
**TAC: Mechanical**

**This document created by the Florida Department of Business and Professional Regulation -**

**850-487-1824**

# TAC: Mechanical

Total Mods for **Mechanical** in **Pending Review : 20**

Total Mods for report: 20

## Sub Code: Mechanical

### M12145

1

| | | | | | |
|---|---|---|---|---|---|
| **Date Submitted** | 02/14/2025 | **Section** | 202 | **Proponent** | Amanda Hickman |
| **Chapter** | 2 | **Affects HVHZ** | No | **Attachments** | No |
| **TAC Recommendation** | Pending Review | | | | |
| **Commission Action** | Pending Review | | | | |

**Comments**

**General Comments No** **Alternate Language No**

### Related Modifications

12050, 12142, 12144

### Summary of Modification

Updates code regarding A2L products.

### Rationale

This is one of several code modifications that updates the 9th edition code to reflect the necessary changes to permit the use of A2L refrigerants. As of January 1st, 2025, federal regulations prohibit the manufacturing of R-410A and other high-Global Warming potential (GWP) refrigerants. With the change to Low GWP Refrigerants, the Mechanical Code needs to be updated to address the use of Group A2L refrigerants in high probability (direct) systems. All of the commonly used Low GWP replacement refrigerants for direct systems fall into the category of Group A2L in the 2022 edition of ASHRAE 34. The safety requirements in ASHRAE 15 address the concerns regarding the use of a mildly flammable refrigerant. There are provisions for listing of equipment, installation of refrigerant detectors, and ventilation to mitigate any leak of refrigerant. By referencing ASHRAE 15 directly, the requirements become an enforceable part of the code. ASHRAE 15 requires an A2L appliance or equipment to be listed to UL/CSA 60335-2-40-2022 or UL/CSA 60335-2-89-2021 or newer editions. Failure to update the code could result in not having air conditioning and refrigeration products that are allowed to be used in Florida. Manufacturers are transitioning away from UL 1995 to UL 60335-2-40 and UL 60335-2-89 because UL 1995 will be sunsetting in the year 2024. The 4th edition of UL 60335-2-40 was published December 2022 and the 2nd edition of UL 60335-2-89 was published in October of 2021. Both of these standards have many new requirements for electrical and refrigerant safety. Nationally Recognized Testing Laboratories (or NRTLs) will use the latest version of the appropriate safety standard for certification testing. Reference to the latest editions of both standards included in this proposal are as issued by ICC in the 2024 IMC.

### Fiscal Impact Statement

**Impact to local entity relative to enforcement of code**

Will assist code enforcement regarding A2L products.

**Impact to building and property owners relative to cost of compliance with code**

These code changes will not increase the cost of construction, they only grant permission to use A2L products. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

**Impact to industry relative to the cost of compliance with code**

These code changes will not increase the cost of construction, they only grant permission to use A2L products. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

**Impact to small business relative to the cost of compliance with code**

These code changes will not increase the cost of construction, they only grant permission to use A2L products. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

## Requirements

**Has a reasonable and substantial connection with the health, safety, and welfare of the general public**

Updates code to ensure air conditioning products are permitted in the state of Florida.

**Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction**

Updates code to ensure air conditioning products are permitted in the state of Florida.

**Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities**

No. Only permits the use of A2L products.

**Does not degrade the effectiveness of the code**

No. Only permits the use of A2L products.

M12145Text Modification

**FLAMMABILITY CLASSIFICATION (REFRIGERANT).** The alphabetical/numerical designation used to identify the flammability of refrigerants.
**Class 1.** Indicates a refrigerant with no flame propogation.
**Class 2.** Indicates a refrigerant with low flammability.
**Class 2L.** Indicates a refrigerant with low flammability and low burning velocity.
**Class 3.** Indicates a refrigerant with high flammability.

**MACHINERY ROOM.** A room meeting prescribed safety requirements and in which refrigeration systems or components thereof are located (see Sections 1105 and 1106). An enclosed space that is required by Chapter 11 to contain refrigeration equipment and to comply with Sections 1105 and 1106.

**REFRIGERANT SAFETY GROUP CLASSIFICATION.** The alphabetical/numerical designation that indicates both the toxicity and flammability classifications of refrigerants in accordance with ASHRAE 34.
**Flammability.** See Flammability classification (Refrigerant).
**Toxicity.** See Toxicity classification (Refrigerant).

**Flammability classification (refrigerant).** The alphanumeric designation used to identify the flammability of refrigerants.
Class 1. Indicates a refrigerant with no flame propagation.
Class 2. Indicates a refrigerant with low flammability.
Class 2L. Indicates a refrigerant with low flammability and low burning velocity.
Class 3. Indicates a refrigerant with high flammability.

**Toxicity classification (refrigerant).** An alphabetical designation used to identify the toxicity of refrigerants. Class A indicates a refrigerant with low toxicity. Class B indicates a refrigerant with high toxicity.

**TOXICITY CLASSIFICATION (REFRIGERANT).** An alphabetical designation used to identify the toxicity of refrigerants. Class A indicates a refrigerant with lower toxicity. Class B indicates a refrigerant with higher toxicity.

Class A. Refrigerants that have an occupational exposure limit (OEL) of 400 parts per million (ppm) or greater.

Class B. Refrigerants that have an OEL of less than 400 ppm.

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Mod12145_TextOfModification.pdf

# TAC: Mechanical

Total Mods for **Mechanical** in **Pending Review : 20**

Total Mods for report: 20

## Sub Code: Mechanical

### M11775

2

| | | | | | |
|---|---|---|---|---|---|
| **Date Submitted** | 01/17/2025 | **Section** | 307.2.2 | **Proponent** | Rolando Soto |
| **Chapter** | 3 | **Affects HVHZ** | No | **Attachments** | Yes |
| **TAC Recommendation** | Pending Review | | | | |
| **Commission Action** | Pending Review | | | | |

**Comments**

**General Comments No** **Alternate Language No**

#### Related Modifications

#### Summary of Modification

Requires insulation for condensate piping located inside a building's unconditioned space.

#### Rationale

Uninsulated condensate piping carries a cold fluid, condensate water from cooling coils. The moisture that is present in unconditioned spaces condensates on the pipes exterior surface and can drip onto walls and ceilings. This drip can cause water damage and support the grows of mold inside the building.

#### Fiscal Impact Statement

**Impact to local entity relative to enforcement of code**

No impact to local government relative to enforcement. Condensate piping inspection are already part of the inspection for air conditioning or refrigeration installation permits.

**Impact to building and property owners relative to cost of compliance with code**

Minimal impact. Insulating the condensate piping is common. Pipe insulation is relatively inexpensive. Attached is the retail cost of one of the more common insulation sizes. Uninsulated pipes can do water damage, that expensive to repair, and cause disruption in building use.

**Impact to industry relative to the cost of compliance with code**

Minimal impact. Insulating the condensate piping is common. Pipe insulation is relatively inexpensive. Attached is the retail cost of one of the more common insulation sizes. Uninsulated pipes can do water damage, that expensive to repair, and cause disruption in building use.

**Impact to small business relative to the cost of compliance with code**

Minimal impact. Insulating the condensate piping is common. Pipe insulation is relatively inexpensive. Attached is the retail cost of one of the more common insulation sizes. Uninsulated pipes can do water damage, that expensive to repair, and cause disruption in building use.

#### Requirements

**Has a reasonable and substantial connection with the health, safety, and welfare of the general public**

Uninsulated pipes can do water damage and support the grows of mold inside the building that will negatively affect the health, safety, and welfare of the general public.

**Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction**

The proposed modification strengthens and improves the code by the insulation of condensate piping. Insulating the condensate piping is a common practice but it is not clearly mandated in the codes.

**Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities**

The modification does not mandate a specific type of insulation, only the R value.

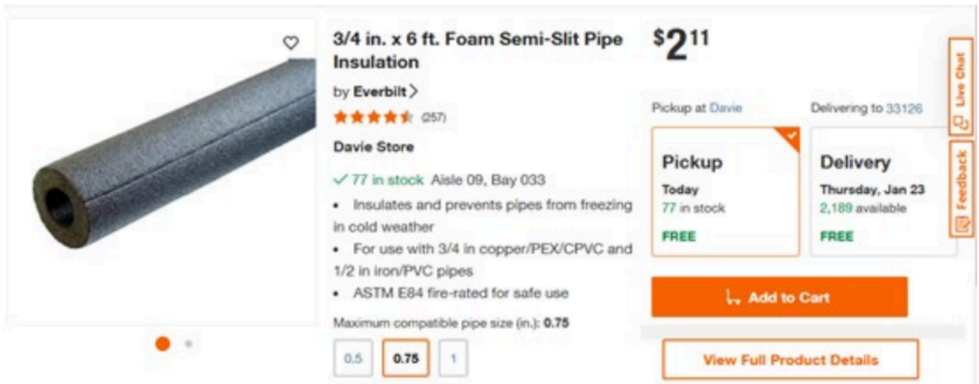
**Does not degrade the effectiveness of the code**

The proposed modification does not degrade the effectiveness of the code, it strengthens and improves the code.

307.2.2 Drain pipe materials and sizes.

Components of the condensate disposal system shall be ABS, cast iron, copper and copper alloy, CPVC, cross-linked polyethylene, galvanized steel, PE-RT, polyethylene, polypropylene, PVC or PVDF pipe or tubing. Components shall be selected for the pressure and temperature rating of the installation. Joints and connections shall be made in accordance with the applicable provisions of Chapter 7 of the Florida Building Code, Plumbing relative to the material type. Condensate waste and drain line size shall be not less than 3/4-inch (19.1 mm) pipe size and shall not decrease in size from the drain pan connection to the place of condensate disposal. Where the drain pipes from more than one unit are manifolded together for condensate drainage, the pipe or tubing shall be sized in accordance with Table 307.2.2. Drain pipes conveying condensate from cooling coils and evaporators shall be insulated with a minimum of R-3 when located inside a building's unconditioned space.

M11775Impact Statement




Page: 1

Mod_11775_Impact_Insulation cost.pdf

# TAC: Mechanical

Total Mods for **Mechanical** in **Pending Review : 20**

Total Mods for report: 20

## Sub Code: Mechanical

### SP12019

3

| | | | | | |
|---|---|---|---|---|---|
| **Date Submitted** | 02/13/2025 | **Section** | 301.16 | **Proponent** | Rebecca Quinn obo FL Div Emerg Mgnt |
| **Chapter** | 3 | **Affects HVHZ** | No | **Attachments** | No |
| **TAC Recommendation** | Pending Review | | | | |
| **Commission Action** | Pending Review | | | | |

**Comments**

**General Comments No** **Alternate Language No**

#### Related Modifications

12018, 12020

#### Summary of Modification

For clarity, carry into other codes the change made in 8th to require elevation of exterior equipment and exterior appliances that are damaged by flood (see FBC EB Sec. 701.3 and FBCR Sec. R322.1.6).

#### Rationale

Many buildings in floodplains were built before communities started regulating and requiring buildings to be elevated and constructed to minimize exposure to flooding. During floods, exterior equipment that serves those buildings gets damaged, even when the building itself is not substantially damaged. When buildings are flooded and elevated exterior equipment remains functional, clean up and drying out are easier and faster. This means dangerous mold conditions are less likely to develop and buildings can more quickly be reoccupied. The code change clarifies the existing requirement in FBCEB Sec. 701.3 and FBCR Sec. R322.1.6) by adding it to FBCEB Repairs, FBC Mechanical, and FBC Fuel Gas so that it is clear that the requirement that is already in the code applies, whether it is called an alteration or repair, and whether a permit is issued under only the Mechanical or Fuel Gas codes. Methods used to raise the replacement exterior equipment are the same as the methods used when equipment is installed to serve new construction (pedestal, platforms, platforms that are cantilevered from or knee braced to the structure; wall brackets for mini-splits). FEMA's Mitigation Assessment Team reports prepared after some significant flood events document widespread damage to non-elevated exterior equipment. Elevating equipment at the time of replacement also saves building owners from having to pay for replacement equipment after the subsequent flood event.

#### Fiscal Impact Statement

**Impact to local entity relative to enforcement of code**

None; the 8th Ed requirements already apply to exterior equipment/appliances replaced because of flood damage.

**Impact to building and property owners relative to cost of compliance with code**

None; the 8th Ed requirements already apply to exterior equipment/appliances replaced because of flood damage.

**Impact to industry relative to the cost of compliance with code**

None; the 8th Ed requirements already apply to exterior equipment/appliances replaced because of flood damage.

**Impact to small business relative to the cost of compliance with code**

None; the 8th Ed requirements already apply to exterior equipment/appliances replaced because of flood damage.

## Requirements

**Has a reasonable and substantial connection with the health, safety, and welfare of the general public**

No change because the 8th Ed requirements already apply to exterior equipment/appliances replaced because of flood damage.

**Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction**

No change because the 8th Ed requirements already apply to exterior equipment/appliances replaced because of flood damage.

**Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities**

No change because the 8th Ed requirements already apply to exterior equipment/appliances replaced because of flood damage.

**Does not degrade the effectiveness of the code**

No change because the 8th Ed requirements already apply to exterior equipment/appliances replaced because of flood damage.

SP12019Text Modification

**301.16 Flood hazard.** For structures located in flood hazard areas, mechanical systems, *equipment* and *appliances* shall be located at or above the elevation required by Section 1612 of the *International Building Code* for utilities and attendant *equipment*. Replacement of exterior equipment and exterior appliances damaged by *flood* shall meet the requirements of this section.

**Exception:** Mechanical systems, *equipment* and *appliances* are permitted to be located below the elevation required by Section 1612 of the *International Building Code* for utilities and attendant equipment provided that they are designed and installed to prevent water from entering or accumulating within the components and to resist hydrostatic and hydrodynamic loads and stresses, including the effects of buoyancy, during the occurrence of flooding up to such elevation.

# TAC: Mechanical

Total Mods for **Mechanical** in **Pending Review : 20**

Total Mods for report: 20

## Sub Code: Mechanical

### M11941

4

| | | | | | |
|---|---|---|---|---|---|
| **Date Submitted** | 02/14/2025 | **Section** | 403.3.1.1 | **Proponent** | Rolando Soto |
| **Chapter** | 4 | **Affects HVHZ** | No | **Attachments** | Yes |
| **TAC Recommendation** | Pending Review | | | | |
| **Commission Action** | Pending Review | | | | |

**Comments**

**General Comments No** **Alternate Language No**

#### Related Modifications

SECTION M1507 MECHANICAL VENTILATION Same criteria in residential code would also need change proposed for code consistency.

#### Summary of Modification

Toilet/bathroom exhaust fans shall be controlled by a timer switch or rated or listed for continued use.

#### Rationale

In 2017, the U. S. Consumer Products Safety Commission (CPSC) did an assessment on exhaust fan fires. They said, “Staff searched the CPSC Injury or Potential Injury Incident (IPII) database for incidents involving exhaust fans for the 20-year period from January 1, 1997 to September 21, 2017. Staff identified 494 known incidents in that period related to permanently installed exhaust fans. The majority of these incidents occurred in residential bathrooms.” The results of this assessment pointed strongly toward exhaust fans as the culprit in causing fires. More than 75 percent (318/423) of the known incidents occurred in a bathroom or restroom. The most likely origin of the incident in these cases was the exhaust fan. The incidents ranged in severity from minor smoke to fire spreading through the structure. Of the 318 incidents that occurred in a bathroom or restroom, almost 80 percent (254/318) occurred in a residence.

#### Fiscal Impact Statement

**Impact to local entity relative to enforcement of code**
No impact. No new inspections or plan review is required.

**Impact to building and property owners relative to cost of compliance with code**
Time switches retail from around seven dollars and up. See attachments.

**Impact to industry relative to the cost of compliance with code**
Time switches retail from around seven dollars and up. See attachments.

**Impact to small business relative to the cost of compliance with code**
Time switches retail from around seven dollars and up. See attachments.

#### Requirements

**Has a reasonable and substantial connection with the health, safety, and welfare of the general public**
Yes. it will provide a safer, less fire prone building.

**Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction**
Yes. Yes. it will provide a safer, less fire prone building.

**Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities**
It does not.

**Does not degrade the effectiveness of the code**
It does not.

TABLE 403.3.1.1 MINIMUM VENTILATION RATES

| OCCUPANCY CLASSIFICATION | OCCUPANT DENSITY #/1000 FT$^2$ a | PEOPLE OUTDOOR AIRFLOW RATE IN BREATHING ZONE, $R_p$ CFM/PERSON | AREA OUTDOOR AIRFLOW RATE IN BREATHING ZONE, $R_a$ CFM/FT$^2$ a | EXHAUST AIRFLOW RATE CFM/FT$^2$ a |
|---|---|---|---|---|
| **Private dwellings, single and multiple** | | | | |
| | | | | |
| **Toilet rooms and bathrooms** g, i | — | — | — | **20/50** f |

For SI: 1 cubic foot per minute = 0.0004719 m$^3$/s, 1 ton = 908 kg, 1 cubic foot per minute per square foot = 0.00508 m$^3$/(s · m$^2$), °C = [(°F) -32]/1.8, 1 square foot = 0.0929 m$^2$.

a.Based upon *net occupiable floor area*.
b.Mechanical exhaust required and the recirculation of air from such spaces is prohibited. Recirculation of air that is contained completely within such spaces shall not be prohibited (see Section 403.2.1, Item 3).
c.Spaces unheated or maintained below 50°F are not covered by these requirements unless the occupancy is continuous.
d.Ventilation systems in enclosed parking garages shall comply with Section 404.
e.Rates are per water closet or urinal. The higher rate shall be provided where the exhaust system is designed to operate intermittently. The lower rate shall be permitted only where the exhaust system is designed to operate continuously while occupied.
f.Rates are per room unless otherwise indicated. The higher rate shall be provided where the exhaust system is designed to operate intermittently. The lower rate shall be permitted only where the exhaust system is designed to operate continuously while occupied.
g.Mechanical exhaust is required and recirculation from such spaces is prohibited except that recirculation shall be permitted where the resulting supply airstream consists of not more than 10 percent air recirculated from these spaces. Recirculation of air that is contained completely within such spaces shall not be prohibited (see Section 403.2.1, Items 2 and 4).
h.For nail salons, each manicure and pedicure station shall be provided with a *source capture system* capable of exhausting not less than 50 cfm per station. Exhaust inlets shall be located in accordance with Section 502.20. Where one or more required source capture systems operate continuously during occupancy, the exhaust rate from such systems shall be permitted to be applied to the exhaust flow rate required by Table 403.3.1.1 for the nail salon.
i. Toilet/bathroom exhaust fans shall be controlled by a timer switch. Exception: Fans rated or listed for continued use.

M11941Text Modification

SECTION 403 MECHANICAL VENTILATION

TABLE 403.3.1.1 MINIMUM VENTILATION RATES

| OCCUPANCY CLASSIFICATION | OCCUPANT DENSITY #/1000 FT[2 a] | PEOPLE OUTDOOR AIRFLOW RATE IN BREATHING ZONE, $R_p$ CFM/PERSON | AREA OUTDOOR AIRFLOW RATE IN BREATHING ZONE, $R_a$ CFM/FT[2 a] | EXHAUST AIRFLOW RATE CFM/FT[2 a] |
|---|---|---|---|---|
| **Private dwellings, single and multiple** | | | | |
| | | | | |
| **Toilet rooms and bathrooms** g, i | — | — | — | **20/50** f |

For SI: 1 cubic foot per minute = 0.0004719 m³/s, 1 ton = 908 kg, 1 cubic foot per minute per square foot = 0.00508 m³/(s · m²), °C = [(°F) -32]/1.8, 1 square foot = 0.0929 m².

a.Based upon *net occupiable floor area*.
b.Mechanical exhaust required and the recirculation of air from such spaces is prohibited. Recirculation of air that is contained completely within such spaces shall not be prohibited (see Section 403.2.1, Item 3).
c.Spaces unheated or maintained below 50°F are not covered by these requirements unless the occupancy is continuous.
d.Ventilation systems in enclosed parking garages shall comply with Section 404.
e.Rates are per water closet or urinal. The higher rate shall be provided where the exhaust system is designed to operate intermittently. The lower rate shall be permitted only where the exhaust system is designed to operate continuously while occupied.
f.Rates are per room unless otherwise indicated. The higher rate shall be provided where the exhaust system is designed to operate intermittently. The lower rate shall be permitted only where the exhaust system is designed to operate continuously while occupied.
g.Mechanical exhaust is required and recirculation from such spaces is prohibited except that recirculation shall be permitted where the resulting supply airstream consists of not more than 10 percent air recirculated from these spaces. Recirculation of air that is contained completely within such spaces shall not be prohibited (see Section 403.2.1, Items 2 and 4).
h.For nail salons, each manicure and pedicure station shall be provided with a *source capture system* capable of exhausting not less than 50 cfm per station. Exhaust inlets shall be located in accordance with Section 502.20. Where one or more required source capture systems operate continuously during occupancy, the exhaust rate from such systems shall be permitted to be applied to the exhaust flow rate required by Table 403.3.1.1 for the nail salon.
i. Toilet/bathroom exhaust fans shall be controlled by a timer switch. Exception: Fans rated or listed for continued use.

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Mod_11941_Text_403.3.11 Table.pdf

**DRAFT**

202? Florida Building Code, Residential, ?th Edition

SECTION M1507 MECHANICAL VENTILATION

**M1507.4 Local exhaust rates.**
*Local exhaust* systems shall be designed to have the capacity to exhaust the minimum air flow rate determined in accordance with Table M1507.4.

**TABLE M1507.4**
**MINIMUM REQUIRED LOCAL EXHAUST RATES FOR ONE- AND TWO-FAMILY DWELLINGS**

| AREA TO BE EXHAUSTED | EXHAUST RATES |
|---|---|
| Kitchens | 100 cfm intermittent or 25 cfm continuous |
| Bathrooms-Toilet Rooms [a] | Mechanical exhaust capacity of 50 cfm intermittent or 20 cfm continuous |

For SI: 1 cubic foot per minute = 0.0004719 $m^3/s$.

a. Toilet/bathroom exhaust fans shall be thermally protected or controlled by a timer switch. Exception: Fans rated or listed for continued use.

In 2017, the U. S. Consumer Products Safety Commission (CPSC) did an assessment on exhaust fan fires.

They said, "Staff searched the CPSC Injury or Potential Injury Incident (IPII) database for incidents involving exhaust fans for the 20-year period from January 1, 1997 to September 21, 2017. Staff identified 494 known incidents in that period related to permanently installed exhaust fans. The majority of these incidents occurred in residential bathrooms."

The results of this assessment pointed strongly toward exhaust fans as the culprit in causing fires.

> *More than 75 percent (318/423) of the known incidents occurred in a bathroom or restroom. The most likely origin of the incident in these cases was the exhaust fan. The incidents ranged in severity from minor smoke to fire spreading through the structure. Of the 318 incidents that occurred in a bathroom or restroom, almost 80 percent (254/318) occurred in a residence.*

Consumer Product Safety Commission

See attached CPSC report.

M11941Rationale

**From:** Beck, Michael
**To:** Soto, Rolando
**Subject:** FW: Ventilation Bathroom Fan Fires
**Date:** Tuesday, March 21, 2023 11:08:47 AM
**Attachments:** image001.png
image003.jpg
image004.png
image002.png
image005.png
image006.png
image007.png

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**From:** Banyas, Ryan <RBanyas@coconutcreek.net>
**Sent:** Monday, March 20, 2023 3:38 PM
**To:** Beck, Michael <MBeck@coconutcreek.net>
**Cc:** 'BParks@broward.org' <BParks@broward.org>; rsoto@broward.org
**Subject:** Ventilation Bathroom Fan Fires

Good Afternoon,

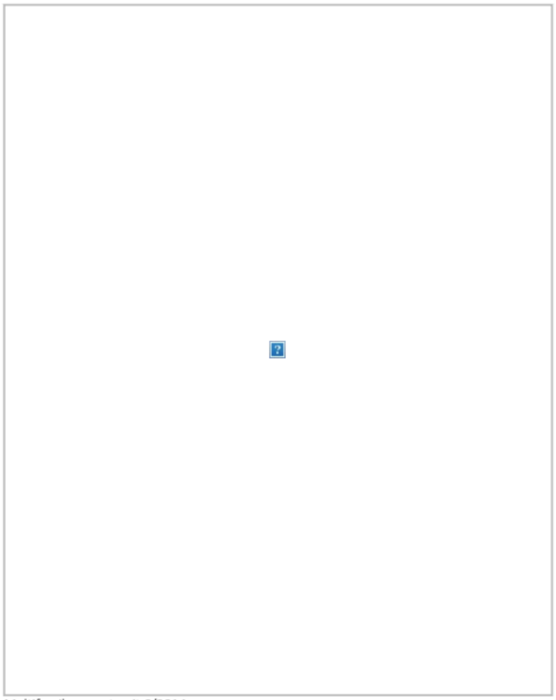
Please see the 5 fires located in bathroom ventilation fans in Coconut Creek that I am aware of. There were two other fires that were undetermined fires that I did not include because the fire damage was too extreme to determine the cause to be the fan. It would be great to see all new fan installations requiring thermal couplings.

Barbershop 02/2013

Multifamily Building 2/2014

Mod_11941_Rationale_Ventilation Bathroom Fan Fires.pdf Page: 1

M11941Rationale



Multifamily vacant unit 6/2014

Mod_11941_Rationale_Ventilation Bathroom Fan Fires.pdf Page: 2

Multifamily building 7/2022

Daycare facility 3/2023

M11941Rationale

Thank you,

**Ryan Banyas, MPA, CFPS**
Fire Marshal
4800 W. Copans Road
Coconut Creek, FL 33063
954-956-1563
954-420-5855 fax
www.coconutcreek.net

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vision 2030 inclusive, innovative, progressive

M11941Requirements

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About 25,200,000 results (0.63 seconds)

WKRG
https://www.wkrg.com › northwest-florida › ecfr-bath...

ECFR: Bathroom exhaust fan causes fire at Escambia ...

Jan 13, 2021 — (WKRG) — Escambia County **Fire** Rescue say a faulty **bathroom exhaust fan** caused a **fire** at a duplex on Waveland St. Tuesday afternoon. **Fire** units ...

People also ask

- Can bathroom vent fans cause fires?
- What can cause a bathroom fan to catch fire?
- Can exhaust fans cause a fire?
- Is it OK to vent bathroom fan into attic in Florida?

Feedback

WTSP
https://www.wtsp.com › local › hillsboroughcounty

Tampa apartment set ablaze from bathroom exhaust fan ...

Feb 6, 2022 — TAMPA, **Fla.** — Hillsborough County **Fire** Rescue spent Sunday morning working to put out a **fire** at an apartment complex in Tampa.

Sun Sentinel
https://www.sun-sentinel.com › broward › hallandale › fl...

Bathroom exhaust fan blamed for fire at Hallandale Beach ...

Aug 31, 2017 — A malfunctioning **bathroom exhaust fan** sparked a **fire** at a flower shop that left a firefighter injured, officials said.

YouTube
https://www.youtube.com › watch

Bathroom vents: a hidden fire danger in your home - YouTube

In Mesa alone, Smith says there have been 22 confirmed **fires** linked to **bathroom exhaust fans** in the past 30 months including five since ...

YouTube · ABC15 Arizona · Jun 16, 2017

WFLA
https://www.wfla.com › news › national › lightning-bl...

Lightning blows up toilet after traveling through apartment ...

May 7, 2022 — No one was injured, but the **toilet** was "severely damaged," **Fire** Chief Dewayne Hurt wrote in a statement shared with Nexstar. The lightning first ...

Sarasota Herald-Tribune
https://www.heraldtribune.com › news › 2008/07/13 › e...

Exhaust fan faulted in fatal fire

Jul 13, 2008 — A police spokesman said Saturday a faulty **exhaust fan** sparked a **fire** at a Tallahassee day-care center that killed a 4-year-old girl Friday.
Missing: ~~florida~~ | Show results with: florida

Law.com
https://www.law.com › 2022/09/22 › goldberg-segalla...

Goldberg Segalla to Rep Broan-Nutone Over House Fire ...

Sep 22, 2022 — The case, for alleged property damage claims arising from a defective **bathroom exhaust fan**, was filed Aug. 8 in Pennsylvania Eastern District ...

Page: 1

Mod_11941_Requirements_Web search of toilet fan fires in Florida.pdf

**From:** Beck, Michael
**To:** Soto, Rolando
**Subject:** FW: Ventilation Bathroom Fan Fires
**Date:** Tuesday, March 21, 2023 11:08:47 AM
**Attachments:** image001.png
image003.jpg
image004.png
image002.png
image005.png
image006.png
image007.png



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**To:** Beck, Michael <MBeck@coconutcreek.net>
**Cc:** 'BParks@broward.org' <BParks@broward.org>; rsoto@broward.org
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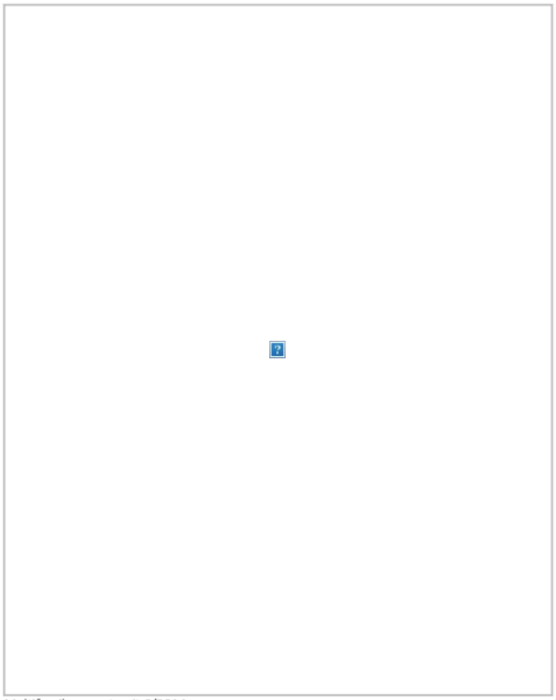
Barbershop 02/2013

Multifamily Building 2/2014



Multifamily vacant unit 6/2014

M11941Requirements

Multifamily building 7/2022

Mod_11941_Requirements_FW_ Ventilation Bathroom Fan Fires.pdf Page: 3

M11941Requirements

Daycare facility 3/2023

Mod_11941_Requirements_FW_ Ventilation Bathroom Fan Fires.pdf Page: 4

Thank you,

**Ryan Banyas, MPA, CFPS**
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Toilet exhaust fan fires in City of Coconut Creek courtesy of Ryan Banyas, MPA, CFPS, Fire Marshal

Barbershop 02/2013

Multifamily Building 2/2014

Multifamily vacant unit 6/2014

Multifamily building 7/2022

Daycare facility 3/2023

# CPSC Staff Assessment on Eutectic-Type Thermal-Cutoff Fuse Failures in Shaded-Pole Motors Used in Exhaust Fans

December 2017

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***The views expressed in this report are those of the CPSC staff and have not been reviewed or approved by, and may not necessarily reflect the views of, the Commission.***

Revision Changes

None

U.S. CONSUMER PRODUCT SAFETY COMMISSION
Directorate for Engineering Sciences

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## EXECUTIVE SUMMARY


Staff searched the CPSC Injury or Potential Injury Incident (IPII) database for incidents involving exhaust fans for the 20-year period from January 1, 1997 to September 21, 2017. Staff identified 494 known incidents in that period related to permanently installed exhaust fans. The majority of these incidents occurred in residential bathrooms.

CPSC field staff collected 100 exhaust fan samples in 2017 from part of a larger inventory that had been collected and stored by a military base housing authority. The exhaust fans had been replaced base-wide due to a large number of failures. CPSC Engineering Sciences (ES) staff's testing of these motors showed that the winding temperatures can reach high temperatures sufficient to ignite the motor during a lock-rotor condition when the eutectic-type thermal cutoffs (TCO) fail to activate. ES staff conducted additional investigation to evaluate factors that may contribute to the TCO failing to activate. During locked-rotor operation, a TCO may reach elevated temperatures while remaining below its functioning temperature. These elevated temperatures may result in thermally aging the TCO, potentially altering its set functioning temperature. A fan that has entered into a lock-rotor condition may experience multiple events of thermal heating without causing the TCO to activate.  These multiple heating events may have compounding effects on the TCO properties, thus causing either a delay in TCO activation or a failure to activate.

Even though the tested motors were listed to the appropriate voluntary UL standards, CPSC staff testing suggests that, in practice, thermal aging of the motors can cause the eutectic-type TCOs to fail. A contributing factor to this deviation from the original certification may be improper bending of the TCO wire leads, resulting in cracking the epoxy seal around the wire leads. During thermal heating, the melting properties of the thermal linkage in the TCO may be altered and cause either a delay in TCO-activation or failure to activate. If the TCOs in the motors fail to activate during a lock-rotor condition, the motor may overheat and ignite.

The results of this testing, and the fact that TCOs are used in many other consumer products, in addition to exhaust fans, support changes to the voluntary standards.

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## 1.0 INTRODUCTION

ES staff conducted an analysis of thermal cutoff fuse TCO failures in exhaust fan applications, specifically for fans that use eutectic-type thermal devices in shaded-pole motors. This report documents staff's analysis and assessment.

## 2.0 INCIDENTS

The CPSC's IPII database includes information on consumer product-related incidents that are collected through various reports and reporting systems.[1] The amount of information or detail can vary by the type of report. News reports typically contain minimal detail on the products and the events surrounding the incident. CPSC field investigators conduct In-Depth Investigations (IDIs) on specific incidents that may have originated from an IPII record. These investigations are conducted by CPSC field staff via phone or in-person interviews, and the investigations can include collection of police and injury reports. The investigation is documented in a report that typically contains detailed information on the products and events surrounding the incident, but the completeness of the reports depends on the information that the field investigator was able to collect.

### 2.1 Incidents

CPSC staff searched the IPII database for incidents involving exhaust fans, specifically the product code 380 (fans) that mentioned the word "exhaust" and indicated a fire or fire hazard. The search is not representative of any national statistics or estimates. The search produced 571incidents occurring between January 1, 1997 and September 21, 2017. Staff reviewed the search results; 77 of the incidents did not relate to structurally or permanently installed exhaust fans. The remaining 494 incidents contained sufficient information to determine that the incident involved a structurally or permanently installed exhaust fan. Of the 494 incidents 118 IDI reports resulted.

Of the 494 incidents with structurally or permanently installed fans, 71 incidents did not contain sufficient information to determine the exhaust fan's purpose. For example, staff could not determine in what room the fan was installed or for what purpose the fan was used. The remaining 423 incident reports contained sufficient information to determine the location of the exhaust fan and the likely use of the exhaust fan. The 423 incidents were categorized into five categories based on fan location (bathroom/restroom, kitchen, attic, laundry, and general). Incidents categorized as "general" involved locations that could not be assigned to one of the specific location categories. Table 1 lists the number of exhaust fan incidents by location.

[1] The incidents are gathered from news reports, consumer self-reporting, Medical Examiners and Coroners Alert Program (MECAP), attorney reports, referals, and Section 15 reports.

Table 1. Dataset from January 1, 1997 to September 21, 2017

| Incident Categories by Location | Count | Percent of Known |
|---|---|---|
| Bathroom/Restroom | 318 | 75.18% |
| Kitchen | 54 | 12.77% |
| Attic | 27 | 6.38% |
| Laundry | 8 | 1.89% |
| General | 16 | 3.78% |
| Known incidents only | 423 | 100% |
| Unknown | 71 | |
| Total Incidents related to exhaust fans | 494 | |

More than 75 percent (318/423) of the known incidents occurred in a bathroom or restroom. The most likely origin of the incident in these cases was the exhaust fan. The incidents ranged in severity from minor smoke to fire spreading through the structure. Of the 318 incidents that occurred in a bathroom or restroom, almost 80 percent (254/318) occurred in a residence. “Residences” were defined as a single- or multi-family home, apartment, condominium, senior citizen living facility, and dormitory. Of the 318 incidents that occurred in a bathroom/restroom, almost 19 percent of incidents occurred in a commercial building. “Commercial facilities” were defined as a commercial store or workplace, public facility, restaurant, or hotel. There was insufficient information for four incidents, which were classified as Unknown. Table 2 lists the types of structures for incidents that occurred in a bathroom or restroom.

Table 2. Bathroom/Restroom incidents

| Type of location | Count | Percent of Total |
|---|---|---|
| Residential | 254 | 79.9% |
| Commercial | 60 | 18.9% |
| Unknown | 4 | 1.2% |
| Bathroom dataset total | 318 | 100% |

Almost 13 percent of the known incidents occurred in a kitchen. These incidents occurred in either a residential or commercial structure, such as a home or restaurant. The exhaust fans that were involved in these incidents appear to have been mostly used to exhaust the area above or near a cooking appliance. For residential incidents, the exhaust fan may have been integral to a microwave oven/hood or a range hood. For commercial locations, the exhaust fan incidents appear to be related to inadequate maintenance of the exhaust hood, such as excessive grease from cooking. For commercial locations, there were several incidents where the exhaust fans were used to exhaust the space above cooked food or the kitchen area.

There were 27 incidents involving attic fans. These incident reports specifically contained descriptions that the products were attic exhaust fans that were used to ventilate the air within the attic and not bathroom exhaust fans mounted in the ceiling where there was attic space above the ceiling. These incidents occurred in both residential and commercial structures.

There were eight incidents involving exhaust fans in laundry rooms. These incident reports specifically contained descriptions that the exhaust fans were in laundry-type rooms that were used to wash and dry clothes. These incidents occurred in both residential and commercial structures.

There were 16 incidents involving exhaust fans that were categorized as "general" because the rooms in which these incidents occurred did not fall into any of the other categories. These incidents occurred in rooms such as sheds, factory rooms, medication rooms, basements, or dining rooms.

There were 77 incidents that were not within scope of the report. Some of the "not-within-scope" incidents involved cooking fires that ignited exhaust fans, heater fans, window fans, portable product fans, such as leaf blowers, and HVAC fans.

2.2 Selected Incident Cases

The incidents below, which involved exhausts fan in a bathroom or restroom, were selected to illustrate some of the differences and similarities in the incidents.

IDI 90611CCN0306

This incident occurred in a 10-year-old duplex/multi-family home in May 1998. On the day of the incident, the consumer was home and turned on the bathroom exhaust fan located on the ceiling. The family left the home around 2:00 p.m. and left the bathroom exhaust fan running for about seven (7) hours until the family returned around 9:00 pm. Upon returning, the family heard the smoke alarm sounding and witnessed smoke in the home. The family called the fire department, which determined that the bathroom exhaust ceiling fan had overheated, causing the plastic cover to catch fire and fall onto the toilet. The toilet seat cover had ignited, which fell into the toilet.

IDI 010402CCN474

In March 2001, at about 6:50 a.m. the fire department responded to an apartment structure fire. Firefighters discovered fire in the walls and the attic above the bathroom where the incident exhaust fan was located. Fire had spread into the common bathroom wall between apartment units and in the adjacent bedroom walls. The fire department determined that the fire started from a 30-year-old exhaust fan located in the bathroom of the apartment.

IDI 031125CNE1123

The incident occurred in November 2003. The day before the incident, the bathroom exhaust fan was left "on." On the morning of the incident, the family dog began running in and out of the bathroom and barking. Shortly thereafter, a smoke alarm located in the hallway outside the bathroom began sounding. The family observed smoke and flames coming from the bathroom exhaust fan. The fire marshal concluded that the fan motor overheated and determined that the home insulating material in the attic was not a contributing factor in the fan overheating because there was adequate space between the insulation and the fan housing.

IDI 050506CNE2395

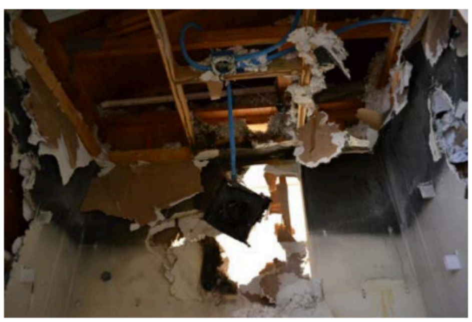
The fire occurred in a women's restroom of a closed nightclub section of a bar and restaurant business. An adjacent bar restaurant section was open for business and occupied by a bartender and several customers at the time of the incident. The owner indicated that even though the nightclub section had been closed, employees routinely used the bathrooms in that area. The men's and women's restrooms located in the nightclub were equipped with exhaust fans. The manager of the business reported that the fan in the women's restroom had been making a noise for about a week before the incident. At the time of the incident, the fire department extinguished the fire, which had traveled upward from the women's restroom into the second floor and attic, where it burned through parts of the roof.

IDI 050907CNE2758

On a morning in August 2008, the electricity in the residence and surrounding area had a power outage. After power had been restored in the afternoon, the occupants went throughout the home checking the light switches. This included the two switches in the second floor bathroom, which controlled the lights and incident exhaust fan. The occupants stated that the exhaust fan had "stopped" working about 3 years before the incident. Before the fan "stopped" working, the occupants reported that the exhaust fan had begun to make a noise. Before leaving the home, the occupant went around turning off the lights in the home, which they thought the second floor bathroom fan had been turned off. When they returned home in the evening, the homeowner found smoke coming from the roof vents of the structure. The fan had overheated and ignited and spread into the attic of the structure.

IDI 110322CCC2391

The incident occurred at a daycare facility. The building was built in 1995, and has been used as a daycare facility since its construction. The fans were original when the building was constructed. The lights and fans were controlled by a single switch. Five days a week, the switch was turned on at approximately 6:30 a.m. and turned off at about 7:00 p.m. The incident occurred in March 2011. After the daycare lights and fans were switched on, the daycare heat was also turned on. Approximately 1 hour later, a teacher and her assistant smelled something burning and assumed it was related to the heating system. Even though after the heating system was turned off, the burning smell persisted. The director went to the infant room and localized the burning smell to the changing room/bathroom. The director notified the owner of the daycare and was advised to disconnect the exhaust fans because they were old. The director was unplugging the exhaust fan when a "large fireball shot out" of the exhaust fan. The daycare was evacuated and the fire department was summoned to extinguish the fire.



IDI 130208CCC3391 and IDI 130326HWE0001

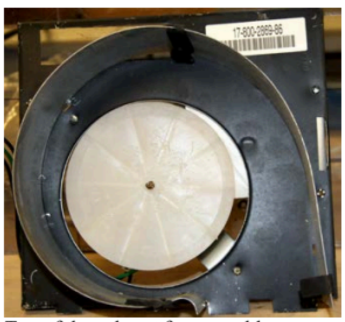
On two separate occasions, incidents involving bathroom exhaust fans occurred at Picerne Military Housing located on Ft. Riley Military Base, KS. The first incident occurred in June 2012, and was documented under IDI 130326HWE0001. The second occurred in February 2013, and was documented under IDI 130208CCC3391. The fans were installed sometime since 2007, when the housing construction was initiated. The housing authority stated that the same type of exhaust fans were installed in all the military homes constructed during that period. The housing authority reported that the fan motors had been seizing up. Because of this, the housing authority discontinued installing them in the homes in 2013, and removed all of the exhaust fans.

The June 12 incident occurred in a half bath in a single-family home. The Fort Riley Fire Department was dispatched to a structure fire at the residence. Upon arrival, the fire responders did not witness any signs of fire outside the home. Fire personnel entered the home to investigate and found water pouring from the first floor bathroom exhaust fan on the ceiling. The fire had been extinguished before fire fighters entered the home. The report identified that the plastic inside the fan had ignited, which then ignited the plastic vent hose. A plastic water line located above the fan had melted, which extinguished the fire. The cause of the incident was an overheated exhaust fan.

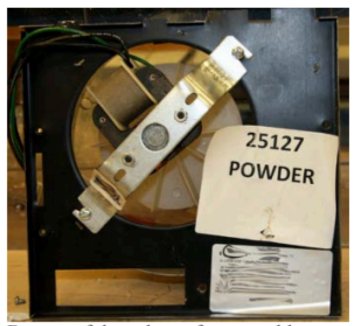
The February 5 incident occurred in a full bath on the second floor of a single-family home. There was extensive damage to the attic above the bathroom. The field investigator noted that the incident fan switch was in the “up” position, suggesting that the fan was on when the incident occurred. When the fire department arrived at the scene, fire personnel determined that the fire had spread into the attic area. An overheated exhaust fan caused the incident.

2.3 Incident Bathroom Exhaust Fans

The majority of the incidents (75 percent, 318/423) involved bathroom/restroom exhaust fans. Where photographs were available, the fans appear to have similar construction. The exhaust fans contain an external housing, a motor, an impeller, and a grill cover. The exhaust fans may incorporate a light option, but the incidents did not report the lighting assembly as the cause of the incident or fire. The "box" type exhaust fans contain a box housing that is mounted to the building structure. A fan assembly is mounted in the box housing. The fan assembly typically contains a mounting frame, fan motor, impeller, and power cord as shown in Figure 1. The box housing contains the electrical connections for the fan and light option and connection for the ducting.




Top of the exhaust fan assembly




Bottom of the exhaust fan assembly

Figure 1. Fan assembly for "box" type housing

A shaded-pole motor is an AC single-phase induction motor. The auxiliary winding, which is composed of a copper ring, is called a shading coil. The current in shading coil delays the phase of magnetic flux to provide a rotating magnetic field. The direction of rotation is from the unshaded side to the shaded ring. Typical components of a shaded pole-type motor are shown in Figure 2. Since these motors typically have low starting torque, low efficiency and a low power factor, these motors are typically suitable for low-power applications and are either thermally or impedance protected to prevent overheating. The type of protection can be identified by "T.P." or "Z.P." on the motor label, as shown in Figure 3. A Z.P. motor relies solely upon the impedance of the windings alone to prevent overheating; whereas, a T.P. motor relies upon a thermal protective device to prevent overheating.

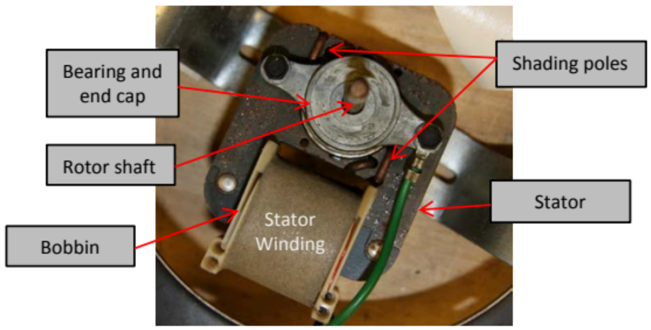



Figure 2. Shaded-pole motor

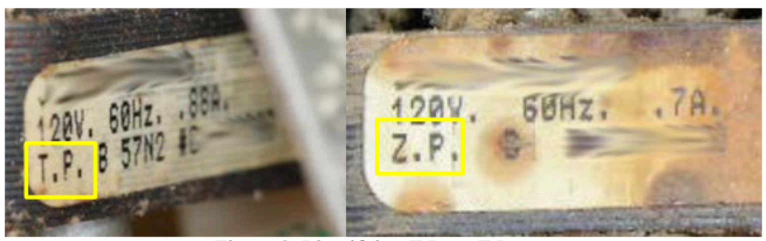



Figure 3. Identifying T.P. or Z.P.

Staff reviewed the IDIs to identify the types of fan motors used in the incidents. The dataset consisted of 118 IDIs. Of the 118 IDIs, 60 IDIs contained images of the incident exhaust fan. Of the 60 IDIs, 57 IDIs had sufficient information to identify the fan motor as a shaded pole-type motor. Three of the fans were not shaded pole-type motors; these were attic exhaust fans and appeared to be universal-type motors. Fifty-nine IDIs did not contain any identifiable information to determine the type of fan motor. Table 3 lists the number of identifiable shaded pole-type fan motors in the 118 IDIs.

Table 3. Shaded-pole motors

| | Motor type count | Percentage of known |
|---|---|---|
| Shaded pole motor | 57 | 95 % |
| Not shaded pole motor | 3 | 5 % |
| Identified motor type | 60 | 100 % |
| Unildentified motor type | 58 | |
| Total IDIs | 118 | |

## 3.0 RECALLS INVOLVING THERMAL PROTECTION

Consumer products with thermal protection have failed in the past. The most notable product recalls due to thermal protection failures in a consumer product occurred about 25 years ago involving drip coffeemakers. Beginning in the early 1990s, CPSC announced several recalls from different manufacturers of coffeemakers, where the thermostats and/or thermal fuses malfunctioned, thus, causing an overheating condition and a potential fire hazard.[2] The recalls involved more than 1 million coffeemakers.

Because of the recalls and coffeemaker fire incidents, CPSC staff discovered that the thermal devices used in these products can have the set point drift higher, or not function at all. Staff believed that thermal aging and/or heating of the thermal devices was causing the contact force to be reduced until the pressure between the contacts within the thermal device was nearly zero.[3] The episode resulted in Underwriters Laboratories (UL) incorporating construction and perfomance changes in the appropriate voluntary standards to addresss thermal devices used in coffeemakers. One of the new test methods was the "Conductive Heat Ageing Test" (CHAT), which represented slow aging of the thermal device under load, while mounted directly to a heated surface. This and other proposed requirements in UL 1082, *Standard for Household Electric Coffee Makers and Brewing-Type Appliances,* became effective in 1993 and 1994.

## 4.0 VOLUNTARY STANDARDS

Through collaboration with UL, a voluntary standard organization, safety standards are developed for a variety of consumer products, including exhaust fans. In many cases, these standards bring industry groups, government agencies, and consumer groups together to agree on the best consumer product safety practices. These standards have helped lead the way toward the development of safer consumer products.

Safety standards are constantly evolving and improving to adjust to the environmental changes, behavioral use, and technology. Below is a list of UL standards that may apply currently to exhaust fans or may have applied to exhaust fans in the past, but are no longer current:

UL 507, Standard for Electric Fans

UL 507 is intended to cover a large assortment of fan types, including exhaust fans. Exhaust fans are categorized as fans for use in unattended areas. These fan products are built into or within the building structure and may be operated unattended or in situations in which the operator may not detect a lock-rotor condition.

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[2] https://www.cpsc.gov/Recalls/1990/Proctor-Silex-Voluntarily-Recalls-Certain-Automatic-Drip-Coffeemakers-Made-In-198586-That-May-Pose-Fire-Hazard/; https://www.cpsc.gov/Recalls/1991/General-Electric-Voluntarily-Recalls-Certain-Drip-Coffeemakers-That-May-Pose-A-Fire-Hazard/; https://www.cpsc.gov/Recalls/1994/750000-1984-To-1988-Black--Decker-And-General-Electric-Under-The-Cabinet-Coffeemakers-Recalled-Possible-Fire-Hazard.

[3] *Temperature cutoffs (Thermal-links) for coffeemakers Extended Holding Temperature TH-100 rated TCOs*, InterControl. Hermann Köhler Elektrik GmbH & Co KG Schafhofstraße 30. 90411 Nuremberg. Germany.

ANSI/UL 2111, UL Standard for Overheating Protection for Motors

ANSI/UL 2111 was withdrawn and superseded by three dedicated standards, UL 1004-2, *Standard for Impedance Protected Motors*, UL 1004-3, *Standard for Thermally Protected Motors*, and UL 60730-2-2, *Standard for Automatic Electrical Controls for Household and Similar Use*; Part 2 *Particular Requirements for Thermal Motor Protectors*, beginning in 2013.

UL 1004-2, Standard for Impedance Protected Motors

UL 1004-2 is intended to be read with the *Standard for Rotating Electrical Machines – General Requirements*, UL 1004-1. The Standard applies to motors that rely solely upon the impedance of the motor windings to prevent overheating.

UL 1004-3, Standard for Thermally Protected Motors

UL 1004-3 is intended to be read with the *Standard for Rotating Electrical Machines – General Requirements*, UL 1004-1. The Standard applies to motors that rely upon a device (thermal motor protector) to prevent overheating.

ANSI/UL 1020, Standard for Thermal Cutoffs for Use in Electrical Appliances and Components

UL 1020 was withdrawn and superseded by UL 60691, *Thermal Links - Requirements and Application Guide* around 2003. The scope for ANSI/UL 1020 contained requirements that applied to thermal cutoffs intended to be embedded in windings or for freestanding use in end products.

UL 60691, Thermal Links - Requirements and Application Guide

The scope for UL 60691 is applicable to thermal links intended for incorporation into electrical appliances, electronic equipment, and component parts thereof, normally intended for use indoors to protect these products from excessive temperatures under abnormal conditions, including lock-rotor conditions.

## 5.0 FIELD SAMPLES[4]

The two incidents that occurred at Picerne Military Housing on Ft. Riley, KS military base in 2012 and 2013 provided an opportunity to collect a large number of samples for testing. CPSC field staff collected 100 exhaust fan samples in 2017. The fans were part of a larger inventory that had been collected and stored by the base housing authority when the exhaust fans had been replaced after a large number of exhaust fan failures. The fans were originally installed in the homes between June 2007 to February 2012. The fans were removed between April 15, 2013 and April 22, 2013. All the fans had similar manufacture dates from 2008 through 2010.[5] After the units were removed, the fans were placed into storage, initially office trailers, then into Conex units on post.

All of the fans collected were sold under the same brand name and contained the same motor manufacturer. The fan motors were shaded pole-type motors and had the same or similar construction. The main lot (96) of fan motors were constructed with a paper wrap around the winding core and had 25 stacked plates for the stator. Four fan motors had a slightly different construction, which included a plastic wrap around the winding core and had 35 stacked plates for the stator. All of the fans were thermally protected with a radial eutectic-type TCO.

### 5.1 Eutectic-Type Thermal Cutoff Fuses

A eutectic alloy is a homogeneous solid mixture of at least two metals or lattice components that is made up of the specific atomic/molecular ratio that yields the lowest possible complete melting point (eutectic temperature), which causes the solid mixture to change uniformly into a liquid mixture, as illustrated in Figure 4. In all other proportions, the mixture will not have a uniform melting point; some of the mixture will remain solid and some liquid. Eutectic TCO fuses contain a joint or linkage that is a eutectic alloy that will melt and open at the eutectic temperature.

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[4] The sections presented in this report were arranged for readability and understandability, not chronological order of the testing.

[5] The manufacturer date of the fan assembly does not necessarily represent the manufacture date of the fan motor. Staff believes that the fan motors were manufactured around 2000.

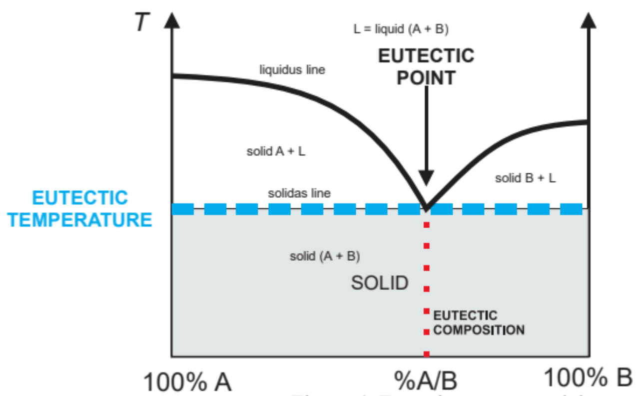



Figure 4. Eutectic system model

Eutectic TCOs are available with axial or radial lead wires, both having the same basic design as shown in Figure 5.[6] The fusible thermal linkage (thermal element) is a eutectic alloy that is welded across a pair of wire leads. The eutectic alloy is coated with a special compound to protect it from oxidation and allow wetting of the wire leads. Surface tension then separates the eutectic alloy, opening the circuit, thus activating the TCO. The fusible linkage is sealed in a special insulated housing.

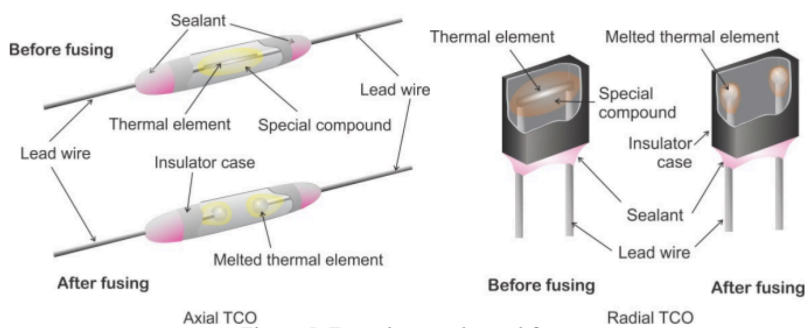



Figure 5. Eutectic-type thermal fuse

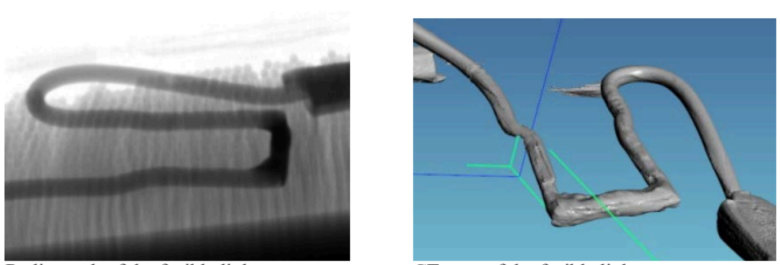
[6] Chatham Components Inc., Thermal Cutoffs, Elcut Brand Thermal Fuses, http://www.cci-tco.com/products/elcut-brand-thermal-fuse/.

5.2 Thermal Cutoff Fuses in the Fan Samples

All the fan samples contained radial eutectic-type thermal fuses. The fuses are marked with a functioning temperature of 136°C and rated for 250V 3A, as shown in Figure 6.

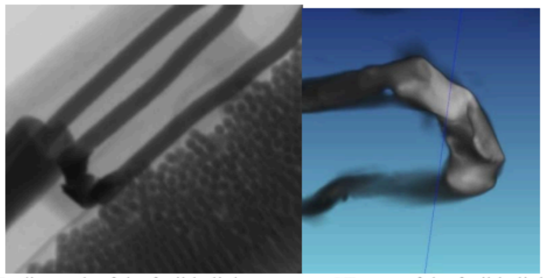
Figure 6. Radial eutectic-type thermal fuse in the sample fans

All 100 TCOs in the fans were x-rayed and 3-D imaged by computed tomography (CT). CT imaging can reveal detailed images of the internal TCO without destructive analysis. The CT scan allows cross-sectional details of the thermal linkage that cannot be seen in conventional radiographs by X-rays. The thermal linkage connects the two wire leads, as shown in the radiograph and CT images in Figure 7. In the examined thermal linkages in the fan samples, the thermal linkages varied with the shape of the linkage, such that some of the linkages were not uniform, as shown in Figure 8. It is unknown if the variations were caused from manufacturing or usage before collection.

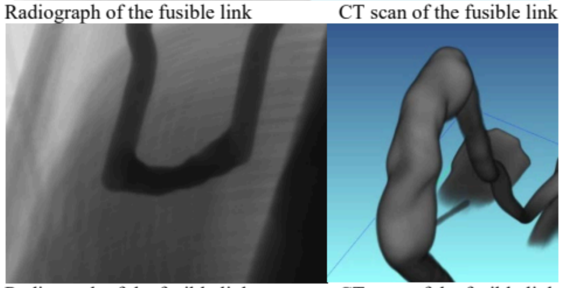


Radiograph of the fusible link CT scan of the fusible link

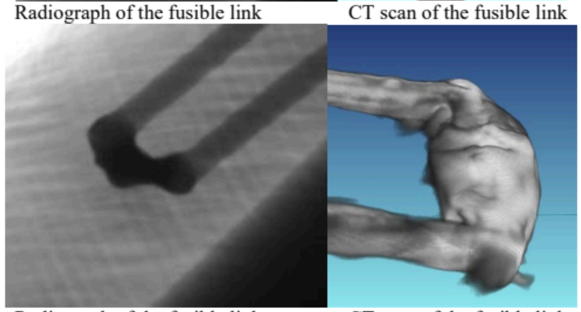
Figure 7. Smooth and uniform solder linkage (Sub 44)



Radiograph of the fusible link CT scan of the fusible link



Radiograph of the fusible link CT scan of the fusible link



Radiograph of the fusible link CT scan of the fusible link

Figure 8. Fusible link with irregular thermal linkages (Sub 91, 20 and 62)

## 5.3 Normal Fan Test

Staff measured and recorded the temperatures on the winding and within the TCO for one of the shaded-pole, motor-fan samples during normal fan operation. To record the temperatures, a fan (indexed as sub 60) was instrumented with three thermocouples on the paper wrap exterior of the winding, and within the TCO, as shown in Figure 9; the TCO was not in the circuit, *i.e.*, it was not carrying current. The top, side, and bottom thermocouples were secured against the winding wrap with thermal tape and a nylon plastic tie. To measure the temperature within a TCO, an activated or used TCO from another fan motor was removed and then modified with a thermocouple. The TCO was modified by drilling a small hole through the epoxy of the TCO and inserting a thermocouple, as shown in Figure 10. The hole was then resealed with an epoxy. The existing TCO within the motor was moved away from the winding and the thermocoupled TCO was located in its place. This allowed the modified TCO with the thermocouple to record the temperature as if the original TCO was installed. It would be expected that the thermocoupled TCO would measure a slightly lower temperature than an actual TCO because the lack of conductive heating from the winding and no current flow. The TCO plastic sleeve and winding wrap and tape were reinstalled and sealed before testing.

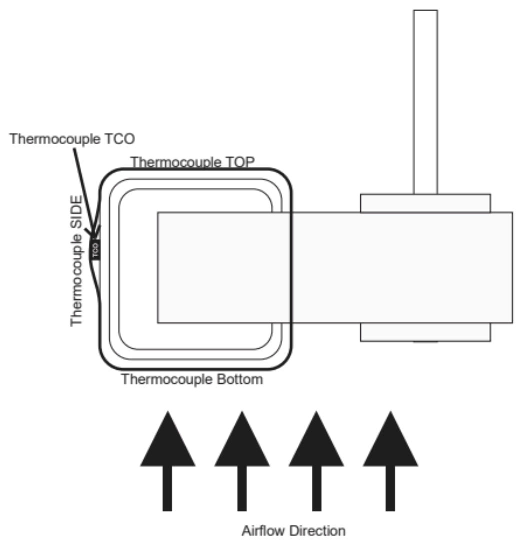
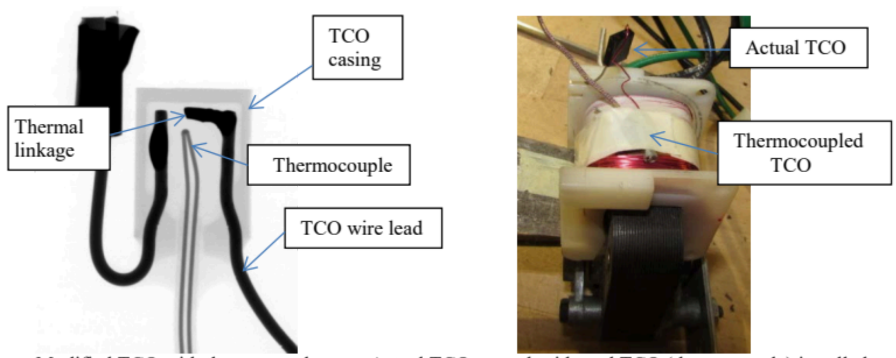



Figure 9. Thermocouple locations on the motor (side view)




Modified TCO with thermocouple        Actual TCO moved aside and TCO (thermocouple) installed

Figure 10. TCO with thermocouple

The testing showed that the TCO's internal temperature for this freely spinning motor with impeller is about 73°C. The thermocouple at the top of the winding measured slightly higher, at 76°C, than the TCO temperature as shown in Figure 11. When the fan was de-energized, the thermocouples located on the winding wrap measured an increase in the winding temperature because of the lack of airflow over the thermocouples when the impeller stopped spinning. The temperature within the TCO did not measure the same increase in temperature when the fan was de-energized. This is most likely caused by the TCO being located below the wrap, which caused the TCO not to be affected by the airflow.

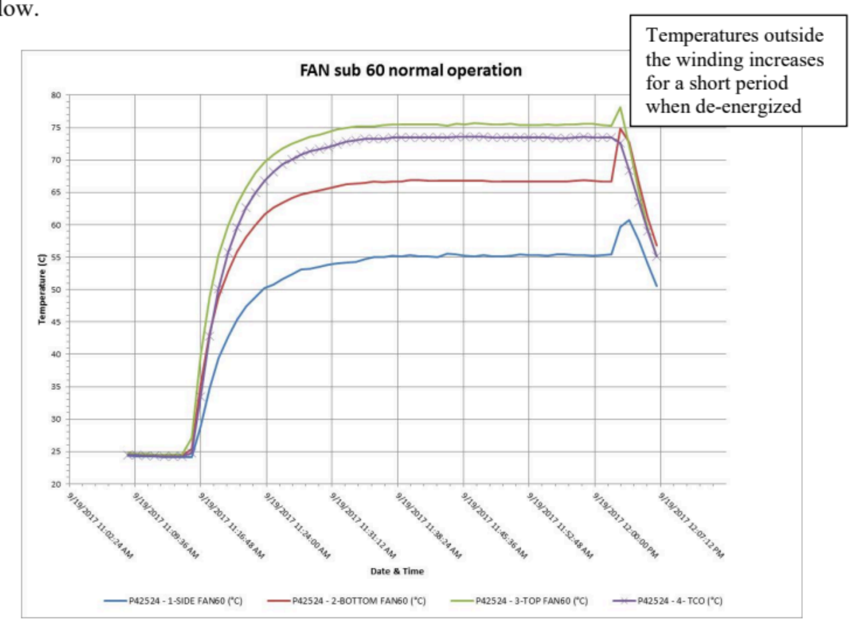



Figure 11. Temperature measurements on the winding and within the TCO (Fan 60)

## 5.4 Abnormal Fan Test

Fan sub 45 rotor did not turn freely in the condition in which it was received because of what appears to be dust and grime build-up at the bearings. When the sample was energized, the impeller/rotor did not spin; thus, it was in "locked-rotor" condition. Figure 12 shows sub 45 before any testing.

The fan was tested in its as-received condition, *i.e.*, locked-rotor condition. A single thermocouple was placed on the side of the winding, on the outside of the wrap, adjacent to the TCO location. After being energized, the TCO activated after 22 minutes, as shown by the temperature traces in Figure 13. For the location of this thermocouple, the temperature shows a maximum of 120ºC, but this location is about 20ºC cooler than the actual TCO or at the top of the winding. The actual TCO functioning temperature ($T_f$) was calculated to be about 140ºC (120ºC + 20ºC), which corresponds closely to the $T_f$ of 136ºC. This testing in lock-rotor condition also verified that the side thermocouple measurements on the paper wrap were about 20ºC lower than the actual TCO or the top of the windings. Figure 14 shows the radiographs of the TCO's fusible link after lock-rotor testing, which shows the thermal linkage melted or open.

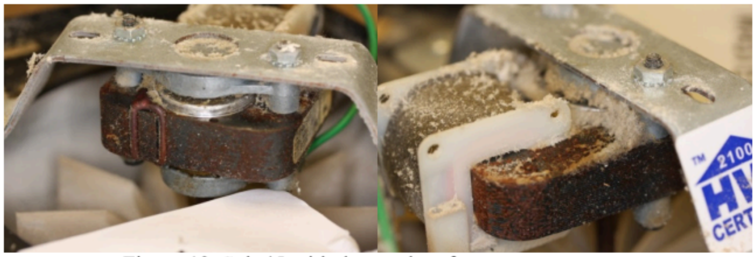


Figure 12. Sub 45 with dust and surface rust on core

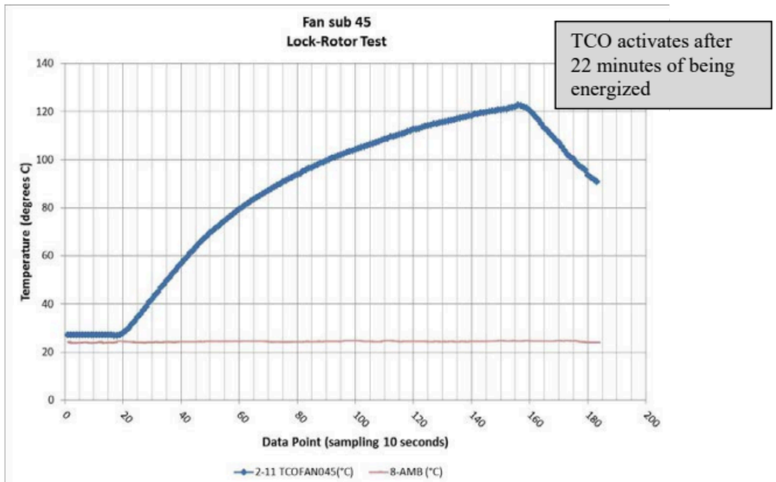


Figure 13. Sub 45 temperature measurement outside the winding

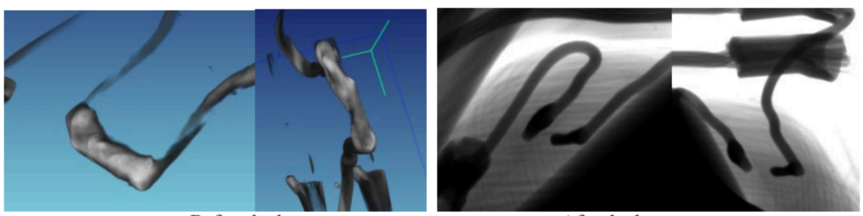

Before lock-rotor test After lock-rotor test

Figure 14. Radiograph and CT scans of the TCO before and after lock-rotor testing (Sub 45)

In other testing, where the TCO opened during lock-rotor conditions around the same elapsed time of 20 minutes, the thermal linkage had the same characteristic of only one end of the thermal linkage melting, as shown in Figure 15. This appeared to be caused by the TCO wire lead that is connected to the winding having a higher temperature than the wire lead connected to the power conductor. The wire lead would conduct the thermal energy from the winding during locked-rotor operation, thus causing one TCO wire lead to heat faster than the other TCO wire lead. Staff observed that for cases when the elapsed time was longer during the lock-rotor condition for the TCO to trip, and the temperature was higher than average, the thermal linkage would have inconsistent melting patterns, as shown in Figure 16. Staff expected that the delayed opening would result in a uniform temperature gradient within the TCO, thus causing the fusible linkage to melt completely or uniformly. But this was not the case, because the thermal linkage had irregularities, which suggests that other factors may be affecting the melting characteristics of the linkage.

Sub 04 Sub 40 Sub 36

Figure 15. Radiographs of TCOs after lock-rotor testing with consistent shape

Sub 69 Sub 10 Sub 58

Figure 16. Radiographs of TCOs after lock-rotor testing with unusual shapes

The same fan sub 60 that was instrumented with a thermocouple inside a TCO was used to measure the temperatures during lock-rotor conditions. Similar to the normal operation test, fan sub 60 had the three thermocouples on the paper wrap exterior of the winding and thermocoupled TCO. The lock-rotor condition was operated for 20 minutes to simulate the TCO tripping after 20 minutes in lock-rotor testing, as seen in Sub 45. After 9 minutes 12 seconds, the TCO temperature reached 105°C, as shown in Figure 17. At 15 minutes, the TCO temperatures reached 130°C. Shortly before 20 minutes, the TCO temperature reached 140°C. The TCO temperature measured approximately 142°C at 20 minutes or the manual trip time. The measurements in this test closely correspond to the sub 45 locked-rotor test. As mentioned previously, the TCO in sub 45 tripped at a measured temperature on the side of the winding around 120°C, and the temperature measured on the side of the winding in the test after 20 minutes of operation was about 123°C.


Figure 17. Temperature on the winding and within the TCO during a lock-rotor test

5.5 Lock-Rotor Test with TCO Bypassed

To evaluate worst-case scenario, fan sub 42, which had been previously tested in the lock-rotor test and the TCO tripped, was modified with the TCO bypassed. The tripped TCO was left intact in the motor, and a short piece of wire was soldered across the TCO wire leads to create a permanent linkage, thus bypassing the TCO. The test was to evaluate this motor if the TCO were to fail or not activate during a lock-rotor condition.

The fan was instrumented with a thermocouple located at the bottom of the winding, as viewed with the fan installed (see Figure 9 - Thermcouple BOTTOM). A second thermocouple was located exterior to the motor winding and on the same side as the TCO (see Figure 9 - Thermcouple SIDE). The lock-rotor test was conducted by blocking the impeller and energizing the fan. The thermocouple temperature measurements were recorded every 5 seconds.

The testing was conducted in three separate test periods. The first test period lasted 2 hours. The winding reached a steady-state temperature of 160ºC. After an elapsed time of 2 hours, the test was manually terminated. The fan was allowed to cool to room temperature before re-testing. The second test period was 2 hours. The winding reached a steady-state temperature of 200ºC. The test was manually terminated after 2 hours. The fan was allowed to cool to room temperature before re-testing.

For the third test period, the fan was energized in the lock-rotor condition, and after about 30 minutes, the temperature increased rapidly, which resulted in smoke and flames. The thermocouple temperature traces are shown in Figure 18. The motor winding ignited, which then ignited the plastic impeller, as shown in Figure 19. The plastic impeller resulted in dripping, flaming plastic. The total lock-rotor test time was about 4.5 hours (period 1 + period 2 + period 3).

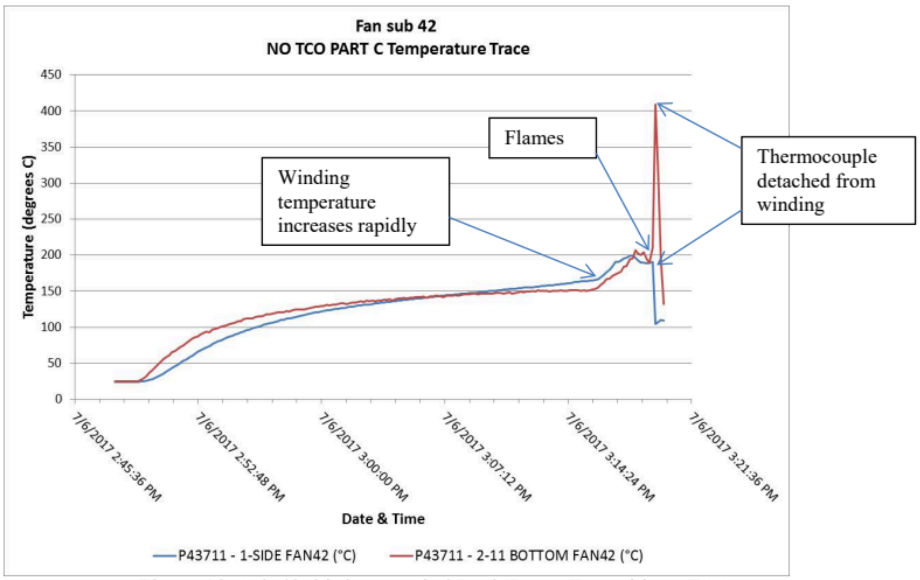



Figure 18. Sub 42 third test period Lock-Rotor Test with no TCO

Figure 19. Bypassed TCO lock-rotor test

5.6 TCO Trip-Time Testing

The 100 samples that were collected from Picerne Military Housing on Ft. Riley, KS military base were randomly assigned to seven different test groups. Table 4 lists the fan motor subs as assigned to the seven test groups. Test groups 1, 2, 4, 5, and 6 had 15 fan samples. Test group 3 had 14 fan samples, and test group 7 had 11 fan samples.

Table 4. Sample Test Group

| Test Group 1 | | Test Group 2 | | Test Group 3 | | Test Group 4 | | Test Group 5 | | Test Group 6 | | Test Group 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Sub No. | No. | Sub No. | No. | Sub No. | No. | Sub No. | No. | Sub No. | No. | Sub No. | No | Sub No. |
| 1 | 60 | 1 | 53 | 1 | 39 | 1 | 81 | 1 | 46 | 1 | 72 | 1 | 91 |
| 2 | 80 | 2 | 83 | 2 | 71 | 2 | 45 | 2 | 22 | 2 | 38 | 2 | 8 |
| 3 | 98 | 3 | 4 | 3 | 64 | 3 | 11 | 3 | 57 | 3 | 61 | 3 | 74 |
| 4 | 13 | 4 | 95 | 4 | 75 | 4 | 28 | 4 | 37 | 4 | 97 | 4 | 86 |
| 5 | 70 | 5 | 40 | 5 | 3 | 5 | 67 | 5 | 48 | 5 | 96 | 5 | 31 |
| 6 | 78 | 6 | 12 | 6 | 30 | 6 | 58 | 6 | 23 | 6 | 25 | 6 | 65 |
| 7 | 52 | 7 | 88 | 7 | 55 | 7 | 66 | 7 | 50 | 7 | 24 | 7 | 18 |
| 8 | 27 | 8 | 16 | 8 | 42 | 8 | 9 | 8 | 33 | 8 | 34 | 8 | 85 |
| 9 | 36 | 9 | 26 | 9 | 99 | 9 | 17 | 9 | 14 | 9 | 32 | 9 | 21 |
| 10 | 69 | 10 | 20 | 10 | 19 | 10 | 84 | 10 | 59 | 10 | 44 | 10 | 56 |
| 11 | 2 | 11 | 7 | 11 | 10 | 11 | 1 | 11 | 94 | 11 | 29 | 11 | 62 |
| 12 | 76 | 12 | 90 | 12 | 63 | 12 | 51 | 12 | 68 | 12 | 77 | | |
| 13 | 92 | 13 | 87 | 13 | 41 | 13 | 6 | 13 | 54 | 13 | 47 | | |
| 14 | 89 | 14 | 79 | 14 | 5 | 14 | 93 | 14 | 73 | 14 | 15 | | |
| 15 | 35 | 15 | 100 | | | 15 | 43 | 15 | 49 | 15 | 82 | | |

Two test frames were constructed for the testing. One test setup included a large test frame that allowed up to 15 fans to be tested at the same time, as shown in Figure 20. A second smaller test setup was constructed using a test frame that can accommodate up to two fans to be tested, as shown in Figure 21. Since the testing was lock-rotor condition, no vent hose was connected to the fan exhaust box housing.

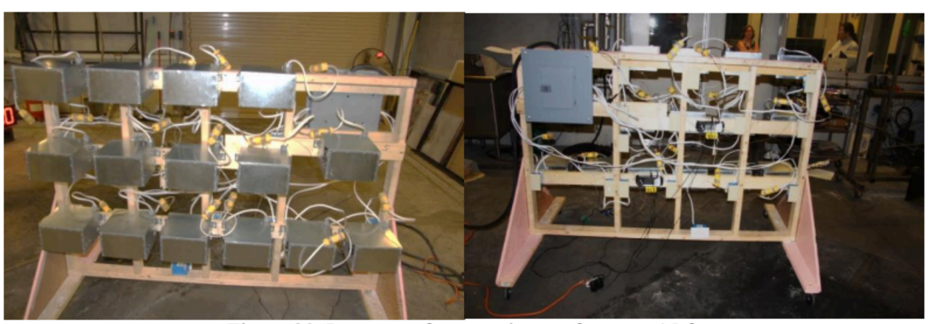


Figure 20. Large test frame and setup for up to 15 fans

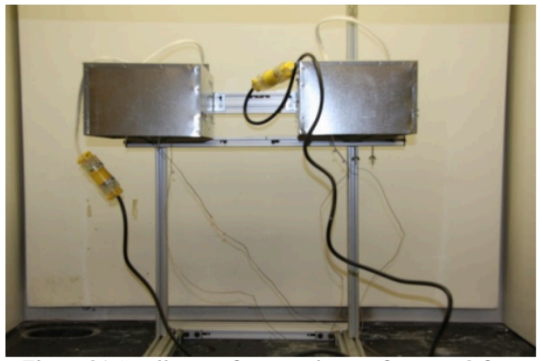


Figure 21 Smaller test frame and setup for up to 2 fans

*5.6.1 Test Groups 1 and 2 - Lock-Rotor Test (15 fans per group)*

Test Groups 1 and 2 each had 15 fans. Both groups of fans were tested on June 22, 2017. Each fan was instrumented with a thermocouple located on the exterior of the motor winding wrap on the side. Staff conducted a locked-rotor test by blocking the impeller with a nail through the side of the housing and energizing the fan with 120 VAC. The average ambient temperature at the start of the test was 26.8°C. Staff recorded the thermocouple measurements every 30 seconds.

All the TCOs activated (except Sub 60 due to the power connector coming loose early in the test). The measured temperature at the side of the winding when the TCO activated was between 110°C and 151°C (average 123°C). Sub 60 was later used for testing under the Section 5.3 Normal Fan Test to record temeprature traces during normal operation. Based on the sub 60 temperature traces under Normal Fan Test, we assume that the TCO temperatures should be about 20°C higher than the temperature on the side of the windings. This would translate to between 130°C and 171°C at the TCO and an average of 143°C . The activation times varied between 20 to 50 minutes for both test groups.

*5.6.2 Test Group 3 - 105°C Variable Duration Conditioning and Lock-Rotor Test*

Test Group 3 had 14 fans. All 14 fans were placed in a conditioning oven at 4 p.m. on June 23, 2017. The conditioning oven temperature was set at 105°C. The 105°C conditioning temperature corresponds to approximately 50 percent of the temperature difference (mean) between the TCO temperatures at trip and normal operation, as shown in equation [1] below. The fans were conditioned continuously at 105°C for a minimum duration of 64.3 hours to a maximum of 305 hours. The fans were removed from the conditioning oven at different times. After a fan sample was removed from the conditioning oven for testing, the fan motor was allowed to cool to room temperature before conducting the lock-rotor test.

$$(TCO\ temp_{at\ trip} - TCO\ temp_{normal}) \times 50\% + TCO\ temp_{normal} = Conditioning\ Temp \quad [1]$$

$$(143℃ - 73℃) \times 73℃ = 107.5℃ \approx 105℃$$

During lock-rotor testing, each fan was instrumented with two thermocouples. One thermocouple was located on the exterior of the motor winding wrap on the side of the winding. The second thermocouple was located on the bottom of the winding as viewed when the fan is installed. The lock-rotor test was conducted by blocking the impeller and energizing the fan. The thermocouple temperature measurements were recorded every 10 seconds.

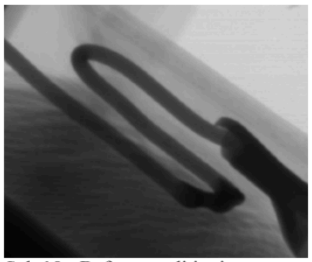
The smaller test setup was used during this testing series. Two fans were randomly removed from the conditioning oven at different conditioning periods to be tested. Table 5 lists the test frame location, thermocouple number, and conditioning period associated with each fan sub number.

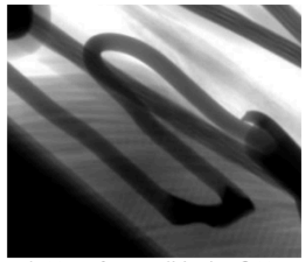
Table 5. Conditioning periods for Test group 3 subs

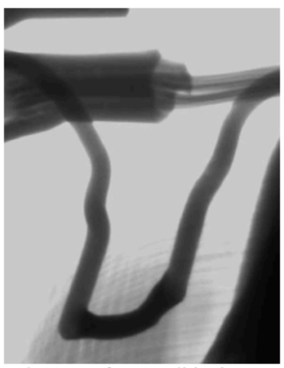
| Sub | Start Conditioning | End Conditioning | Conditioning Period (hh:mm) |
|---|---|---|---|
| 42 | 6/23/17 4:00 PM | 6/26/17 8:30 AM | 64:30 |
| 10 | 6/23/17 4:00 PM | 6/26/17 8:30 AM | 64:30 |
| 63 | 6/23/17 4:00 PM | 6/28/17 9:00 AM | 113:00 |
| 5 | 6/23/17 4:00 PM | 6/28/17 9:00 AM | 113:00 |
| 19 | 6/23/17 4:00 PM | 7/3/17 8:30 AM | 232:30 |
| 41 | 6/23/17 4:00 PM | 7/3/17 8:30 AM | 232:30 |
| 64 | 6/23/17 4:00 PM | 7/5/17 8:00 AM | 280:00 |
| 75 | 6/23/17 4:00 PM | 7/5/17 10:00 AM | 282:00 |
| 99 | 6/23/17 4:00 PM | 7/5/17 4:00 PM | 288:00 |
| 71 | 6/23/17 4:00 PM | 7/5/17 4:00 PM | 288:00 |
| 39 | 6/23/17 4:00 PM | 7/6/17 9:00 AM | 305:00 |
| 3 | 6/23/17 4:00 PM | 7/6/17 9:00 AM | 305:00 |
| 30 | 6/23/17 4:00 PM | 7/6/17 9:00 AM | 305:00 |
| 55 | 6/23/17 4:00 PM | 7/6/17 9:00 AM | 305:00 |

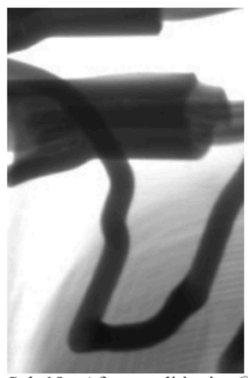
Effects of Conditioning to the Thermal Linkages

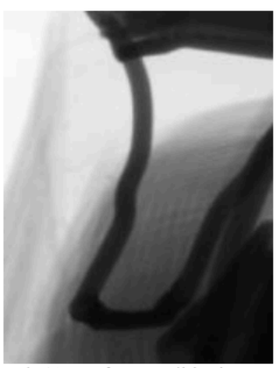
For test group 3, all of the TCOs were x-rayed before and after conditioning. The thermal linkages did not appear visually to have changed after conditioning at 105ºC for up to 305 hours. Figure 22 shows radiographs of the thermal linkages before and after conditioning for various lengths of time.

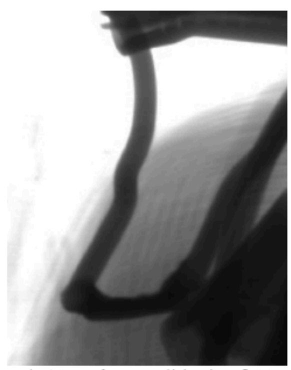

Sub 10 - Before conditioning

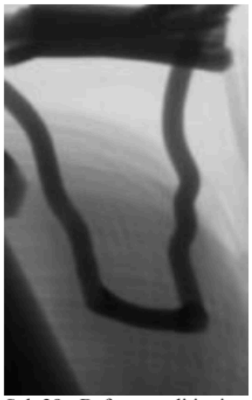

Sub 10 - After conditioning@105°C 64.5 hours


Sub 19 - Before conditioning


Sub 19 - After conditioning@105°C 232.5 hours


Sub 41 - Before conditioning


Sub 41 - After conditioning@105°C 232.5 hours



Sub 39 - Before conditioning

Sub 39 - After conditioning@105°C 305 hours

Figure 22 Thermal linkages before and after conditioning

## Results

Of the 14 units tested, one unit failed to open, allowing the winding to overheat and smoke. The unit's bobbin melted from overheating and arcing within the winding. Eight of the 14 units' TCOs opened within 24 minutes. Two of the 14 units' TCOs opened around 50 minutes, reaching temperatures above the rated $T_f$ for the TCO. Eight of the 14 units had elevated temperatures that exceeded the TCOs' rated opening temperature of 136°C. Table 6 lists data for Test Group 3.

Table 6. Test Group 3 - 105°C Conditioning and Lock-rotor Test Data

| Sub | Condition Period (hh:mm) | Max. Temp. at side (°C) | Calculated Functioning Temperature (°C) | Max. Temp. at bottom (°C) | Elapsed Time to Trip (hh:mm:ss) | TCO Open or Activated | Smoke or Fire | Failed to Trip at 136°C |
|---|---|---|---|---|---|---|---|---|
| 42 | 64:30 | 111.9 | ~132 | Loose thermocouple | 0:19:30 | Yes | No | No |
| 10 | 64:30 | 127.5 | ~148 | 181.6 | 0:52:00 | Yes | No | Yes |
| 63 | 113:00 | 109.0 | ~129 | Loose thermocouple | 0:22:00 | Yes | No | No |
| 5 | 113:00 | 131.0 | ~151 | 141.9 | 0:18:00 | Yes | No | Yes |
| 19 | 232:30 | 138.6 | ~159 | 127.2 | 0:54:00 | Yes | No | Yes |
| 41 | 232:30 | 209.8 | N/A | 302.0 | 2:40:00 | No | Yes | Yes |
| 64 | 280:00 | 155.8 | ~176 | 203.8 | 3:26:00 | Yes | No | Yes |
| 75 | 282:00 | 128.8 | ~149 | 157.5 | 0:24:00 | Yes | No | Yes |
| 99 | 288:00 | 151.6 | ~172 | 183.2 | 4:00:00 | Yes | No | Yes |
| 71 | 288:00 | 116.4 | ~136 | 146.4 | 0:19:00 | Yes | No | No |
| 39 | 305:00 | 111.9 | ~132 | 153.4 | 0:18:00 | Yes | No | No |
| 3 | 305:00 | 109.4 | ~121 | 140.2 | 0:22:00 | Yes | No | No |
| 30 | 305:00 | 158.5 | ~179 | 213.4 | 1:37:00 | Yes | No | Yes |

| Sub | Condition Period (hh:mm) | Max. Temp. at side (°C) | Calculated Functioning Temperature (°C) | Max. Temp. at bottom (°C) | Elapsed Time to Trip (hh:mm:ss) | TCO Open or Activated | Smoke or Fire | Failed to Trip at 136°C |
|---|---|---|---|---|---|---|---|---|
| 55 | 305:00 | 105.4 | ~125 | 154.3 | 0:22:00 | Yes | No | No |

<u>Sub 10 - Lock-Rotor Test</u>

Staff conditioned the fan (sub 10) for 64 hours 30 minutes. During the locked-rotor testing, the TCO activated. The TCO activated approximately 52 minutes after the rotor was locked. The activation time was about 30 miutes longer than seen during typical lock-rotor testing, which activated around 20 minutes within the testing. Figure 23 shows the temperature traces for the thermocouples during the lock-rotor test.

Figure 24 shows the CT scan of the fusible link after the lock-rotor test. As seen in prior testing when the trip time is longer than average, the fusible link melts at the center of the link. The figure does show a partial wetting of the electrodes occurred, which allowed the solder link to bead.

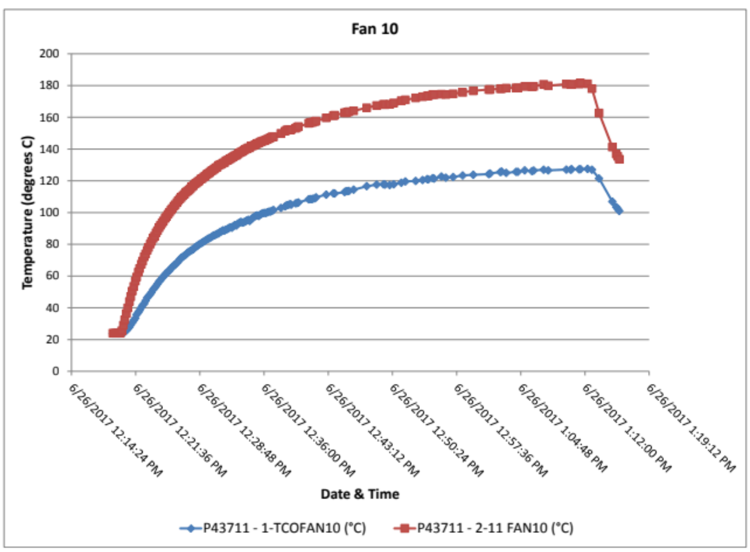



Figure 23. Temperature traces for Sub 10 Test Group 3 - Lock-Rotor Test

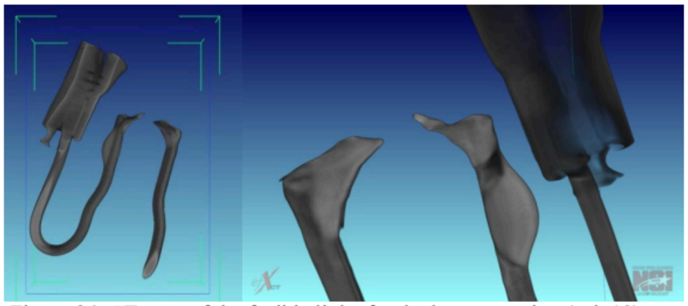


Figure 24. CT scan of the fusible link after lock-rotor testing (sub 10)

Sub 41- Lock-Rotor Test

Staff conditioned the fan (sub 41) for 232 hours 30 minutes. During the lock-rotor testing, the TCO did not activate. After about an hour, the temperature appeared to have leveled to a constant temperature or steady state. Staff terminated the lock-rotor testing after approximately 2 hours 30 minutes. Figure 25 shows the temperature traces for the thermocouples during the lock-rotor test on July 3, 2017.

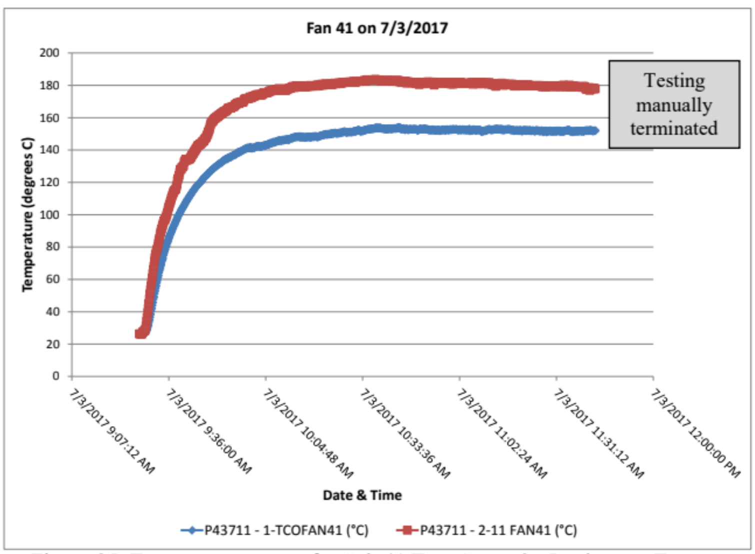



Figure 25. Temperature traces for Sub 41 Test Group 3 - Lock-rotor Test

Staff allowed the fan to cool to room temperature before retesting. During the second lock-rotor test, the temperatures increased rapidly, and the unit began to smoke. The temperature suddenly increased and arcing could be heard. Suddenly the arcing ceased, and the temperature began to decrease. Figure 26 shows the temperature traces for the thermocouples during the lock-rotor test on July 5, 2017. The thermocouple located at the

TCO (blue trace) detached from the surface of the winding when the unit began to smoke, which resulted in a sudden drop in temperature. The elapsed time to maximum temperature was about 9 minutes, 50 seconds.

Figure 27 shows the fan producing significant smoke during the second lock-rotor testing. There were no visible flames during the testing. Examination of the motor shows localized overheating and arcing in the winding. The full elapsed time for the first and second lock-rotor tests was about 2 hours 40 minutes.

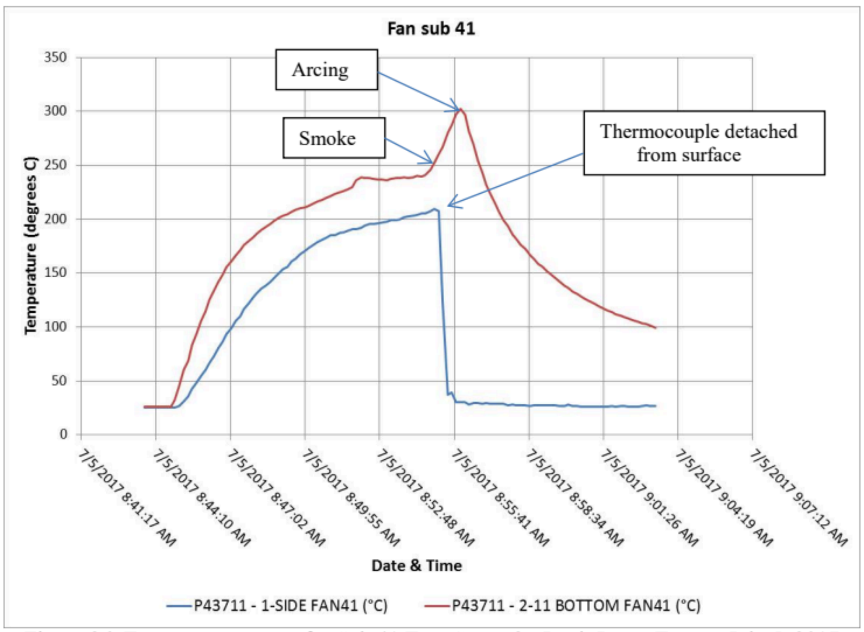



Figure 26. Temperature traces for Sub 41 Test Group 3 - Lock-Rotor Test on July 5, 2017

Figure 27. Sub 41 Test Group 3 - Lock-Rotor Test producing smoke and post examination

Post examination shows the TCO's fusible link to be intact, as shown by CT scans in Figure 28. During lock-rotor testing, the TCO failed to activate, but the event ended because the motor winding opened, thus de-energizing the motor.

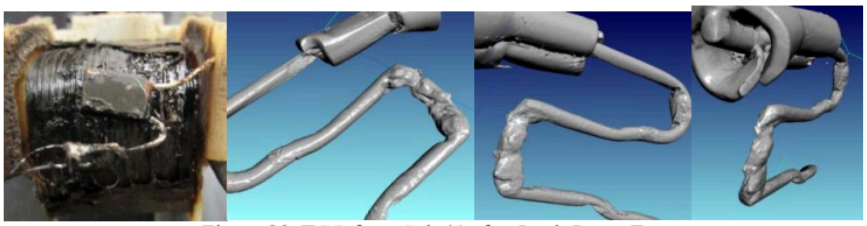


Figure 28. TCO from Sub 41 after Lock-Rotor Test

Sub 64 - Lock-Rotor Test

Staff conditioned the fan (sub 64) for 280 hours. During the initial lock-rotor testing on July 5, 2017, the TCO did not activate. The temperature appeared to have leveled to a constant temperature or steady state. Staff manually terminated the testing at noon, after approximately 3 hours 15 minutes.

Staff allowed the fan to cool for 45 minutes (to approximately room temperature) before retesting. During the second lock-rotor test, the TCO activated. Figure 29 shows the temperature traces for the thermocouples during the second lock-rotor test. The TCO tripped after approximately 11 minutes during the second lock-rotor test.

Post examination revealed a solder bead external to the TCO casing, as highlighted by the yellow circle shown in Figure 30. Microscopic images of the TCO show that the solder bead originated from inside the TCO because solder was located in cracks between the epoxy seal and the lead wire, as shown in Figure 31. Figure 32 shows the CT scans with the partially melted fusible link after the testing, thus, indicating the TCO did activate, but abnormally. Visible in the CT scan is the solder bead, highlighted by the yellow circles.

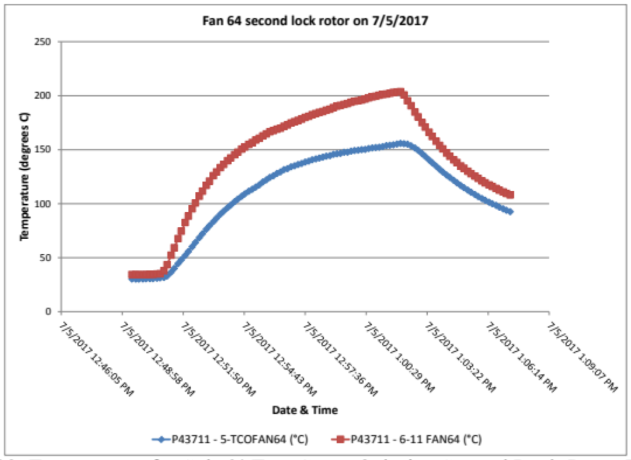



Figure 29. Temperature for Sub 64 Test Group 3 during Second Lock-Rotor Test

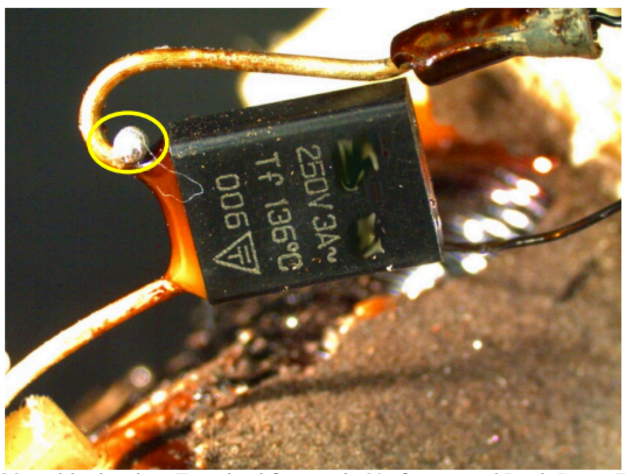
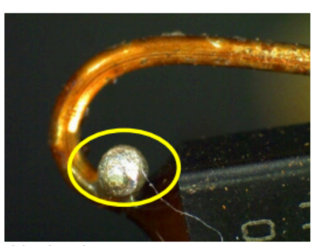
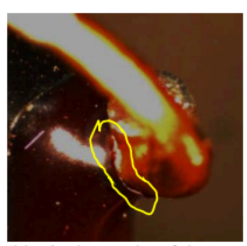



Figure 30. Solder bead on TCO lead from Sub 64 after second Lock-Rotor Test



Solder bead



Solder in the cracks of the epoxy/electrode

Figure 31. Microscopic images of the solder bead and solder in the cracks (Sub 64)

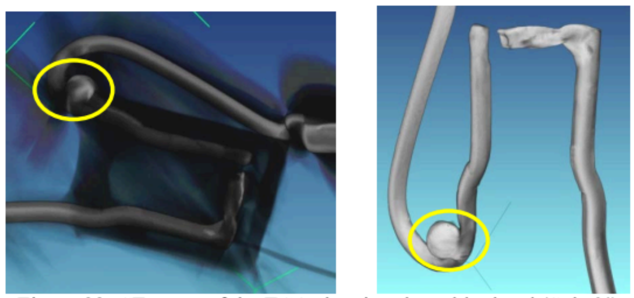


Figure 32. CT scans of the TCO showing the solder bead (Sub 64)

Sub 99 - Lock-rotor Test

Staff conditioned the fan (sub 99) for 288 hours before being subjected to three lock-rotor test periods as summarized in Table 7. During the initial lock-rotor test (segment A), the TCO did not activate. During the second lock-rotor test (segment B), the TCO did not activate. The TCO activated during the third lock-rotor test (segment C). Figures 33 and 34 show the temperature traces for the thermocouples during the three segments of lock-rotor test. The TCO tripped after approximately 30 minutes during the third lock-rotor test, but after almost 5 hours of combined lock-rotor testing (sum of the test duration for all of the segments up to the activation).

Table 7. Segment lock-rotor testing (Sub 99)

| Testing Segment | Test Duration (hh:mm:ss) | Maximum temperature at Side Windings (C) | Calculated TCO Temperature (C) | Maximum temperature at Bottom Windings (C) | Notes |
|---|---|---|---|---|---|
| PART A | 3:09:36 | 150 | ~170 | 182.6 | Manually terminated |
| PART B | 1:12:06 | 151.6 | ~172 | 183.2 | Manually terminated |
| PART C | 0:29:42 | 140.9 | ~161 | 173.3 | TCO tripped |

Post examination revealed the TCO had a solder bead external to the TCO casing. Figure 35 shows the CT scans with the partially melted fusible link after the testing, thus, indicating the TCO did activate, but abnormally. Microscopic images show that the solder originated from inside the TCO because of solder located within the cracks between the epoxy seal and the lead wires. Figure 36 shows the microscope images of the solder bead and solder in the cracks.

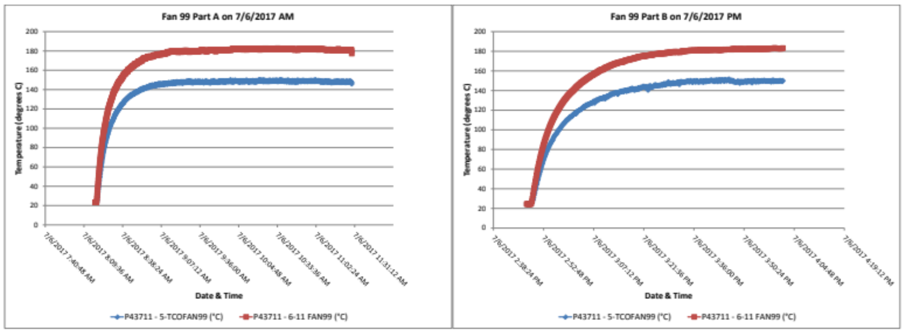



Figure 33. Segment Part A and B temperatures for Sub 99 Test Group 3 - Lock-Rotor Test

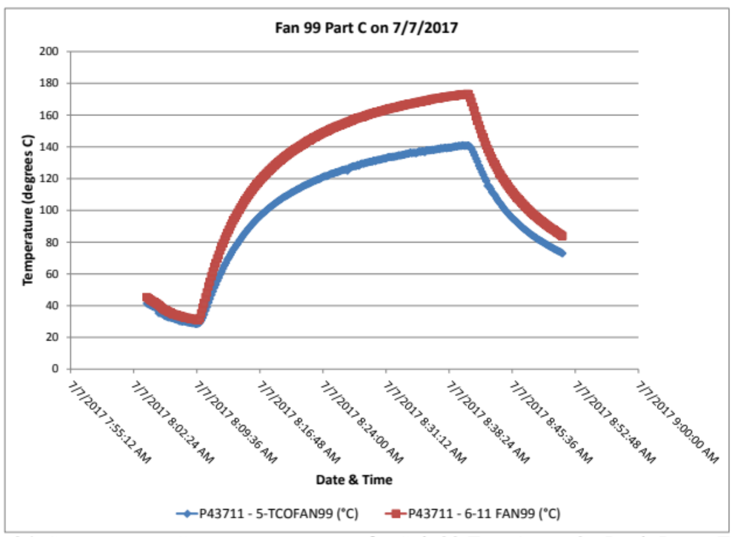



Figure 34. Segment part C temperature traces for Sub 99 Test Group 3 - Lock-Rotor Test

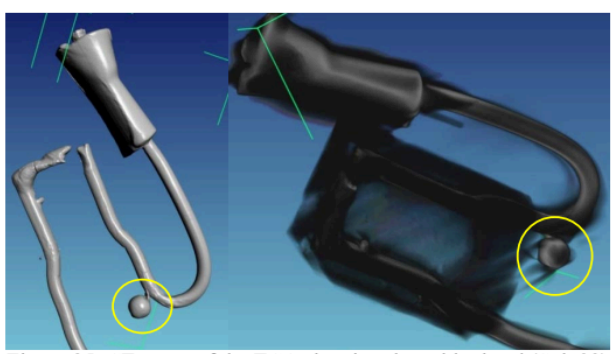
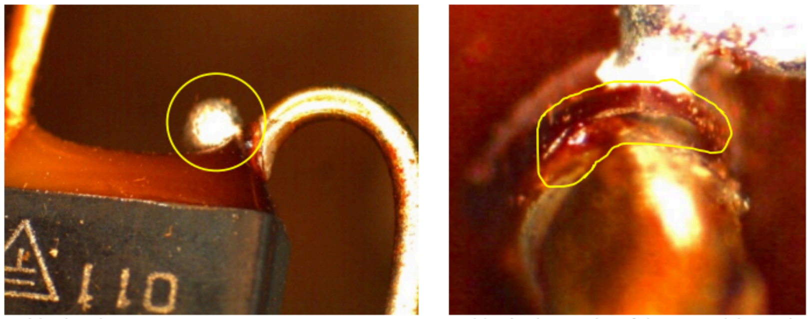


Figure 35. CT scans of the TCO showing the solder bead (Sub 99)



Solder bead Solder in the cracks of the epoxy/electrode

Figure 36. Microscopic images of the solder bead and solder in the cracks (Sub 99)

### *5.6.3 Test Group 4 - 105°C 165 Hours Conditioning and Lock-Rotor Tests*

Test Group 4 had 15 fans. Staff placed the 15 fans in the conditioning oven at 2:30 p.m. on July 6, 2017. Staff set the conditioning oven at 105°C. After 165 hours (July 13, 2017 at 11:30 am), all 15 units were removed from the conditioning oven and installed in the large test frame. The fans were allowed to cool to room temperature before testing. A single thermocouple was placed on the side of the winding for each fan sample. The fans were tested in a lock-rotor condition on July 14, 2017. Figure 37 shows the temperature traces for Test Group 4 – Lock-Rotor Test.

Eleven of the 15 fans had the TCO activate in less than 45 minutes during the lock-rotor testing. One fan's TCO opened shortly after 2 hours (sub 58). Three of the 15 fans' TCOs (sub 6, 51 and 66) failed to activate or open after 4 hours of lock-rotor, and staff manually terminated the test. Table 8 lists the test results from Test Group 4 lock-rotor testing.

Table 8. Test Group 4 - 105°C Conditioning and Lock-Rotor Test Result

| Test Group 4 | | | TCO | | |
|---|---|---|---|---|---|
| Test Frame Location Number | Fan Sub No. | Thermocouple id | Tripped | Elapsed Time | TCO Failed to Activate Normally |
| 1 | 81 | P43711-1-11FAN01 | Yes | 32 m 35 s | No |
| 2 | 45 | P43711-2-11FAN02 | Yes | 32 m 35 s | No |
| 3 | 11 | P43711-3-11FAN03 | Yes | 33 m 34 s | No |
| 4 | 28 | P43711-4-11FAN04 | Yes | 37 m 24 s | No |
| 5 | 67 | P43711-1-11FAN05 | Yes | 40 m 15 s | No |
| 6 | 58 | P43711-6-11FAN06 | Yes | 2 h 3 m 43 s | Yes |
| 7 | 66 | P43711-7-11FAN07 | No | Over 4 hours | Yes |
| 8 | 9 | P43711-8-11FAN08 | Yes | 34 m 54 s | No |
| 9 | 17 | P42524-1-11FAN09 | Yes | 35 m 53 s | No |
| 10 | 84 | P42524-2-24FAN10 | Yes | 40 m 52 s | No |
| 11 | 1 | P42524-3-24FAN11 | Yes | 44 m 12 s | No |

| | | | | | |
|---|---|---|---|---|---|
| 12 | 51 | P42524-4-24FAN12 | No | Over 4 hours | Yes |
| 13 | 6 | P42524-5-24FAN13 | No | Over 4 hours | Yes |
| 14 | 93 | P42524-6-24FAN14 | Yes | 38 m 1 s | No |
| 15 | 43 | P42524-7-24FAN15 | Yes | 30 m 11 s | No |
| Ambient | | P42524-8-24Amb | | | |

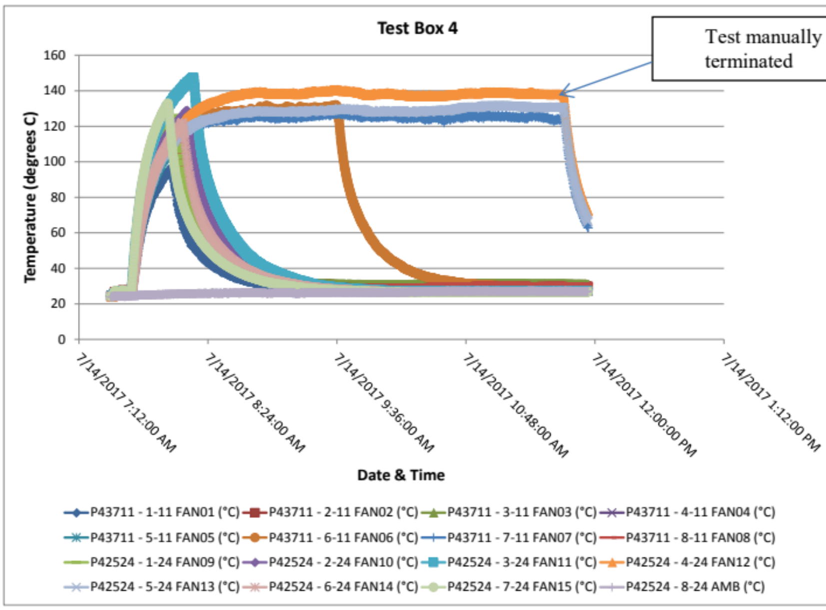



Figure 37. Temperature traces for Test Group 4 - Lock-Rotor Test

Figure 38 shows fan subs 6, 51, 58 and 66 temperature traces for Test Group 4 – Lock-rotor Test. These subs had a TCO that had activation trip times that were long or never tripped. The TCOs were x-rayed and CT scanned.

Figure 39 shows the TCO from sub 58, which tripped but took more than 2 hours. As seen in previous TCOs that had a long trip time, the melted linkage would bead to both wire leads; but in this case, the radiograph shows a thin portion of the fusible link still present.

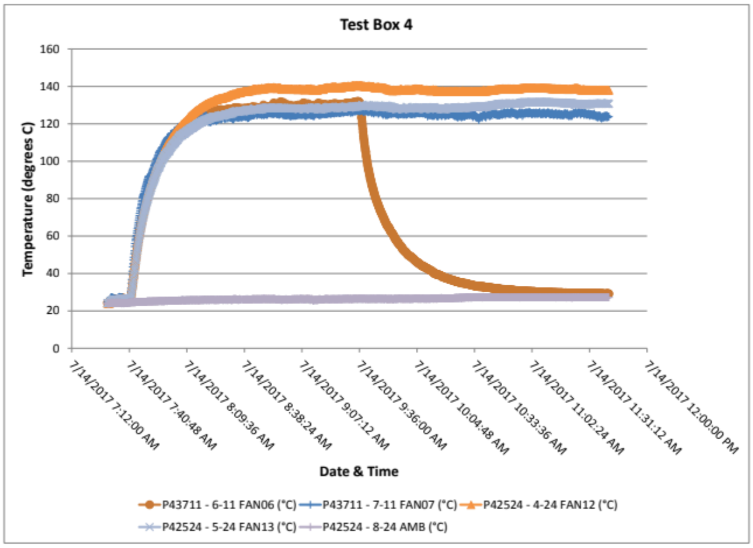
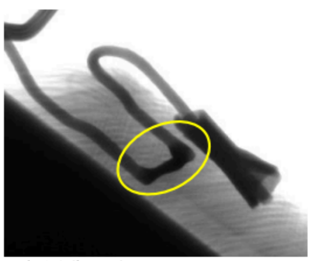
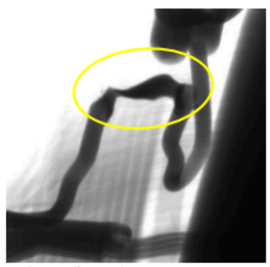


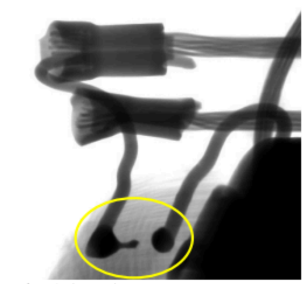

Figure 38. Temperature traces for Subs 6, 7, 12 and 13 (Test Group 4 - Lock-Rotor Test)



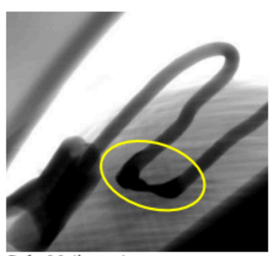
Sub 06 (intact)



Sub 51 (intact)



Sub 58 (open)



Sub 66 (intact)

Figure 39. Radiograph of subs 6, 51, 58 and 66 after Lock-Rotor test

### *5.6.4 Test Group 5 - 105°C 330 Hours Conditioning and Lock-Rotor Tests*

Test Group 5 had 15 fans, but only 13 fans were subjected to the lock-rotor test. All 15 fans were in the conditioning oven continuously for 330 hours at 105°C. After 330 hours, all 15 units were removed from the conditioning oven and allowed to cool to room temperature (approximately 23°C) before testing.

Each fan was instrumented with three thermocouples. Channel 1 thermocouple (T) was located at the top of the winding wrap, as viewed with the fan installed. Channel 2 thermocouple (M) was located on the exterior of the winding wrap and on the side of the motor winding on the same side as the TCO. The third thermocouple (B) was located at the bottom or on the lowest side of the winding wrap when the fan is installed. The lock-rotor test was conducted by blocking the impeller and energizing the fan. The thermocouple temperature measurements were recorded every 10 seconds.

Results

Seven of the 13 fans had the TCO activate in less than 34 minutes during the lock-rotor testing. The average maximum winding temperature measured was 160°C before the TCO tripped. On average for the seven fans, the TCO tripped about 20 minutes into the lock-rotor testing. Two (Fan subs 46 and 68) of the 13 fans ran in lock-rotor condition for at least 1 hour before the TCO tripped. One (Fan sub 94) of the 13 fans ran in a lock-rotor condition for almost 37 minutes on the first day before the test was manually terminated (end of the day). When the same unit (Fan sub 94) was lock-rotor tested on the second day, the TCO tripped after about 32 minutes. One (Fan sub 54) of the 13 fans was tested in the lock-rotor condition for a continuous 22 hours, which did not result in the TCO to open or a fire. Staff manually terminted the testing  (the fan was de-energized). Two (Fan subs 73 and 23) of the 13 fans ignited during the lock-rotor testing. The TCOs failed to activate in both of these units. Table 9 lists the test results from Test Group 5 lock-rotor testing.

Table 9. Test Group 5 – Conditioning 330 hours at 105°C and Lock-Rotor Test Results

| Test Group 5 | | TCO | | | | |
|---|---|---|---|---|---|---|
| Test date | Sub No. | Tripped | Elapsed time | Maximum temperature | TCO failed to activate normally | Results |
| 7/31/2017 | 46 | Yes | 1 h 1 m 55 s | 163°C | Abnormal | Steady state before tripping, Late TCO trip |
| 8/1/2017 – 8/2/2017 | 94 | Yes | 36 m 57 s (Day 1)<br>31 m 57 s (Day 2) | 202°C | Abnormal | Late TCO trip |
| 8/2/2017 | 57 | Yes | 33 m 42 s | 202°C | Normal | |
| 8/3/2017 -8/4/2017 | 37 | Yes | 15 m 12 s | 159.6°C | Normal | |
| | 54 | No | Steady state for 22 hours continuous | 224.8°C | Failed to open | Manually terminated testing |

| | | | | | | |
|---|---|---|---|---|---|---|
| 8/2/2017 | 73 | No | steady state (~189°C) 1 h 55 m 40 s | 507.4°C | Failed to open | Fire |
| | 33 | Yes | 18 m 52 s | 145.7°C | Normal | |
| 8/2/2017 | 14 | Yes | 20 m 52 s | 137.4°C | Normal | |
| | 49 | Yes | 17 m 01 s | 163.9°C | Normal | |
| 8/4/2017 | 48 | Yes | 18 m 21 s | 147.7°C | Normal | |
| | 23 | No | steady state (~186°C) 2 h 03 m 41 s | 547.3°C | Failed to open | Fire |
| 8/4/2017 | 50 | Yes | 15 m 02 s | 165.2°C | Normal | |
| | 68 | Yes | 2 h 6 m 12 s | 206.2°C | Abnormal | Steady state before tripping |

Sub 73 – Conditioning and Lock-Rotor Test

Fan sub 73 was in lock-rotor condition for about 1 hour and 56 minutes before the unit ignited, as shown in Figure 40. The fan's winding temperature was at a steady-state temperature (~188°C) above the TCO function temperature for about 1 hour, until the winding temperature began to increase rapidly. This rapid increase in temperature is an indication of shorting in the winding, which reduces the winding resistance and increases the current. Before ignition, with the winding temperature at about 233ºC, the unit was producing visible white smoke. When the unit ignited around 289°C, there was a large flash and flames for a brief moment. It appears that the gaseous vapors driven off the winding coating ignited. The flames subsided slightly until the wrap around the winding and the coating on the windings started to burn, growing in intensity. The flames impinged on and ignited the plastic impeller. The burning impeller and bobbin resulted in dripping flaming plastic. Four layers of cheesecloth were placed under the fan to be used as an ignition indicator to verify that the dripping plastic continued to burn as it landed on the surface below. The dripping flaming plastic caused the cheesecloth to ignite, which indicates that the fan's plastic grill could also ignite in this type of situation. Figure 41 shows a sequence of photographs demonstrating the progression during lock-rotor testing on sub 73.

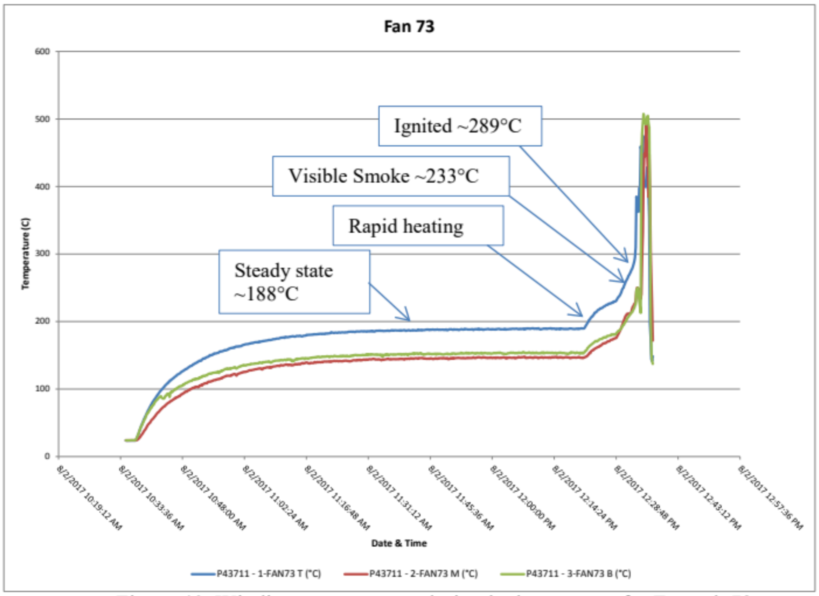
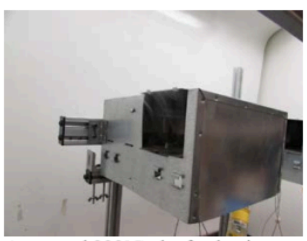



Figure 40. Winding temperatures during lock-rotor test for Fan sub 73



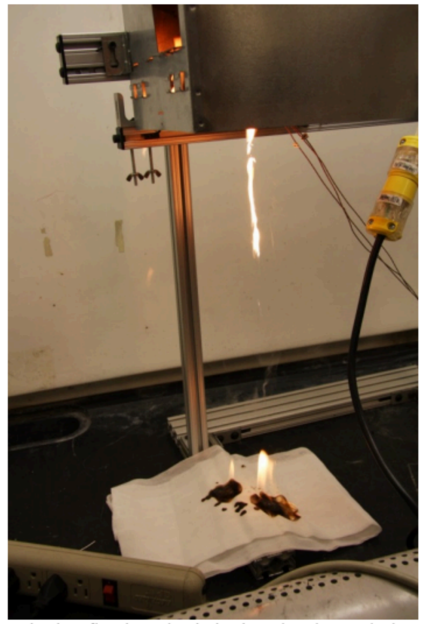
At around 233ºC, the fan begins producing white smoke

At sufficient temperatures, there appears to be an ignition of gases around the motor around 288°C

The large flames subside and the winding wrap and/or the winding coating appears to be burning

More of the winding wrap and the coating on the winding burns, thus creating a larger flame

The impeller has ignited and begins to sag onto the motor



Dripping flaming plastic ignites the cheesecloth ignition indicator

Figure 41. Fan sub 73 during lock-rotor test

Figure 42 shows a radiograph of the TCO after the test. Post-test radiographs of the TCO show the TCO is open, which was caused by the intense heat from the flames. This would suggest that any analysis of a TCO after a fire incident does not necessarily indicate the status of the TCO during the incident.

Figure 42. Radiograph of the TCO after the test (sub 73)

CPSC staff reviewed the CT scans of the thermal linkage for fan sub 73. The thermal linkage shows abonormalities as shown in Figure 43. The CT scans appear to show the linkage to take partial form of the TCO case, such that a flat section had formed. In theory, temperatures below $T_f$ may be causing the thermal linkage to soften. This may cause changes in the eutectic materials, where it may alter the eutectic temperature or $T_f$.

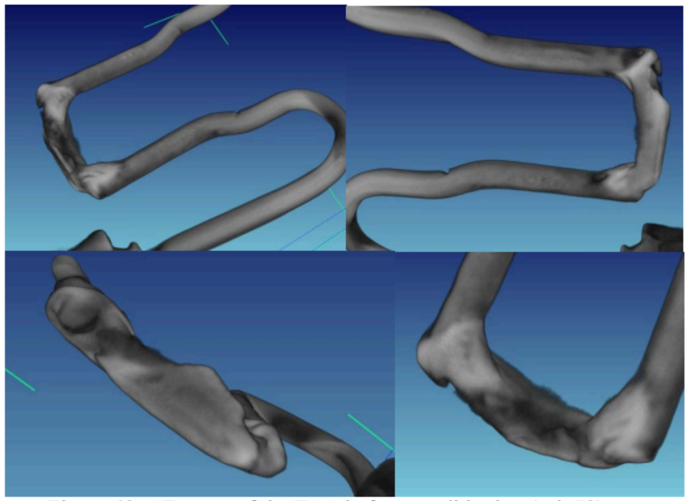


Figure 43. CT scans of the TCO before conditioning (sub 73)

Sub 23 – Conditioning and Locked-Rotor Test

Fan sub 23 was in lock-rotor for about 2 hours and 40 minutes before the unit ignited, as shown in Figure 44. The fan's winding temperature, ~186°C, was at steady state, above the TCO specified activation temperature, until the winding temperature began to increase rapidly. This rapid increase in temperature indicates shorting in the winding, which reduces the winding resistance. Before ignition, at about ~292ºC, the unit was producing visible white smoke. Similar to Fan sub 73, when the unit ignited at ~340°C, it produced a large flash and flames for a brief moment. The large flames subsided slightly, until the flames ignited more of the wrap around the winding and/or the coating of the winding. The flames impinged on and ignited the plastic impeller. The burning impeller and bobbin resulted in dripping flaming plastic. Four layers of cheesecloth were placed under the fan to be used as an ignition indicator. The dripping flaming plastic ignited the cheesecloth, which indicates that the fan's plastic grill could also ignite in this type of situation. Figure 45 is a sequence of photographs during lock-rotor testing for sub 23.

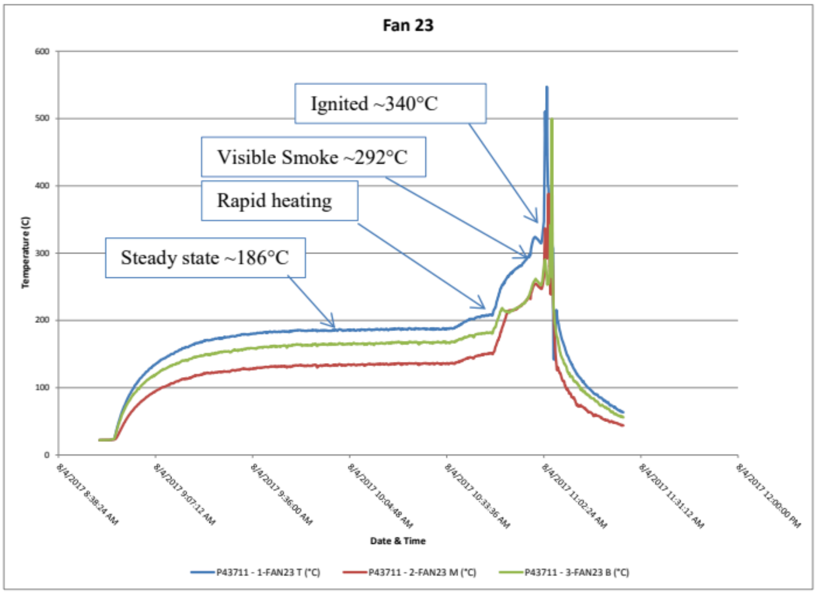


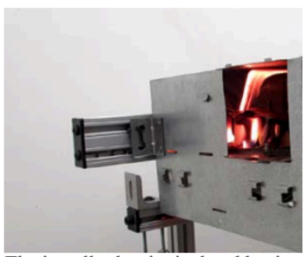

Figure 44. Winding temperatures during lock-rotor test for Fan sub 23

At around 292ºC, the fan begins producing white smoke

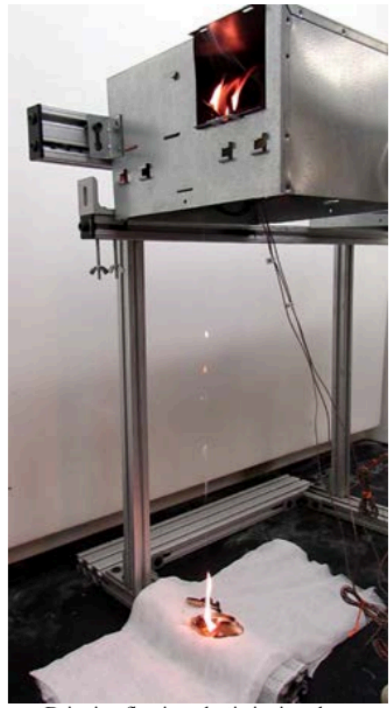
At approximately 340°C, there appears to be an ignition of gases around the motor

The large flames subside and the winding wrap and/or the winding coating appears to be burning

More of the winding wrap and the coating on the winding burns, thus creating a larger flame



The impeller has ignited and begins to sag onto the motor



Dripping flaming plastic ignites the cheesecloth ignition indicator

Figure 45. Fan sub 23 during lock-rotor test

Figure 46 shows a radiograph of the TCO after the test. Post-test radiographs of the TCO show the TCO is open, which was caused by the intense heat from the flames. This would suggest that any analysis of a TCO after a fire incident does not necessarily indicate the status of the TCO during the incident. The radiograph shows a thin portion of the thermal linkage intact. It would appear even at the high temperatures when the motor ignited, portions of the eutectic material in the thermal linkage could not melt.

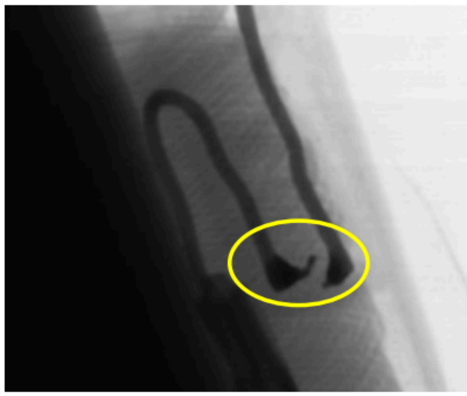


Figure 46. Radiograph of the TCO after the test (sub 23)

The CT scans of the thermal linkage for fan sub 23 were reviewed. The thermal linkage shows some abonormalities, as shown in Figure 47. The CT scans appear to show the linkage uneven and bulging in some areas.

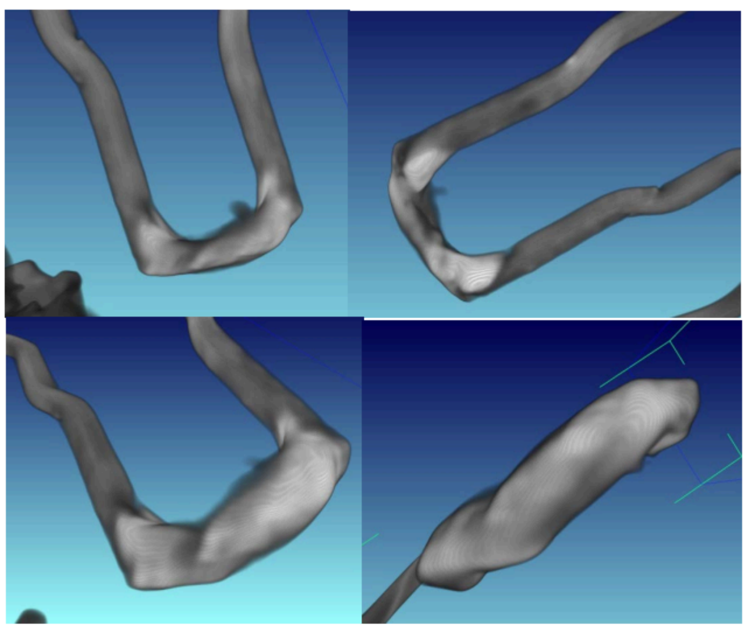


Figure 47. CT scans of the TCO before conditioning (sub 23)

Sub 54 – Fails to Open After 22 Hours of Lock-Rotor Testing

As previously indicated, fan sub 54 was tested in lock-rotor condition for 22 hours. After the initial 3 hours, the temperature increased and then leveled off. The fan maintained a steady temperature that was well above the TCO activation temperature for the majority of the testing, as shown in Figure 48. The TCO did not activate, and staff manually terminated the test after 22 hours. Figure 49 shows radiographs of the TCO after the test. The linkage appears to have thinned out, but is still intact. The figure shows a bead had formed outside the TCO casing.

Figure 50 shows radiographs of the TCO before and after the test. From these angles, the thermal linkage appears not to have changed shape significantly, but depending on the viewing angle, the thermal linkage is thicker or thinner.

Figure 51 shows CT scans of the TCO after the test. CT scans of the TCO confirm the solder link within the TCO is intact. The radiographs and CT scans show a solder bead has formed outside the TCO casing. This would suggest that the TCO is no longer hermetically sealed when thermally aged or placed under thermal stress. The reason that the windings were operating at such an elevated temperature for so long without eventually breaking down is not known, but it can be surmised that the winding coating would eventually deteriorate and cause shorts within the winding because the eurectic temperature has changed from $T_f$.

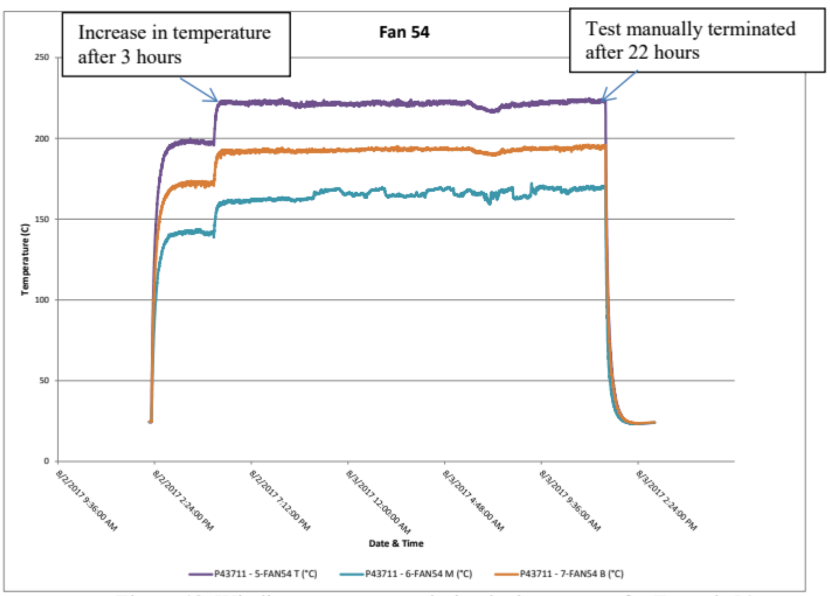



Figure 48. Winding temperatures during lock-rotor test for Fan sub 54

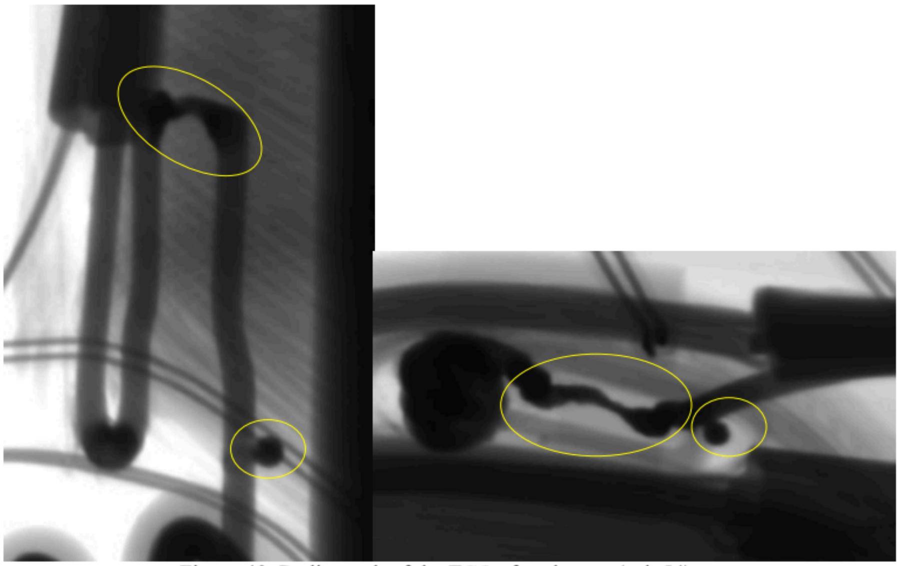
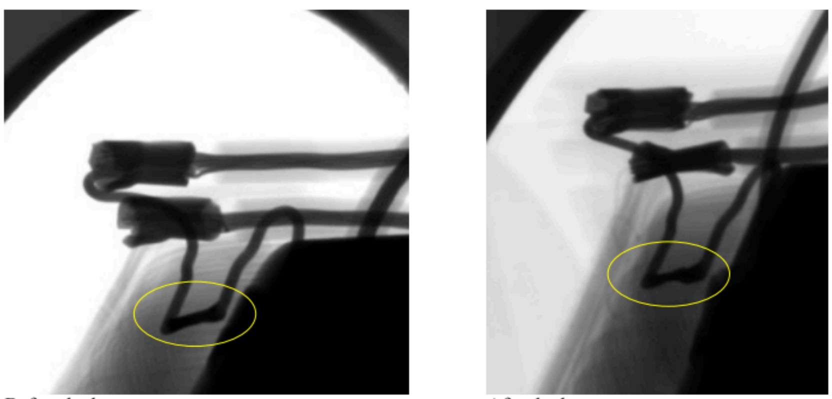


Figure 49. Radiograph of the TCO after the test (sub 54)



Before lock-rotor test After lock-rotor test

Figure 50. Radiograph of the TCO before and after the test (sub 54)

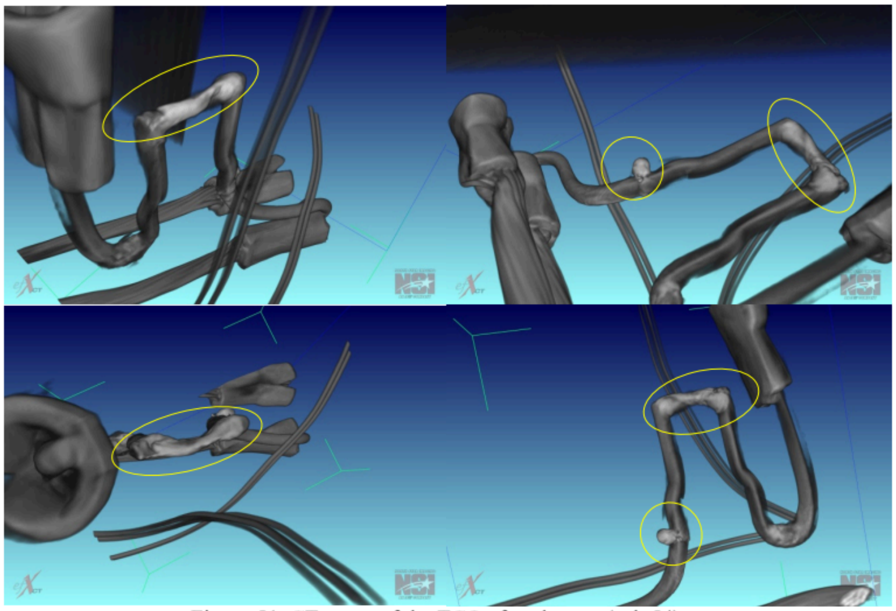
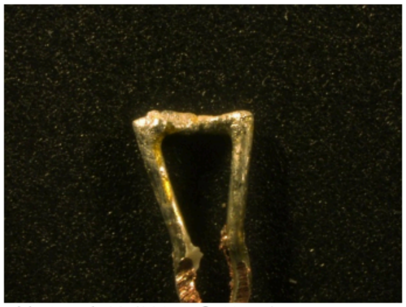
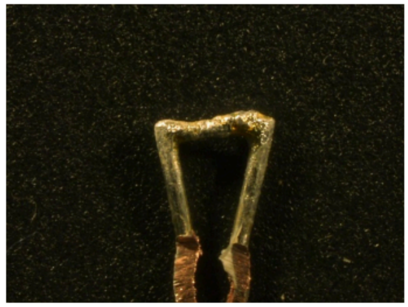


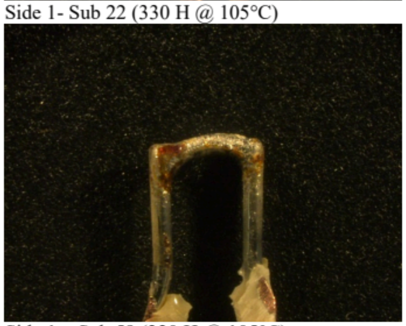
Figure 51. CT scans of the TCO after the test (sub 54)

**6.0 Analysis of the Special Compound (Flux) and Solder Link**

Subs 22 and 59 (conditioned for 330 hours at 105°C) from Test Group 5 were reserved for analysis of the solder link within the TCO. The TCO casing was opened and the internal components were removed. For comparison, two TCOs, sub 74 and 85 (no conditioning), from Test Group 7 were also reserved for TCO analysis where the TCO casing was opened and the internal components removed. Figure 52 shows the solder links from Fan subs 22 and 59, which have been conditioned 330 hours at 105°C. Figure 53 shows the solder links from Fan subs 74 and 85, which have not been conditioned. Sub 85 shows some deformation in the solder link, where part of the solder link has flattened and formed to the interior of the TCO casing, but this was already present before any conditioning of the TCO. The mechanical structure of the solder linkage appeared unchanged as a result of the conditioning, when the before and after radiographs were compared.


Side 1- Sub 22 (330 H @ 105°C)


Side 2 – Sub 22 (330 H @ 105°C)


Side 1 – Sub 59 (330 H @ 105°C)

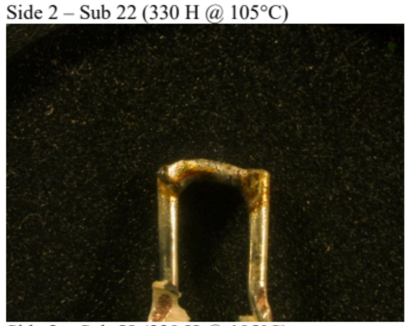
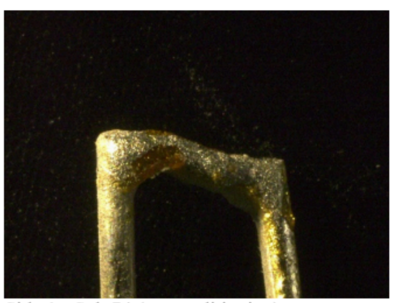
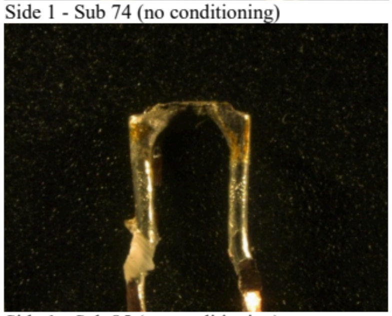

Side 2 – Sub 59 (330 H @ 105°C)

Figure 52. TCO solder link from Fan subs 22 and 59 (conditioned 330 hours @ 105°C)


Side 1 - Sub 74 (no conditioning)

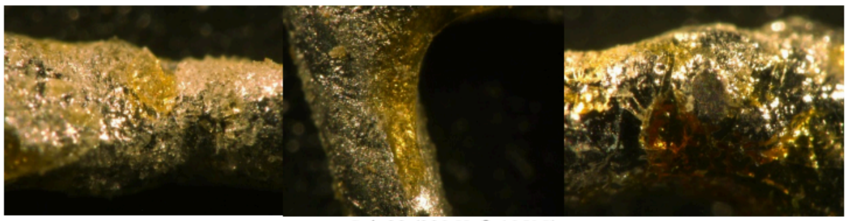

Side 2 - Sub 74 (no conditioning)


Side 1 - Sub 85 (no conditioning)

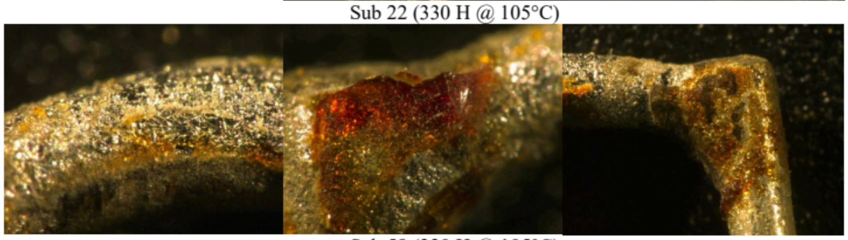

Side 2 - Sub 85 (no conditioning)

Figure 53. TCO solder link from Fan subs 74 and 85 (no conditioning)

Staff observed under a microscope that a yellowish substance was on the solder link, as shown in Figures 54 and 55. This was thought to be the special coating or flux material. Staff also observed that the conditioned TCOs appeared to have less of the yellowish substance than the TCOs that were unconditioned, but staff did not measure an actual mass content or volume of the substance for each sample.

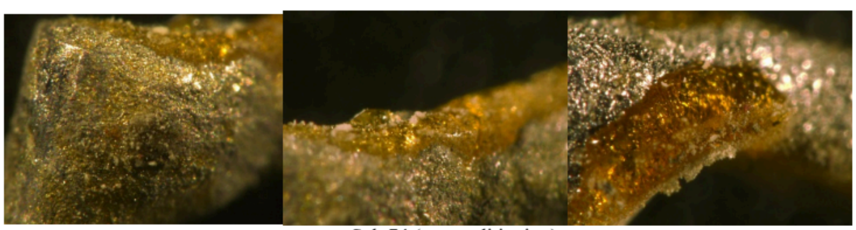


Sub 22 (330 H @ 105°C)

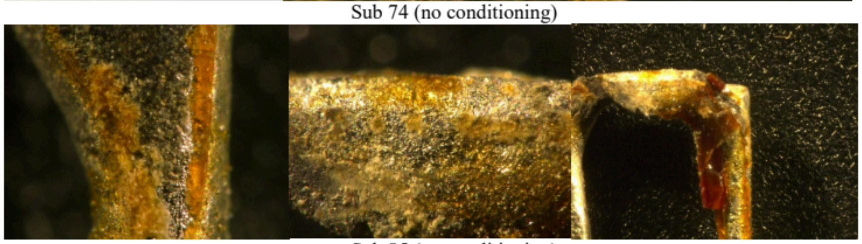


Sub 59 (330 H @ 105°C)

Figure 54. Close-up images of the TCO solder link (conditioned 330 hours @ 105°C)



Sub 74 (no conditioning)



Sub 85 (no conditioning)

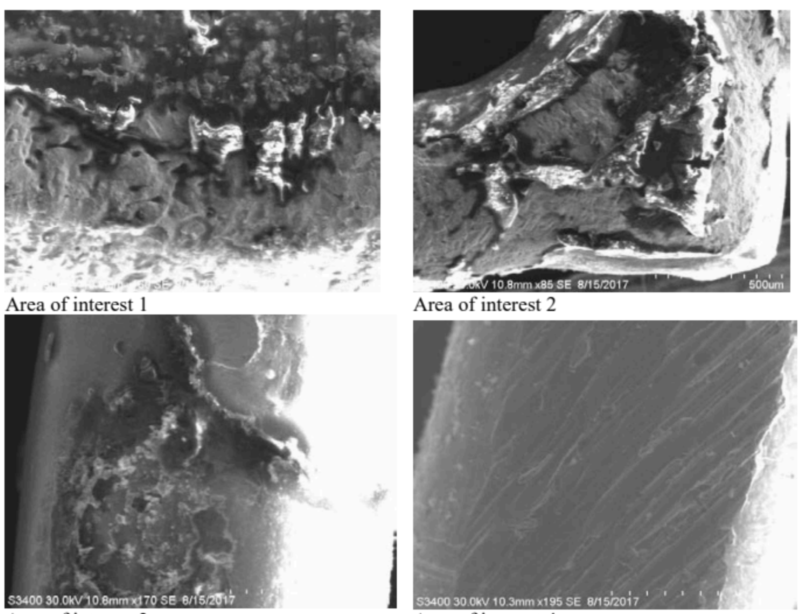
Figure 55. Close-up images of the TCO solder link (no conditioning)

The TCOs were further explored using a scanning electronic microscope (SEM) and x-ray diffraction (XRD). SEM is used for topographical, compositional and morphological characterization. XRD is used to study nature of phases/microstructure and their crystal structure. Figure 56 shows SEM scans of the solder link and terminals. SEM and XRD analysis for sub 59, which was conditioned at 105ºC, show that the wire leads are copper and the thermal linkage is comprised of mainly tin, indium, and lead.

Area of interest 1 is the solder link. This is mainly comprised of carbon (C), oxygen (O), indium (In), tin (Sn), and lead (Pb). There is a trace amount of Silicon (Si). The indium, tin, and lead are most likely the elements that make up the solder link. Carbon and oxygen are most likely the elements that make up the special compound coating.

Area of interest 2 is the solder link connection to the copper terminal. This is mainly comprised of C, O, In, Sn and Pb. There is a trace amount of silicon (Si) and copper (Cu). Copper shows up because it is the bulk material of the terminal.

Areas of interest 3 and 4 are the copper terminals. This is mainly comprised of Cu and Sn. There are lower amounts of C and O.

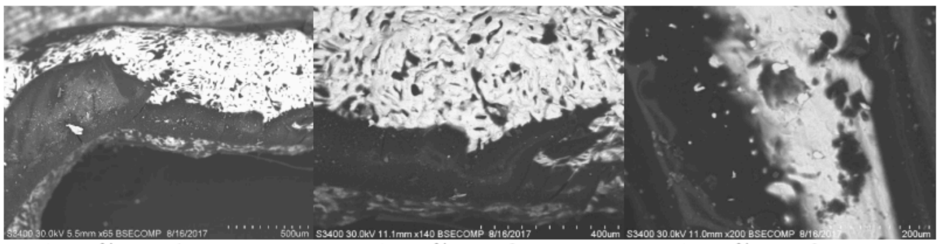



Area of interest 1 | Area of interest 2 | Area of interest 3 | Area of interest 4

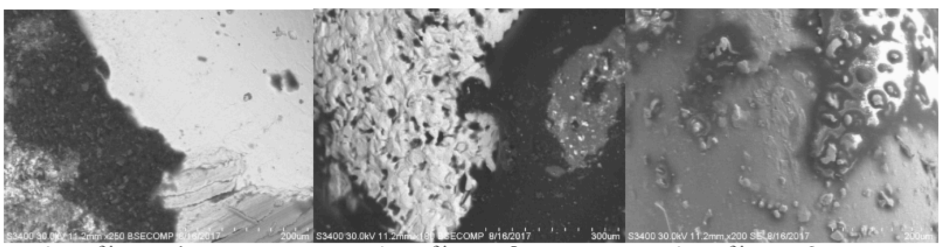
Figure 56. SEM scans for Sub 59

SEM analysis for sub 74, which was not conditioned, is shown in Figure 57. Area of interest 1 is the solder link. This is mainly comprised of C, In, Sn, and Pb. The Indium, Tin, and Lead are most likely the elements that make up the solder linkage. Carbon and Oxygen are most likely the elements that make up the special coating. Area of interest 2 is a close-up of an area from area interest 1. This is mainly comprised of C, O, In, Sn, and Pb. There is a trace amount of Si.

Areas of interest 3, 4, 5, and 6 are areas that had coating on the terminals or solder link.



Area of interest 1 Area of interest 2 Area of interest 3



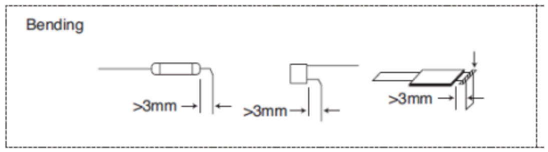
Area of interest 4 Area of interest 5 Area of interest 6

Figure 57. SEM scans for Sub 74

**7.0 Bending and Forming TCO Leads (Design Applications - Forming and Cutting)**

Staff conducted research to determine whether there is standard practice for bending the lead wires on TCOs. Below is a list of precautious in bending the wire leads. The general practice appears that the bend should occur 3 to 4 mm from the seal. It is also recommended that the wire lead is held during the bending to prevent stress on the seal, which may cause the seal to leak. Lock-rotor testing has shown that solder from the thermal linkage can seep out of the seal, forming a solder bead on the wire lead outside the casing. This would suggest that a crack has formed between the seal on the wire lead.

- Lead wires (terminals) are to be bent or cut at least 3mm away from the TCO seals to avoid damaging the TCO (axial/radial type) or body (thin type). The TCO seals (axial/radial type) shall not be grasped with any tools or holders. Terminals of thin type TCO are to be grasped before they are bent. (See Fig. 1) (Reference - XICON PASSIVE COMPONENTS, Thermal Cutoffs (TCO)/Thermal-Links 447-XYP 1BF145-RC).




- Lead wires (terminals) are to be bent or cut at least 3 mm away from the TCO seals to avoid damaging the TCO (axial/radial type) or body (thin type). The TCO seals (axial/radial type) shall not be grasped with any tools or holders. Terminals of thin type TCO are to be grasped before they are bent. (See Fig.1) (Reference - PANASONIC, Thermal Cutoffs (TCO))

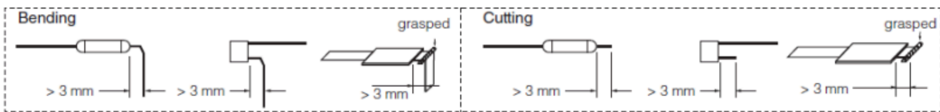



Fig-1

- When bending a lead wire for installation, fix the part of the lead between the body and the lead section to be bent using a tool, and gently bend the lead section that is at least 3 mm from the body. Never hold the body with a tool. (Reference - Bending Lead Wires – Cautions (http://www.cci-tco.com/bending-lead-wires-cautions/)
- When bending a lead, bend at a location 3mm minimum from the body of the thermal cutoff. See below. (Reference - Thermtrol, Mechanical Thermal Cutoffs (0.5 to 7 amp))
- Bend the lead wire at least 4 mm away from the molding. Otherwise, the damage of the molding worsens the airtightness and impedes the normal operation of the thermal fuse. Use a nipper or other tool to prevent damage. (Reference - SUNGWOO INDUSTRIAL, No.1 Thermal Cutoff Fuse Manufacturer in Korea | Sung Woo Industrial Co. – Precautions)
- When bending the lead wire, to avoid applying excessive pressure to the root of the lead wire, secure the lead wire close to the case, and bend the part beyond the secured section. The lead wire should be bent at a distance of 3 mm or more from the body of the fuse, and should not be twisted. (Reference - NEC/SCHOTT, Thermal Fuse)
- If the lead has to be used by bending it, bend it at approx. 3mm in minimum away from the molded section. Use radio pinchers to bend the wire, as shown in Fig.1 and not to damage the molded section of the case and the lead wire. (Reference - Xiamen SET Electronics Co.,Ltd, Thermal cutoffs (TCO))

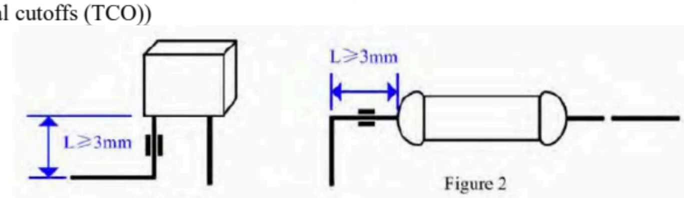



Figure 1 Figure 2

- Bend the lead wire at least 4 mm away from the seal. The damage of the sealant worsens the air tightness. Note that bending is conducted with care, since the worst air tightness impedes the normal operation of TCO. Holders or tools used during lead forming must not grasp the body, but lead wire. Doing so can protect from damage to the body of TCO. (Reference - US ELECTRONICS, INC, Thermal Cutoff Fuses)

UL 60691, *Thermal-Links – Requirements and Application Guide*, contains construction requirements under Section 9 – Mechanical Requirements. The section specifies that "Leads and terminal parts shall be secured so that stress on them during installation and normal use does not impair operation of the THERMAL-LINK. THERMAL-LINKS using seals with formed leads for use in appliances or components shall not be bent less than 3 mm from the THERMAL-LINK seal." The section states that the leads are to be bent at least 3 mm from the seal, unless the following two exceptions are met:

Exception: Leads may be bent less than 3 mm from the seal, if

a) the THERMAL-LINK manufacturer's bending fixture and procedure does not transmit stress to the THERMAL-LINK operating mechanism, and

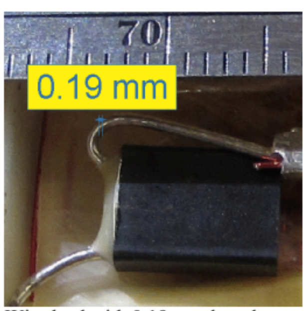
b) formed test samples shall be subjected to the bending/twist lead secureness test of 9.4 and the RATED FUNCTIONING TEMPERATURE test of 11.2.

To determine the installation construction of the wire leads on the TCOs for the motor fan samples in this testing, 15 units were randomly selected from Test groups 1 and 2. These units all functioned when previously tested in the lock-rotor testing, and the testing should not have altered the TCO position and the wire lead positions and configuration. Table 10 lists the fan samples selected and the measured distances between the seal and the bend in the wire leads. Two of the 15 samples measured had wire lead lengths greater than 3 mm between the seal and the inside bend. The average length between the seal and inside bend in the wire lead was 1.28 mm. This suggests that the TCOs' seal can be damaged during the bending of the wire leads, which can allow oxygen to enter into the TCO case. From the literature, damaged seals may alter TCOs' functioning temperature.

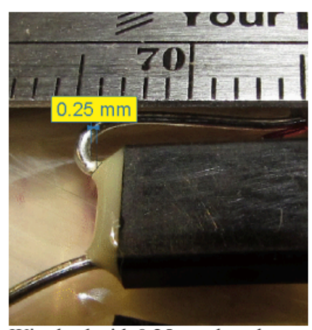
Table 10. Distance between the seal and the wire lead bend

| | Sub # | Distance (mm) |
|---|---|---|
| Test 1 | 60 | 4.14 |
| | 98 | 0.19 |
| | 52 | 1.10 |
| | 27 | 4.52 |
| | 36 | 0.56 |
| | 89 | 0.52 |
| | 35 | 0.55 |
| Test 2 | Sub # | Distance (mm) |
| | 53 | 0.83 |
| | 4 | 1.00 |
| | 88 | 1.43 |
| | 16 | 1.13 |
| | 26 | 0.25 |
| | 20 | 1.86 |
| | 79 | 0.38 |
| | 100 | 0.80 |
| | Average (mm) | 1.28 |

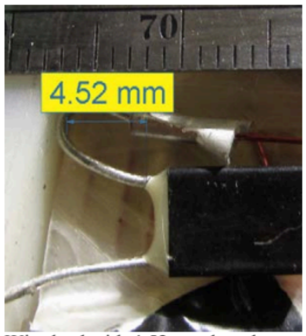
Figure 58 shows the TCO wire lead bends can vary between fan motors. Even though sub 27 shows the wire lead bend greater than 3 mm, it appears that the base of the wire lead near the seal was not secured when the wire lead was bent, which is evident by the outward angle of the wire lead.



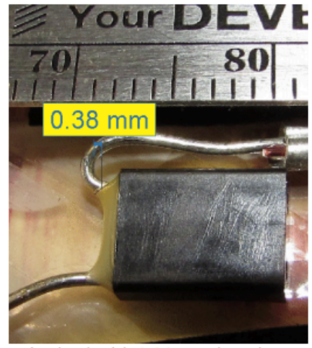

Wire lead with 0.19 mm length between the seal and bend (Sub 98)




Wire lead with 0.25 mm length between the seal and bend (Sub 26)



Wire lead with 4.52 mm length between the seal and bend (Sub 27)



Wire lead with 0.38 mm length between the seal and bend (Sub 79)

Figure 58. Wire bend lengths vary between TCOs in the Fan samples

**8.0 Discussion**

The CPSC lab testing of field samples supports that during the life of the fan motor, the eutectic thermal fuses may fail due to thermal aging, thus presenting a fire hazard. The observations indicate that exposure of the TCO to heat and oxygen over time may delay the opening, and in some cases, result in failure to open. Because the conditioning at 105ºC over a period time did not change the thermal linkage shape, it is theorized that either the properties of the thermal linkage or the special compound that coats the thermal linkage can change with heat and time. The amount of special compound that coats the thermal linkage may also influence the effects of thermal aging, but this was not investigated.

Improper bending of the wire lead may result in cracking of the epoxy seal, thus allowing solder to flow out and oxygen to enter the TCO and alter the functioning temperature of the TCO. Oxygen along with heat and time may also be a combination that could be accelerating the changes in the properties for the thermal linkage and the special compound.

The testing of these motors showed that the winding temperatures can reach sufficiently high temperatures to ignite the motor during a lock-rotor condition, if the TCO fails to activate. During a lock-rotor condition for these tests, the TCO temperature may reach temperatures at or above 140°C before the TCO activates; thus, short periods of "on" time may thermally age the TCO and alter the functioning temperature of the TCO. Testing showed the TCO can experience temperatures up to 140°C in less than 20 minutes. Staff surmised that a fan entering into a lock-rotor condition may experience multiple events of thermal heating if the fan is not energized for sufficient time to cause the TCO to activate. These multiple heating events may have compounding effects on the TCO properties, thus causing the TCO to delay or fail to activate.

Figure 59 shows Fan sub 60 temperatures for normal and lock-rotor operation. In normal operations, the TCO temperature stabilizes at around 68ºC. For lock-rotor condition, the TCO activates at a TCO temperature around 142ºC after 20 minutes. This would suggest that an exhaust fan that is in lock-rotor condition, but is operated for less than 20 minutes, can have the TCO heated to temperatures up to 142°C. If the exhaust fan is operated for more than 3 minutes, the TCO is experiencing temperatures above normal operation.

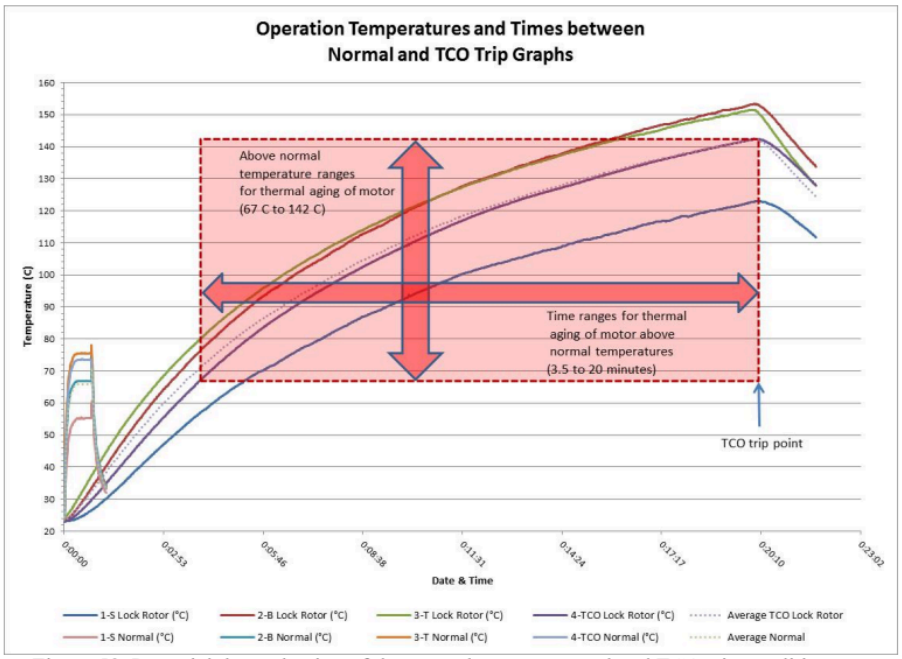



Figure 59. Potential thermal aging of the motor between normal and TCO trip conditions

## Aging in UL Standards

UL 60691, Thermal-Links – Requirements and Application Guide, Section 11, Temperature test addresses aging for thermal links. Similar to the Thermal-Element Stability Test that was in UL 1020, UL 60691 incorporates the same aging test. The Aging Tests assess whether aging at high temperatures has a deleterious effect on the thermal links. The TCO is subjected to a series of test steps where the conditioning temperature and period change. If a TCO trips, the remaining TCOs are tested at the next step. The test is considered successful if all TCOs have functioned after the first two steps. In summary, the six steps are as follows;

- Step 1 If requested by the manufacturer, the specimens are subjected to a temperature chosen between Tf–15 K and Th for a period of 3 weeks. At the conclusion of the test, at least 50 percent of the specimens shall not have functioned.

- Step 2 Tf – 15 K for 3 weeks. At the conclusion of the test, at least 50 percent of the specimens shall not have functioned, unless the specimens have already been submitted to Step 1, in which case all specimens may have functioned.
- Step 3 Tf – 10 K for 2 weeks.
- Step 4 Tf – 5 K for 1 week.
- Step 5 Tf – 3 K for 1 week.
- Step 6 Tf + 3 K for 24 hours.

UL 60691specifies in Annex C, Conductive Heat Ageing Test. The test is conducted on thermal links with a $T_f$ rating of 175°C or above and is optional for thermal links with a $T_f$ rating less than 175°C. The section includes an exception, where the test does not need to be performed if the thermal link is eutectic type and is constructed without contacts. This test was most likley derived in the early 1990s when there were a high number of fire incidents with coffeemakers. To address TCOs failures that were being caused by thermal conductive heat aging, UL develeoped the Conductive Heat Ageing Test. The TCOs typically used in coffeemakers are higher-rated, pellet-type TCOs.

UL 507, *Standard for Electric Motors,* and UL 1004-3, *Standard for Safety Thermally Protected Motors*, do not account for thermal aging of the motor as a system before the motor is operated in lock-rotor conditions. As seen in the testing, the installation of the TCO and thermal aging may cause the TCO not to function at $T_f$. Thus, incorporating a performance aging test is a realistic evaluation of the system to verify whether aging at high temperatures, but at less than the functioning temperature, has a deleterious effect on the motor and its safety components. A fan that has entered into a lock-rotor condition may experience multiple events of thermal heating if the fan is not energized for sufficient time to cause the TCO to activate. These multiple-heating events may have compounding effects on the TCO properties, thus causing the TCO to delay or fail to activate.

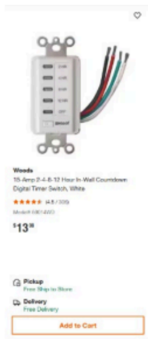
## 9.0 Conclusion

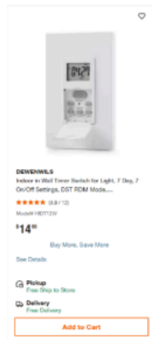
Although the tested motors were compliant with the voluntary standard, consistent with their UL listing, thermal aging of the motors can cause the TCOs to fail to activate. A contributing factor to the failures may have been the improper bending of the TCO wire leads and cracking of the epoxy seal around the wire leads. During thermal aging, the melting properties of the solder linkage and the special compound in the TCO may be altered, which may cause a delay in the TCO activating and in some cases, failure to activate. If the TCOs in the motors fail to open during a lock-rotor condition, the motor may overheat and ignite.

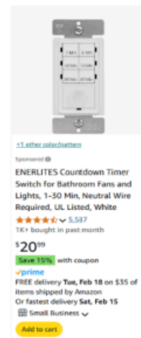
The results of this testing support changes to UL 60691 to include conductive heat aging of all eutectic-type TCOs, incorporating a thermal aging performance test within UL 507. If similar motor applications have a sufficient operating window between normal and lock-rotor that could allow thermal aging of the motor such changes may also be appropriate to UL 1004-3.

M11941Impact Statement

Timer switches price examples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Mod_11941_Impact_Timer switches price examples.pdf

# TAC: Mechanical

Total Mods for **Mechanical** in **Pending Review : 20**

Total Mods for report: 20

## Sub Code: Mechanical

### M11880

5

| | | | | | |
|---|---|---|---|---|---|
| **Date Submitted** | 01/31/2025 | **Section** | 602.2.1 | **Proponent** | Rolando Soto |
| **Chapter** | 6 | **Affects HVHZ** | No | **Attachments** | Yes |
| **TAC Recommendation** | Pending Review | | | | |
| **Commission Action** | Pending Review | | | | |

**Comments**

**General Comments No** **Alternate Language No**

#### Related Modifications

#### Summary of Modification

Allows PVC pipes and fittings for the removal of condensate in air handler closets used as plenums in the dwelling units of R-2 and R-3 occupancies with conditions:

#### Rationale

PVC pipes for condensate removal are allowed in the residential code in similar applications. PVC pipes used for condensate account for a very small amount of the fuel load present in typical residential conditions. According to the attached SAFETY DATA SHEET, PVC will not support combustion and requires a continuous source of ignition to burn.

#### Fiscal Impact Statement

**Impact to local entity relative to enforcement of code**
No impact.
**Impact to building and property owners relative to cost of compliance with code**
Will reduce cost of compliance.
**Impact to industry relative to the cost of compliance with code**
Will reduce cost of compliance.
**Impact to small business relative to the cost of compliance with code**
Will reduce cost of compliance.

#### Requirements

**Has a reasonable and substantial connection with the health, safety, and welfare of the general public**
PVC condensate pipes are allowed in the residential code. PVC pipes are a very small amount of the fuel load in typical residential conditions. According to the attached SAFETY DATA SHEET, PVC will not support combustion and requires a continuous source of ignition to burn.
**Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction**

Improves the code and provides equivalent or better methods, or systems of construction by allowing the use of more economical and readily available material, PVC pipes.

**Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities**

Does not discriminate against materials, products, methods, or systems, simply allows the use of more economical and readily available material, PVC pipes.

**Does not degrade the effectiveness of the code**

Does not degrade the effectiveness of the code, simply allows the use of more economical and readily available material, PVC pipes.

M11880Text Modification

602.3 Materials within plenums. Materials within plenums shall be noncombustible or shall be in compliance with the applicable requirements in Sections 602.3.1 through 602.3.10.

Exceptions: This section shall not apply to the following:

1 Materials exposed within plenums in one- and two-family dwellings.

2. Combustible materials fully enclosed within one of the following:

2.1 Continuous noncombustible raceways or enclosures.

2.2 Approved gypsum board assemblies.

2.3 Materials listed and labeled for installation within a plenum and listed for the application.

3. Materials in Group H, Division 5 fabrication areas and the areas above and below the fabrication area that share a common air recirculation path with the fabrication area.

4. PVC pipes and fittings for the removal of condensate in air handler closets used as plenums in the dwelling units of R-2 and R-3 occupancies are acceptable when complying with all the following conditions:

4.1 Acceptance is limited to schedule 40 PVC pipe and fittings of 3/4” or 1” nominal diameter.

4.2 Acceptance is limited to a total pipe length of 48” or less.

4.3 PVC pipes and fittings shall comply with ASTM standards referred to in FMC 1202.4 and 1202.5.

Mod11880_TextOfModification.pdf Page: 1

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# SAFETY DATA SHEET

## SECTION 1. PRODUCT IDENTIFICATION

**MATERIAL NAME:** **PVC Pipe and Fittings**

**PRODUCT USE:** Water, sewer, conduit and industrial piping

**MANUFACTURER/SUPPLIER:** IPEX Inc.
807 Pharmacy Avenue
Scarborough, Ontario
Canada
M1L 3K2

**TELEPHONE NO.:** 866-473-9462 (Canada)
800-463-9572 (USA)

**PREPARED BY:** Health, Safety and Environment

## SECTION 2. HAZARDS IDENTIFICATION

This product is an article and therefore is not subject to the requirements of the federal Hazardous Products Act (HPA) and Health Canada's Hazard Products Regulations (HPR) to provide a Safety Data Sheet (SDS). This product should not present a health or safety hazard under recommended or normal use.
This product is an article and therefore is not subject to the requirements of the US Hazard Communication Standard (HCS) (29 CFR 1910.1200) to provide a Safety Data Sheet (SDS). This product should not present a health or safety hazard under recommended or normal use.

**Classification GHS** Not Classified
**GHS labelling** No Labeling Applicable

## SECTION 3. HAZARDOUS INGREDIENTS

This article does not contain any substances required to be mentioned according to the Canadian or American criteria.

## SECTION 4. FIRST AID MEASURES

**SPECIFIC FIRST AID MEASURES:** No situation is likely to arise from routine handling of PVC pipes.

**EYES:** Remove particles with clean water. If irritation persists, consult a physician.

**SKIN:** Wash with soap and water.

**INGESTION:** Do not induce vomiting: consult a physician.

**INHALATION:** If irritation persists, consult a physician

**ACUTE/CHRONIC (LONG-TERM) SYMPTOMS AND EFFECTS:** Not expected to present a significant hazard under anticipated conditions of normal use.

## SECTION 5. FIRE-FIGHTING MEASURES

**FIRE FIGHTING:** Wear self-contained breathing apparatus (SCBA) equipped with a full face piece and operated in a pressure-demand mode or other positive-pressure mode and protective clothing. Personnel not having suitable respiratory protection must leave the area to prevent significant exposure to toxic gases from combustion, burning, or decomposition. In an enclosed or poorly ventilated area, wear SCBA during cleanup immediately after a fire as well as during the attack

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phase of fire fighting operations. Run off water from fire fighting may have corrosive effects.

**EXTINGUISHING MEDIA:** Water spray, carbon dioxide, foam, dry chemical.

**HAZARDOUS COMBUSTION PRODUCTS:** Hydrogen Chloride, Carbon Dioxide, Carbon Monoxide, benzene, aromatic and aliphatic hydrocarbons other substances dependent on fire conditions.

## SECTION 6. ACCIDENTAL RELEASE MEASURES

**PERSONAL PRECAUTIONS:** No special personal precautions required.

**ENVIRONMENTAL PRECAUTIONS:** No special environmental precautions required.

**MATERIALS NOT TO BE USED FOR CONTAINMENT AND CLEAN UP:** None applicable

**PROCEDURES TO BE FOLLOWED IN CASE OF LEAK OR SPILL:** Pipe fragments and debris should be swept up and removed to a disposal container.

## SECTION 7. HANDLING AND STORAGE

**HANDLING PROCEDURES AND EQUIPMENT:** Avoid creating and breathing PVC dust.

**STORAGE REQUIREMENTS:** None

## SECTION 8. EXPOSURE CONTROLS/ PERSONAL PROTECTION

**EXPOSURE LIMITS:** Not required for articles.

**PERSONAL PROTECTIVE EQUIPMENT TO BE USED:** When cutting, the use of eye protection and a NIOSH-approved respirator for dust is recommended.

**ENGINEERING CONTROLS TO BE USED:** Ventilate adequately when cutting.

## SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

**PHYSICAL STATE:** Solid

**ODOUR AND APPEARANCE:** White, blue, green, grey or orange, odourless

**BOILING POINT:** Not applicable

**MELTING POINT:** > 66 $^{o}$C (> 150 °F)

**FREEZING POINT:** Not applicable

**VAPOUR PRESSURE:** Not applicable

**VAPOUR DENSITY:** Not applicable

**SPECIFIC GRAVITY:** 1.38 – 1.40

M11880Text Modification

IPEX
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| | |
|---|---|
| **pH:** | Not applicable |
| **ODOUR THRESHOLD:** | Not applicable |
| **EVAPORATION RATE:** | Not applicable |
| **COEFFICIENT WATER/OIL DISTR:** | Not applicable |
| **FLASH POINT:** | Not applicable |
| **LOWER FLAMMABLE LIMIT:** | Not applicable. |
| **UPPER FLAMMABLE LIMIT:** | Not applicable. |
| **AUTOIGNITION:** | 450 – 507°C (842 – 945°F) |
| **CONDITIONS OF FLAMMABILITY:** | Only if highly heated and exposed to a continuous source of ignition. PVC pipe will not support combustion. |
| **IMPACT SENSITIVITY:** | Not available |
| **STATIC DISCHARGE:** | Not available |
| **SOLUBILITY:** | Not applicable |
| **DECOMPOSITION TEMPERATURE:** | 150 – 250°C (302 – 482°F) |
| **VISCOSITY:** | Not applicable |

## SECTION 10. STABILITY AND REACTIVITY DATA

| | |
|---|---|
| **STABILITY:** | Not available. |
| **REACTIVITY:** | Not available |
| **CONDITIONS TO AVOID:** | Avoid all possible sources of ignition, heat and flames |
| **HAZARDOUS POLYMERIZATION:** | Will not occur |
| **INCOMPATIBILITY WITH OTHER SUBSTANCES:** | Acetal, acetal copolymers, amines |
| **HAZARDOUS DECOMPOSITION:** | See section 5 |

## SECTION 11. TOXICOLOGICAL INFORMATION

| | |
|---|---|
| **EFFECTS OF ACUTE EXPOSURE TO PRODUCT:** | No acute health effects reported with the inhalation of PVC dust; dust may irritate the eyes. |
| **EFFECTS OF CHRONIC EXPOSURE TO PRODUCT:** | Vinyl resin is not known to cause any disease. Dust exposure should always be minimized. Routine inhalation of dust of any kind should be avoided. Exercise care when dumping bags, sweeping, mixing or doing other tasks which can create dust. |
| **ROUTES OF ENTRY:** | Inhalation, eye contact with dust (only when cutting or grinding). |

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Mod_11880_Text_Msds-caen-ipex-pvc-pipe-and-fittings.pdf

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**SENTITIZATION**: None known

**IRRITANCY**: Not available

**CHRONIC/CARCINOGENICITY**: Not available

**REPRODUCTIVE TOXICITY**: Not available

**TERATOGENICITY**: Not available

**MUTAGENICITY**: Not available

**TOXICOLOGICALLY SYNERGISTIC PRODUCTS:** Not available

## SECTION 12. ECOLOGICAL INFORMATION

**ECOTOXICITY:** The product is not considered harmful to aquatic organisms or to cause long-term adverse effects in the environment.

**PERSISTENCE AND DEGRADABILITY:** Not established.

**BIOACCUMULATIVE POTENTIAL:** Not established.

**MOBILITY IN SOIL:** No additional information available.

**OTHER ADVERSE EFFECTS:** Not established.

## SECTION 13. DISPOSAL CONSIDERATIONS

Handle in accordance with federal, state, provincial and municipal regulations.

## SECTION 14. TRANSPORT INFORMATION

**SPECIAL SHIPPING INFORMATION:** Not applicable

## SECTION 15. REGULATORY INFORMATION

No information available.

## SECTION 16. OTHER INFORMATION

**DATE OF PREPARATION:** August 2019
**REVISION DATE:** August 2019

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**FMC Chapter 6**

**602.3 Materials within plenums.** Materials within plenums shall be noncombustible or shall be in compliance with the applicable requirements in Sections 602.3.1 through 602.3.10.

Exceptions: This section shall not apply to the following:

1. Materials exposed within plenums in one- and two-family dwellings.
2. Combustible materials fully enclosed within one of the following:
   2.1 Continuous noncombustible raceways or enclosures.
   2.2 Approved gypsum board assemblies.
   2.3 Materials listed and labeled for installation within a plenum and listed for the application.
3. Materials in Group H, Division 5 fabrication areas and the areas above and below the fabrication area that share a common air recirculation path with the fabrication area.
4. PVC pipes and fittings for the removal of condensate in air handler closets used as plenums in the dwelling units of R-2 and R-3 occupancies are acceptable when complying with all the following conditions:
   4.1 Acceptance is limited to schedule 40 PVC pipe and fittings of 3/4” or 1” nominal diameter.
   4.2 Acceptance is limited to a total pipe length of 48” or less.
   4.3 PVC pipes and fittings shall comply with ASTM standards referred to in FMC 1202.4 and 1202.5.

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# Fire Properties of Polyvinyl Chloride

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Polyvinyl chloride (PVC, or vinyl) possesses excellent fire performance properties. All organic polymers (whether they are plastics or natural materials like wood, cotton or rubber) are combustible: when sufficient heat is supplied to any organic polymer, it will thermally decompose, and its thermal decomposition products will burn. However, PVC will typically not burn once the source of heat or flame is removed. This results from PVC having 56.8% chlorine in its base polymer weight and it is well known that chlorine is one of the few elements that confers good fire properties to a polymer[1,2].

When polymers burn they give off gaseous products, which usually generate flames (most likely with light emission and soot).[3-6]

Polymer + Heat →→→ Thermal Decomposition Products
Decomposition Products + Oxygenated Radicals →→→ Combustion Products + Heat

A few polymers break down completely so that virtually no solid residue remains and all decomposition products become gaseous (and can burn). Most polymers, however, leave behind some solid residues, typically as char. Thermal decomposition of PVC occurs mostly by chain stripping, whereby hydrogen chloride (HCl) species are given off, followed by some cross-linking. Therefore, PVC is an example of a charring material that leaves much of the original carbon content as a solid residue, meaning that less of it can burn in the gas phase. The presence of chlorine in PVC exerts its influence in two ways: causing an increase in char formation (meaning that less flammable decomposition products are formed) and generating HCl, which then acts as a gas phase scavenger slowing down further reactions of flammable products in the gas phase[1, 7].

The actual fire properties of PVC have been assessed based on the results of small-scale and full-scale tests, and interpreted in terms of overall fire hazard, and this document summarizes some of the multiple studies conducted.

Samples of unplasticized (rigid) vinyl, such as those found in pipe, siding or vertical blinds, have better fire performance, especially in terms of having lower flame spread and lower heat released in a fire than similar samples of many other combustible materials, including wood. However, the fire properties of PVC typically deteriorate when PVC is plasticized, which is necessary to make it into flexible products such as wire coatings, upholstery, medical blood bags or wall coverings, depending on the amount and kind of plasticizer and other additives used. However, in fact many of the plasticized PVC products in use will not continue to burn once the flame source is removed, even if not additionally fire-retarded. Moreover, technologies were developed in the 1980's and 1990's, using combinations of plasticizers and other additives, which resulted in plasticized PVC materials with fire (and smoke) properties better than those of unplasticized PVC[8]. This allowed the use of PVC materials in applications, such as plenum cables, for which PVC materials were previously not suitable.

## FIRE HAZARD

Overall fire safety is generally achieved by deciding if materials meet certain pre-set safety objectives. However, it is usually necessary to combine various properties and calculate results based on certain fire models. The fire hazard of a product is determined by a combination of factors including its ignitability and flammability, the amount (and rate) of heat released from it when it burns, the rate at which this heat is released, the flame spread, the smoke production and the toxicity of the smoke. It has now been determined that the rate of heat release (which determines the intensity of a fire[9-12]) is the key property controlling fire hazard. Analyses of the various fire properties of PVC materials, and comparisons with those of alternate materials, follow. Some examples of fire hazard assessments performed on PVC materials and products will also be discussed later.

## IGNITABILITY

If a material does not ignite, it will not contribute to fire hazard and thereby cannot endanger lives. All organic materials do, however, ignite. The danger of ignition was formerly assessed based on ignition temperature (the lower the ignition temperature, the greater the hazard), using tests such as ASTM D1929 (or ISO 871). It is now accepted that ease of ignition is better assessed based on either the time to ignition at a specific incident heat flux or the critical heat flux for ignition to occur, for example using the cone calorimeter (ASTM E1354 or ISO 5660)[13]. Table 1 indicates that PVC materials are among the least easily ignitable polymers, using either of these criteria, at various incident heat fluxes (ranging from low to high). Ignition temperature data and further information on ignition of other materials can be found in a chapter on PVC flammability[2] and a further discussion of ignition sources has also been published[14]. Table 2 describes the materials assessed in Table 1, many of which are also used in several other tables.

## EASE OF EXTINCTION

The oxygen index test (also known as OI or LOI, ASTM D2863 or ISO 4589-2) is a reliable measure of the limiting concentration of oxygen in the atmosphere needed for sustained combustion. Since normal atmospheres have about 21% oxygen the higher the LOI the less likely it is that the material will continue burning in air (so that the test is occasionally considered an ignition test). In fact, materials with high LOI (e.g. above 30) will tend to burn only when a source of flame is present and extinguish otherwise. The test is not a reliable predictor of fire hazard but is frequently used in material data sheets to indicate fire properties. Table 3 shows some results and PVC materials are usually among the very best performers.

## SMALL-SCALE FLAMMABILITY

Once ignited, the greater the flammability of a material, higher will be the hazard associated with it. Small-scale flammability tests extensively used for plastic materials are the family of UL 94 tests (also standardized in ASTM, ISO and IEC, but most widely known from the UL standard). In this test, a small sample of material is exposed vertically to a small Bunsen-burner type flame from underneath and the results show a rating, ranging from V-0 (best), through V-1, V-2 to "B" (for Burn). One aspect that this test assesses is whether the material produces, on burning, flaming particles capable of igniting a combustible product found underneath (surgical cotton is used in the test). Materials that produce flaming particles will be assessed V-2 or B, depending on whether they continue to burn. Materials with a "B" rating on the UL 94 Vertical test can also be tested in the less severe UL 94 HB (for horizontal burning), which measures simply a flame spread rate. The UL 94 test is the most widely used fire test for plastic materials, especially fire retarded ones, and the results are almost always found in specifications and in data sheets. PVC materials will typically not produce flaming particles unless they have been heavily plasticized and have not been fire retarded. Table 4 presents some UL 94 fire test results for wire and cable materials; it shows that PVC materials usually present a UL 94 V-0 rating down to the least thickness usually measured, typically 1 mm, while many other materials will fail (or "Burn").

**FLAME SPREAD**

The tendency of a material to spread a flame away from the fire source is critical to understand the potential fire hazard. Flame spread tests are used with the materials themselves or with the products in diverse applications (such as textiles or electrical insulation), preferably with all components of an assembly. Sample sizes range widely and range up to the large Steiner tunnel samples (7.3 m × 0.56 m, or 24 ft × 22 in, ASTM E84, a test widely used in building applications).

Two other test apparatuses are used to assess flame spread: ASTM E162 (radiant panel) and ASTM E1321 (Lateral Ignition and Flame Spread Test, or LIFT). Because of its wide use, a number of applications tests were developed from it, primarily for products to be used in plenums. They include NFPA 262 (for electrical and optical fiber cables), UL 1820 (for pneumatic tubing, UL 1887 (for sprinkler piping), UL 2024 (for communications raceways) and UL 2846 (for water distribution pipe). The fire source, two gas burners, ignites the sample from below with an 89 kW fire source. The results are presented in terms of flame spread index (FSI), calculated based on the area under the flame spread distance vs. time curve and, for smoke obscuration, smoke developed index (SDI). The alternate product tests described above use classifications based on flame spread and optical density (see Table 5). Table 6 displays FSI value ranges for a variety of products and it is clear that rigid PVC will exhibit an FSI less than 25 and that flexible PVC materials tend to range in FSI up to 40. With regard to plenum cables, multiple formulations exist using PVC jackets and even some formulations use both PVC jackets and PVC insulations; all of them meet the NFPA 262 requirements of the National Electrical Code. Note that the National Electrical Code (NEC, NFPA 70) regulates the fire performance requirements for electrical materials (especially cables) throughout the US.

ASTM E162 is used to assess flame spread via a radiant panel index. This test method is frequently used in regulations, particularly for transportation environments and large appliances, and results are quoted in data sheets.

Results from this test for some materials are shown in Table 7. In general results for rigid PVC range from 10 to 25 (which usually meets the needed requirements) while flexible PVC materials can have higher radiant panel index results, typically ranging up to 50.

The LIFT apparatus, which is an improvement on the radiant panel apparatus in ASTM E162, is extensively used for regulation in marine applications. PVC materials are shown to perform very well. The test method determines the critical flux for flame spread and is useful as a predictor of full-scale flame spread performance[15].

**HEAT RELEASE**

The key question to ask in a fire is: "How big is the fire?" The single fire property that answers that question is the maximum rate of heat release. A burning product will spread a fire to nearby products only if it gives off enough heat to ignite them. Moreover, in order for fire to propagate heat has to be released sufficiently quickly that it is not dissipated or lost while traversing the "cold" air surrounding anything that is not on fire. Thus, fire hazard is dominated by the rate of heat release, which has been shown to be much more important than either ease of ignition, smoke toxicity, or flame spread in controlling time available for escape or rescue[16].

The first bench-scale (meaning that it uses small test samples) heat release test instrument was developed in the late 1960s, the Ohio State University (OSU) calorimeter (ASTM E906)[17]. This instrument is still important primarily because it forms the basis for regulation of major aircraft materials by the US Federal Aviation Administration (FAA) in conjunction with the regulatory authorities of most other developed countries; the regulations are contained in the regularly-updated FAA Aircraft Materials Fire Test Handbook[18]. In heat release testing, fire performance improves when the heat release rate is lower. Table 8 contains peak heat release rate results for a variety of materials at an incident heat flux of 20 kW/m2 measured in the OSU calorimeter. Note that the PVC materials exhibit very low heat release rates.

In the early 1980s, the National Institute of Standards and Technology (NIST, then National Bureau of Standards) developed a more advanced bench-scale test method to measure heat release rate: the cone calorimeter (ASTM E1354, ISO 5660). It was discussed earlier that this fire test can also be used to assess ignitability (see Table 1) but its primary goal is to conduct measurements of heat release, while at the same time assessing smoke release and mass loss. Moreover, cone calorimeter test results have been shown to predict full scale fire test results for many products, including upholstered furniture, mattresses, electrical cables, wall linings and aircraft panels among them (highlighted because they are the products most likely to contribute heavily to real fires)[19-25]. In order to obtain a good overall understanding of the fire performance of materials, it is important to test the materials under a variety of conditions, which means a variety of incident heat fluxes in the cone calorimeter. The peak heat release rates (and total heat released) of the materials in Table 2 at three incident heat fluxes are shown in Table 9[13]. It is again clear that PVC materials tend to outperform many of the alternate materials. The table also contains another important parameter, namely the fire performance index (FPI) for the same materials at all three fluxes. The fire performance index (which is the ratio between the time to ignition and the peak heat release rate) has been shown to be a reasonable first-order indicator of propensity to flashover[23-24]. Just like the time to ignition, better results in the fire performance index correspond to those materials with higher numbers and PVC materials invariably appear among the best performers.

It has been found of interest to assess the fire performance of minute specimens of materials (in the mg range), using a technique called the micro-calorimeter (or the pyrolysis combustion flow calorimeter, standardized as ASTM D7309). This instrument[26] measures (among other parameters) the heat release capacity of materials (a fundamental property that is well correlated to the heat release rate). Table 10 contains data for heat release capacity of a variety of polymeric materials and PVC is one of the best performers.

The heat release tests discussed above use small-scale samples of materials. In order to confirm that these test results are meaningful, it is often necessary to assess materials (or products) at a larger scale. A number of modern full-scale fire test methods have been developed for products, and they rely mainly on heat release rate measurements. They address wall lining products (via room-corner tests such as NFPA 265 and NFPA 286), upholstered furniture, mattresses, stacking chairs, display stands and other decorative products and electrical cables. In fact, room-corner tests are being used in codes as preferred alternatives to replace the ASTM E84 Steiner tunnel test, thus generating more useful results. Table 11 contains information from one of the relatively few studies[2] of the same materials in a room corner test and the cone calorimeter. It shows cone calorimeter data at four incident heat fluxes for seven wall lining materials (peak heat release rate and fire performance index) and includes comparisons to room-corner test results (using a 6.3 kg wood crib as ignition source) in terms of heat and smoke release. It is clear that all rigid vinyl materials give very low heat release and none of them causes flashover. The table also contains total smoke yield in the full scale tests as well as additional small scale smoke obscuration data, to be discussed later.

Table 12 contains data from a series of tests in which various halogenated (PVC and fluorinated ethylene propylene, FEP) materials intended for wire and cable insulation and jacket applications were compared with materials that were non halogenated (LDPE, EVA and other polyolefins)[27]. In this series both large-scale and small-scale tests were conducted. However, the data presented shows results from large scale (2.4-3.0 m high) cable tray tests, namely CSA FT4 (or UL 1685/FT4, used in North America) and IEC 60332-3 (used in Europe). It is clear that the PVC materials perform much better than the halogen-free cable materials.

Although it is not possible to give easy summaries of heat release data for vinyl materials, the data shown makes it clear that PVC materials exhibit extremely low heat release, and tend to have low propensity to flashover (as shown by high fire performance indices).

**SMOKE OBSCURATION**

Smoke obscuration is a serious concern in fires, because when visibility decreases it hinders both escape from the fire and rescue by safety personnel. The main way in which visibility decreases in a fire is through smoke emission. A decrease in visibility is the result of a combination of two factors: how much material is burnt in the real fire (which will be less if the material has better fire performance) and how much smoke is released per unit material burnt.

In spite of the fact that it is clear that smoke obscuration needs to be measured in large scale tests, or by a method which can predict large scale smoke release, the most common small scale test used to measure smoke from burning products is the traditional smoke chamber in the vertical mode (ASTM E662). The test results are expressed in terms of the "specific optical density", something which has now been shown not to be representative of real smoke release. For example, when melting materials, which melt or drip when exposed to flame, are exposed vertically in the test, the molten portions will have escaped the effect of the heat source and will not burn (or give off smoke) during the test, while in a real fire, all the molten material will burn and generate smoke. Moreover, the ASTM E662 smoke chamber is a static system, in which smoke accumulates, in contrast with real fires, where smoke flows from one compartment to another. Smoke chamber test results for several materials[2] are shown in Table 13.

As discussed above, the cone calorimeter, a dynamic flow-through fire test, can also be used to assess smoke obscuration. The results in terms of the relative rankings of materials tend to be very different from those found in the static smoke chamber. Table 14 contains obscuration data from the cone calorimeter for the materials in Table 2[13]. Empirical parameters have been proposed to compensate for incomplete sample consumption in small scale tests. A key one is the smoke factor (SmkFct), determined in the cone calorimeter[28]; it combines light obscuration (as total smoke released) and the peak heat release rate. The results shown in Table 14 are presented in terms of the average specific extinction area (SEA, ratio of the extinction coefficient of smoke to the mass loss, at each measurement point), the total smoke released in the test (TSR) and the smoke factor. The results show that PVC materials, when assessed properly, can release smoke in the same range as most other materials, or even less in some cases, when properly formulated.

Studies of room-corner tests have shown that the majority of materials with low flame spread (or low heat release, like PVC materials) tend to also exhibit low smoke release. In a series of studies only some 10% of the materials tested (8 out of 84) exhibited adequate heat release (or fire growth) characteristics, but very high smoke release[29, 30]. This needs to be taken into account when assessing PVC materials in products that occupy large surfaces, because PVC materials have intrinsically high smoke release, but only when the entire material is forced to burn.

**SMOKE TOXICITY**

The majority of fire fatalities result from the inhalation of smoke and combustion products, and not from burns. However, that does not mean that people die in fires because the smoke from some materials is much more toxic than the average. In fact, the following facts are now widely accepted by fire scientists31-38 and they are critical to understand how to assess fire hazard:

- Fire fatalities usually occur in fires that became very large; in the US such fires account for over six times more deaths than all other fires[39-40].

- Carbon monoxide concentrations in flashover fires (the fires most likely to cause fatalities) are virtually unaffected by chemical composition of fuels. The yields of CO in full-scale flashover fires are roughly 0.2 g/g, which corresponds to a toxicity of 25 mg/l[41-42]. This consistent yield of CO results from compiling 24 studies[43]. A comprehensive study of fatalities (fire and non-fire) associated with CO[37] showed that the CO found in blood statistically tracks fire fatalities, without needing to include other factors, normally.

- Toxic potency values from the most suitable small-scale smoke toxicity test (NIST radiant test, using rats as the animal model, but only for confirmatory purposes, standardized in ASTM E 1678 and NFPA 269) have been well validated with regard to toxicity in full-scale fires. However, toxicity comparisons between small-scale and full-scale cannot be done to better than a factor of 3. This is illustrated by the fact that the range of the toxic potency of the smoke of almost all materials (including PVC) is so small that it pales in comparison with the ranges of toxic potencies of typical poisons. All smoke is extremely toxic, irrespective of what is burning. Figure 1 compares the toxic potency of the smoke of plastics with those of categories and individual chemicals.

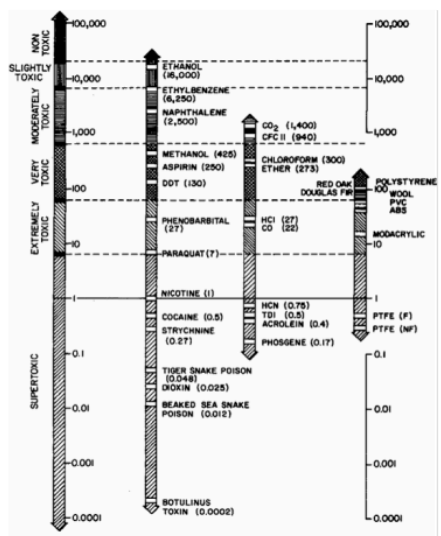


Figure 1.
*Levels of smoke toxicity (in orders of magnitude)*

- The consequence of this is that any toxic potency (which is usually expressed as an LC50) higher than 8 mg/l (meaning a value lower than that number) will become of no consequence because of the toxicity of the atmosphere. Thus, common materials have virtually the same smoke toxicity and their associated fire hazard will not be a function of smoke toxic potency but of how much they burn and how high their heat release rate is.

Neither PVC nor any of the products into which it decomposes (by burning or by simple thermal action) is included in any list of substances of concern. Note that PVC does not depolymerize to form vinyl chloride monomer and that commercial PVC materials do not contain such monomer. In the past, PVC compounds contained some traditional plasticizers that have since found their ways into such lists; they are no longer in use, at least in the US or in developed countries.

Chlorinated dioxins and furans can be formed when PVC materials are thermally decomposed at relatively low temperatures. However, studies of incineration of municipal solid waste, with and without added PVC, showed that the use of efficient incinerators (i.e. ones operating at high enough temperatures) ensures that PVC in such waste has very little, if any, effect on dioxin emissions[44]. Moreover, studies have also demonstrated that the amount of dioxins generated from PVC in dwelling fires is negligible compared to the overall emissions of dioxins[45].

## HYDROGEN CHLORIDE DECAY

During the 1980's a series of 23 studies were conducted to investigate the "lifetime" of HCl in a fire atmosphere. These studies were summarized more recently[38]; they showed that HCl reacts very rapidly with most common construction surfaces (cement block, ceiling tile, gypsum board, etc.) and that, therefore, the peak HCl concentration found in a fire is much lower than would be predicted from the chlorine content of the burning PVC. Moreover, this peak HCl concentration soon decreases and HCl disappears almost completely from the fire atmosphere. Figure 2 shows the HCl concentration-time pattern for several identical experiments where PVC cables (containing the chlorine equivalent of 8,700 ppm of HCl) was electrically decomposed in the presence of sorptive surfaces (which represent construction surfaces). In one case, with a simulated plenum, the peak HCl concentration found was only 10% of the expected value[46-47]. A consequence of this HCl decay is that toxicity tests carried out in typical (non-sorptive) glass or plastic exposure chambers will exaggerate the toxicity of PVC smoke, because HCl does not decay as fast as on construction surfaces, so that HCl is present longer than in real fires.

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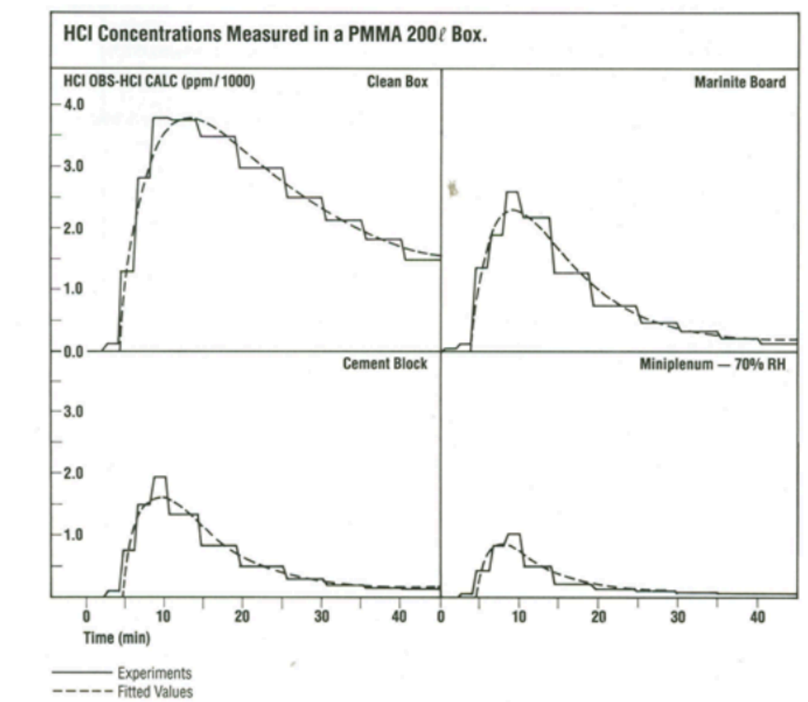


**Figure 2.**

*HCl from Thermal Decomposition of PVC Cables in a Lined PMMA Box*

Additionally, full-scale experiments were conducted in a real plenum and in a long corridor, among others. The plenum tests[48] showed that even if massive amounts of PVC are thermally decomposed in a plenum space above a room, no detectable HCl filters down into the room below (unless driven by an air conditioning system) while other gases (such as CO) do accumulate in the room. Even when driven by the air conditioning system, the HCl concentrations measured were found to have no toxicological concern. Thus, HCl from PVC is unlikely to affect victims outside the room of fire origin (meaning that they won't affect victims in the post-flashover period).

## FIRE HAZARD, FIRE RISK AND PVC PERFORMANCE IN REAL FIRES

Overall fire safety is generally achieved by deciding if materials meet certain pre-set safety objectives. Many of the prescriptive techniques used most often for fire safety requirements (standard fire tests) were developed many years ago, and tend to have some deficiencies when applied to materials not commonly used when the test was developed.



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As PVC does not normally melt away from flames, it often appears to perform less well in traditional tests than typical melting thermoplastics, when the test involves vertical or ceiling mounting, both of which can generate misleading results with melting materials. This has resulted in the development of techniques where all relevant fire properties and the entire fire scenario are considered, instead of pass/fail criteria based on individual tests. Such a process is called a fire hazard assessment. Fire hazard needs to be differentiated from fire risk. Fire hazard is the potential for harm to result when a fire occurs and fire risk is the combination of fire hazard and the probability that a fire will occur. PVC products have been shown to perform very well when both fire hazard and fire risk assessments are made. Four fire hazard assessments and one fire risk assessment were conducted in the 1980's and 1990's addressing burning of PVC electrical products in concealed spaces. The fire hazard assessment studies, as shown below, indicated that such PVC products exhibit low fire hazard. In all cases, it was found that the temperatures and concentrations of toxic gases in the room would have been lethal long before there would be any effect resulting from burning the PVC products, and that the materials involved were safe for the corresponding applications. The studies involved PVC non-metallic tubing installed behind walls[49], PVC conduit, PVC non-metallic tubing, or PVC wire coating, installed in a plenum, with a fire starting in the room below[50], PVC wire coating installed in a plenum, with a fire starting in the plenum51 and PVC wall linings in a cafeteria[52]. The fire risk assessment study, conducted through an NFPA project by NIST[53], involved PVC cables installed in concealed spaces in hotels. It indicated that cables with the fire performance of PVC were unlikely to add significantly to the fire risk associated with the other materials present.

It is of interest to point out an interesting aspect of a study by NIST investigating smoke toxicity predictions but using products made of 3 materials: wood (Douglas fir planks), polyurethane rigid foam and rigid PVC sheets[33]. In the full-scale tests the authors found that both the wood and foam products were able to be ignited while using small cribs of the same material and ignited by adding heptane contained in a pan under the crib. On the other hand, neither the PVC cribs nor the PVC sheets ignited under those conditions and a 450 kW gas burner had to be used to get the toxicity information needed. This is another example to show the excellent fire performance of rigid PVC in real-scale fires.

## SUMMARY

- PVC is less flammable than most polymeric materials, natural or synthetic and it will not normally continue to burn unless a source of a sizeable fire exposure remains present.
- The heat release rate of PVC is lower than that of most combustible materials and it has been demonstrated that heat release rate governs the intensity of a fire.
- That means that, when PVC eventually burns, it both gives off less heat than most materials and it gives off heat more slowly than others.
- The smoke produced by PVC in small-scale tests is in the same range as many other materials and the smoke generated in full scale fires is usually lower because PVC materials burn less than most others.
- The smoke toxicity of PVC materials is in the exact same range as that of most commercial materials.
- PVC is one of the safer materials when fire safety is an essential consideration.

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| Table 1: Ignitability of Materials in the Cone Calorimeter | | | | | |
|---|---|---|---|---|---|
| | Time to ignition (in s) at heat flux | | | Heat flux (in kW/m²) for a time to ignition of | |
| | 20 kW/m² | 40 kW/m² | 70 kW/m² | 600 s | 100 s |
| **Vinyl Materials** | | | | | |
| PVC PL 3 | 10,000 | 1,212 | 17 | 45 | 64 |
| PVC PL 2 | 10,000 | 1,253 | 424 | 60 | 110 |
| PVC PL 4 | 10,000 | 10,000 | 1,583 | 86 | 115 |
| PVC PL 1 | 10,000 | 1,271 | 60 | 47 | 65 |
| CPVC | 10,000 | 621 | 372 | 42 | 90 |
| PVC CIM | 5,159 | 73 | 45 | 30 | 39 |
| PVC WC FR | 236 | 47 | 12 | ≤ 15 | 31 |
| PVC LS | 5171 | 187 | 43 | 33 | 44 |
| PVC WC SM | 176 | 36 | 14 | ≤ 15 | 27 |
| PVC EXT | 3591 | 85 | 48 | 30 | 39 |
| PVC WC | 117 | 27 | 11 | ≤ 15 | 22 |
| FL PVC | 102 | 21 | 15 | ≤ 15 | 20 |
| **Non Vinyl Materials** | | | | | |
| PTFE | 10,000 | 10,000 | 252 | 63 | 83 |
| PCARB | 10,000 | 182 | 75 | 34 | 43 |
| ACR FR | 200 | 38 | 12 | ≤ 15 | 28 |
| PCARB B | 6400 | 144 | 45 | 32 | 42 |
| XLPE | 750 | 105 | 35 | 22 | 40 |
| PPO GLAS | 465 | 45 | 35 | 18 | 33 |
| PPO/PS | 479 | 87 | 39 | 17 | 38 |
| ABS FV | 5198 | 61 | 39 | 30 | 38 |
| ABS FR | 212 | 66 | 39 | ≤ 15 | 33 |
| DFIR | 254 | 34 | 12 | ≤ 15 | 29 |
| PS FR | 244 | 90 | 51 | ≤ 15 | 38 |
| ACET | 259 | 74 | 24 | ≤ 15 | 35 |
| PU | 12 | 1 | 1 | ≤ 15 | ≤ 15 |
| PMMA | 176 | 36 | 11 | ≤ 15 | 27 |
| THM PU | 302 | 60 | 38 | ≤ 15 | 34 |
| NYLON | 1,923 | 65 | 31 | 27 | 37 |
| ABS | 236 | 69 | 48 | ≤ 15 | 34 |
| PS | 417 | 97 | 50 | 15 | 40 |
| EPDM/SAN | 486 | 68 | 36 | 18 | 36 |
| PBT | 609 | 113 | 59 | 20 | 41 |
| PET | 718 | 116 | 42 | 22 | 42 |
| PE | 403 | 159 | 47 | ≤ 15 | 50 |
| PP | 218 | 86 | 41 | ≤ 15 | 37 |

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**Table 2:** Materials Used for Various Series of Experiments (*Samples are 6 mm thick unless noted differently*)

| # | Abbreviation | Description and Source – including trade name |
|---|---|---|
| 1 | PTFE | Polytetrafluoroethylene sheet (samples were two sheets at 3 mm thickness each, Du Pont) |
| 2 | PVC PL 3 | Flexible PVC thermoplastic elastomer alloy cable jacketing plenum compound |
| 3 | PVC PL 2 | Flexible PVC thermoplastic elastomer alloy cable jacketing plenum compound |
| 4 | PVC PL 4 | Semi flexible PVC thermoplastic elastomer alloy cable jacketing plenum compound, containing PVC and CPVC (BFGoodrich) |
| 5 | PCARB | Polycarbonate sheeting (Lexan 141-111, General Electric) |
| 6 | PVC PL 1 | Flexible PVC thermoplastic elastomer alloy cable jacketing plenum compound |
| 7 | CPVC | Chlorinated PVC sheet compound (BFGoodrich) |
| 8 | PVC CIM | PVC custom injection molding compound with impact modifiers (BFGoodrich) |
| 9 | PVC WC FR | Flexible cable PVC compound (containing flame retardants) (BFGoodrich) |
| 10 | PVC LS | PVC rigid sheet extrusion compound with smoke suppressants (BFGoodrich) |
| 11 | XLPE | Black non-halogen flame retarded, irradiation cross-linkable, polyethylene copolymer cable jacketing compound (DEQD-1388, Union Carbide) |
| 12 | PVC WC SM | Flexible cable PVC compound (with minimal amounts of flame retardants) (BFGoodrich) |
| 13 | PVC EXT | PVC rigid weatherable extrusion compound with minimal additives (BFGoodrich) |
| 14 | PVC WC | Flexible cable PVC compound (not flame retarded) (BFGoodrich) |
| 15 | ACR FR | Kydex: flame retarded acrylic paneling, blue, (samples were 4 sheets at 1.5 mm thickness each, Kleerdex) |
| 16 | PCARB B | Commercial polycarbonate sheeting (Commercial Plastics) |
| 17 | PPO GLAS | Blend of polyphenylene oxide and polystyrene containing 30% fiberglass (Noryl GFN-3-70, General Electric) |
| 18 | PPO/PS | Blend of polyphenylene oxide and polystyrene (Noryl N190, General Electric) |
| 19 | ABS FV | Polymeric system containing ABS and some PVC as additive |
| 20 | ABS FR | Cycolac KJT ABS terpolymer flame retarded with Br compounds (Borg Warner) |
| 21 | FL PVC | Standard flexible PVC compound (non-commercial; similar to a cable compound) used for various sets of testing (contains PVC resin 100 phr; diisodecyl phthalate 65 phr; tribasic lead sulphate 5 phr; calcium carbonate 40 phr; stearic acid 0.25 phr) |
| 22 | DFIR | Douglas fir wood board |
| 23 | PS FR | Flame retarded polystyrene, Huntsman 351 (Huntsman) |
| 24 | ACET | Polyacetal: polyformaldehyde (Delrin, Commercial Plastics) |
| 25 | PU | Polyurethane flexible foam, non-flame retarded (Jo-Ann Fabrics) |
| 26 | PMMA | Poly(methyl methacrylate) (25 mm thick, lined with cardboard, standard HRR sample) |
| 27 | THM PU | Thermoplastic polyurethane containing flame retardants (estane, BFGoodrich) |
| 28 | NYLON | Nylon 6,6 compound (Zytel 103 HSL, Du Pont) |
| 29 | ABS | Cycolac CTB ABS terpolymer (Borg Warner) |
| 30 | PS | Polystyrene, Huntsman 333 (Huntsman) |
| 31 | EPDM | Copolymer of EPDM rubber and SAN (Rovel 701) |
| 32 | PBT | Polybutylene terephthalate sheet (Celanex 2000-2 polyester, Hoechst Celanese) |
| 33 | PET | Polyethylene terephthalate soft drink bottle compound |
| 34 | PE | Polyethylene (Marlex HXM 50100) |
| 35 | PP | Polypropylene (Dypro 8938) |

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**Table 3:** Oxygen Index of a Variety of Materials

| Material | LOI | Vinyl or Non Vinyl |
|---|---|---|
| PTFE | 95.0 | NV |
| CPVC | 62.2 | V |
| PVDC | 60.0 | NV |
| Carbon black rod | 59.9 | NV |
| PVC PL 4 | 49.4 | V |
| PVC PL 2 | 48.0 | V |
| PVC (rigid) | 47.0 | V |
| PVDF | 43.7 | NV |
| Polyimide | 36.5 | NV |
| Leather (FR) | 34.8 | NV |
| Polysulphone | 31.1 | NV |
| Nomex | 28.5 | NV |
| Modacrylic | 26.8 | NV |
| Neoprene rubber | 26.3 | NV |
| Polycarbonate | 26.2 | NV |
| Wool | 25.2 | NV |
| Nylon 6,6 | 25.1 | NV |
| PVF | 22.6 | NV |
| PET | 20.0 | NV |
| Cellulose | 19.0 | NV |
| Rayon | 18.8 | NV |
| Polyacrylonitrile | 18.0 | NV |
| SAN | 18.0 | NV |
| PMMA | 17.9 | NV |
| Polystyrene | 17.7 | NV |
| ABS | 17.6 | NV |
| Natural Rubber | 17.2 | NV |
| Polypropylene | 17.1 | NV |
| Polyethylene | 17.0 | NV |
| Cotton | 16.5 | NV |
| Polyacetal | 15.8 | NV |
| Polyoxymethylene | 15.7 | NV |

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| Table 4: UL 94 Test Results of Wire and Cable Materials | | | | |
|---|---|---|---|---|
| **Material #** | **V-0 @ 1 mm** | **V-0 @ 2 mm** | **V-0 @ 3 mm** | **HB** |
| PVC Cable FR1 | V-0 | V-0 | V-0 | |
| PVC Cable FR2 | V-0 | V-0 | V-0 | |
| PVC Cable FR3 | V-0 | V-0 | V-0 | |
| PVC Cable FR4 | V-0 | V-0 | V-0 | |
| PVC Cable Non FR | V-1 | V-2 | V-0 | |
| Chlorosulphonated PE | V-1 | V-0 | V-0 | |
| PTFE | V-0 | V-0 | V-0 | |
| LDPE Cable Non FR | B | B | B | 2 in/min |
| EVA Cable FR1 | B | | | |
| EPR Cable FR2 | B | | | |
| EVA Cable FR3 | V-1 | V-0 | V-0 | |
| EVA Cable FR4 | B | B | B | |
| EVA Cable FR5 | V-0 | V-0 | V-0 | |
| Polyphenylene Oxide | B | B | B | |
| EVA Cable FR6 | B | B | V-0 | |
| PVC PL2 | V-0 | V-0 | V-0 | |

**Table 5:** Steiner Tunnel Test Classifications

| ASTM E84 Class | FS | S |
|---|---|---|
| A | ≤ 25 | ≤ 450 |
| B | > 25 & ≤ 75 | ≤ 450 |
| Class | > 75 & ≤ 200 | ≤ 450 |
| Plenum | ≤ 25 | ≤ 50 |
| Other tunnel standards: flame spread ≤ 5ft, peak optical density ≤ 0.50 and average optical density ≤ 0.15 | | |

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| Table 6: Flame Spread Index from the ASTM E84 Test | | |
|---|---|---|
| **Material/Product** | **Flame Spread Index Range** | |
| | **Low** | **High** |
| ABS | 200 | 275 |
| Douglas fir/cedar plywood | 190 | 230 |
| Ponderosa pine A | 170 | 230 |
| Acrylic plastic | 220 | |
| Northern white pine A | 190 | 215 |
| Southern yellow pine | 130 | 195 |
| Hemlock/cedar plywood | 190 | |
| Red oak flakeboard | 70 | 190 |
| Poplar | 170 | 185 |
| Particleboard | 135 | 180 |
| Northern white pine B | 120 | 180 |
| Modified polyphenyl oxide | 170 | |
| Lauan hardwood | 150 | 170 |
| Ponderosa pine B | 105 | 170 |
| Red Gum (25 mm) | 140 | 155 |
| Cypress (25 mm) | 145 | 150 |
| Plywood panelling over gypsum | 130 | 150 |
| Red pine | 140 | |
| Walnut | 130 | 140 |
| Douglas fir overlay | 110 | 140 |
| Vinyl faced plywood | 110 | 130 |
| Polycarbonate | 80 | 120 |
| Cottonwood (25 mm) | 115 | |
| Polyether imide | 110 | |
| Yellow birch (25 mm) | 105 | 110 |
| Maple flooring | 105 | |
| Western spruce | 100 | |
| Red oak flooring (20 mm) | 100 | 100 |
| Douglas fir (25 mm) | 70 | 100 |
| ABS FR | 10 | 100 |
| Lodgepole pine | 95 | |
| Eastern white pine | 85 | |
| Pacific yellow cedar (25 mm) | 80 | |
| Cellulose fiberboard ceiling tile | 70 | 80 |
| Western white pine | 75 | |
| Western red cedar (25 mm) | 70 | |
| Pacific silver fir (25 mm) | 70 | |
| Varnished pine (10 mm) | 70 | |
| Redwood | 65 | 70 |
| West coast hemlock (25 mm) | 60 | 70 |



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| **Table 6:** Flame Spread Index from the ASTM E84 Test – *Continued* | | |
|---|---|---|
| Fire retarded polycarbonate | 10 | 65 |
| FR Polyester B | 35 | 45 |
| FR Treated plywood (6 mm) | 40 | |
| Vinyl faced wallboard | 20 | 35 |
| FR Polyester A | 20 | 30 |
| PVC wallcovering on gypsum board | 10 | 25 |
| PVC rigid profile | 15 | 20 |
| Polypropylene scrim foil | 15 | 20 |
| Cellulosic ceiling tile (15 mm) | 15 | |
| Phenolic foam (38 mm) | 15 | |
| Gypsum wallboard | 10 | 20 |
| Polypropylene scrim kraft paper | 10 | 15 |
| PVC siding (1 mm) | 10 | 15 |
| PVC vapor barrier | 10 | 15 |
| PVC sheet (3 mm) | 5 | 10 |
| Polyimide foam (51 mm) | 0 | |
| Mineral wool unfaced (51 mm) | 0 | 0 |
| Asbestos cement board | 0 | 0 |

| **Table 7:** Radiant Panel Index Results from ASTM E162 | | |
|---|---|---|
| **Material** | **Thickness (mm)** | **Radiant Panel Index** |
| Chlorinated PVC | 3 | 4 |
| Polyether sulphone | 3 | 5 |
| PVC (rigid) | 4 | 10 |
| Polyester | 3 | 43 |
| FR polystyrene | 3 | 59 |
| FR polycarbonate | 6 | 73 |
| Modified polyphenylene oxide | 6 | 84 |
| Polycarbonate | 3 | 88 |
| Red oak | 19 | 99 |
| Phenolic resin | 2 | 114 |
| ABS | 6 | 131 |
| Plywood (fir) | 6 | 143 |
| Hardboard | 6 | 185 |
| GRP polyester (21%) | 2 | 239 |
| FR acrylic | 3 | 316 |
| Polystyrene | 2 | 355 |
| Acrylic | 6 | 416 |
| Polyurethane foam (flexible) | | 1490 |
| Polyurethane foam (rigid) | | 2220 |

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| Table 8: Results from OSU Heat Release Testing | |
|---|---|
| **Material (#)** | **Pk HRR (kW/m²)** |
| PMMA | 586.8 |
| PE | 476.9 |
| PP | 451.2 |
| EPDM | 402.8 |
| PS (non FR) | 398.9 |
| ABS (non FR) | 391.1 |
| Polystyrene | 376.7 |
| ABS (non FR) | 344.5 |
| Polyester PBT | 316 |
| Hardboard | 227.1 |
| Polycarbonate | 192.5 |
| Polystyrene (FR) | 189.3 |
| PPO Glass | 170.4 |
| THM PU | 158.1 |
| ABS FV | 152.4 |
| PPO/PS | 136.4 |
| Polycarbonate | 132.5 |
| Plywood | 113.6 |
| PS (FR) | 103.8 |
| Pine (25 mm) | 79.5 |
| Oak (25 mm) | 79.5 |
| Vinyl tile | 75.7 |
| ABS (FR) | 70.7 |
| FL PVC | 56.8 |
| Gypsum board | 47.3 |
| PVC CIM | 43 |
| PVC EXT | 40 |
| LS PVC | 39.3 |
| PVC PL4 | 17.5 |

**Table 9:** Heat Release and Fire Performance Index Test Results in the Cone Calorimeter (*Materials in Table 2*)



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| | Flux 20 kW/m² | | | Flux 40 kW/m² | | | Flux 70 kW/m² | | |
|---|---|---|---|---|---|---|---|---|---|
| Material | Pk RHR (kW/m²) | THR (MJ/m²) | FPI (s m²/kW) | Pk RHR (kW/m²) | THR (MJ/m²) | FPI (s m²/kW) | Pk RHR (kW/m²) | THR (MJ/m²) | FPI (s m²/kW) |
| PTFE | 3 | 0.3 | 6780 | 13 | 11.7 | 839 | 161 | 69.1 | 1.56 |
| PVC PL3 | 4 | 5.1 | 2850 | 43 | 31.5 | 36.4 | 70 | 48.8 | 0.24 |
| PVC PL2 | 9 | 5.7 | 1301 | 64 | 66.1 | 21.4 | 100 | 39 | 6.01 |
| PVC PL4 | 14 | 13.2 | 1027 | 87 | 25.9 | 115 | 66 | 57.4 | 24.3 |
| PCARB | 16 | 0.1 | 5173 | 429 | 119.2 | 0.43 | 342 | 121.7 | 0.22 |
| PVC PL1 | 19 | 12.2 | 591 | 77 | 48.1 | 16.7 | 120 | 63.4 | 0.49 |
| CPVC | 25 | 14.7 | 392 | 84 | 37.4 | 7.44 | 93 | 44.9 | 4.06 |
| PVC CIM | 40 | 3 | 1343 | 175 | 24.3 | 0.42 | 191 | 93 | 0.24 |
| PVC WC FR | 72 | 36.5 | 3.49 | 92 | 51.7 | 0.5 | 134 | 65.5 | 0.09 |
| PVC LS | 75 | 6.6 | 72.4 | 111 | 73.6 | 1.65 | 126 | 75.5 | 0.34 |
| XLPE | 88 | 87.6 | 8.08 | 192 | 126.2 | 0.55 | 268 | 129.2 | 0.13 |
| PVC WC SM | 90 | 49 | 1.96 | 142 | 75.4 | 0.25 | 186 | 73.4 | 0.07 |
| PVC EXT | 102 | 2.9 | 31.4 | 183 | 90.8 | 0.46 | 190 | 96.5 | 0.25 |
| PVC WC | 116 | 47.3 | 1 | 167 | 95.7 | 0.16 | 232 | 94.4 | 0.05 |
| ACR FR | 117 | 20.5 | 1.7 | 176 | 86.7 | 0.22 | 242 | 77.2 | 0.05 |
| PCARB B | 144 | 35.4 | 474 | 420 | 134.7 | 0.34 | 535 | 143.5 | 0.08 |
| PPO GLAS | 154 | 111 | 3.03 | 276 | 125.8 | 0.16 | 386 | 125.7 | 0.09 |
| PPO/PS | 219 | 103.6 | 2.45 | 265 | 128.5 | 0.33 | 301 | 134.3 | 0.13 |
| ABS FV | 224 | 80.7 | 66.3 | 291 | 108.5 | 0.21 | 409 | 114.1 | 0.1 |
| ABS FR | 224 | 38.3 | 0.93 | 402 | 70.3 | 0.16 | 419 | 61 | 0.09 |
| FL PVC | 233 | 116.4 | 0.44 | 237 | 98.2 | 0.09 | 252 | 86.3 | 0.06 |
| DFIR | 237 | 46.5 | 1.1 | 221 | 64.1 | 0.15 | 196 | 50 | 0.06 |
| PS FR | 277 | 93 | 0.9 | 334 | 94.5 | 0.27 | 445 | 82 | 0.11 |
| ACET | 290 | 143.9 | 0.9 | 360 | 141.3 | 0.2 | 566 | 167.1 | 0.04 |
| PU | 290 | 9.4 | 0.04 | 710 | 13.2 | 0.0014 | 1221 | 13.3 | 0.0008 |
| PMMA | 409 | 691.5 | 0.43 | 665 | 827.9 | 0.05 | 988 | 757.1 | 0.01 |
| THM PU | 424 | 110 | 0.72 | 221 | 119.3 | 0.28 | 319 | 120.1 | 0.12 |
| NYLON | 517 | 188 | 3.85 | 1313 | 226.3 | 0.05 | 2019 | 233.8 | 0.02 |
| ABS | 614 | 160 | 0.38 | 944 | 162.5 | 0.07 | 1311 | 162.5 | 0.04 |
| PS | 723 | 202.6 | 0.58 | 1101 | 210.1 | 0.09 | 1555 | 197.8 | 0.03 |
| EPDM | 737 | 213.1 | 0.66 | 956 | 199.8 | 0.07 | 1215 | 215.7 | 0.03 |
| PBT | 850 | 96.7 | 0.75 | 1313 | 169.9 | 0.09 | 1984 | 197.4 | 0.09 |
| PET | 881 | 93.3 | 0.82 | 534 | 113.7 | 0.22 | 616 | 125.5 | 0.07 |
| PE | 913 | 161.9 | 0.44 | 1408 | 221 | 0.06 | 2735 | 227.5 | 0.02 |
| PP | 1170 | 231.3 | 0.19 | 1509 | 206.9 | 0.06 | 2421 | 231.1 | 0.02 |

M11880Text Modification

| Table 10: Heat Release Capacity of Polymeric Materials | |
|---|---|
| **Polymer** | **Heat Release Capacity** |
| - | (J/g K) |
| High density polyethylene | 1450 |
| Polypropylene | 1106 |
| Polystyrene | 1088 |
| High impact polystyrene | 873 |
| Acrylonitrile butadiene styrene | 585 |
| Polycarbonate | 578 |
| Polyamide 6,6 | 565 |
| Poly(methyl methacrylate) | 480 |
| Polyethylene terephthalate | 366 |
| Poly ether ether ketone | 345 |
| Poly(vinylidene fluoride) | 309 |
| Polyphenylene sulfide | 230 |
| Polyphenyl sulfone | 219 |
| Polyoxymethylene | 200 |
| Polyether imide | 197 |
| PVC | 157 |
| Fluorinated ethylene propylene | 82 |

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Mod_11880_Text_Fire-Properties-of-Polyvinyl-Chloride_0.pdf

M11880Text Modification

**Table 11:** Fire Properties of Wall Lining Materials (Full scale and Small Scale)

| | | | Rigid PVC | Wood Panel | Low Smoke PVC | CPVC | Polycarbonate | FR ABS | FR Acrylic Paneling |
|---|---|---|---|---|---|---|---|---|---|
| Cone Calorimeter | 20 kW/m² | Pk HRR (kW/m²) | 109 | 385 | 62 | 17 | 363 | 158 | 62 |
| | | FPI (sm²/kW) | 4.14 | 0.72 | 69.03 | 588.24 | 5.97 | 4.37 | 15.90 |
| | 25 kW/m² | Pk HRR (kW/m²) | 105 | 367 | 54 | 42 | 351 | 165 | 124 |
| | | FPI (sm²/kW) | 1.45 | 0.37 | 18.87 | 8.19 | 2.83 | 0.47 | 0.67 |
| | 40 kW/m² | Pk HRR (kW/m²) | 224 | 435 | 91 | 54 | 233 | 264 | 109 |
| | | FPI (sm²/kW) | 0.21 | 0.09 | 0.54 | 3.15 | 0.34 | 0.14 | 0.21 |
| | 70 kW/m² | Pk HRR (kW/m²) | 270 | 661 | 95 | 94 | 297 | 341 | 183 |
| | | FPI (sm²/kW) | 0.07 | 0.03 | 0.13 | 0.64 | 0.09 | 0.04 | 0.05 |
| Room Corner Test (6.3 kg wood crib) | Avg HRR | (kW) | 2.6 | 73.2 | 0 | 3 | 135.6 | 54 | 10.9 |
| | THR | (MJ) | 29.9 | 85.2 | 25.6 | 30.2 | 133.9 | 70.2 | 36.6 |
| | Smoke Yield | (g) | 368 | 868 | 202 | 26 | 4218 | 3432 | 483 |
| ASTM E662 | Dm | (-) | 780 | 106 | 94 | 53 | 247 | 900 | 435 |



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Mod_11880_Text_Fire-Properties-of-Polyvinyl-Chloride_0.pdf

**Table 12:** CSA FT4 (UL 1685/CSA) and IEC 60332-3 Cable Tray Test Results on Various Electrical Cables

| **Cable Materials** | | **CSA FT4 - UL 1685/CSA** | | | | | | | | | **IEC 60332-3** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Insulation | Jacket | Pk HRR | Avg HRR | THR | Pk RSR | TSR | Mass loss | Ht Comb | Char | Flame Ht | Char | Flame Ht |
| | | kW | kW | MJ | $m^2/s$ | $m^2$ | % combust | MJ/kg | m | m | m | m |
| PVC | PVC FR | 59 | 33 | 10 | 0.74 | 187 | 16.54 | 13.6 | 1.11 | 1.25 | 1.02 | 1.20 |
| PVC | PVC FR2 | 52 | 27 | 8 | 0.64 | 168 | 14.45 | 12.5 | 1.12 | 1.30 | 1.11 | 1.25 |
| PVC | EVA FR | 232 | 72 | 64 | 0.40 | 166 | 56.16 | 26.5 | 2.44 | 3.10 | 1.08 | 1.40 |
| PVC FR | PVC | 55 | 32 | 13 | 0.70 | 185 | 16.58 | 15.7 | 1.06 | 1.25 | 1.15 | 1.35 |
| PVC FR | PVC FR2 | 38 | 25 | 5 | 0.67 | 179 | 12.49 | 8.3 | 0.91 | 1.00 | 0.90 | 1.10 |
| PVC FR | PVC PL2 | 33 | 25 | 6 | 0.38 | 115 | 13.36 | 8.4 | 1.00 | 0.98 | 0.97 | 1.25 |
| PVC FR | EVA FR2 | 52 | 30 | 12 | 0.14 | 54 | 15.33 | 16.0 | 0.99 | 1.23 | 0.96 | 1.25 |
| PVC FR | Polyolef FR | 46 | 30 | 12 | 0.20 | 61 | 13.37 | 16.6 | 0.97 | 1.10 | 0.86 | 1.25 |
| LDPE | PVC | 510 | 101 | 100 | 0.86 | 233 | 74.52 | 35.9 | 2.44 | 3.30 | 3.50 | 3.30 |
| LDPE | PVC FR2 | 325 | 82 | 84 | 0.82 | 360 | 67.75 | 32.7 | 2.44 | 3.30 | 3.50 | 3.30 |
| LDPE | PVC PL2 | 184 | 82 | 74 | 0.56 | 310 | 65.27 | 30.4 | 2.44 | 3.00 | 2.72 | 2.75 |
| LDPE | EVA FR2 | 280 | 106 | 105 | 0.23 | 74 | 69.22 | 39.6 | 2.44 | 3.10 | 2.25 | 2.25 |
| LDPE | Polyolef FR | 368 | 117 | 115 | 0.22 | 87 | 67.12 | 45.4 | 2.44 | 3.30 | 3.50 | 3.30 |
| EVA FR2 | PVC FR | 67 | 30 | 33 | 0.37 | 184 | 19.37 | 34.8 | 1.43 | 1.19 | 1.16 | 1.45 |
| EVA FR2 | PVC FR2 | 66 | 30 | 27 | 0.35 | 146 | 16.57 | 32.7 | 1.28 | 1.23 | 1.22 | 1.30 |
| EVA FR2 | EVA FR | 206 | 31 | 105 | 0.13 | 77 | 48.69 | 42.4 | 2.44 | 3.00 | 1.35 | 1.65 |
| FEP | PVC PL2 | 26 | 23 | 3 | 0.05 | 27 | 9.75 | 7.1 | 0.80 | 0.75 | 0.94 | 1.00 |
| FEP | EVA FR2 | 66 | 34 | 13 | 0.14 | 36 | 15.80 | 22.6 | 1.14 | 1.28 | 0.91 | 0.90 |
| PEEK | PVC PL2 | 29 | 22 | 2 | 0.08 | 27 | 8.84 | 8.5 | 0.77 | 0.80 | 0.92 | 1.00 |
| PEEK | EVA FR2 | 54 | 33 | 15 | 0.06 | 27 | 10.25 | 42.6 | 1.02 | 1.13 | 0.92 | 0.95 |
| FEP | FEP | 28 | 25 | 5 | 0.02 | 10 | 5.89 | 23.5 | 0.76 | 0.75 | 0.52 | 0.80 |

M11880Text Modification

| Table 13: Maximum Specific Optical Density of Materials in ASTM E662 Test | | | |
|---|---|---|---|
| **Material** | **Flaming or Non Flaming** | **Dm** | **Thickness (mm)** |
| Acrylonitrile butadiene styrene | .F | 780 | 6 |
| Polystyrene | .F | 780 | 6 |
| Acrylonitrile butadiene styrene | NF | 780 | 6 |
| Polypropylene | NF | 780 | 6 |
| Natural rubber foam | .F | 660 | 6 |
| PVC rigid | .F | 535 | 6 |
| PVC rigid | NF | 470 | 6 |
| Polyethylene | NF | 470 | 6 |
| Black walnut | NF | 460 | 6 |
| Polystyrene | NF | 395 | 6 |
| Red oak | NF | 395 | 6 |
| Douglas fir | NF | 380 | 6 |
| Natural rubber foam | NF | 372 | 6 |
| White pine | NF | 325 | 6 |
| Nylon rug | NF | 320 | 8 |
| Nylon rug | .F | 269 | 8 |
| Douglas fir | .F | 156 | 6 |
| White pine | .F | 155 | 6 |
| Polyethylene | .F | 150 | 6 |
| Polypropylene | .F | 119 | 6 |
| Black walnut | .F | 91 | 6 |
| Red oak | .F | 76 | 6 |
| Polytetrafluoroethylene | .F | 53 | 6 |
| Polytetrafluoroethylene | NF | 0 | 6 |

| Table 14: Smoke Release Test Results in the Cone Calorimeter for Materials in Table 2 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Flux 20 kW/m² | | | Flux 40 kW/m² | | | Flux 70 kW/m² | | |
| **Material** | **SEA** | **TSR** | **SmkFct** | **SEA** | **TSR** | **SmkFct** | **SEA** | **TSR** | **SmkFct** |
| | **(m²/g)** | **(-)** | **(MW/m²)** | **(m²/g)** | **(-)** | **(MW/m²)** | **(m²/g)** | **(-)** | **(MW/m²)** |
| PTFE | 0 | 200 | 0.4 | 673 | 376 | 0.3 | 33 | 764 | 4.4 |
| PVC PL3 | 305 | 730 | 0.4 | 319 | 1571 | 13.5 | 302 | 2077 | 42.4 |
| PVC PL2 | 94 | 422 | 0.6 | 358 | 2253 | 24.9 | 266 | 1725 | 80.3 |
| PVC PL4 | 131 | 417 | 1.1 | 246 | 670 | 35.9 | 174 | 945 | 25.7 |
| PCARB | 3 | 15 | 0.1 | 993 | 3620 | 733.2 | 978 | 3900 | 728.4 |
| PVC PL1 | 331 | 1249 | 4.3 | 547 | 3198 | 76.1 | 572 | 4888 | 239.1 |
| CPVC | 51 | 225 | 1.3 | 18 | 200 | 3.8 | 33 | 405 | 7.9 |
| PVC CIM | 96 | 934 | 13.7 | 569 | 6653 | 298.2 | 1041 | 6920 | 701.8 |
| PVC WC FR | 440 | 2149 | 27.7 | 566 | 2391 | 104.6 | 664 | 3754 | 283.9 |
| PVC LS | 54 | 465 | 9.3 | 591 | 1937 | 78.6 | 528 | 2285 | 148.6 |
| XLPE | 607 | 387 | 1.5 | 93 | 837 | 24 | 198 | 1427 | 133.8 |
| PVC WC SM | 645 | 4127 | 77.6 | 937 | 5880 | 473 | 1020 | 6512 | 872.6 |
| PVC EXT | 186 | 1227 | 24.3 | 3459 | 7027 | 459.6 | 1130 | 8917 | 1143.8 |
| PVC WC | 676 | 3608 | 100.4 | 939 | 5652 | 503.5 | 1046 | 6419 | 969.7 |
| ACR FR | 512 | 1409 | 65 | 839 | 6825 | 535 | 951 | 7786 | 1368.9 |
| PCARB B | 415 | 1033 | 2.7 | 814 | 3142 | 616 | 879 | 4784 | 1124.1 |
| PPO GLAS | 0 | 4145 | 1.8 | 1342 | 5550 | 853.8 | 1334 | 6160 | 1830.5 |
| PPO/PS | 0 | 7830 | 25.9 | 1731 | 8056 | 1143.3 | 1627 | 7830 | 1519 |
| ABS FV | 0 | 6650 | 22.3 | 1527 | 9692 | 1499.2 | 1243 | 8612 | 2561.8 |
| ABS FR | 0 | 9053 | 456.2 | 1772 | 9705 | 3740.9 | 1331 | 8222 | 3438.2 |
| FL PVC | 914 | 4912 | 481.6 | 1053 | 6075 | 914.5 | 1156 | 6809 | 1277 |
| DFIR | 114 | 318 | 30.4 | 65 | 287 | 42.9 | 96 | 307 | 59.7 |
| PS FR | 865 | 12090 | 290.1 | 1870 | 12799 | 3461.7 | 1445 | 10575 | 4490.1 |
| ACET | 74 | 249 | 13 | 10 | 198 | 17.5 | 25 | 477 | 103.3 |
| PU | 225 | 138 | 33.1 | 572 | 301 | 134.4 | 545 | 297 | 239.9 |
| PMMA | 67 | 2506 | 51.6 | 77 | 3646 | 429 | 97 | 3009 | 1012.1 |
| THM PU | 0 | 3970 | 216.3 | 566 | 3592 | 367.6 | 684 | 4037 | 746.1 |
| NYLON | 118 | 1966 | 2.7 | 217 | 3088 | 887.9 | 251 | 2130 | 4003.4 |
| ABS | 0 | 5520 | 793.3 | 885 | 4773 | 4457.4 | 666 | 3897 | 5035.5 |
| PS | 107 | 6653 | 44.6 | 1293 | 7738 | 6791.5 | 852 | 5906 | 9152.8 |
| EPDM | 0 | 7795 | 28.6 | 1014 | 7570 | 5785.4 | 1162 | 8586 | 10375.9 |
| PBT | 7 | 41362 | 1.4 | 466 | 3941 | 4711.2 | 660 | 4704 | 9656.5 |
| PET | 1 | 2308 | 2.8 | 286 | 2837 | 1207.9 | 503 | 4009 | 2355.9 |
| PE | 1982 | 892 | 29.9 | 299 | 1870 | 1822 | 275 | 4009 | 3975.8 |
| PP | 0 | 2700 | 536 | 475 | 2503 | 3416.5 | 429 | 2317 | 5509.4 |

# TAC: Mechanical

Total Mods for **Mechanical** in **Pending Review : 20**

Total Mods for report: 20

## Sub Code: Mechanical

### M12146

6

| | | | | | |
|---|---|---|---|---|---|
| **Date Submitted** | 02/14/2025 | **Section** | 908.1 | **Proponent** | Amanda Hickman |
| **Chapter** | 9 | **Affects HVHZ** | No | **Attachments** | No |
| **TAC Recommendation** | Pending Review | | | | |
| **Commission Action** | Pending Review | | | | |

**Comments**

**General Comments No** **Alternate Language No**

### Related Modifications

12145

### Summary of Modification

Updates code to permit A2L products.

### Rationale

As of January 1st, 2025, federal regulations prohibit the manufacturing of R-410A and other high-Global Warming potential (GWP) refrigerants. With the change to Low GWP Refrigerants, the Mechanical Code needs to be updated to address the use of Group A2L refrigerants in high probability (direct) systems. All of the commonly used Low GWP replacement refrigerants for direct systems fall into the category of Group A2L in the 2022 edition of ASHRAE 34. The safety requirements in ASHRAE 15 address the concerns regarding the use of a mildly flammable refrigerant. There are provisions for listing of equipment, installation of refrigerant detectors, and ventilation to mitigate any leak of refrigerant. By referencing ASHRAE 15 directly, the requirements become an enforceable part of the code. ASHRAE 15 requires an A2L appliance or equipment to be listed to UL/CSA 60335-2-40-2022 or UL/CSA 60335-2-89-2021 or newer editions. Failure to update the code could result in not having air conditioning and refrigeration products that are allowed to be used in Florida. Manufacturers are transitioning away from UL 1995 to UL 60335-2-40 and UL 60335-2-89 because UL 1995 will be sunsetting in the year 2024. The 4th edition of UL 60335-2-40 was published December 2022 and the 2nd edition of UL 60335-2-89 was published in October of 2021. Both of these standards have many new requirements for electrical and refrigerant safety. Nationally Recognized Testing Laboratories (or NRTLs) will use the latest version of the appropriate safety standard for certification testing. Reference to the latest editions of both standards included in this proposal are as issued by ICC in the 2024 IMC.

### Fiscal Impact Statement

**Impact to local entity relative to enforcement of code**

Will assist code enforcement regarding A2L products.

**Impact to building and property owners relative to cost of compliance with code**

These code changes will not increase the cost of construction, they only grant permission to use A2L products. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

**Impact to industry relative to the cost of compliance with code**

These code changes will not increase the cost of construction, they only grant permission to use A2L products. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

**Impact to small business relative to the cost of compliance with code**

These code changes will not increase the cost of construction, they only grant permission to use A2L products. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

## Requirements

**Has a reasonable and substantial connection with the health, safety, and welfare of the general public**

Updates code to ensure air conditioning products are permitted in the state of Florida.

**Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction**

Updates code to ensure air conditioning products are permitted in the state of Florida.

**Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities**

No. Only permits the use of A2L products.

**Does not degrade the effectiveness of the code**

No. Only permits the use of A2L products.

M12146Text Modification

# Chapter 9: SPECIFIC APPLIANCES, FIREPLACES AND SOLID FUEL-BURNING EQUIPMENT

**908.1 General. A cooling tower used in conjunction with an air-conditioning appliance shall be installed in accordance with the manufacturer's instructions. Factory-built cooling towers shall be listed in accordance with UL 1995 or UL/CSA 60335-2-40.**

**916.1 General. Pool and spa heaters shall be installed in accordance with the manufacturer's instructions. Oil-fired pool and spa heaters shall be tested in accordance with UL 726. Electric pool and spa heaters shall be tested in accordance with UL 1261. Pool and spa heat pump water heaters shall comply with UL 1995, UL/CSA 60335-2-40 or CSA C22.2 No. 236.**

**~~Exception: Portable residential spas and portable residential exercise spas shall comply with UL 1563 or CSA C22.2 No. 218.1.~~**

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# TAC: Mechanical

Total Mods for **Mechanical** in **Pending Review : 20**

Total Mods for report: 20

## Sub Code: Mechanical

### M11757

7

| | | | | | |
|---|---|---|---|---|---|
| **Date Submitted** | 01/15/2025 | **Section** | 1006 | **Proponent** | Mo Madani |
| **Chapter** | 10 | **Affects HVHZ** | No | **Attachments** | Yes |
| **TAC Recommendation** | Pending Review | | | | |
| **Commission Action** | Pending Review | | | | |

**Comments**

**General Comments No** **Alternate Language No**

#### Related Modifications

#### Summary of Modification

Clarifies use of piping to use hydronic piping section 1202

#### Rationale

See attached.

#### Fiscal Impact Statement

**Impact to local entity relative to enforcement of code**
Overlap
**Impact to building and property owners relative to cost of compliance with code**
Overlap
**Impact to industry relative to the cost of compliance with code**
Overlap
**Impact to small business relative to the cost of compliance with code**
Overlap

#### Requirements

**Has a reasonable and substantial connection with the health, safety, and welfare of the general public**
Overlap
**Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction**
Overlap
**Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities**
Overlap
**Does not degrade the effectiveness of the code**
Overlap

M11757Text Modification

See attached.

Mod11757_TextOfModification.pdf Page: 1

M11757Text Modification

2024 IMC

**1006.6 Safety and relief valve discharge.** Safety and relief valve discharge pipes shall be of rigid pipe that is *approved* for the temperature of the system. High-pressure-steam safety valves shall be vented to the outside of the structure. The discharge piping serving pressure relief valves, temperature relief valves and combinations of such valves shall:

1. Not be directly connected to the drainage system.
2. Discharge through an air break located in the same room as the *appliance*.
3. Not be smaller than the diameter of the outlet of the valve served and shall discharge full size to the air break.
4. Serve a single relief device and shall not connect to piping serving any other relief device or *equipment*.
5. Discharge to the floor, to the pan serving the boiler or storage tank, to a waste receptor or to the outdoors.
6. Discharge in a manner that does not cause personal injury or structural damage.
7. Discharge to a termination point that is readily observable by the building occupants.
8. Not be trapped.
9. Be installed so as to flow by gravity.
10. Not terminate more than 6 inches (152 mm) above the floor or waste receptor.
11. Not have a threaded connection at the end of such piping.
12. Not have valves or tee fittings.
13. Be constructed of those materials listed in Section 605.4 of the *International Plumbing Code* or materials tested, rated and approved for such use in accordance with ASME A112.4.1. Utilize piping material complying with Section 1202.

8th Edition (2023) FBC, Mechanical

**1006.6 Safety and relief valve discharge.** Safety and relief valve discharge pipes shall be of rigid pipe that is approved for the temperature of the system. The discharge pipe shall be the same diameter as the safety or relief valve outlet. Safety and relief valves shall not discharge so as to be a hazard, a potential cause of damage or otherwise a nuisance. Highpressure-steam safety valves shall be vented to the outside of the structure. Where a low-pressure safety valve or a relief valve discharges to the drainage system, the installation shall conform to the Florida Building Code, Plumbing.

(M11333 / M67-21 AS) Overlap

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Mod_11757_Text_1006.6 Mechanical.pdf

M11757Rationale

# M67-21

## Original Proposal

**IMC: 1006.6**
**Proponents:** Julius Ballanco, JB Engineering and Code Consulting, P.C., Self (JBENGINEER@aol.com)

## 2021 International Mechanical Code

**Revise as follows:**

**1006.6 Safety and relief valve discharge.** Safety and relief valve discharge pipes shall be of rigid pipe that is *approved* for the temperature of the system. High-pressure-steam safety valves shall be vented to the outside of the structure. The discharge piping serving pressure relief valves, temperature relief valves and combinations of such valves shall:

1. Not be directly connected to the drainage system.
2. Discharge through an air break located in the same room as the*appliance*.
3. Not be smaller than the diameter of the outlet of the valve served and shall discharge full size to the air break.
4. Serve a single relief device and shall not connect to piping serving any other relief device or*equipment*.
5. Discharge to the floor, to the pan serving the boiler or storage tank, to a waste receptor or to the outdoors.
6. Discharge in a manner that does not cause personal injury or structural damage.
7. Discharge to a termination point that is readily observable by the building occupants.
8. Not be trapped.
9. Be installed so as to flow by gravity.
10. Not terminate more than 6 inches (152 mm) above the floor or waste receptor.
11. Not have a threaded connection at the end of such piping.
12. Not have valves or tee fittings.
13. ~~Be constructed of those materials listed in Section 605.4 of the*International Plumbing Code* or materials tested, rated and approved for such use in accordance with ASME A112.4.1.~~ Utilize piping material complying with Section 1202.

**Reason:** It is inappropriate to reference the Plumbing Code potable water piping section to regulate the piping material for boiler relief valves. The appropriate reference is to the hydronic piping section in the Mechanical Code. One of the differences is the allowance of black steel pipe. Prior to the change made during the last cycle, black steel pipe was always permitted to be used for a relief valve discharge pipe. This material has been used on boilers for relief valve discharge for many years. No problem were presented during the last cycle whereby black steel pipe did not properly perform as a discharge pipe for a relief valve. There were only perceptions that galvanized steel pipe should be used rather than black steel pipe. Section 1202, referenced in the new text, is the hydronic piping material section.

**Cost Impact:** The code change proposal will decrease the cost of construction
Black steel pipe costs less than galvanized steel pipe. Hence, the allowance of black steel pipe will lower the cost of construction.

## Public Hearing Results

**Committee Action** **As Submitted**

**Committee Reason:** This proposal was passed as submitted because it will appropriately allow use of black pipe for hydronic

Mod_11757_Rationale_M11333 M67-21.pdf Page: 1

equipment. (Vote: 11-0)

| Final Hearing Results | |
|---|---|
| M67-21 | AS |

# TAC: Mechanical

Total Mods for **Mechanical** in **Pending Review : 20**

Total Mods for report: 20

## Sub Code: Mechanical

### M12147

8

| | | | | | |
|---|---|---|---|---|---|
| **Date Submitted** | 02/14/2025 | **Section** | 1101.2 | **Proponent** | Amanda Hickman |
| **Chapter** | 11 | **Affects HVHZ** | No | **Attachments** | Yes |
| **TAC Recommendation** | Pending Review | | | | |
| **Commission Action** | Pending Review | | | | |

**Comments**

**General Comments No** **Alternate Language No**

#### Related Modifications

12145, 12146, 12148

#### Summary of Modification

Updates code to permit A2L products

#### Rationale

As of January 1st, 2025, federal regulations prohibit the manufacturing of R-410A and other high-Global Warming potential (GWP) refrigerants. With the change to Low GWP Refrigerants, the Mechanical Code needs to be updated to address the use of Group A2L refrigerants in high probability (direct) systems. All of the commonly used Low GWP replacement refrigerants for direct systems fall into the category of Group A2L in the 2022 edition of ASHRAE 34. The safety requirements in ASHRAE 15 address the concerns regarding the use of a mildly flammable refrigerant. There are provisions for listing of equipment, installation of refrigerant detectors, and ventilation to mitigate any leak of refrigerant. By referencing ASHRAE 15 directly, the requirements become an enforceable part of the code. ASHRAE 15 requires an A2L appliance or equipment to be listed to UL/CSA 60335-2-40-2022 or UL/CSA 60335-2-89-2021 or newer editions. Failure to update the code could result in not having air conditioning and refrigeration products that are allowed to be used in Florida. Manufacturers are transitioning away from UL 1995 to UL 60335-2-40 and UL 60335-2-89 because UL 1995 will be sunsetting in the year 2024. The 4th edition of UL 60335-2-40 was published December 2022 and the 2nd edition of UL 60335-2-89 was published in October of 2021. Both of these standards have many new requirements for electrical and refrigerant safety. Nationally Recognized Testing Laboratories (or NRTLs) will use the latest version of the appropriate safety standard for certification testing. Reference to the latest editions of both standards included in this proposal are as issued by ICC in the 2024 IMC.

#### Fiscal Impact Statement

**Impact to local entity relative to enforcement of code**

Will assist code enforcement regarding A2L products.

**Impact to building and property owners relative to cost of compliance with code**

These code changes will not increase the cost of construction, they only grant permission to use A2L products. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

**Impact to industry relative to the cost of compliance with code**

These code changes will not increase the cost of construction, they only grant permission to use A2L products. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

**Impact to small business relative to the cost of compliance with code**

These code changes will not increase the cost of construction, they only grant permission to use A2L products. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

## Requirements

**Has a reasonable and substantial connection with the health, safety, and welfare of the general public**

Updates code to ensure air conditioning products are permitted in the state of Florida.

**Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction**

Updates code to ensure air conditioning products are permitted in the state of Florida.

**Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities**

No. Only permits the use of A2L products.

**Does not degrade the effectiveness of the code**

No. Only permits the use of A2L products.

M12147Text Modification

See attached PDF.

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Mod12147_TextOfModification.pdf

Modification # 12147

# CHAPTER 11: REFRIGERATION

**1101.2 Factory-Built Equipment and Appliances.** Listed and labeled self-contained, factory-built equipment and appliances shall be tested in accordance with ~~UL 207, 412, 471 or 1995., UL/CSA 60335-2-40 or UL 60335-2-89~~ the applicable standards specified in Table 1101.2. Such equipment and appliances are deemed to meet the design, manufacture and factory test requirements of this code if installed in accordance with their listing and the manufacturer's instructions.

**TABLE 1101.2**
**FACTORY-BUILT EQUIPMENT AND APPLIANCES**

| EQUIPMENT | STANDARDS |
|---|---|
| Air-conditioning equipment | UL 1995 or UL/CSA 60335-2-40 |
| Packaged terminal air conditioners and heat pumps | UL 484 or UL/CSA 60335-2-40 |
| Split-system air conditioners and heat pumps | UL 1995 or UL/CSA 60335-2-40 |
| Dehumidifiers | UL 474 or UL/CSA 60335-2-40 |
| Unit coolers | UL 412 or UL/CSA 60335-2-89 |
| Commercial refrigerators, freezers, beverage coolers and walk-in coolers | UL 471 or UL/CSA 60335-2-89 |
| Refrigerating units and walk-in coolers | UL 427 or UL 60335-2-89 |
| Refrigerant-containing components and accessories | UL 207 |

**1101.10 Locking access port caps.** Refrigerant circuit access ports located outdoors shall be fitted with locking-type tamper-resistant caps or shall be otherwise secured to prevent unauthorized access.
**Exception:** This section shall not apply to refrigerant circuit access ports on equipment installed in controlled areas such as on roofs with locked access hatches or doors.

**1102.3 Access port protection.** Refrigerant access ports shall be protected in accordance with Section 1101.10 whenever refrigerant is added to or recovered from refrigeration or air-conditioning systems.

**DELETE TABLE 1103.1 in its entirety and replace as follows:**

**TABLE 1103.1**
**REFRIGERANT CLASSIFICATION, AMOUNT AND OEL**

| CHEMICAL REFRIGERANT | FORMULA | CHEMICAL NAME OF BLEND | REFRIGERANT SAFETY GROUP CLASSIFICATION | AMOUNT OF REFRIGERANT PER OCCUPIED SPACE | | | | | | | [F] DEGREES OF HAZARD[a] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | RCL | | | LFL | | | OEL | |
| | | | | ~~Pounds per 1,000 cubic feet~~ lb/MCf | ppm | g/m3 | lb/MCf | ppm | g/m3 | ~~OEL e~~ ppm | |
| R-11~~[d]~~[c] | $CCl_3F$ | trichlorofluoromethane | A1 | 0.39 | 1,100 | ~~6.2~~ 6.1 | | | | ~~C~~1,000 | 2-0-0[b] |
| R-12~~[d]~~[c] | $CCl_2F_2$ | dichlorodifluoromethane | A1 | 5.6 | 18,000 | 90 | | | | 1,000 | 2-0-0[b] |
| R-13~~[d]~~[c] | $CClF_3$ | chlorotrifluoromethane | A1 | — | — | — | | | | 1,000 | 2-0-0[b] |
| R-13B1~~[d]~~[c] | $CBrF_3$ | bromotrifluoromethane | A1 | — | — | — | | | | 1,000 | 2-0-0[b] |
| R-13I1 | $CF_3I$ | trifluoroiodomethane | A1 | 1.0 | 2,000 | 16 | | | | 500 | |
| R-14 | $CF_4$ | tetrafluoromethane (carbon tetrafluoride) | A1 | 25 | 110,000 | 400 | | | | 1,000 | 2-0-0[b] |
| R-22 | $CHClF_2$ | chlorodifluoromethane | A1 | 13 | 59,000 | 210 | | | | 1,000 | 2-0-0[b] |
| R-23 | $CHF_3$ | trifluoromethane (fluoroform) | A1 | 7.3 | 41,000 | 120 | | | | 1,000 | 2-0-0[b] |
| R-30 | $CH_2Cl_2$ | dichloromethane (methylene chloride) | B1 | — | — | — | | | | — | — |
| R-31 | $CH_2ClF$ | Chlorofluoromethane | — | — | — | — | | | | — | — |
| R-32 | $CH_2F_2$ | difluoromethane (methylene fluoride) | ~~A2[c]~~ A2L | 4.8 | 36,000 | 77 | 19.1 | 144,000 | 306 | 1,000 | 1-4-0 |
| R-40 | $CH_3Cl$ | chloromethane (methyl chloride) | B2 | — | — | — | | | | — | — |
| R-41 | $CH_3F$ | Fluoromethane (methyl fluoride) | — | — | — | — | | | | — | |
| R-50 | $CH_4$ | methane | A3 | — | — | — | | 50,000 | | 1,000 | — |
| R-113~~[d]~~[c] | $CCl_2FCClF_2$ | 1,1,2-trichloro-1,2,2-trifluoroethane | A1 | 1.2 | 2,600 | 20 | | | | 1,000 | 2-0-0[b] |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| R-114~~d~~ c | $CClF_2CClF_2$ | 1,2-dichloro-1,1,2,2-tetrafluoroethane | A1 | 8.7 | 20,000 | 140 | | | | 1,000 | 2-0-0b |
| R-115 | $CClF_2CF_3$ | chloropentafluoroethane | A1 | 47 | 120,000 | 760 | | | | 1,000 | — |
| R-116 | $CF_3CF_3$ | hexafluoroethane | A1 | 34 | 97,000 | 550 | | | | 1,000 | 1-0-0 |
| R-123 | $CHCl_2CF_3$ | 2,2-dichloro-1,1,1-trifluoroethane | B1 | 3.5 | 9,100 | 57 | | | | 50 | 2-0-0b |
| R-124 | $CHClFCF_3$ | 2-chloro-1,1,1,2-tetrafluoroethane | A1 | 3.5 | 10,000 | 56 | | | | 1,000 | 2-0-0b |
| R-125 | $CHF_2CF_3$ | pentafluoroethane | A1 | 23 | 75,000 | 370 | | | | 1,000 | 2-0-0b |
| R-134a | $CH_2FCF_3$ | 1,1,1,2-tetrafluoroethane | A1 | 13 | 50,000 | 210 | | | | 1,000 | 2-0-0b |
| R-141b | $CH_3CCl_2F$ | 1,1-dichloro-1-fluoroethane | — | 0.78 | 2,600 | 12 | 17.8 | 60,000 | 287 | 500 | 2-1-0 |
| R-142b | $CH_3CClF_2$ | 1-chloro-1, 1-difluoroethane | A2 | 5.1 | 20,000 | ~~83~~ 82 | 20.4 | 80,000 | 329 | 1,000 | 2-4-0 |
| R-143a | $CH_3CF_3$ | 1,1,1-trifluoroethane | ~~A2c~~ A2L | ~~4.5~~ 4.4 | 21,000 | 70 | 17.5 | 82,000 | 282 | 1,000 | 2-0-0b |
| R-152a | $CH_3CHF_2$ | 1,1-difluoroethane | A2 | 2.0 | 12,000 | 32 | 8.1 | 48,000 | 130 | 1,000 | 1-4-0 |
| R-170 | $CH_3CH_3$ | ethane | A3 | 0.54 | 7,000 | ~~8.7~~ 8.6 | 2.4 | 31,000 | 38 | 1,000 | 2-4-0 |
| R-E170 | $CH_3OCH_3$ | Methoxymethane (dimethyl ether) | A3 | 1.0 | 8,500 | 16 | 4.0 | 34,000 | 64 | 1,000 | — |
| R-218 | $CF_3CF_2CF_3$ | octafluoropropane | A1 | 43 | 90,000 | 690 | | | | 1,000 | 2-0-0b |
| R-227ea | $CF_3CHFCF_3$ | 1,1,1,2,3,3,3-heptafluoropropane | A1 | 36 | 84,000 | 580 | | | | 1,000 | — |
| R-236fa | $CF_3CH_2CF_3$ | 1,1,1,3,3,3-hexafluoropropane | A1 | 21 | 55,000 | 340 | | | | 1,000 | 2-0-0b |
| R-245fa | $CHF_2CH_2CF_3$ | 1,1,1,3,3-pentafluoropropane | B1 | 12 | 34,000 | 190 | | | | 300 | 2-0-0b |
| R-290 | $CH_3CH_2CH_3$ | propane | A3 | ~~0.56~~ 0.59 | 5,300 | 9.5 | 2.4 | 21,000 | 38 | 1,000 | 2-4-0 |
| R-C318 | $-(CF_2)_4-$ | octafluorocyclobutane | A1 | 41 | 80,000 | ~~660~~ 650 | | | | 1,000 | — |
| R-400~~d~~ c | zeotrope | R-12/114 (50.0/50.0) | A1 | 10 | 28,000 | 160 | | | | 1,000 | 2-0-0b |
| R-400~~d~~ c | zeotrope | R-12/114 (60.0/40.0) | A1 | 11 | 30,000 | 170 | | | | 1,000 | — |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| R-401A | zeotrope | R-22/152a/124 (53.0/13.0/34.0) | A1 | 6.6 | 27,000 | 110 | | | | 1,000 | 2-0-0[b] |
| R-401B | zeotrope | R-22/152a/124 (61.0/11.0/28.0) | A1 | 7.2 | 30,000 | 120 | | | | 1,000 | 2-0-0[b] |
| R-401C | zeotrope | R-22/152a/124 (33.0/15.0/52.0) | A1 | 5.2 | 20,000 | 84 | | | | 1,000 | 2-0-0[b] |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| R-402A | zeotrope | R-125/290/22 (60.0/2.0/38.0) | A1 | 17 | 66,000 | 270 | | | | 1,000 | 2-0-0[b] |
| R-402B | zeotrope | R-125/290/22 (38.0/2.0/60.0) | A1 | 15 | 63,000 | 240 | | | | 1,000 | 2-0-0[b] |
| R-403A | zeotrope | R-290/22/218 (5.0/75.0/20.0) | A2 | 7.6 | 33,000 | 120 | | | | 1,000 | 2-0-0[b] |
| R-403B | zeotrope | R-290/22/218 (5.0/56.0/39.0) | A1 | 18 | ~~70,000~~ 68,000 | 290 | | | | 1,000 | 2-0-0[b] |
| R-404A | zeotrope | R-125/143a/134a (44.0/52.0/4.0) | A1 | 31 | 130,000 | 500 | | | | 1,000 | 2-0-0[b] |
| R-405A | zeotrope | R-22/152a/142b/C318 (45.0/7.0/5.5/2.5) | — | 16 | 57,000 | 260 | | | | 1,000 | — |
| R-406A | zeotrope | R-22/600a/142b (55.0/4.0/41.0) | A2 | 4.7 | 21,000 | ~~25~~ 75 | 18.8 | 82,000 | 301.9 | 1,000 | — |
| R-407A | zeotrope | R-32/125/134a (20.0/40.0/40.0) | A1 | 19 | 83,000 | 300 | | | | 1,000 | 2-0-0[b] |
| R-407B | zeotrope | R-32/125/134a (10.0/70.0/20.0) | A1 | 21 | 79,000 | 330 | | | | 1,000 | 2-0-0[b] |
| R-407C | zeotrope | R-32/125/134a (23.0/25.0/52.0) | A1 | 18 | 81,000 | 290 | | | | 1,000 | 2-0-0[b] |
| R-407D | zeotrope | R-32/125/134a (15.0/15.0/70.0) | A1 | 16 | 68,000 | 250 | | | | 1,000 | 2-0-0[b] |
| R-407E | zeotrope | R-32/125/134a (25.0/15.0/60.0) | A1 | 17 | 80,000 | 280 | | | | 1,000 | 2-0-0[b] |
| R-407F | zeotrope | R-32/125/134a (30.0/30.0/40.0) | A1 | 20 | 95,000 | 320 | | | | 1,000 | — |
| R-407G | zeotrope | R-32/125/134a (2.5/2.5/95.0) | A1 | 13 | 52,000 | 210 | | | | 1,000 | — |
| R-407H | zeotrope | R-32/125/134a (32.5/15.0/52.5) | A1 | 19 | 92,000 | 300 | | | | 1,000 | — |
| R-407I | zeotrope | R-32/125/124a (19.5/8.5/72.0) | A1 | 16 | 71,100 | 250 | | | | 1,000 | |
| R-408A | zeotrope | R-125/143a/22 (7.0/46.0/47.0) | A1 | 21 | ~~95,000~~ 94,000 | ~~340~~ 330 | | | | 1,000 | 2-0-0[b] |
| R-409A | zeotrope | R-22/124/142b (60.0/25.0/15.0) | A1 | 7.1 | 29,000 | 110 | | | | 1,000 | 2-0- |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | 0[b] |
| R-409B | zeotrope | R-22/124/142b (65.0/25.0/10.0) | A1 | 7.3 | 30,000 | 120 | | | | 1,000 | 2-0-0[b] |
| R-410A | zeotrope | R-32/125 (50.0/50.0) | A1 | 26 | 140,000 | 420 | | | | 1,000 | 2-0-0[b] |
| R-410B | zeotrope | R-32/125 (45.0/55.0) | A1 | 27 | 140,000 | 430 | | | | 1,000 | 2-0-0[b] |
| R-411A | zeotrope | R-127/22/152a (1.5/87.5/11.0) | A2 | 2.9 | 14,000 | 46 | 11.6 | 55,000 | 185.6 | ~~990~~ 970 | — |
| R-411B | zeotrope | R-1270/22/152a (3.0/94.0/3.0) | A2 | 2.8 | 13,000 | 45 | 14.8 | 70,000 | 238.3 | ~~980~~ 940 | — |
| R-412A | zeotrope | R-22/218/142b (70.0/5.0/25.0) | A2 | 5.1 | 22,000 | 82 | 20.5 | 87,000 | 328.6 | 1,000 | — |
| R-413A | zeotrope | R-218/134a/600a (9.0/88.0/3.0) | A2 | 5.8 | 22,000 | ~~94~~ 93 | 23.4 | 88,000 | 374.9 | 1,000 | — |
| R-414A | zeotrope | R-22/124/600a/142b (51.0/28.5/4.0/16.5) | A1 | 6.4 | 26,000 | 100 | | | | 1,000 | — |
| R-414B | zeotrope | R-22/124/600a/142b (50.0/39.0/1.5/9.5) | A1 | 6.0 | 23,000 | ~~95~~ 96 | | | | 1,000 | — |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| R-415A | zeotrope | R-22/152a (82.0/18.0) | A2 | 2.9 | 14,000 | 47 | 11.7 | 56,000 | 187.9 | 1,000 | — |
| R-415B | zeotrope | R-22/152a (25.0/75.0) | A2 | 2.1 | 12,000 | 34 | 8.4 | 47,000 | 135.1 | 1,000 | — |
| R-416A | zeotrope | R-134a/124/600 (59.0/39.5/1.5) | A1 | 3.9 | 14,000 | 62 | | | | 1,000 | 2-0-0b |
| R-417A | zeotrope | R-125/134a/600 (46.6/50.0/3.4) | A1 | 3.5 | 13,000 | ~~56~~ 55 | | | | 1,000 | 2-0-0b |
| R-417B | zeotrope | R-125/134a/600 (79.0/18.3/2.7) | A1 | 4.3 | 15,000 | ~~70~~ 69 | | | | 1,000 | — |
| R-417C | zeotrope | R-125/134a/600 (19.5/78.8/1.7) | A1 | 5.4 | 21,000 | 87 | | | | 1,000 | — |
| R-418A | zeotrope | R-290/22/152a (1.5/96.0/2.5) | A2 | 4.8 | 22,000 | 77 | 19.2 | 89,000 | 308.4 | 1,000 | — |
| R-419A | zeotrope | R-125/134a/E170 (77.0/19.0/4.0) | A2 | 4.2 | 15,000 | 67 | 16.7 | 60,000 | 268.6 | 1,000 | — |
| R-419B | zeotrope | R-125/134a/E170 (48.5/48.0/3.5) | A2 | 4.6 | 17,000 | 74 | 18.5 | 69,000 | 297.3 | 1,000 | — |
| R-420A | zeotrope | R-134a/142b (88.0/12.0) | A1 | 12 | ~~45,000~~ 44,000 | ~~190~~ 180 | | | | 1,000 | 2-0-0b |
| R-421A | zeotrope | R-125/134a (58.0/42.0) | A1 | 17 | 61,000 | 280 | | | | 1,000 | 2-0-0b |
| R-421B | zeotrope | R-125/134a (85.0/15.0) | A1 | 21 | 69,000 | 330 | | | | 1,000 | 2-0-0b |
| R-422A | zeotrope | R-125/134a/600a (85.1/11.5/3.4) | A1 | 18 | 63,000 | 290 | | | | 1,000 | 2-0-0b |
| R-422B | zeotrope | R-125/134a/600a (55.0/42.0/3.0) | A1 | 16 | 56,000 | 250 | | | | 1,000 | 2-0-0b |
| R-422C | zeotrope | R-125/134a/600a (82.0/15.0/3.0) | A1 | 18 | 62,000 | 290 | | | | 1,000 | 2-0-0b |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R-422D | zeotrope | R-125/134a/600a (65.1/31.5/3.4) | A1 | 16 | 58,000 | 260 | | | | | 1,000 | 2-0-0b |
| R-422E | zeotrope | R-125/134a/600a (58.0/39.3/2.7) | A1 | 16 | 57,000 | 260 | | | | | 1,000 | — |
| R-423A | zeotrope | R-134a/227ea (52.5/47.5) | A1 | 19 | 59,000 | ~~310~~ 300 | | | | | 1,000 | 2-0-0c |
| R-424A | zeotrope | R-125/134a/600a/600/601a (50.5/47.0/0.9/1.0/0.6) | A1 | 6.2 | 23,000 | 100 | | | | | ~~970~~ 990 | 2-0-0b |
| R-425A | zoetrope | R-32/134a/227ea (18.5/69.5/12.0) | A1 | 16 | 72,000 | 260 | | | | | 1,000 | 2-0-0b |
| R-426A | zeotrope | R-125/134a/600a/601a (5.1/93.0/1.3/0.6) | A1 | 5.2 | 20,000 | 83 | | | | | 990 | — |
| R-427A | zeotrope | R-32/125/143a/134a (15.0/25.0/10.0/50.0) | A1 | 18 | 79,000 | 290 | | | | | 1,000 | 2-1-0 |
| R-428A | zeotrope | R-125/143a/290/600a (77.5/20.0/0.6/1.9) | A1 | 23 | ~~83,000~~ 84,000 | 370 | | | | | 1,000 | — |
| R-429A | zeotrope | R-E170/152a/600a (60.0/10.0/30.0) | A3 | 0.81 | 6,300 | 13 | 3.2 | 25,000 | 83.8 | | 1,000 | — |
| R-430A | zeotrope | R-152a/600a (76.0/24.0) | A3 | 1.3 | 8,000 | 21 | 5.2 | 32,000 | 44.0 | | 1,000 | — |
| R-431A | zeotrope | R-290/152a (71.0/29.0) | A3 | ~~0.69~~ 0.68 | 5,500 | 11 | 2.7 | 22,000 | 38.6 | | 1,000 | — |
| R-432A | zeotrope | R-1270/E170 (80.0/20.0) | A3 | 0.13 | 1,200 | 2.1 | 2.4 | 22,000 | 39.2 | | ~~700~~ 550 | — |
| R-433A | zeotrope | R-1270/290 (30.0/70.0) | A3 | 0.34 | 3,100 | 5.5 | 2.4 | 20,000 | 32.4 | | ~~880~~ 760 | — |
| R-433B | zeotrope | R-1270/290 (5.0-95.0) | A3 | ~~0.51~~ 0.39 | ~~4,500~~ 3,500 | ~~8.1~~ 6.3 | 2.0 | 18,000 | 32.1 | | 950 | — |
| R-433C | zeotrope | R-1270/290 (25.0-75.0) | A3 | 0.41 | ~~3,600~~ 3,700 | ~~6.6~~ 6.5 | 2.0 | 18,000 | 83.8 | | 790 | — |
| R-434A | zeotrope | R-125/143a/600a (63.2/18.0/16.0/2.8) | A1 | 20 | 73,000 | 320 | | | | | 1,000 | — |
| R-435A | zeotrope | R-E170/152a (80.0/20.0) | A3 | 1.1 | 8,500 | 17 | 4.3 | 34,000 | 68.2 | | 1,000 | — |
| R-436A | zeotrope | R-290/600a (56.0/44.0) | A3 | 0.50 | 4,000 | 8.1 | 2.0 | 16,000 | 32.3 | | 1,000 | — |

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| R-436B | zeotrope | R-290/600a (52.0/48.0) | A3 | 0.51 | 4,000 | ~~8.1~~ 8.2 | 2.0 | 16,000 | 32.7 | 1,000 | — |
| R-436C | zeotrope | R-290/600a (95.0/5.0) | A3 | 0.57 | 5,000 | 9.1 | 2.3 | 20,000 | 36.5 | 1,000 | |
| R-437A | zeotrope | R-125/134a/600/601 (19.5/78.5/1.4/0.6) | A1 | ~~5.0~~ 5.1 | 19,000 | 82 | | | | 990 | — |
| R-438A | zeotrope | R-32/125/134a/600/601a (8.5/45.0/44.2/1.7/0.6) | A1 | 4.9 | 20,000 | 79 | | | | 990 | — |
| R-439A | zeotrope | R-32/125/600a (50.0/47.0/3.0) | A2 | 4.7 | 26,000 | 76 | 18.9 | 104,000 | 303.3 | ~~990~~ 1,000 | — |
| R-440A | zeotrope | R-290/134a/152a (0.6/1.6/97.8) | A2 | 1.9 | 12,000 | 31 | 7.8 | 46,000 | 124.7 | 1,000 | — |
| R-441A | zeotrope | R-170/290/600a/600 (3.1/54.8/6.0/36.1) | A3 | 0.39 | 3,200 | 6.3 | 2.0 | 16,000 | 31.7 | 1,000 | — |
| R-442A | zeotrope | R-32/125/134a/152a/227ea (31.0/31.0/30.0/3.0/5.0) | A1 | 21 | 100,000 | 330 | | | | 1,000 | — |
| R-443A | zeotrope | R-1270/290/600a (55.0/40.0/5.0) | A3 | 0.19 | 1,700 | 3.1 | 2.2 | 20,000 | 35.6 | ~~580~~ 640 | — |
| R-444A | zeotrope | R-32/152a/1234ze(E) (12.0/5.0/83.0) | ~~A2[c]~~ A2L | 5.1 | 21,000 | 81 | 19.9 | 82,000 | 324.8 | 850 | — |
| R-444B | zeotrope | R-32/152a/1234ze(E) (41.5/10.0/48.5) | ~~A2[c]~~ A2L | 4.3 | 23,000 | 69 | 17.3 | 93,000 | 277.3 | ~~890~~ 930 | — |
| R-445A | zeotrope | R-744/134a/1234ze(E) (6.0/9.0/85.0) | ~~A2[c]~~ A2L | 4.2 | 16,000 | 67 | 2.7 | 63,000 | 347.4 | 930 | — |
| R-446A | zeotrope | R-32/1234ze(E)/600 (68.0/29.0/3.0) | ~~A2[c]~~ A2L | 2.5 | 16,000 | 39 | 13.5 | 62,000 | 217.4 | 960 | — |
| R-447A | zeotrope | R-32/125/1234ze(E) (68.0/3.5/28.5) | ~~A2[c]~~ A2L | 2.6 | 16,000 | 42 | 18.9 | 65,000 | 303.5 | ~~900~~ 960 | — |
| R-447B | zeotrope | R-32/125/1234ze(E) (68.0/8.0/24.0) | ~~A2[c]~~ A2L | ~~232.~~ 6 | ~~30,000~~ 16,000 | ~~360~~ 42 | 20.6 | 121,000 | 312.7 | 970 | |
| R-448A | zeotrope | R-32/125/1234yf/134a/1234ze(E) (26.0/26.0/20.0/21.0/7.0) | A1 | 24 | 110,000 | 390 | | | | ~~890~~ 860 | — |
| R-449A | zeotrope | R-32/125/1234yf/134a (24.3/24.7/25.3/25.7) | A1 | 23 | 100,000 | 370 | | | | ~~830~~ 840 | — |
| R-449B | zeotrope | R-32/125/1234yf/134a (25.2/24.3/23.2/27.3) | A1 | 23 | 100,000 | 370 | | | | 850 | |
| R-449C | zeotrope | R-32/125/1234yf/134a (20.0/20.0/31.0/29.0) | A1 | 23 | 98,000 | 360 | | | | 800 | |
| R-450A | zeotrope | R-134a/1234ze(E) (42.0/58.0) | A1 | 20 | 72,000 | 320 | | | | 880 | — |
| R-451A | zeotrope | R-1234yf/134a (89.8/10.2) | ~~A2[c]~~ A2L | ~~5.3~~ 5.0 | 18,000 | 81 | 20.3 | 70,000 | 326.6 | ~~520~~ 530 | — |
| R-451B | zeotrope | R-1234yf/134a (88.8/11.2) | ~~A2[c]~~ A2L | ~~5.3~~ 5.0 | 18,000 | 81 | 20.3 | 70,000 | 326.6 | 530 | — |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| R-452A | zeotrope | R-32/125/1234yf (11.0/59.0/30.0) | A1 | 27 | ~~10,000~~ 100,000 | 440 | | | | ~~780~~ 790 | — |
| R-452B | zeotrope | R-32/125/1234yf (67.0/7.0/26.0) | ~~A2$^{c}$~~ A2L | ~~23~~ 4.8 | 30,000 | ~~360~~ 77 | 19.3 | 119,000 | 310.5 | 870 | — |
| R-452C | zeotrope | R-32/125/1234yf (12.5/61.0/26.5) | A1 | 27 | 100,000 | 430 | | | | ~~800~~ 810 | |
| R-453A | zeotrope | R-32/125/134a/227ea/600/601a (20.0/20.0/53.8/5.0/0.6/0.6) | A1 | 7.8 | 34,000 | 120 | | | | 1,000 | |
| R-454A | zeotrope | R-32/1234yf (35.0/65.0) | ~~A2$^{c}$~~ A2L | ~~28~~ 3.2 | 16,000 | ~~450~~ 52 | 18.3 | 63,000 | 293.9 | 690 | |
| R-454B | zeotrope | R-32/1234yf (68.9/31.1) | ~~A2$^{c}$~~ A2L | ~~22~~ 3.1 | 19,000 | ~~360~~ 49 | 22.0 | 77,000 | 352.6 | 850 | |
| R-454C | zeotrope | R-32/1234yf (21.5/78.5) | ~~A2$^{c}$~~ A2L | ~~29~~ 4.4 | 19,000 | ~~460~~ 71 | 18.0 | 62,000 | 289.5 | 620 | |
| R-455A | zeotrope | R-744/32/1234yf (3.0/21.5/75.5) | ~~A2$^{c}$~~ A2L | ~~23~~ 4.9 | ~~30,000~~ 22,000 | ~~380~~ 79 | 26.9 | 118,000 | 432.1 | 650 | |
| R-456A | zeotrope | R-32/134a/1234ze(E) (6.0/45.0/49.0) | A1 | 20 | 77,000 | 320 | | | | 900 | |
| R-457A | zeotrope | R-32/1234yf/152a (18.0/70.0/12.0) | ~~A2$^{c}$~~ A2L | ~~25~~ 3.4 | 15,000 | ~~400~~ 54 | 13.5 | 60,000 | 216.3 | 650 | |
| R-457B | zeotrope | R-32/1234yf/152a (35.0/55.0/10.0) | A2L | 3.7 | 19,000 | 59 | 14.9 | 76,000 | 239 | 730 | |
| R-458A | zeotrope | R-32/125/134a/227ea/236fa (20.5/4.0/61.4/13.5/0.6) | A1 | 18 | 76,000 | 280 | | | | 1,000 | |
| R-459A | zeotrope | R-32/1234yf/1234ze(E) (68.0/26.0/6.0) | ~~A2$^{c}$~~ A2L | ~~23~~ 4.3 | 27,000 | ~~360~~ 69 | 17.4 | 107,000 | 278.7 | 870 | |
| R-459B | zeotrope | R-32/1234yf/1234ze(E) (21.0/69.0/10.0) | ~~A2$^{c}$~~ A2L | 30 | ~~16,000~~ 25,000 | ~~470~~ 92 | 23.3 | 99,000 | 373.5 | 640 | |
| R-460A | zeotrope | R-32/125/134a/1234ze(E) (12.0/52.0/14.0/22.0) | A1 | 24 | 92,000 | 380 | | | | ~~650~~ 950 | |
| R-460B | zeotrope | R-32/125/134a/1234ze(E) (28.0/25.0/20.0/27.0) | A1 | 25 | 120,000 | 400 | | | | 950 | |
| R-460C | zeotrope | R-32/125/134a/1234ze(E) (2.5/2.5/46.0/49.0) | A1 | 20 | 73,000 | 310 | | | | 900 | |
| R-461A | zeotrope | R-32/125/134a/1234ze(E) (2.5/2.5/46.0/49.0) | A1 | 17 | 61,000 | 270 | | | | 1,000 | |
| R-462A | zeotrope | R-125/143a/134a/227ea/600a (55.0/5.0/32.0/5.0/3.0) | A2 | 3.9 | 16,000 | 62 | 16.6 | 105,000 | 265.8 | 1,000 | |
| R-463A | zeotrope | R-744/32/125/1234yf/134a (6.0/36.0/30.0/14.0/14.0) | A1 | 19 | 98,000 | 300 | | | | 990 | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R-464A | zeotrope | R-32/125/1234ze(E)/227ea (27.0/27.0/40.0/6.0) | A1 | 27 | 120,000 | 430 | | | | | 930 | |
| R-465A | zeotrope | R-32/290/1234yf (21.0/7.9/71.1) | A2 | 2.5 | 12,000 | 40 | 10.0 | 98,000 | 160.9 | | 660 | |
| R-466A | zeotrope | R-32/125/13I1 (49.0/11.5/39.5) | A1 | 6.2 | 30,000 | 99 | | | | | 860 | |
| R-467A | zeotrope | R-32/125/134a/600a (22.0/5.0/72.4/0.6) | A2L | 6.7 | 31,000 | 110 | | | | | 1,000 | |
| R-468A | zeotrope | R-1132a/32/1234yf (3.5/21.5/75.0) | A2L | 4.1 | 18,000 | 66 | | | | | 610 | |
| R-469A | zeotrope | R-744/R-32/R-125 (35.0/32.5/32.5) | A1 | 8 | 53,000 | 130 | | | | | 1,600 | |
| R-470A | zeotrope | R-744/32/125/134a/1234ze(E)/227ea (10.0/17.0/19.0/7.0/44.0/3.0) | A1 | 17 | 77,000 | 270 | | | | | 1,100 | |
| R-470B | zeotrope | R-744/32/125/134a/1234ze(E)/227ea (10.0/11.5/11.5/3.0/57.0/7.0) | A1 | 16 | 72,000 | 260 | | | | | 1,100 | |
| R-471A | zeotrope | R-1234ze(E)/227ea/1336mzz(E) (78.7/4.3/17.0) | A1 | 9.7 | 31,000 | 160 | | | | | 710 | |
| R-472A | zeotrope | R-744/32/134a (69.0/12.0/19.0) | A1 | 4.5 | 35,000 | 72 | | | | | 2,700 | |
| R-500~~[e]~~ [d] | azeotrope | R-744/32/125/1234yf/134a (6.0/36.0/30.0/14.0/14.0) | A1 | ~~7.6~~ 7.4 | ~~30,000~~ 29,000 | 120 | | | | | 1,000 | 2-0-0[b] |
| R-501~~[d]~~ [c] | azeotrope | R-22/12 (75.0/25.0) | A1 | 13 | 54,000 | 210 | | | | | 1,000 | — |
| R-502~~[e]~~ [d] | azeotrope | R-22/115 (48.8/51.2) | A1 | 21 | 73,000 | 330 | | | | | 1,000 | 2-0-0[b] |
| R-503~~[e]~~ [d] | azeotrope | R-23/13 (40.1/59.9) | — | — | — | — | | | | | 1,000 | 2-0-0[b] |
| R-504~~[d]~~ [c] | azeotrope | R-32/115 (48.2/51.8) | — | 28 | 140,000 | 450 | | | | | 1,000 | — |
| R-507A | azeotrope | R-125/143a (50.0/50.0) | A1 | 32 | 130,000 | ~~520~~ 510 | | | | | 1,000 | 2-0-0[b] |
| R-508A | azeotrope | R-23/116 (39.0/61.0) | A1 | 14 | 55,000 | 220 | | | | | 1,000 | 2-0-0[b] |
| R-508B | azeotrope | R-23/116 (46.0/54.0) | A1 | 13 | 52,000 | 200 | | | | | 1,000 | 2-0-0[b] |
| R-509A | azeotrope | R-22/218 (44.0/56.0) | A1 | 24 | 75,000 | ~~390~~ 38 | | | | | 1,000 | 2-0-0[b] |

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| | | | | | | 0 | | | | | | |
| R-510A | azeotrope | R-E170/600a (88.0/12.0) | A3 | 0.87 | 7,300 | 14 | 3.5 | 29,000 | 56.1 | 1,000 | — |
| R-511A | azeotrope | R-290/E170 (95.0/5.0) | A3 | 0.59 | 5,300 | 9.5 | 2.4 | 21,000 | 38.0 | 1,000 | — |
| R-512A | azeotrope | R-134a/152a (5.0/95.0) | A2 | 1.9 | 11,000 | 31 | 7.7 | 45,000 | 123.9 | 1,000 | — |
| R-513A | azeotrope | R-1234yf/134a (56.0/44.0) | A1 | 20 | 72,000 | 320 | | | | 650 | — |
| R-513B | azeotrope | R-1234yf/134a (58.5/41.5) | A1 | 21 | 74,000 | 330 | | | | 640 | |
| R-514A | azeotrope | R-1336mzz(Z)/1130 (E) (74.7/25.3) | B1 | 0.86 | 2,400 | 14 | | | | 320 | |
| R-515A | azeotrope | R-1234ze(E)/227ea (88.0/12.0) | A1 | 19 | ~~62,000~~ 63,000 | 300 | | | | 810 | |
| R-515B | azeotrope | R-1234ze(E)/227ea (91.1/8.9) | A1 | 18 | 61,000 | 290 | | | | 810 | |
| R-516A | azeotrope | R-1234yf/134a/152a (77.5/8.5/14.0) | A2 | ~~7.0~~ 3.2 | ~~27,000~~ 13,000 | ~~110~~ 52 | 13.1 | 50,000 | 210.1 | 590 | |
| R-600 | $CH_3CH_2CH_2CH_3$ | butane | A3 | 0.15 | 1,000 | 2.4 | 3.0 | 20,000 | 48 | 1,000 | 1-4-0 |
| R-600a | $CH(CH_3)_2CH_3$ | 2-methylpropane (isobutane) | A3 | 0.59 | 4,000 | ~~9.6~~ 9.5 | 2.4 | 16,000 | 38 | 1,000 | 2-4-0 |
| R-601 | $CH_3CH_2CH_2CH_2CH_3$ | pentane | A3 | 0.18 | 1,000 | 2.9 | 2.2 | 12,000 | 35 | 600 | — |
| R-601a | $(CH_3)_2CHCH_2CH_3$ | 2-methylbutane (isopentane) | A3 | 0.18 | 1,000 | 2.9 | 2.4 | 13,000 | 38 | 600 | — |
| R-610 | ethoxyethane (ethyl ether) | $CH_3CH_2OCH_2CH_3$ | — | — | — | — | | | | 400 | — |
| R-611 | methylformate | $HCOOCH_3$ | B2 | — | — | — | | | | 100 | — |
| R-718 | $H_2O$ | water | A1 | — | — | — | | | | — | 0-0-0 |
| R-744 | $CO_2$ | carbon dioxide | A1 | 4.5 | 40,000 | 72 | | | | 5,000 | 2-0-0b |
| R-1130(E) | CHCl=CHCl | Trans-1,2-dichloroethene | ~~B1~~B2 | 0.25 | 1,000 | 4 | 16 | 65,000 | 258 | 200 | |
| R-1132a | $CF_2 = CH_2$ | 1, 1-difluoroethylene | A2 | 2.0 | 13,000 | 33 | 8.1 | 50,000 | 131 | 500 | |
| R-1150 | $CH_2=CH_2$ | ethene (ethylene) | A3 | — | — | — | 2.2 | 31,000 | 36 | 200 | 1-4-2 |
| R-1224yd(Z) | $CF_3CF=CHCl$ | (Z)-1-chloro-2,3,3,3-tetrafluoropropen | A1 | 23 | 60,000 | ~~360~~ | | | | 1,000 | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 370 | | | | | | |
| R-1233zd(E) | $CF_3CH=CHCl$ | trans-1-chloro-3,3,3-trifluoro- 1-propene | A1 | 5.3 | 16,000 | 85 | | | | 800 | — | |
| R-1234yf | $CF_3CF=CH_2$ | 2,3,3,3-tetrafluoro-1 propene | ~~A2[c]~~ A2L | ~~4.7~~ 4.5 | 16,000 | 75 | 18.0 | 62,000 | 289 | 500 | — | |
| R-1234ze(E) | ~~$CF_3CH=CHF$~~ $CF_3CH=CFH$ | trans-1,3,3,3-tetrafluoro-1 -propene | ~~A2[c]~~ A2L | 4.7 | 16,000 | ~~75~~ 76 | 18.8 | 65,000 | 303 | 800 | — | |
| R-1270 | $CH_3CH=CH_2$ | Propene (propylene) | A3 | 0.1 | 1,000 | 1.7 | | | | 500 | 1-4-1 | |
| R-1336mzz(E) | $CF_3CH=CHCF_3$ | trans 1,1,1,4,4,4-hexafluoro-2-butene | A1 | 3.0 | 7,200 | 48 | | | | 400 | | |
| R-1336mzz(Z) | $CF_3CH=CHCF_3$ | Cis-1,1,1,4,4,4-hexaflouro-2-butene | A1 | ~~5.4~~ 5.2 | 13,000 | ~~87~~ 84 | | | | 500 | | |

SI: 1 pound = 0.454 kg, 1 cubic foot = 0.02832 $m^3$

a. Degrees of hazard are for health, fire, and reactivity, respectively, in accordance with NFPA 704.
b. Reduction to 1-0-0 is allowed if analysis satisfactory to the code official shows that the maximum concentration for a rupture or full loss of refrigerant charge would not exceed the IDLH, considering both the refrigerant quantity and room volume.
c. Class I ozone depleting substance; prohibited for new installations.
d. Occupational Exposure Limit based on the OSHA PEL, ACGIH TLV-TWA, the TERA WEEL or consistent value on a time-weighed average (TWA) basis (unless noted C for ceiling) for an 8 hr/d and 40 hr/wk.

**1104.3.2** ~~**Nonindustrial occupancies**~~ **Group A2, A3, B2 and B3 refrigerants.** ~~Group A2 and B2 refrigerants shall not be used in high-probability systems where the quantity of refrigerant in any independent refrigerant circuit exceeds the amount shown in Table 1104.3.2.~~ Group A2 and B2 refrigerants shall not be used in high-probability systems. Group A3 and B3 refrigerants shall not be used except where *approved*.

**Exceptions:** This section does not apply to:

1. Laboratories where the floor area per occupant is not less than 100 square feet (9.3 $m^2$).
2. Listed self-contained systems having a maximum of 0.331 pounds (150 g) of Group A3 refrigerant.
3. Industrial occupancies.
4. Equipment listed for and used in residential occupancies containing a

maximum of 6.6 pounds (3 kg) of Group A2 or B2 refrigerant.
5. Equipment listed for and used in commercial occupancies containing a maximum of 22 pounds (10 kg) of Group A2 or B2 refrigerant.

**1105.6.1.1 Indoor exhaust opening location.** Indoor mechanical exhaust intake openings shall be located where refrigerant leakage is likely to concentrate based on the refrigerant's relative density to air, and the locations of the air current paths and refrigerating machinery.

**[F] 1105.9 Emergency pressure control system.** ~~Permanently installed refrigeration systems containing more than 6.6 pounds (3 kg) of flammable, toxic or highly toxic refrigerant or ammonia shall be provided with an e~~Emergency pressure control system shall be provided in accordance with the Florida Fire Prevention Code.

**[BE] 1105.10 Means of egress.** Machinery rooms larger than 1,000 square feet (93 m2) shall have not less than two exits or exit access doorways. Where two exit access doorways are required, one such doorway is permitted to be served by a fixed ladder or an alternating tread device. Exit access doorways shall be separated by a horizontal distance equal to one-half the maximum horizontal dimension of the room. All portions of machinery rooms shall be within 150 feet (45 720 mm) of an exit or exit access doorway. An increase in exit access travel distance is permitted in accordance with Section 1017.1 of the Florida Building Code. Exit and exit access doorways shall swing in the direction of egress travel and shall be equipped with panic hardware, regardless of the occupant load served. Exit and exit access doorways shall be tight fitting and self-closing.

**1106.4 ~~Flammable~~ Class 2 and 3 refrigerants.** Where refrigerants of Groups A2, A3, B2 and B3 are used, the *machinery room* shall conform to the Class I, Division 2, *hazardous location* classification requirements of NFPA 70.

**Exceptions:** Ammonia machinery rooms that are provided with ventilation in accordance with Section 1106.3.

**DELETE SECTIONS [F] 1106.5 thru [F] 1106.6 in their entirety and replace with SECTION 1106.5 thru [F] 1106.7 as follows:**

**1106.5 Group A2L and B2L refrigerant.** Machinery rooms for Group A2L and B2L refrigerant shall comply with Sections 1106.5.1 through Section 1106.5.3.

**1106.5.1 Elevated temperatures.** Open flame-producing devices or continuously operating hot surfaces over 1290 °F (700 °C) shall not be permanently installed in the room.

**1106.5.2 Refrigerant detector.** In addition to the requirements of Section 1105.3, refrigerant detectors shall signal an alarm and activate the ventilation system in accordance with the response time specified in Table 1106.5.2.

**TABLE 1106.5.2 GROUP A2L and B2L DETECTOR ACTIVATION**

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| Activation Level | Maximum Response Time (seconds) | ASHRAE 15 Ventilation Level | Alarm Reset | Alarm Type |
|---|---|---|---|---|
| Less than or equal to the OEL in Table 1103.1 | 300 | 1 | Automatic | Trouble |
| Less than or equal to the refrigerant concentration level in Table 1103.1 | 15 | 2 | Manual | Emergency |

**1106.5.3 Mechanical ventilation.** The machinery room shall have a mechanical ventilation system complying with ASHRAE 15.

**[F] ~~1106.5~~ 1106.6 Remote controls.** Remote control of the mechanical equipment and appliances located in the machinery room shall comply with Sections ~~1106.5.1~~ 1106.6.1 and ~~1106.5.2~~ 1106.6.2.

**[F] ~~1106.5.1~~ 1106.6.1 Refrigeration system emergency shutoff.** A clearly identified switch of the break-glass type or with an approved tamper-resistant cover shall provide off-only control of refrigerant compressors, refrigerant pumps, and normally closed, automatic refrigerant valves located in the machinery room. Additionally, this equipment shall be automatically shut off whenever the refrigerant vapor concentration in the machinery room exceeds the vapor detector's upper detection limit or 25 percent of the LEL, whichever is lower.

**[F] ~~1106.5.2~~ 1106.6.2 Ventilation system.** A clearly identified switch of the break-glass type or with an approved tamper-resistant cover shall provide on-only control of the machinery room ventilation fans.

**[F] ~~1106.6~~ 1106.7 Emergency signs and labels.** Refrigeration units and systems shall be provided with approved emergency signs, charts, and labels in accordance with the Florida Fire Prevention Code.

**DELETE SECTION 1107 REFRIGERANT PIPING in its entirety and replace with new SECTION 1107 as follows:**

**SECTION 1107**
**PIPING MATERIAL**

**1107.1 Piping.** Refrigerant piping material shall conform to the requirements in this section.

**1107.2 Used materials.** Used pipe, fittings, valves and other materials that are to be reused shall be clean and free from foreign materials and shall be approved for reuse.

**1107.3 Materials rating.** Materials, joints and connections shall be rated for the operating temperature and pressure of the refrigeration system. Materials shall be suitable for the type of refrigerant and type of lubricant in the refrigeration system. Magnesium alloys shall not be used in contact with any

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halogenated refrigerants. Aluminum, zinc, magnesium and their alloys shall not be used in contact with R-40 (methyl chloride).

**1107.4 Piping materials standards.** Refrigerant pipe shall conform to one or more of the standards listed in Table 1107.4. The exterior of the pipe shall be protected from corrosion and degradation.

**TABLE 1107.4**
**REFRIGERANT PIPE**

| PIPING MATERIAL | STANDARD |
|---|---|
| Aluminum tube | ASTM B210, ASTM B491/B491M |
| Brass (copper alloy) pipe | ASTM B43 |
| Copper linesets | ASTM B280, ASTM B1003 |
| Copper pipe | ASTM B42, ASTM B302 |
| Copper tube[a] | ASTM B68, ASTM B75, ASTM B88, ASTM B280, ASTM B819 |
| Steel pipe[b] | ASTM A53, ASTM A106, ASTM A333 |
| Steel tube | ASTM A254, ASTM A334 |

a. Soft annealed copper tubing larger than 13/8 inch (35 mm) O.D. shall not be used for field-assembled refrigerant piping unless it is protected from mechanical damage.
b. ASTM A53, Type F steel pipe shall only be permitted for discharge lines in pressure relief systems.

**1107.4.1 Steel pipe Groups A2, A3, B2, and B3.** The minimum weight of steel pipe for Group A2, A3, B2 and B3 refrigerants shall be Schedule 80 for sizes 1 1/2 inches or less in diameter.

**1107.5 Pipe fittings.** Refrigerant pipe fittings shall be approved for installation with the piping materials to be installed, and shall conform to one of more of the standards listed in Table 1107.5 or shall be listed and labeled as complying with UL 207.

**TABLE 1107.5**
**REFRIGERANT PIPE FITTINGS**

| FITTING MATERIAL | STANDARD |
|---|---|
| Aluminum | ASTM B361 |
| Copper and copper alloy (brass) | ASME B16.15, ASME B16.18, ASME B16.22, ASME B16.24, ASME B16.26, ASME B16.50 |
| Steel | ASTM A105, ASTM A181, ASTM A193, ASTM A234, ASTM A420, ASTM A707 |

**1107.5.1 Copper brazed field swaged.** The minimum and maximum cup depth of field-fabricated copper brazed swaged fitting connections shall comply with Table 1107.5.1.

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**TABLE 1107.5.1**
**COPPER BRAZED SWAGED CUP DEPTHS**

| FITTING SIZE (inch) | MINIMUM DEPTH (inch) | MAXIMUM DEPTH (inch) |
|---|---|---|
| 1/8 | 0.15 | 0.23 |
| 3/16 | 0.16 | 0.24 |
| 1/4 | 0.17 | 0.26 |
| 3/8 | 0.20 | 0.30 |
| 1/2 | 0.22 | 0.33 |
| 5/8 | 0.24 | 0.36 |
| 3/4 | 0.25 | 0.38 |
| 1 | 0.28 | 0.42 |
| 1 1/4 | 0.31 | 0.47 |
| 1 1/2 | 0.34 | 0.51 |
| 2 | 0.40 | 0.60 |
| 2 1/2 | 0.47 | 0.71 |
| 3 | 0.53 | 0.80 |
| 3 1/2 | 0.59 | 0.89 |
| 4 | 0.64 | 0.96 |

For SI: 1 inch = 25.4 mm.

**1107.6 Valves.** Valves shall be of materials that are compatible with the type of piping material, refrigerants and oils in the refrigeration system. Valves shall be listed and labeled and rated for the temperatures and pressures of the refrigeration systems in which the valves are installed.

**1107.7 Flexible connectors, expansion and vibration compensators.** Flexible connectors and expansion and vibration control devices shall be listed and labeled for use in refrigeration systems and pressures at which the components are installed.

**DELETE SECTION 1108 FIELD TEST in its entirety and replace new SECTION 1108 as follows:**

**SECTION 1108**
**JOINTS AND CONNECTIONS**

**1108.1 Approval.** Joints and connections shall be of an approved type. Joints and connections shall be tight for the pressure of the refrigeration system when tested in accordance with Section 1110.

**1108.1.1 Joints between different piping materials.** Joints between different piping materials shall be made with approved adapter fittings. Joints between dissimilar metallic piping materials shall be made with a dielectric fitting or a dielectric union conforming to dielectric tests of ASSE 1079. Adapter fittings with threaded ends between different materials shall be joined with thread lubricant in accordance with Section 1108.3.4.

**1108.2 Preparation of pipe ends.** Pipe shall be cut square, reamed and chamfered, and shall be free from burrs and obstructions. Pipe ends shall have full-bore openings and shall not be undercut.

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**1108.3 Joint preparation and installation.** Where required by Sections 1108.4 through 1108.9, the preparation and installation of brazed, flared, mechanical, press-connect, soldered, threaded and welded joints shall comply with Sections 1108.3.1 through 1108.3.5.

**1108.3.1 Brazed joints.** Joint surfaces shall be cleaned. An approved flux shall be applied where required by the braze filler metal manufacturer. The piping being brazed shall be purged of air to remove the oxygen and filled with one of the following inert gases: oxygen-free nitrogen, helium or argon. The piping system shall be prepurged with an inert gas for a minimum time corresponding to five volume changes through the piping system prior to brazing. The pre-purge rate shall be at a minimum velocity of 100 feet per minute (0.508 m/s). The inert gas shall be directly connected to the tube system being brazed to prevent the entrainment of ambient air. After the pre-purge, the inert gas supply shall be maintained through the piping during the brazing operation at a minimum pressure of 1.0 psi (6.89 kPa) and a maximum pressure of 3.0 psi (20.67 kPa). The joint shall be brazed with a filler metal conforming to AWS A5.8.

**1108.3.2 Mechanical joints.** Mechanical joints shall be installed in accordance with the manufacturer's instructions.

**1108.3.2.1 Flared joints.** Flared fittings shall be installed in accordance with the manufacturer's instructions. The flared fitting shall be used with the tube material specified by the fitting manufacturer. The flared tube end shall be made by a tool designed for that operation.

**1108.3.2.2 Press-connect joints.** Press-connect joints shall be installed in accordance with the manufacturer's instructions.

**1108.3.3 Soldered joints.** Joint surfaces to be soldered shall be cleaned and a flux conforming to ASTM B813 shall be applied. The joint shall be soldered with a solder conforming to ASTM B32. Solder joints shall be limited to refrigeration systems using Group A1 refrigerant and having a pressure of less than or equal to 200 psi (1378 kPa).

**1108.3.4 Threaded joints.** Threads shall conform to ASME B1.1, ASME B1.13M, ASME B1.20.1 or ASME B1.20.3. Thread lubricant, pipe-joint compound or thread tape shall be applied on the external threads only and shall be approved for application on the piping material.

**1108.3.5 Welded joints.** Joint surfaces to be welded shall be cleaned by an approved procedure. Joints shall be welded with an approved filler metal.

**1108.4 Aluminum tube.** Joints between aluminum tubing or fittings shall be brazed, mechanical, press-connect or welded joints conforming to Section 1108.3.

**1108.5 Copper pipe.** Joints between copper or copper-alloy pipe or fittings shall be brazed, mechanical, press-connect, soldered, threaded or welded joints conforming to Section 1108.3.

**1108.6 Copper tube.** Joints between copper or copper-alloy tubing or fittings shall be brazed, flared, mechanical, press-connect or soldered joints.

**1108.7 Steel pipe.** Joints between steel pipe or fittings shall be mechanical joints, threaded, press-

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connect or welded joints conforming to Section 1108.3.

**1108.8 Steel tube.** Joints between steel tubing or fittings shall be flared, mechanical, press-connect or welded joints conforming to Section 1108.3.

**DELETE SECTION [F] 1109 PERIODIC TESTING in its entirety and replace new SECTION 1109, SECTION 1110, AND SECTION 1111 as follows:**

## SECTION 1109
## REFRIGERANT PIPE INSTALLATION

**1109.1 General.** Refrigerant piping installations, other than R-717 (ammonia) refrigeration systems, shall comply with the requirements of this section. The design of refrigerant piping shall be in accordance with ASME B31.5.

**1109.2 Piping location.** Refrigerant piping shall comply with the installation location requirements of Sections 1109.2.1 through 1109.2.7. Refrigerant piping for Groups A2L and B2L shall also comply with the requirements of Section 1109.3. Refrigerant piping for Groups A2, A3, B2 and B3 shall also comply with the requirements of Section 1109.4.

**1109.2.1 Minimum height.** Exposed refrigerant piping installed in open spaces that afford passage shall be not less than 7 feet 3 inches (2210 mm) above the finished floor.

**1109.2.2 Refrigerant pipe enclosure.** Refrigerant piping shall be protected by locating it within the building elements or within protective enclosures.

**Exception:** Piping protection within the building elements or protective enclosure shall not be required in any of the following locations:

1. Where installed without ready access or located more than 7 feet 3 inches (2210 mm) above the finished floor.
2. Where located within 6 feet (1829 mm) of the refrigerant unit or *appliance*.
3. Where located in a *machinery room* complying with Section 1105.
4. Outside the building:
   - 4.1 Where protected from damage from the weather, including but not limited to hail, ice and snow loads.
   - 4.2 Where protected from damage within the expected foot or traffic path.
   - 4.3 Where installed underground not less than 8 inches (200 mm) below finished grade and protected against corrosion.

**1109.2.3 Prohibited locations.** Refrigerant piping shall not be installed in any of the following locations:

1. Exposed within a fire-resistance-rated exit access corridor.
2. Exposed within an interior exit stairway.
3. Within an interior exit ramp.
4. Within an exit passageway.
5. Within an elevator, dumbwaiter or other shaft containing a moving object.

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**1109.2.4 Piping in concrete floors.** Refrigerant piping installed in concrete floors shall be encased in pipe, conduit or ducts. The piping shall be protected to prevent damage from vibration, stress and corrosion.

**1109.2.5 Refrigerant pipe shafts.** Refrigerant piping that penetrates two or more floor/ceiling assemblies shall be enclosed in a fire-resistance-rated shaft enclosure. The fire-resistance-rated shaft enclosure shall comply with Section 713 of the Florida Building Code.

**Exceptions:**

1. Refrigeration systems using R-718 refrigerant (water).
2. Piping in a direct refrigeration system using Group A1 refrigerant where the refrigerant quantity does not exceed the limits of Table 1103.1 for the smallest occupied space through which the piping passes.
3. Piping located on the exterior of the building where vented to the outdoors.

**1109.2.6 Exposed piping surface temperature.** Exposed piping having surface temperatures greater than 120°F (49°C) or less than 5°F (-15°C) with ready access to nonauthorized personnel shall be protected from contact or shall have thermal insulation that limits the exposed insulation surface temperature to a range of 5°F (-15°C) to 120°F (49°C).

**1109.2.7 Pipe identification.** Refrigerant pipe located in areas other than the room or space where the refrigerating *equipment* is located shall be identified. The pipe identification shall be located at intervals not exceeding 20 feet (6096 mm) on the refrigerant piping or pipe insulation. The minimum height of lettering of the identification label shall be $^{1}/_{2}$ inch (12.7 mm). The identification shall indicate the refrigerant designation and safety group classification of refrigerant used in the piping system. For Group A2L and B2L refrigerants, the identification shall also include the following statement: “WARNING – Risk of Fire. Flammable Refrigerant.” For Group A2, A3, B2 and B3 refrigerants, the identification shall also include the following statement: "DANGER—Risk of Fire or Explosion. Flammable Refrigerant." For any Group B refrigerant, the identification shall also include the following statement: "DANGER—Toxic Refrigerant."

**1109.3 Installation requirements for Group A2L, A2, A3, B2L, B2, or B3 refrigerant.** Piping systems using Group A2L, A2, A3, B2L, B2, or B3 refrigerant shall comply with the requirements of Sections 1109.3.1 and 1109.3.2.

**1109.3.1 Protection against physical damage.** In addition to the requirements of Section 305.5, aluminum, copper and steel tube used for Group A2, A3, B2L, B2, and B3 refrigerants and located in concealed locations where tubing is installed in studs, joists, rafters or similar member spaces, and located less than $1^{1}/_{4}$ inches (32 mm) from the nearest edge of the member, shall be continuously protected by shield plates. Protective steel shield plates shall cover the area of the tube plus the area extending not less
than 2 inches (51 mm) beyond both sides of the tube.

**1109.3.1.1 Shield plates.** Shield plates shall be of steel material having a thickness of not less than 0.0575 inch (1.46 mm) (No.16 gage).

**1109.3.2 Shaft ventilation.** Refrigerant pipe shafts with systems using Group A2L or B2L refrigerant shall be naturally or mechanically ventilated. Refrigerant pipe shafts with one or more systems using any Group A2, A3, B2, or B3 refrigerant shall be continuously mechanically ventilated and shall include a refrigerant detector. The shaft ventilation exhaust outlet shall comply with Section 501.3.1. Naturally

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ventilated shafts shall have a pipe, duct or conduit not less than 4 inches (102 mm) in diameter that connects to the lowest point of the shaft and extends to the outdoors. The pipe, duct or conduit shall be level or pitched downward to the outdoors. Mechanically ventilated shafts shall have a minimum airflow velocity in accordance with Table 1109.3.2. The mechanical ventilation shall be continuously operated or activated by a refrigerant detector. Systems utilizing a refrigerant detector shall activate the mechanical ventilation at a maximum refrigerant concentration of 25 percent of the lower flammable limit of the refrigerant. The detector, or a sampling tube that draws air to the detector, shall be located in an area where refrigerant from a leak will concentrate. The shaft shall not be required to be ventilated for double-wall refrigerant pipe where the interstitial space of the double-wall pipe is vented to the outdoors.

**TABLE 1109.3.2**
**SHAFT VENTILATION VELOCITY**

| CROSS-SECTIONAL AREA OF SHAFT (square inches) | MINIMUM VENTILATION VELOCITY (feet per minute) |
|---|---|
| ≤ 20 | 100 |
| > 20 ≤ 250 | 200 |
| > 250 ≤ 1,250 | 300 |
| > 1,250 | 400 |

For SI: 1 square inch = 645 mm2, 1 foot per minute = 0.0058 m/s.

**1109.4 Refrigerant pipe penetrations.** The annular space between the outside of a refrigerant pipe and the inside of a pipe sleeve or opening in a building envelope wall, floor or ceiling assembly penetrated by a refrigerant pipe shall be sealed in an approved manner with caulking material or foam sealant or closed with a gasketing system. The caulking material, foam sealant or gasketing system shall be designed for the conditions at the penetration location and shall be compatible with the pipe, sleeve and building materials in contact with the sealing materials. Refrigerant pipes penetrating fire-resistance-rated assemblies or membranes of fire-resistance-rated assemblies shall be sealed or closed in accordance with Section 714 of the Florida Building Code.

**1109.5 Stress and strain.** Refrigerant piping shall be installed so as to prevent strains and stresses that exceed the structural strength of the pipe. Where necessary, provisions shall be made to protect piping from damage resulting from vibration, expansion, contraction and structural settlement.

**1109.6 Stop valves.** Stop valves shall be installed in specified locations in accordance with Sections 1109.6.1 and 1109.6.2. Stop valves shall be supported in accordance with Section 1109.6.3 and identified in accordance with Section 1109.6.4.

**Exceptions:**

1. Systems that have a refrigerant pumpout function capable of storing the entire refrigerant charge in a receiver or heat exchanger.
2. Systems that are equipped with provisions for pumping out the refrigerant using either portable or permanently installed refrigerant recovery equipment.
3. Self-contained listed and labeled systems.

**1109.6.1 Refrigeration systems containing more than 6.6 pounds (3.0 kg) of refrigerant.** Stop valves shall be installed in the following locations on refrigeration systems containing more than 6.6 pounds (3.0 kg) of refrigerant:

1. The suction inlet of each compressor, compressor unit or condensing unit.
2. The discharge outlet of each compressor, compressor unit or condensing unit.
3. The outlet of each liquid receiver.

**1109.6.2 Refrigeration systems containing more than 100 pounds (45 kg) of refrigerant.** In addition to stop valves required by Section 1109.6.1, refrigeration systems containing more than 100 pounds (45 kg) of refrigerant shall have stop valves installed in the following locations:

1. Each inlet of each liquid receiver.
2. Each inlet and each outlet of each condenser where more than one condenser is used in parallel.

**Exceptions:**

1. Stop valves shall not be required at the inlet of a receiver in a condensing unit nor at the inlet of a receiver that is an integral part of the condenser.
2. Refrigeration systems utilizing nonpositive displacement compressors.

**1109.6.3 Stop valve support.** Stop valves shall be supported to prevent detrimental stress and strain on the refrigerant piping system. The piping system shall not be utilized to support stop valves on copper tubing or aluminum tubing 1 inch (25.4 mm) outside diameter or larger.

**1109.6.4 Identification.** Stop valves shall be identified where their intended purpose is not obvious. Where valves are identified by a numbering or lettering system, legend(s) or key(s) for the valve identification shall be located in the room containing the indoor refrigeration equipment. The minimum height of lettering of the identification label shall be 1/2 inch (12.7 mm).

## SECTION 1110
## REFRIGERATION PIPING SYSTEM TEST

**1110.1 General.** Refrigerant piping systems, other than R-717 (ammonia) refrigeration systems, that are erected in the field shall be pressure tested for strength and leak tested for tightness, in accordance with the requirements of this section, after installation and before being placed in operation. Tests shall include both the high- and low-pressure sides of each system.

**Exception:** Listed and labeled equipment, including compressors, condensers, vessels, evaporators, gas bulk storage tanks, safety devices, pressure gauges and control mechanisms, shall not be required to be tested.

**1110.2 Exposure of refrigerant piping system.** Refrigerant pipe and joints installed in the field shall be exposed for visual inspection and testing prior to being covered or enclosed.

**1110.3 Field test gases.** The medium used for field pressure testing the refrigeration system shall be one of the following inert gases: oxygen-free nitrogen, helium argon or premixed nonflammable oxygen-free nitrogen with a tracer gas of hydrogen or helium. For R-744 refrigeration systems, carbon dioxide shall be allowed as the test medium. For R-718 refrigeration systems, water shall be allowed as the test medium.

**1110.3.1 Test gases not permitted.** Oxygen, air, refrigerants other than those identified in Section 1110.3, combustible gases and mixtures containing such gases shall not be used as the pressure test medium.

**1110.4 Factory test procedure.** Factory tests shall be performed with dry nitrogen or other nonflammable, nonreactive, dried gas. Oxygen, air or mixtures containing them shall not be used. The means used to build up the test pressure shall have either a pressure-limiting device or a pressure-reducing device and a gauge on the outlet side. The pressure-relief device shall be set above the test pressure but low enough to prevent permanent deformation of the refrigeration system's components.

**Exceptions:**

1. Mixtures of dry nitrogen, inert gases or a combination of them with Class 1 refrigerant in concentrations of a refrigerant weight fraction (mass fraction) not exceeding 5 percent shall be permitted for tests.
2. Mixtures of dry nitrogen, inert gases or a combination of them with Class 2L, Class 2 and Class 3 refrigerants in concentrations not exceeding the lower of a refrigerant weight fraction (mass fraction) of 5 percent or 25 percent of the LFL shall be permitted for tests.
3. Compressed air without added refrigerants shall be permitted for tests, provided that the refrigeration system is subsequently evacuated to less than 1,000 microns (0.1333 kPa) before charging with refrigerant. The required evacuation level is atmospheric pressure for refrigeration systems using R-718 (water) or R-744 (carbon dioxide) as the refrigerant.
4. Systems erected on the premises using Group A1 refrigerant and with copper tubing not exceeding 0.62 of an inch (15.7 mm) outside diameter shall be tested by means of the refrigerant charged into the system at the saturated vapor pressure of the refrigerant at not less than 68°F (20°C).

**1110.5 Test apparatus.** The means used to pressurize the refrigerant piping system shall have on its outlet side a test pressure measuring device and either a pressure-limiting device or a pressure-reducing device. The test pressure measuring device shall have an accuracy of ±3 percent or less of the test pressure and shall have a resolution of 5 percent or less of the test pressure.

**1110.6 Piping system strength test.** Refrigeration system components and refrigerant piping shall be tested in accordance with ASME B31.5 or this section. Separate tests for isolated portions of the system are permitted, provided that all required portions are tested at least once. Pressurize with test gas for a minimum of 10 minutes to not less than the lower of (a) the lowest design pressure for any system component or (b) the lowest value of set pressure for any pressure relief devices in the system. The design pressures for determination of test pressure shall be the pressure identified on the label nameplate of the condensing unit, compressor, compressor unit, pressure vessel or other system component with a nameplate. A passing test result shall have no rupture or structural failure of any system component or refrigerant piping.

Refrigerant piping and tubing greater than 3/4 inch (19 mm) in diameter shall be tested in accordance with ASHRAE 15.

**1110.7 Contractor or engineer declaration.** The installing contractor or registered design professional of record shall issue a certificate of test to the code official for all refrigeration systems containing 55 pounds (25 kg) or more of refrigerant. The certificate shall give the test date, name of the refrigerant, test medium and the field test pressure applied to the high-pressure side and the low-pressure side of the system. The certification of test shall be signed by the installing contractor or registered design professional and shall be made part of the public record.

## [F] SECTION 1111
## PERIODIC TESTING

M12147Text Modification

**[F] ~~1109.1~~ 1111.1 Testing required**. The following emergency devices and systems shall be periodically tested in accordance with the manufacturer's instructions and as required by the code official:

1. Treatment and flaring systems.
2. Valves and appurtenances necessary to the operation of emergency refrigeration control boxes.
3. Fans and associated equipment intended to operate emergency ventilation systems.
4. Detection and alarm systems.

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# TAC: Mechanical

Total Mods for **Mechanical** in **Pending Review : 20**

Total Mods for report: 20

## Sub Code: Mechanical

### M12218

9

| | | | | | |
|---|---|---|---|---|---|
| **Date Submitted** | 02/17/2025 | **Section** | 1101.6 | **Proponent** | Robert Glass |
| **Chapter** | 11 | **Affects HVHZ** | No | **Attachments** | No |
| **TAC Recommendation** | Pending Review | | | | |
| **Commission Action** | Pending Review | | | | |

**Comments**

**General Comments No** **Alternate Language No**

### Related Modifications

Exception: Refrigeration systems that use A2L refrigerant shall be designed and installed in accordance with ASHRAE 15.

### Summary of Modification

This exception was added to the 8th edition via Supplement 5 to the 8th Edition (2023) of the Florida Building Code. This exception is critical to bring forward to the 9th Edition and this proposal is intended to ensure that this be considered/added.

### Rationale

This exception was added to the 2023 Florida Building Code through Supplement 5. This is critical to carry forward into the 9th Edition of the Florida Building Code. This proposal is intended to simply ensure that this is considered/added to the 9th Edition during this code cycle. ASHRAE 15 is the proper document to reference for the correct installation of A2L equipment for air conditioning/heating and refrigeration.

### Fiscal Impact Statement

**Impact to local entity relative to enforcement of code**

There are no cost implications by continuing to add this exception into the 9th Edition.

**Impact to building and property owners relative to cost of compliance with code**

There is no cost impact to building and property owners for compliance with code. This proposal is simply to ensure that A2L installations are addressed appropriately and ASHRAE 15 is the appropriate document.

**Impact to industry relative to the cost of compliance with code**

There are no impact to industry relating to cost of compliance - except to ensure that A2L installations are done properly.

**Impact to small business relative to the cost of compliance with code**

There is no impact to small businesses on cost of compliance - only clear directions on how to install A2L equipment properly.

### Requirements

**Has a reasonable and substantial connection with the health, safety, and welfare of the general public**

Ensuring that A2L installations are done properly by directly referencing ASHRAE 15 in this exception will help ensure safety and welfare for the general public.

**Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction**

This provide direct refeence to ASHRAE 15 for the proper installation requirements for A2L equipment.

**Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities**

This proposal does not create any discrimination against materials, products, methods or systems. It purely ensure that A2L products (as required by federal law) are properly installed.

**Does not degrade the effectiveness of the code**

This proposal does not degrade the effectiveness of the cost as it has already been approved previously by Supplement 5 adoption to the 8th Edition of the FL Building Code.

M12218Text Modification

Refrigeration systems shall comply with the requirements of this code and, except as modified by this code, ASHRAE 15. Ammonia-refrigerating systems shall comply with this code and, except as modified by this code, ASHRAE 15 and IIAR 2.

Exception: Refrigeration systems that use A2L refrigerant shall be designed and installed in accordance with ASHRAE 15.

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# TAC: Mechanical

Total Mods for **Mechanical** in **Pending Review : 20**

Total Mods for report: 20

## Sub Code: Mechanical

### M12027

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| | | | | | |
|---|---|---|---|---|---|
| **Date Submitted** | 02/11/2025 | **Section** | 102.4 | **Proponent** | Bryan Holland |
| **Chapter** | 15 | **Affects HVHZ** | No | **Attachments** | Yes |
| **TAC Recommendation** | Pending Review | | | | |
| **Commission Action** | Pending Review | | | | |

**Comments**

**General Comments No** **Alternate Language No**

### Related Modifications

A related modification has been submitted to the FBC-B, FBC-R, FBC-EC, and FBC-EB to update the reference to NFPA 70-23, including all published TIAs.

### Summary of Modification

This proposed modification recommends adoption of NFPA 70-23, including all published Tentative Interim Amendments (TIAs)

### Rationale

This proposed modification recommends updating the adopted edition of NFPA 70 to the 2023 edition, including all published TIAs (TIA 23-1 through TIA 23-16). Tentative Interim Amendments (TIAs) are important revisions to the code that have been issued by the NFPA Standards Council after publication of the document. All issued TIAs have been reviewed and approved through consensus voting on the basis of "technical merit" and "emergency nature" by the corresponding Code Making Panel, without creating a correlation issue with any other sections of the code. For the 2023 edition of NFPA 70, TIAs 23-1 through 23-6 were issued prior to publication of the code and incorporated into the first printing. This proposed modification recommends all TIAs, 23-1 through 23-16 be officially adopted and incorporated into the code. This will help reduce conflicts in the field and improve consistent enforcement across all Florida jurisdictions.

### Fiscal Impact Statement

**Impact to local entity relative to enforcement of code**

This proposed modification will improve the consistent enforcement of the code by the local entity.

**Impact to building and property owners relative to cost of compliance with code**

This proposed modification will not change the cost of compliance with code.

**Impact to industry relative to the cost of compliance with code**

This proposed modification will not change the cost of compliance with code.

**Impact to small business relative to the cost of compliance with code**

This proposed modification will not change the cost of compliance with code.

## Requirements

**Has a reasonable and substantial connection with the health, safety, and welfare of the general public**

The changes made to the 2023 NEC along with all issued TIAs represent important improvements and corrections to the published code. All (16) TIAs have been deemed to have both technical merit and emergency in nature, thus increasing the health, safety, and welfare of the general public.

**Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction**

This proposed modification improves the code by updating to the most current edition of the NEC and by incorporating corrections made after initial publication.

**Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities**

This proposed modification does not discriminate against materials, products, methods, or systems of construction.

**Does not degrade the effectiveness of the code**

This proposed modification improves the effectiveness of the code.

Chapter 15 Referenced Standards

NFPA

70 - ~~20~~ 23 National Electrical Code (NEC), including all published Tentative Interim Amendments (TIAs) published until December 4, 2024

NFPA

Tentative Interim Amendment

# NFPA® 70®

## *National Electrical Code*®

### 2023 Edition

**Reference:** Definition of Pool, and 680.26
**TIA 23-9**
*(SC 23-3-8 / TIA Log #1687)*

Pursuant to Section 5 of the NFPA *Regulations Governing the Development of NFPA Standards*, the National Fire Protection Association has issued the following Tentative Interim Amendment to NFPA 70®, *National Electrical Code*®, 2023 edition. The TIA was processed by the NEC Code-Making Panel 17 and the NEC Correlating Committee, and was issued by the Standards Council on March 21, 2023, with an effective date of April 10, 2023.

*1. Revise the definition of "Pool" to read as follows:*

**Pool.** Manufactured or field-constructed equipment designed to contain water on a permanent or semipermanent basis and used by persons for swimming, wading, immersion, or therapeutic purposes, but not including bodies of water incorporated as part of an industrial process or lakes, lagoons, surf parks, or other natural and man-made bodies of water that may incorporate swimming and swimming areas. (680) (CMP-17)

**Informational Note:** Natural and man-made bodies of water, which includes lakes, lagoons, surf parks, or other similar bodies of water, are addressed in Article 682.

*2. Revise section paragraph 680.26 to read as follows:*

**680.26 Equipotential Bonding.**

**(A) Performance.** The equipotential bonding required by 680.26(B) and (C) to reduce voltage gradients in the pool area shall be installed for pools with or without associated electrical equipment related to the pool.

Informational Note No. 1: Some causes of voltage gradients originate outside the premises wiring system and are not within the scope of the *NEC*. Measures identified in Rule 097D2 of ANSI C2, *National Electrical Safety Code,* can also serve to address voltage gradients originating on the utility side of the service point.

Informational Note No. 2: By its nature, equipotential bonding of swimming pools and perimeter surfaces involves contact between various metallic materials and the earth. This can, in some cases, expose various specific metals to a corrosive environment, depending on factors such as the type and chemical content of the soil and the specific metal. Corrosive environments are also addressed in 680.14.

**(B) Bonded Parts. …**

**(1) Conductive Pool Shells. …**

**(2) Perimeter Surfaces.** The perimeter surface to be bonded shall be considered to extend for ~~1 m~~ 900 mm (3 ft) horizontally beyond the inside walls of the pool ~~and~~ while also at a height between 900 mm (3 ft) above and 600 mm (2 ft) below the maximum water level. The perimeter surface shall include unpaved surfaces, concrete, and other types of paving. Perimeter surfaces separated from the pool by a permanent wall or building 1.5 m (5 ft) in height or more shall require equipotential bonding only on the pool side of the permanent wall or building. Bonding to perimeter surfaces shall be provided as specified in 680.26(B)(2)(a), (B)(2)(b), or (B)(2)(c), and (B)(2)(d). and For conductive pool shells where bonding to perimeter surfaces is required, it shall be attached to the pool reinforcing steel or copper conductor grid at a minimum of four points uniformly spaced around the perimeter of the pool, or if the bonded perimeter surface does not surround the entire pool, it shall be attached to the pool reinforcing steel or copper conductor grid at a minimum of four uniformly spaced points along the bonded perimeter surface. For nonconductive pool shells where bonding to the perimeter surfaces is required, bonding at four points shall not be required, and the perimeter bonding shall be attached to the 8 AWG copper equipotential bonding conductor and, if present, to any conductive support structure for the pool.

> Informational Note: Because the perimeter surface can incorporate various types of materials at various locations and elevations above and below maximum water level, the perimeter surface required to be bonded might not surround the entire pool. The 8 AWG copper equipotential bonding conductor can encircle the entire pool to facilitate connection of bonded parts.

(a) *Structural Reinforcing Steel.* Structural reinforcing steel shall be bonded in accordance with 680.26(B)(1)(a). *Conductive Paved Portions of Perimeter Surfaces.* Conductive paved portions of perimeter surfaces, including masonry pavers, if used, shall be bonded with unencapsulated structural reinforcing steel in accordance with 680.26(B)(1)(a), or with unencapsulated steel structural welded wire reinforcement (welded wire mesh, welded wire fabric), bonded together by steel tie wires or the equivalent. Steel welded wire reinforcement shall be fully embedded within the pavement unless the pavement will not allow for embedding. If the reinforcing steel is absent, or is encapsulated in a nonconductive compound, or embedding is not possible, unencapsulated welded wire steel reinforcement or a copper conductor grid shall be provided and shall be secured directly under the paving, and not more than 150 mm (6 in.) below finished grade.

Unencapsulated steel welded wire reinforcement that is not fully embedded in concrete, and copper grid regardless of location, where used for equipotential bonding, shall be listed for corrosion resistance and mechanical performance. This listing requirement shall become effective January 1, 2025. The copper grid or unencapsulated steel welded wire reinforcement shall also meet the following:

(1) Copper grid is constructed of 8 AWG solid bare copper and arranged in accordance with 680.26(B)(1)(b)(3).
(2) Steel welded wire reinforcement is minimum ASTM 6x6-W2.0 x W2.0 or minimum No. 3 rebar constructed in a 300 mm (12 in.) grid.
(3) Copper grid and steel welded wire reinforcement follow the contour of the perimeter surface extending not less than 900 mm (3 ft) horizontally beyond the inside walls of the pool.
(4) Only listed splicing devices or exothermic welding are used.

> Informational Note No. 1: Performance of the equipotential bonding system at the perimeter surface is improved as the distance between the bonding means and finished grade is minimized, either by embedding within, or by direct contact with the underside of, the finished pavement.

> Informational Note No. 2: See ASTM A615/A615M, *Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement;* A1064/A1064M, *Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete;* A1022/A1022M, *Standard Specification for Deformed and Plain Stainless Steel Wire and Welded Wire for Concrete Reinforcement;* A1060A/A1060M, *Standard Specification for Zinc-Coated (Galvanized) Steel Welded Wire Reinforcement, Plain and Deformed, for Concrete;* and ACI Standard ACI 318, *Building Code Requirements for Structural Concrete,* for examples of standards currently used in the listing of reinforcing steel bars and steel welded wire reinforcement.

(b) *Unpaved Portions of Perimeter Surfaces.* Unpaved portions of perimeter surfaces shall be bonded with any of the following methods:
(1) *Copper Ring.* Where structural reinforcing steel is not available or is encapsulated in a nonconductive compound, a cCopper conductor(s) shall be utilized where the following requirements are met meet the following:
(1)a. At least one minimum 8 AWG bare solid copper conductor, including the 8 AWG copper equipotential bonding conductor if available shall be provided.
(2)b. The conductors shall follow the contour of the perimeter surface.
(3)c. Only listed splicing devices or exothermic welding are used. shall be permitted.
(4)d. The required conductor(s) is shall be 450 mm to 600 mm (18 in. to 24 in.) from the inside walls of the pool.
(5)e. The required conductor(s) shall be secured within or is under the unpaved portion of the perimeter surface 100 mm to 150 mm (4 in. to 6 in.) below the subgradefinished grade.
f. Be installed only in perimeter surfaces not intended to have direct access to swimmers in the pool.

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(~~c~~2) ~~*Copper Grid*. Where structural reinforcing steel is not available or is encapsulated in a nonconductive compound, c~~Copper grid or unencapsulated steel welded wire reinforcement used for equipotential bonding of unpaved portions of perimeter surfaces shall ~~be utilized where the following requirements are met~~ meet the following:
~~(1)~~a. ~~The copper grid shall be constructed of 8 AG solid bare copper and be arranged~~ Be installed in accordance with 680.26~~(B)(1)(b)(3)~~(B)(2)(a).
~~(2) The copper grid shall follow the contour of the perimeter surface extending 1 m (3 ft) horizontally beyond the inside walls of the pool.~~
~~(3) Only listed splicing devices or exothermic welding shall be permitted.~~
~~(4)~~b. ~~The copper grid shall be secured~~ Be located within ~~or under~~ the ~~deck or~~ unpaved surface(s) between 100 mm to 150 mm (4 in. to 6 in.) below ~~the subgrade~~finished grade.

(c) *Nonconductive Perimeter Surfaces.* Equipotential bonding shall not be required for nonconductive portions of perimeter surfaces that are separated from earth or raised on nonconducting supports, and it shall not be required for any perimeter surface that is electrically separated from the pool structure and raised on nonconductive supports above an equipotentially bonded surface.

Informational Note: Nonconductive materials include, but are not limited to, wood, plastic, wood-plastic composites, fiberglass, and fiberglass composites.

(d) *Interconnection of Bonded Portions of Perimeter Surfaces.* All surfaces where equipotential bonding is required shall be interconnected using listed splicing devices or exothermic welding. Where copper wire is used for this purpose, it shall be solid copper, not smaller than 8 AWG. The conductor shall be permitted to encircle the pool to facilitate bonding connections to portions of the perimeter covered in 680.26(B)(2)(a) and (B)(2)(b) that are not contiguous.

**Issue Date:** March 21, 2023

**Effective Date:** April 10, 2023

**(Note: For further information on NFPA Codes and Standards, please see www.nfpa.org/docinfo)**



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Tentative Interim Amendment

# NFPA® 70®

## *National Electrical Code®*

## 2023 Edition

**Reference:** 300.26
**TIA 23-8**
*(SC 23-3-9 / TIA Log #1688)*

Pursuant to Section 5 of the NFPA *Regulations Governing the Development of NFPA Standards*, the National Fire Protection Association has issued the following Tentative Interim Amendment to NFPA 70®, *National Electrical Code®*, 2023 edition. The TIA was processed by the NEC Code-Making Panel 3 and the NEC Correlating Committee, and was issued by the Standards Council on March 21, 2023, with an effective date of April 10, 2023.

*1. Revise paragraph 300.26 to read as follows:*

**300.26 Remote-Control and Signaling Circuits Classification.**
Remote-control and signaling circuits shall be classified as either power-limited or non-power-limited and comply with ~~the following~~300.26(A) through (C).

(~~1~~A) **Class 1 Power-Limited Remote-Control and Signaling Circuits**. Class 1 power-limited remote-control and signaling circuits shall comply with 724.3.

(~~2~~B) **Class 2 and Class 3 Power-Limited Remote-Control and Signaling Circuits**. Class 2 and Class 3 power-limited remote-control and signaling circuits shall comply with 725.3.

(~~3~~C) **Non-Power-Limited Remote-Control and Signaling Circuits**. Non-power-limited remote-control and signaling circuits shall be installed in accordance with 300.2 through 300.25 and comply with 300.26(C)(1) through (C)(3).

**(1) Sizes and Use.**

(a) Conductors that are 18 AWG and 16 AWG copper shall be permitted to be used if they supply loads that do not exceed the ampacities specified in 402.5 and are installed in a raceway, an approved enclosure, or a listed cable.

(b) Conductors that are 14 AWG copper-clad aluminum shall be permitted to be used in Type MC cable and Type TC cable. The continuous load shall not exceed 8 amperes.

(c) Conductors larger than 16 AWG copper or 14 AWG copper-clad aluminum shall not supply loads greater than the ampacities specified in 310.14.

(d) Flexible cords shall comply with the applicable general requirements, applications, and construction specifications for flexible cords and flexible cables in accordance with Article 400 Parts I and II.

**(2) Insulation.**

(a) Insulation on conductors shall be rated for the system voltage and not less than 600 volts.

(b) Conductors larger than 16 AWG copper or 14 AWG copper-clad aluminum shall comply with the applicable general requirements for conductors rated up to and including 2000 volt for type designations, insulations, markings, ampacity ratings, and uses in accordance with 310.3, 310.4, 310.6, 310.8, 310.10, and 310.14.

(c) Conductors that are 18 AWG copper, 16 AWG copper, or 14 AWG copper-clad aluminum shall be Type FFH-2, Type KF-2, Type KFF-2, Type PAF, Type PAFF, Type PF, Type PFF, Type PGF, Type PGFF, Type PTF, Type PTFF, Type RFH-2, Type RFHH-2, Type RFHH-3, Type SF-2, SFF-2, Type TF, Type TFF, Type TFFN, Type TFN, Type ZF, or Type ZFF.

(d) Conductors with other types and thicknesses of insulation shall be permitted if listed for Class 1 circuit use.

**(3) Overcurrent Protection.**

(a) Overcurrent protection for conductors 14 AWG copper and larger shall be provided in accordance with the conductor ampacity, without applying the ampacity adjustment and correction factors specified in 310.15 to the ampacity calculation.

(b) Overcurrent protection shall not exceed 7 amperes for 18 AWG copper conductors and 10 amperes for 16 AWG copper and 14 AWG copper-clad aluminum.

*Exception: The overcurrent protection specified in 300.26(C)(3)(1) and 300.26(C)(3)(2) shall not be required where this Code requires or permits other overcurrent protection ratings.*

**Issue Date:** March 21, 2023

**Effective Date:** April 10, 2023

**(Note: For further information on NFPA Codes and Standards, please see www.nfpa.org/docinfo)**

Tentative Interim Amendment

# NFPA® 70®

## *National Electrical Code®*

### 2023 Edition

**Reference:** Table C.18, Table C.19 and Table C.20
**TIA 23-7**
*(SC 22-12-7 / TIA Log #1678)*

Pursuant to Section 5 of the NFPA *Regulations Governing the Development of NFPA Standards*, the National Fire Protection Association has issued the following Tentative Interim Amendment to NFPA 70®, *National Electrical Code®*, 2023 edition. The TIA was processed by the NEC Code-Making Panel 8, and the NEC Correlating Committee, and was issued by the Standards Council on December 8, 2022, with an effective date of December 28, 2022.

*1. Revise Table Headers **only** for Table C.18, Table, C.19 and Table C.20 to read as follows:*

**Table C.18 Number of Single Conductor Cables Permitted in Cable Tray**
**(Based on fill in accordance with 392.22, Table 392.22~~(A)~~(B)(1), column 1, ampacity in accordance with 392.80)**

**Table C.19 Number of Single Conductor Cables Permitted in Cable Tray**
**(Based on fill in accordance with 392.22, Table 392.22~~(A)~~(B)(1), column 1, ampacity in accordance with 392.80)**

**Table C.20 Number of Single Conductor Cables Permitted in Cable Tray**
**(Based on fill in accordance with 392.22, Table 392.22~~(A)~~(B)(1), column 1, ampacity in accordance with 392.80)**

**Issue Date:** December 8, 2022

**Effective Date:** December 28, 2022

**(Note: For further information on NFPA Codes and Standards, please see www.nfpa.org/docinfo)**

Tentative Interim Amendment

# NFPA® 70®

## *National Electrical Code®*

### 2023 Edition

**Reference:** 555.35
**TIA 23-6**
*(SC 22-8-23 / TIA Log #1660)*

**Note:** Text of the TIA was issued and approved for incorporation into the document prior to printing.

*1. Revise paragraph 555.35 to read as follows:*

**555.35 Ground-Fault Protection of Equipment (GFPE) and Ground-Fault Circuit Interrupter.** For other than floating buildings, ground-fault protection for docking facilities shall be provided in accordance with 555.35(A) through (~~F~~D).

~~**(A) Sources Directly Supplying Docking Facilities or Wharfs.** Listed GFPE, rated not more than 100 milliamperes, shall be provided for sources directly supplying all docking facilities or wharfs. Coordination with downstream GFPE shall be permitted.~~

**(~~B~~A) Feeder.** …

*Exception: Transformer secondary conductors of a separately derived system that do not exceed 3 m (10 ft) and are installed in a raceway shall be permitted to be installed without ground-fault protection. This exception shall also apply to the supply terminals of the equipment supplied by the transformer secondary conductors.*

**(~~C~~B) Branch-Circuits.**

**(1) Receptacles Providing Shore Power.** …

**(2) Outlets for Other than Shore Power.** Outlets supplied by branch circuits not exceeding 150 volts to ground and 60 amperes, single phase, and 150 volts or less to ground, 100 amperes or less, three phase, shall be provided with GFCI protection for personnel.

*Exception to (~~C~~B): Low-voltage circuits not requiring grounding, not exceeding the low-voltage contact limit and supplied by listed transformers or power supplies that comply with 680.23(A)(2) shall be permitted to be installed without ground-fault protection.*

**(~~D~~C) Boat Hoists.** …

**(~~E~~D) Leakage Current Measurement Device.** …

Informational Note No. 1: …

Informational Note No. 2: …

*Exception: Where the shore power equipment includes a leakage indicator and leakage alarm, a separate leakage test device shall not be required.*

**Issue Date:** August 12, 2022

**Effective Date:** September 1, 2022

**(Note: For further information on NFPA Codes and Standards, please see www.nfpa.org/docinfo)**

Tentative Interim Amendment

# NFPA® 70®

## *National Electrical Code®*

## 2023 Edition

**Reference:** 555.30
**TIA 23-5**
*(SC 22-8-22 / TIA Log #1659)*

**Note:** Text of the TIA was issued and approved for incorporation into the document prior to printing.

*1. Revise paragraph 555.30 to read as follows:*

**555.30 Electrical Equipment and Connections.**

**(A) General.** All electrical components within electrical equipment (excluding wiring methods) and connections not intended for operation while submerged shall be located at least 305 mm (12 in.) above the deck of a fixed or floating structure, but not below the electrical datum plane. Conductor splices, within junction boxes identified for wet locations, utilizing sealed wire connector systems listed and identified for submersion shall be required for floating structures where located above the waterline but below the electrical datum plane.

**(B) Replacements.** …

**Issue Date:** August 12, 2022

**Effective Date:** September 1, 2022

**(Note: For further information on NFPA Codes and Standards, please see www.nfpa.org/docinfo)**

Tentative Interim Amendment

# NFPA® 70®

## *National Electrical Code®*

## 2023 Edition

**Reference:** 215.15
**TIA 23-4**
*(SC 22-8-18 / TIA Log #1655)*

**Note:** Text of the TIA was issued and approved for incorporation into the document prior to printing.

*1. Revise paragraph 215.15 to read as follows:*

**215.15 Barriers.** Barriers shall be placed such that no energized, uninsulated, ungrounded busbar or terminal is exposed to inadvertent contact by persons or maintenance equipment while servicing load terminations in panelboards, switchboards, switchgear, or motor control centers supplied by feeder taps in 240.21(B) or transformer secondary conductors in 240.21(C) when the disconnecting device, to which the tap conductors are terminated, is in the open position.

**Issue Date:** August 12, 2022

**Effective Date:** September 1, 2022

**(Note: For further information on NFPA Codes and Standards, please see www.nfpa.org/docinfo)**

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# NFPA® 70®

## *National Electrical Code®*

## 2023 Edition

**Reference:** 210.8(F) and Exception No. 2(new)
**TIA 23-3**
*(SC 22-8-17 / TIA Log #1654)*

**Note:** Text of the TIA was issued and approved for incorporation into the document prior to printing.

*1. Revise paragraph 210.8(F) to read as follows:*

**210.8(F) Outdoor Outlets.**
For dwellings, all outdoor outlets, other than those covered in 210.8(A), Exception No. 1, including outlets installed in the following locations, and supplied by single-phase branch circuits rated 150 volts or less to ground, 50 amperes or less, shall be provided with GFCI protection:

(1) Garages that have floors located at or below grade level
(2) Accessory buildings
(3) Boathouses

If equipment supplied by an outlet covered under the requirements of this section is replaced, the outlet shall be supplied with GFCI protection.
*Exception No. 1: GFCI protection shall not be required on lighting outlets other than those covered in 210.8(C).*
*Exception No. 2: GFCI protection shall not be required for listed HVAC equipment. This exception shall expire September 1, 2026.*

**Issue Date:** August 12, 2022

**Effective Date:** September 1, 2022

**(Note: For further information on NFPA Codes and Standards, please see www.nfpa.org/docinfo)**



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# NFPA® 70®

## *National Electrical Code®*

### 2023 Edition

**Reference:** Article 100 (Ignitible Fibers/Flyings), 506.5, and 506.9(B)
**TIA 23-2**
*(SC 22-4-8 / TIA Log #1617)*

**Note:** Text of the TIA was issued and approved for incorporation into the document prior to printing.

*1. Revise Article 100 Ignitible Fibers/Flyings to read as follows:*

**Ignitible Fibers/Flyings.** Fibers/flyings where any dimension is greater than 500 µm in nominal size, which are not likely to be in suspension in quantities to produce an explosible mixture, but could produce an ignitible layer fire hazard. [**499:**3.3.4.2]

Informational Note No.1: This definition and Informational Note No. 2 have been extracted from NFPA 499-2021, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas.* The NFPA 499 reference is in brackets. Only editorial changes were made to the extracted text to make it consistent with this *Code.*

Informational Note No. 2: Section 500.5 of this *Code* prescribes a Class III location as one where ignitible fibers/flyings are present, but not likely to be in suspension in the air in quantities sufficient to produce ignitible mixtures. This description addresses fibers/flyings that do not present a flash-fire hazard or explosion hazard by test. This could be because those fibers/flyings are too large or too agglomerated to be suspended in air in sufficient concentration, or at all, under typical test conditions. Alternatively, this could be because they burn so slowly that, when suspended in air, they do not propagate combustion at any concentration. In this document the zone classification system includes ignitible fibers/flyings as a fire hazard in a layer, which is not addressed in the IEC zone system (see IEC 60079-10-2, *Explosive atmospheres — Part 10-2: Classification of areas — Explosive dust atmospheres*). Where these are present, the user could also consider installation in accordance with Article 503 of this *Code.* [**499:**A.3.3.4.2]

*2. Revise Section 506.5 to read as follows:*

**506.5 Classification of Locations.**

**(A) Classifications of Locations. …**

**(B) Zone 20, Zone 21, and Zone 22 Locations. …**

**(1) Zone 20.** A Zone 20 location is a location where one of the following apply:

(1) Ignitible concentrations of combustible dust, ~~or~~ combustible fibers/flyings, or ignitible fibers/flyings are present continuously or for long periods of time.

…

**(2) Zone 21. …**

**(3) Zone 22.** A Zone 22 location is a location where one of the following apply:

(1) …

(2) Combustible dust, combustible fibers/flyings, or ignitible fibers/flyings are handled, processed, or used…

(3) …

*3. Revise Section 506.9(B) to read as follows:*

**506.9 Equipment Requirements.**

**…**

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**(B) Listing.** Equipment that is listed for Zone 20 shall be permitted in a Zone 21 or Zone 22 location of the same combustible dust, combustible fiber/flying, or ignitible fiber/flying. Equipment that is listed for Zone 21 ~~can be used~~ shall be permitted in a Zone 22 location of the same combustible dust, combustible fiber/flying, or ignitible fiber/flying.

**Issue Date:** April 12, 2022

**Effective Date:** May 2, 2022

**(Note: For further information on NFPA Codes and Standards, please see** www.nfpa.org/docinfo**)**



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# NFPA® 70®

## *National Electrical Code®*

### 2023 Edition

**Reference:** 680.43, Exception No. 3
**TIA 23-16**
*(SC 24-12-6 / TIA Log #1800)*

Pursuant to Section 5 of the NFPA *Regulations Governing the Development of NFPA Standards*, the National Fire Protection Association has issued the following Tentative Interim Amendment to NFPA 70®, *National Electrical Code®*, 2023 edition. The TIA was processed by the NEC Code-Making Panel 17, and the Correlating Committee on National Electrical Code, and was issued by the Standards Council on December 4, 2024, with an effective date of December 24, 2024.

*1. Delete Exception No. 3 of 680.43 as follows:*

**680.43 Indoor Installations.** A spa or hot tub installed indoors shall comply with the provisions of Parts I and II of this article except as modified by this section and shall be connected by the wiring methods of Chapter 3.

*Exception No. 1: Listed spa and hot tub …*

*Exception No. 2: The equipotential bonding …*

~~*Exception No. 3: For a dwelling unit(s) only, where a listed spa or hot tub is installed indoors, the wiring method requirements of 680.42(C) shall also apply.*~~

**Issue Date:** December 4, 2024

**Effective Date:** December 24, 2024

**(Note: For further information on NFPA Codes and Standards, please see www.nfpa.org/docinfo)**



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# NFPA® 70®

## *National Electrical Code®*

### 2023 Edition

**Reference:** 210.70
**TIA 23-15**
*(SC 23-11-10/ TIA Log #1753)*

Pursuant to Section 5 of the NFPA *Regulations Governing the Development of NFPA Standards*, the National Fire Protection Association has issued the following Tentative Interim Amendment to NFPA 70®, *National Electrical Code®*, 2023 edition. The TIA was processed by the NEC Code-Making Panel 2, and the Correlating Committee on National Electrical Code and was issued by the Standards Council on November 30, 2023, with an effective date of December 20, 2023.

*1. Revise section 210.70 to read as follows:*

**210.70 Lighting Outlets Required.** Lighting outlets shall be installed where specified in 210.70(A), (B), and (C). The switch or listed wall-mounted control device shall not rely exclusively on ~~a~~ battery power unless ~~a~~ it incorporates a positive means of notification of impending battery depletion. ~~is provided for automatically energizing the lighting outlets upon battery failure.~~



**Issue Date:** November 30, 2023

**Effective Date:** December 20, 2023



**(Note: For further information on NFPA Codes and Standards, please see www.nfpa.org/docinfo)**

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# NFPA® 70®

## *National Electrical Code*®

## 2023 Edition

**Reference:** 517.30(B)(3)(a)
**TIA 23-14**
*(SC 23-11-9 / TIA Log #1752)*

Pursuant to Section 5 of the NFPA *Regulations Governing the Development of NFPA Standards*, the National Fire Protection Association has issued the following Tentative Interim Amendment to NFPA 70®, *National Electrical Code*®, 2023 edition. The TIA was processed by the NEC Code-Making Panel 15, and the Correlating Committee on National Electrical Code and was issued by the Standards Council on November 30, 2023, with an effective date of December 20, 2023.

*1. Revise section 517.30(B)(3)(a) to read as follows:*

**517.30(B)(3) Fuel Cell Systems.** Fuel cell systems shall be permitted to serve as the alternate power source for all or part of an EES. [**99:**6.7.1.5.1]

(a) Installation of fuel cells shall comply with the requirements in Parts I through VI ~~VII~~ of Article 692~~ for 1000 volts or less and Part VIII for over 1000 volts~~.

**Issue Date:** November 30, 2023

**Effective Date:** December 20, 2023

**(Note: For further information on NFPA Codes and Standards, please see www.nfpa.org/docinfo)**



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# NFPA® 70®

## *National Electrical Code®*

### 2023 Edition

**Reference:** 400.47
**TIA 23-13**
*(SC 23-8-57 / TIA Log #1731)*

Pursuant to Section 5 of the NFPA *Regulations Governing the Development of NFPA Standards*, the National Fire Protection Association has issued the following Tentative Interim Amendment to NFPA 70®, *National Electrical Code*®, 2023 edition. The TIA was processed by Code-Making Panel 6 and the Correlating Committee on National Electrical Code, and was issued by the Standards Council on August 25, 2023, with an effective date of September 14, 2023.

*1. Revise section 400.47 to read as follows:*

> **400.47. ~~Minimum~~ Conductor Bending ~~Radii~~ Radius**. ~~The minimum bending radii for~~ P~~p~~ortable power feeder cables rated from 2000 volts to 5000 volts shall not ~~exceed~~ be bent to a radius less than six times the overall cable outer diameter. ~~The minimum bending radii for~~ P~~p~~ortable power feeder cables rated from 5001 volts to 25,000 volts shall not ~~exceed~~ be bent to a radius less than eight~~-~~times the overall cable outer diameter.





**Issue Date:** August 25, 2023

**Effective Date:** September 14, 2023

**(Note: For further information on NFPA Codes and Standards, please see www.nfpa.org/docinfo)**

Tentative Interim Amendment

# NFPA® 70®

## *National Electrical Code®*

### 2023 Edition

**Reference:** 408.6
**TIA 23-12**
*(SC 23-8-56 / TIA Log #1699)*

Pursuant to Section 5 of the NFPA *Regulations Governing the Development of NFPA Standards*, the National Fire Protection Association has issued the following Tentative Interim Amendment to NFPA 70®, *National Electrical Code®*, 2023 edition. The TIA was processed by Code-Making Panel 9 and the Correlating Committee on National Electrical Code, and was issued by the Standards Council on August 25, 2023, with an effective date of September 14, 2023.

*1. Revise 408.6 to read as follows:*

**408.6 Short-Circuit Current Rating.** Switchboards, switchgear, and panelboards shall have a short-circuit current rating not less than the available fault current. In other than one- and two-family dwelling units, the available fault current and the date the calculation was performed shall be field marked on the enclosure at the point of supply. The marking shall be of sufficient durability to withstand the environment involved. ~~comply with 110.21(B)(3).~~

**Issue Date:** August 25, 2023

**Effective Date:** September 14, 2023

**(Note: For further information on NFPA Codes and Standards, please see www.nfpa.org/docinfo)**

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# NFPA® 70®

## *National Electrical Code®*

### 2023 Edition

**Reference:** 700.32(C), 701.32(C), and 708.54(C)
**TIA 23-11**
*(SC 23-8-54 / TIA Log #1692)*

Pursuant to Section 5 of the NFPA *Regulations Governing the Development of NFPA Standards*, the National Fire Protection Association has issued the following Tentative Interim Amendment to NFPA 70®, *National Electrical Code®*, 2023 edition. The TIA was processed by Code-Making Panel 13 and the Correlating Committee on National Electrical Code, and was issued by the Standards Council on August 25, 2023, with an effective date of September 14, 2023.

*1. Revise 700.32(C) Informational Note and title of Figure for the Informational Note to read as follows:*

**700.32 Selective Coordination.**

**700.32(A) General.** Emergency system(s) overcurrent protective devices (OCPDs) shall be selectively coordinated with all supply-side and load-side OCPDs.

Selective coordination shall be selected by a licensed professional engineer or other qualified persons engaged primarily in the design, installation, or maintenance of electrical systems. The selection shall be documented and made available to those authorized to design, install, inspect, maintain, and operate the system.

**700.32(B) Replacements.** Where emergency system(s) OCPDs are replaced, they shall be reevaluated to ensure selective coordination is maintained with all supply-side and load-side OCPDs.

**700.32(C) Modifications.** If modifications, additions, or deletions to the emergency system(s) occur, selective coordination of the emergency system(s) OCPDs with all supply-side and load-side OCPDs shall be reevaluated.

*Exception: Selective coordination shall not be required between two overcurrent devices located in series if no loads are connected in parallel with the downstream device.*

Informational Note: See Informational Note Figure 700.32~~(C)~~ for an example of how emergency system OCPDs selectively coordinate with all supply-side OCPDs.

~~OCPD D selectively coordinates with OCPDs C, F, E, B, and A.~~
~~OCPD C selectively coordinates with OCPDs F, E, B, and A.~~
~~OCPD F selectively coordinates with OCPD E.~~
~~OCPD B is not required to selectively coordinate with OCPD A because OCPD B is not an emergency system OCPD.~~

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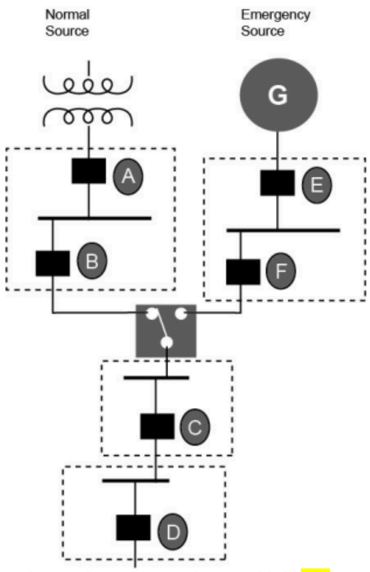


**Informational Note Figure 700.32~~(C)~~ Emergency System Selective Coordination.**
OCPD D selectively coordinates with OCPDs C, F, E, B, and A.
OCPD C selectively coordinates with OCPDs F, E, B, and A.
OCPD F selectively coordinates with OCPD E.
OCPD B is not required to selectively coordinate with OCPD A because OCPD B is not an emergency system OCPD.

*2. Revise 701.32(C) Informational Note and title of Figure for the Informational Note to read as follows:*

**701.32 Selective Coordination.**

**701.32(A) General.** Legally required standby system(s) overcurrent protective devices (OCPDs shall be selectively coordinated with all supply-side and load-side OCPDs.

Selective coordination shall be selected by a licensed professional engineer or other qualified persons engaged primarily in the design, installation, or maintenance of electrical systems. The selection shall be documented and made available to those authorized to design, install, inspect, maintain, and operate the system.

**701.32(B) Replacements.** Where legally required standby OCPDs are replaced, they shall be reevaluated to ensure selective coordination is maintained with all supply-side and load-side OCPDs.

**701.32(C) Modifications.** If modifications, additions, or deletions to the legally required standby system(s) occur, selective coordination of the legally required system(s) OCPDs with all supply-side and load-side OCPDs shall be reevaluated.

*Exception: Selective coordination shall not be required between two overcurrent devices located in series if no loads are connected in parallel with the downstream device.*

Informational Note: See Informational Note Figure 701.32~~(C)~~ for an example of how legally required standby system OCPDs selectively coordinate with all supply-side OCPDs.

~~OCPD D selectively coordinates with OCPDs C, F, E, B, and A.~~
~~OCPD C selectively coordinates with OCPDs F, E, B, and A.~~
~~OCPD F selectively coordinates with OCPD E.~~
~~OCPD B is not required to selectively coordinate with OCPD A because OCPD B is not a legally required standby system OCPD.~~

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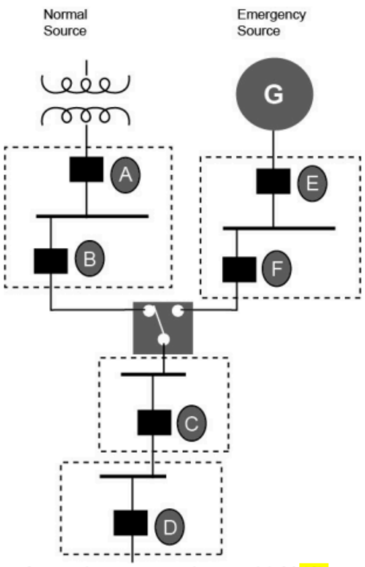



**Informational Note Figure 701.32~~(C)~~ Legally Required Standby System Selective Coordination.**
<u>OCPD D selectively coordinates with OCPDs C, F, E, B, and A.</u>
<u>OCPD C selectively coordinates with OCPDs F, E, B, and A.</u>
<u>OCPD F selectively coordinates with OCPD E.</u>
<u>OCPD B is not required to selectively coordinate with OCPD A because OCPD B is not a legally required standby system OCPD.</u>

*3. Revise 708.54(C) Informational Note and title of Figure for the Informational Note to read as follows:*

**708.54(A) General.** Critical operations power system(s) overcurrent protective devices (OCPDs) shall be selectively coordinated with all supply-side and load-side OCPDs.

Selective coordination shall be selected by a licensed professional engineer or other qualified persons engaged primarily in the design, installation, or maintenance of electrical systems. The selection shall be documented and made available to those authorized to design, install, inspect, maintain, and operate the system.

**708.54(B) Replacements.** Where critical operations power system(s) OCPDs are replaced, they shall be reevaluated to ensure selective coordination is maintained with all supply-side and load-side OCPDs.

**708.54(C) Modifications.** If modifications, additions, or deletions to the critical operations power system(s) occur, selective coordination of the critical operations power system(s) OCPDs with all supply-side and load-side OCPDs shall be reevaluated.

*Exception: Selective coordination shall not be required between two overcurrent devices located in series if no loads are connected in parallel with the downstream device.*

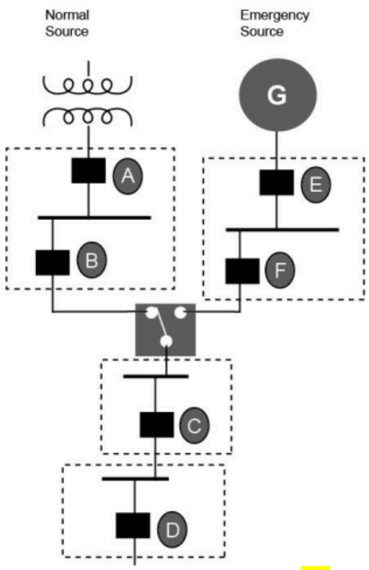
Informational Note: See Informational Note Figure 708.54~~(C)~~ for an example of how critical operations power system OCPDs selectively coordinate with all supply-side OCPDs.

~~OCPD D selectively coordinates with OCPDs C, F, E, B, and A.~~
~~OCPD C selectively coordinates with OCPDs F, E, B, and A.~~
~~OCPD F selectively coordinates with OCPD E.~~
~~OCPD B is not required to selectively coordinate with OCPD A because OCPD B is not a critical operations power system OCPD.~~

Page: 3

Mod_12027_Text_TIA 23-11.pdf

M12027Text Modification




**Informational Note Figure 708.54~~(C)~~ Critical Operations Power System Selective Coordination.**
OCPD D selectively coordinates with OCPDs C, F, E, B, and A.
OCPD C selectively coordinates with OCPDs F, E, B, and A.
OCPD F selectively coordinates with OCPD E.
OCPD B is not required to selectively coordinate with OCPD A because OCPD B is not a critical operations power system OCPD.

**Issue Date:** August 25, 2023

**Effective Date:** September 14, 2023

**(Note: For further information on NFPA Codes and Standards, please see www.nfpa.org/docinfo)**



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Mod_12027_Text_TIA 23-11.pdf

M12027Text Modification

NFPA

Tentative Interim Amendment

# NFPA® 70®

## *National Electrical Code®*

### 2023 Edition

**Reference:** 314.29(A)
**TIA 23-10**
*(SC 23-3-10 / TIA Log #1690)*

Pursuant to Section 5 of the NFPA *Regulations Governing the Development of NFPA Standards*, the National Fire Protection Association has issued the following Tentative Interim Amendment to NFPA 70®, *National Electrical Code®*, 2023 edition. The TIA was processed by the NEC Code-Making Panel 9 and the NEC Correlating Committee, and was issued by the Standards Council on March 21, 2023, with an effective date of April 10, 2023.

*1. Revise paragraph 314.29(A) to read as follows:*

**314.29 Boxes, Conduit Bodies, and Handhole Enclosures to Be Accessible.** Boxes, conduit bodies, and handhole enclosures shall be installed so that wiring and devices contained in the boxes, conduit bodies, or handhole enclosures can be rendered accessible in accordance with 314.29(A) and (B).

**(A) In Buildings and Other Structures.** Boxes and conduit bodies shall be installed so the contained wiring and devices are accessible. Boxes and conduit bodies that are recessed into or behind finished surfaces of buildings shall have access to their internal contents maintained by openings in their covers and in the building finish that comply with 314.29(A)(1), (A)(2), or (A)(3) as applicable. Removable finished covers and faceplates that maintain this access shall be permitted.

**(1) Boxes 1650 cm³ (100 in.³) or Less in Size.** The openings in the building surfaces, if reduced from the outer walls of the box, shall be centered not more than 25 mm (1 in.) from the centerline of the box, and shall not extend beyond the walls of the box. If rectangular, the opening shall be not less than 73 mm (2 7/8 in.) by 45 mm (1 3/4 in.) in size. If circular, the opening shall not be less than 90 mm (3½ in.) in diameter.

*Exception: Smaller openings in building surfaces that accommodate one or more individual devices shall be permitted if all of the following conditions are met:*

*(1) The outlet box that supplies the device(s) is nonmetallic.*
*(2) The branch circuit wiring that supplies each device consists of a separate nonmetallic cable assembly originating outside the box, or individual sets of conductors in a single nonmetallic raceway, all of which originate outside the box. Other than the connections to a single device, these conductors are not spliced in the box or continued to another device, and no other wiring or raceways enter the box.*
*(3) Each device is capable of removal from the building surface opening without being damaged. If a special tool is required for this purpose, the applicable circuit directory for the device records the location of the tool, together with a product code/QR code for acquiring a replacement if necessary.*
*(4) All connections for each device to the branch circuit wiring are made with listed clamping-type wire connectors, which are supplied with the devices. The branch-circuit conductors are arranged to permit the connector(s) to be exposed after the device has been fully removed.*
*(5) The device assemblies are listed for this application.*

**(2) Boxes Larger Than 1650 cm³ (100 in.³) in Size.** The openings shall not be smaller than the outer walls of the box.
**(3) Conduit Bodies.** The openings shall not be smaller than outer walls of the conduit body.
**(B) Underground.** Underground boxes and handhole enclosures shall be installed …

Page: 1

Mod_12027_Text_TIA 23-10.pdf

**Issue Date:** March 21, 2023

**Effective Date:** April 10, 2023

M12027Text Modification

Tentative Interim Amendment

# NFPA® 70®

## *National Electrical Code®*

## 2023 Edition

**Reference:** 250.114(3)e and 250.114(4)e
**TIA 23-1**
*(SC 21-12-13 / TIA Log #1608)*

**Note:** Text of the TIA was issued and approved for incorporation into the document prior to printing.

*1. Revise 250.114(3)e and (4)e to read as follows:*

**250.114 Equipment Connected by Cord and Plug.** Exposed, normally non-current-carrying metal parts of cord-and-plug-connected equipment shall be connected to the equipment grounding conductor under any of the following conditions:

…

(3) In residential occupancies:

…

e. Portable handlamps ~~and portable luminaires~~

(4) In other than residential occupancies:

…

e. Portable handlamps ~~and portable luminaires~~

…

**Issue Date:** December 8, 2021

**Effective Date:** December 28, 2021

**(Note: For further information on NFPA Codes and Standards, please see www.nfpa.org/docinfo)**



Mod_12027_Text_TIA 23-1.pdf Page: 1

# TAC: Mechanical

Total Mods for **Mechanical** in **Pending Review : 20**

Total Mods for report: 20

## Sub Code: Mechanical

### M12148

11

| | | | | | |
|---|---|---|---|---|---|
| **Date Submitted** | 02/14/2025 | **Section** | 0 | **Proponent** | Amanda Hickman |
| **Chapter** | 15 | **Affects HVHZ** | No | **Attachments** | Yes |
| **TAC Recommendation** | Pending Review | | | | |
| **Commission Action** | Pending Review | | | | |

**Comments**

**General Comments No** **Alternate Language No**

### Related Modifications

12145, 12146, 12147

### Summary of Modification

Updates code to permit A2L products.

### Rationale

As of January 1st, 2025, federal regulations prohibit the manufacturing of R-410A and other high-Global Warming potential (GWP) refrigerants. With the change to Low GWP Refrigerants, the Mechanical Code needs to be updated to address the use of Group A2L refrigerants in high probability (direct) systems. All of the commonly used Low GWP replacement refrigerants for direct systems fall into the category of Group A2L in the 2022 edition of ASHRAE 34. The safety requirements in ASHRAE 15 address the concerns regarding the use of a mildly flammable refrigerant. There are provisions for listing of equipment, installation of refrigerant detectors, and ventilation to mitigate any leak of refrigerant. By referencing ASHRAE 15 directly, the requirements become an enforceable part of the code. ASHRAE 15 requires an A2L appliance or equipment to be listed to UL/CSA 60335-2-40-2022 or UL/CSA 60335-2-89-2021 or newer editions. Failure to update the code could result in not having air conditioning and refrigeration products that are allowed to be used in Florida. Manufacturers are transitioning away from UL 1995 to UL 60335-2-40 and UL 60335-2-89 because UL 1995 will be sunsetting in the year 2024. The 4th edition of UL 60335-2-40 was published December 2022 and the 2nd edition of UL 60335-2-89 was published in October of 2021. Both of these standards have many new requirements for electrical and refrigerant safety. Nationally Recognized Testing Laboratories (or NRTLs) will use the latest version of the appropriate safety standard for certification testing. Reference to the latest editions of both standards included in this proposal are as issued by ICC in the 2024 IMC.

### Fiscal Impact Statement

**Impact to local entity relative to enforcement of code**

Will assist code enforcement regarding A2L products.

**Impact to building and property owners relative to cost of compliance with code**

These code changes will not increase the cost of construction, they only grant permission to use A2L products. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

**Impact to industry relative to the cost of compliance with code**

These code changes will not increase the cost of construction, they only grant permission to use A2L products. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

**Impact to small business relative to the cost of compliance with code**

These code changes will not increase the cost of construction, they only grant permission to use A2L products. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

## Requirements

**Has a reasonable and substantial connection with the health, safety, and welfare of the general public**

Updates code to ensure air conditioning products are permitted in the state of Florida.

**Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction**

Updates code to ensure air conditioning products are permitted in the state of Florida.

**Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities**

No. Only permits the use of A2L products.

**Does not degrade the effectiveness of the code**

No. Only permits the use of A2L products.

M12148Text Modification

See attached PDF.

Mod12148_TextOfModification.pdf Page: 1

M12148Text Modification

Modification # 12148

Chapter 15: Referenced standards

## ASTM

ASTM
International 100
Barr Harbor Drive,
P.O. Box C700
West
Conshohocken,
PA 19428

| | |
|---|---|
| **A333-18** | **Standard Specification for Seamless and Welded Steel Pipe for Low-Temperature Service and other Applications with required Notch Toughness** |

## UL

UL LLC
333 Pfingsten Road
Northbrook, IL 60062-2096

| | |
|---|---|
| **UL/CSA 60335-2-40—~~2019~~ 2022** | **Household and Similar Electrical Appliances—Safety—Part 2-40: Particular Requirements for Electrical Heat Pumps, Air-Conditioners and Dehumidifiers~~– 3rd Edition~~ 4th Edition** |
| **UL/CSA 60335-2-89—~~2017~~ 2021** | **Household and Similar Electrical Appliances—Safety—Part 2-89: Particular Requirements for Commercial Refrigerating Appliances with an Incorporated or Remote Refrigerant Unit or Compressor, 2nd Edition** |

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Mod_12148_Text_12148.pdf

# TAC: Mechanical

Total Mods for **Mechanical** in **Pending Review : 20**

Total Mods for report: 20

## Sub Code: Residential

### CA11777

12

| | | | | | |
|---|---|---|---|---|---|
| **Date Submitted** | 01/18/2025 | **Section** | 101.1 | **Proponent** | Greg Burke |
| **Chapter** | 1 | **Affects HVHZ** | No | **Attachments** | No |
| **TAC Recommendation** | Pending Review | | | | |
| **Commission Action** | Pending Review | | | | |

**Comments**

**General Comments No** **Alternate Language No**

#### Related Modifications

FBCR302 FBCB901.6.1 FBCB901.6.2 FBCB903.3.1.3 FBCB907.6.6 FBCEx505.2 FBCEx505.3 FBCEx702.4 FBCEx702.5 FBCFG101.2

#### Summary of Modification

Adds three- and four- family dwellings to the scope.

#### Rationale

Housing and skilled labor is at a crisis point in the United States. Demand is outpacing supply in a critical way. To entice development and local authorities in providing more options for first time buyers or those who are wishing to down-size, the scope change will enable an opportunity for choice, Moving these two dwelling types into the FBC,R allows construction in an equivalent manner to single-, two-family, and townhouses buildings. More cost savings can come in the form of reduced egress requirements. Single exits could be required that would have stairs meet the riser/tread dimensions reduced from the commercial maximum requirement to the residential requirements for treads and risers. In Occupancy Group R2, under the FBC,B live load will be reduced to 40 psf from the commercial requirement of 100 psf. Other sections of the FBC,R may allow for potential for smaller HVAC units. Financial institutions finance these two types of dwelling units as single-family homes. It is not until a building has five or more residential units that the financing is a commercial loan. For this reason alone, three-family, and four-family dwelling units should be included in the FBC,R. It is possible to purchase these dwellings with an FHA Loan. Realtors in Florida are also permitted to sell up to four units on a residential license. With proper zoning, three-family and four-family dwelling units can be designed and constructed to be compatible in single-family neighborhoods. Most can be constructed within a 35-foot height limit, common in many parts of the state. Normally, three-family, and four-family dwellings are two, two and one-half or three stories above the grade plane making them compatible with a single-family or two-family home. The footprint of either a three- or a four-family building could be designed and constructed in dimensions of forty feet by sixty feet.

#### Fiscal Impact Statement

**Impact to local entity relative to enforcement of code**

The less restrictive application of a residential code souldlessen the burden on enforcement.

**Impact to building and property owners relative to cost of compliance with code**

Less expensive construction and sales cost.

**Impact to industry relative to the cost of compliance with code**

None

**Impact to small business relative to the cost of compliance with code**

May provide more opportunity for small developers and contractors.

## Requirements

**Has a reasonable and substantial connection with the health, safety, and welfare of the general public**

The design of three- and four-family dwelligs are similar in nature to a duplex. As such the dgree of health, safety and elfare is enhanced by admitting these two dwelling types to the residential code.

**Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction**

The modification is in line with industry standards for financing and sales.

**Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities**

No.

**Does not degrade the effectiveness of the code**

No.

CA11777Text Modification

**FBC,B 101.2 Scope.**

The provisions of the *Florida Building Code, Residential* shall apply to the construction, alteration, movement, enlargement, replacement, repair, equipment, use and occupancy, removal, and demolition of detached one-, ~~and~~ two-, three- and four- family dwellings and *townhouses* not more than three stories above *grade plane* in height with a separate means of egress and their *accessory structures* not more than three stories above *grade plane* in height.

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Mod11777_TextOfModification.pdf

# TAC: Mechanical

Total Mods for **Mechanical** in **Pending Review : 20**

Total Mods for report: 20

## Sub Code: Residential

### M12181

13

| | | | | | |
|---|---|---|---|---|---|
| **Date Submitted** | 02/16/2025 | **Section** | 1307.3.1 | **Proponent** | Joseph Belcher |
| **Chapter** | 13 | **Affects HVHZ** | Yes | **Attachments** | No |
| **TAC Recommendation** | Pending Review | | | | |
| **Commission Action** | Pending Review | | | | |

**Comments**

**General Comments No** **Alternate Language No**

#### Related Modifications

#### Summary of Modification

Modifies appliance protection in dwelling garage

#### Rationale

This change is a clarification intended to incorporate a longtime standard practice for providing appliance protection in dwelling garages. This is not a life safety but a property protection issue. While a three-inch difference in elevation will not stop a car from moving at high speed, it will provide protection for normal situations. The code cannot be written to protect people from all possible situations. This change will provide code enforcement with some needed guidelines. We encountered one situation where a jurisdiction required barriers as required for ramps in commercial parking garages to protect an electric washer and dryer. The plan reviewer stated there was no guidance except in commercial parking garages. Fortunately, common sense prevailed, and the building official accepted the change in elevation as adequate protection.

#### Fiscal Impact Statement

**Impact to local entity relative to enforcement of code**

None.

**Impact to building and property owners relative to cost of compliance with code**

None as this has been standard practice for many years. In the event a jurisdiction is requiring barriers there would be a reduction in cost.

**Impact to industry relative to the cost of compliance with code**

None as this has been standard practice for many years. In the event a jurisdiction is requiring barriers there would be a reduction in cost.

**Impact to small business relative to the cost of compliance with code**

None as this has been standard practice for many years. In the event a jurisdiction is requiring barriers there would be a reduction in cost.

#### Requirements

**Has a reasonable and substantial connection with the health, safety, and welfare of the general public**

: Improves the welfare of the public by providing guidance for adequate protection of electric appliances located in a dwelling garage

**Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction**

Strengthens the code by providing guidance for adequate protection of electric appliances located in a dwelling garage .

**Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities**

The change does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities.

**Does not degrade the effectiveness of the code**

The proposed change does not degrade the effectiveness of the code and improves the effectiveness of the code.

M12181Text Modification

**M1307.3.1 Protection from impact.** *Appliances* shall not be installed in a location subject to vehicle damage except where protected by *approved* barriers.

> **Exception:** Appliances not using a flammable or combustible fuel in garages located a minimum 3 inches above the garage floor by means of a step or change in garage floor elevation shall not be required to provide barriers.

# TAC: Mechanical

Total Mods for **Mechanical** in **Pending Review : 20**

Total Mods for report: 20

## Sub Code: Residential

### M11776

14

| | | | | | |
|---|---|---|---|---|---|
| **Date Submitted** | 01/17/2025 | **Section** | 1411.3.2 | **Proponent** | Rolando Soto |
| **Chapter** | 14 | **Affects HVHZ** | No | **Attachments** | Yes |
| **TAC Recommendation** | Pending Review | | | | |
| **Commission Action** | Pending Review | | | | |

**Comments**

**General Comments No** **Alternate Language No**

### Related Modifications

Modification # 11775 proposes similar language to the FMC Section 307.2.2.

### Summary of Modification

This proposed modification clarifies the code regarding the insulation of condensate piping. Insulating the condensate piping is a common practice but it is not clearly mandated in the codes.

### Rationale

Uninsulated condensate piping carries a cold fluid, condensate water from cooling coils. The moisture that is present in unconditioned spaces condensates on the pipes exterior surface and can drip onto walls and ceilings. This drip can cause water damage and or support the grows of mold inside the building.

### Fiscal Impact Statement

**Impact to local entity relative to enforcement of code**

No impact to local government relative to enforcement. Condensate piping inspection are already part of the inspection for air conditioning or refrigeration installation permits.

**Impact to building and property owners relative to cost of compliance with code**

Minimal impact. Insulating the condensate piping is common. Pipe insulation is relatively inexpensive. Attached is the retail cost of one of the more common insulation sizes. Uninsulated pipes can do water damage, that expensive to repair, and cause disruption in building use.

**Impact to industry relative to the cost of compliance with code**

Minimal impact. Insulating the condensate piping is common. Pipe insulation is relatively inexpensive. Attached is the retail cost of one of the more common insulation sizes. Uninsulated pipes can do water damage, that expensive to repair, and cause disruption in building use.

**Impact to small business relative to the cost of compliance with code**

Minimal impact. Insulating the condensate piping is common. Pipe insulation is relatively inexpensive. Attached is the retail cost of one of the more common insulation sizes. Uninsulated pipes can do water damage, that expensive to repair, and cause disruption in building use.

## Requirements

**Has a reasonable and substantial connection with the health, safety, and welfare of the general public**

Uninsulated pipes can do water damage and support the grows of mold inside the building that will negatively affect the health, safety, and welfare of the general public.

**Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction**

The proposed modification strengthens and improves the code by the insulation of condensate piping. Insulating the condensate piping is a common practice but it is not clearly mandated in the codes.

**Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities**

The modification does not mandate a specific type of insulation, only the R value.

**Does not degrade the effectiveness of the code**

The proposed modification does not degrade the effectiveness of the code, it strengthens and improves the code.

M11776Text Modification

M1411.3.2 Drain pipe materials and sizes.
Components of the condensate disposal system shall be ABS, cast iron, copper, cross-linked polyethylene, CPVC, galvanized steel, PE-RT, polyethylene, polypropylene or PVC pipe or tubing. Components shall be selected for the pressure and temperature rating of the installation. Joints and connections shall be made in accordance with the applicable provisions of Chapter 30. Condensate waste and drain line size shall be not less than 3/4-inch (19 mm) nominal diameter from the drain pan connection to the place of condensate disposal. Where the drain pipes from more than one unit are manifolded together for condensate drainage, the pipe or tubing shall be sized in accordance with an approved method. Drain pipes conveying condensate from cooling coils and evaporators shall be insulated with a minimum of R-3 when located inside a building's unconditioned space.

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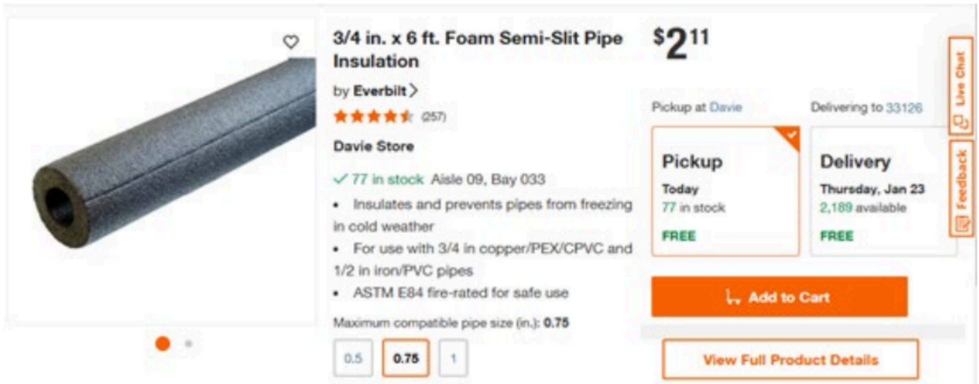
Mod11776_TextOfModification.pdf

M11776Requirements




Page: 1

Mod_11776_Requirements_Insulation cost.pdf

# TAC: Mechanical

Total Mods for **Mechanical** in **Pending Review : 20**

Total Mods for report: 20

## Sub Code: Residential

### M12050

15

| | | | | | |
|---|---|---|---|---|---|
| **Date Submitted** | 02/14/2025 | **Section** | 1412.1 | **Proponent** | Amanda Hickman |
| **Chapter** | 14 | **Affects HVHZ** | No | **Attachments** | No |
| **TAC Recommendation** | Pending Review | | | | |
| **Commission Action** | Pending Review | | | | |

**Comments**

**General Comments No** **Alternate Language No**

#### Related Modifications

yes

#### Summary of Modification

Updates on A2L

#### Rationale

This is one of several code modifications that updates the 9th edition code to reflect the necessary changes to permit the use of A2L refrigerants. As of January 1st, 2025, federal regulations prohibit the manufacturing of R-410A and other high-Global Warming potential (GWP) refrigerants. Manufacturers are transitioning away from UL 1995 to UL 60335-2-40 because UL 1995 will be sunsetting in the year 2024. The 4th edition of UL 60335-2-40 was published December 2022. This standard has many new requirements for electrical and refrigerant safety. Nationally Recognized Testing Laboratories (or NRTLs) will use the latest edition of the safety standard for certification testing. Failure to update the code could result in not having air conditioning products that are allowed to be used in Florida. With the change to Low GWP Refrigerants, the Residential Code needs to be updated to address the use of Group A2L refrigerants. All of the commonly used Low GWP replacement refrigerants for direct systems fall into the category of Group A2L in the 2022 edition of ASHRAE 34. All of these changes are consistent with the 2024 International Residential Code.

#### Fiscal Impact Statement

**Impact to local entity relative to enforcement of code**

Provides clarity to code enforcement with respect to A2L refrigerant permitted use.

**Impact to building and property owners relative to cost of compliance with code**

Ensures equipment will remain available in the state of FL which will ensure cost-effectiveness is maintained. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

**Impact to industry relative to the cost of compliance with code**

Ensures equipment will remain available in the state of FL which will ensure cost-effectiveness is maintained. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

**Impact to small business relative to the cost of compliance with code**

Ensures equipment will remain available in the state of FL which will ensure cost-effectiveness is maintained. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

## Requirements

**Has a reasonable and substantial connection with the health, safety, and welfare of the general public**

Ensures equipment will remain available in the state of FL and provides for lower GWP refrigerants.

**Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction**

Ensures equipment will remain available in the state of FL. GWP refrigerants.

**Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities**

No. Meets industry standards.

**Does not degrade the effectiveness of the code**

No. Improves by updating to federal requirements.

M12050Text Modification

## SECTION M1412—ABSORPTION COOLING EQUIPMENT

**M1412.1 ~~Approval of~~ Listed equipment.** Absorption systems shall be installed in accordance with the manufacturer's instructions. Absorption *equipment* shall ~~comply~~ be *listed* and *labeled* in accordance with UL 1995 or UL/CSA/ANCE 60335-2-40.

Page: 1

Mod12050_TextOfModification.pdf

# TAC: Mechanical

Total Mods for **Mechanical** in **Pending Review : 20**

Total Mods for report: 20

## Sub Code: Residential

### M12105

16

| | | | | | |
|---|---|---|---|---|---|
| **Date Submitted** | 02/14/2025 | **Section** | 1507.4 | **Proponent** | Rolando Soto |
| **Chapter** | 15 | **Affects HVHZ** | No | **Attachments** | Yes |
| **TAC Recommendation** | Pending Review | | | | |
| **Commission Action** | Pending Review | | | | |

**Comments**

**General Comments No** **Alternate Language No**

### Related Modifications

SECTION TABLE 403.3.1.1 MINIMUM VENTILATION RATES Same criteria in the mechanical code would also need change proposed for code consistency.

### Summary of Modification

Toilet/bathroom exhaust fans shall be controlled by a timer switch or rated or listed for continued use.

### Rationale

In 2017, the U. S. Consumer Products Safety Commission (CPSC) did an assessment on exhaust fan fires. They said, "Staff searched the CPSC Injury or Potential Injury Incident (IPII) database for incidents involving exhaust fans for the 20-year period from January 1, 1997 to September 21, 2017. Staff identified 494 known incidents in that period related to permanently installed exhaust fans. The majority of these incidents occurred in residential bathrooms." The results of this assessment pointed strongly toward exhaust fans as the culprit in causing fires. More than 75 percent (318/423) of the known incidents occurred in a bathroom or restroom. The most likely origin of the incident in these cases was the exhaust fan. The incidents ranged in severity from minor smoke to fire spreading through the structure. Of the 318 incidents that occurred in a bathroom or restroom, almost 80 percent (254/318) occurred in a residence.

### Fiscal Impact Statement

**Impact to local entity relative to enforcement of code**
No impact. No new inspections or plan review is required.
**Impact to building and property owners relative to cost of compliance with code**
Time switches retail from around seven dollars and up. See attachments.
**Impact to industry relative to the cost of compliance with code**
Time switches retail from around seven dollars and up. See attachments.
**Impact to small business relative to the cost of compliance with code**
Time switches retail from around seven dollars and up. See attachments.

### Requirements

**Has a reasonable and substantial connection with the health, safety, and welfare of the general public**

Yes. it will provide a safer, less fire prone building.

**Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction**

Yes. Yes. it will provide a safer, less fire prone building.

**Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities**

It does not.

**Does not degrade the effectiveness of the code**

It does not.

M12105Text Modification

**M1507.4 Local exhaust rates.**

*Local exhaust* systems shall be designed to have the capacity to exhaust the minimum air flow rate determined in accordance with Table M1507.4.

**TABLE M1507.4**
**MINIMUM REQUIRED LOCAL EXHAUST RATES FOR ONE- AND TWO-FAMILY DWELLINGS**

| AREA TO BE EXHAUSTED | EXHAUST RATES |
|---|---|
| Kitchens | 100 cfm intermittent or 25 cfm continuous |
| Bathrooms-Toilet Rooms a | Mechanical exhaust capacity of 50 cfm intermittent or 20 cfm continuous |

For SI: 1 cubic foot per minute = 0.0004719 $m^3/s$.

ilet/bathroom exhaust fans shall be controlled by a timer switch. Exception: Fans rated or listed for continued use.

Page: 1

Mod12105_TextOfModification.pdf

SECTION M1507 MECHANICAL VENTILATION

**M1507.4 Local exhaust rates.**
*Local exhaust* systems shall be designed to have the capacity to exhaust the minimum air flow rate determined in accordance with Table M1507.4.

**TABLE M1507.4**
**MINIMUM REQUIRED LOCAL EXHAUST RATES FOR ONE- AND TWO-FAMILY DWELLINGS**

| AREA TO BE EXHAUSTED | EXHAUST RATES |
|---|---|
| Kitchens | 100 cfm intermittent or 25 cfm continuous |
| Bathrooms-Toilet Rooms a | Mechanical exhaust capacity of 50 cfm intermittent or 20 cfm continuous |

For SI: 1 cubic foot per minute = 0.0004719 $m^3/s$.

a. Toilet/bathroom exhaust fans shall be controlled by a timer switch. Exception: Fans rated or listed for continued use.

**From:** Beck, Michael
**To:** Soto, Rolando
**Subject:** FW: Ventilation Bathroom Fan Fires
**Date:** Tuesday, March 21, 2023 11:08:47 AM
**Attachments:** image001.png
image003.jpg
image004.png
image002.png
image005.png
image006.png
image007.png

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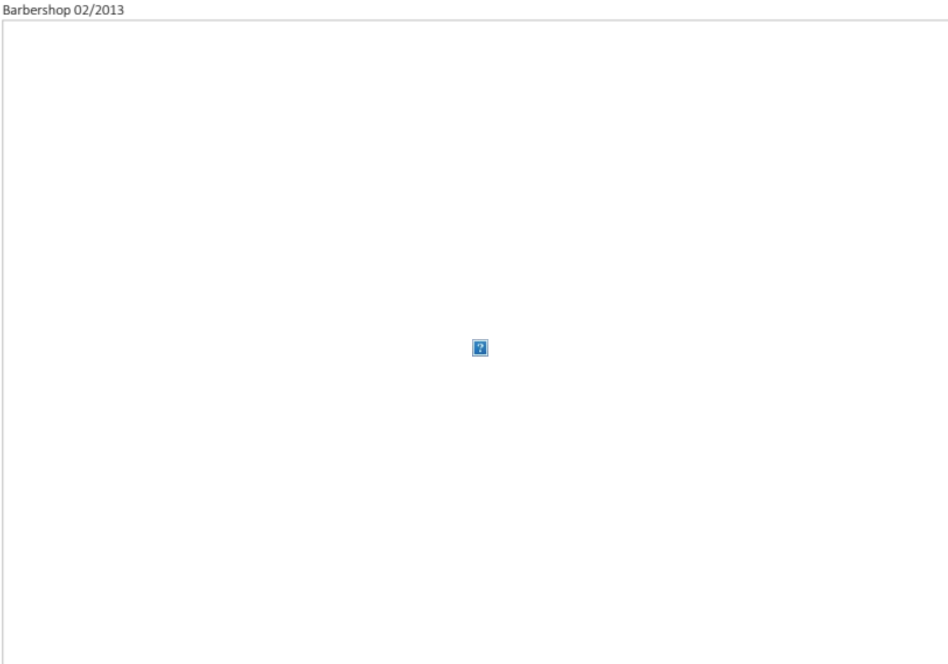
**Sent:** Monday, March 20, 2023 3:38 PM
**To:** Beck, Michael <MBeck@coconutcreek.net>
**Cc:** 'BParks@broward.org' <BParks@broward.org>; rsoto@broward.org
**Subject:** Ventilation Bathroom Fan Fires

Good Afternoon,

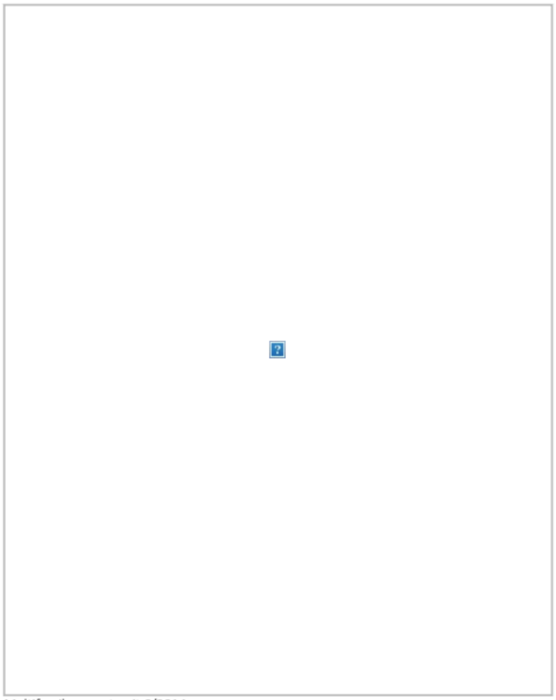
Please see the 5 fires located in bathroom ventilation fans in Coconut Creek that I am aware of. There were two other fires that were undetermined fires that I did not include because the fire damage was too extreme to determine the cause to be the fan. It would be great to see all new fan installations requiring thermal couplings.

Barbershop 02/2013



Multifamily Building 2/2014

M12105Rationale



Multifamily vacant unit 6/2014

M12105Rationale

Multifamily building 7/2022

Mod_12105_Rationale_Ventilation Bathroom Fan Fires.pdf Page: 3

Daycare facility 3/2023

Thank you,

**Ryan Banyas, MPA, CFPS**
Fire Marshal
4800 W. Copans Road
Coconut Creek, FL 33063
954-956-1563
954-420-5855 fax
www.coconutcreek.net

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M12105Requirements

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Mod_12105_Requirements_Web search of toilet fan fires in Florida.pdf

Google — toilet exhaust fan fires in florida

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**ECFR: Bathroom exhaust fan causes fire at Escambia ...**

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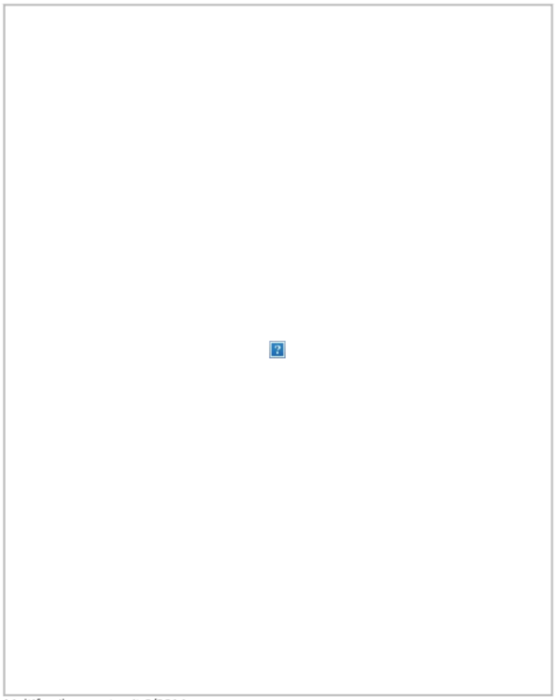

Multifamily vacant unit 6/2014

Multifamily building 7/2022

M12105Requirements

Daycare facility 3/2023

Mod_12105_Requirements_FW_ Ventilation Bathroom Fan Fires.pdf Page: 4

Thank you,

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954-420-5855 fax
www.coconutcreek.net

---

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Toilet exhaust fan fires in City of Coconut Creek courtesy of Ryan Banyas, MPA, CFPS, Fire Marshal

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M12105Requirements

Daycare facility 3/2023

Mod_12105_Requirements_Fan fires Coconut Creek.pdf Page: 5

# CPSC Staff Assessment on Eutectic-Type Thermal-Cutoff Fuse Failures in Shaded-Pole Motors Used in Exhaust Fans

December 2017

Arthur Lee
U.S. Consumer Product Safety Commission
Directorate for Engineering Sciences
Division of Electrical Engineering and Fire Sciences
5 Research Place
Rockville, MD 20850

***The views expressed in this report are those of the CPSC staff and have not been reviewed or approved by, and may not necessarily reflect the views of, the Commission.***

Revision Changes

None

U.S. CONSUMER PRODUCT SAFETY COMMISSION
Directorate for Engineering Sciences

# CPSC Staff Assessment on Eutectic Type Thermal Cutoff Fuse Failures in Shaded-Pole Motors used in Exhaust Fans

December 2017

Arthur Lee
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## EXECUTIVE SUMMARY

Staff searched the CPSC Injury or Potential Injury Incident (IPII) database for incidents involving exhaust fans for the 20-year period from January 1, 1997 to September 21, 2017. Staff identified 494 known incidents in that period related to permanently installed exhaust fans. The majority of these incidents occurred in residential bathrooms.

CPSC field staff collected 100 exhaust fan samples in 2017 from part of a larger inventory that had been collected and stored by a military base housing authority. The exhaust fans had been replaced base-wide due to a large number of failures. CPSC Engineering Sciences (ES) staff's testing of these motors showed that the winding temperatures can reach high temperatures sufficient to ignite the motor during a lock-rotor condition when the eutectic-type thermal cutoffs (TCO) fail to activate. ES staff conducted additional investigation to evaluate factors that may contribute to the TCO failing to activate. During locked-rotor operation, a TCO may reach elevated temperatures while remaining below its functioning temperature. These elevated temperatures may result in thermally aging the TCO, potentially altering its set functioning temperature. A fan that has entered into a lock-rotor condition may experience multiple events of thermal heating without causing the TCO to activate.  These multiple heating events may have compounding effects on the TCO properties, thus causing either a delay in TCO activation or a failure to activate.

Even though the tested motors were listed to the appropriate voluntary UL standards, CPSC staff testing suggests that, in practice, thermal aging of the motors can cause the eutectic-type TCOs to fail. A contributing factor to this deviation from the original certification may be improper bending of the TCO wire leads, resulting in cracking the epoxy seal around the wire leads. During thermal heating, the melting properties of the thermal linkage in the TCO may be altered and cause either a delay in TCO-activation or failure to activate. If the TCOs in the motors fail to activate during a lock-rotor condition, the motor may overheat and ignite.

The results of this testing, and the fact that TCOs are used in many other consumer products, in addition to exhaust fans, support changes to the voluntary standards.

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## 1.0 INTRODUCTION

ES staff conducted an analysis of thermal cutoff fuse TCO failures in exhaust fan applications, specifically for fans that use eutectic-type thermal devices in shaded-pole motors. This report documents staff's analysis and assessment.

## 2.0 INCIDENTS

The CPSC's IPII database includes information on consumer product-related incidents that are collected through various reports and reporting systems.[1] The amount of information or detail can vary by the type of report. News reports typically contain minimal detail on the products and the events surrounding the incident. CPSC field investigators conduct In-Depth Investigations (IDIs) on specific incidents that may have originated from an IPII record. These investigations are conducted by CPSC field staff via phone or in-person interviews, and the investigations can include collection of police and injury reports. The investigation is documented in a report that typically contains detailed information on the products and events surrounding the incident, but the completeness of the reports depends on the information that the field investigator was able to collect.

### 2.1 Incidents

CPSC staff searched the IPII database for incidents involving exhaust fans, specifically the product code 380 (fans) that mentioned the word "exhaust" and indicated a fire or fire hazard. The search is not representative of any national statistics or estimates. The search produced 571incidents occurring between January 1, 1997 and September 21, 2017. Staff reviewed the search results; 77 of the incidents did not relate to structurally or permanently installed exhaust fans. The remaining 494 incidents contained sufficient information to determine that the incident involved a structurally or permanently installed exhaust fan. Of the 494 incidents 118 IDI reports resulted.

Of the 494 incidents with structurally or permanently installed fans, 71 incidents did not contain sufficient information to determine the exhaust fan's purpose. For example, staff could not determine in what room the fan was installed or for what purpose the fan was used. The remaining 423 incident reports contained sufficient information to determine the location of the exhaust fan and the likely use of the exhaust fan. The 423 incidents were categorized into five categories based on fan location (bathroom/restroom, kitchen, attic, laundry, and general). Incidents categorized as "general" involved locations that could not be assigned to one of the specific location categories. Table 1 lists the number of exhaust fan incidents by location.

---

[1] The incidents are gathered from news reports, consumer self-reporting, Medical Examiners and Coroners Alert Program (MECAP), attorney reports, referals, and Section 15 reports.

Table 1. Dataset from January 1, 1997 to September 21, 2017

| Incident Categories by Location | Count | Percent of Known |
|---|---|---|
| Bathroom/Restroom | 318 | 75.18% |
| Kitchen | 54 | 12.77% |
| Attic | 27 | 6.38% |
| Laundry | 8 | 1.89% |
| General | 16 | 3.78% |
| Known incidents only | 423 | 100% |
| Unknown | 71 | |
| Total Incidents related to exhaust fans | 494 | |

More than 75 percent (318/423) of the known incidents occurred in a bathroom or restroom. The most likely origin of the incident in these cases was the exhaust fan. The incidents ranged in severity from minor smoke to fire spreading through the structure. Of the 318 incidents that occurred in a bathroom or restroom, almost 80 percent (254/318) occurred in a residence. "Residences" were defined as a single- or multi-family home, apartment, condominium, senior citizen living facility, and dormitory. Of the 318 incidents that occurred in a bathroom/restroom, almost 19 percent of incidents occurred in a commercial building. "Commercial facilities" were defined as a commercial store or workplace, public facility, restaurant, or hotel. There was insufficient information for four incidents, which were classified as Unknown. Table 2 lists the types of structures for incidents that occurred in a bathroom or restroom.

Table 2. Bathroom/Restroom incidents

| Type of location | Count | Percent of Total |
|---|---|---|
| Residential | 254 | 79.9% |
| Commercial | 60 | 18.9% |
| Unknown | 4 | 1.2% |
| Bathroom dataset total | 318 | 100% |

Almost 13 percent of the known incidents occurred in a kitchen. These incidents occurred in either a residential or commercial structure, such as a home or restaurant. The exhaust fans that were involved in these incidents appear to have been mostly used to exhaust the area above or near a cooking appliance. For residential incidents, the exhaust fan may have been integral to a microwave oven/hood or a range hood. For commercial locations, the exhaust fan incidents appear to be related to inadequate maintenance of the exhaust hood, such as excessive grease from cooking. For commercial locations, there were several incidents where the exhaust fans were used to exhaust the space above cooked food or the kitchen area.

There were 27 incidents involving attic fans. These incident reports specifically contained descriptions that the products were attic exhaust fans that were used to ventilate the air within the attic and not bathroom exhaust fans mounted in the ceiling where there was attic space above the ceiling. These incidents occurred in both residential and commercial structures.

There were eight incidents involving exhaust fans in laundry rooms. These incident reports specifically contained descriptions that the exhaust fans were in laundry-type rooms that were used to wash and dry clothes. These incidents occurred in both residential and commercial structures.

There were 16 incidents involving exhaust fans that were categorized as "general" because the rooms in which these incidents occurred did not fall into any of the other categories. These incidents occurred in rooms such as sheds, factory rooms, medication rooms, basements, or dining rooms.

There were 77 incidents that were not within scope of the report. Some of the "not-within-scope" incidents involved cooking fires that ignited exhaust fans, heater fans, window fans, portable product fans, such as leaf blowers, and HVAC fans.

## 2.2 Selected Incident Cases

The incidents below, which involved exhausts fan in a bathroom or restroom, were selected to illustrate some of the differences and similarities in the incidents.

<u>IDI 90611CCN0306</u>

This incident occurred in a 10-year-old duplex/multi-family home in May 1998. On the day of the incident, the consumer was home and turned on the bathroom exhaust fan located on the ceiling. The family left the home around 2:00 p.m. and left the bathroom exhaust fan running for about seven (7) hours until the family returned around 9:00 pm. Upon returning, the family heard the smoke alarm sounding and witnessed smoke in the home. The family called the fire department, which determined that the bathroom exhaust ceiling fan had overheated, causing the plastic cover to catch fire and fall onto the toilet. The toilet seat cover had ignited, which fell into the toilet.

<u>IDI 010402CCN474</u>

In March 2001, at about 6:50 a.m. the fire department responded to an apartment structure fire. Firefighters discovered fire in the walls and the attic above the bathroom where the incident exhaust fan was located. Fire had spread into the common bathroom wall between apartment units and in the adjacent bedroom walls. The fire department determined that the fire started from a 30-year-old exhaust fan located in the bathroom of the apartment.

IDI 031125CNE1123

The incident occurred in November 2003. The day before the incident, the bathroom exhaust fan was left "on." On the morning of the incident, the family dog began running in and out of the bathroom and barking. Shortly thereafter, a smoke alarm located in the hallway outside the bathroom began sounding. The family observed smoke and flames coming from the bathroom exhaust fan. The fire marshal concluded that the fan motor overheated and determined that the home insulating material in the attic was not a contributing factor in the fan overheating because there was adequate space between the insulation and the fan housing.

IDI 050506CNE2395

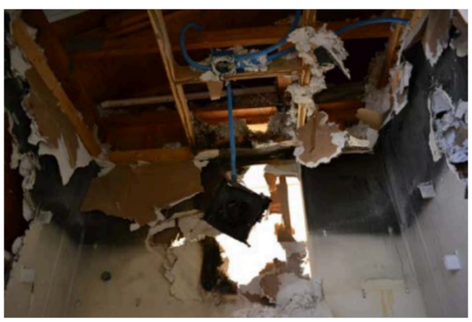
The fire occurred in a women's restroom of a closed nightclub section of a bar and restaurant business. An adjacent bar restaurant section was open for business and occupied by a bartender and several customers at the time of the incident. The owner indicated that even though the nightclub section had been closed, employees routinely used the bathrooms in that area. The men's and women's restrooms located in the nightclub were equipped with exhaust fans. The manager of the business reported that the fan in the women's restroom had been making a noise for about a week before the incident. At the time of the incident, the fire department extinguished the fire, which had traveled upward from the women's restroom into the second floor and attic, where it burned through parts of the roof.

IDI 050907CNE2758

On a morning in August 2008, the electricity in the residence and surrounding area had a power outage. After power had been restored in the afternoon, the occupants went throughout the home checking the light switches. This included the two switches in the second floor bathroom, which controlled the lights and incident exhaust fan. The occupants stated that the exhaust fan had "stopped" working about 3 years before the incident. Before the fan "stopped" working, the occupants reported that the exhaust fan had begun to make a noise. Before leaving the home, the occupant went around turning off the lights in the home, which they thought the second floor bathroom fan had been turned off. When they returned home in the evening, the homeowner found smoke coming from the roof vents of the structure. The fan had overheated and ignited and spread into the attic of the structure.

IDI 110322CCC2391

The incident occurred at a daycare facility. The building was built in 1995, and has been used as a daycare facility since its construction. The fans were original when the building was constructed. The lights and fans were controlled by a single switch. Five days a week, the switch was turned on at approximately 6:30 a.m. and turned off at about 7:00 p.m. The incident occurred in March 2011. After the daycare lights and fans were switched on, the daycare heat was also turned on. Approximately 1 hour later, a teacher and her assistant smelled something burning and assumed it was related to the heating system. Even though after the heating system was turned off, the burning smell persisted. The director went to the infant room and localized the burning smell to the changing room/bathroom. The director notified the owner of the daycare and was advised to disconnect the exhaust fans because they were old. The director was unplugging the exhaust fan when a “large fireball shot out” of the exhaust fan. The daycare was evacuated and the fire department was summoned to extinguish the fire.



IDI 130208CCC3391 and IDI 130326HWE0001

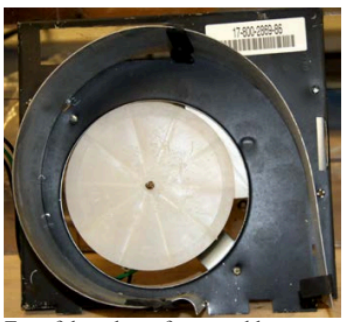
On two separate occasions, incidents involving bathroom exhaust fans occurred at Picerne Military Housing located on Ft. Riley Military Base, KS. The first incident occurred in June 2012, and was documented under IDI 130326HWE0001. The second occurred in February 2013, and was documented under IDI 130208CCC3391. The fans were installed sometime since 2007, when the housing construction was initiated. The housing authority stated that the same type of exhaust fans were installed in all the military homes constructed during that period. The housing authority reported that the fan motors had been seizing up. Because of this, the housing authority discontinued installing them in the homes in 2013, and removed all of the exhaust fans.

The June 12 incident occurred in a half bath in a single-family home. The Fort Riley Fire Department was dispatched to a structure fire at the residence. Upon arrival, the fire responders did not witness any signs of fire outside the home. Fire personnel entered the home to investigate and found water pouring from the first floor bathroom exhaust fan on the ceiling. The fire had been extinguished before fire fighters entered the home. The report identified that the plastic inside the fan had ignited, which then ignited the plastic vent hose. A plastic water line located above the fan had melted, which extinguished the fire. The cause of the incident was an overheated exhaust fan.

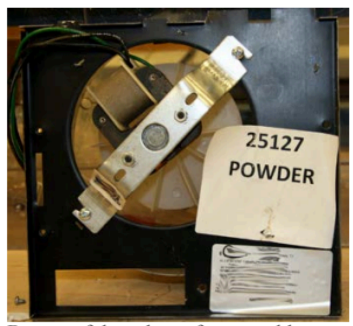
The February 5 incident occurred in a full bath on the second floor of a single-family home. There was extensive damage to the attic above the bathroom. The field investigator noted that the incident fan switch was in the “up” position, suggesting that the fan was on when the incident occurred. When the fire department arrived at the scene, fire personnel determined that the fire had spread into the attic area. An overheated exhaust fan caused the incident.

2.3 Incident Bathroom Exhaust Fans

The majority of the incidents (75 percent, 318/423) involved bathroom/restroom exhaust fans. Where photographs were available, the fans appear to have similar construction. The exhaust fans contain an external housing, a motor, an impeller, and a grill cover. The exhaust fans may incorporate a light option, but the incidents did not report the lighting assembly as the cause of the incident or fire. The "box" type exhaust fans contain a box housing that is mounted to the building structure. A fan assembly is mounted in the box housing. The fan assembly typically contains a mounting frame, fan motor, impeller, and power cord as shown in Figure 1. The box housing contains the electrical connections for the fan and light option and connection for the ducting.




Top of the exhaust fan assembly




Bottom of the exhaust fan assembly

Figure 1. Fan assembly for "box" type housing

A shaded-pole motor is an AC single-phase induction motor. The auxiliary winding, which is composed of a copper ring, is called a shading coil. The current in shading coil delays the phase of magnetic flux to provide a rotating magnetic field. The direction of rotation is from the unshaded side to the shaded ring. Typical components of a shaded pole-type motor are shown in Figure 2. Since these motors typically have low starting torque, low efficiency and a low power factor, these motors are typically suitable for low-power applications and are either thermally or impedance protected to prevent overheating. The type of protection can be identified by "T.P." or "Z.P." on the motor label, as shown in Figure 3. A Z.P. motor relies solely upon the impedance of the windings alone to prevent overheating; whereas, a T.P. motor relies upon a thermal protective device to prevent overheating.

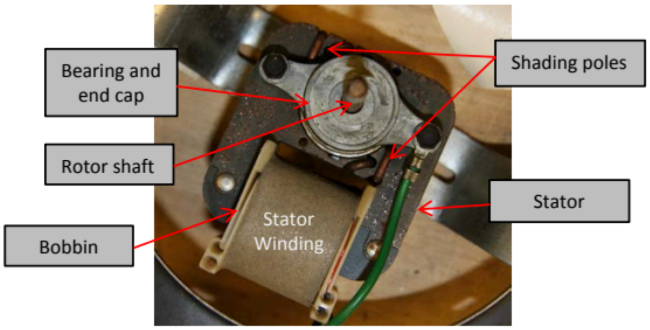



Figure 2. Shaded-pole motor

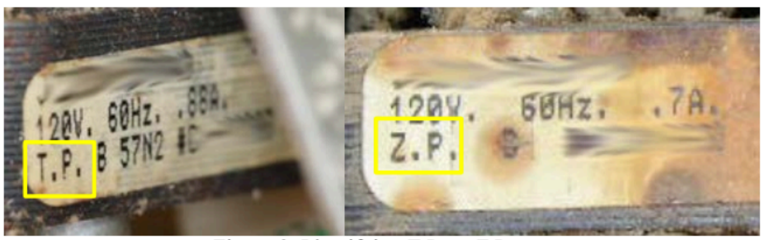



Figure 3. Identifying T.P. or Z.P.

Staff reviewed the IDIs to identify the types of fan motors used in the incidents. The dataset consisted of 118 IDIs. Of the 118 IDIs, 60 IDIs contained images of the incident exhaust fan. Of the 60 IDIs, 57 IDIs had sufficient information to identify the fan motor as a shaded pole-type motor. Three of the fans were not shaded pole-type motors; these were attic exhaust fans and appeared to be universal-type motors. Fifty-nine IDIs did not contain any identifiable information to determine the type of fan motor. Table 3 lists the number of identifiable shaded pole-type fan motors in the 118 IDIs.

Table 3. Shaded-pole motors

| | Motor type count | Percentage of known |
|---|---|---|
| Shaded pole motor | 57 | 95 % |
| Not shaded pole motor | 3 | 5 % |
| Identified motor type | 60 | 100 % |
| Unildentified motor type | 58 | |
| Total IDIs | 118 | |

## 3.0 RECALLS INVOLVING THERMAL PROTECTION

Consumer products with thermal protection have failed in the past. The most notable product recalls due to thermal protection failures in a consumer product occurred about 25 years ago involving drip coffeemakers. Beginning in the early 1990s, CPSC announced several recalls from different manufacturers of coffeemakers, where the thermostats and/or thermal fuses malfunctioned, thus, causing an overheating condition and a potential fire hazard.[2] The recalls involved more than 1 million coffeemakers.

Because of the recalls and coffeemaker fire incidents, CPSC staff discovered that the thermal devices used in these products can have the set point drift higher, or not function at all. Staff believed that thermal aging and/or heating of the thermal devices was causing the contact force to be reduced until the pressure between the contacts within the thermal device was nearly zero.[3] The episode resulted in Underwriters Laboratories (UL) incorporating construction and perfomance changes in the appropriate voluntary standards to addresss thermal devices used in coffeemakers. One of the new test methods was the "Conductive Heat Ageing Test" (CHAT), which represented slow aging of the thermal device under load, while mounted directly to a heated surface. This and other proposed requirements in UL 1082, *Standard for Household Electric Coffee Makers and Brewing-Type Appliances,* became effective in 1993 and 1994.

## 4.0 VOLUNTARY STANDARDS

Through collaboration with UL, a voluntary standard organization, safety standards are developed for a variety of consumer products, including exhaust fans. In many cases, these standards bring industry groups, government agencies, and consumer groups together to agree on the best consumer product safety practices. These standards have helped lead the way toward the development of safer consumer products.

Safety standards are constantly evolving and improving to adjust to the environmental changes, behavioral use, and technology. Below is a list of UL standards that may apply currently to exhaust fans or may have applied to exhaust fans in the past, but are no longer current:

UL 507, Standard for Electric Fans

UL 507 is intended to cover a large assortment of fan types, including exhaust fans. Exhaust fans are categorized as fans for use in unattended areas. These fan products are built into or within the building structure and may be operated unattended or in situations in which the operator may not detect a lock-rotor condition.

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[2] https://www.cpsc.gov/Recalls/1990/Proctor-Silex-Voluntarily-Recalls-Certain-Automatic-Drip-Coffeemakers-Made-In-198586-That-May-Pose-Fire-Hazard/; https://www.cpsc.gov/Recalls/1991/General-Electric-Voluntarily-Recalls-Certain-Drip-Coffeemakers-That-May-Pose-A-Fire-Hazard/; https://www.cpsc.gov/Recalls/1994/750000-1984-To-1988-Black--Decker-And-General-Electric-Under-The-Cabinet-Coffeemakers-Recalled-Possible-Fire-Hazard.

[3] *Temperature cutoffs (Thermal-links) for coffeemakers Extended Holding Temperature TH-100 rated TCOs*, InterControl. Hermann Köhler Elektrik GmbH & Co KG Schafhofstraße 30. 90411 Nuremberg. Germany.

ANSI/UL 2111, UL Standard for Overheating Protection for Motors

ANSI/UL 2111 was withdrawn and superseded by three dedicated standards, UL 1004-2, *Standard for Impedance Protected Motors*, UL 1004-3, *Standard for Thermally Protected Motors*, and UL 60730-2-2, *Standard for Automatic Electrical Controls for Household and Similar Use*; Part 2 *Particular Requirements for Thermal Motor Protectors*, beginning in 2013.

UL 1004-2, Standard for Impedance Protected Motors

UL 1004-2 is intended to be read with the *Standard for Rotating Electrical Machines – General Requirements*, UL 1004-1. The Standard applies to motors that rely solely upon the impedance of the motor windings to prevent overheating.

UL 1004-3, Standard for Thermally Protected Motors

UL 1004-3 is intended to be read with the *Standard for Rotating Electrical Machines – General Requirements*, UL 1004-1. The Standard applies to motors that rely upon a device (thermal motor protector) to prevent overheating.

ANSI/UL 1020, Standard for Thermal Cutoffs for Use in Electrical Appliances and Components

UL 1020 was withdrawn and superseded by UL 60691, *Thermal Links - Requirements and Application Guide* around 2003. The scope for ANSI/UL 1020 contained requirements that applied to thermal cutoffs intended to be embedded in windings or for freestanding use in end products.

UL 60691, Thermal Links - Requirements and Application Guide

The scope for UL 60691 is applicable to thermal links intended for incorporation into electrical appliances, electronic equipment, and component parts thereof, normally intended for use indoors to protect these products from excessive temperatures under abnormal conditions, including lock-rotor conditions.

## 5.0 FIELD SAMPLES[4]

The two incidents that occurred at Picerne Military Housing on Ft. Riley, KS military base in 2012 and 2013 provided an opportunity to collect a large number of samples for testing. CPSC field staff collected 100 exhaust fan samples in 2017. The fans were part of a larger inventory that had been collected and stored by the base housing authority when the exhaust fans had been replaced after a large number of exhaust fan failures. The fans were originally installed in the homes between June 2007 to February 2012. The fans were removed between April 15, 2013 and April 22, 2013. All the fans had similar manufacture dates from 2008 through 2010.[5] After the units were removed, the fans were placed into storage, initially office trailers, then into Conex units on post.

All of the fans collected were sold under the same brand name and contained the same motor manufacturer. The fan motors were shaded pole-type motors and had the same or similar construction. The main lot (96) of fan motors were constructed with a paper wrap around the winding core and had 25 stacked plates for the stator. Four fan motors had a slightly different construction, which included a plastic wrap around the winding core and had 35 stacked plates for the stator. All of the fans were thermally protected with a radial eutectic-type TCO.

### 5.1 Eutectic-Type Thermal Cutoff Fuses

A eutectic alloy is a homogeneous solid mixture of at least two metals or lattice components that is made up of the specific atomic/molecular ratio that yields the lowest possible complete melting point (eutectic temperature), which causes the solid mixture to change uniformly into a liquid mixture, as illustrated in Figure 4. In all other proportions, the mixture will not have a uniform melting point; some of the mixture will remain solid and some liquid. Eutectic TCO fuses contain a joint or linkage that is a eutectic alloy that will melt and open at the eutectic temperature.

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[4] The sections presented in this report were arranged for readability and understandability, not chronological order of the testing.

[5] The manufacturer date of the fan assembly does not necessarily represent the manufacture date of the fan motor. Staff believes that the fan motors were manufactured around 2000.

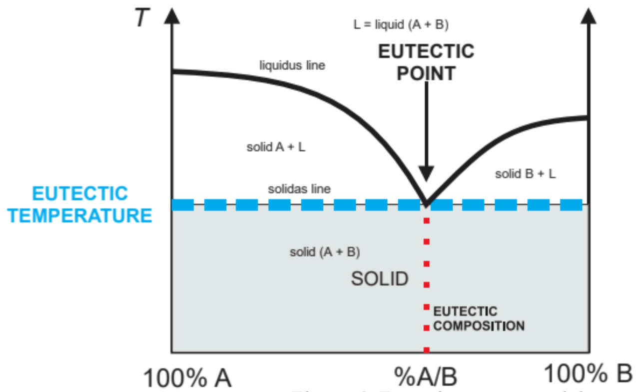



Figure 4. Eutectic system model

Eutectic TCOs are available with axial or radial lead wires, both having the same basic design as shown in Figure 5.[6] The fusible thermal linkage (thermal element) is a eutectic alloy that is welded across a pair of wire leads. The eutectic alloy is coated with a special compound to protect it from oxidation and allow wetting of the wire leads. Surface tension then separates the eutectic alloy, opening the circuit, thus activating the TCO. The fusible linkage is sealed in a special insulated housing.

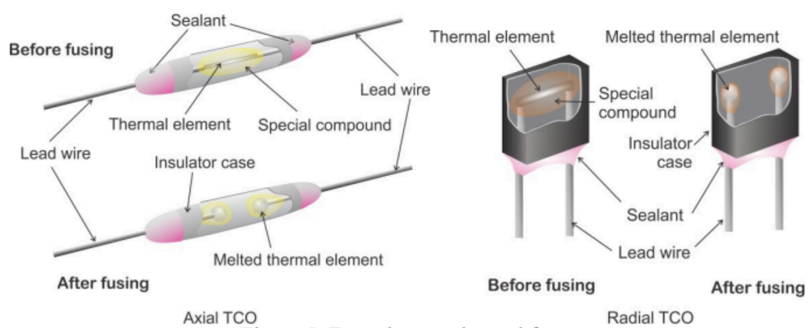



Figure 5. Eutectic-type thermal fuse

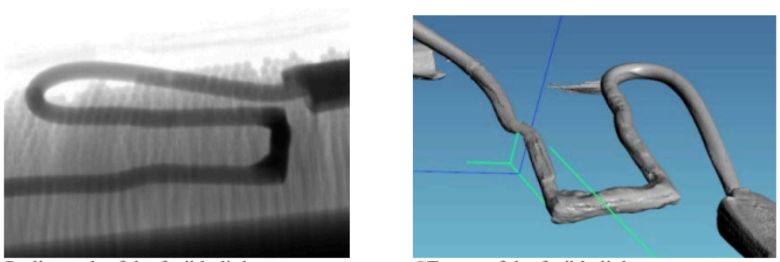
[6] Chatham Components Inc., Thermal Cutoffs, Elcut Brand Thermal Fuses, http://www.cci-tco.com/products/elcut-brand-thermal-fuse/.

5.2 Thermal Cutoff Fuses in the Fan Samples

All the fan samples contained radial eutectic-type thermal fuses. The fuses are marked with a functioning temperature of 136°C and rated for 250V 3A, as shown in Figure 6.

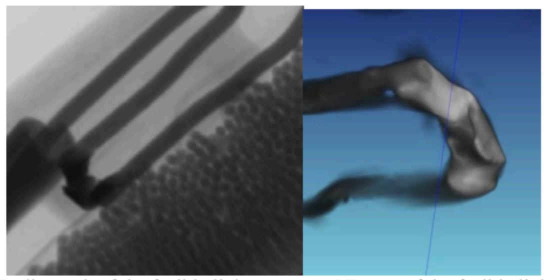

Figure 6. Radial eutectic-type thermal fuse in the sample fans

All 100 TCOs in the fans were x-rayed and 3-D imaged by computed tomography (CT). CT imaging can reveal detailed images of the internal TCO without destructive analysis. The CT scan allows cross-sectional details of the thermal linkage that cannot be seen in conventional radiographs by X-rays. The thermal linkage connects the two wire leads, as shown in the radiograph and CT images in Figure 7. In the examined thermal linkages in the fan samples, the thermal linkages varied with the shape of the linkage, such that some of the linkages were not uniform, as shown in Figure 8. It is unknown if the variations were caused from manufacturing or usage before collection.

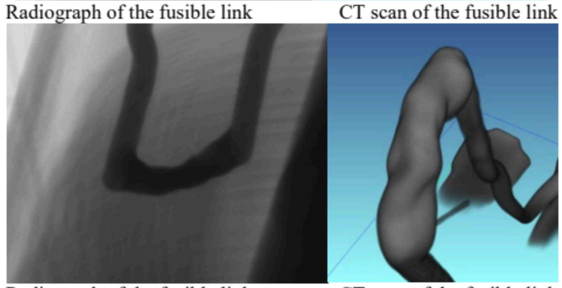


Radiograph of the fusible link CT scan of the fusible link

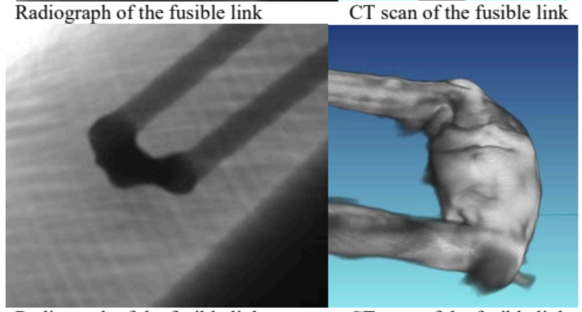
Figure 7. Smooth and uniform solder linkage (Sub 44)



Radiograph of the fusible link CT scan of the fusible link



Radiograph of the fusible link CT scan of the fusible link



Radiograph of the fusible link CT scan of the fusible link

Figure 8. Fusible link with irregular thermal linkages (Sub 91, 20 and 62)

### 5.3 Normal Fan Test

Staff measured and recorded the temperatures on the winding and within the TCO for one of the shaded-pole, motor-fan samples during normal fan operation. To record the temperatures, a fan (indexed as sub 60) was instrumented with three thermocouples on the paper wrap exterior of the winding, and within the TCO, as shown in Figure 9; the TCO was not in the circuit, *i.e.*, it was not carrying current. The top, side, and bottom thermocouples were secured against the winding wrap with thermal tape and a nylon plastic tie. To measure the temperature within a TCO, an activated or used TCO from another fan motor was removed and then modified with a thermocouple. The TCO was modified by drilling a small hole through the epoxy of the TCO and inserting a thermocouple, as shown in Figure 10. The hole was then resealed with an epoxy. The existing TCO within the motor was moved away from the winding and the thermocoupled TCO was located in its place. This allowed the modified TCO with the thermocouple to record the temperature as if the original TCO was installed. It would be expected that the thermocoupled TCO would measure a slightly lower temperature than an actual TCO because the lack of conductive heating from the winding and no current flow. The TCO plastic sleeve and winding wrap and tape were reinstalled and sealed before testing.

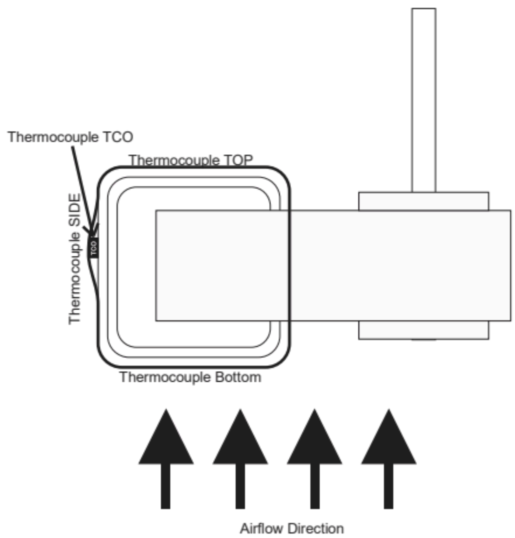
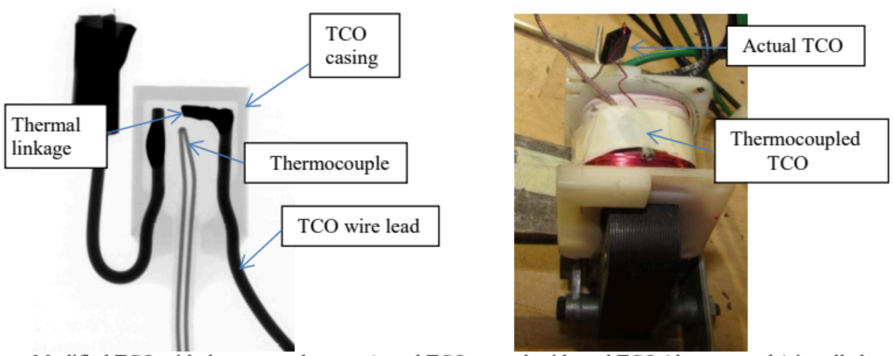



Figure 9. Thermocouple locations on the motor (side view)




Modified TCO with thermocouple Actual TCO moved aside and TCO (thermocouple) installed

Figure 10. TCO with thermocouple

The testing showed that the TCO's internal temperature for this freely spinning motor with impeller is about 73°C. The thermocouple at the top of the winding measured slightly higher, at 76°C, than the TCO temperature as shown in Figure 11. When the fan was de-energized, the thermocouples located on the winding wrap measured an increase in the winding temperature because of the lack of airflow over the thermocouples when the impeller stopped spinning. The temperature within the TCO did not measure the same increase in temperature when the fan was de-energized. This is most likely caused by the TCO being located below the wrap, which caused the TCO not to be affected by the airflow.

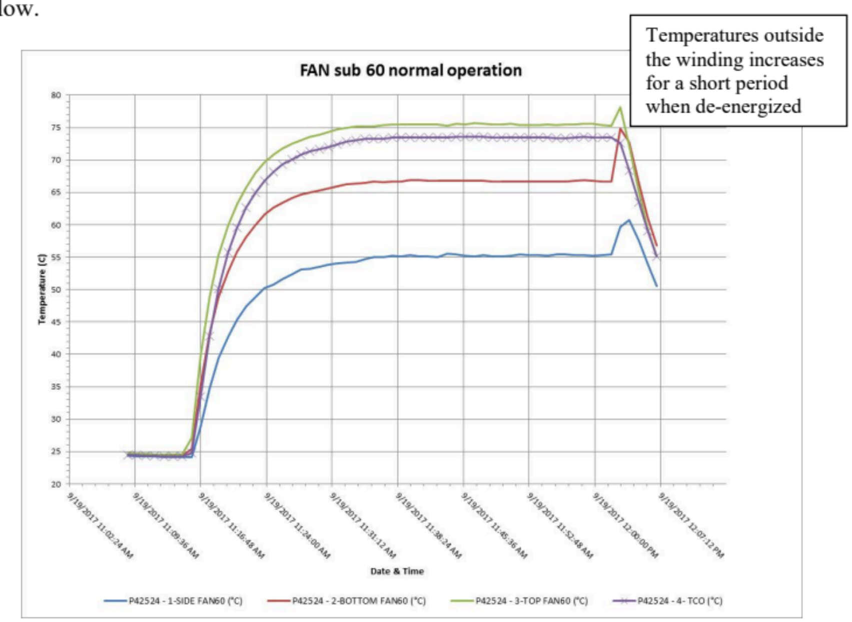



Figure 11. Temperature measurements on the winding and within the TCO (Fan 60)

## 5.4 Abnormal Fan Test

Fan sub 45 rotor did not turn freely in the condition in which it was received because of what appears to be dust and grime build-up at the bearings. When the sample was energized, the impeller/rotor did not spin; thus, it was in "locked-rotor" condition. Figure 12 shows sub 45 before any testing.

The fan was tested in its as-received condition, *i.e.*, locked-rotor condition. A single thermocouple was placed on the side of the winding, on the outside of the wrap, adjacent to the TCO location. After being energized, the TCO activated after 22 minutes, as shown by the temperature traces in Figure 13. For the location of this thermocouple, the temperature shows a maximum of 120ºC, but this location is about 20ºC cooler than the actual TCO or at the top of the winding. The actual TCO functioning temperature ($T_f$) was calculated to be about 140ºC (120ºC + 20ºC), which corresponds closely to the $T_f$ of 136ºC. This testing in lock-rotor condition also verified that the side thermocouple measurements on the paper wrap were about 20ºC lower than the actual TCO or the top of the windings. Figure 14 shows the radiographs of the TCO's fusible link after lock-rotor testing, which shows the thermal linkage melted or open.

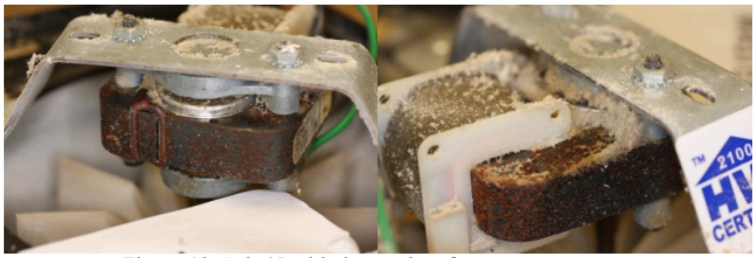


Figure 12. Sub 45 with dust and surface rust on core

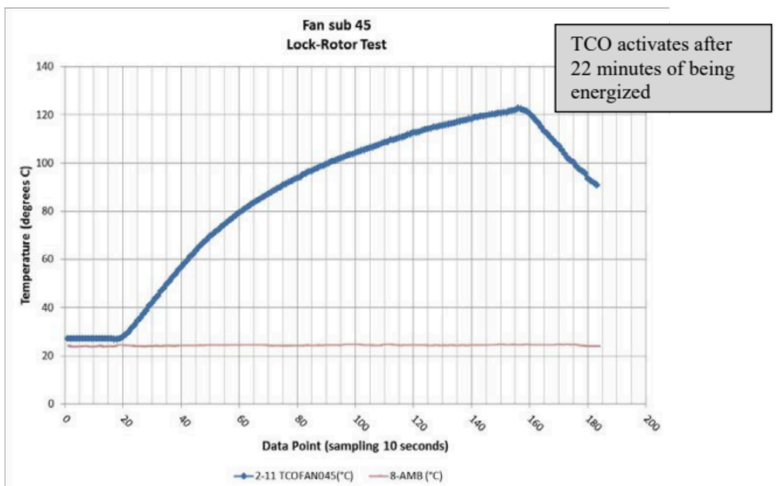
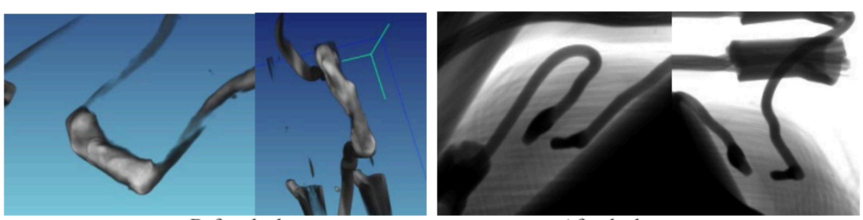



Figure 13. Sub 45 temperature measurement outside the winding



Before lock-rotor test After lock-rotor test

Figure 14. Radiograph and CT scans of the TCO before and after lock-rotor testing (Sub 45)

In other testing, where the TCO opened during lock-rotor conditions around the same elapsed time of 20 minutes, the thermal linkage had the same characteristic of only one end of the thermal linkage melting, as shown in Figure 15. This appeared to be caused by the TCO wire lead that is connected to the winding having a higher temperature than the wire lead connected to the power conductor. The wire lead would conduct the thermal energy from the winding during locked-rotor operation, thus causing one TCO wire lead to heat faster than the other TCO wire lead. Staff observed that for cases when the elapsed time was longer during the lock-rotor condition for the TCO to trip, and the temperature was higher than average, the thermal linkage would have inconsistent melting patterns, as shown in Figure 16. Staff expected that the delayed opening would result in a uniform temperature gradient within the TCO, thus causing the fusible linkage to melt completely or uniformly. But this was not the case, because the thermal linkage had irregularities, which suggests that other factors may be affecting the melting characteristics of the linkage.

Sub 04 Sub 40 Sub 36

Figure 15. Radiographs of TCOs after lock-rotor testing with consistent shape

Sub 69 Sub 10 Sub 58

Figure 16. Radiographs of TCOs after lock-rotor testing with unusual shapes

The same fan sub 60 that was instrumented with a thermocouple inside a TCO was used to measure the temperatures during lock-rotor conditions. Similar to the normal operation test, fan sub 60 had the three thermocouples on the paper wrap exterior of the winding and thermocoupled TCO. The lock-rotor condition was operated for 20 minutes to simulate the TCO tripping after 20 minutes in lock-rotor testing, as seen in Sub 45. After 9 minutes 12 seconds, the TCO temperature reached 105°C, as shown in Figure 17. At 15 minutes, the TCO temperatures reached 130°C. Shortly before 20 minutes, the TCO temperature reached 140°C. The TCO temperature measured approximately 142°C at 20 minutes or the manual trip time. The measurements in this test closely correspond to the sub 45 locked-rotor test. As mentioned previously, the TCO in sub 45 tripped at a measured temperature on the side of the winding around 120°C, and the temperature measured on the side of the winding in the test after 20 minutes of operation was about 123°C.


Figure 17. Temperature on the winding and within the TCO during a lock-rotor test

5.5 Lock-Rotor Test with TCO Bypassed

To evaluate worst-case scenario, fan sub 42, which had been previously tested in the lock-rotor test and the TCO tripped, was modified with the TCO bypassed. The tripped TCO was left intact in the motor, and a short piece of wire was soldered across the TCO wire leads to create a permanent linkage, thus bypassing the TCO. The test was to evaluate this motor if the TCO were to fail or not activate during a lock-rotor condition.

The fan was instrumented with a thermocouple located at the bottom of the winding, as viewed with the fan installed (see Figure 9 - Thermcouple BOTTOM). A second thermocouple was located exterior to the motor winding and on the same side as the TCO (see Figure 9 - Thermcouple SIDE). The lock-rotor test was conducted by blocking the impeller and energizing the fan. The thermocouple temperature measurements were recorded every 5 seconds.

The testing was conducted in three separate test periods. The first test period lasted 2 hours. The winding reached a steady-state temperature of 160ºC. After an elapsed time of 2 hours, the test was manually terminated. The fan was allowed to cool to room temperature before re-testing. The second test period was 2 hours. The winding reached a steady-state temperature of 200ºC. The test was manually terminated after 2 hours. The fan was allowed to cool to room temperature before re-testing.

For the third test period, the fan was energized in the lock-rotor condition, and after about 30 minutes, the temperature increased rapidly, which resulted in smoke and flames. The thermocouple temperature traces are shown in Figure 18. The motor winding ignited, which then ignited the plastic impeller, as shown in Figure 19. The plastic impeller resulted in dripping, flaming plastic. The total lock-rotor test time was about 4.5 hours (period 1 + period 2 + period 3).

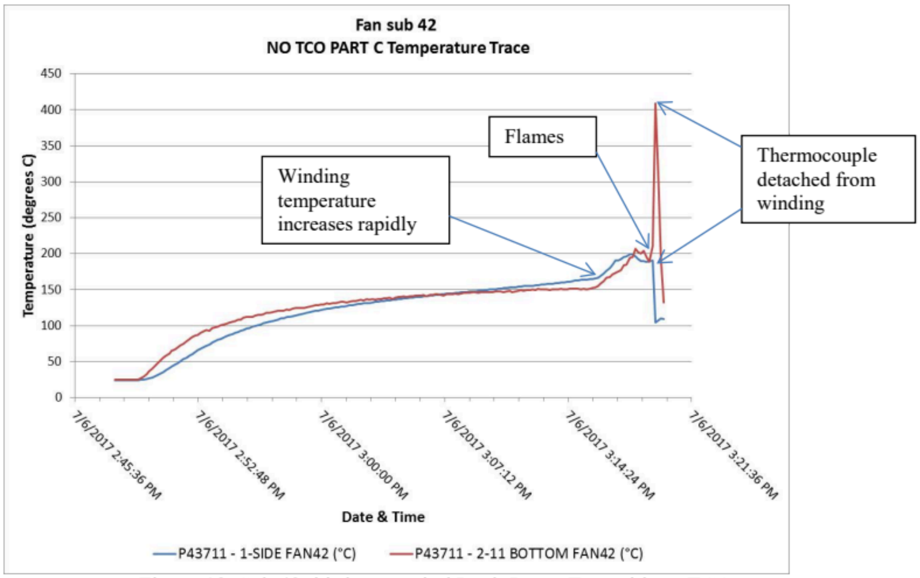



Figure 18. Sub 42 third test period Lock-Rotor Test with no TCO

Figure 19. Bypassed TCO lock-rotor test

5.6 TCO Trip-Time Testing

The 100 samples that were collected from Picerne Military Housing on Ft. Riley, KS military base were randomly assigned to seven different test groups. Table 4 lists the fan motor subs as assigned to the seven test groups. Test groups 1, 2, 4, 5, and 6 had 15 fan samples. Test group 3 had 14 fan samples, and test group 7 had 11 fan samples.

Table 4. Sample Test Group

| Test Group 1 | | Test Group 2 | | Test Group 3 | | Test Group 4 | | Test Group 5 | | Test Group 6 | | Test Group 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Sub No. | No. | Sub No. | No. | Sub No. | No. | Sub No. | No. | Sub No. | No. | Sub No. | No | Sub No. |
| 1 | 60 | 1 | 53 | 1 | 39 | 1 | 81 | 1 | 46 | 1 | 72 | 1 | 91 |
| 2 | 80 | 2 | 83 | 2 | 71 | 2 | 45 | 2 | 22 | 2 | 38 | 2 | 8 |
| 3 | 98 | 3 | 4 | 3 | 64 | 3 | 11 | 3 | 57 | 3 | 61 | 3 | 74 |
| 4 | 13 | 4 | 95 | 4 | 75 | 4 | 28 | 4 | 37 | 4 | 97 | 4 | 86 |
| 5 | 70 | 5 | 40 | 5 | 3 | 5 | 67 | 5 | 48 | 5 | 96 | 5 | 31 |
| 6 | 78 | 6 | 12 | 6 | 30 | 6 | 58 | 6 | 23 | 6 | 25 | 6 | 65 |
| 7 | 52 | 7 | 88 | 7 | 55 | 7 | 66 | 7 | 50 | 7 | 24 | 7 | 18 |
| 8 | 27 | 8 | 16 | 8 | 42 | 8 | 9 | 8 | 33 | 8 | 34 | 8 | 85 |
| 9 | 36 | 9 | 26 | 9 | 99 | 9 | 17 | 9 | 14 | 9 | 32 | 9 | 21 |
| 10 | 69 | 10 | 20 | 10 | 19 | 10 | 84 | 10 | 59 | 10 | 44 | 10 | 56 |
| 11 | 2 | 11 | 7 | 11 | 10 | 11 | 1 | 11 | 94 | 11 | 29 | 11 | 62 |
| 12 | 76 | 12 | 90 | 12 | 63 | 12 | 51 | 12 | 68 | 12 | 77 | | |
| 13 | 92 | 13 | 87 | 13 | 41 | 13 | 6 | 13 | 54 | 13 | 47 | | |
| 14 | 89 | 14 | 79 | 14 | 5 | 14 | 93 | 14 | 73 | 14 | 15 | | |
| 15 | 35 | 15 | 100 | | | 15 | 43 | 15 | 49 | 15 | 82 | | |

Two test frames were constructed for the testing. One test setup included a large test frame that allowed up to 15 fans to be tested at the same time, as shown in Figure 20. A second smaller test setup was constructed using a test frame that can accommodate up to two fans to be tested, as shown in Figure 21. Since the testing was lock-rotor condition, no vent hose was connected to the fan exhaust box housing.

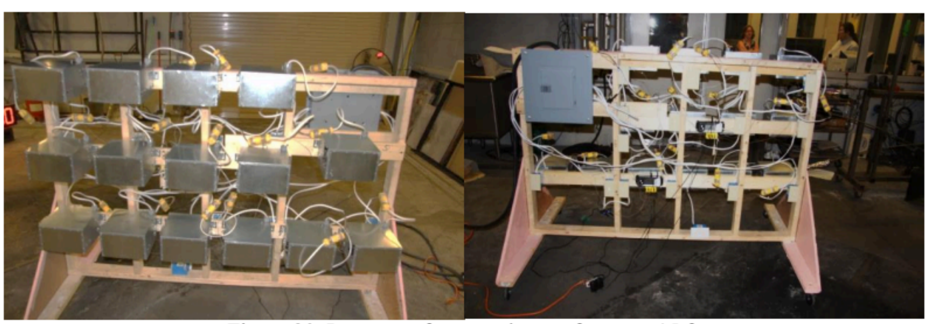


Figure 20. Large test frame and setup for up to 15 fans

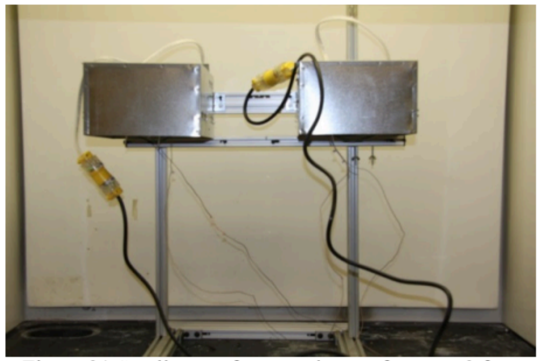


Figure 21 Smaller test frame and setup for up to 2 fans

*5.6.1 Test Groups 1 and 2 - Lock-Rotor Test (15 fans per group)*

Test Groups 1 and 2 each had 15 fans. Both groups of fans were tested on June 22, 2017. Each fan was instrumented with a thermocouple located on the exterior of the motor winding wrap on the side. Staff conducted a locked-rotor test by blocking the impeller with a nail through the side of the housing and energizing the fan with 120 VAC. The average ambient temperature at the start of the test was 26.8°C. Staff recorded the thermocouple measurements every 30 seconds.

All the TCOs activated (except Sub 60 due to the power connector coming loose early in the test). The measured temperature at the side of the winding when the TCO activated was between 110°C and 151°C (average 123°C). Sub 60 was later used for testing under the Section 5.3 Normal Fan Test to record temeprature traces during normal operation. Based on the sub 60 temperature traces under Normal Fan Test, we assume that the TCO temperatures should be about 20°C higher than the temperature on the side of the windings. This would translate to between 130°C and 171°C at the TCO and an average of 143°C . The activation times varied between 20 to 50 minutes for both test groups.

*5.6.2 Test Group 3 - 105°C Variable Duration Conditioning and Lock-Rotor Test*

Test Group 3 had 14 fans. All 14 fans were placed in a conditioning oven at 4 p.m. on June 23, 2017. The conditioning oven temperature was set at 105°C. The 105°C conditioning temperature corresponds to approximately 50 percent of the temperature difference (mean) between the TCO temperatures at trip and normal operation, as shown in equation [1] below. The fans were conditioned continuously at 105°C for a minimum duration of 64.3 hours to a maximum of 305 hours. The fans were removed from the conditioning oven at different times. After a fan sample was removed from the conditioning oven for testing, the fan motor was allowed to cool to room temperature before conducting the lock-rotor test.

$$\left(TCO\ temp_{at\ trip} - TCO\ temp_{normal}\right) \times 50\% + TCO\ temp_{normal} = Conditioning\ Temp \quad [1]$$

$$(143℃ - 73℃) \times 73℃ = 107.5℃ \approx 105℃$$

During lock-rotor testing, each fan was instrumented with two thermocouples. One thermocouple was located on the exterior of the motor winding wrap on the side of the winding. The second thermocouple was located on the bottom of the winding as viewed when the fan is installed. The lock-rotor test was conducted by blocking the impeller and energizing the fan. The thermocouple temperature measurements were recorded every 10 seconds.

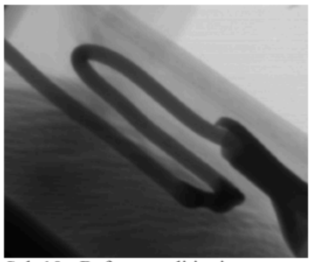
The smaller test setup was used during this testing series. Two fans were randomly removed from the conditioning oven at different conditioning periods to be tested. Table 5 lists the test frame location, thermocouple number, and conditioning period associated with each fan sub number.

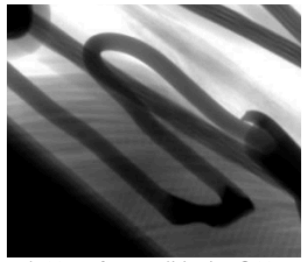
Table 5. Conditioning periods for Test group 3 subs

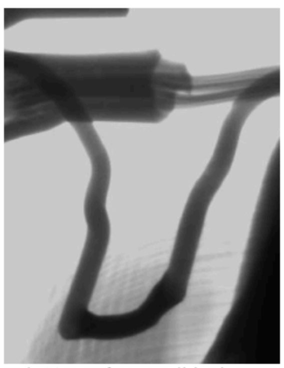
| Sub | Start Conditioning | End Conditioning | Conditioning Period (hh:mm) |
|---|---|---|---|
| 42 | 6/23/17 4:00 PM | 6/26/17 8:30 AM | 64:30 |
| 10 | 6/23/17 4:00 PM | 6/26/17 8:30 AM | 64:30 |
| 63 | 6/23/17 4:00 PM | 6/28/17 9:00 AM | 113:00 |
| 5 | 6/23/17 4:00 PM | 6/28/17 9:00 AM | 113:00 |
| 19 | 6/23/17 4:00 PM | 7/3/17 8:30 AM | 232:30 |
| 41 | 6/23/17 4:00 PM | 7/3/17 8:30 AM | 232:30 |
| 64 | 6/23/17 4:00 PM | 7/5/17 8:00 AM | 280:00 |
| 75 | 6/23/17 4:00 PM | 7/5/17 10:00 AM | 282:00 |
| 99 | 6/23/17 4:00 PM | 7/5/17 4:00 PM | 288:00 |
| 71 | 6/23/17 4:00 PM | 7/5/17 4:00 PM | 288:00 |
| 39 | 6/23/17 4:00 PM | 7/6/17 9:00 AM | 305:00 |
| 3 | 6/23/17 4:00 PM | 7/6/17 9:00 AM | 305:00 |
| 30 | 6/23/17 4:00 PM | 7/6/17 9:00 AM | 305:00 |
| 55 | 6/23/17 4:00 PM | 7/6/17 9:00 AM | 305:00 |

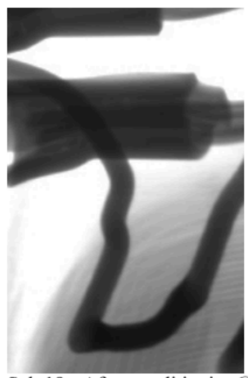
Effects of Conditioning to the Thermal Linkages

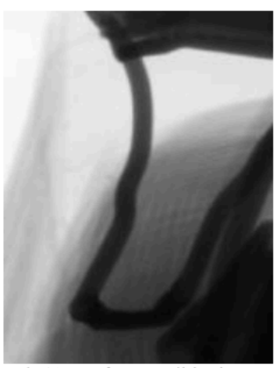
For test group 3, all of the TCOs were x-rayed before and after conditioning. The thermal linkages did not appear visually to have changed after conditioning at 105ºC for up to 305 hours. Figure 22 shows radiographs of the thermal linkages before and after conditioning for various lengths of time.

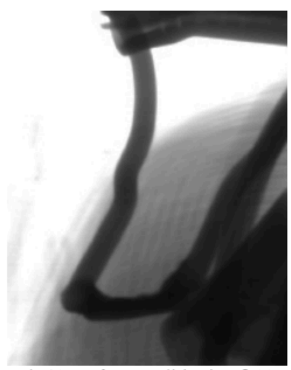

Sub 10 - Before conditioning


Sub 10 - After conditioning@105°C 64.5 hours


Sub 19 - Before conditioning


Sub 19 - After conditioning@105°C 232.5 hours


Sub 41 - Before conditioning


Sub 41 - After conditioning@105°C 232.5 hours


Sub 39 - Before conditioning


Sub 39 - After conditioning@105°C 305 hours

Figure 22 Thermal linkages before and after conditioning

## Results

Of the 14 units tested, one unit failed to open, allowing the winding to overheat and smoke. The unit's bobbin melted from overheating and arcing within the winding. Eight of the 14 units' TCOs opened within 24 minutes. Two of the 14 units' TCOs opened around 50 minutes, reaching temperatures above the rated $T_f$ for the TCO. Eight of the 14 units had elevated temperatures that exceeded the TCOs' rated opening temperature of 136°C. Table 6 lists data for Test Group 3.

Table 6. Test Group 3 - 105°C Conditioning and Lock-rotor Test Data

| Sub | Condition Period (hh:mm) | Max. Temp. at side (°C) | Calculated Functioning Temperature (°C) | Max. Temp. at bottom (°C) | Elapsed Time to Trip (hh:mm:ss) | TCO Open or Activated | Smoke or Fire | Failed to Trip at 136°C |
|---|---|---|---|---|---|---|---|---|
| 42 | 64:30 | 111.9 | ~132 | Loose thermocouple | 0:19:30 | Yes | No | No |
| 10 | 64:30 | 127.5 | ~148 | 181.6 | 0:52:00 | Yes | No | Yes |
| 63 | 113:00 | 109.0 | ~129 | Loose thermocouple | 0:22:00 | Yes | No | No |
| 5 | 113:00 | 131.0 | ~151 | 141.9 | 0:18:00 | Yes | No | Yes |
| 19 | 232:30 | 138.6 | ~159 | 127.2 | 0:54:00 | Yes | No | Yes |
| 41 | 232:30 | 209.8 | N/A | 302.0 | 2:40:00 | No | Yes | Yes |
| 64 | 280:00 | 155.8 | ~176 | 203.8 | 3:26:00 | Yes | No | Yes |
| 75 | 282:00 | 128.8 | ~149 | 157.5 | 0:24:00 | Yes | No | Yes |
| 99 | 288:00 | 151.6 | ~172 | 183.2 | 4:00:00 | Yes | No | Yes |
| 71 | 288:00 | 116.4 | ~136 | 146.4 | 0:19:00 | Yes | No | No |
| 39 | 305:00 | 111.9 | ~132 | 153.4 | 0:18:00 | Yes | No | No |
| 3 | 305:00 | 109.4 | ~121 | 140.2 | 0:22:00 | Yes | No | No |
| 30 | 305:00 | 158.5 | ~179 | 213.4 | 1:37:00 | Yes | No | Yes |

| Sub | Condition Period (hh:mm) | Max. Temp. at side (°C) | Calculated Functioning Temperature (°C) | Max. Temp. at bottom (°C) | Elapsed Time to Trip (hh:mm:ss) | TCO Open or Activated | Smoke or Fire | Failed to Trip at 136°C |
|---|---|---|---|---|---|---|---|---|
| 55 | 305:00 | 105.4 | ~125 | 154.3 | 0:22:00 | Yes | No | No |

Sub 10 - Lock-Rotor Test

Staff conditioned the fan (sub 10) for 64 hours 30 minutes. During the locked-rotor testing, the TCO activated. The TCO activated approximately 52 minutes after the rotor was locked. The activation time was about 30 miutes longer than seen during typical lock-rotor testing, which activated around 20 minutes within the testing. Figure 23 shows the temperature traces for the thermocouples during the lock-rotor test.

Figure 24 shows the CT scan of the fusible link after the lock-rotor test. As seen in prior testing when the trip time is longer than average, the fusible link melts at the center of the link. The figure does show a partial wetting of the electrodes occurred, which allowed the solder link to bead.

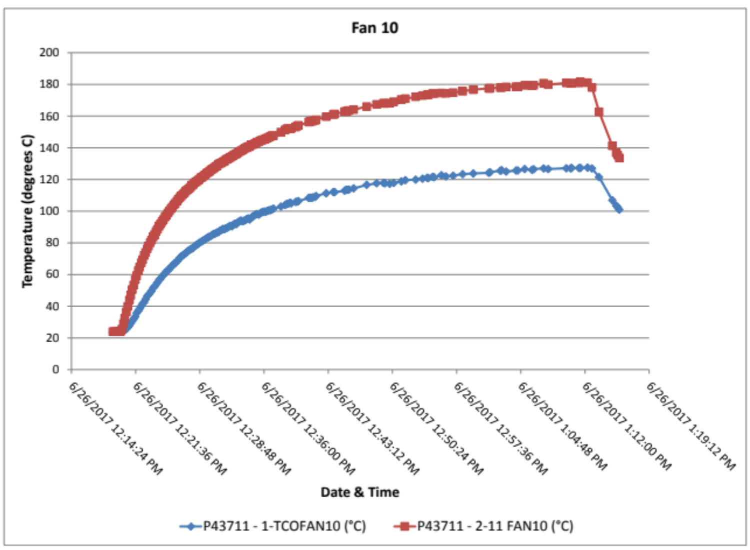



Figure 23. Temperature traces for Sub 10 Test Group 3 - Lock-Rotor Test

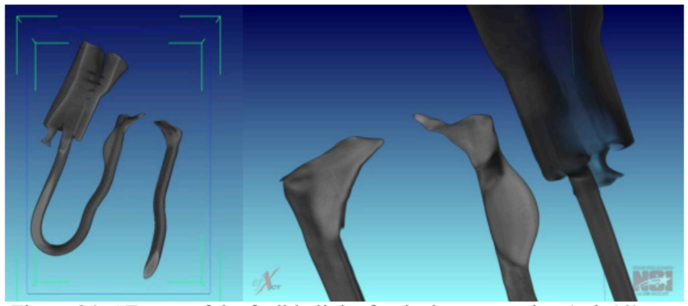


Figure 24. CT scan of the fusible link after lock-rotor testing (sub 10)

<u>Sub 41- Lock-Rotor Test</u>

Staff conditioned the fan (sub 41) for 232 hours 30 minutes. During the lock-rotor testing, the TCO did not activate. After about an hour, the temperature appeared to have leveled to a constant temperature or steady state. Staff terminated the lock-rotor testing after approximately 2 hours 30 minutes. Figure 25 shows the temperature traces for the thermocouples during the lock-rotor test on July 3, 2017.

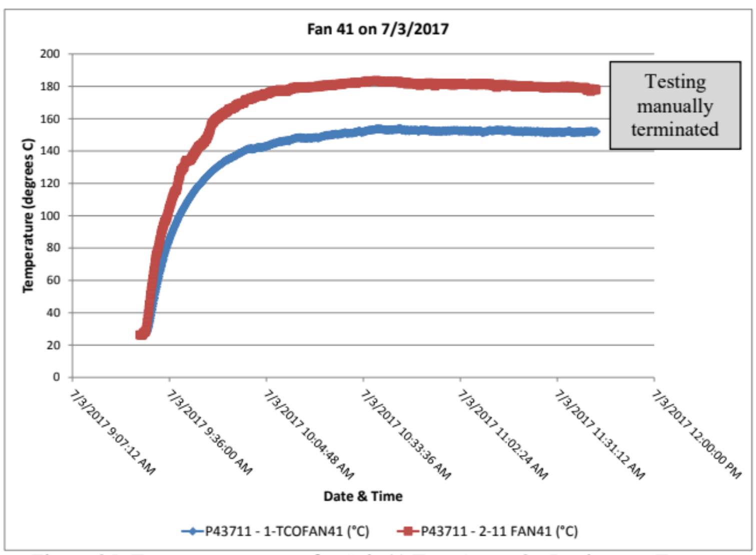



Figure 25. Temperature traces for Sub 41 Test Group 3 - Lock-rotor Test

Staff allowed the fan to cool to room temperature before retesting. During the second lock-rotor test, the temperatures increased rapidly, and the unit began to smoke. The temperature suddenly increased and arcing could be heard. Suddenly the arcing ceased, and the temperature began to decrease. Figure 26 shows the temperature traces for the thermocouples during the lock-rotor test on July 5, 2017. The thermocouple located at the

TCO (blue trace) detached from the surface of the winding when the unit began to smoke, which resulted in a sudden drop in temperature. The elapsed time to maximum temperature was about 9 minutes, 50 seconds.

Figure 27 shows the fan producing significant smoke during the second lock-rotor testing. There were no visible flames during the testing. Examination of the motor shows localized overheating and arcing in the winding. The full elapsed time for the first and second lock-rotor tests was about 2 hours 40 minutes.

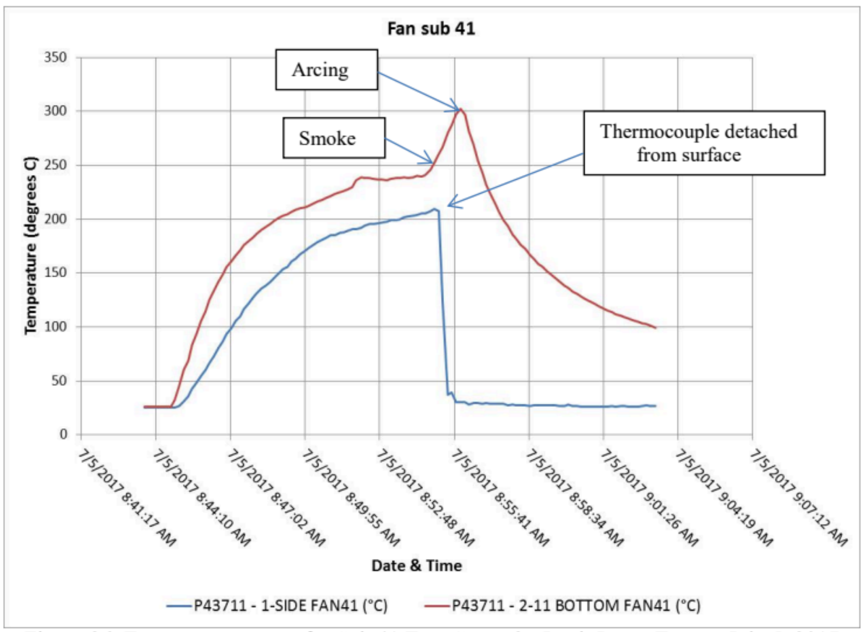



Figure 26. Temperature traces for Sub 41 Test Group 3 - Lock-Rotor Test on July 5, 2017

Figure 27. Sub 41 Test Group 3 - Lock-Rotor Test producing smoke and post examination

Post examination shows the TCO's fusible link to be intact, as shown by CT scans in Figure 28. During lock-rotor testing, the TCO failed to activate, but the event ended because the motor winding opened, thus de-energizing the motor.

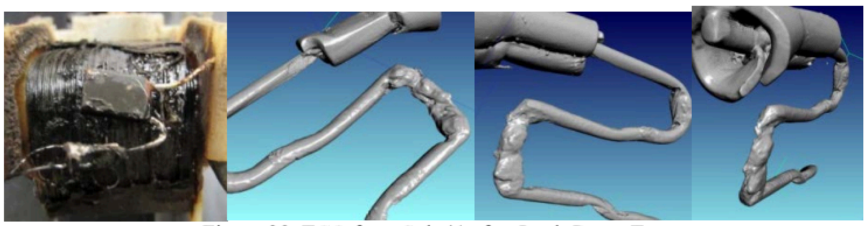


Figure 28. TCO from Sub 41 after Lock-Rotor Test

<u>Sub 64 - Lock-Rotor Test</u>

Staff conditioned the fan (sub 64) for 280 hours. During the initial lock-rotor testing on July 5, 2017, the TCO did not activate. The temperature appeared to have leveled to a constant temperature or steady state. Staff manually terminated the testing at noon, after approximately 3 hours 15 minutes.

Staff allowed the fan to cool for 45 minutes (to approximately room temperature) before retesting. During the second lock-rotor test, the TCO activated. Figure 29 shows the temperature traces for the thermocouples during the second lock-rotor test. The TCO tripped after approximately 11 minutes during the second lock-rotor test.

Post examination revealed a solder bead external to the TCO casing, as highlighted by the yellow circle shown in Figure 30. Microscopic images of the TCO show that the solder bead originated from inside the TCO because solder was located in cracks between the epoxy seal and the lead wire, as shown in Figure 31. Figure 32 shows the CT scans with the partially melted fusible link after the testing, thus, indicating the TCO did activate, but abnormally. Visible in the CT scan is the solder bead, highlighted by the yellow circles.

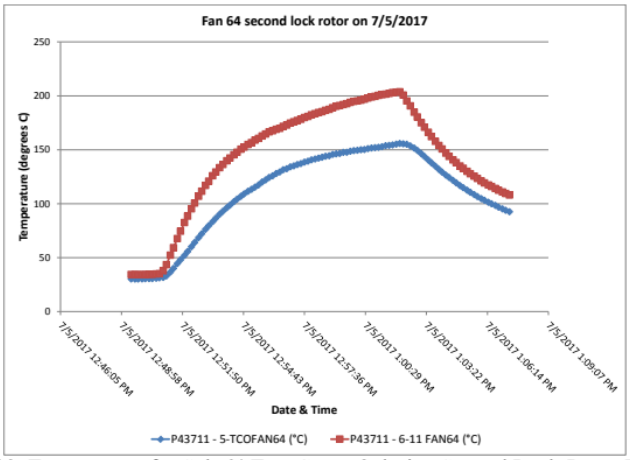



Figure 29. Temperature for Sub 64 Test Group 3 during Second Lock-Rotor Test

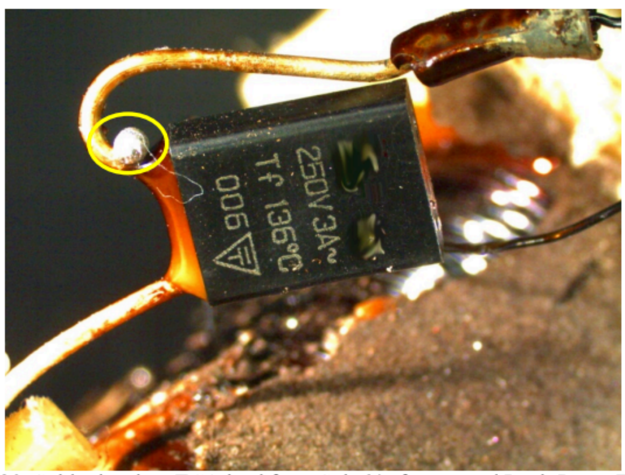
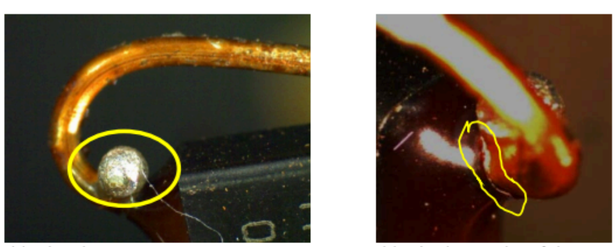



Figure 30. Solder bead on TCO lead from Sub 64 after second Lock-Rotor Test



Solder bead Solder in the cracks of the epoxy/electrode

Figure 31. Microscopic images of the solder bead and solder in the cracks (Sub 64)

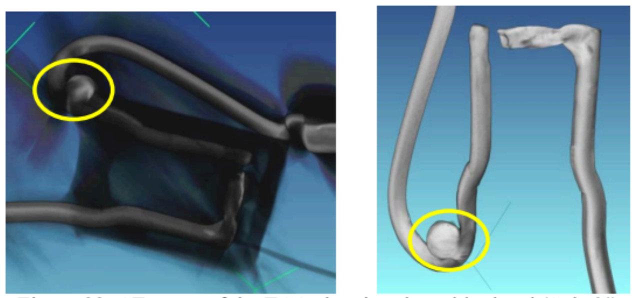


Figure 32. CT scans of the TCO showing the solder bead (Sub 64)

Sub 99 - Lock-rotor Test

Staff conditioned the fan (sub 99) for 288 hours before being subjected to three lock-rotor test periods as summarized in Table 7. During the initial lock-rotor test (segment A), the TCO did not activate. During the second lock-rotor test (segment B), the TCO did not activate. The TCO activated during the third lock-rotor test (segment C). Figures 33 and 34 show the temperature traces for the thermocouples during the three segments of lock-rotor test. The TCO tripped after approximately 30 minutes during the third lock-rotor test, but after almost 5 hours of combined lock-rotor testing (sum of the test duration for all of the segments up to the activation).

Table 7. Segment lock-rotor testing (Sub 99)

| Testing Segment | Test Duration (hh:mm:ss) | Maximum temperature at Side Windings (C) | Calculated TCO Temperature (C) | Maximum temperature at Bottom Windings (C) | Notes |
|---|---|---|---|---|---|
| PART A | 3:09:36 | 150 | ~170 | 182.6 | Manually terminated |
| PART B | 1:12:06 | 151.6 | ~172 | 183.2 | Manually terminated |
| PART C | 0:29:42 | 140.9 | ~161 | 173.3 | TCO tripped |

Post examination revealed the TCO had a solder bead external to the TCO casing. Figure 35 shows the CT scans with the partially melted fusible link after the testing, thus, indicating the TCO did activate, but abnormally. Microscopic images show that the solder originated from inside the TCO because of solder located within the cracks between the epoxy seal and the lead wires. Figure 36 shows the microscope images of the solder bead and solder in the cracks.

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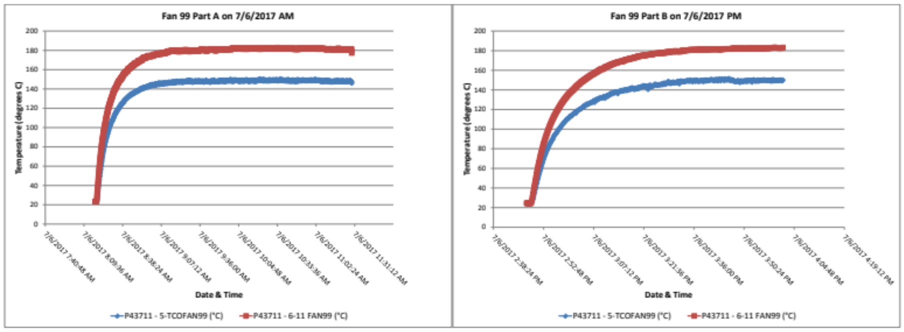



Figure 33. Segment Part A and B temperatures for Sub 99 Test Group 3 - Lock-Rotor Test

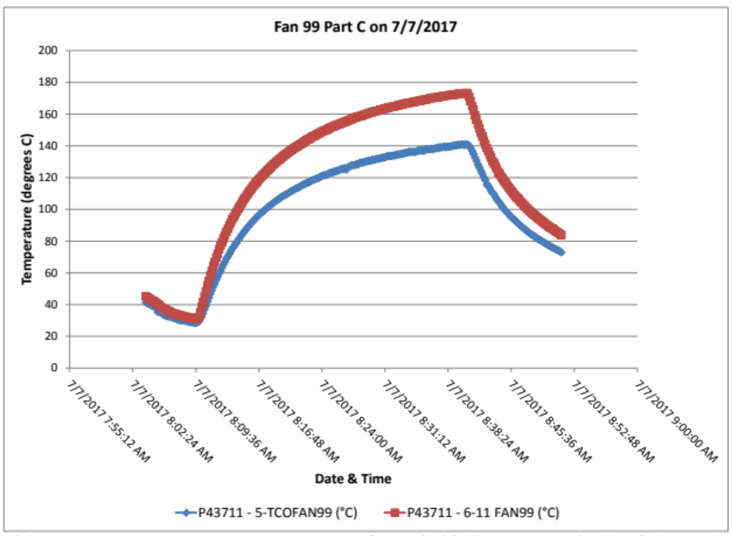



Figure 34. Segment part C temperature traces for Sub 99 Test Group 3 - Lock-Rotor Test

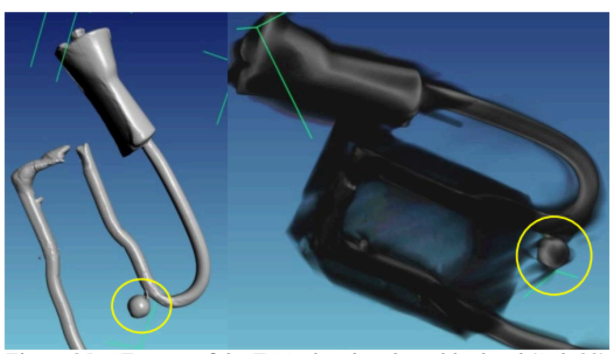
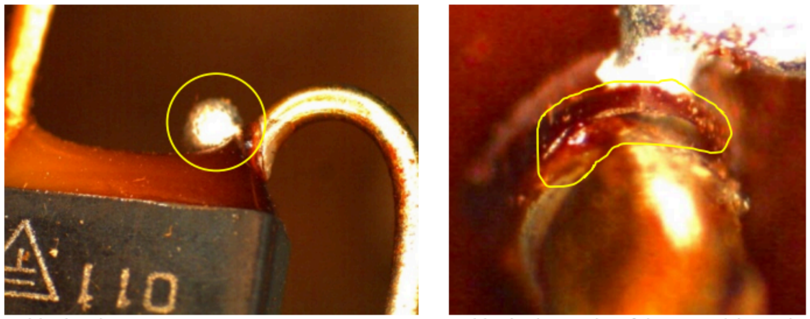


Figure 35. CT scans of the TCO showing the solder bead (Sub 99)




Solder bead | Solder in the cracks of the epoxy/electrode

Figure 36. Microscopic images of the solder bead and solder in the cracks (Sub 99)

### *5.6.3 Test Group 4 - 105°C 165 Hours Conditioning and Lock-Rotor Tests*

Test Group 4 had 15 fans. Staff placed the 15 fans in the conditioning oven at 2:30 p.m. on July 6, 2017. Staff set the conditioning oven at 105°C. After 165 hours (July 13, 2017 at 11:30 am), all 15 units were removed from the conditioning oven and installed in the large test frame. The fans were allowed to cool to room temperature before testing. A single thermocouple was placed on the side of the winding for each fan sample. The fans were tested in a lock-rotor condition on July 14, 2017. Figure 37 shows the temperature traces for Test Group 4 – Lock-Rotor Test.

Eleven of the 15 fans had the TCO activate in less than 45 minutes during the lock-rotor testing. One fan's TCO opened shortly after 2 hours (sub 58). Three of the 15 fans' TCOs (sub 6, 51 and 66) failed to activate or open after 4 hours of lock-rotor, and staff manually terminated the test. Table 8 lists the test results from Test Group 4 lock-rotor testing.

Table 8. Test Group 4 - 105°C Conditioning and Lock-Rotor Test Result

| Test Group 4 | | | TCO | | |
|---|---|---|---|---|---|
| Test Frame Location Number | Fan Sub No. | Thermocouple id | Tripped | Elapsed Time | TCO Failed to Activate Normally |
| 1 | 81 | P43711-1-11FAN01 | Yes | 32 m 35 s | No |
| 2 | 45 | P43711-2-11FAN02 | Yes | 32 m 35 s | No |
| 3 | 11 | P43711-3-11FAN03 | Yes | 33 m 34 s | No |
| 4 | 28 | P43711-4-11FAN04 | Yes | 37 m 24 s | No |
| 5 | 67 | P43711-1-11FAN05 | Yes | 40 m 15 s | No |
| 6 | 58 | P43711-6-11FAN06 | Yes | 2 h 3 m 43 s | Yes |
| 7 | 66 | P43711-7-11FAN07 | No | Over 4 hours | Yes |
| 8 | 9 | P43711-8-11FAN08 | Yes | 34 m 54 s | No |
| 9 | 17 | P42524-1-11FAN09 | Yes | 35 m 53 s | No |
| 10 | 84 | P42524-2-24FAN10 | Yes | 40 m 52 s | No |
| 11 | 1 | P42524-3-24FAN11 | Yes | 44 m 12 s | No |

| | | | | | |
|---|---|---|---|---|---|
| 12 | 51 | P42524-4-24FAN12 | No | Over 4 hours | Yes |
| 13 | 6 | P42524-5-24FAN13 | No | Over 4 hours | Yes |
| 14 | 93 | P42524-6-24FAN14 | Yes | 38 m 1 s | No |
| 15 | 43 | P42524-7-24FAN15 | Yes | 30 m 11 s | No |
| Ambient | | P42524-8-24Amb | | | |

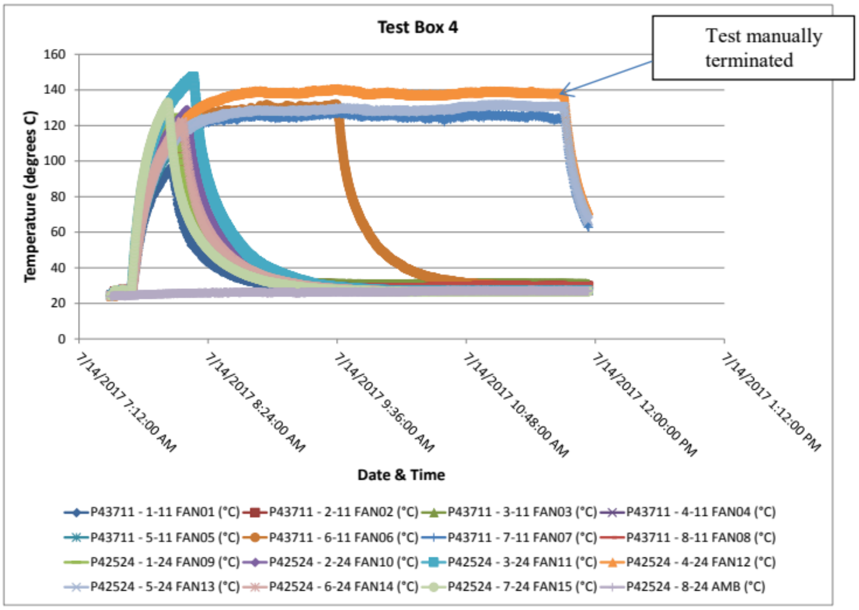



Figure 37. Temperature traces for Test Group 4 - Lock-Rotor Test

Figure 38 shows fan subs 6, 51, 58 and 66 temperature traces for Test Group 4 – Lock-rotor Test. These subs had a TCO that had activation trip times that were long or never tripped. The TCOs were x-rayed and CT scanned.

Figure 39 shows the TCO from sub 58, which tripped but took more than 2 hours. As seen in previous TCOs that had a long trip time, the melted linkage would bead to both wire leads; but in this case, the radiograph shows a thin portion of the fusible link still present.

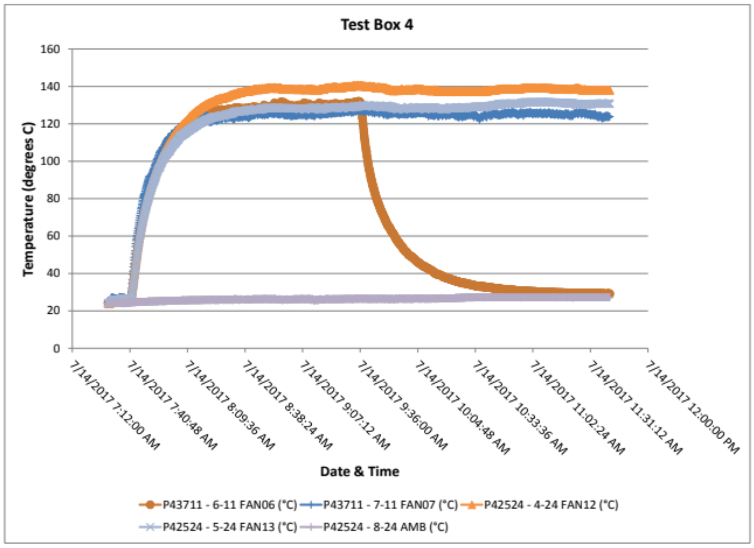
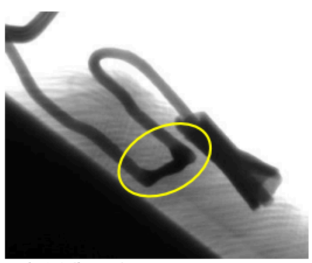
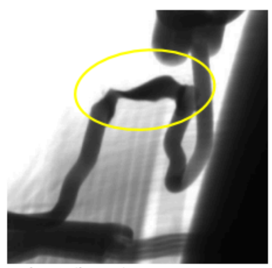


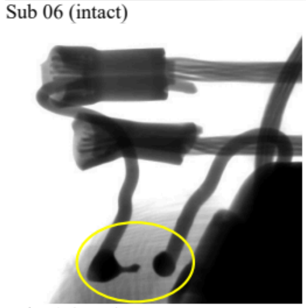

Figure 38. Temperature traces for Subs 6, 7, 12 and 13 (Test Group 4 - Lock-Rotor Test)



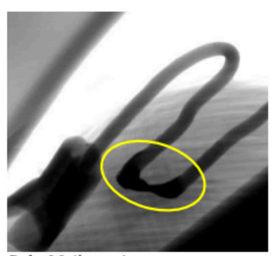
Sub 06 (intact)



Sub 51 (intact)



Sub 58 (open)



Sub 66 (intact)

Figure 39. Radiograph of subs 6, 51, 58 and 66 after Lock-Rotor test

*5.6.4 Test Group 5 - 105°C 330 Hours Conditioning and Lock-Rotor Tests*

Test Group 5 had 15 fans, but only 13 fans were subjected to the lock-rotor test. All 15 fans were in the conditioning oven continuously for 330 hours at 105°C. After 330 hours, all 15 units were removed from the conditioning oven and allowed to cool to room temperature (approximately 23°C) before testing.

Each fan was instrumented with three thermocouples. Channel 1 thermocouple (T) was located at the top of the winding wrap, as viewed with the fan installed. Channel 2 thermocouple (M) was located on the exterior of the winding wrap and on the side of the motor winding on the same side as the TCO. The third thermocouple (B) was located at the bottom or on the lowest side of the winding wrap when the fan is installed. The lock-rotor test was conducted by blocking the impeller and energizing the fan. The thermocouple temperature measurements were recorded every 10 seconds.

Results

Seven of the 13 fans had the TCO activate in less than 34 minutes during the lock-rotor testing. The average maximum winding temperature measured was 160°C before the TCO tripped. On average for the seven fans, the TCO tripped about 20 minutes into the lock-rotor testing. Two (Fan subs 46 and 68) of the 13 fans ran in lock-rotor condition for at least 1 hour before the TCO tripped. One (Fan sub 94) of the 13 fans ran in a lock-rotor condition for almost 37 minutes on the first day before the test was manually terminated (end of the day). When the same unit (Fan sub 94) was lock-rotor tested on the second day, the TCO tripped after about 32 minutes. One (Fan sub 54) of the 13 fans was tested in the lock-rotor condition for a continuous 22 hours, which did not result in the TCO to open or a fire. Staff manually terminted the testing (the fan was de-energized). Two (Fan subs 73 and 23) of the 13 fans ignited during the lock-rotor testing. The TCOs failed to activate in both of these units. Table 9 lists the test results from Test Group 5 lock-rotor testing.

Table 9. Test Group 5 – Conditioning 330 hours at 105°C and Lock-Rotor Test Results

| Test Group 5 | | TCO | | | | |
|---|---|---|---|---|---|---|
| Test date | Sub No. | Tripped | Elapsed time | Maximum temperature | TCO failed to activate normally | Results |
| 7/31/2017 | 46 | Yes | 1 h 1 m 55 s | 163°C | Abnormal | Steady state before tripping, Late TCO trip |
| 8/1/2017 – 8/2/2017 | 94 | Yes | 36 m 57 s (Day 1)<br>31 m 57 s (Day 2) | 202°C | Abnormal | Late TCO trip |
| 8/2/2017 | 57 | Yes | 33 m 42 s | 202°C | Normal | |
| 8/3/2017 -8/4/2017 | 37 | Yes | 15 m 12 s | 159.6°C | Normal | |
| | 54 | No | Steady state for 22 hours continuous | 224.8°C | Failed to open | Manually terminated testing |

| | | | | | | |
|---|---|---|---|---|---|---|
| 8/2/2017 | 73 | No | steady state (~189°C) 1 h 55 m 40 s | 507.4°C | Failed to open | Fire |
| | 33 | Yes | 18 m 52 s | 145.7°C | Normal | |
| 8/2/2017 | 14 | Yes | 20 m 52 s | 137.4°C | Normal | |
| | 49 | Yes | 17 m 01 s | 163.9°C | Normal | |
| 8/4/2017 | 48 | Yes | 18 m 21 s | 147.7°C | Normal | |
| | 23 | No | steady state (~186°C) 2 h 03 m 41 s | 547.3°C | Failed to open | Fire |
| 8/4/2017 | 50 | Yes | 15 m 02 s | 165.2°C | Normal | |
| | 68 | Yes | 2 h 6 m 12 s | 206.2°C | Abnormal | Steady state before tripping |

Sub 73 – Conditioning and Lock-Rotor Test

Fan sub 73 was in lock-rotor condition for about 1 hour and 56 minutes before the unit ignited, as shown in Figure 40. The fan's winding temperature was at a steady-state temperature (~188°C) above the TCO function temperature for about 1 hour, until the winding temperature began to increase rapidly. This rapid increase in temperature is an indication of shorting in the winding, which reduces the winding resistance and increases the current. Before ignition, with the winding temperature at about 233ºC, the unit was producing visible white smoke. When the unit ignited around 289°C, there was a large flash and flames for a brief moment. It appears that the gaseous vapors driven off the winding coating ignited. The flames subsided slightly until the wrap around the winding and the coating on the windings started to burn, growing in intensity. The flames impinged on and ignited the plastic impeller. The burning impeller and bobbin resulted in dripping flaming plastic. Four layers of cheesecloth were placed under the fan to be used as an ignition indicator to verify that the dripping plastic continued to burn as it landed on the surface below. The dripping flaming plastic caused the cheesecloth to ignite, which indicates that the fan's plastic grill could also ignite in this type of situation. Figure 41 shows a sequence of photographs demonstrating the progression during lock-rotor testing on sub 73.

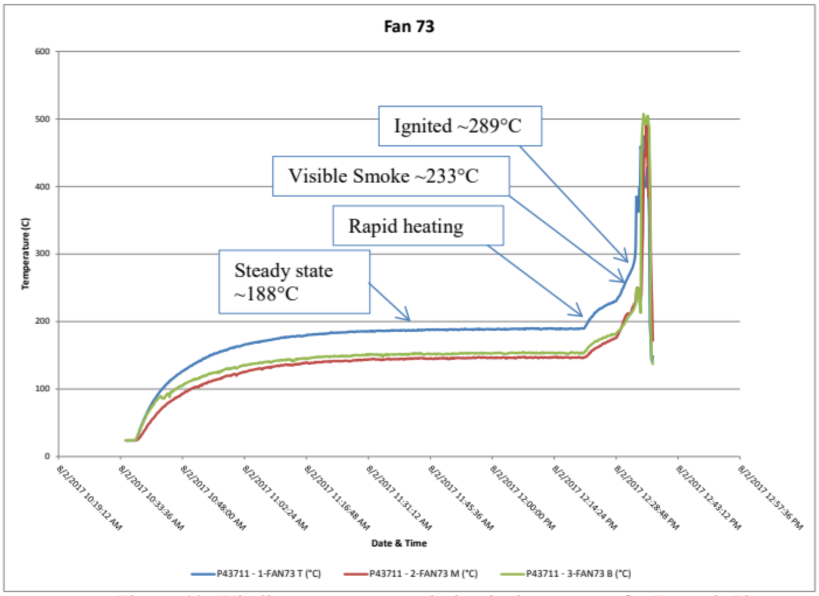
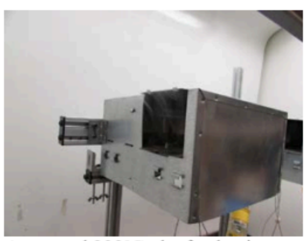



Figure 40. Winding temperatures during lock-rotor test for Fan sub 73



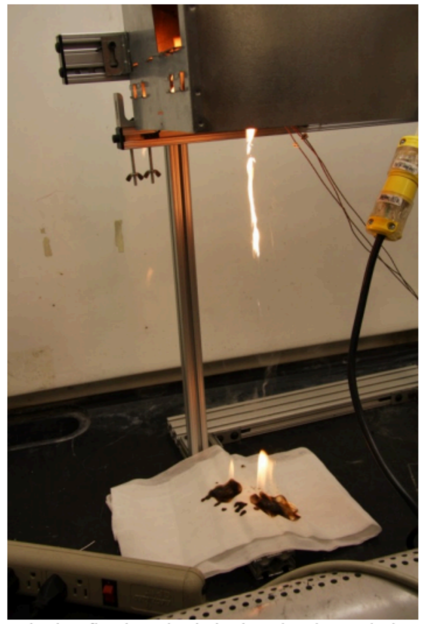
At around 233ºC, the fan begins producing white smoke

At sufficient temperatures, there appears to be an ignition of gases around the motor around 288°C

The large flames subside and the winding wrap and/or the winding coating appears to be burning

More of the winding wrap and the coating on the winding burns, thus creating a larger flame

The impeller has ignited and begins to sag onto the motor



Dripping flaming plastic ignites the cheesecloth ignition indicator

Figure 41. Fan sub 73 during lock-rotor test

Figure 42 shows a radiograph of the TCO after the test. Post-test radiographs of the TCO show the TCO is open, which was caused by the intense heat from the flames. This would suggest that any analysis of a TCO after a fire incident does not necessarily indicate the status of the TCO during the incident.

Figure 42. Radiograph of the TCO after the test (sub 73)

CPSC staff reviewed the CT scans of the thermal linkage for fan sub 73. The thermal linkage shows abonormalities as shown in Figure 43. The CT scans appear to show the linkage to take partial form of the TCO case, such that a flat section had formed. In theory, temperatures below $T_f$ may be causing the thermal linkage to soften. This may cause changes in the eutectic materials, where it may alter the eutectic temperature or $T_f$.

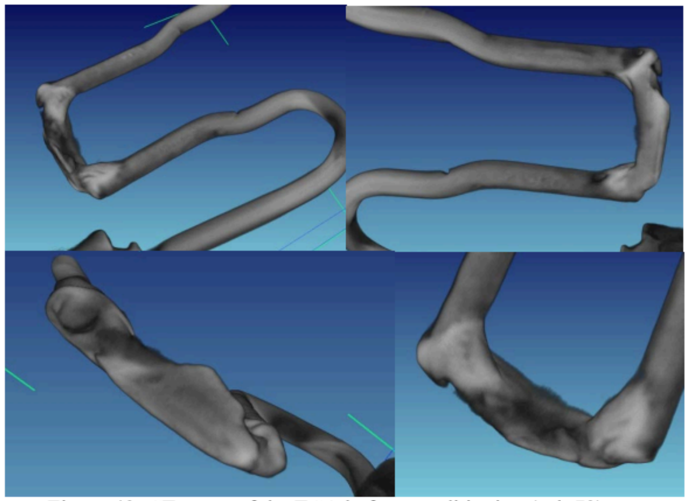


Figure 43. CT scans of the TCO before conditioning (sub 73)

Sub 23 – Conditioning and Locked-Rotor Test

Fan sub 23 was in lock-rotor for about 2 hours and 40 minutes before the unit ignited, as shown in Figure 44. The fan's winding temperature, ~186°C, was at steady state, above the TCO specified activation temperature, until the winding temperature began to increase rapidly. This rapid increase in temperature indicates shorting in the winding, which reduces the winding resistance. Before ignition, at about ~292ºC, the unit was producing visible white smoke. Similar to Fan sub 73, when the unit ignited at ~340°C, it produced a large flash and flames for a brief moment. The large flames subsided slightly, until the flames ignited more of the wrap around the winding and/or the coating of the winding. The flames impinged on and ignited the plastic impeller. The burning impeller and bobbin resulted in dripping flaming plastic. Four layers of cheesecloth were placed under the fan to be used as an ignition indicator. The dripping flaming plastic ignited the cheesecloth, which indicates that the fan's plastic grill could also ignite in this type of situation. Figure 45 is a sequence of photographs during lock-rotor testing for sub 23.

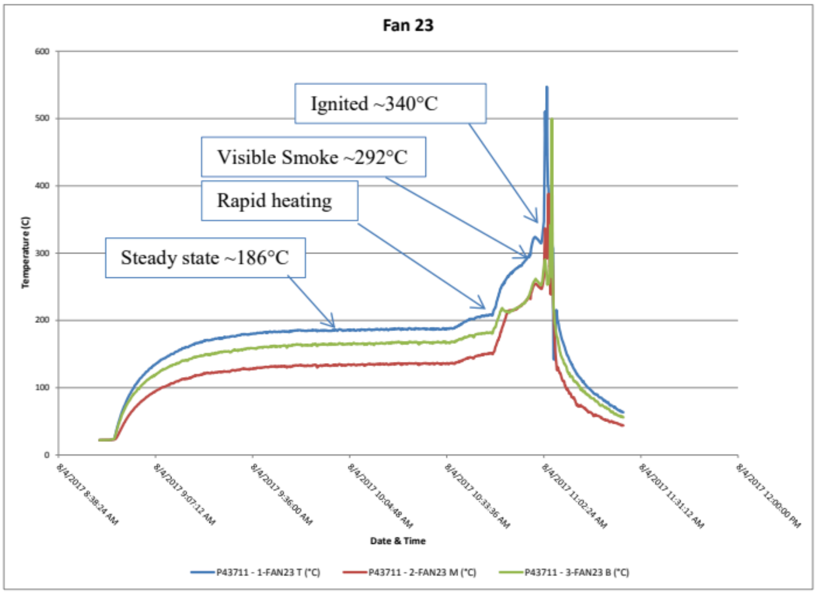


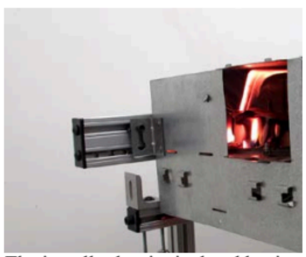

Figure 44. Winding temperatures during lock-rotor test for Fan sub 23

At around 292ºC, the fan begins producing white smoke

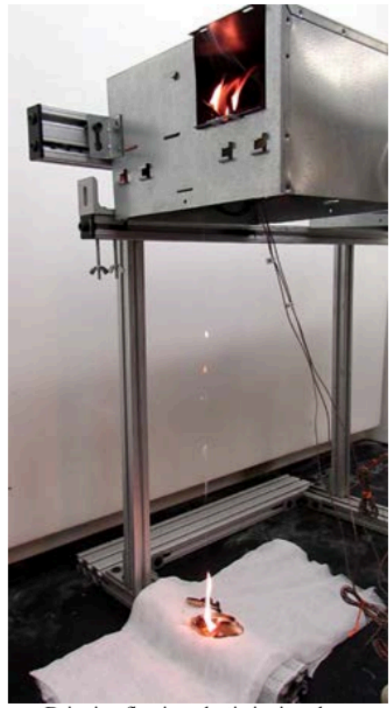
At approximately 340°C, there appears to be an ignition of gases around the motor

The large flames subside and the winding wrap and/or the winding coating appears to be burning

More of the winding wrap and the coating on the winding burns, thus creating a larger flame



The impeller has ignited and begins to sag onto the motor



Dripping flaming plastic ignites the cheesecloth ignition indicator

Figure 45. Fan sub 23 during lock-rotor test

Figure 46 shows a radiograph of the TCO after the test. Post-test radiographs of the TCO show the TCO is open, which was caused by the intense heat from the flames. This would suggest that any analysis of a TCO after a fire incident does not necessarily indicate the status of the TCO during the incident. The radiograph shows a thin portion of the thermal linkage intact. It would appear even at the high temperatures when the motor ignited, portions of the eutectic material in the thermal linkage could not melt.

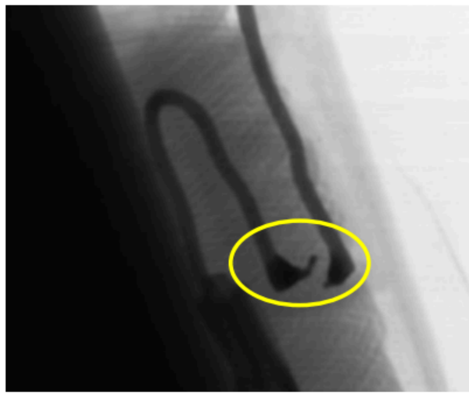


Figure 46. Radiograph of the TCO after the test (sub 23)

The CT scans of the thermal linkage for fan sub 23 were reviewed. The thermal linkage shows some abonormalities, as shown in Figure 47. The CT scans appear to show the linkage uneven and bulging in some areas.

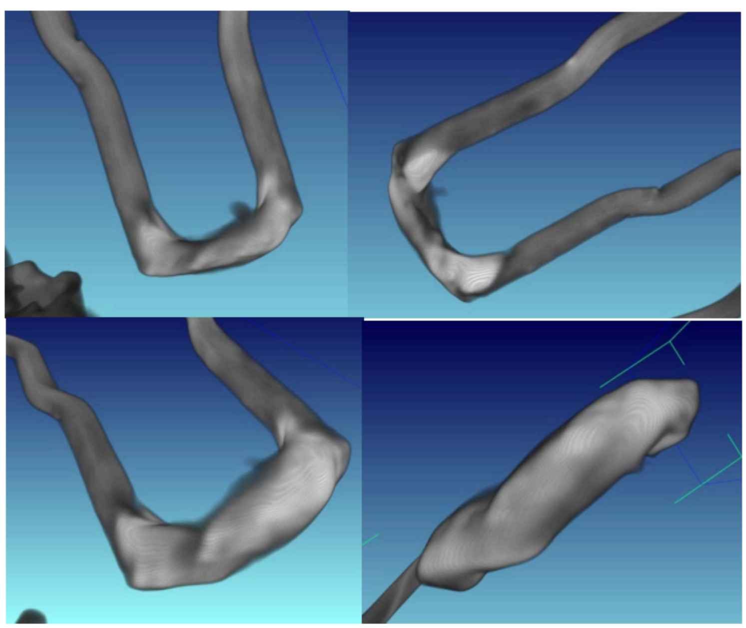


Figure 47. CT scans of the TCO before conditioning (sub 23)

Sub 54 – Fails to Open After 22 Hours of Lock-Rotor Testing

As previously indicated, fan sub 54 was tested in lock-rotor condition for 22 hours. After the initial 3 hours, the temperature increased and then leveled off. The fan maintained a steady temperature that was well above the TCO activation temperature for the majority of the testing, as shown in Figure 48. The TCO did not activate, and staff manually terminated the test after 22 hours. Figure 49 shows radiographs of the TCO after the test. The linkage appears to have thinned out, but is still intact. The figure shows a bead had formed outside the TCO casing.

Figure 50 shows radiographs of the TCO before and after the test. From these angles, the thermal linkage appears not to have changed shape significantly, but depending on the viewing angle, the thermal linkage is thicker or thinner.

Figure 51 shows CT scans of the TCO after the test. CT scans of the TCO confirm the solder link within the TCO is intact. The radiographs and CT scans show a solder bead has formed outside the TCO casing. This would suggest that the TCO is no longer hermetically sealed when thermally aged or placed under thermal stress. The reason that the windings were operating at such an elevated temperature for so long without eventually breaking down is not known, but it can be surmised that the winding coating would eventually deteriorate and cause shorts within the winding because the eurectic temperature has changed from $T_f$.

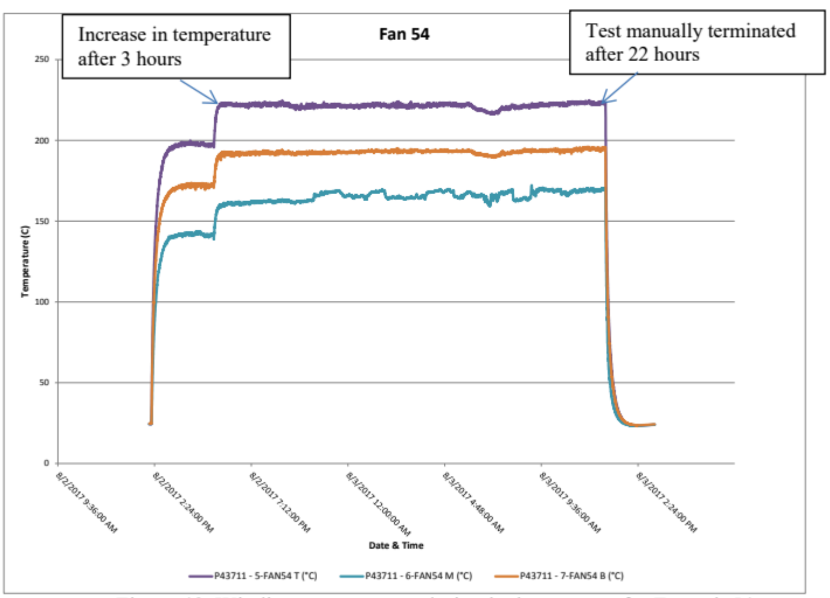


Figure 48. Winding temperatures during lock-rotor test for Fan sub 54

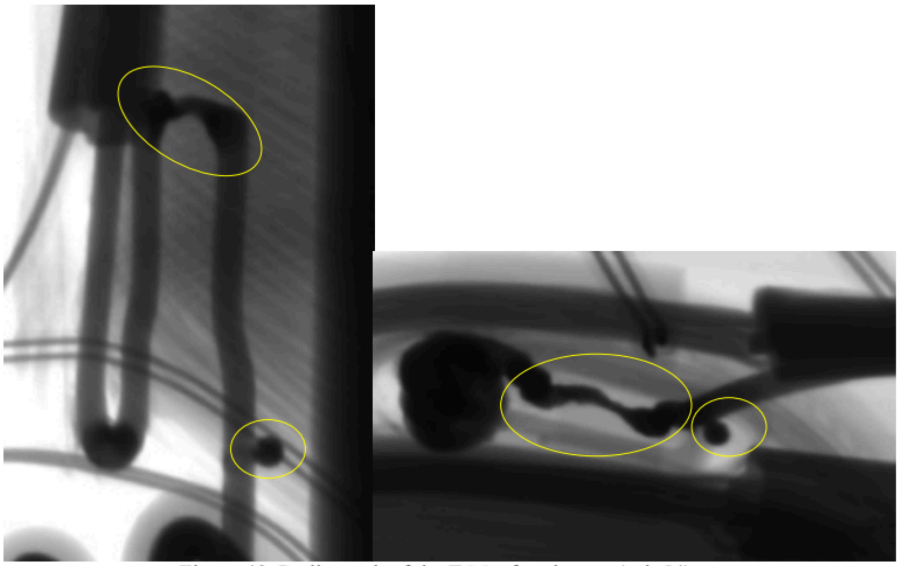
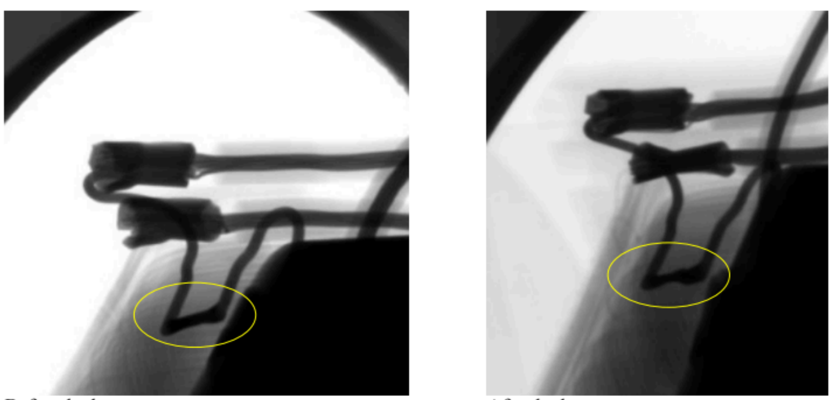


Figure 49. Radiograph of the TCO after the test (sub 54)



Before lock-rotor test After lock-rotor test

Figure 50. Radiograph of the TCO before and after the test (sub 54)

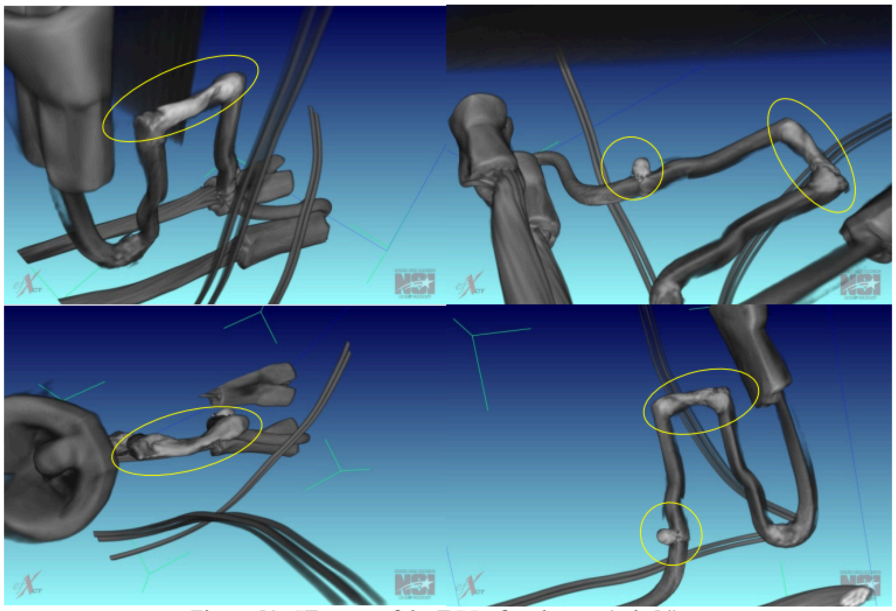
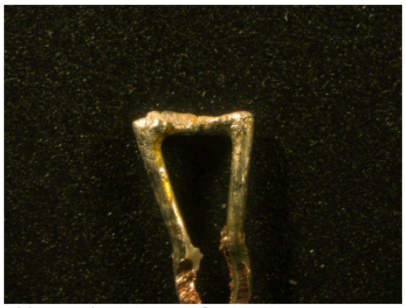
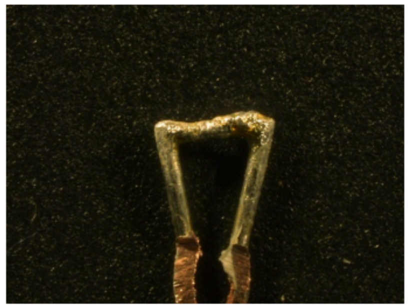


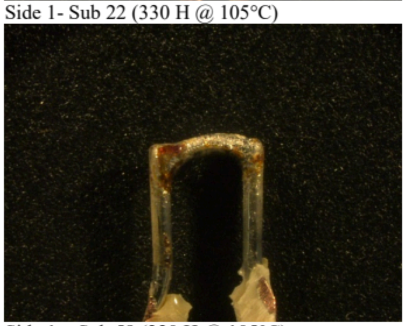
Figure 51. CT scans of the TCO after the test (sub 54)

### 6.0 Analysis of the Special Compound (Flux) and Solder Link

Subs 22 and 59 (conditioned for 330 hours at 105°C) from Test Group 5 were reserved for analysis of the solder link within the TCO. The TCO casing was opened and the internal components were removed. For comparison, two TCOs, sub 74 and 85 (no conditioning), from Test Group 7 were also reserved for TCO analysis where the TCO casing was opened and the internal components removed. Figure 52 shows the solder links from Fan subs 22 and 59, which have been conditioned 330 hours at 105°C. Figure 53 shows the solder links from Fan subs 74 and 85, which have not been conditioned. Sub 85 shows some deformation in the solder link, where part of the solder link has flattened and formed to the interior of the TCO casing, but this was already present before any conditioning of the TCO. The mechanical structure of the solder linkage appeared unchanged as a result of the conditioning, when the before and after radiographs were compared.


Side 1- Sub 22 (330 H @ 105°C)


Side 2 – Sub 22 (330 H @ 105°C)


Side 1 – Sub 59 (330 H @ 105°C)

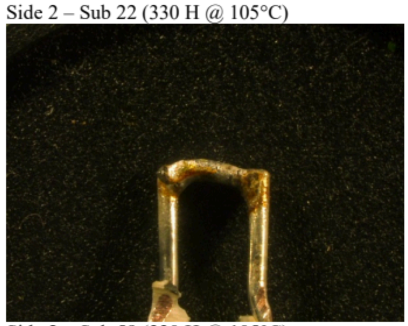
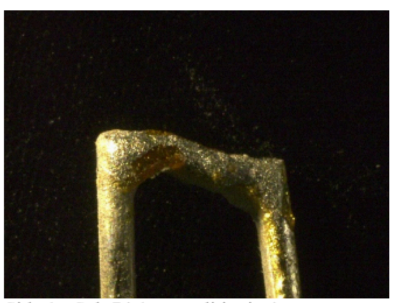
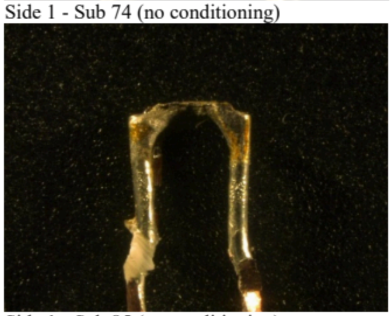

Side 2 – Sub 59 (330 H @ 105°C)

Figure 52. TCO solder link from Fan subs 22 and 59 (conditioned 330 hours @ 105°C)


Side 1 - Sub 74 (no conditioning)

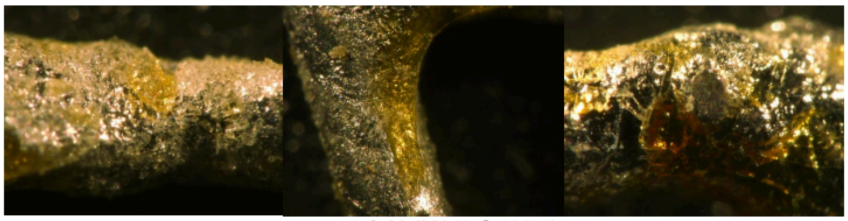

Side 2 - Sub 74 (no conditioning)


Side 1 - Sub 85 (no conditioning)

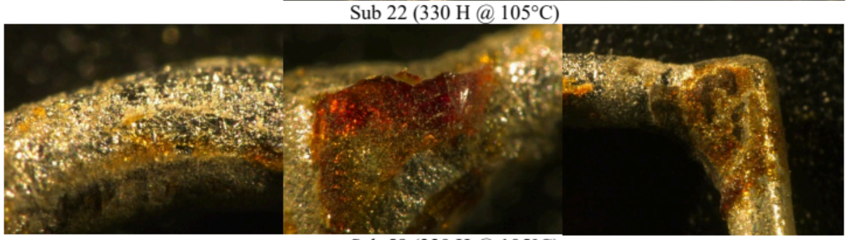

Side 2 - Sub 85 (no conditioning)

Figure 53. TCO solder link from Fan subs 74 and 85 (no conditioning)

Staff observed under a microscope that a yellowish substance was on the solder link, as shown in Figures 54 and 55. This was thought to be the special coating or flux material. Staff also observed that the conditioned TCOs appeared to have less of the yellowish substance than the TCOs that were unconditioned, but staff did not measure an actual mass content or volume of the substance for each sample.

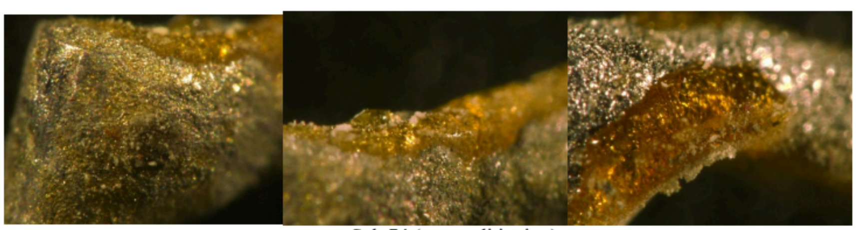


Sub 22 (330 H @ 105°C)

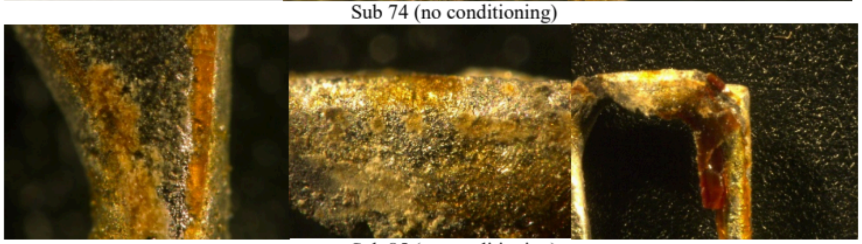


Sub 59 (330 H @ 105°C)

Figure 54. Close-up images of the TCO solder link (conditioned 330 hours @ 105°C)



Sub 74 (no conditioning)



Sub 85 (no conditioning)

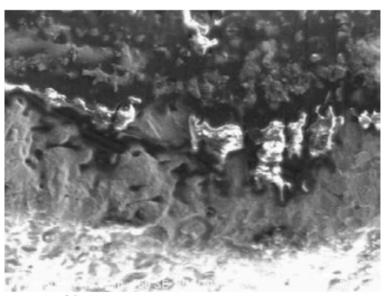
Figure 55. Close-up images of the TCO solder link (no conditioning)

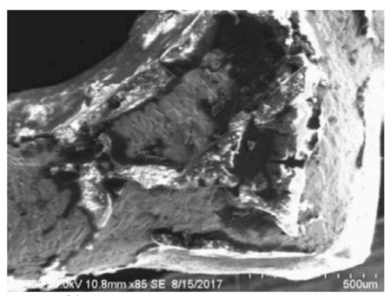
The TCOs were further explored using a scanning electronic microscope (SEM) and x-ray diffraction (XRD). SEM is used for topographical, compositional and morphological characterization. XRD is used to study nature of phases/microstructure and their crystal structure. Figure 56 shows SEM scans of the solder link and terminals. SEM and XRD analysis for sub 59, which was conditioned at 105ºC, show that the wire leads are copper and the thermal linkage is comprised of mainly tin, indium, and lead.

Area of interest 1 is the solder link. This is mainly comprised of carbon (C), oxygen (O), indium (In), tin (Sn), and lead (Pb). There is a trace amount of Silicon (Si). The indium, tin, and lead are most likely the elements that make up the solder link. Carbon and oxygen are most likely the elements that make up the special compound coating.

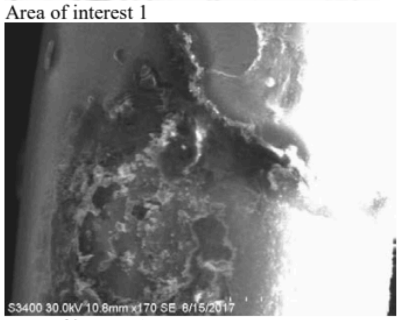
Area of interest 2 is the solder link connection to the copper terminal. This is mainly comprised of C, O, In, Sn and Pb. There is a trace amount of silicon (Si) and copper (Cu). Copper shows up because it is the bulk material of the terminal.

Areas of interest 3 and 4 are the copper terminals. This is mainly comprised of Cu and Sn. There are lower amounts of C and O.

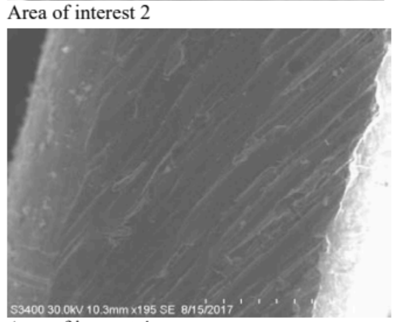

Area of interest 1



Area of interest 2



Area of interest 3

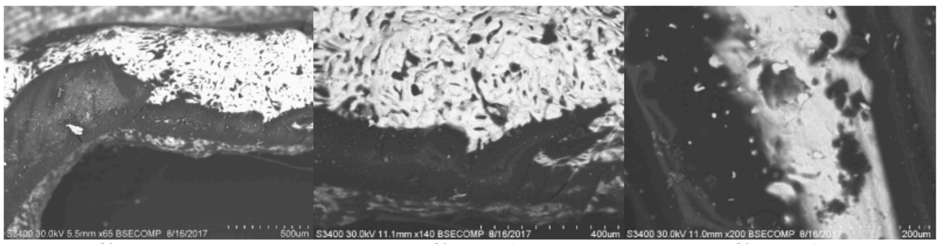


Area of interest 4

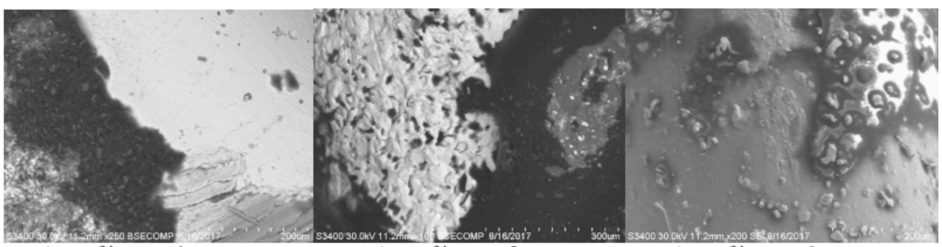
Figure 56. SEM scans for Sub 59

SEM analysis for sub 74, which was not conditioned, is shown in Figure 57. Area of interest 1 is the solder link. This is mainly comprised of C, In, Sn, and Pb. The Indium, Tin, and Lead are most likely the elements that make up the solder linkage. Carbon and Oxygen are most likely the elements that make up the special coating. Area of interest 2 is a close-up of an area from area interest 1. This is mainly comprised of C, O, In, Sn, and Pb. There is a trace amount of Si.

Areas of interest 3, 4, 5, and 6 are areas that had coating on the terminals or solder link.



Area of interest 1 Area of interest 2 Area of interest 3



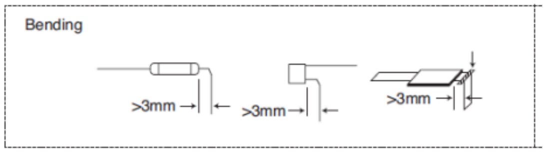
Area of interest 4 Area of interest 5 Area of interest 6

Figure 57. SEM scans for Sub 74

## 7.0 Bending and Forming TCO Leads (Design Applications - Forming and Cutting)

Staff conducted research to determine whether there is standard practice for bending the lead wires on TCOs. Below is a list of precautious in bending the wire leads. The general practice appears that the bend should occur 3 to 4 mm from the seal. It is also recommended that the wire lead is held during the bending to prevent stress on the seal, which may cause the seal to leak. Lock-rotor testing has shown that solder from the thermal linkage can seep out of the seal, forming a solder bead on the wire lead outside the casing. This would suggest that a crack has formed between the seal on the wire lead.

- Lead wires (terminals) are to be bent or cut at least 3mm away from the TCO seals to avoid damaging the TCO (axial/radial type) or body (thin type). The TCO seals (axial/radial type) shall not be grasped with any tools or holders. Terminals of thin type TCO are to be grasped before they are bent. (See Fig. 1) (Reference - XICON PASSIVE COMPONENTS, Thermal Cutoffs (TCO)/Thermal-Links 447-XYP 1BF145-RC).




- Lead wires (terminals) are to be bent or cut at least 3 mm away from the TCO seals to avoid damaging the TCO (axial/radial type) or body (thin type). The TCO seals (axial/radial type) shall not be grasped with any tools or holders. Terminals of thin type TCO are to be grasped before they are bent. (See Fig.1) (Reference - PANASONIC, Thermal Cutoffs (TCO))

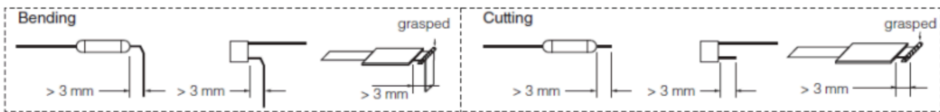
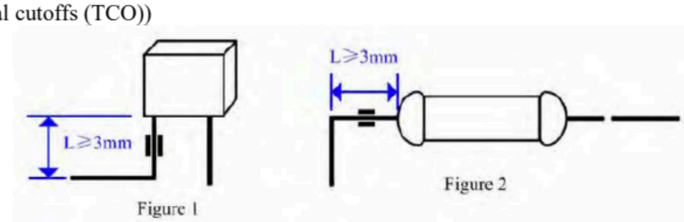



Fig-1

- When bending a lead wire for installation, fix the part of the lead between the body and the lead section to be bent using a tool, and gently bend the lead section that is at least 3 mm from the body. Never hold the body with a tool. (Reference - Bending Lead Wires – Cautions (http://www.cci-tco.com/bending-lead-wires-cautions/)
- When bending a lead, bend at a location 3mm minimum from the body of the thermal cutoff. See below. (Reference - Thermtrol, Mechanical Thermal Cutoffs (0.5 to 7 amp))
- Bend the lead wire at least 4 mm away from the molding. Otherwise, the damage of the molding worsens the airtightness and impedes the normal operation of the thermal fuse. Use a nipper or other tool to prevent damage. (Reference - SUNGWOO INDUSTRIAL, No.1 Thermal Cutoff Fuse Manufacturer in Korea | Sung Woo Industrial Co. – Precautions)
- When bending the lead wire, to avoid applying excessive pressure to the root of the lead wire, secure the lead wire close to the case, and bend the part beyond the secured section. The lead wire should be bent at a distance of 3 mm or more from the body of the fuse, and should not be twisted. (Reference - NEC/SCHOTT, Thermal Fuse)
- If the lead has to be used by bending it, bend it at approx. 3mm in minimum away from the molded section. Use radio pinchers to bend the wire, as shown in Fig.1 and not to damage the molded section of the case and the lead wire. (Reference - Xiamen SET Electronics Co.,Ltd, Thermal cutoffs (TCO))




- Bend the lead wire at least 4 mm away from the seal. The damage of the sealant worsens the air tightness. Note that bending is conducted with care, since the worst air tightness impedes the normal operation of TCO. Holders or tools used during lead forming must not grasp the body, but lead wire. Doing so can protect from damage to the body of TCO. (Reference - US ELECTRONICS, INC, Thermal Cutoff Fuses)

UL 60691, *Thermal-Links – Requirements and Application Guide*, contains construction requirements under Section 9 – Mechanical Requirements. The section specifies that "Leads and terminal parts shall be secured so that stress on them during installation and normal use does not impair operation of the THERMAL-LINK. THERMAL-LINKS using seals with formed leads for use in appliances or components shall not be bent less than 3 mm from the THERMAL-LINK seal." The section states that the leads are to be bent at least 3 mm from the seal, unless the following two exceptions are met:

Exception: Leads may be bent less than 3 mm from the seal, if

a) the THERMAL-LINK manufacturer's bending fixture and procedure does not transmit stress to the THERMAL-LINK operating mechanism, and

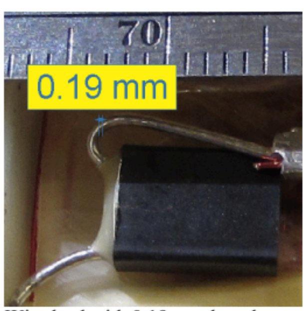
b) formed test samples shall be subjected to the bending/twist lead secureness test of 9.4 and the RATED FUNCTIONING TEMPERATURE test of 11.2.

To determine the installation construction of the wire leads on the TCOs for the motor fan samples in this testing, 15 units were randomly selected from Test groups 1 and 2. These units all functioned when previously tested in the lock-rotor testing, and the testing should not have altered the TCO position and the wire lead positions and configuration. Table 10 lists the fan samples selected and the measured distances between the seal and the bend in the wire leads. Two of the 15 samples measured had wire lead lengths greater than 3 mm between the seal and the inside bend. The average length between the seal and inside bend in the wire lead was 1.28 mm. This suggests that the TCOs' seal can be damaged during the bending of the wire leads, which can allow oxygen to enter into the TCO case. From the literature, damaged seals may alter TCOs' functioning temperature.

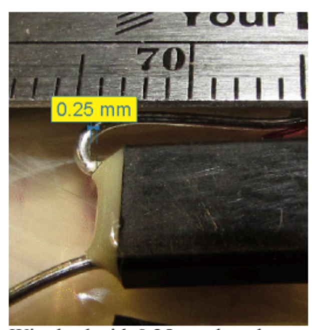
Table 10. Distance between the seal and the wire lead bend

| | Sub # | Distance (mm) |
|---|---|---|
| Test 1 | 60 | 4.14 |
| | 98 | 0.19 |
| | 52 | 1.10 |
| | 27 | 4.52 |
| | 36 | 0.56 |
| | 89 | 0.52 |
| | 35 | 0.55 |
| Test 2 | Sub # | Distance (mm) |
| | 53 | 0.83 |
| | 4 | 1.00 |
| | 88 | 1.43 |
| | 16 | 1.13 |
| | 26 | 0.25 |
| | 20 | 1.86 |
| | 79 | 0.38 |
| | 100 | 0.80 |
| | Average (mm) | 1.28 |

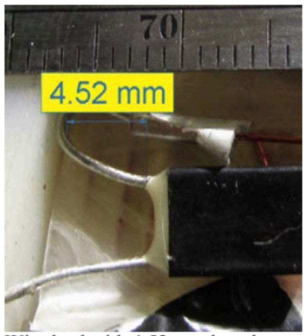
Figure 58 shows the TCO wire lead bends can vary between fan motors. Even though sub 27 shows the wire lead bend greater than 3 mm, it appears that the base of the wire lead near the seal was not secured when the wire lead was bent, which is evident by the outward angle of the wire lead.



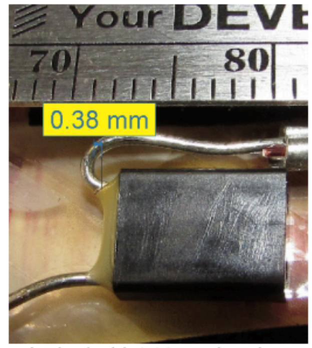

Wire lead with 0.19 mm length between the seal and bend (Sub 98)




Wire lead with 0.25 mm length between the seal and bend (Sub 26)




Wire lead with 4.52 mm length between the seal and bend (Sub 27)




Wire lead with 0.38 mm length between the seal and bend (Sub 79)

Figure 58. Wire bend lengths vary between TCOs in the Fan samples

**8.0 Discussion**

The CPSC lab testing of field samples supports that during the life of the fan motor, the eutectic thermal fuses may fail due to thermal aging, thus presenting a fire hazard. The observations indicate that exposure of the TCO to heat and oxygen over time may delay the opening, and in some cases, result in failure to open. Because the conditioning at 105ºC over a period time did not change the thermal linkage shape, it is theorized that either the properties of the thermal linkage or the special compound that coats the thermal linkage can change with heat and time. The amount of special compound that coats the thermal linkage may also influence the effects of thermal aging, but this was not investigated.

Improper bending of the wire lead may result in cracking of the epoxy seal, thus allowing solder to flow out and oxygen to enter the TCO and alter the functioning temperature of the TCO. Oxygen along with heat and time may also be a combination that could be accelerating the changes in the properties for the thermal linkage and the special compound.

The testing of these motors showed that the winding temperatures can reach sufficiently high temperatures to ignite the motor during a lock-rotor condition, if the TCO fails to activate. During a lock-rotor condition for these tests, the TCO temperature may reach temperatures at or above 140°C before the TCO activates; thus, short periods of "on" time may thermally age the TCO and alter the functioning temperature of the TCO. Testing showed the TCO can experience temperatures up to 140°C in less than 20 minutes. Staff surmised that a fan entering into a lock-rotor condition may experience multiple events of thermal heating if the fan is not energized for sufficient time to cause the TCO to activate. These multiple heating events may have compounding effects on the TCO properties, thus causing the TCO to delay or fail to activate.

Figure 59 shows Fan sub 60 temperatures for normal and lock-rotor operation. In normal operations, the TCO temperature stabilizes at around 68ºC. For lock-rotor condition, the TCO activates at a TCO temperature around 142ºC after 20 minutes. This would suggest that an exhaust fan that is in lock-rotor condition, but is operated for less than 20 minutes, can have the TCO heated to temperatures up to 142°C. If the exhaust fan is operated for more than 3 minutes, the TCO is experiencing temperatures above normal operation.

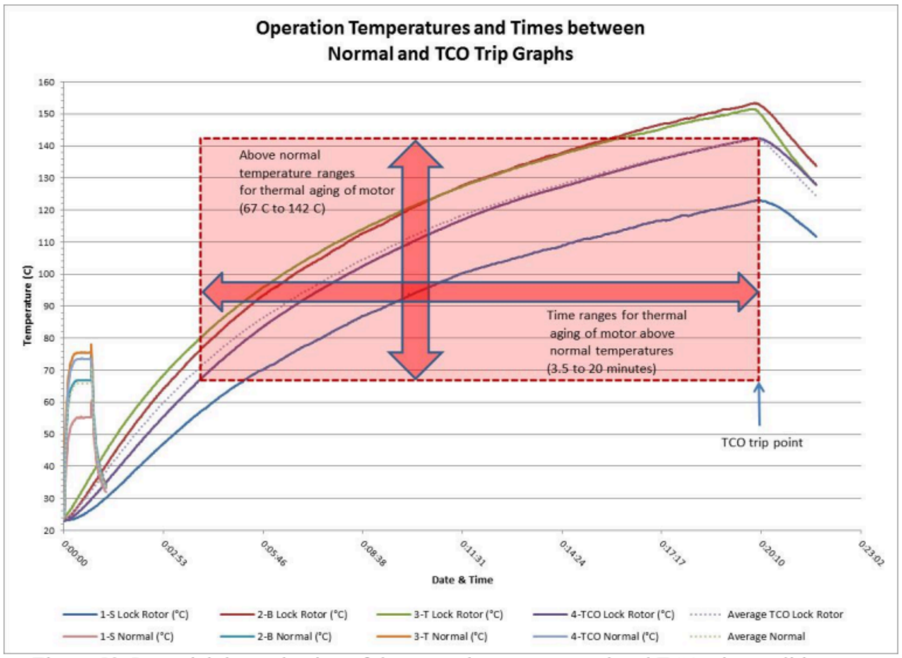



Figure 59. Potential thermal aging of the motor between normal and TCO trip conditions

Aging in UL Standards

UL 60691, Thermal-Links – Requirements and Application Guide, Section 11, Temperature test addresses aging for thermal links. Similar to the Thermal-Element Stability Test that was in UL 1020, UL 60691 incorporates the same aging test. The Aging Tests assess whether aging at high temperatures has a deleterious effect on the thermal links. The TCO is subjected to a series of test steps where the conditioning temperature and period change. If a TCO trips, the remaining TCOs are tested at the next step. The test is considered successful if all TCOs have functioned after the first two steps. In summary, the six steps are as follows;

- Step 1 If requested by the manufacturer, the specimens are subjected to a temperature chosen between Tf–15 K and Th for a period of 3 weeks. At the conclusion of the test, at least 50 percent of the specimens shall not have functioned.

- Step 2 Tf – 15 K for 3 weeks. At the conclusion of the test, at least 50 percent of the specimens shall not have functioned, unless the specimens have already been submitted to Step 1, in which case all specimens may have functioned.
- Step 3 Tf – 10 K for 2 weeks.
- Step 4 Tf – 5 K for 1 week.
- Step 5 Tf – 3 K for 1 week.
- Step 6 Tf + 3 K for 24 hours.

UL 60691specifies in Annex C, Conductive Heat Ageing Test. The test is conducted on thermal links with a $T_f$ rating of 175°C or above and is optional for thermal links with a $T_f$ rating less than 175°C. The section includes an exception, where the test does not need to be performed if the thermal link is eutectic type and is constructed without contacts. This test was most likley derived in the early 1990s when there were a high number of fire incidents with coffeemakers. To address TCOs failures that were being caused by thermal conductive heat aging, UL develeoped the Conductive Heat Ageing Test. The TCOs typically used in coffeemakers are higher-rated, pellet-type TCOs.

UL 507, *Standard for Electric Motors,* and UL 1004-3, *Standard for Safety Thermally Protected Motors*, do not account for thermal aging of the motor as a system before the motor is operated in lock-rotor conditions. As seen in the testing, the installation of the TCO and thermal aging may cause the TCO not to function at $T_f$. Thus, incorporating a performance aging test is a realistic evaluation of the system to verify whether aging at high temperatures, but at less than the functioning temperature, has a deleterious effect on the motor and its safety components. A fan that has entered into a lock-rotor condition may experience multiple events of thermal heating if the fan is not energized for sufficient time to cause the TCO to activate. These multiple-heating events may have compounding effects on the TCO properties, thus causing the TCO to delay or fail to activate.

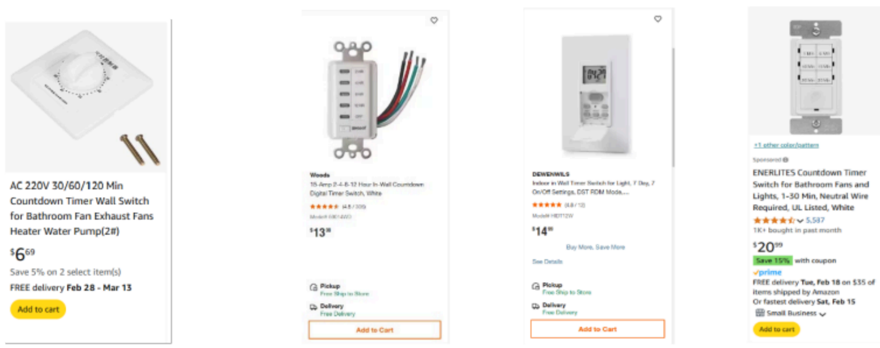
## 9.0 Conclusion

Although the tested motors were compliant with the voluntary standard, consistent with their UL listing, thermal aging of the motors can cause the TCOs to fail to activate. A contributing factor to the failures may have been the improper bending of the TCO wire leads and cracking of the epoxy seal around the wire leads. During thermal aging, the melting properties of the solder linkage and the special compound in the TCO may be altered, which may cause a delay in the TCO activating and in some cases, failure to activate. If the TCOs in the motors fail to open during a lock-rotor condition, the motor may overheat and ignite.

The results of this testing support changes to UL 60691 to include conductive heat aging of all eutectic-type TCOs, incorporating a thermal aging performance test within UL 507. If similar motor applications have a sufficient operating window between normal and lock-rotor that could allow thermal aging of the motor such changes may also be appropriate to UL 1004-3.

M12105Impact Statement

Timer switches price examples




Page: 1

Mod_12105_Impact_Timer switches price examples.pdf

# TAC: Mechanical

Total Mods for **Mechanical** in **Pending Review : 20**

Total Mods for report: 20

## Sub Code: Residential

### M11742

17

| | | | | | |
|---|---|---|---|---|---|
| **Date Submitted** | 01/13/2025 | **Section** | 1602.2 | **Proponent** | Mo Madani |
| **Chapter** | 16 | **Affects HVHZ** | No | **Attachments** | Yes |
| **TAC Recommendation** | Pending Review | | | | |
| **Commission Action** | Pending Review | | | | |

**Comments**

**General Comments No** **Alternate Language No**

#### Related Modifications

NA

#### Summary of Modification

Allowing a limited amount of return air provides a means of controlling closet moisture levels. Providing supply air to a closet exacerbates the problem by making closet surfaces colder.

#### Rationale

See attached.

#### Fiscal Impact Statement

**Impact to local entity relative to enforcement of code**
Overlap
**Impact to building and property owners relative to cost of compliance with code**
Overlap
**Impact to industry relative to the cost of compliance with code**
Overlap
**Impact to small business relative to the cost of compliance with code**
Overlap

#### Requirements

**Has a reasonable and substantial connection with the health, safety, and welfare of the general public**
Overlap
**Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction**
Overlap
**Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities**

**Does not degrade the effectiveness of the code**

Overlap

M11742Text Modification

See attached.

Mod11742_TextOfModification.pdf Page: 1

**Overlap**

**8th Edition (2023) FBC – Residential**

**M1602.2 Return air openings.** Return air openings for heating, ventilation and air conditioning systems shall comply with all of the following:

1. Openings shall not be located less than 10 feet (3048 mm) measured in any direction from an open combustion chamber or draft hood of another appliance located in the same room or space.
2. The amount of return air taken from any room or space shall be not greater than the flow rate of supply air delivered to such room or space.

3. Return and transfer openings shall be sized in accordance with the appliance or equipment manufacturers' installation instructions, Manual D or the design of the registered design professional.

4. Return air shall not be taken from a closet~~, bathroom,~~ toilet room, kitchen, garage, mechanical room, boiler room, furnace room or unconditioned attic.

**Exceptions:**

1. Taking return air from a kitchen is not prohibited where such return air openings serve the kitchen only, and are located not less than 10 feet (3048 mm) from the cooking appliances.

2. Dedicated forced-air systems serving only the garage shall not be prohibited from obtaining return air from the garage.

3. Dedicated independent dehumidification systems shall be allowed to take return air from spaces such as closets and bathrooms and discharge the air back into the spaces, provided that the air is filtered and dehumidified prior to the air being reintroduced back into the spaces.

4. Taking return air from a closet is not prohibited where such return air taken from closets shall serve only the closet and may be taken from closets that have no dedicated supply duct. Where return air is taken from a closet smaller than 30 square feet (2.8 m2), the return air shall be no more than 30 cfm (15 l/s), shall serve only the closet and shall not require a dedicated supply duct. Where return air is taken from a closet smaller than 30 square feet (2.8 m2), the closet door shall be undercut a minimum of 1.5 inches (38 mm) or the closet shall include a louvered door or transfer grille with a minimum net free area of 30 square inches (194 cm2).

5. Taking return air from an unconditioned crawl space shall not be accomplished through a direct connection to the return side of a forced-air furnace. Transfer openings in the crawl space enclosure shall not be prohibited.

6. Return air from one dwelling unit shall not be discharged into another dwelling unit.

(M11617) (RM19-21 AMPC1)

M11742Text Modification

**M1602.2 Return air openings.** Return air openings for heating, *ventilation* and air-conditioning systems shall comply with all of the following:

1. Openings shall not be located less than 10 feet (3048 mm) measured in any direction from an open combustion chamber or draft hood of another *appliance* located in the same room or space.
2. The amount of return air taken from any room or space shall be not greater than the flow rate of supply air delivered to such room or space.
3. Return and transfer openings shall be sized in accordance with the *appliance* or *equipment* manufacturer's installation instructions, Manual D or the design of the *registered design professional*.
4. Where return air is taken from a closet smaller than 30 ft2 (2.8 m2) the return air shall be no more than 30 cfm (15 l/s), shall serve only the closet, and shall not require a dedicated supply duct.
5. Where return air is taken from a closet smaller than 30 ft2 (2.8 m2) the closet door shall be undercut a minimum of 1.5 inches (38 mm) or the closet shall include a louvered door or transfer grille with a minimum net free area of 30 inch2 (194 cm2).

4 6. Return air shall not be taken from a ~~closet,~~ bathroom, toilet room, kitchen, garage, mechanical room, boiler room, furnace room or unconditioned attic.

**Exceptions:**

1. Taking return air from a kitchen is not prohibited where such return air openings serve the kitchen only, and are located not less than 10 feet (3048 mm) from the cooking *appliances*.
2. Dedicated forced-air systems serving only the garage shall not be prohibited from obtaining return air from the garage.
3. Return air taken from closets shall serve only the closet and may shall be permitted to be taken from closets that have no dedicated supply duct.

5 7. For other than dedicated HVAC systems, return air shall not be taken from indoor swimming pool enclosures and associated deck areas except where the air in such spaces is dehumidified,

6 8. Taking return air from an unconditioned *crawl space* shall not be accomplished through a direct connection to the return side of a forced-air furnace. Transfer openings in the *crawl space* enclosure shall not be prohibited.

7 9. Return air from one *dwelling unit* shall not be discharged into another *dwelling unit*.

## Public Comment 1

**M1602.2 Return air openings .** Return air openings for heating, *ventilation* and air-conditioning systems shall comply with all of the following:

1. Openings shall not be located less than 10 feet (3048 mm) measured in any direction from an open combustion chamber or draft hood of another *appliance* located in the same room or space.
2. The amount of return air taken from any room or space shall be not greater than the flow rate of supply air delivered to such room or space.
3. Return and transfer openings shall be sized in accordance with the *appliance* or *equipment*

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M11742Text Modification

manufacturer's installation instructions, Manual D or the design of the *registered design professional*.

4. ~~Where return air is taken from a closet smaller than 30 ft2 (2.8 m2) the return air shall be no more than 30 cfm (15 l/s), shall serve only the closet, and shall not require a dedicated supply duct.~~

5. ~~Where return air is taken from a closet smaller than 30 ft2 (2.8 m2) the closet door shall be undercut a minimum of 1.5 inches (38 mm) or the closet shall include a louvered door or transfer grille with a minimum net free area of 30 inch2 (194 cm2).~~

1. Where return air is taken from a closet the return air shall be no more than 30 cfm (15 l/s), shall serve only the closet, shall not require a dedicated supply duct and the closet door shall be undercut a minimum of 1.5 inches (38 mm) or the closet shall include a louvered door or transfer grille with a minimum net free area of 30 inch2 (194 cm2).

2. ~~6.~~ Return air shall not be taken from a bathroom, toilet room, kitchen, garage, mechanical room, boiler room, furnace room or unconditioned attic.

**Exceptions:**

1. Taking return air from a kitchen is not prohibited where such return air openings serve the kitchen only, and are located not less than 10 feet (3048 mm) from the cooking *appliances*.
2. Dedicated forced-air systems serving only the garage shall not be prohibited from obtaining return air from the garage.
3. Return air taken from closets shall serve only the closet~~and may shall~~ and ~~may~~ shall be permitted to be taken from closets that have no dedicated supply duct.

3. ~~7.~~ For other than dedicated HVAC systems, return air shall not be taken from indoor swimming pool enclosures and associated deck areas except where the air in such spaces is dehumidified,

4. ~~8.~~ Taking return air from an unconditioned *crawl space* shall not be accomplished through a direct connection to the return side of a forced-air furnace. Transfer openings in the *crawl space* enclosure shall not be prohibited.

5. ~~9.~~ Return air from one *dwelling unit* shall not be discharged into another *dwelling unit*.

(M11617) (RM19-21 AMPC1)

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M11742Rationale

# RM19-21

**Original Proposal**

**IRC: M1602.2**

**Proponents:** Craig Conner, self, self (craig.conner@mac.com); Joseph Lstiburek, Building Science Corporation, Myself (joe@buildingscience.com)

## 2021 International Residential Code

**Revise as follows:**

**M1602.2 Return air openings.** Return air openings for heating, *ventilation* and air-conditioning systems shall comply with all of the following:

1. Openings shall not be located less than 10 feet (3048 mm) measured in any direction from an open combustion chamber or draft hood of another *appliance* located in the same room or space.
2. The amount of return air taken from any room or space shall be not greater than the flow rate of supply air delivered to such room or space.
3. Return and transfer openings shall be sized in accordance with the*appliance* or *equipment* manufacturer's installation instructions, Manual D or the design of the *registered design professional*.
4. Where return air is taken from a closet smaller than 30 ft2 (2.8 m2) the return air shall be no more than 30 cfm (15 l/s), shall serve only the closet, and shall not require a dedicated supply duct.
5. Where return air is taken from a closet smaller than 30 ft2 (2.8 m2) the closet door shall be undercut a minimum of 1.5 inches (38 mm) or the closet shall include a louvered door or transfer grille with a minimum net free area of 30 inch2 (194 cm2).

4 6. Return air shall not be taken from ~~a closet,~~ bathroom, toilet room, kitchen, garage, mechanical room, boiler room, furnace room or unconditioned attic.

**Exceptions:**

1. Taking return air from a kitchen is not prohibited where such return air openings serve the kitchen only, and are located not less than 10 feet (3048 mm) from the cooking *appliances*.
2. Dedicated forced-air systems serving only the garage shall not be prohibited from obtaining return air from the garage.
3. Return air taken from closets shall serve only the closet and may shall be permitted to be taken from closets that have no dedicated supply duct.

5 7. For other than dedicated HVAC systems, return air shall not be taken from indoor swimming pool enclosures and associated deck areas except where the air in such spaces is dehumidified,

6 8. Taking return air from an unconditioned*crawl space* shall not be accomplished through a direct connection to the return side of a forced-air furnace. Transfer openings in the *crawl space* enclosure shall not be prohibited.

7 9. Return air from one *dwelling unit* shall not be discharged into another *dwelling unit*.

**Reason:** Mold growth is now common in closets due to higher interior moisture loads and less heat gain in closets. Allowing a limited amount of return air provides a means of controlling closet moisture levels. Providing supply air to a closet exacerbates the problem by making closet surfaces colder.
This is one of six separate proposed changes related to controlling mold in closets, bathrooms and mechanical room. The six changes fix problems caused by an increase in code thermal resistance over the past several code cycles.

For a more detailed explanation see:

https://www.buildingscience.com/documents/building-science-insights/bsi-109-how-changing-filters-led-condensation-and-mold-problem

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M11742Rationale

**Cost Impact:** The code change proposal will increase the cost of construction
The code change proposal increases the cost of construction. The cost is the cost of adding the return duct. However, this code change is not a requirement. It gives builders an option to solve and avoid problems.

## Public Hearing Results

**Committee Action** **Disapproved**

**Committee Reason:** The supporting document indicated that ASHRAE needs to continue looking at the issue. The proposed language is confusing. (7-4)

## Public Comments

*Public Comment 1*

**Proponents:** Craig Conner, self, self (craig.conner@mac.com); Joseph Lstiburek, Building Science Corporation, Myself (joe@buildingscience.com) requests As Modified by Public Comment

**Modify as follows:**

### 2021 International Residential Code

**M1602.2 Return air openings .** Return air openings for heating, *ventilation* and air-conditioning systems shall comply with all of the following:

1. Openings shall not be located less than 10 feet (3048 mm) measured in any direction from an open combustion chamber or draft hood of another *appliance* located in the same room or space.
2. The amount of return air taken from any room or space shall be not greater than the flow rate of supply air delivered to such room or space.
3. Return and transfer openings shall be sized in accordance with the*appliance* or *equipment* manufacturer's installation instructions, Manual D or the design of the *registered design professional*.
4. ~~Where return air is taken from a closet smaller than 30 ft2 (2.8 m2) the return air shall be no more than 30 cfm (15 l/s), shall serve only the closet, and shall not require a dedicated supply duct.~~
5. ~~Where return air is taken from a closet smaller than 30 ft2 (2.8 m2) the closet door shall be undercut a minimum of 1.5 inches (38 mm) or the closet shall include a louvered door or transfer grille with a minimum net free area of 30 inch2 (194 cm2).~~
4. Where return air is taken from a closet the return air shall be no more than 30 cfm (15 l/s), shall serve only the closet, shall not require a dedicated supply duct and the closet door shall be undercut a minimum of 1.5 inches (38 mm) or the closet shall include a louvered door or transfer grille with a minimum net free area of 30 inch2 (194 cm2).

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5. ~~6.~~ Return air shall not be taken from a bathroom, toilet room, kitchen, garage, mechanical room, boiler room, furnace room or unconditioned attic.

   **Exceptions:**

   1. Taking return air from a kitchen is not prohibited where such return air openings serve the kitchen only, and are located not less than 10 feet (3048 mm) from the cooking *appliances*.
   2. Dedicated forced-air systems serving only the garage shall not be prohibited from obtaining return air from the garage.
   3. Return air taken from closets shall serve only the closet~~and may shall~~ and ~~may~~ shall be permitted to be taken from closets that have no dedicated supply duct.

6. ~~7.~~ For other than dedicated HVAC systems, return air shall not be taken from indoor swimming pool enclosures and associated deck areas except where the air in such spaces is dehumidified,

7. ~~8.~~ Taking return air from an unconditioned*crawl space* shall not be accomplished through a direct connection to the return side of a forced-air furnace. Transfer openings in the *crawl space* enclosure shall not be prohibited.

8. ~~9.~~ Return air from one *dwelling unit* shall not be discharged into another *dwelling unit*.

**Commenter's Reason:** Modify the text to be less confusing and remove an unneeded restriction on the closet size.
The return openings are sized so as to not produce negative pressure in the closet.

**Cost Impact:** The net effect of the Public Comment and code change proposal will increase the cost of construction
The code change proposal increases the cost of construction. The cost is the cost of adding the return duct. However, this code change is not a requirement. It gives builders an option to solve and avoid problems.

| Final Hearing Results |
| --- |

RM19-21 AMPC1

# TAC: Mechanical

Total Mods for **Mechanical** in **Pending Review : 20**

Total Mods for report: 20

## Sub Code: Residential

### M11743

18

| | | | | | |
|---|---|---|---|---|---|
| **Date Submitted** | 01/13/2025 | **Section** | 2006 | **Proponent** | Mo Madani |
| **Chapter** | 20 | **Affects HVHZ** | No | **Attachments** | Yes |
| **TAC Recommendation** | Pending Review | | | | |
| **Commission Action** | Pending Review | | | | |

**Comments**

**General Comments No** **Alternate Language No**

#### Related Modifications

NA

#### Summary of Modification

This proposal clarifies that various types of equipment shall be "listed and labeled", which are defined terms in the code, and is consistent with the style used in other sections of the code, such as M1403.1.

#### Rationale

See attached.

#### Fiscal Impact Statement

**Impact to local entity relative to enforcement of code**
Overlap
**Impact to building and property owners relative to cost of compliance with code**
Overlap
**Impact to industry relative to the cost of compliance with code**
Overlap
**Impact to small business relative to the cost of compliance with code**
Overlap

#### Requirements

**Has a reasonable and substantial connection with the health, safety, and welfare of the general public**
Overlap
**Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction**
Overlap
**Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities**

**Does not degrade the effectiveness of the code**

Overlap

M11743Text Modification

See attached.

Mod11743_TextOfModification.pdf Page: 1

M11743Text Modification

**2024 IRC**

**M2006.1 General.** Pool and spa heaters shall be installed in accordance with the manufacturer's installation instructions. Oil-fired pool heaters shall ~~comply~~ be *listed* and *labeled* in accordance with UL 726. Electric pool and spa heaters shall ~~comply~~ ~~be *listed* and *labeled* in~~ ~~accordance~~ with UL 1261. Pool and spa heat pump water heaters shall ~~comply~~ be *listed* and *labeled* in accordance with UL 1995, or UL/CSA~~/ANCE~~ 60335-2-40 ~~or CSA C22.2 No. 236~~.

**Exception:** Portable residential spas and portable residential exercise spas shall ~~comply~~ be *listed* and *labeled* in accordance with UL 1563 or CSA C22.2 No. 218.1.

8th Edition (2023) FBC, Residential

M2006.1 General. Pool and spa heaters shall be installed in accordance with the manufacturer's installation instructions. Oil-fired pool heaters shall comply with UL 726. Electric pool and spa heaters shall comply with UL 1261.

(M11608) (RM4-21 AS) Overlap

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M11743Rationale

# RM4-21

## Original Proposal

**IRC: M1402.1, M1403.1, M1412.1, M2006.1**

**Proponents:** Jonathan Roberts, UL LLC, UL LLC (jonathan.roberts@ul.com)

## 2021 International Residential Code

**Revise as follows:**

**M1402.1 General.** Oil-fired central furnaces shall ~~conform to~~ be *listed* and *labeled* in accordance with ~~ANSI /~~UL 727. Electric furnaces shall ~~conform to~~ be *listed* and *labeled* in accordance with UL 1995 or UL/CSA~~/ANCE~~ 60335-2-40.

**M1403.1 Heat pumps.** Electric heat pumps shall be *listed* and *labeled* in accordance with UL 1995 or UL/CSA~~/ANCE~~ 60335-2-40.

**M1412.1 ~~Approval of~~ Listed equipment.** Absorption systems shall be installed in accordance with the manufacturer's instructions. Absorption *equipment* shall ~~comply~~ be *listed* and *labeled* in accordance with UL 1995 or UL/CSA~~/ANCE~~ 60335-2-40.

**M2006.1 General.** Pool and spa heaters shall be installed in accordance with the manufacturer's installation instructions. Oil-fired pool heaters shall ~~comply~~ be *listed* and *labeled* in accordance with UL 726. Electric pool and spa heaters shall~~comply be *listed* and *labeled* in accordance~~ with UL 1261. Pool and spa heat pump water heaters shall~~comply~~ be *listed* and *labeled* in accordance with UL 1995, or UL/CSA~~/ANCE~~ 60335-2-40 ~~or CSA C22.2 No. 236~~.

> **Exception:** Portable residential spas and portable residential exercise spas shall~~comply~~ be *listed* and *labeled* in accordance with UL 1563 or CSA C22.2 No. 218.1.

**Reason:** This proposal clarifies that these various types of equipment shall be "listed and labeled", which are defined terms in the code, and is consistent with the style used in other sections of the code, such as M1403.1.
The first edition of the UL/CSA 60335-2-40 was jointly published with ANCE, but subsequent editions have not. The designation used for UL 727 should be shown without the prefix "ANSI/" for consistency with how all other UL standards are referenced in the I-codes.

CSA C22.2 No. 236 has been withdrawn due to the publication of UL/CSA 60335-2-40. The referenced standard of "C22.2 No. 218.1" in the exception for M2006.1 needs to be clearly identified as a CSA standard.

**Cost Impact:** The code change proposal will not increase or decrease the cost of construction
Clarifies the requirements and corrects the references of existing standards.

## Public Hearing Results

**Committee Action** **As Submitted**

**Committee Reason:** The committee agreed with the published reason statement. (11-0)

## Final Hearing Results

RM4-21 AS

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Mod_11743_Rationale_M11608 RM4-21 M2006.1.pdf

# TAC: Mechanical

Total Mods for **Mechanical** in **Pending Review : 20**

Total Mods for report: 20

## Sub Code: Residential

### M12142

19

| | | | | | |
|---|---|---|---|---|---|
| **Date Submitted** | 02/14/2025 | **Section** | 2006.1 | **Proponent** | Amanda Hickman |
| **Chapter** | 20 | **Affects HVHZ** | No | **Attachments** | No |
| **TAC Recommendation** | Pending Review | | | | |
| **Commission Action** | Pending Review | | | | |

**Comments**

**General Comments No** **Alternate Language No**

#### Related Modifications

yes 12050

#### Summary of Modification

Updates to permit A2L.

#### Rationale

This is one of several code modifications that updates the 9th edition code to reflect the necessary changes to permit the use of A2L refrigerants. As of January 1st, 2025, federal regulations prohibit the manufacturing of R-410A and other high-Global Warming potential (GWP) refrigerants. Manufacturers are transitioning away from UL 1995 to UL 60335-2-40 because UL 1995 will be sunsetting in the year 2024. The 4th edition of UL 60335-2-40 was published December 2022. This standard has many new requirements for electrical and refrigerant safety. Nationally Recognized Testing Laboratories (or NRTLs) will use the latest edition of the safety standard for certification testing. Failure to update the code could result in not having air conditioning products that are allowed to be used in Florida. With the change to Low GWP Refrigerants, the Residential Code needs to be updated to address the use of Group A2L refrigerants. All of the commonly used Low GWP replacement refrigerants for direct systems fall into the category of Group A2L in the 2022 edition of ASHRAE 34. All of these changes are consistent with the 2024 International Residential Code.

#### Fiscal Impact Statement

**Impact to local entity relative to enforcement of code**

Provides guidance to code enforcement with respect to permitting A2L.

**Impact to building and property owners relative to cost of compliance with code**

These code changes will not increase the cost of construction, they only grant permission to use A2L products. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

**Impact to industry relative to the cost of compliance with code**

These code changes will not increase the cost of construction, they only grant permission to use A2L products. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

**Impact to small business relative to the cost of compliance with code**

These code changes will not increase the cost of construction, they only grant permission to use A2L products. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

## Requirements

**Has a reasonable and substantial connection with the health, safety, and welfare of the general public**

Updates code to ensure appropriate language is added to permit A2L products.

**Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction**

Updates code to ensure appropriate language is added to permit A2L.

**Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities**

No. Permits A2L products. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

**Does not degrade the effectiveness of the code**

No. Permits A2L products. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

M12142Text Modification

**SECTION M2006—POOL HEATERS**

**M2006.1 General.**

**Pool and spa heaters shall be installed in accordance with the manufacturer's installation instructions. Oil-fired pool heaters shall ~~comply~~ be *listed* and *labeled* in accordance with UL 726. Electric pool and spa heaters shall ~~comply~~ be listed and *labeled* in accordance with UL 1261. Pool and spa heat pump water heaters shall be *listed* and *labeled* in accordance with UL 1995 or UL/CSA/ANCE 60335-2-40.**

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Mod12142_TextOfModification.pdf

# TAC: Mechanical

Total Mods for **Mechanical** in **Pending Review : 20**

Total Mods for report: 20

## Sub Code: Residential

### M12144

20

| | | | | | |
|---|---|---|---|---|---|
| **Date Submitted** | 02/14/2025 | **Section** | 0 | **Proponent** | Amanda Hickman |
| **Chapter** | 2712 | **Affects HVHZ** | No | **Attachments** | No |
| **TAC Recommendation** | Pending Review | | | | |
| **Commission Action** | Pending Review | | | | |

**Comments**

**General Comments No** **Alternate Language No**

### Related Modifications

Yes 12050, 12142

### Summary of Modification

Updates code to permit A2L products

### Rationale

This is one of several code modifications that updates the 9th edition code to reflect the necessary changes to permit the use of A2L refrigerants. As of January 1st, 2025, federal regulations prohibit the manufacturing of R-410A and other high-Global Warming potential (GWP) refrigerants. Manufacturers are transitioning away from UL 1995 to UL 60335-2-40 because UL 1995 will be sunsetting in the year 2024. The 4th edition of UL 60335-2-40 was published December 2022. This standard has many new requirements for electrical and refrigerant safety. Nationally Recognized Testing Laboratories (or NRTLs) will use the latest edition of the safety standard for certification testing. Failure to update the code could result in not having air conditioning products that are allowed to be used in Florida. With the change to Low GWP Refrigerants, the Residential Code needs to be updated to address the use of Group A2L refrigerants. All of the commonly used Low GWP replacement refrigerants for direct systems fall into the category of Group A2L in the 2022 edition of ASHRAE 34. All of these changes are consistent with the 2024 International Residential Code.

### Fiscal Impact Statement

**Impact to local entity relative to enforcement of code**

Provides guidance to code enforcement with respect to permitting A2L.

**Impact to building and property owners relative to cost of compliance with code**

Permits the use of A2L products. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

**Impact to industry relative to the cost of compliance with code**

Permits the use of A2L products. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

**Impact to small business relative to the cost of compliance with code**

Permits the use of A2L products. Existing R-410A equipment can continue to be used, maintained, and repaired for its full useful life.

## Requirements

**Has a reasonable and substantial connection with the health, safety, and welfare of the general public**

Yes. Permits the use of A2L products.

**Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction**

Yes. Permits the use of A2L products.

**Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities**

No. Only permits the use of A2L products.

**Does not degrade the effectiveness of the code**

No. Only permits the use of A2L products.

M12144Text Modification

ASHRAE 34 2019 2022 Designation and Safety Classification of Refrigerants

UL/CSA/ANCE 60335-2-40-2012 2022 Standard for Household and Similar Electrical Appliances, Household and Similar Electrical Appliances – Safety – Part 2-40: Particular Requirements for Electrical Heat Pumps, Air-Conditioners and Dehumidifiers Motor Compressors

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