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Gabriel Taylor (Gabriel.Taylor@nrc.gov)
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USNRC/RES/PRAB
Washington, DC 20555

Dear Mr. Taylor,

Subject: Letter report on the evaluation of cables from the HEAF fire event at the H. B. Robinson Steam Electric Plant

Please find attached the evaluation of some electrical cable segments that were affected by the high energy arcing fault incident that occurred on March 28, 2010, at the H. B. Robinson Steam Electric Plant. This effort was sponsored under NRC job code N6982. Please feel free to contact me if you have any questions.

Sincerely,

Carlos Lopez

Attachment: *"Evaluation of Cables from the March 2010 HEAF Fire at H. B. Robinson Steam Electric Plant"*

Evaluation of Cables from the March 2010 HEAF Fire at H. B. Robinson Steam Electric Plant

(by Jason Brown and Carlos Lopez, Sandia National Laboratories*)

Background

On March 28, 2010, at the H. B. Robinson Steam Electric Plant, cable insulation failure on the 4 kV supply to Bus 5 led to an arc flash within a rigid metal conduit (see Figure 1 and Figure 2). It is believed that the first fault was in the switchgear where the cables exited the conduit mouth. The initial arc flash event also caused internal damage to the Unit Auxiliary Transformer (UAT) and a subsequent fire within the conduit (see Figure 3). When the fault occurred, the circuit breaker did not trip on over current as anticipated and remained closed throughout the event. A defective fuse disabled the breaker trip control circuit, which caused the fault to persist on buses 4 and 5. After the UAT failed internally and tripped on fault protection, the fault was then transferred from the UAT to the startup transformer (SUT) and continued for several seconds before the breaker was actuated. This cleared the fault and ended the first electrical fault event.

Figure 1: Photo of the conduit damage above Bus 5

After the recovery procedures were conducted, the plant operators attempted to reset the electrical generator lockout relays. This action resulted in the SUT being reconnected to the uncleared fault on the 4 kV Bus 5. A second fault lasting several seconds occurred in the back of a switchgear cubicle before the breaker tripped. During this second arc flash, both safety-related 125 Vdc battery buses developed electrical grounds that were likely caused by arc flash and fire damage. The damage caused by this arc may be observed in Figure 4.

Figure 2: Photo of the conduit damage above Bus 5 (different view)

Figure 3: Photo within Bus 5 displaying the junction between the conduit and the cabinet

Figure 4: Damage caused by the second arc

Cable Shipment

In an attempt to gain a better understanding of the arcing events and subsequent fires at Robinson, the US Nuclear Regulatory Commission (NRC) collected samples of cables and shipped them to Sandia National Laboratories. The cables arrived in a 1.2 m x 1.2 m x 1.2 m (4 ft X 4 ft X 4 ft) wooden box; however, only the lower portion was occupied. Padding was not used during the shipment, although the longer sections of cable were wrapped with tape or zip ties as seen in Figure 5. Since the cables were packaged in this manner, additional damage to the jacketing or the insulation materials may have occurred during transit.

Figure 5: Cable shipment with the front panel removed

After removing the front panel of the shipping box, the cables were separated into individual samples (see Figure 6). Some of the samples were labeled with the tray and location along the tray (see Figure 7) and some were not labeled (see Figure 8). After the cables were removed from the shipping container, two loose tags (Figure 9) were found at the bottom of the box, but placing these tags with the appropriate samples appears to be possible, as seen in Figure 10.

Figure 6: All cables separated out from box

Figure 7: Cable Item 5 with tray location labels

Figure 8: Cable Item 9 sample without labels

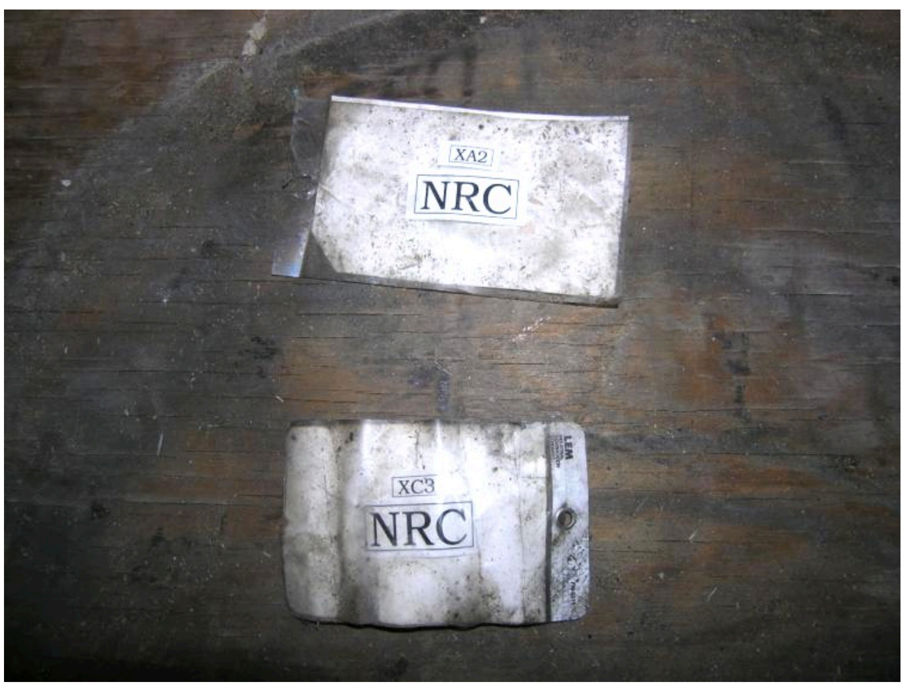

Figure 9: Tags separated from the cable samples

Figure 10: Possible location for separated tags

The cables varied in conductor count, gauge, and insulation/jacketing materials. The cables shipped to SNL are listed in Table 1. Availability of cable markings on each sample varied (e.g., gauge and manufacturer) and some cables were too damaged to distinguish any present writing. Also, there were samples that did not include any jacket markings. In such instances, fields for the gauge, manufacturer, and voltage rating were left as "Unknown". For the cable location in Table 1, the labels fixed to the cable by staff at Robinson were used to determine the location of the cable sample in proximity to the fire event. If there were no labels attached to the cable, the Origin was designated as "Unspecified."

Table 1: Cable inventory from Robinson

Item Number	Conductor/ Gauge	Manufacturer	Length (ft)	Origin	Voltage Rating	Notes
1	1C/Unknown	Unknown	1	Unspecified	Unknown	Unshielded
2	1C/350 MCM	Okonite	3	Unspecified	5000 V	Shielded
3	1C/350 MCM	Okonite	3	Unspecified	5000 V	Shielded
4	1C/350 MCM	Okonite	3	Unspecified	5000 V	Shielded
5	2C/Unknown	Unknown	16	Tray 1	Unknown	Silicon Rubber
6	3C/Unknown	Unknown	10 (ea.)	Tray 3	Unknown	Bundle of three
7	1C/750 MCM	Okonite	20	Tray 2	5000 V	Shielded
8	1C/750 MCM	Okonite	15	Unspecified	5000 V	Shielded
9	2C/Unknown	Unknown	16	Unspecified	Unknown	Silicon Rubber
10	1C/750 MCM	Okonite	20	Tray 4	5000 V	Shielded

In general, each sample displayed different levels of damage severity. This may be observed in Figure 11, Figure 12, and Figure 13. Some samples displayed evidence of corrosion of the metal wrap beneath the jacket while other cables showed little damage. This difference is elaborated upon in the subsequent section.

Figure 11: Close up of exposed metal wrap and cable damage for Item 2, 3, and 4

Figure 12: Close up of Cable Item 1

Figure 13: Indication of limited cable damage

Fire Scene Reconstruction

As depicted in Figure 14, the tray directly above Bus 5 is denoted as Tray 1 with horizontal locations of A, B, and C from left to right. This tray is open on the top and bottom. Tray 2 is located directly above Tray 1 and is labeled similarly with A, B, and C from left to right. From the photo information package, the bottom of the tray is open and the top is covered. Given the information from the labels fixed to the samples, some of the cables were removed from these two locations. Other cables within the shipment were labeled as coming from Tray 3 and Tray 4; however, these tray locations were not depicted or defined in any of the photos provided by the NRC.

It may be observed that both trays above Bus 5 were loaded with varying amounts of cables that were not well described in the information package. Additionally, it was not clear where the shipped samples of cable were located within the tray. As an example, it is unclear if these cables were located along the rail, in the center of the tray, or top/middle/bottom layer of cables. When comparing Figure 15, Figure 16, and Figure 17, the level of damage on the cables exposed directly to the fire appears to be much greater than the sample that was shipped to SNL. This implies that the cable shipped to SNL for analysis was not from the area of greatest heat impact. When tested for continuity, the cable taken from Tray 1 did not display insulation degradation between conductors. Continuity measurements were made using a Fluke 87V True-RMS multimeter.

Figure 14: Labels of the cable location for Bus 5

Figure 15: Damage of cables at location B in Tray 1

Figure 16: Cables located in Tray 1 and above Bus 5

Figure 17: Cable located within Tray 1 at location B which was received from Robinson displays very limited damage

Tray 2 is located above Tray 1 and, as shown in Figure 18 and Figure 19, has a covered top and open bottom. In the latter picture, the level of damage may be observed, albeit limitedly. The cable from this tray is 750 MCM in size and contains a metallic, sub-jacket wrap. The cable shipped to SNL (shown in Figure 20) displayed less damage than depicted in the photograph of the cables within the tray. Electrical continuity was checked between the copper strands and the wrap and it was determined that there was no measurable shorting between the two. These continuity measurements were also made using a Fluke 87V True-RMS multimeter.

Figure 18: Photo of the tray cover attached to Tray 2

Figure 19: Photo of cables located within Tray 2 at an undefined horizontal location

Figure 20: Close up of the received cable found in Tray 2

General Observations and Conclusions

All the cables supplied to SNL varied in terms of fire damage, as some displayed more thermal impact than others. Without detailed knowledge of origin, including specific tray and location within the tray, scene reconstruction was only limitedly useful. To gain some perspective on the electrical integrity, each sample was tested for continuity between adjacent conductors or the metal wrap. Although all the results indicated that the insulation maintained electrical isolation between the conductors and metal wrap, it is not certain that the samples shipped to SNL were the most damaged from each tray location. As indicated in the prior section of this report, the level of damage depicted in the photographs was not well represented by the samples received.

Two of the cable samples were located within Tray 3 and Tray 4. The information package provided by NRC, however, did not identify the position of these trays in the context of the fire scene. Because of this, additional details are necessary to properly place the cable samples from these locations and to quantify the damage from the fires. This information would also be useful to identify differences between the photos from the incident to the cables received from Robinson as well as the loading for each tray.

There were several samples of cable that were unlabeled and not described in the information package, specifically Items 1 through 4, 8, and 9. Without any description, these samples were not helpful in reconstructing the fire scene.

It was not possible to estimate the zone of influence of the HEAF event using the cables and information provided. It would be possible to use some of these cables to run limited Penlight exposure tests to gain insights on the thermal impacts received at designated cable locations. However, since there is a lack of information, such as the location of the cable within the tray bundle, this exercise may not be as useful as anticipated. Additionally, such tests would be outside of the scope of work for this task.

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