Duncan has 1 vault with three oil filled transformers fed from a junction bar. Drawings for these vaults are included in Appendix E.

Victoria has 9 vaults identified as not in scope. Identified vaults V-201, 202, 203, 204, 205, and 511 are planned to be upgraded by VI-SVI-254. Identified vaults V1, 2, and 12 are identified to be upgraded by a combination of maintenance and VI-SVI-259. Drawings for these vaults are included in Appendix F.

White Rock reported they have several underground transformer installations which at the time of this report had been slated for replacement by SI project LM-FVW-409 therefore are not examined in detail.
Prince George reported three vaults which contain non-standard junction bar installations. Drawings showing the non-standard installations in White Rock, and Prince George are shown in Appendix F.

Four customer structures appear to possibly contain RAL switches per our DAD database. Three of these customers are IPPs. These four are located at Lougheed, Cascades, Field, and Kitimat.

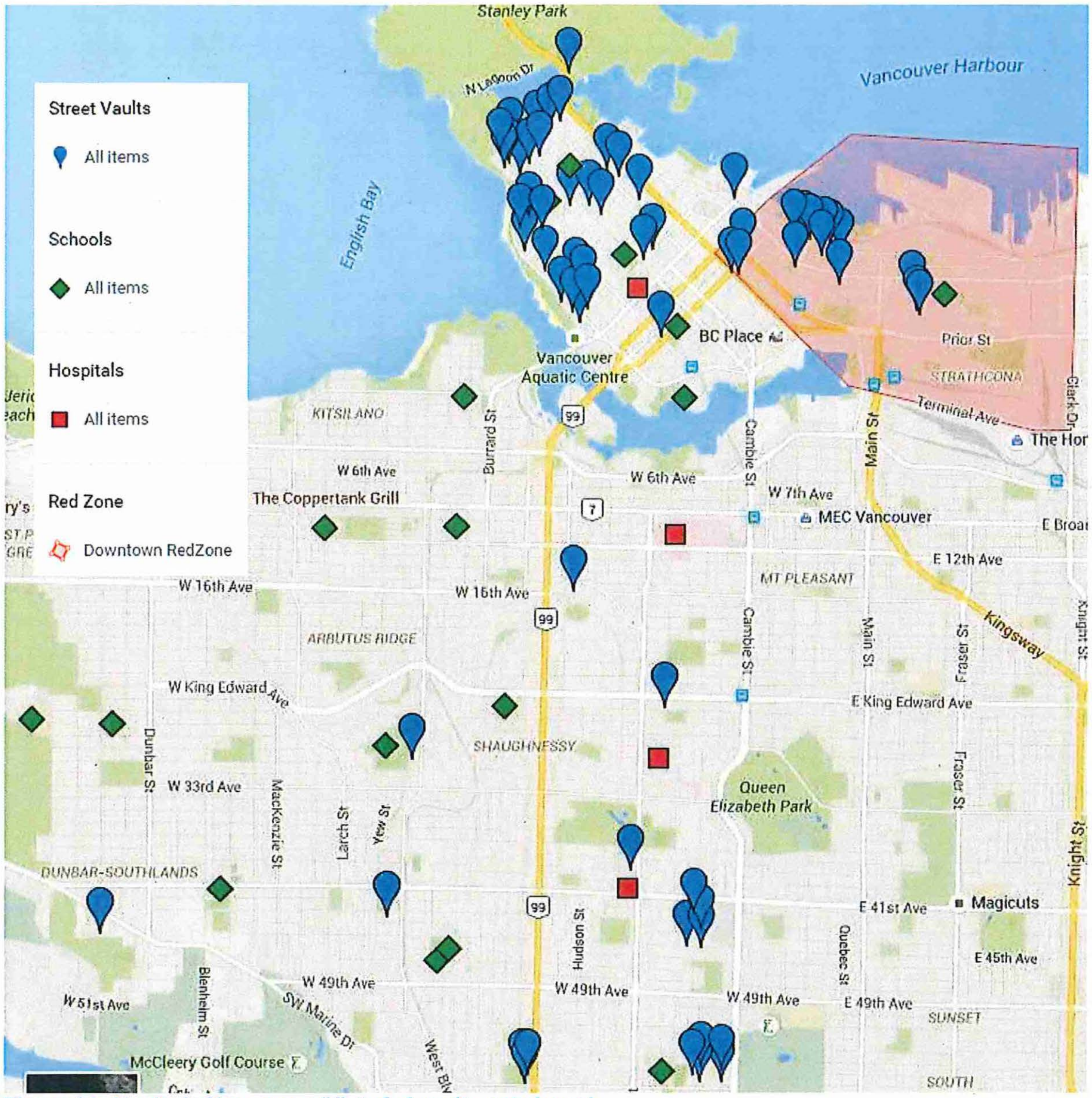

Figure 14 - Vaults in Vancouver (Vista fed vaults not shown)

6. RISK ANALYSIS

This section uses the findings of equipment to identify the associated hazards, the possible event sequence, consequence of those hazards, and past events relevant to determining the validity of the consequences. This was used to identify escalation factors to a vault event, highlight applicable barriers, and evaluate the effectiveness of various barriers. The priority vaults are then identified.

6.1. Hazards associated with Vaults

This section discusses the key hazards typical of street vaults. Hazards which do not pose immediate risk to public and worker life are shown in Appendix G.

1. Energy
    a. Electrical Energy from grid (12kV)
    b. Chemical Energy from
        i. oil in oil filled equipment
        ii. built up methane gasses from decomposition
2. Equipment
    a. Poor maintenance

6.2. Vault Event Sequences

The following vault event sequences were considered. Additional event sequences were discussed, and are shown in Appendix G.

In this report, any reference to a "Vault Event" refers to the following two scenarios.

1. High current (low impedance) fault in switch or transformer causes immediate failure
    a. Fault causes pressure to build rapidly
    b. If present, a CLF is expected to trip fast enough to prevent tank rupture in most instances
    c. If pressure causes tank to rupture, overheated oil, air, and spark mix may create an event which rapidly releases energy in a sudden heat and pressure wave
2. Low current (high impedance) fault in switch or transformer causes oil release
    a. Pressure builds until tank ruptures, problem is noticed, or protection operates
    b. Sprays or leaks hot oil possibly causing fire

The events and scenarios above could lead to several consequences including

- Severe burns or death to public in vicinity of vault
- Severe burns or death to workers in vault
- Exposure to PCBs

This report does not study in detail the procedures or work methods used in the vaults. Worker risk evaluation is based on exposure to the events above.

6.3. Past BC Hydro and Industry Incidents

Past events were researched to verify the validity of the vault event sequences presented in section 6.2.

BC Hydro Incidents:

- BC Hydro incident #82695 Level 1 employee injury. A RAL switch faulted during work on live switch. This lead to investigation 3363. The incident was caused by human error, but could have been prevented by either reduced frequency of maintenance or equipment which did not require maintenance which involved touching components of switch that would normally be live.

Utility Incidents (Public):

- Winnipeg 1976 a man received burns from a vault explosion (Ottawa Citizen, July 14, 1984 Page 13).

- Winnipeg July 11 1984 transformer explosion severely burned mother and two children, son died of burns on October 2 1984 after being in critical and intensive cares and on life support (Ottawa Citizen, October 4, 1984 Page A15). Several people believed to be exposed to PCB oil (Ottawa Citizen, July 12, 1984 Page 3).
- UC Berkeley September 30 2013 an underground oil switch manufactured by Trayer Engineering Corporation exploded causing 2nd degree burns to a student (~130 gallons oil capacity)
- San Francisco PG&E UG Transformer explosion August 19, 2005 burned head and neck of nearby woman and broke windows of nearby building.

6.4. Identification of Barriers and Escalation Factors

Given the findings for vault event sequences, the critical event was chosen to be the release of a wave of heat and pressure due to the sudden release of energy from both the electrical grid and available combustible sources. The hazard which initiates this event is the potential for a fault to occur.

Control barriers prevent the potential for an electrical fault from causing a Vault Event are shown in Figure 16 to be insulation and protection. Insulation is protected from oil deterioration and leaks by maintenance and equipment condition (Equipment Condition prevents oil contamination). Protection is protecting a fault from occurring due to transient over voltage, and preventing a fault creating a vault event by reducing the energy delivered to the fault.

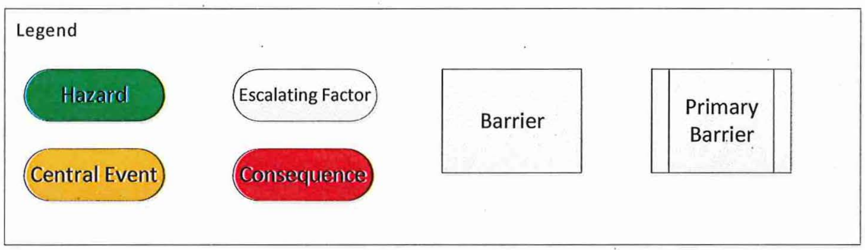

Figure 15 - Legend for following figures

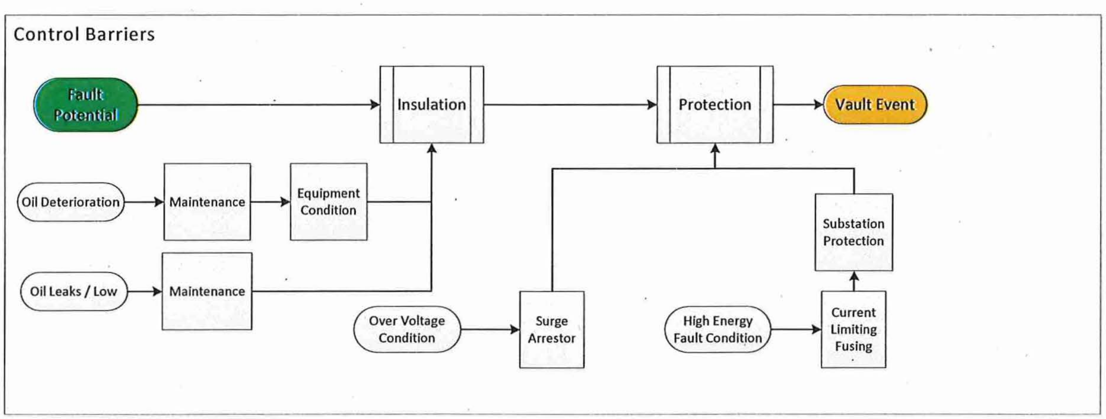

Figure 16 - Control Barriers

Mitigation barriers reduce the occurrence of injury to public or worker given the occurrence of a Vault Event. These mitigation barriers include isolation to reduce fault energy delivered, equipment which does not contribute to the available energy for the Vault Event, distance between the Vault Event and a person, and the Emergency Response available to aid the people affected. The escalation factors and barriers associated with post vault event incident mitigation are shown in Figure 17.

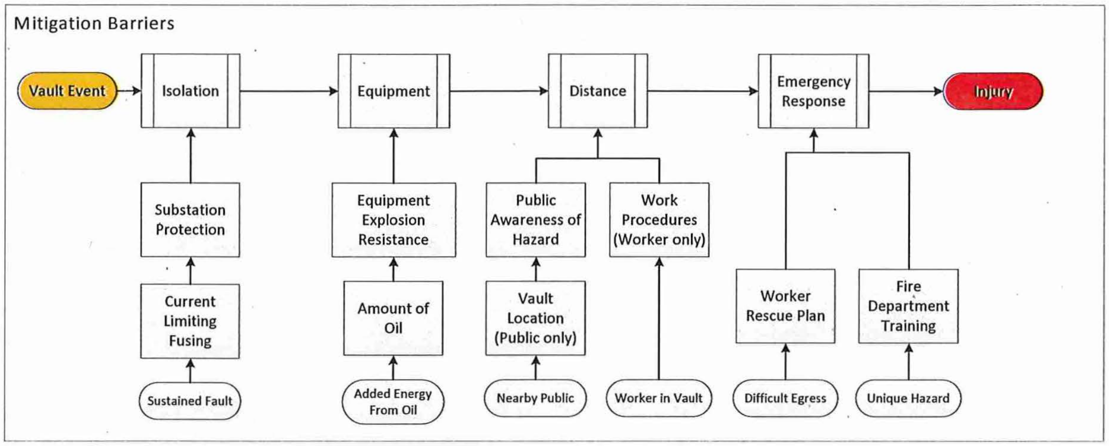

Figure 17 - Mitigation Barriers

6.5. Extract of Barriers to Use for Risk Reduction

Several of the barriers from Figure 16 and Figure 17 were identified as plausible options which would be a possible risk reduction option for some vaults, these are listed below

1. Add CLF
2. Replace poor condition equipment like for like
3. Maintain equipment with dirty or low oil
4. Repair equipment with oil leaks
5. Replace oil switches with a modern alternative (done correctly this could also; reduce worker exposure to being in the vault by reducing maintenance requirements, reduce the complexity of switching, improve the barrier which keeps workers at a distance from switching from work procedure to equipment design, and address the PCB in the oil fused cutouts by using a switch which provides overload protection)
6. Re-configure vaults to be fed by vista switchgear and contain only a transformer. *(Note: Refer to Engineering Standards Technical Report (ETR 050 R0 D2) on the options and other technical considerations for the replacement of oil filled switches, transformers and fuses)*
7. Place alternative switchgear outside of the vault
8. Increase vault inspection frequency
9. Move the vault to lower public exposure area (such as lane instead of sidewalk)

Other barriers, such as substation protection may be effective if improved but the consideration was not possible for this analysis as the effects of any changes have widespread impacts and thus should be carefully considered.

6.6. Barrier Effectiveness Evaluation

Using section 6.5 various risk reduction options were evaluated to determine how well they addressed the escalating factors which deteriorate the effect of either control or mitigation barriers. Table 2 presents which risk factors each mitigation strategy addresses.

Explosion chance and severity are considered the most important to control, as these affect both workers and public. Public and Worker exposure are on similar grounds.

Table 2 - Evaluation of remedial action alternatives

		Barrier Improvement Activity					
		Add CLF	Repair switch	Upgrade switch	Repair Tx	Upgrade Tx	Relocate Vault
Control	Tx Fault						
	Switch Fault						
Mitigate	Public						
	Worker						

Control: Evaluated on ability to control or prevent an vault event **Mitigate**: Evaluated on ability to reduce consequences given a vault event has occurred.	Legend:	Improvement Some Improvement No Change

Add CLF

The addition of a CLF above all oil filled equipment is both a control and mitigation barrier. By reducing available fault energy a CLF reduces the likelihood of oil filled equipment bursting. If the equipment does rupture, it is likely to be less severe, resulting in a more controlled oil air mixture rather than a severe Vault Event.

Repair Switch

Repairing the switch prevents oil loss and deterioration. Repair may also improve the condition of the switch, reducing the chance of the tank rupturing if a fault occurs within it.

Upgrade Switch

Upgrading the switch to a modern day non-oil switch has several improvements. Modern switches do not have oil which eliminates a source of energy which could contribute to a vault event. Additionally, they offer protection which can assist in mitigating the effects of a vault event caused by a fault in the transformer. The final benefit of upgrading the switch is to allow the removal of the oil fused cutouts which are likely to contain PCB oil and thus must be removed by December 31, 2025.

Repair Transformer

Repairing the transformer prevents the occurrence of a transformer fault similar to repairing a switch.

Upgrade Transformer

Upgrading the transformer allows for the specification of a blast resistant transformer with built in CLF, which mitigates the effect of a vault event on crew within the vault.

Relocate Vault

Relocating the vault provides the opportunity to increase the distance between vault and public. Relocation could be to a nearby alley, or to the street instead of sidewalk if in an area where loitering in alleys is a concern.

6.7. Ranking Qualitative Escalation Factors

As it was found that equipment condition and maintenance were important factors in the likelihood of a vault event, vaults were given a ranking for equipment condition as described in Table 3 in order to ensure consistency or risk ranking across vaults. A separate ranking was given for each vault for public exposure level, as this is an important mitigation control.

Quantifying vault condition was done based on maintenance information and condition notes from recent inspections. Maintenance records for transformers were not considered as part of condition rating due to consistently inconsistent records. Transformer condition notes were considered.

As over 50 vaults have no verified CLF, this was not considered in equipment condition rating under the intention that all vaults are to be retrofitted to be CLF protected.

Table 3 - Equipment Condition Ratings

Equipment Condition Rating (database value)	Description of equipment
Poor (1)	Heavily damaged or severe condition per either SAM or 2012 asbestos reports. Noted as overdue for inspection in SAM or unknown condition/maintenance
Fair (2)	Fair condition, may have slight oil leaks and corrosion or hot connection
Good (3)	Good condition equipment. No known defects Requires field validation.
Excellent (4)	No high risk equipment (except asbestos)

Quantifying public exposure was done by area, and particular risk factors.

Table 4 - Public Exposure Ratings

Public Exposure Rating	Description
1	High pedestrian traffic, parks, schools, commercial, entertainment districts, and the red zone. This includes the first block off of major beaches.
2	Other metropolitan areas
3	Suburban areas (single family dwellings) and rural. Additionally alleyways not in the red zone.

6.8. Vault Risk Results

Vaults were categorized into risk levels, which were consolidated into priorities. Table 5 shows the number of vaults ranked at each priority, assuming that a CLF has been added to all vaults. Condition 1 vaults are listed in Appendix A. Priority 1 vaults are the most urgent to address.

Table 5 - Number of vaults by priority

Rating		Priority	Number of Vaults
Equipment Condition	Public Exposure		
Poor	1	1	9
Poor	2	2	3
Poor	3	3	2
Fair	1	4	8
Fair	2	5	13
Fair	3	6	7
Good	1	7	21
Good	2		
Good	3		
Excellent	X	NA	27

7. RECOMMENDED ACTION ITEMS

This section presents immediate term, mid-term, and long-term recommended actions. Strategic opportunities have been identified which help BC Hydro meet regulatory requirements moving forwards.

7.1. *Immediate Term (F17 and F18)*

- Verify the database information in the field, repeat the risk prioritization method for new information, and update SAM/DAD.
- Install overhead current limiting fuses (CFLs) to protect three phase underground oil filled equipment in single radial and OH fed street vaults. While, the best safety informed solution requires a CLF installed for all oil filled equipment, given the space constraint in dual radial vaults fed by UG supply, continued close monitoring of UG fed dual radial vaults with immediate action on those which become poor condition can be a practical safety informed solution.
- Replace and upgrade the five dual radial street vaults (V58, V67, V69, V70, and V73). To align with System Planning's recommendation to upgrade to an open loop configuration with dual ratio submersible transformers with built-in CLFs.
- Repair, maintain and implement the recommendations for the remaining 9 units as outlined in appendix A.
- Investigate suitable replacements for RAL, VacPac, and non-vista SF6 switches, as well as oil fused cutouts.
- Sample all oil filled switches to determine if PCB contaminated and assess condition and action.
- Develop oil sampling procedure for transformers.

7.2. *Mid Term (F19 and F20)*

- Sample transformer oil using the procedure developed in F17 and F18 to determine if PCB contamination is greater than 50 ppm.
- The remaining oil filled switches and transformers that are identified to be in fair condition are maintained, repaired, or replaced with suitable alternative (if feasible) to align with the strategy for downtown redevelopment project.
- Continued close monitoring of dual radial vaults without CLF and immediate action on poor and fair condition
- Investigate to improve tracking and record keeping for oil tests.
- Fix sumps to prevent standing water causing corrosion issues.

7.3. *Long Term (F21 and beyond)*

- Replace all remaining oil filled switches by December 31, 2025
- Replace transformers with PCB contamination greater than 50 ppm by December 31, 2025.
- Replace all remaining <u>non-oil filled</u> three phase switch (e.g. SF6, VacPac) with vista or suitable alternative aligning with downtown redevelopment strategy.

7.4. *Strategic Opportunities*

- Since the oil fused cutouts were installed around 50 years ago, it is likely that they contain PCBs and thus should be removed from service as opportunities arise. BC Hydro must meet a deadline of no PCBs greater than 50 ppm by December 31, 2025.
- There is an opportunity to proactively address WSBC regulation 9.4 by investigating non-oil type transformers for confined spaces.

- When installing new equipment into existing vault, the civil structures must be assessed to ensure its suitability for the life of the new equipment and to ensure that the condition and the size of the structures can accommodate the new equipment.

8. ADDITIONAL FINDINGS AND RECOMMENDATIONS

There were findings through this investigation not related immediately to vault risk for explosion. These are presented in the table below.

Table 6 - Additional Findings

Finding	Recommendation
Poor reference between civil and electrical drawings	Implement drafting process to include electrical reference on civil drawings and vice versa
Confusion due to repeated use of terms for different meanings over time	Implement process to ensure drawing type names are not recycled for different purposes over time (for instance UDD)
Inaccurate or out of date information in DAD	Add component of DAD training which tells users who to contact about inaccurate information (for instance drawing references)
Records are spread out and difficult to find	Consider a record keeping system that kept reference to all drawings and maintenance records in one place for a given vault, and searchable by equipment type to be able to find all of a given type of equipment more accurately than currently available through DAD

9. CONCLUSION

Risk analysis was performed for underground oil switches and other aging underground equipment. A database was created to collect information about these switches which will be a resource for both continued vault risk monitoring and maintenance. Following the recommended action items will reduce the risks to public and contribute to reduced risk to workers represented by aging oil filled equipment in BC Hydro underground structures.

10. REFERENCES

BC Hydro. (n.d.). *Business Case F15, F16 Underground Equipment Replacement Program.*

BC Hydro. (n.d.). *ES 64-C-03.03.*

Boy dies of burns from transformer blast. (1984, October 4). *Ottawa Citizen*, p. A15.

Engineering, P. (2008, 11 01). *Oil-Filled Transformer Explosions*. Retrieved 04 2016, from Power Engineering: http://www.power-eng.com/articles/print/volume-112/issue-11/features/oil-filled-transformer-explosions.html

Experts still baffled by fiery explosion of hydro transformer. (1984, July 14). *Ottawa Citizen*, p. 13.

Mom kids scorched as Winnipeg blast hurls fireball. (1984, July 12). *Ottawa Citizen*, p. 3.

Park, S. (2013, 12 16). Dirks states Sept 30 explosion likely caused from short in electrical switch. *The Daily Californian.*

Subject Matter Experts. (2016, February - March). (See Aknowledgements).

Suit filed in Winnipeg blast. (1984, September 07). *Ottawa Citizen*, p. 12.

Vrecko, B. (2016, March 10). Email RE: V63 drawing - 603-D522682. (H. C. Luk, Interviewer)

Wahlgren, C., Leix, K., & Webb, J. (1992). Current Limiting Fuses Address Safety and Power Quality Concerns. *Rural Electric Power Conference* (pp. C4-1 - C4-5). New Orleans, Louisiana: IEEE.

Work Safe BC. (n.d.). *Part 9 Confined Spaces*. Retrieved 04 2016, from Work Safe BC: https://www2.worksafebc.com/Publications/OHSRegulation/part9.asp#SectionNumber:9.4

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APPENDIX A: LIST OF "POOR CONDITION VAULTS"

This Appendix shows the 14 vaults considered in poor condition (to be verified), ordered first by location, then severity.

Public Exposure	Vault	Configuration	Location Description	Main Issue	Recommended Action
	V8	3	E Georgia st, 49ft E of Dunlevy	Tx and switch bad shape. Single RAL used for dual radial service.	Assess condition. Replace with suitable alternative if condition is poor
	V70	3	on Abbott St 20' N of Water	Tx needs replacement for damage and corrosion. 7*C elbow heating	Rebuild vault with new equipment (i.e. 3-way vista and submersible transformer). Replace elbow.
	V69	3	On Water 170' E of cambie	Tx corroded and needs replacement	Rebuild vault with new equipment (i.e. 3-way vista and submersible transformer)
	V49	2	Broughton st, lane N of beach	Severe corrosion on all equipment, oil dark and low	Change Oil, assess condition. Replace with suitable alternative if condition is poor.
	V15	2	Lane W of Arbutus, S of Valley	Lid welded on (no maintenance)	Change Oil, assess condition. Replace with suitable alternative if condition is poor.
	V28	2	Lane S of Alberni St E of Jervis	Dark RAL oil and unclear viewing window, no oil sample, swollen splice	Change oil, assess condition. Replace with suitable alternative if condition is poor. Replace splice.
	V67	3	On Water, 220' W of cambie	Oil failed insulation test	Rebuild vault with new equipment (i.e. 3-way Vista and submersible transformer)
	V58	3	Carrall St and Lane N of Cordova	Switch 1685 has rusting on top, little information	Rebuild vault with new equipment

				in butterfly	(i.e. 3-way Vista and submersible transformer)
	V12	1	Lane N of Burnaby on Bidwell	Inspection overdue, corrosion, cutouts may be bypassed.	Repair equipment
2	V73	3	on Burrard St 72' N of Hastings	Oil failed insulation test, not shown on UDD	Rebuild vault with new equipment (i.e. 3-way Vista and submersible transformer)
	V21	2	Lane N of Pendrell at Gilford St	RAL leaking, oil level "not in sight" (too full or empty?)	Replace RAL with spare unit
	V22	2	Lane N of Barclay on Chilco St	Switch oil dark and low	Change oil
3	V29	1	St Clair Place rear 46 at olympic	Tx connection loose (fixed yet?)	Repair equipment
	V40	2	Lane S of Robson E of Chilco	5 year inspection last done 2005	Change oil

APPENDIX B: VAULT INFORMATION SOURCES

Below describes typical information sources, along with the method used to ensure the best possible information was kept. The table correlates sources to information gathered. Exceptions to these typical information sources are listed in Appendix C by vault.

- Asbestos photos, entry logs (butterfly reports), and consultant reports
- Vault Diagrams (historical) provided by field crews responsible for maintenance
- Underground Distribution Diagrams (historical UC series)
- Underground Distribution Diagrams (current series)
- U06 drawings
- U07 drawings
- GIS (DAD and SAM)
- PowerTech oil sampling records
- Dual radial vault inspection whiteboard from HPN
- Vault inspection logs from CLF check
- Google Maps and Streetview
- Subject Matter Experts (see acknowledgements)
- Other drawings and historical drawings as required to fill in information gaps

Appendix B shows details to assist the reader in understanding where each specific type of information was gathered from. Appendix C shows vault specific information sourcing exceptions. As some information had multiple sources, conflicts were found. Where conflicts arose either the most recent reliable information or most conservative information was kept, as described below.

Example of where most recent reliable information is kept. Much information comes from street vault diagrams or distribution operating diagrams (depending on era), which show the original build, typically including revisions and modifications up to the late 80's or early 90's. If a more recent source, such as DAD contradicts this, the more current source is taken as correct, unless 2012 asbestos photo's support the original design in which case a risk note is entered to raise awareness of the conflict.

Example of where information retention overrules currency. If the 2012 butterfly report indicated that the transformer was leaking, but DAD zone awareness did not, the information is kept that the transformer is leaking, as the butterfly is considered reliable, entry may have been missed into DAD, and we seek to be conservative. However for inspections it is assumed that DAD/SAM is correct.

Type	Typical Source
Configuration	Amalgamated from all vault information
Dimensions	Vault List from David Calder
Location	Vault List from David Calder
Area	Vault List from David Calder
Civil Drawing Number	Vault List from David Calder
UDD	UDD lookup by intersection
CCT #	Various, including DAD which was considered most reliable.
Configuration	Various, including vault list from David Calder, U06 drawings, DAD. Considered OH if the upstream CLF to protect whole vault would be placed on a TP
Cable Type	Based on Cable size code, U06 drawing, photos, DAD zone awareness
Cable Size	U06 Drawing, or UDD(UC series)
Primary Duct	U07 drawing, may include some secondary ducts, Vista vaults appear to follow trend of 2x4" and 2x5", some note that the 4" are primary, it is assumed this is typical. Some may even include communications ducts if indistinguishable
Transite Duct	U07 drawing or DAD, or Asbestos report if duct or collar specified as Transite. Any asbestos material not either conduit or collar is not considered in this column. (Ex. V25 has ACM putty near collars, this means the vault has asbestos but not "Transite duct" with the assumption this could be removed before pulling cable.
Feed CLF	Street Vault diagram notes, UDD(UC series),
Feed CLF Verified	Verification by field reports from David Calder
Tx CLF	Street vault diagram, in many instances fuse known to be S&C by observing the revision date which added CLF (~1988) on the vault diagram, along with CLF model number pattern to be similar to that of Vault 72 known to be S&C by picture
Tx CLF Verified	This is either noted by DC inspections, or shown in a picture (a picture may not confirm the CLF is connected)
Switch	Street Vault Diagram, Photo's, DAD
Switch Termination	Switch type, photo's
Switch oil test	Powertech oil sample dates

Type	Typical Source
CTS	Estimate based on cable types at various locations and photos
Cutout	Photos, Butterfly, Street Vault Diagram
Transformer	Street Vault Diagram, Butterfly, DAD,
Transformer age	Butterfly report. Note: Unknown means not noted, where "No Date" means nameplate does not indicate date
Transformer oil test	Powertech oil analysis records,
Next 1 year	This documents the next 1 year inspection date as taken from HPN office tracking system for dual radial oil filled switch vaults around Vancouver. Failed indicates the last oil test was a fail, unknown indicates it is a dual radial vault with oil filled switches that is not tracked.
Standing Water	Butterfly, asbestos report
Asbestos	asbestos report
Public Exposure	Google maps overlaid with vault co-ordinates based on DAD, streetview, and UCC drawings combined. Rankings per table in report. 1 high (many people walking), 3 low (single family dwelling area)
Equipment Condition	Uses condition notes on equipment and equipment type to quantify the likelihood of a failure occurring in a given vault. Ranking per table in report. 1 high (sever condition equipment), 4 low (no standing water or at risk equipment)

APPENDIX C: EXCEPTIONS TO VAULT INFORMATION SOURCES

Vault	Variance
MH 914	Powertech oil lab results, MH 914 inspection folder, dwg 12.67 DGR
V0008	all information usually from David C sourced instead from DAD and inspection.
V0013	additional information source underground feeder diagram 12F77DGR
V0038	additional information source underground feeder diagram 12F77DGR
V0067	cable size from butterfly not electrical drawings
V0069	duct size from DAD not civil
V0069	cable size from butterfly not electrical drawings
V79	No photo verification of termination types or equipment other than GRA switches, assumption of PILC to XLPE transition at GRA switch based on preceding vaults
V82	Source pictures and asbestos inspections and DAD only. No design drawings found
V70	Cable size from butterfly only
V16	size from TD19765 as size in DC list appeared erroneous
V68	Cable size assumption 4/0 for size due to dual radial and lack of drawing
V92	3x500kVA transformers cannot fit in the vault size noted in 455-U07-D1516, it is suspected that the vault size is the standard vista vault 6.3x2.4x3.25m
V42	Location based on DAD as file location appears inaccurate

APPENDIX D: EXCERPT OF DATABASE

The following pages contains the following printed excerpts of the database:

- Safety Consideration Printable Extract
- Reference Material Printable Extract
- Vault Summary Printable Extract
- List of vaults outside scope of project that should be field checked
- List of disqualified vaults, which were at one time believed to contain a switch but determined to be either out of scope or found to not contain a switch

Database column descriptions are shown in appendix H.

APPENDIX E: VAULT DRAWINGS

Appendix E contains vault drawings for vaults contained in the database with known vault drawings

APPENDIX F: NON STANDARD VAULT DRAWINGS

Appendix F contains drawings and email records regarding non-standard vaults found in Whiterock, and Prince George.

Appendixes D, E, and F are large and are contained in separate PDF files, included at the back of printed report.

APPENDIX G: ADDITIONAL HAZARDS AND SEQUENCES

This appendix shows all discussed hazards and safety sequences, including those which did not fit within the scope of the report.

Hazards:

1. This section discusses the hazards typical of street vaults. This appendix includes hazards not considered key hazards therefore not discussed in the report body. Energy
    a. Electrical Energy from grid (12kV)
    b. Chemical Energy from
        i. oil in oil filled equipment
        ii. built up methane gasses from decomposition
        iii. nearby gas lines
2. Equipment
    a. May not meet today's standards (including for visual open verification)
    b. May not be installed to today's standards
    c. May not be installed to industry best practice (No CLF)
    d. End of Life
    e. Poor maintenance
3. Chemical
    a. PCBs
    b. Asbestos
4. Confined Space

Safety Sequences:

1. High current fault in switch or transformer causes immediate failure
    a. Fault causes pressure to build rapidly
    b. Pressure causes tank to rupture at which point overheated oil, air, and spark mix may create an event which releases sudden heat and pressure wave
2. Low current fault in switch or transformer causes oil spray or explosion
    a. Pressure builds until tank ruptures, problem is noticed, or protection operates
    b. Sprays or leaks hot oil possibly causing fire
3. Leaking oil (with PCB)
4. Cable fault creates arc flash, possible cable fire
5. Inability to sample oil for single radial RAL switches due to inability to refill oil on live switch
6. Inability to operate switch due to dirty oil preventing visibility of open

The events and scenarios above could lead to several consequences including

- Severe burns or death to public walking above vault (caused by 1 and 2)
- Severe burns or death to workers in vault (caused by 1 and 2)
- Exposure to PCBs (caused by 1, 2, and 3)
- Lack of knowledge of switch condition (caused by 4)
- Prolonged customer outages (caused by 5)

To match the report scope, risk event sequences 1, 2, and 3 are considered, with emphasis on 1 and 2.

Risk event sequence 4, while presenting an event consequence similar to those of sequences 1 and 2 has been addressed by arc flash requirements and distribution standards modified manhole covers. Therefore consequences are not discussed.

APPENDIX H: DESCRIPTION OF DATABASE COLUMNS

Information		Description
Vault Info	Region	Describes region, for example Vancouver or Kamloops
	Number	The vault identification number (or manhole number)
	Config 1	The configuration of the vault (single or dual radial, etc)
	Dimensions (LWH)	The dimensions of the vault structure itself
	Location Description	Describes vault in relation to street intersections
	Area No	The area number used in drawing numbers describing the vault
	Civil Drawing Number	Typically the digits following "Area no-U07-0..."
	Vault Dwg Number	The drawing number of a drawing which shows electrical configuration of vault
Feed	UC / Elec Dwg Number	The drawing number that shows the feed to the vault
	UDD #	The map section which includes the vault
	CCT #	The circuit numbers which feed the vault
	Config 2	Identifies if feed is overhead or underground, using criteria "where would CLF be placed upstream of vault"
	Cable type	Identifies if PILC cable is used
	Cable size	Identifies cable code believed to feed vault
	Primary Duct	Identifies number and size of primary ducts feeding vault. May include secondary ducts if unclear
	Transite Duct?	Identifies if the duct has been identified as transite or black fiber
	before vault	Identifies if a CLF is shown in design drawings to be before the vault
	b4 vault verified	Identifies if a field check has confirmed presense of the CLF before vault
	before Tx	Identifies if a CLF is shown in design drawings to be before the transformer
	b4 Tx verified	Identifies if a field check has confirmed presense of the CLF before transformer
Switch	type/ make/model	Identifies switch type (Eg. RAL, VacPac, etc)
	Switch Source termination	Identifies if switch termination is PILC or XLPE
	Switch Load termination	Identifies if switch termination is PILC or XLPE
	Powertech Oil Test	Notes date of most recent oil sample received from powertech, for the switch in the vault which was least recently tested
	Next 1 yr Insp	Identifies when the HPN switching vault maintenance whiteboard identifies the next 1 year inspection to be required

	HPN Inspection	Identifies the date of the inspection performed in 2015, "?" suggests a record was received in the 2015 inspection records but not dated
Splice	CTS	Identifies if it appears there is a cable transition splice in the vault
Cutout	type/make	Notes cutout type which could be an oil fused cutout, or a CLF inside vault
	Cutout termination	Identifies if cutout termination is PILC or XLPE
Transformer	Size	Size (kVA) and number of transformers
	Secondary Voltage	Secondary voltage of transformer
	Transformer termination	Primary termination of transformer (PILC or XLPE)
	Age	Age of transformer (if known)
	Powertech Oil Test	Date of most recent powertech record for transformer oil test
Hazards	Standing Water	Identifies if vault is noted to have standing water
	Asbestos testing	Result of 2012 asbestos testing (Positive or Negative)
	Exposure	Rating of 1-3 for how much public exposure the vault has
	Condition	Rating of 1-4 for the condition of the equipmetn in the vault
	Overall Rank	Rating of 1-7 of how immediately further action should be performed on the vault
	Risk Notes	Records condition notes, and other notes on the vault collected through all sources including SAM, Inspection reports, pictures, google maps street view, etc.

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BC Hydro Electrical Explosion Incident – Marine Building, Downtown Vancouver

Attachment 5

2023 BC Hydro Vault Incident Filings

BC Hydro
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March 14, 2023

CONFIDENTIAL

Sara Hardgrave
Acting Commission Secretary and Manager
Regulatory Services
British Columbia Utilities Commission
Suite 410, 900 Howe Street
Vancouver, BC V6Z 2N3

Dear Sara Hardgrave:

RE: British Columbia Utilities Commission (BCUC or Commission)
British Columbia Hydro and Power Authority (BC Hydro)
Electrical Explosion Incident – Marine Building, Downtown Vancouver –
CONFIDENTIAL Responses to Commission Staff Questions

BC Hydro writes to provide its responses to Commission Staff Questions from March 7, 2023.

1.0 Please provide a description of incident, including the location, timelines and a detailed explanation of the cause of the incident.

RESPONSE:

At approximately 6 p.m. on February 24, 2023, there was a fire and explosion in an underground vault located near Burrard and Hastings streets in downtown Vancouver. There was significant damage to the vault as well as the street.

The fire was quickly extinguished, and BC Hydro helped first responders and City of Vancouver officials cordon off the area to keep the public and its crews safe.

BC Hydro does not know the cause of the incident at this time. The investigation is ongoing. We expect to have the findings of the investigation at the end of April.

Once the investigation is finalized, BC Hydro will submit its final employer incident investigation report to WorksSafeBC. BC Hydro is required to submit an employer incident investigation report to WorkSafeBC in accordance with the *Workers Compensation Act* and WorkSafeBC prevention policies. After the report is submitted, WorkSafeBC may conduct their own investigation, follow up with information requests, or decline to inquire further.

2.0 Please explain whether BC Hydro has previously inspected the site of the incident. If so, please provide the date and findings of the most recent inspection prior to the incident. If not, please explain.

RESPONSE:

BC Hydro regularly inspects and maintains its equipment. The vault was inspected in November of 2021 and oil filled switches of interest inside the vault were last inspected in March of 2022 and found to be operating normally.[1] Further, BC Hydro crews were in that vault on February 10, 2023, and no issues were reported at that time.

3.0 Please describe the number of people injured as a result of the incident, the nature of their injuries and an update on the status of the people injured.

RESPONSE:

Two people were injured as a result of the incident. According to media reports and comments from the Vancouver Fire Department, these individuals suffered facial burns and lacerations as a result of the explosion, were taken to the hospital and were in stable condition at that time. Out of respect for the privacy of these individuals, BC Hydro has not requested an update on the status of their injuries and has not asked the agencies involved to disclose their identities to us. However, our Customer Relations team is prepared to immediately respond should they reach out to BC Hydro regarding the event.

No employees or contractors were injured.

4.0 Please describe any similar incidents that have occurred in the past, and whether any lessons learned from those incidents were implemented or relevant to the site and situation of this incident.

[1] The oil filled switches involved in this incident have a long history of safe and reliable operation at BC Hydro since the 1960s and are similar to equipment still used by other utilities in North America. BC Hydro has a program, developed in 2011, to upgrade oil-filled switches. BC Hydro has two remaining electrical vaults that contain similar equipment to the electrical vault that caught fire on February 24, 2023. BC Hydro is expediting the decommissioning of this equipment out of an abundance of caution and expects to complete this work by the end of March 2023.

RESPONSE:

At this time, BC Hydro does not know the cause of the incident. Findings of the investigation are not expected to be available until at least the end of April. It is too early to say whether any past incidents are relevant to this incident.

That said, there have been two other fire and explosion type incidents in the downtown core in the last 15 years.

In July 2008, there was an explosion and fire that lead to an outage. This was found to have been caused by an overheated connector in a maintenance vault. While underground circuit failures are not uncommon, the investigation found this situation to be unique as the equipment was only three years old and typically this equipment has a lifespan of 30 or more years.

In January 2021, there was a fire and explosion involving a different type of equipment. BC Hydro conducted an extensive investigation, and determined the incident was caused by a third-party as a result of a cable damaged during an excavation that was not reported to BC Hydro.

5.0 Please list the total number of customers impacted by the incident and length of the corresponding power outage(s).

RESPONSE:

There were seven customers impacted by the incident:

1. **DAON Developments**
2. **Bank of Canada**
3. **Bank of Commerce**
4. **Office Building (510 Burrard)**
5. **The Vancouver Club**
6. **A parking garage**
7. **A pump station for the City of Vancouver**

The first four customers were re-energized at approximately 1:00 p.m. on February 25, 2023.

The three remaining customers that receive power from a secondary line in the transformer vault were restored with a temporary source the evening of February 25, 2023. Restoring these customers was more complex but was

completed ahead of estimated restoration time. Planning for the permanent service restoration is in progress and a completion date is still to be determined.

BC Hydro will continue to keep the Commission updated on any key developments and findings.

For further information, please contact Alicia Henderson at 604-623-4381 or by email at bchydroregulatorygroup@bchydro.com.

Yours sincerely,

Chris Sandve
Chief Regulatory Officer

cs/ma

BC Hydro
Power smart

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March 29, 2023

CONFIDENTIAL

Sara Hardgrave
Acting Commission Secretary and Manager
Regulatory Services
British Columbia Utilities Commission
Suite 410, 900 Howe Street
Vancouver, BC V6Z 2N3

Dear Sara Hardgrave:

RE: British Columbia Utilities Commission (BCUC or Commission)
British Columbia Hydro and Power Authority (BC Hydro)
Electrical Explosion Incident – Marine Building, Downtown Vancouver –
CONFIDENTIAL Responses to Commission Staff Questions No. 2

BC Hydro writes to provide its responses to Commission Staff Questions No. 2 from March 15, 2023.

1.0 Please describe the equipment that was in the underground vault where the fire and explosion occurred.

RESPONSE:

The equipment that was in the underground vault where the fire and explosion occurred includes:

- **Two Oil Filled Three Phase Switches:**
  - **Switch A connects/disconnects the normal 12.5kV three phase supply; and**
  - **Switch B connects/disconnects the standby 12.5kV three phase supply.**
- **Three Single Phase Primary Junction Bars:**
  - **Connect supply from Switch A and Switch B and provide a point for distributing power to loads at 12.5kV three phase. In this vault, the Primary Junction Bars only supplied power to the fuse box described below.**

- **One Three Phase Fuse Box:**
  - **Provides overcurrent protection to the Step Down Transformer in the vault.**
- **One Oil Filled Three Phase Step Down Transformer:**
  - **Steps voltage down from 12.5kV to 600/347V three phase for BC Hydro secondary voltage customers supplied from this vault.**
- **Four Single Phase Secondary Bus Bars:**
  - **Provide a point for distributing power to various secondary voltage BC Hydro customers at 600/347V three phase.**

2.0 Please provide a list of similar vaults (i.e. with similar equipment) with locations of each. Please include a map of downtown Vancouver showing the locations of the similar vaults.

RESPONSE:

As of March 14, 2023, the two remaining vaults with similar equipment were:

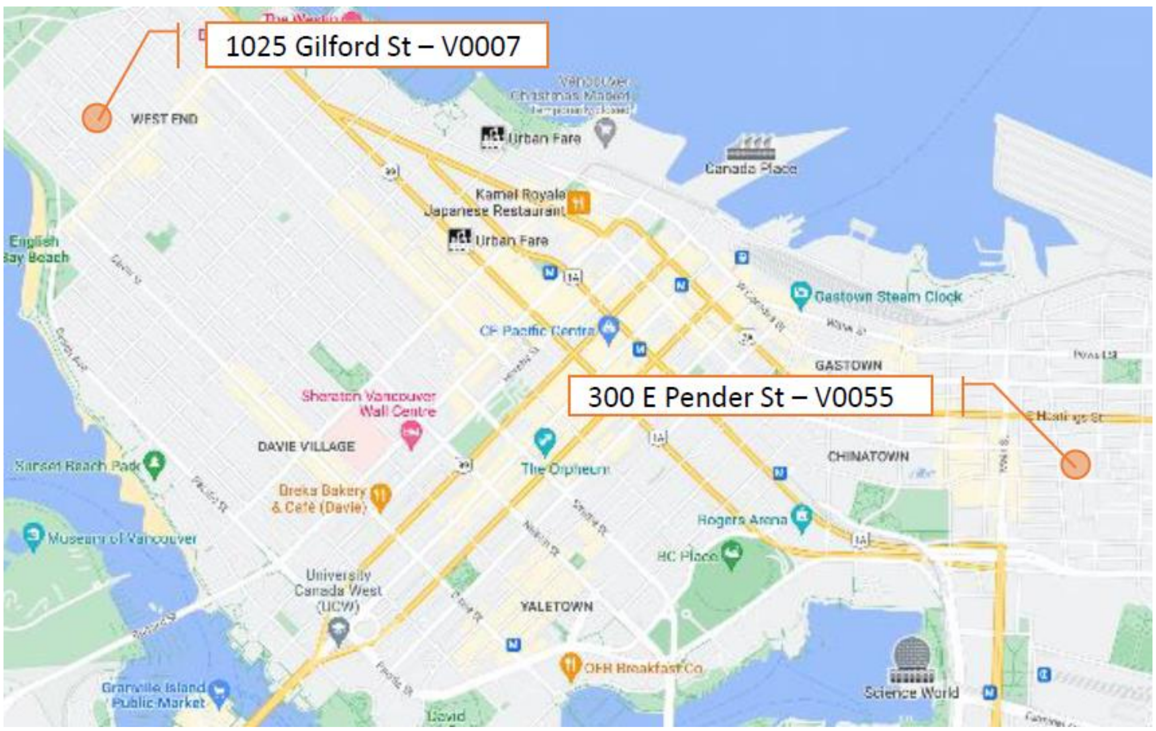
1. **V0007 - 1025 Gilford Street**
2. **V0055 - 300 E Pender Street**

Out of an abundance of caution, BC Hydro has expedited the decommissioning of of the equipment in the two remaining electrical vaults.

The equipment in Vault V0007 has now be decommissioned and has been removed.

BC Hydro is working to decommission and remove the equipment in Vault V0055 by early April 2023.

Vault locations are indicated in the image below.



For further information, please contact Alicia Henderson at 604-623-4381 or by email at bchydroregulatorygroup@bchydro.com.

Yours sincerely,

Chris Sandve
Chief Regulatory Officer

fv/ma

BC Hydro
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May 8, 2023

CONFIDENTIAL

Sara Hardgrave
Acting Commission Secretary and Manager
Regulatory Services
British Columbia Utilities Commission
Suite 410, 900 Howe Street
Vancouver, BC V6Z 2N3

Dear Sara Hardgrave:

RE: British Columbia Utilities Commission (BCUC or Commission)
British Columbia Hydro and Power Authority (BC Hydro)
Electrical Explosion Incident – Marine Building, Downtown Vancouver – CONFIDENTIAL Report - Update on Investigation and Findings on the Cause of the Incident

BC Hydro writes to provide an update on the electrical explosion incident that occurred on February 24, 2023, as requested by the BCUC in its March 15, 2023 letter. BC Hydro's investigation into this incident is ongoing.

Work to date

Following the event, immediate steps were taken to preserve evidence and gather critical data. BC Hydro took oversight of the site and conducted the following activities:

- The vault structure was assessed to ensure worker and public safety.
- Environmental specialists were engaged to mitigate leakage of any remaining oil from equipment in the vault and to sample the oil and debris to establish appropriate health and safety protective measures.
- The site was then secured pending lab results and establishment of environmental protocols for safe entry. Once established, BC Hydro crews and investigators coordinated documentation and evidence removal and further environmental containment controls (e.g., oil removal) with environmental crews.
- A process was developed to secure all of the components within the vault. The cables were cut and the equipment was lifted to the surface where it was further documented.

- More detailed examination took place at Powertech Labs – BC Hydro's testing and research laboratory - including component photographing, cleaning, examination and microscopic inspection as appropriate. Removal of similar oil filled switches in other vaults on the BC Hydro system was expedited and subsequently sent to Powertech for comparison with the switches from the vault. Oil samples were also secured from these other vaults for further evaluation.
- In BC Hydro's response to BCUC Staff Questions No. 2 submitted March 14, 2023, BC Hydro outlined that, out of an abundance of caution, BC Hydro has expedited the decommissioning of the equipment in the two remaining electrical vaults. The equipment in Vault V0007 had been decommissioned and removed. BC Hydro was still working to decommission and remove the equipment in Vault V0055. V0055 has now been decommissioned and the equipment has been removed.

Ongoing work

Work is underway to complete our investigation into the most likely cause(s) of this incident. BC Hydro is working to file an investigation report with WorkSafeBC, as directed, and will update the BCUC when we have completed our investigation and the broader review to understand any other contributing factors that may have indirectly played a role.

BC Hydro is making best efforts to complete and file both the investigation report and the broader review with the BCUC by June 19, 2023; however, the exact timing depends on how work progresses over the coming weeks. BC Hydro will advise the BCUC if there are any indications of a change to this timeline.

For further information, please contact Frankie Vaide by email at bchydroregulatorygroup@bchydro.com.

Yours sincerely,

Chris Sandve
Chief Regulatory Officer

fv/ma