
Fires Involving Air Conditioning Fan Coil Units (2008 – 2014)

The Singapore Civil Defence Force (SCDF) responds to all reported fires in Singapore for firefighting and fire investigation. The archiving of detailed records for all these fires has enabled these studies for the purposes of public education and fire prevention.

The SCDF Fire Analysis Report series aim to make sense of similar fires seen over the years. Each report will provide details on the trends, patterns and other findings from the analysis of a specific type of fire or fire-related topic. Relevant examples of actual fire incidents will also be presented. In addition, fire safety tips or references to sources of information relating to fire prevention will be provided.

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Key Findings

- Air conditioning (A/C) fires are most prevalent among the common electrical household appliances in Singapore with about 2 – 3 cases per month.
- Various parts of the A/C system can catch fire but fires involving the Condensing Unit (CU) and Fan Coil Unit (FCU) account for most of these fires.
- Fires involving the CU are all localised but over a quarter of all fires involving the FCU resulted in secondary fires, causing more damage to the premises.
- Over a quarter of all the FCU fires came about when the FCU was not in use, but on standby mode.
- The use of intermediate connections, by means of twisting electrical wirings together and insulating them with electrical tape, within the FCU was found to be 1 root cause of the FCU fires.

Number of Fires Involving Household Electrical Appliances

Air conditioning (A/C) is an increasingly common find in Singapore households. From an ownership of 58.3% among Singapore households in 1998, this figure has grown to 76.1% in 2013 [1]. In a study on electrical fires in residential premises from 2008 to 2010 [2], it was noted that the A/C was 1 of the top 4 types of entities that were most commonly involved¹.

Another local study on fires involving common household electrical appliances from 2008 – 2013 found that A/C fires top the charts every year [3]. As shown in **Figure 1**, 2014 was no exception. There were 29 reported cases of A/C fires.

¹ Power meters and electrical boxes (in the common areas) were most commonly involved. This was followed by lighting (in both common areas and the residential units) and the consumer unit.

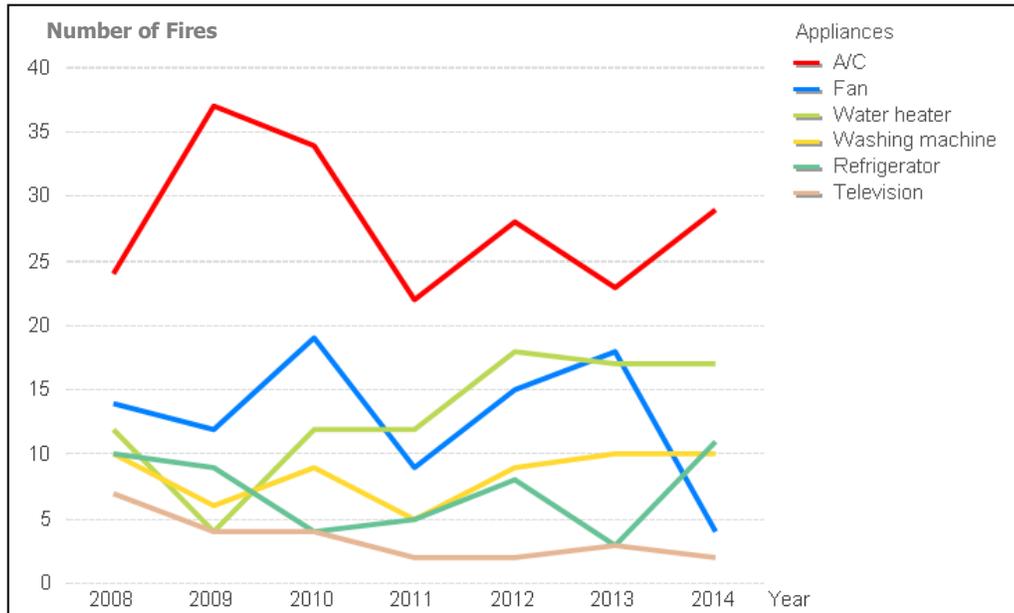


Figure 1. Fires involving household electrical appliances (2008 – 2014)

The Air Conditioning System

The typical A/C used in Singapore homes is the multi-split system which comprises a Condensing Unit (also known as the outdoor unit) and a number of wall-mounted Fan Coil Units (also called the indoor units). The Condensing Unit (CU) sits on a purpose-built A/C ledge (see **Figure 2**) or on brackets (see **Figure 3**) which protrudes out at the exterior of the building. The isolator of the A/C system is usually installed near the CU within the apartment or on an exterior building wall near the CU, which should be within reach from a window. The Fan Coil Unit (FCU), on the other hand, is usually mounted high on 1 of the walls of the rooms which require air conditioning as shown in **Figure 4**.



Figure 2. Condensing Units on A/C ledges



Figure 3. Condensing Units on brackets



Figure 4. A wall-mounted FCU

Air Conditioning System Fires

Various parts of the A/C system can catch fire as shown in **Figure 5**. For all the A/C system fires registered during the 7-year period from 2008 – 2014, 5.6% were noted to involve wirings near the CU while 4.6% involved wirings near the FCU. Fires involving the isolator accounted for 3.0%.

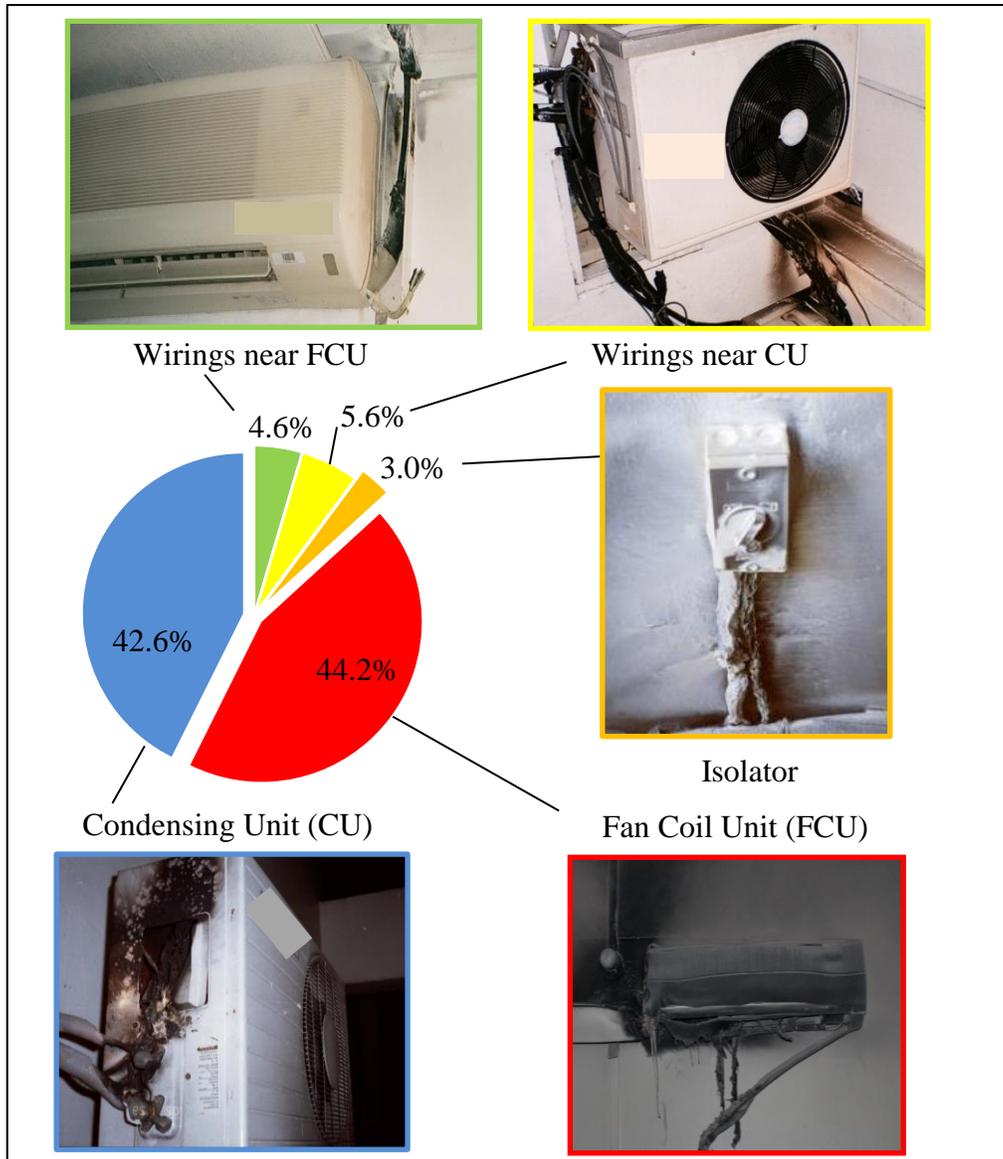


Figure 5. Breakdown of A/C Fires (2008 – 2014)

The detailed breakdown of the specific number of cases can be found in **Table 1**. Evident from the photographs in both **Figure 5** and **Table 1**, all the wirings and isolator fires were localised with most of them burning themselves out without any human intervention.

Parts of A/C System	Total Number of Fires						
	2008	2009	2010	2011	2012	2013	2014
Fan Coil Unit 	8	16	16	6	17	11	13
Wiring near Fan Coil Unit 	2	1	3	1	2	0	0
Condensing Unit 	13	19	10	11	8	10	13
Wirings near Condensing unit 	0	0	4	1	1	2	3
A/C Socket / Isolator 	1	1	1	2	0	1	0

Table 1. Breakdown of fires involving various parts of the A/C system (2008 – 2014)

There were significantly more fires involving the CU and the FCU. From 2008 – 2014, fires involving the CU accounted for 42.6% of all A/C system fires. CU fires were observed to be largely localised (see **Figure 6**) with no potential of extensive fire spread as the CUs are located outdoors, with no other combustibles nearby. FCU fires, on the other hand, account for 44.2% of all A/C system fires from 2008 – 2014. As illustrated in **Figure 7**, FCU fires can possibly result in substantial property damage.

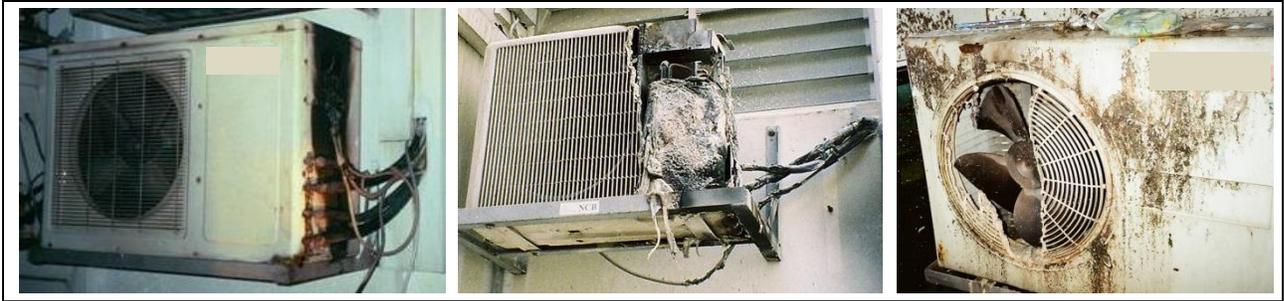


Figure 6. Fires involving the CUs



Figure 7. Fires originating from the FCU



FCU Fires

Fire Development

From the fire investigation photographs of the various FCU fires from 2008 – 2014, 1 possible manner in which some FCU fires develop became evident. As shown in **Figure 8**, fire can start at 1 end where the motor and circuitries are located. From there, the fire will spread laterally. At some point, the FCU dislodges and leaves the mounting plate on the wall. It should be noted that from the point of ignition, drop down² is possible and if there are combustibles beneath, the drop down can possibly start secondary fires below the FCU.

Figure 8. Development of FCU Fires

² The spread of fire by the dropping or falling of burning materials [4]



(a) FCU burn test set-up



(b) 'Dripping fire' observed



(c) Pool fire formed below the FCU

Burn tests conducted on FCUs (see **Figure 9**) show that the plastic cover of the FCU would melt and result in 'dripping fires'. The pool fire formed below the FCU is evidently a competent ignition source that can start a secondary fire involving combustibles placed under the FCU.

For the 87 reported FCU fires from 2008 – 2014, 73.6% were localised to the FCU while 26.4% spread to other parts of the room, after a secondary fire develops below the FCU (see **Figure 10**).

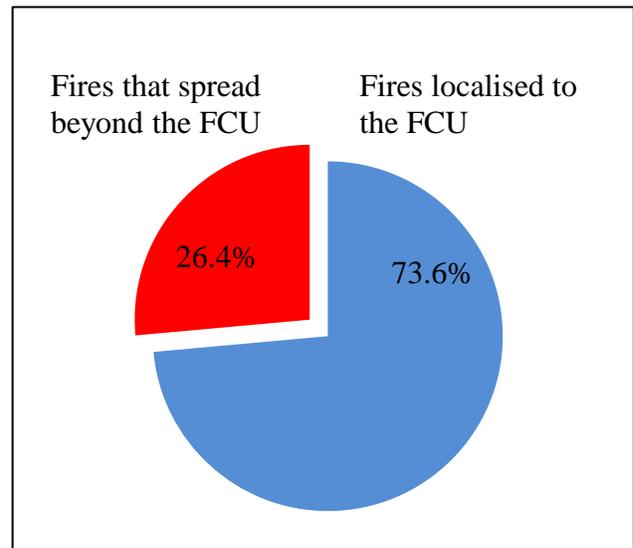


Figure 10. Extent of damage in FCU fires (2008 – 2014)

Figure 9. FCU burn test set-up and the drop down effects observed

Another location where FCU fires can start was observed to be behind the louvers, near the mid-section of the FCU as shown in **Figure 11**. Away from the motor and circuitries, the only possible ignition source for such fires is from the electrical cables that run across the length of the FCU. Such a fire will be examined in greater detail in 1 of the subsequent sections (Be Warned!) of this report.



Figure 11. Fires originating from the mid-section of the FCU

Ignition while on Standby Mode

As stated in the NFPA921: Guide for Fire and Explosion Investigations, for ignition to be from an electrical source, the electrical wiring, equipment or component must have been energised [5]. Unless the isolator near the CU is switched off, current will still be flowing in the wirings to the FCU. While this current that is going to the FCU on standby mode is low, at 0.01A for some brands, it should be noted that ignition is still possible. As shown in **Figure 12**, 26.4% of all FCU fires from 2008 – 2014 were involving FCUs that were not operating but on standby mode. **Figure 13** shows 4 localised fires involving the FCU on standby mode. A clear sign that these FCUs were on standby mode is that the louvers were all closed.

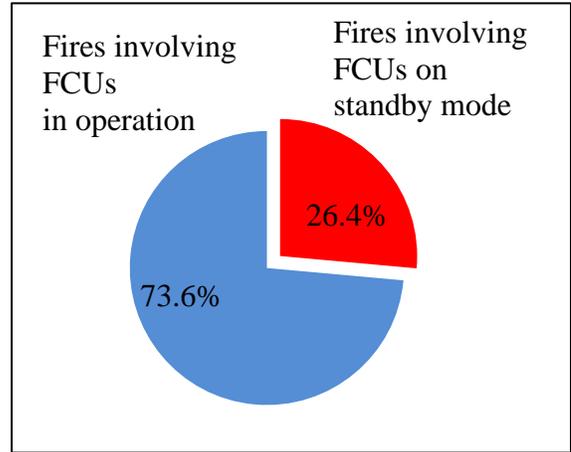


Figure 12. Proportion of fires involving FCUs (standby mode versus in operation) (2008 – 2014)



Figure 13. Localised fires involving FCUs which were on standby mode

From the Case Files

Case #1: May 2012, Bukit Timah

A 10-year-old girl was sleeping on her bed at the upper floor of a 2-storey house when she saw the FCU above her bed catching fire. She got out just before the FCU fell onto her bed and ran to inform her mother next door. When she returned with her mother, the bed already was well alight and they evacuated from the house with the rest of the family members. As a result of the fire, the entire level 2, including the roof, was damaged (see **Figure 14** and **15**).

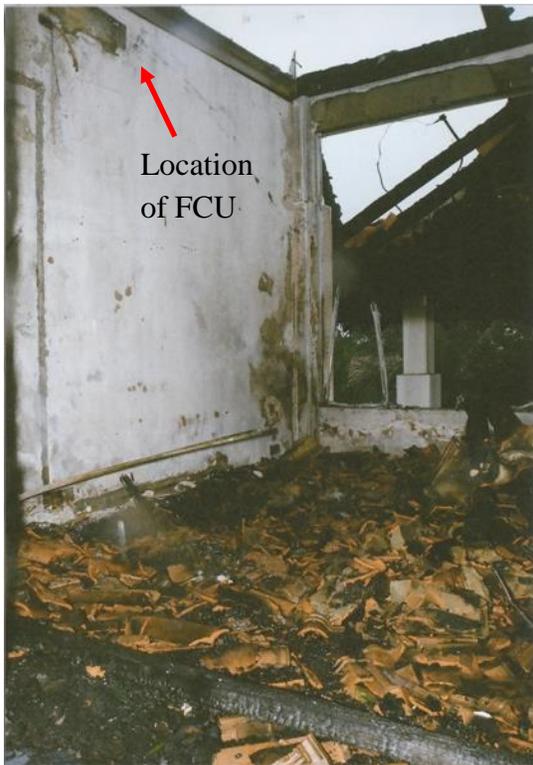


Figure 14. The FCU caught fire and the drop down ignited the bed directly beneath



Figure 15. Another room on level 2 that was gutted by the fire

Case #2: August 2012, Bukit Timah

A janitor was going about her routine in the morning, preparing the various rooms for another day of operations. After turning on the A/C for the office, she went to the rear of the premises to prepare the other rooms. Shortly thereafter, a customer arrived and alerted her of a fire in the office. She rushed to the office and saw fire at the FCU. He instructed her to switch off the power supply while he retrieved the fire extinguisher to fight the FCU fire. The firefighting attempts were unsuccessful and the fire began to spread. They then evacuated from the building.

As a result of the fire, the contents of the office were damaged (see **Figure 16**) while other parts of the building sustained heat, smoke and water damage (see **Figure 17**).



Figure 16. The initial firefighting efforts was unsuccessful and the FCU fire spread to other parts of the office



Figure 17. Other parts of the building sustained heat, smoke and water damage

Case #3: August 2014, Sembawang

A family of 3 was watching television in the living room when they witnessed sparks from the FCU above. Seconds later, smoke emerged and a fire broke out. They hurriedly evacuated from the apartment and proceeded to the Fire Command Centre to seek help.

A project manager was holding a meeting in the same building when he received a call from his colleague informing him of black smoke bellowing from an apartment on 1 of the higher floors. He and 3 of his colleagues then rushed up to the affected apartment to investigate and on seeing the fire, they used a hose reel to extinguish it. Drop down from the FCU fire ignited the TV and other items on the TV console (see **Figure 18**). The apartment sustained heat and smoke damage as a result of the ceiling jet³ and ceiling layer⁴ from the FCU fire (see **Figure 19**).



Figure 18. Drop down from the FCU fire damaged the TV and other items beneath



Figure 19. The apartment sustained heat and smoke damage as a result of the ceiling plume from the FCU fire

³ A relatively thin layer of hot gases that develops under a horizontal surface (e.g. ceiling) as a result of plume impingement and the flowing gas being forced to move horizontally [6]

⁴ A buoyant layer of hot gases and smoke produced by a fire in a compartment [7]

Case #4: October 2014, Bedok

It was 4.45 a.m. and Mdm Chin was just sleeping when she was awakened by bright sparks from the FCU in her bedroom. She then switched off the FCU and proceeded to retrieve a standing fan from the living room. In the midst of retrieving the standing fan, she observed white smoke emerging from her bedroom. She scurried back to her bedroom and saw the FCU on fire. She called SCDF for assistance immediately and evacuated from her residential unit. Fire damage was severe in the bedroom (see **Figure 20**) while other parts of the residential unit sustained heat and smoke damage (see **Figure 21**).



Figure 20. Fire damage was severe in the bedroom



Figure 21. Other parts of the residential unit sustained heat and smoke damage

Causes of FCU Fires

The NFPA 921: Guide for Fire and Explosion Investigations cited several possibilities for the cause of A/C fires. It explained that dust or contamination in the airflow path can settle over electrical components and cause tracking faults leading to a high-resistance fault that could ignite nearby combustible materials. Excessive temperature rise may also occur in compressor and fan motors due to bearing friction, increase in load or capacitor degradation. Motor capacitors can develop internal resistance over time and can cause sufficient heating to self ignite if encased in plastic [8].

For a spate of A/C fires in Australia, the cause was attributed to a possible inherent defect [9] as the manufacturer was involved in the recall of another make of A/C [10]. In the A/C fires reported by the U.S. Fire Administration, the cause was identified to be short circuit or electrical failure in A/C [11]. The New Orleans Fire Department, on the other hand, established the cause of the A/C fires which they investigated to be the use of undersized wirings not meant to carry higher power load required by the A/C [12].

Prevention of Air Conditioning System Fires

Proper installation of the A/C system is the critical first step in the prevention of FCU fires. For people living in HDB flats, there are guidelines for A/C installation works and these are available at the HDB website [13].

Some A/C suppliers offer installation courses [14] which are accredited⁵ by the Singapore Workforce Development Agency. The use of trained A/C installers is highly recommended as these people have undergone a structured course to equip themselves with the relevant skills and knowledge to perform the job.

Always adhere to the instructions in the installation, service or user manuals⁶ provided with the A/C system in your premises. Most of these documents carry comprehensive information about the DOs and DON'Ts with specific details on what could possibly cause a fire or some other grave consequence such as serious injury or death.

Be Warned!

One prominent root cause of FCU fires seen in Singapore is the use of intermediate connections, by means of twisting wires together and insulating them with electrical tape, within the FCU. Such a technique for creating an electrical splice is widely practised in Singapore but can be problematic especially when it is applied in FCUs.

Figure 22 shows a localised FCU fire. A close examination of the motor and circuitries (see **Figure 23** and **Figure 24**) show that both were completely unaffected and hence, ruled out as the cause of fire. The burnt area on the FCU is captured in **Figure 25** with the electrical cable that was running across the FCU being held in place.



Figure 22. A localised FCU fire



Figure 23. A close examination of the motor

⁵ Accreditation under the Singapore Workforce Skills Qualification (WSQ) framework [15]

⁶ Some of these documents may also be available at the official websites of the A/C companies

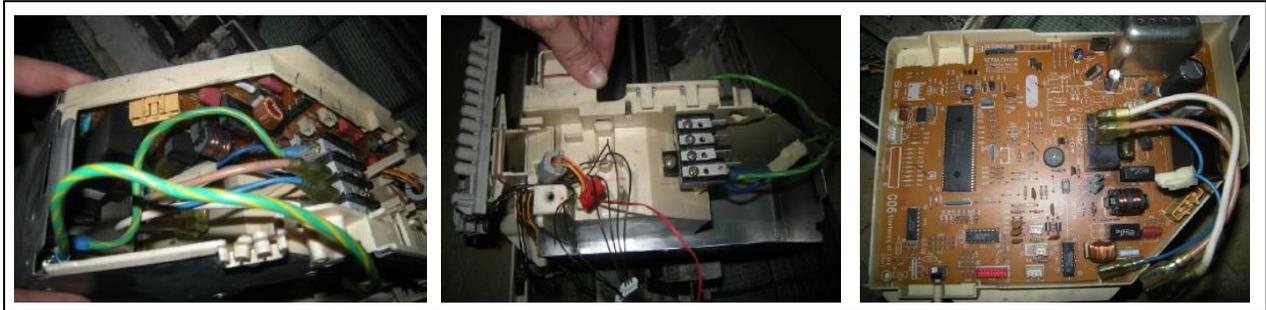


Figure 24. A close examination of the circuitries

The burnt section on the left side of the cable was damaged as a result of the fire as the bulk of the insulation is still intact. Had this section been the cause of fire, the insulation would have been consumed by the fire inside out.



Figure 25. The burnt area on the FCU with the electrical cable that was running across

The burnt section on the right is an intermediate connection achieved by twisting wires together and insulating them with electrical tape. A zoomed-in image of this intermediate connection can be found in **Figure 26**. From **Figure 26**, one would be able to see mass loss to the electrical tape, with the internal wiring exposed. All the above investigation findings are consistent with the ignition source of the fire to have come about from this point on the intermediate connection.

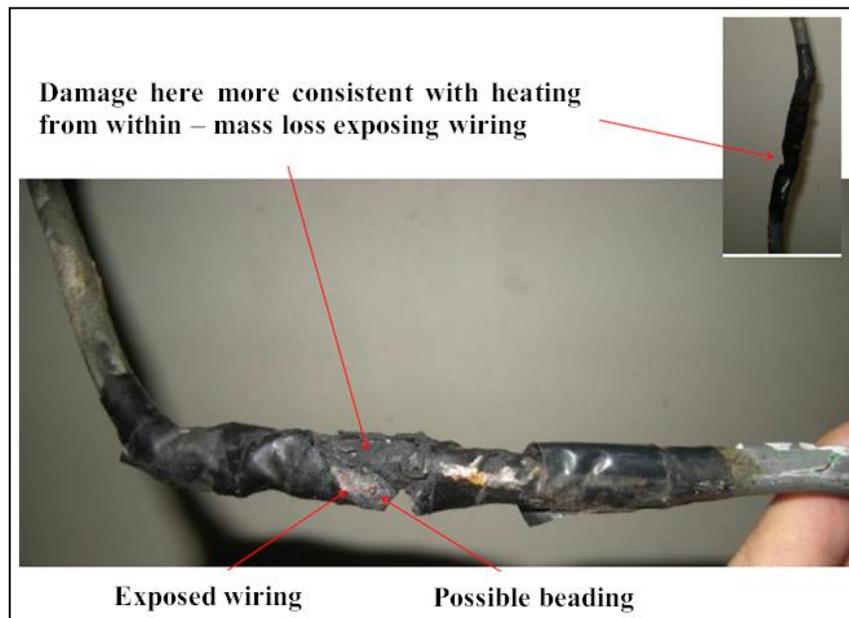


Figure 26. A zoomed-in image of the intermediate connection

Described as ‘a flagrant violation of both regulation [16] and good sense’ in the Ignition Handbook [17], electrical splices achieved by twisting wires together and insulating them with electrical tape are not allowed in the United States as they have been found to be the cause of many fires in the earlier days. The use of such splices in FCUs may greatly heighten fire risk as water from condensation can come into the picture.

References

- [1] Department of Statistics Singapore, 2015, Standard of Living Indicators – Household Ownership of Selected Consumer Durables, <http://www.singstat.gov.sg/statistics/visualising-data/visualiser/standard-of-living-indicators>, [Accessed on 22 May 2015]
- [2] Singapore Civil Defence Force, 2015, Electrical Fires in Residential Premises (2008 – 2010), Fire Analysis Report, Singapore, Available at http://www.scdf.gov.sg/content/scdf_internet/en/general/publications.html, [Accessed on 7 May 2015]
- [3] Lim BH, Rahman Y, Soh SY, 2014, Fires Involving Air Conditioning Fan Coil Units, Proceedings of the International Symposium on Fire Investigation Science and Technology, Maryland, pp. 413 – 421
- [4] National Fire Protection Association (NFPA), 2014, NFPA 921 Guide for Fire and Explosion Investigations, Massachusetts: NFPA, p. 15
- [5] National Fire Protection Association (NFPA), 2014, NFPA 921 Guide for Fire and Explosion Investigations, Massachusetts: NFPA, p. 107
- [6] National Fire Protection Association (NFPA), 2014, NFPA 921 Guide for Fire and Explosion Investigations, Massachusetts: NFPA, p. 14

- [7] National Fire Protection Association (NFPA), 2014, NFPA 921 Guide for Fire and Explosion Investigations, Massachusetts: NFPA, p. 14
- [8] National Fire Protection Association (NFPA), 2014, Fire Investigator: Principles and Practice to NFPA 921 and 1033, Jones and Bartlett Learning, p. 126
- [9] Australian Competition and Consumer Commission, 2008, Bravis Australia Pty Ltd – Evaporative Coolers, Available at <https://www.recalls.gov.au/content/index.phtml/itemId/952980> [Accessed on 11 July 2014]
- [10] Metropolitan Fire Brigade, 2012, Electricity safety authority warning after spate of fires in air conditioners, Available at <http://www.mfb.vic.gov.au/News/Electricity-safety-authority-warning-after-spate-of-fires-in-air-conditioners.html> [Accessed on 11 July 2014]
- [11] U.S. Fire Administration, 2001, Residential Air Conditioner Fires, Topical Fire research Series, Vol. 2, No. 5
- [12] Williams, L., 2012, New Orleans Fire Department warns about AC window unit fires, Available at http://www.nola.com/traffic/index.ssf/2012/04/new_orleans_fire_department_wa.html [Accessed on 10 July 2014]
- [13] Housing Development Board, 2014, Guidelines for Air Conditioner Installation Works, Available at <http://www.hdb.gov.sg/fi10/fi10324p.nsf/w/HomeRenoGuidelinesAirCon>, [Accessed on 29 May 2015]
- [14] Daikin Airconditioning (Singapore) Pte Ltd, Training and Development, Available at <http://www.daikin.com.sg/index.php/trgcalendar>, [Accessed on 25 May 2015]
- [15] Workforce Development Agency, 2012, About WSQ Directory, Singapore, Available at <http://www.wda.gov.sg/content/wdawebbsite/L207-AboutWSQ.html?parent=topnavabtwsq&openTab=3>, [Accessed on 25 May 2015]
- [16] National Fire Protection Association (NFPA) 70, 2014, National Electrical Code, Massachusetts: NFPA, p. 70
- [17] Babrauskas, V., 2003, Ignition Handbook, Fire Science Publishers/ Society of Fire Protection Engineers, Issaquah, Washington, p. 791