JSA
THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY
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Notable Events 71634

Event Title: ENG-17-1012 CHL1 C6 Starter Fire
Response Owner: Will Oren (oren)
Category: Fire / Explosion
Date of Occurrence: 10/12/2017
Event Location: CHL1, building 8
Date Notable Event Report is Due: 11/13/2017

Short Summary of Event and/or Injuries

A fire occurred in the C6 Motor Control Center of CHL1, building 8, at approximately 1:13 p.m. on Thursday, October 12, 2017. A Facilities representative was working in the rear of the building and activated the pull station. JLab staff responded and de-energized the equipment, extinguishing most of the flames. Newport News Fire Department also responded within about 4 minutes and extinguished the remainder with dry chemical. The total length of the fire was less than 10 minutes. There were no injuries, CEBAF Boulevard was closed in the concerned area, and the scene taped off and preserved for forensic work.

The plant had been operating for several hours prior to the event, pumping down from 4 Kelvin to 2 Kelvin in order to support SRF activities. However, C6 was not part of this configuration, as the plant can run on 5 compressors. The fire occurred about 45 minutes after C6 was brought online.

Details of the Event and/or Injuries

A fire occurred in the C6 Motor Control Center of CHL1, building 8, at approximately 1:13 p.m. on Thursday, October 12, 2017. A Facilities representative was working in the rear of the building and activated the pull station. JLab staff responded and de-energized the equipment, extinguishing most of the flames. Newport News Fire Department also responded within about 4 minutes and extinguished the remainder with dry chemical. The fire was out within 10 minutes. There were no injuries, CEBAF Boulevard was closed in the concerned area, and the scene taped off and preserved for forensic work.

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A restart team was gathered immediately after the all-clear and determined a path forward for evaluating damage and conditions / timing for a restart of CHL1 Operations. A primary and secondary plan was developed and after a thorough AHA and team discussion, work proceeded. The damaged equipment was electrically isolated and the appropriate locks and tags placed. Nearby equipment was then evaluated, cleaned and inspected by a combination of trained subcontractor electricians and Lab subject matter experts. Power was safely restored to the other five compressors at about 7p.m. on October 12. This allowed CHL1 to return to normal 4 Kelvin operations.

The apparent cause of the fire is the C6 starter being stuck at the 80% level, causing the autotransformer to overheat and thus the insulation to burn. This apparent cause takes into account significant equipment damage and no available controls data.

C6's associated autotransformer, designed to provide brief starting power only, operated a 1.6 MW compressor for at least 45 minutes, significantly beyond its design intent. The 30 year old transformer subsequently overheated and caught fire. Subcontracted fire safety and electrical engineers later independently confirmed this as the specific cause. An extent of condition check shows that CHL1 compressors 4 and 5 are also vulnerable to this failure mode, thus alarms have been installed for this condition and all operators trained to recognize this abnormal situation. Approximately $17,000 stock of Helium was lost and the schedule was negatively impacted by a week.

It was decided early in the event that the Lab's Emergency Operations Committee would not be stood up. A TJSO representative informed the DOE Emergency Operations Center of the event at various points in time. DOE EOC requires no additional follow up.

The event is reportable as an ORPS "High". The specific threshold tripped is "any fire that disrupts normal operations in the facility for more than four hours". The Lab has until COB of Monday, 10-16-2017, to enter the initial notification report and 60 days to enter a final report with the identified corrective actions.

Timeline, all times in PM

1:13 - Pull station activated, 911 call

1:17 NNFD onsite
1:26 CEBAF Boulevard closed
1:28 TJSO notifified by Reporting Officer(PH)
1:30 COO discussion; informed recommended "no" on standing up EOC
1:38 Sitewide alert "fire discovered / extinguished in building 8 /CHL. CEBAF Boulevard closed, NNFD and NNPD onsite"
1:50 - Confirmed no EOC activation with Emergency Manager
2:10 Last of NNFD equipment broken down in prep for leaving, remained onsite
2:10 JLab Damage Assessment team went into building 8 to investigate
2:19 Informed by Emergency Manager that there were no injuries
2:22 Informed that C6 of CHL1 was source of fire
2:27 Barrier tape erected
2:44 CEBAF Boulevard open

Causal Analysis

Root Cause

Control system failure to increase C6 starter motor from 80% to 100% voltage. This caused an excessive load to be applied to the motor/compressor and the autotransformer dealing with a current beyond its rated capacity.

Root Cause Corrective Action:

Action Owner: Jonathan Creel (creel) **Due Date:** 10/01/2018

Consider replacing the entire motor control center, taking into account factors such as cost, operational schedule windows, skill / resources, etc. Consideration should be given to using newer technologies, such as soft starts and logic controllers, for better control.

Root Cause Corrective Action:

Action Owner: Jonathan Creel (creel) **Due Date:** 02/28/2018

Plan and begin conducting additional tests above the standard recommended maintenance procedures. Specifically, test the operation of every control relay and interlock.

Root Cause Corrective Action:

Action Owner: Jonathan Creel (creel) **Due Date:** 02/28/2018

Install additional controls to forbid loading the compressor until the motor is at 100% voltage.

Root Cause Corrective Action:

Action Owner: Jonathan Creel (creel) **Due Date:** 02/28/2018

Replace or repair the damaged C6 motor starter.

Extent of Condition Check

Compressors 4 and 5 have similar equipment and thus the potential for similar failure modes.

Does this event involve failed equipment? YES

Is there similar equipment in other areas? YES

Extent of Condition Corrective Action

Action Owner: Jonathan Creel (creel) **Due Date:** 02/28/2018

Evaluate compressors 4 and 5 for susceptibility to failure, i.e., whether or not they show similar conditions and operating characteristics that will cause them to fail in what JLab considers to be an unreasonable amount of time. Prioritize their MCCs for replacement as appropriate.

Witness Accounts

[No Data]

Records, Documents, Pictures, and Other References

See attachments for A&E Fire Engineer report. This also contains 8 pics of the damage.

Emergency Notifications Made (Subsequent to the Event)

Fire, Rescue & Emergency Medical (9-911): 10/12/2017
Guard Post (x5822; 269-7539): 10/12/2017
ESH&Q Reporting Officer (876-1750): 10/12/2017
Crew Chief (630-7050): 10/12/2017
Other (TJSO): 10/12/2017

Documentation of Findings

Notable Event Number: ENG-17-1012
CATS Number: NE-2017-09
Lessons Learned Number: TBD
ORPS Number: SC--TJSO-JSA-TJNAF-2017-0007
NTS Number: TBD
CAIRS Entry: NA
DOE Cause Code: [No Data]
ISM Code: [No Data]

Signatures

Investigation Team: Steve Smith (sjsmith)
Investigation Team: Todd Kujawa (kujawa)
Investigation Team: Paul Vasilauskis (vasilaus)
Investigation Team: Dana Arenius (arenius)
Investigation Team: Paul Powers (powersp)
Associate Director / Department Manager: Will Oren (oren)
Associate Director / Department Manager: Mary Logue (logue)
Associate Director / Department Manager: Jonathan Creel (creel)
Associate Director / Department Manager: Rusty Sprouse (sprouse)

Mason&Hanger
A Day & Zimmermann Company

FIELD INVESTIGATION

TO:	Rusty Sprouse, Facilities Management Director	**FROM:**	Mason & Hanger
CC:		**DATE:**	October 23, 2017
PROJECT:	CHL Fire Investigation	**PROJECT #:**	HN.00386
SUBJECT:	Fire Investigation		

Engineers from Mason & Hanger (M&H) met at the Service Support Center at 09:00 with Rusty Sprouse and Paul Powers to investigate the cause of a recent small fire occurring in a motor control center cabinet in the Central Helium Liquefier (CHL) building. The following individuals participated in the investigation.

JLAB	Rusty Sprouse	Facilities Management Director
	Paul Powers	Site Electrical
	Jason Willoughby	Site Electrical
	Jonathan Creel	CHL Facility Manager
	Tim Minga	
M&H	Dann Layou	Senior Life Safety Engineer/ Fire Investigator
	Justin Wheeler	Senior Life Safety Engineer
	Charlie Richardson	Senior Electrical Engineer

Paul Powers took the team to the CHL building where we also met with Jason, Jonathan, and Tim.

Through discussion with site personnel, the investigative team learned the following:

1. At approximately 12:30PM on Thursday 12 October 2017, a fire was observed in the medium voltage motor control center (MCC) starter for Compressor #6. The compressor had been running for approximately 45 minutes prior to the observation of smoke/fire by facility staff. Typical run procedures were being performed.
2. Site personnel indicated they regularly check torque values of bolted connections and that the last check was approximately two years ago.
3. No maintenance or other work was being performed on the MCC or motor at the time of the fire.
4. No noticeable utility issue was observed (black-out, brown-out, voltage spike, etc.) during the event. The site Electrical Engineer had to disconnect power at the source transformer; automatic overcurrent devices did not open.
5. The operators noticed the power consumption of the compressor was greater than previously recorded for similar atmospheric conditions; approximately 1.8 MW versus 1.45MW the previous day. It was determined by site personnel that this may be due to the precision of the instrument.
6. The statuses of control relays or fuses were not yet known at the time of our visit; site personnel wanted to allow the investigative team to view the damage before disturbing those components.

Site personnel plan to continue the investigation, including testing the components for any anomalies, after our visit.

7. Initial reports indicated the power conduits to the motor also experienced fire damage. No visual evidence of this was found, however; it may have been a misunderstanding by the Fire Department. The motor has been tested by site personnel and they have determined the results to be acceptable.

The team spent the morning observing the damage and gathering data.

Basic system information:

1. The MCC is an Allen-Bradley Bulletin 1572, manufactured approximately 1988 and installed in February of 1989. Site has provided a schematic of the starter wiring. Other drawings have been obtained from Rockwell Automation (Allen-Bradley.) The starter uses a three-coil, three-legged autotransformer as a reduced voltage starter, with the tap at 80%.
2. The rating of the MCC unit is 2250 Horsepower, 4160 Volts, 264 Amperes, 60 Hertz, 1.0 Service Factor.
3. The compressor motor is rated 2250 Horsepower, 4160 Volts, 264 Amperes, 60 Hertz, wye-connected.

Visual and limited physical observations made during the survey:

1. The Compressor #6 starter is the right-most set of cabinets in a row of MCC cabinets for three of the six main compressors in this building. See Figure 1, Figure 2.
2. The damage was primarily located in the right-most of three vertical sections. This section houses the autotransformer and external control relays. See Figure 3.
3. There was some indication of limited smoke damage in the top center compartment. Otherwise the center compartment seemed undamaged. This compartment houses the main fuses and contactors. See Figure 4.
4. The left-most compartment appeared undamaged. This compartment houses control relays for the operation of the contactors in the center section as well as an Allen-Bradley 1406-P16 Series B programmable motor protector (PMP). See Figure 5. Earlier reports from responding firefighters of fire in the underground conduit from the MCC to the compressor appear to have been erroneous, this is supported by visual observation of the underground conduit and megger testing by facility personnel.
5. Most of the damage was concentrated on the left side of the autotransformer compartment, and more specifically the 0% tab on A-phase of the autotransformer. See Figure 6, Figure 7. This tab was noticeably looser than all the others. All bolted connections appeared tight. There is a bonding jumper for the door in close proximity to the 0% tab on A-phase of the autotransformer. See Figure 8.
6. The 0% tap conductors were routed above the autotransformer and sustained the most damage, all effectively losing all their insulation. Other conductors routed lower generally showed no signs of damage or were covered in melted insulation.
7. The control equipment in the compartment above the autotransformer was heavily damaged, likely from heat and fire below.

The team discussed the inspection with site personnel and left approximately 12:00 noon.

EVALUATION:

The autotransformer method of induction motor starting dates back to the early 20th century and has been successfully used to limit starting current and torque of the motor, which can reduce the harmful impacts of these on the electrical and mechanical systems, respectively.

This method uses an autotransformer to reduce the applied voltage to the motor during start-up (in this case 80% of line voltage), and then transfers to full voltage once the motor is running. While later versions use current measurement as a trigger to transfer, early versions used timing relays and trial and error to meet motor and system starting requirements. The system investigated uses the older timing technology.

There have been reports of High Voltage Stress failures in these types of starters over the past 30 - 40 years as described by Lawrence B. Farr and Arthur J. Smith, III, in their article “Medium Voltage Reduced Voltage Autotransformer Starter Failures” published by IEEE. Several failures were noticed on the 0% taps of the autotransformers at 4160 volts with timer controls, very similar to this situation.

The autotransformer did not appear to be the source of the fire. Instead, the conductor on A-phase of the autotransformer 0% tap appears to have ignited and burned all combustible material close by. There are several possible reasons for the failure in this starter:

1. Age of equipment. The equipment may have failed due to low-level electrical or mechanical stress over 30 years.

2. Control Failure.
    a. The timer or other control for transfer from reduced voltage to full voltage was defective. This would likely have required at least two failures in the control system. This failure would cause the motor to remain connected to the autotransformer and run at reduced voltage while being loaded. This could lead to a low level increase in motor current (not instantaneous) which may not have been observed by ground fault or overcurrent protection. Over time the conductors could heat to the point of ignition.
    b. The timer transferring from reduced voltage to full voltage occurred too soon, while the motor was still starting. This would force the transfer at near locked rotor and result in excessive voltages at the 0% terminal. The resulting breakdown of insulation could cause an arc and subsequent fire. This could also occur if the motor experienced greater inertia than usual and was not able to accelerate to speed before normal transfer.

3. Zero tap to ground voltage strike. There is a bonding jumper for the door located directly above the 0% tap on the A-phase of the autotransformer and it is possible an arc occurred between the tap and the bonding jumper or the door. No obvious arcing damage was observed but damage to the conductors may hide this. Both the A-phase 0% tap conductor and bonding jumper had complete insulation failure in this area and often the ground conductor insulation is rated 600V, rather than system voltage.

RECOMMENDATIONS:

As stated above, there are a few possible reasons why the A-phase conductor ignited, but the exact cause is difficult to determine. As this equipment is vital to the mission of JLAB, the following recommendations should be considered to reduce the risk of another occurrence:

1. Increase testing and maintenance frequency. Although in line with general industry standards, the age of the equipment and its importance to the process tend to necessitate a shorter interval between testing. This may, however, cause disruption with process needs and should be carefully scheduled. Additional tests should be performed on the control system in addition to the power connection testing already occurring.
2. Install additional controls to forbid loading the compressor until the motor is at full speed, usually by measuring motor current at below 125% of full load.
3. Reroute all grounding conductors away from transformer taps and other exposed connections as much as practical.
4. Replace the motor control center. The existing motor control center is approaching 30 years of age. It is not clear what temperature extremes to which the equipment has been exposed but the plant ambient conditions do not appear to be tightly controlled. Temperature extremes will have an adverse effect on equipment life. Consideration should be given to using newer technologies, such as soft starts and logic controllers, for better control.

Figure 1 The entire bank of motor control center starters for the 2250HP compressors in the building

Figure 2 - Compressor 6 MCC – cabinets left to right, PMP, contactor/fuse, and autotransformer.

Figure 3 - Fire damage in autotransformer/ external control enclosure.

Figure 4 - Interior of the contactor/fuse enclosure.

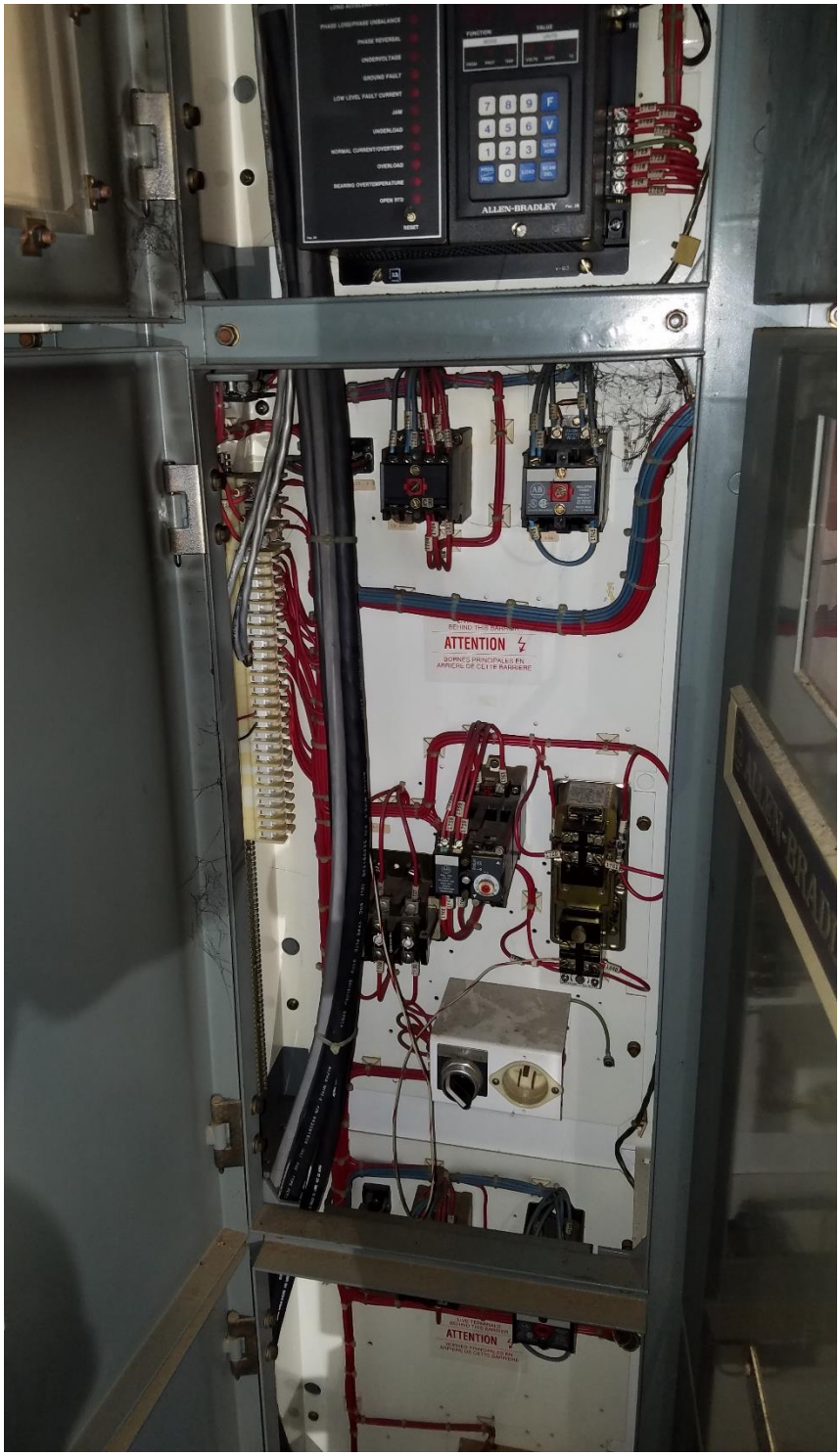

Figure 5 - Interior of the PMP enclosure.

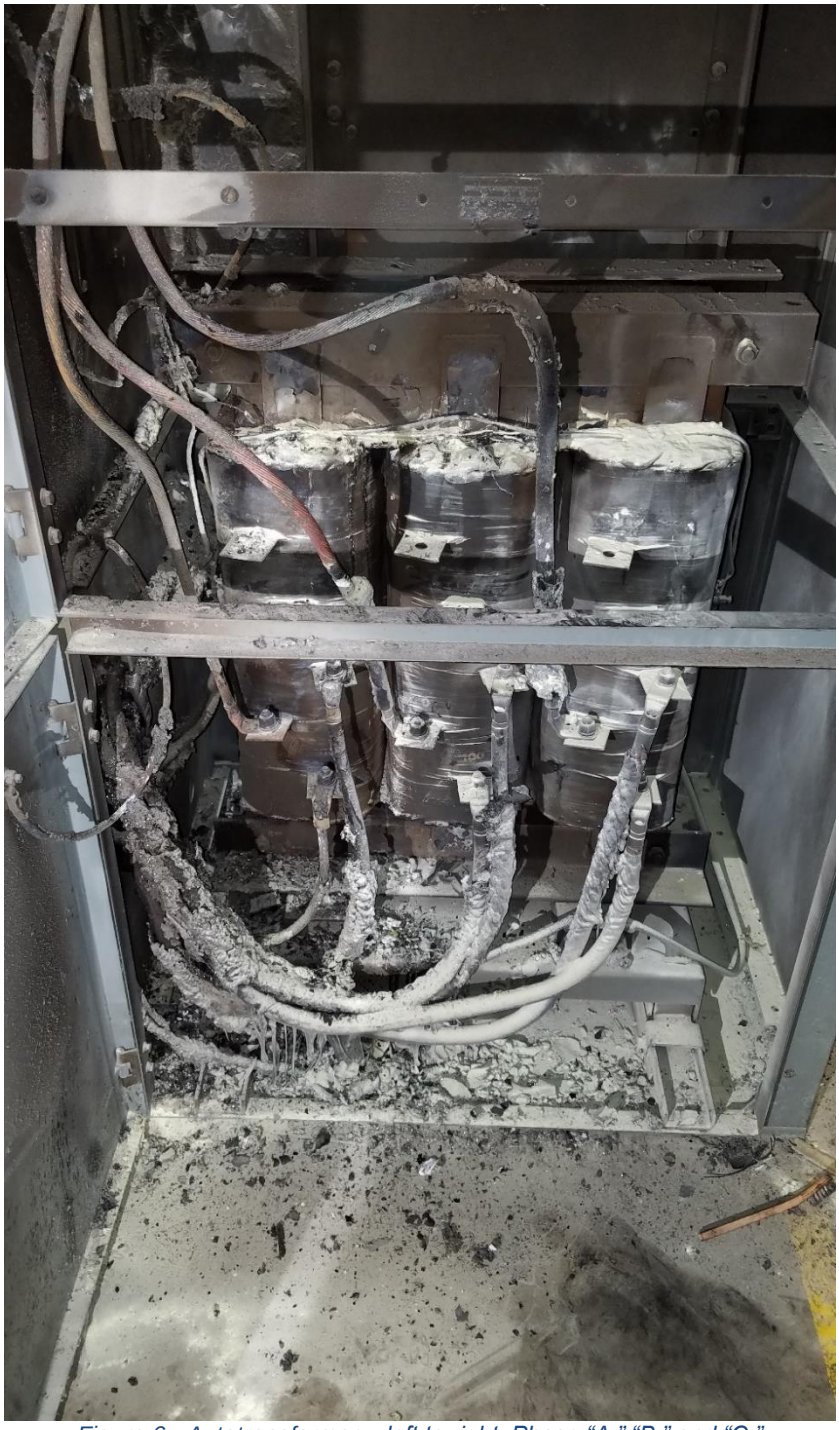

Figure 6 - Autotransformer – left to right, Phase "A," "B," and "C."

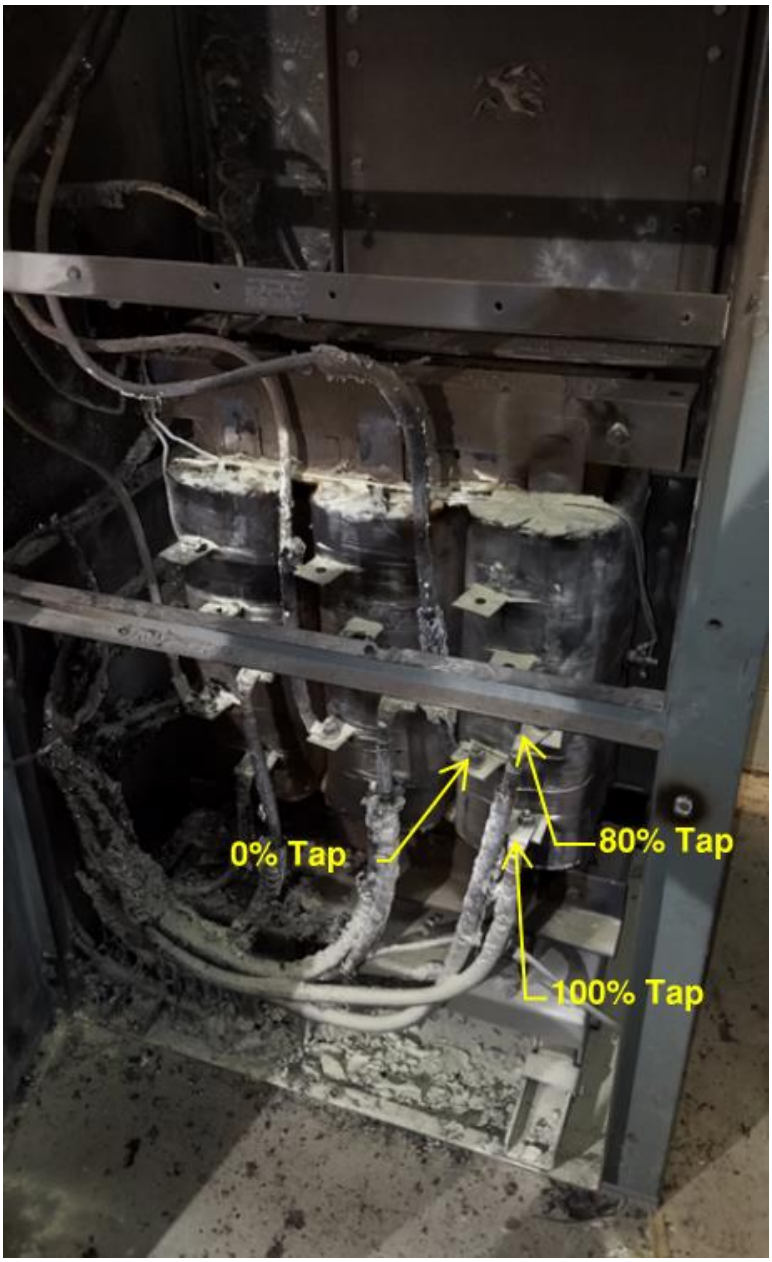

Figure 7 - Autotransformer – 0% tap conductors routed up, 80% and 100% tap conductors routed down.

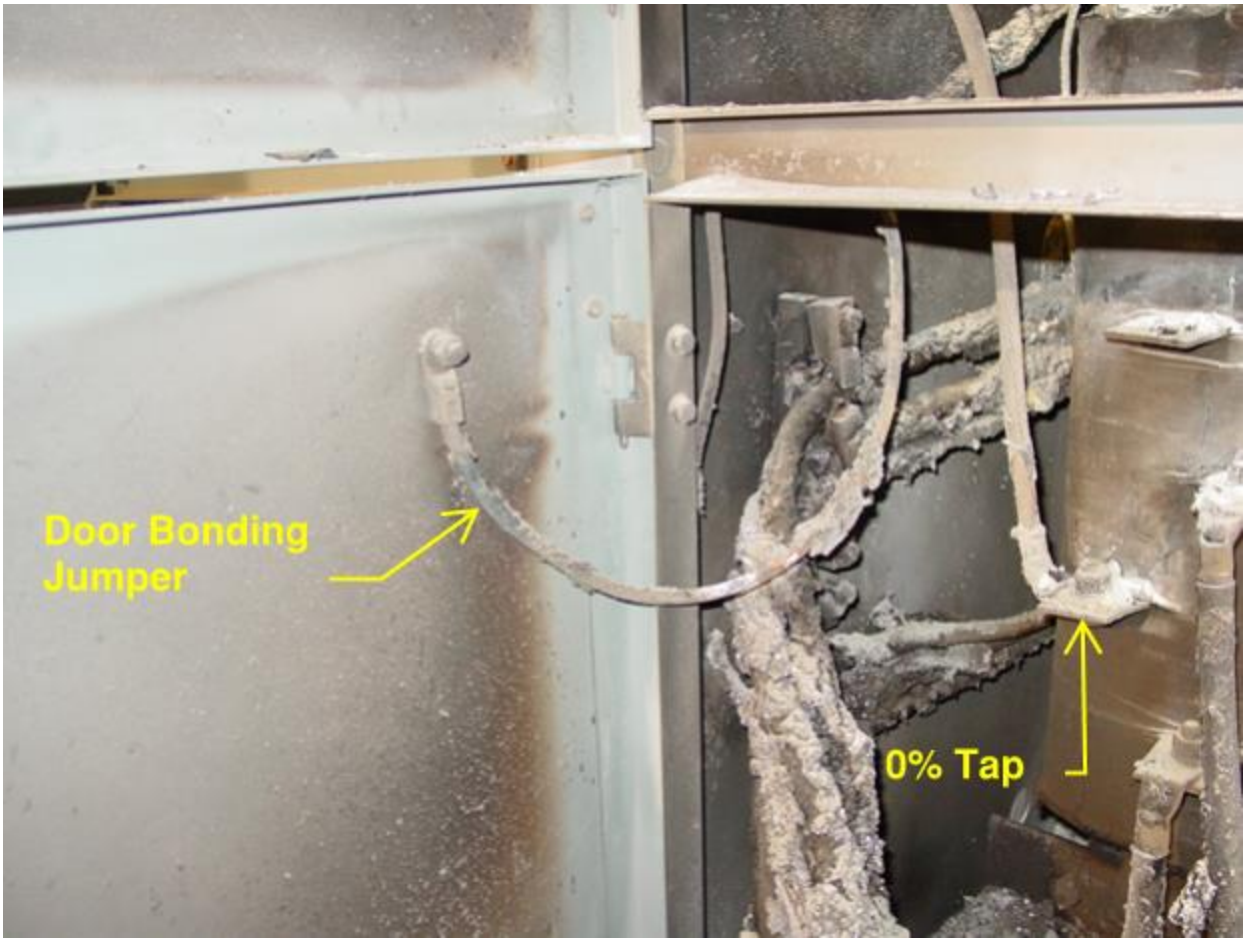

Figure 8 - Door bonding jumper and 0% Phase A tap.