Incident Summary #II-1128363-2021 (#20427) (FINAL)

SUPPORTING INFORMATION	Incident Date		January 9, 2021
	Location		Port Coquitlam
	Regulated industry sector		Electrical - Low voltage electrical system (30V to 750V)
	Impact – Injury	Qty injuries	2
		Injury description	Burns in varying degrees: 1st to 3rd to the head, neck, shoulders, chest, arms, and hands were sustained by one person. Chest pain and breathing difficulties were reported by a second person.
		Injury rating	Major
	Impact – Damage	Damage description	Melting and smoke damage occurred in the main distribution center (MDC). Damage ranged from MDC bus bar jumpers and insulators being melted beyond repair to the MDC circuit breakers, covers and surrounding walls incurring burn and smoke damage.
		Damage rating	Moderate
	Incident rating		Major
	Incident overview		An arc flash exploded out from an energized 600 Volt 4000 Amp 3 phase MDC in a commercial warehouse while an experienced electrician was removing energized components. As a result of the arcing fault, an arc flash including intense heat and molten copper sprayed out and burned the electrician.
INVESTIGATION CONCLUSIONS	Site, system and components		• The commercial warehouse has multiple tenant space units. The tenant space power panels receive power from feeder cables that are individually fed by the MDC. • The high voltage gear, transformer and MDC are contained within a restricted access electrical room constructed of concrete. • The 600 Volt main distribution center has a main breaker for its incoming power and individual circuit breakers for each tenant space unit. • The MDC is fed by a 3500 KVA transformer that converts the 25,000 Volt utility supply down to 600 Volts. The 25,000 Volt service switchgear can be switched off to de-energize and lock out the 600 Volt section. The 4000 Amp main circuit breaker can also be used to de-energize and lock out the 600 Volt section. • The MDC has warnings signs affixed next to the incident location (Figure 1) including wording such as: Hazardous Voltage. Hazard of electrical arc flash. Will cause death or serious injury. Turn off power supplying this equipment before working inside. • Shutdown and lockout procedures are typical components of electrical contractor occupation health and safety programs and apply to alterations to MDC's. • Code and regulatory requirements to deenergize apply when making alterations to electrical equipment. See facts and evidence section for more details. • Electrical bus bars are utilized in equipment where larger currents are involved. They consist of conductive metal bars with isolating supports to hold them in place and prevent them from contacting other parts with different voltage potential. • The circuit breakers and bus bar jumpers in the MDC are secured and connected with various metal bolts.

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	• The horizontal bus bar jumpers connect to the thicker vertical main bus bars and are the final connection point for the feeder circuit breakers. • MDC's include solid metal covers that provide safety barriers from electrical energy and to contain potential faults.
Failure scenario(s)	Roughly 4 hours prior to a scheduled shutdown that was part of a tenant space power upgrade, an electrician with 33 years of experience removed the covers and two 200 Amp circuit breakers from an MDC that was not shut down or locked out. After the breakers were removed, and while the cordless drill's nut driver bit was in contact with energized parts, it is evident that the bus bar jumpers pivoted downwards towards the adjacent bus bar jumpers which had a voltage potential difference of 600 Volts. This resulted in a 600 Volt line to line arcing fault short circuit, and an ensuing arc flash. The energy from the arc flash was released at the ends of the bus bar jumpers where the surrounding air became ionized and conducted electricity in a 3-phase arc flash. The 3-phase arc flash continued to melt the bus bar jumper ends until enough current was drawn to trip the 4000 Amp circuit breaker.
Facts and evidence	Electrical component observations: • The side and the end of the nut driver bit on the cordless drill were melted from arcing indicating they were in direct contact with an energized component(s) when the incident occurred (figure 9 a, b) • The bus bar jumper piece on the ground was melted (figure 10) • Open holes are left where the removed bus bar jumper bolts had attached to the main bus bars (figure 3) • The 600 Volt bus bar jumper travelled down towards the adjacent 600 Volt bus bar (figure 6) • There was no damage to the 2 x 200 Amp circuit breakers including where the bolts connected the breaker to the energized bus bar jumper ends (figure 7). Statements from injured electrician: • Prior to the shutdown, they took the panel covers off to prepare and look at the MDC. • They took the 200 Amp breakers out by removing the screws. • The 400 Amp circuit breaker was laid on the floor ready to be installed. • The electrician stated they do not recall events at the time of the arc flash incident. • After the incident, the electrician recalls having to cut their pant leg with tin snips as the pants were on fire and the fire department pouring liquid over them. • They have been an electrician for 33 years. Statements and evidence from electrical contractor representatives: • An electrical contractor safety meeting and walkthrough for the shutdown was held in the days prior to the incident. The meeting included the electrical project manager, electrical site supervisor, and the electrician involved in the incident. • An electrical shutdown was scheduled by the electrical contractor and the tenant for 2pm on the date of the incident, as warehouse operation was scheduled to be running until 2pm that day. The incident occurred at approximately 10am on the same day. • The shutdown was scheduled to last 3-4 hours, during which time the tenant's server room was to be powered solely by the tenant's existing uninterruptible power supply (UPS). • There was no plan to use arc flash personal protection equipment as the equipment was intended to be de-energized during the scheduled shutdown.

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- A temporary generator and temporary lighting were on site for the scheduled shutdown for the main electrical room area.
- Indications that the MDC was energized included that the transformer would have had a noticeable hum when running and the permanent lights in the electrical room fed from the 600 Volt MDC were on.
- Upon inspection after the incident, there were no signs that the 4000 Amp breaker had been locked out at the time of the incident.
- The electrical supervisor was on site and in an area close to the incident but without a direct line of sight.
- As part of a tenant improvement, a 400 Amp circuit breaker was to be installed in place of two existing 200 Amp circuit breakers.
- The 400 Amp circuit breaker requires a different set of wider bus bar jumpers and removal of the existing 200 Amp jumpers.
- The nut driver bit in the cordless drill directly below the incident location had melting damage indicating it was at the point of arc flash. It was also found to match the size of the bolts that secured the bus bar jumpers and the removed circuit breakers.
- The two 200 Amp circuit breakers have bolts that connect directly to the ends of the bus bar jumpers, but the area where those bolts connect had no damage from arcing. The removed circuit breakers had no damage whatsoever from arcing or dropping.
- Melted copper droplets were found embedded in the plywood on the wall 10 feet away from the arc flash location.

Statements from fire department representatives:

- The main high voltage service switch was found in an energized state after the incident.

Arc flash characteristics:

- Arc flashes can occur when an energized conductor is shorted (makes contact) to another energized conductor or to grounded metal. The severity of the arc flash is dependant on the available voltage and current as well as the time it takes the overcurrent protection to clear the fault.
- During an arc flash the air surrounding the arcing components may become ionized and conduct electricity, like a lightning strike, increasing the distance and range of damage and injury.
- Arc flashes can release vaporized metal, extreme heat, light, sound, and pressure from the electrical equipment. The arc flash can cause severe burns as well as hearing and vision damage to people in the area.
- Metal such as copper bus bars can be melted by the arc flash and may increase up to 67,000 times the original size while vaporizing and exploding out.
- The arc flash can reach temperatures up to 20,000 degrees Celsius.

Requirements to deenergize:

- In accordance with the Technical Safety BC Directive issued pursuant to the Safety Standards Act and BC Electrical Code Rule 2-304 (link below): No repairs or alterations shall be carried out on any live equipment except where complete disconnection of the equipment is not feasible
  - https://www.technicalsafetybc.ca/alerts/directive-bc-electrical-code-section-2-general-rules
- Referenced in the Technical Safety BC bulletin below are the following WorksafeBC Occupational Health and Safety Regulation requirements pertaining to working on electrical equipment:
  - The preferred method is de-energization, isolation, and lockout, as per OHSR s19.10(1).

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	○ https://www.technicalsafetybc.ca/alerts/information-bulletin-section-2-requirements-de-energize-electrical-equipment • The electrical contractor's safety manual includes requirements for disconnection and lockout prior to working on low voltage electrical equipment (under 750 Volt) and states that it is mandatory that each person working on the locked-out equipment places their personal lock on the power source. Photo and diagram list (see below): Figure 1 - Condition of MDC after incident Figure 2,3 - Arcing fault close views Figure 4,5 - Before/ after comparisons of bus bar connectors Figure 6 - Arc flash damage Figure 7 - General work area Figure 8 - Main electrical room layout Figure 9 a, b - Nut driver drill bit melted from arcing Figure 10 - Damaged and removed bus bar jumper Figure 11 - 600 Volt 4000 Amp MDC main breaker lockout location Figure 12 - 25,000 Volt service switch alternate lockout location Figure 13 - Example of an installed 400 Amp circuit breaker Figure 14 - 400 Amp circuit breaker ready for install Figure 15 a, b, c, d - Example and burnt coverall clips and band Figure 16 - Worker's burnt clothes Figure 17 - Worker's burnt gloves
Causes and contributing factors	The cause of the incident is that energized components of a 600 Volt main distribution center were removed without the equipment being shut down. It is very likely that a contributing factor to the incident was the electrician conducting work before the scheduled shut down time. The shut down would have deenergized the equipment so it was safe for the electrician to access for the planned work.

Figure 1 - Condition of MDC after incident (top): Arcing fault location (explosion symbol), Bus bar pivot direction (arrow). Arc flash labels (rectangle) and various components with smoke (yellow) and melting damage.

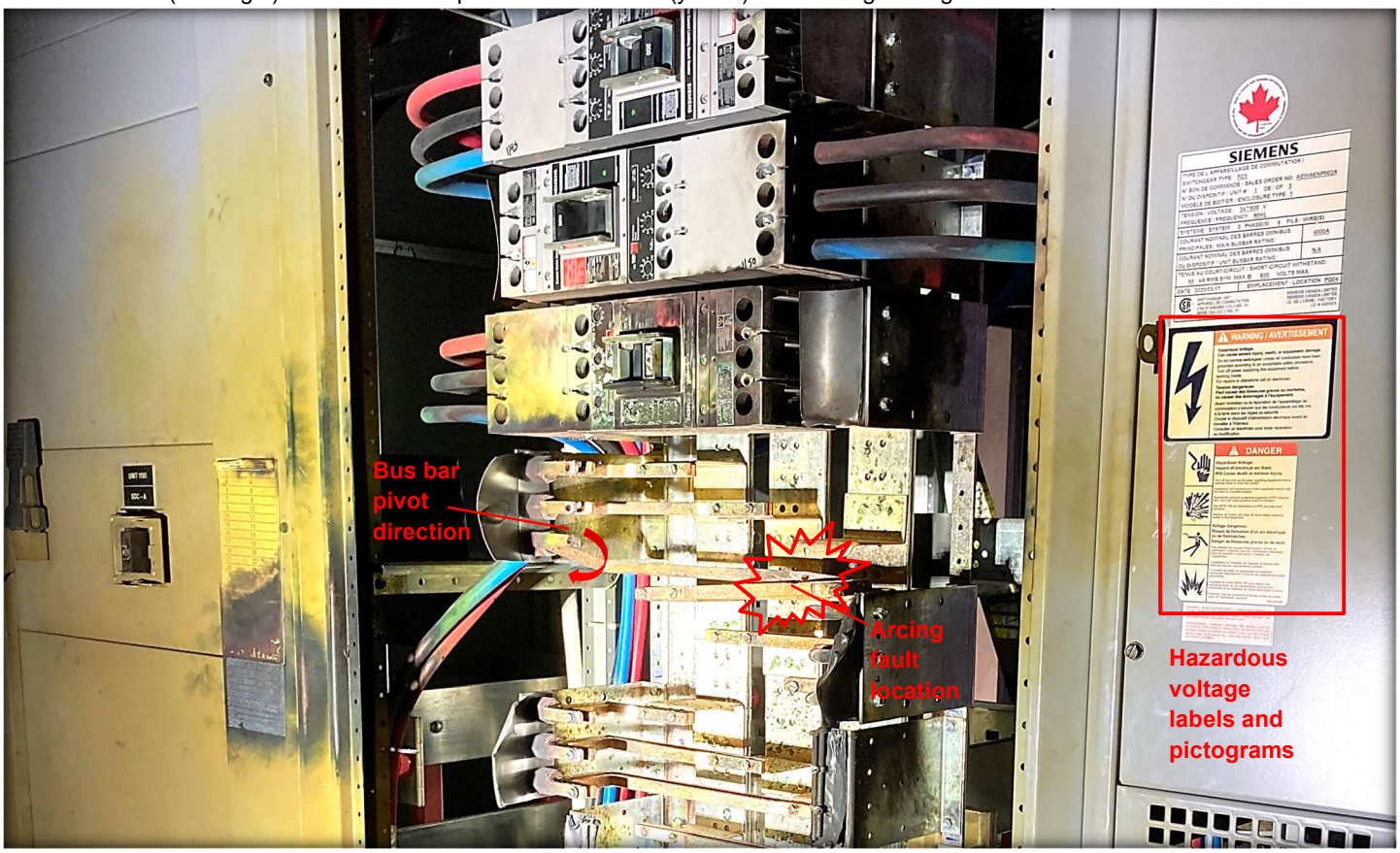


Figure 2 - (bottom left) Arc flash energy released at the ends of the bus bar jumpers, 3 phase arc flash through ionized air (blue arrows)

Figure 3 – (bottom right) Cupping from arcing contact and open holes where the bus bar jumper bolts attached

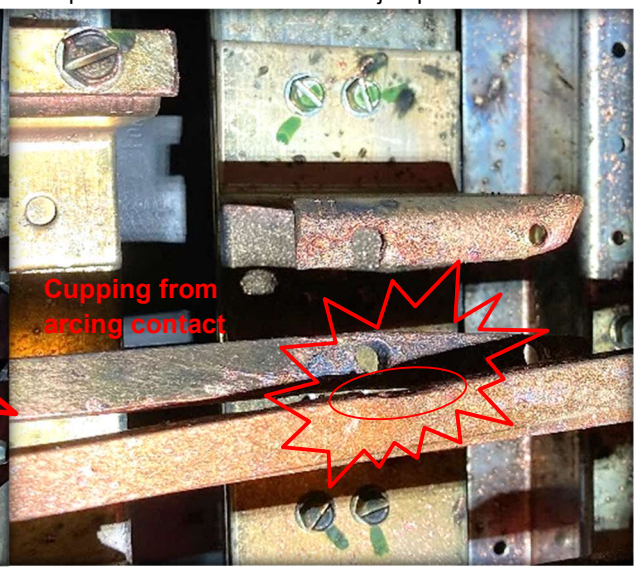


Figure 4 – Before (top left) un-melted bus bar jumper ends

Figure 5 - After (top right) bus bar jumper ends melted from arcing.

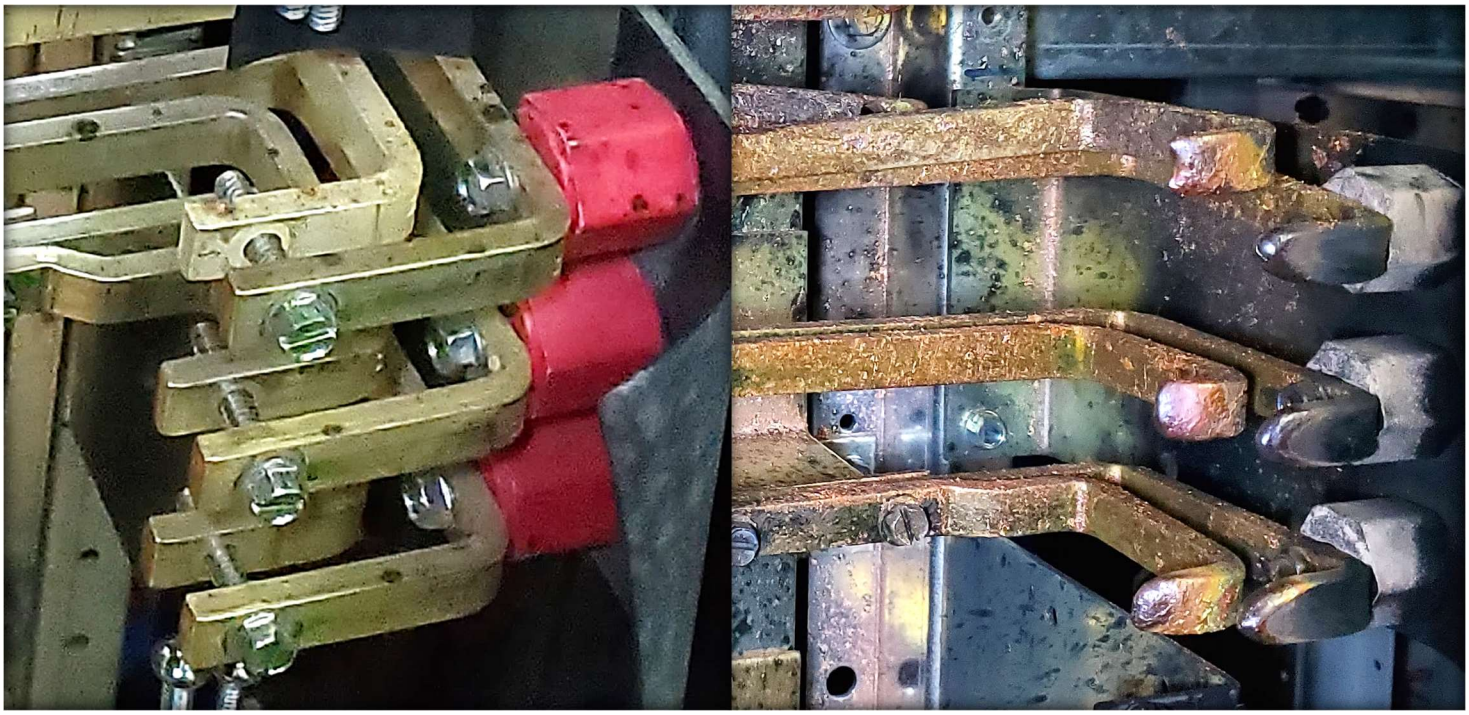
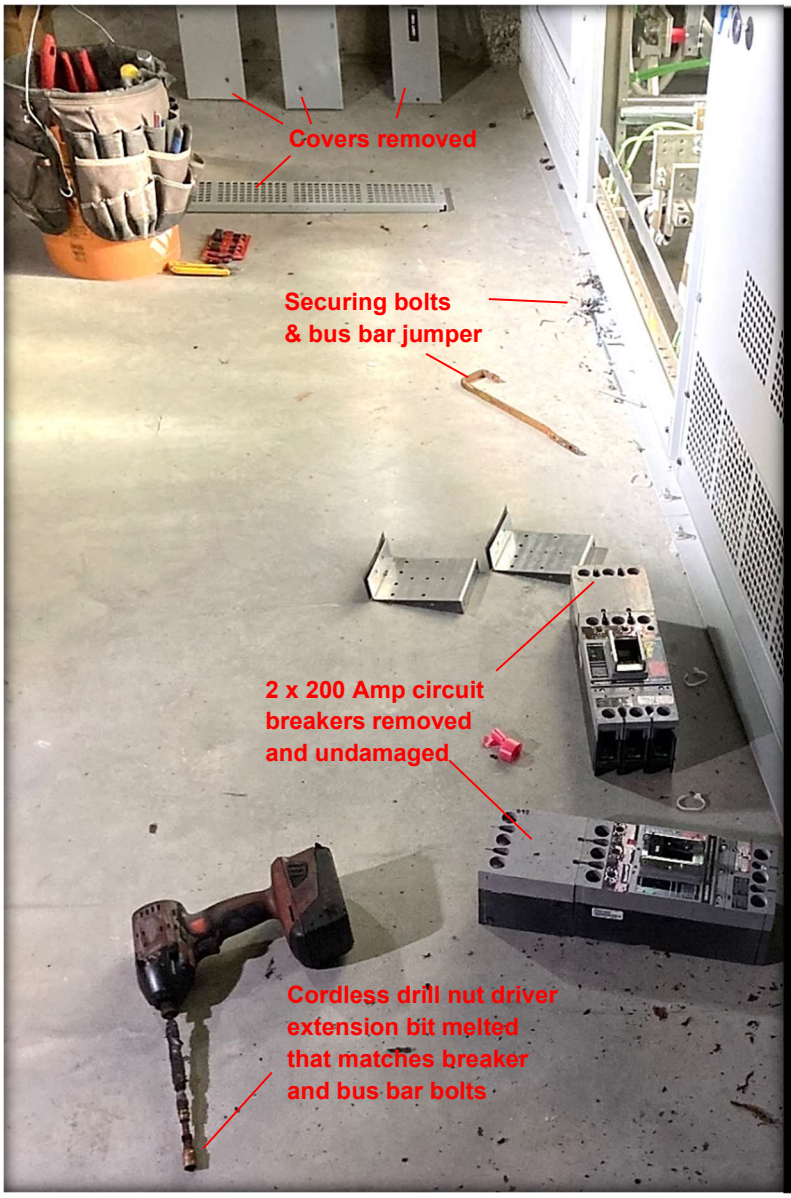


Figure 6 (bottom) – General area of arc flash showing damage to and travel of bus bar jumpers (arrow), and burn marks from arc flash

Figure 7 – (left) General work area: Covers removed, securing bolts and bus bar jumper, 2 x 200 Amp circuit breakers removed and undamaged, cordless drill nut driver extension bit melted that matches breaker and bus bar bolts.

Figure 8 – (right) Main electrical room layout.



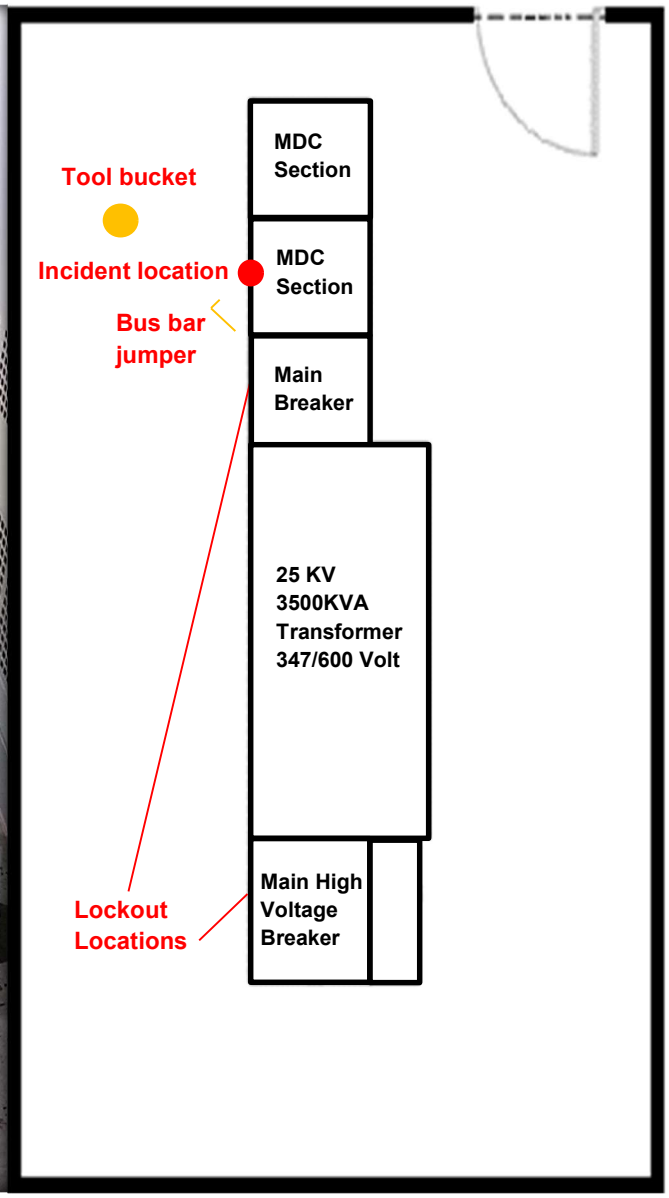


Figure 9 a, b - Nut driver end melted on the side and at the end from arcing to energized component(s)

Figure 10 - Bus bar jumper showing signs of melting damage on the floor in front of the MDC

Figure 11 (top left) 600 Volt 4000 Amp MDC main breaker (Lockout location)

Figure 12 (top right) 25,000 Volt service switch (Alternate lockout location)

Figure 13 (bottom left) - Example 400 Amp circuit breaker installed elsewhere with wider bus bar jumpers (rectangle)

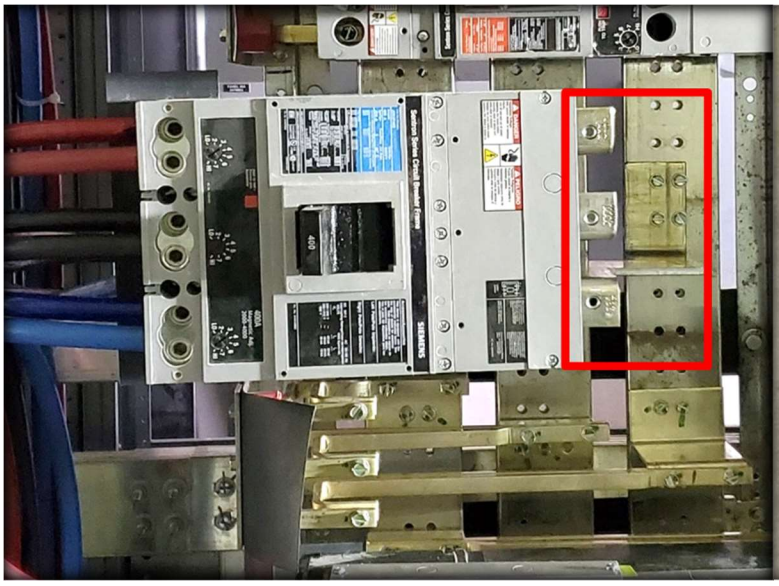


Figure 14 (bottom right) – 400 Amp breaker ready for install

Figure 15 a, b, c, d - Coverall clips and band example (top left) and burnt items on the floor in area of incident

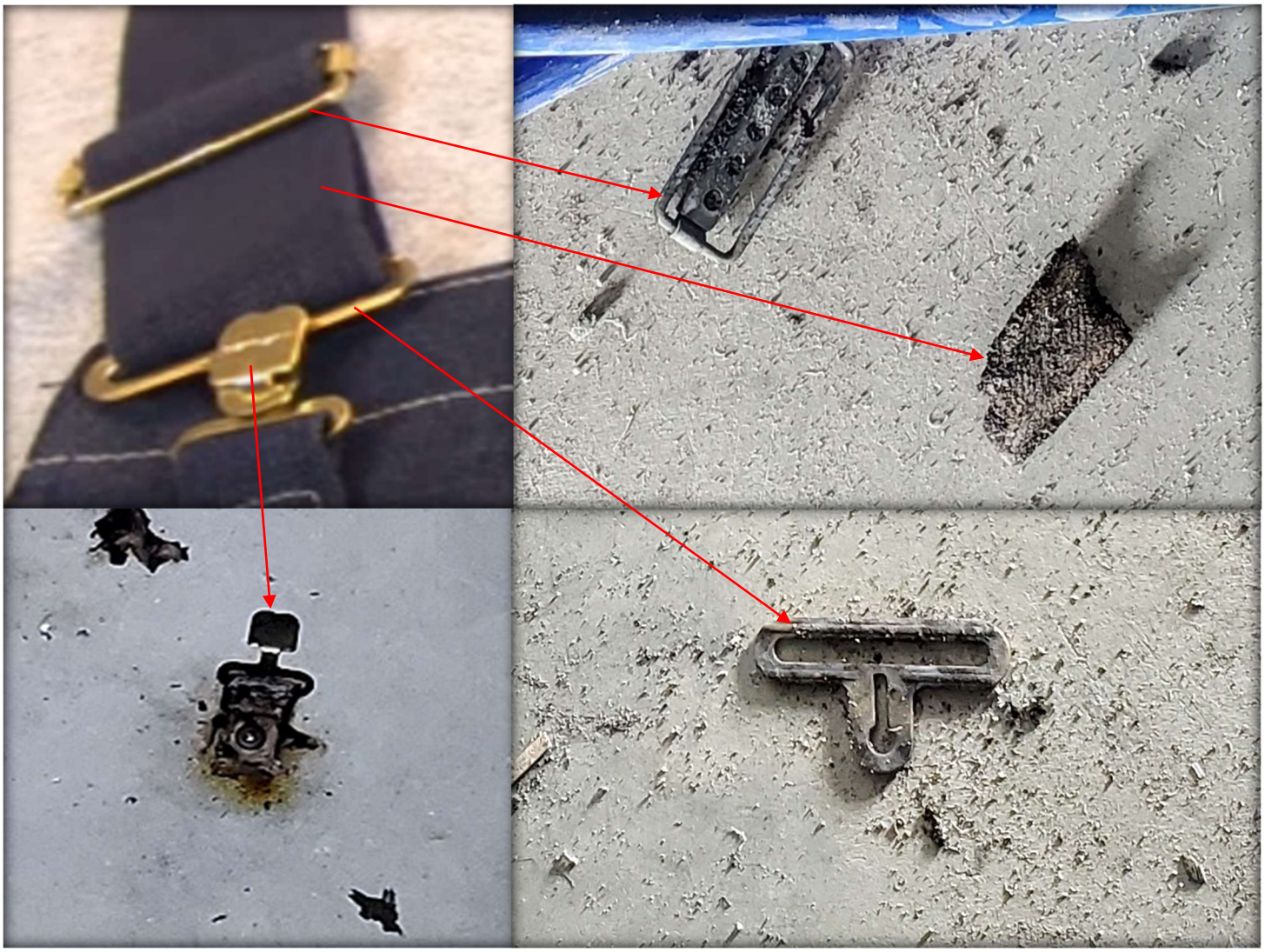


Figure 16 (top left) Workers burnt clothes

Figure 17 (top right) Workers burnt gloves