Fluorescent Lighting

- Developed around turn of century
- Commercially available in 1938 by GE
- Presented at 1939 Worlds Fair
- Made efficient lighting possible during WWII in factories and warehouses

Fluorescence is the conversion of one frequency of electromagnetic radiation to another frequency by a material

Fluorescent Lighting

- **Operates by maintaining a low pressure mercury arc in a linear glass tube**
- **Mercury arc produces UV radiation**
- **UV strikes phosphor on inside of lamp**
- **Phosphor converts UV to visible light**
- **Most of input power creates light, not heat**

Fluorescent Lamps

- **Lamps are a linear soft light source**
- **Last between 10,000 to 25,000 hours**
- **Run cool (about 150°F at their ends)**
- **Very efficient source of light**
  - **About 5 times more light per watt than Incandescent Systems**

Fluorescent Lighting Drawbacks

- **Lamps require additional equipment**
  - **Ballast**
  - **Starter**
  - **More wire**
- **Lamps contain Mercury**
- **Cost more to install**

Why do fluorescent lamps need a ballast?

- Lamps require more than 120 Volts to start.
- Once started, lamps want to draw all the available current.
- Once started, lamps will immediately burn out without ballast
- Lamps have negative resistance behavior

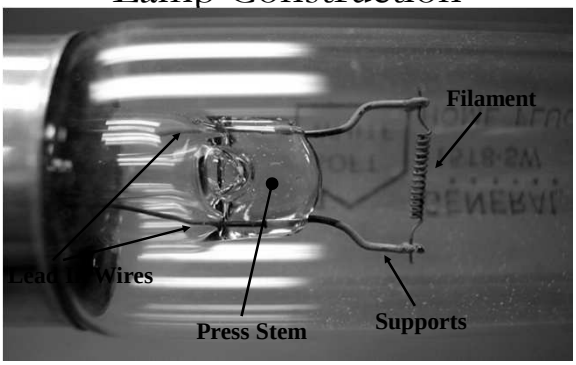
Incandescent v. Fluorescent

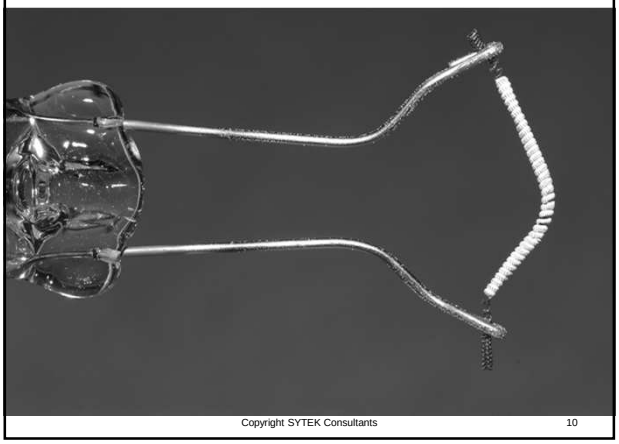
- Incandescent filament resistance goes up when it is heated, thus limiting the current flowing through the lamp.
- In fluorescent lamps, the "resistance" of the mercury arc declines as more current flows through it.

Purpose of a Ballast

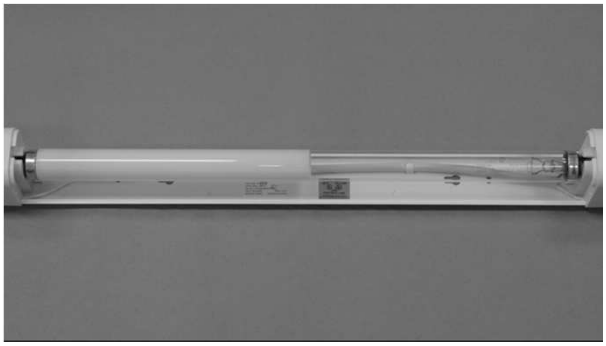
- **The ballast has several purposes:**
  - **Transform the input voltage to high enough level to strike the arc in the tube**
  - **Limit the current flowing through the tube (typically between 0.2 to 0.8 Amps)**

Lamp Construction

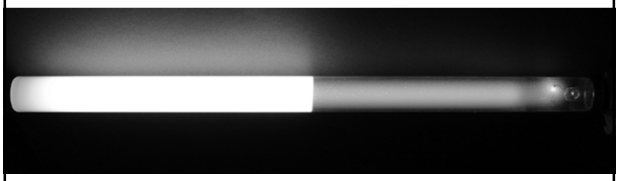




Lamp Operation



Lamp Operation



Phosphor Coated Glass Clear Glass

Lamp Starting

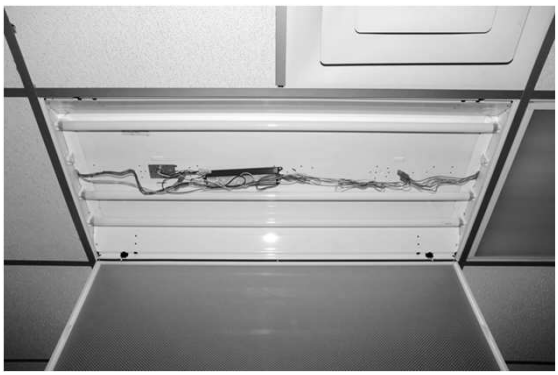
Basic Fixture Types

- Recessed "T bar" troffers
  - Most of fixture above ceiling
- "C" channel strips
  - Typically suspended or surface mounted
- Low Profile Wrap Arounds
  - Surface mounted
  - Has lens "wrapped" around fixture

Typical Troffer

Interior of Troffer

Interior of Troffer



Top Surface of Troffer

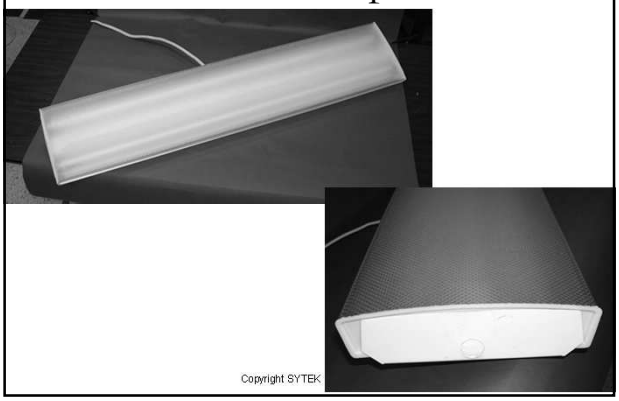
"C" Strip Fixture

 19

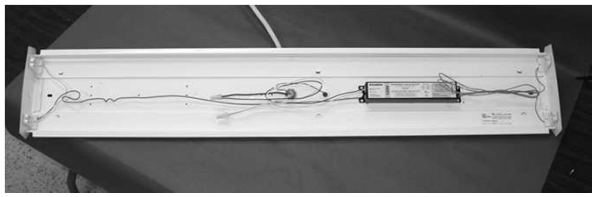
Interior of "C" Strip Fixture

 20

Low Profile Wrap Around



Interior of Low Profile Wrap Around Fixture



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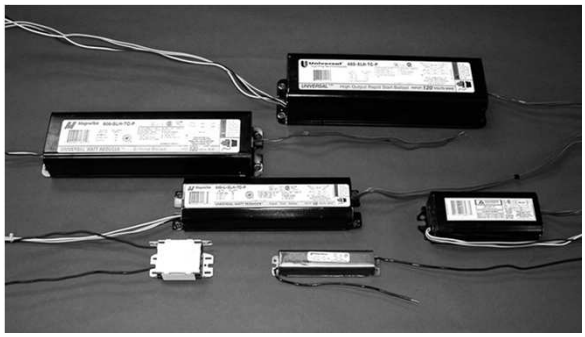
Fluorescent System Types

- Basically three common types of systems
  - Pre-Heat
  - Rapid Start
  - Instant Start
- Can be identified by wiring system

 23

Various Fluorescent Ballasts



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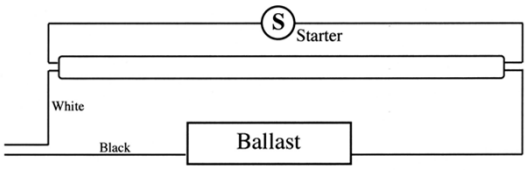
Pre-Heat System

- Mostly used today in desk lamps
- Original system
- Often used starter or push and hold button

Pre-Heat System

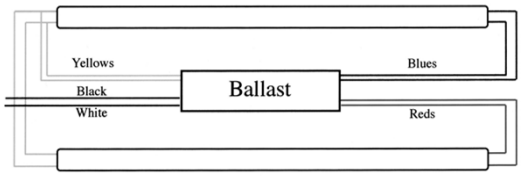


Starter

Rapid Start System

- Lamps come on quickly, but with visible delay
- Ends of lamps heated inside
- Long lamp life

Rapid Start System

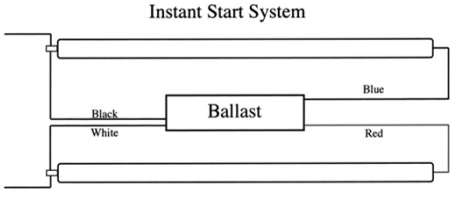


Rapid Start Lamp Ends

Instant Start System

- Lamps come on instantly
- Use high voltage to blast arc down tube
- Short lamp life
- Lower cost to buy and install

Instant Start System



Instant Start Lamp End

Lamps Sizes

- T-12
  - 4, 6 & 8 foot
  - Still very common
- T-8
  - Used mostly with lower current electronic ballasts
  - Physically interchangeable with T-12 lamps
  - Not electrically interchangeable with T-12 lamps
- T-5
  - For electronic ballasts only
  - Very efficient

Purpose of a Ballast

- **The ballast has several purposes:**
  - **Transform the input voltage to high enough level to strike the arc in the tube**
  - **Limit the current flowing through the tube (typically between 0.2 to 0.8 Amps)**

Types of Ballasts

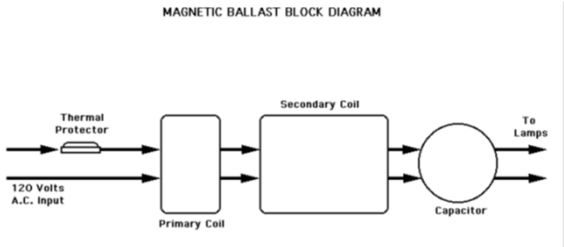
Magnetic Ballasts

Electronic Ballasts

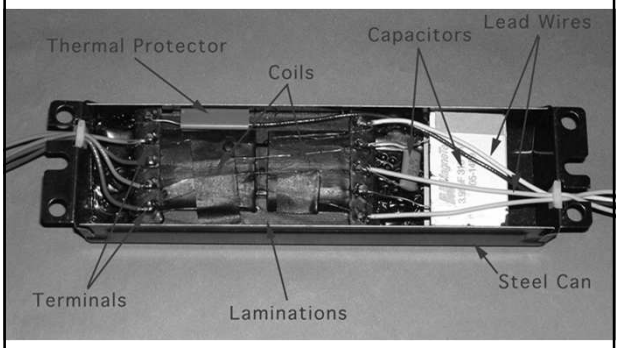
Magnetic Ballasts

- Original type developed
- Proven technology
- Operate lamps at 60 cycles per second
- Lower efficiency light source
- Fewer parts, high reliability
- Lower cost

Magnetic Ballast Operation



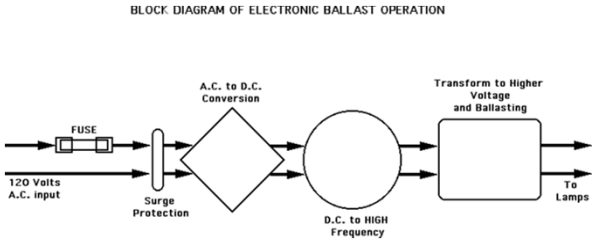
Magnetic Ballast Interior



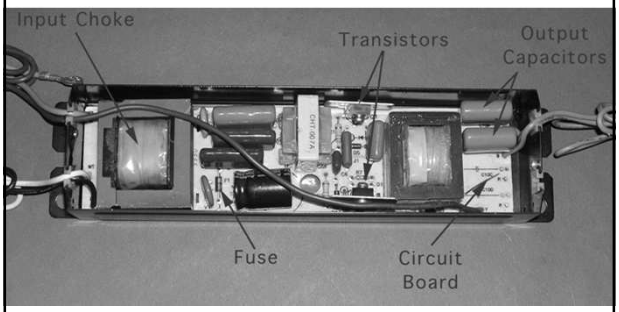
Electronic Ballasts

- Very high operating efficiency
- Operate lamps at high frequency
  - (20 to 40 thousand cycles per second)
- Large number of components inside
- Expensive compared to magnetic ballasts
- Becoming more popular
- Required to meet most energy codes

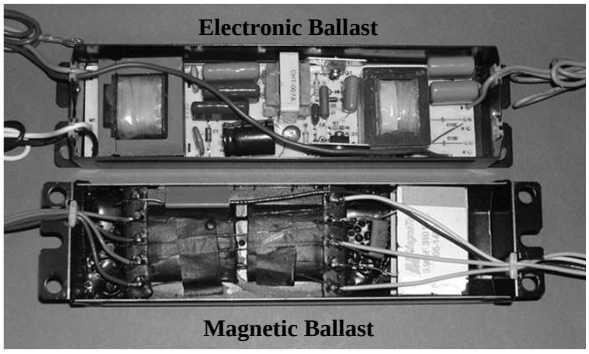
Electronic Ballast Operation



Electronic Ballast Interior



Electronic and Magnetic Ballasts



Potting Compound

- Softens around 250 to 270 F
- "Liquid" at about 360 to 380 F
- Inserted into ballast at about 380 to 400 F
- Flash point > 500 F
- Auto-ignition temperature > 800 F

Fluorescent Fixtures as Fire Causes

- Fires caused by wiring in fixture
- Fires caused by failures at the lamp holders
- Fires caused by the ballast

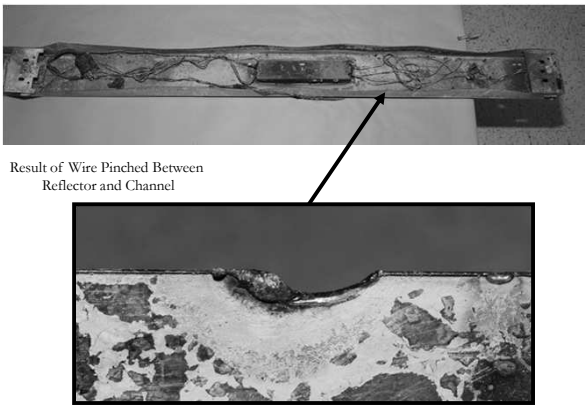
Fluorescent Fixture Fire Causes

- Pinched and arced wires
  - Rare
  - Often arcing is result of fire heat impingement
- Overheated /Arcing lamp holders
  - Usually contact with combustibles or
  - Close proximity of lens to lamp holder
- Arc penetrations through ballast case
  - May be through top, bottom or sides

Typical Reflector

Fires Caused by Wiring in Fixture

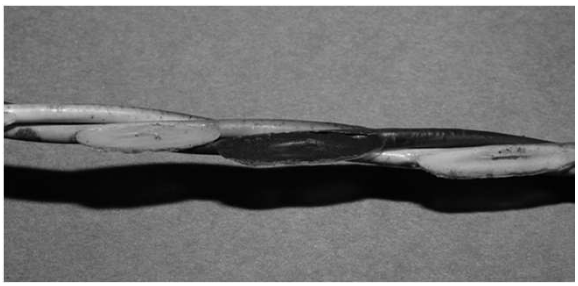
- Fairly rare. Most arcing in fixtures is caused by fire attacking the fixture.
- Arcing in fixture may penetrate fixture body.
- Arcing may ignite light fixture lens.
- Pinched wire may arc producing sparks.



Fire Induced Arcing in Fixture

- Fixture is a heat absorbing "fin".
- Think of the fixture as a piece of conduit.
- Should be considered during arc mapping.

Fire Damage to Fixture Wiring



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Fires Caused By Lamp Holders

- Typically result of poor connection to lamps
- Improper seating of the lamps
- Improper spacing of lamp holders
- Improper installation of lamp holders
- More common with higher current lamps
- Generally only occurs with Instant Start circuits
- Ballast is designed to maintain an arc and it will!

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Fires Caused by Lamp Holders

- Lamp holders are made of some what retardant materials.
- Lamp holders may be made of thermoset or thermoplastic materials.
- Arcing my ignite dust or lint.
- Typically involves fixtures with lenses or combustibles in close proximity to lamp holders.
- Typically not associated with troffers.

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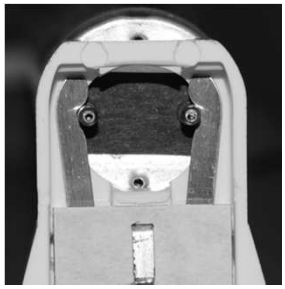
Proper Insertion



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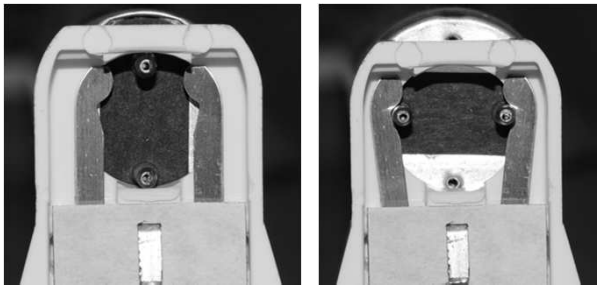
Proper Insertion



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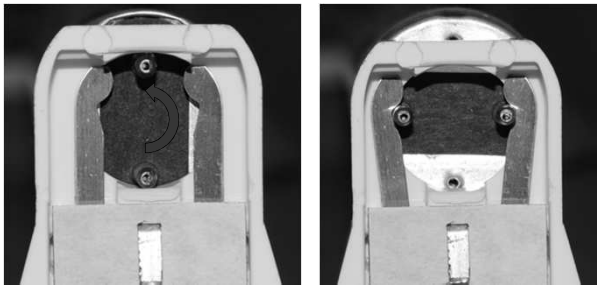
Proper Insertion



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Incorrect Insertion

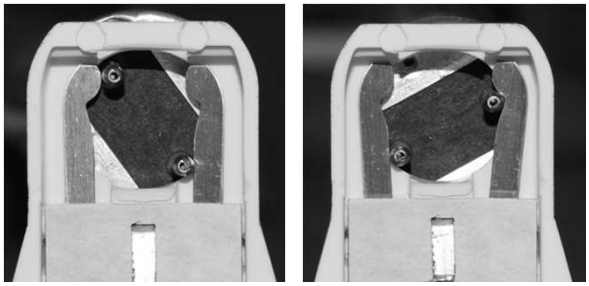

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Photo Courtesy of ATF National Laboratories Fire Research Laboratory

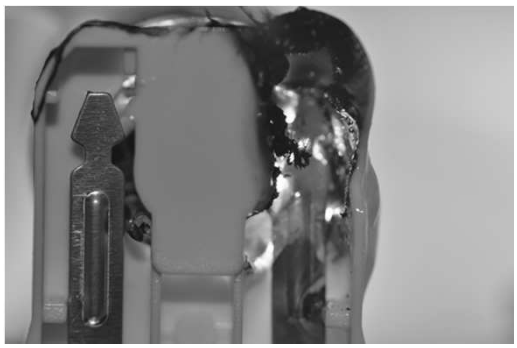

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Photo Courtesy of ATF National Laboratories Fire Research Laboratory

Warning Sticker

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Locking Lamp Holders

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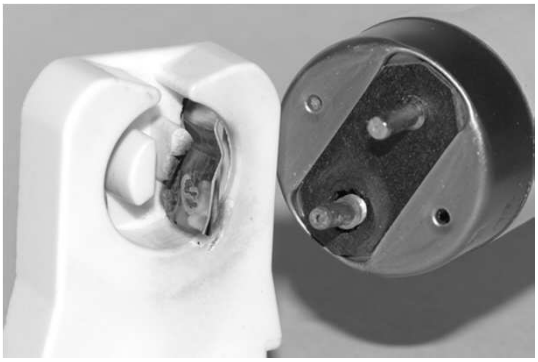
Bi Pin Lamp Holder Overheating



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Bi Pin Lamp Holder Overheating

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Bi Pin Lamp Holder Overheating

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Damage to Lamp

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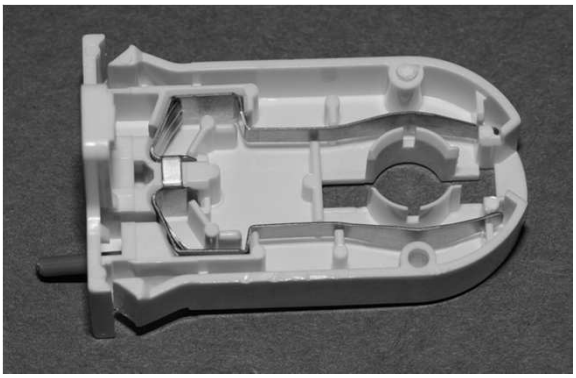

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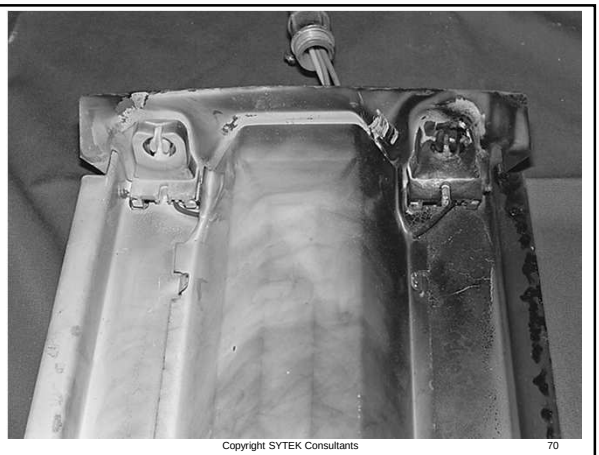

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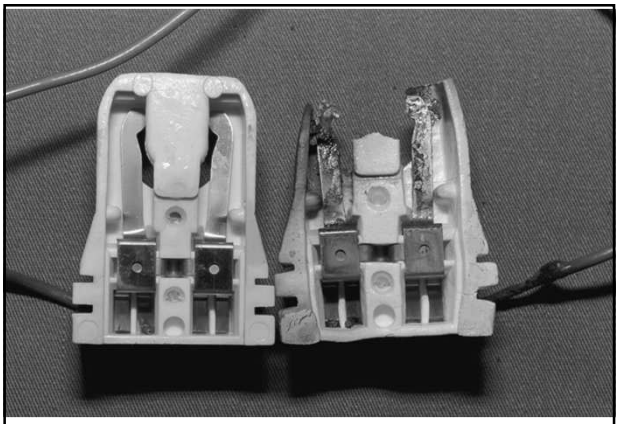

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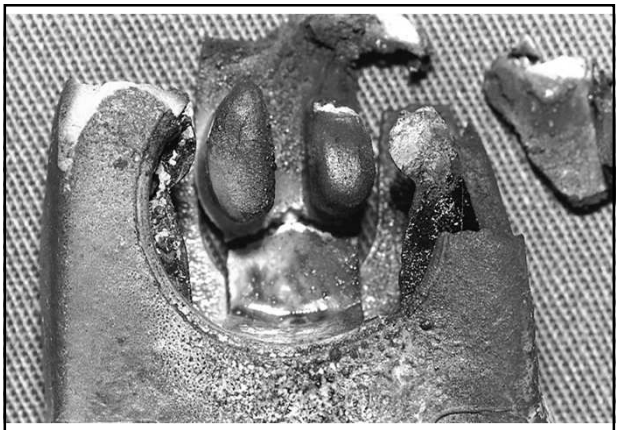

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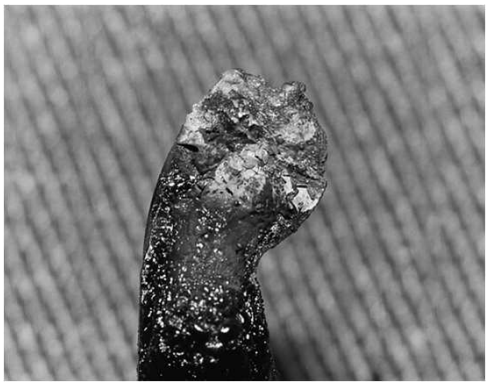

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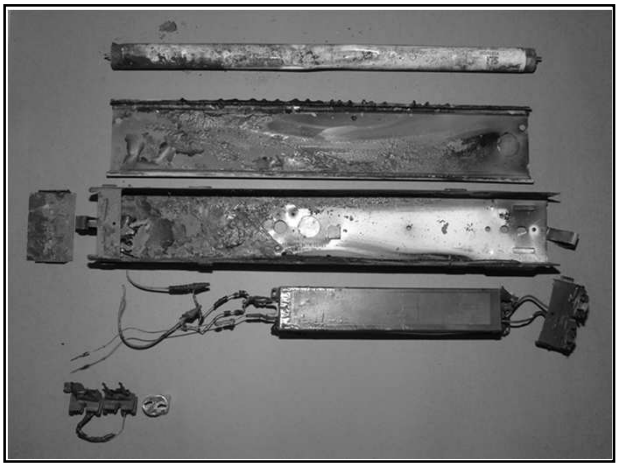

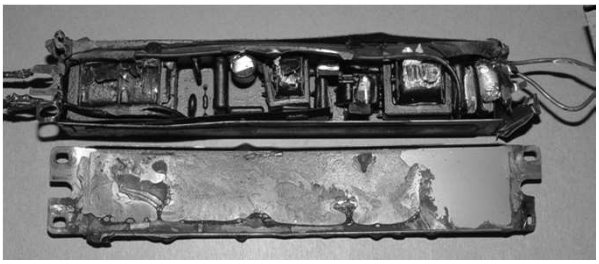

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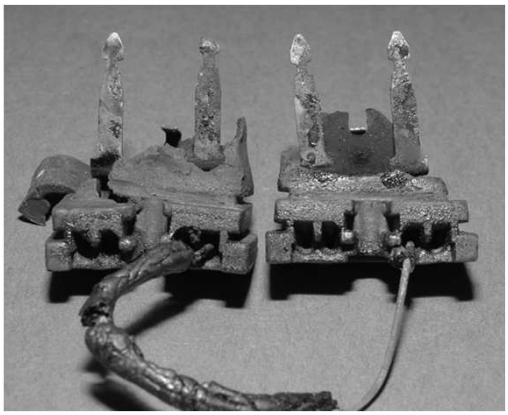

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Some Ballast Fire Producing Failures

- Ballast Overheating
- Upward arcing events
- Downward arcing events
- Arcing through the side of the fixture

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Causes of Ballast Overheating

- **Shorting of coil windings in the transformer**
- **Failure of power capacitor**
- **End of life of instant start lamps**
- **Internal arcing**
- **Improper voltage or lamps**

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Overheated Coil in Ballast

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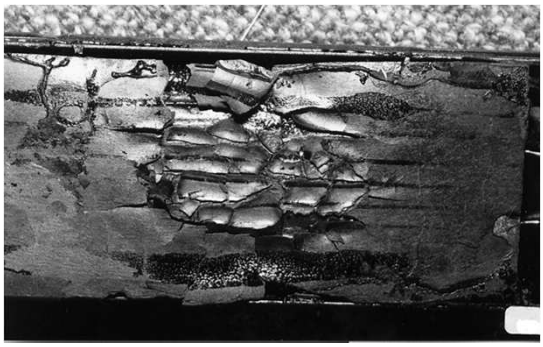
Overheated Coil in Ballast



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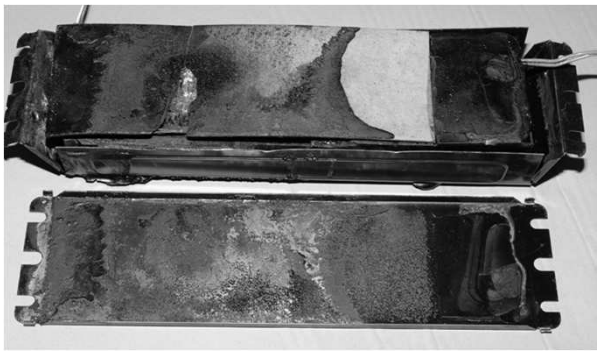
Coil Failure In Ballast



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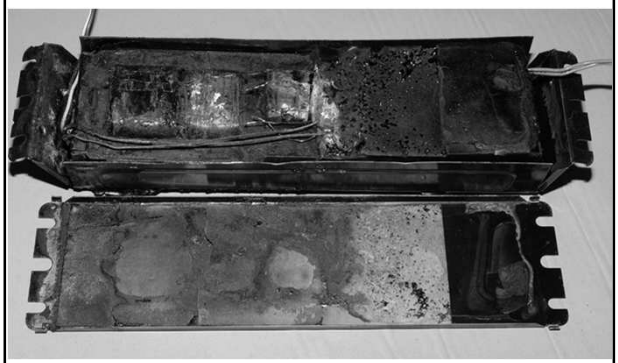
Coil Failure In Ballast



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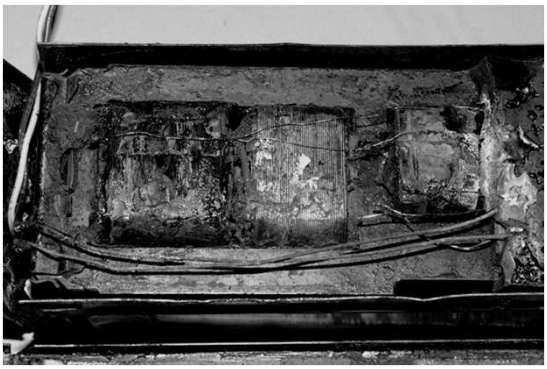
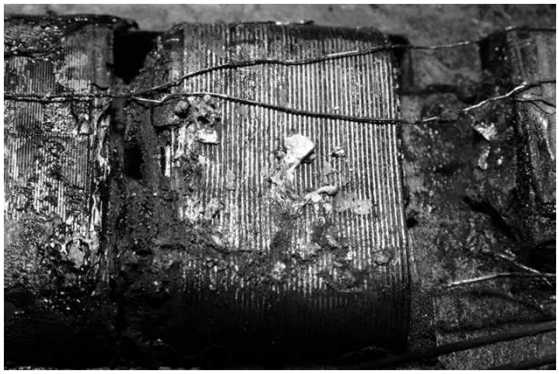
Coil Failure In Ballast



Coil Failure In Ballast



Arc Penetrations Through Ballast Case

- Probably leading cause of ***magnetic*** ballast fires
- Can occur in thermally protected ballasts
- Can burn hole through fixture
- Can ignite materials above fixture such as:
  - Wood
  - Plywood
  - Combustible ceiling tiles

Arc Penetrations Through Ballast Case

- Can occur through side of ballast case
- Can exit top or side of fixture and ignite:
  - Lens
  - Combustibles below
  - Lint or dust
  - Light weight materials

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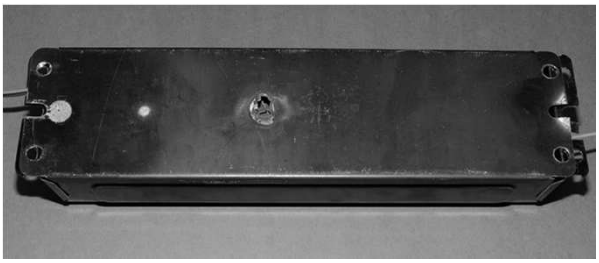
Ballast With Arc Penetration



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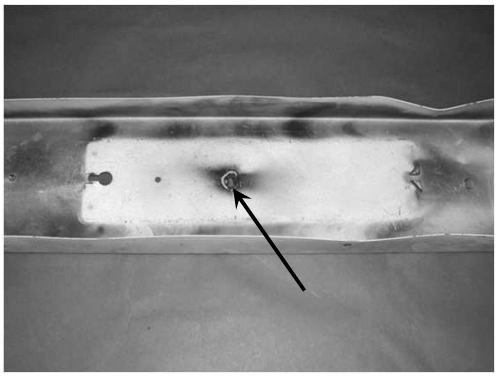
Fixture with Arc Hole



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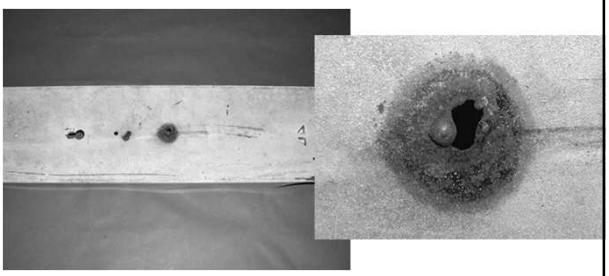
Fixture Top with Arc Hole



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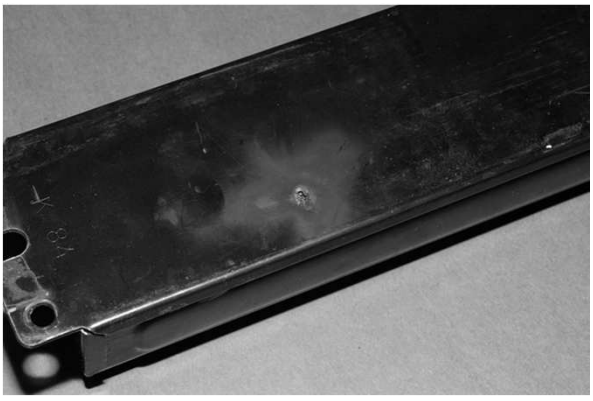

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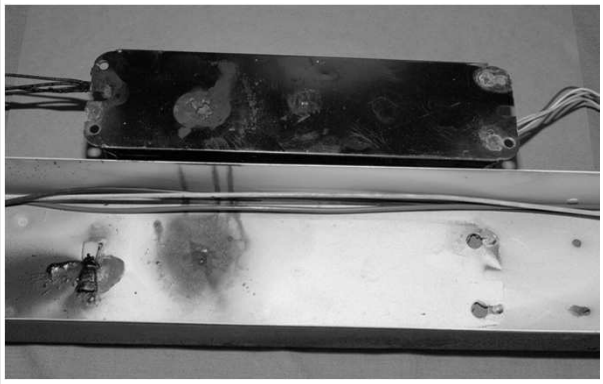

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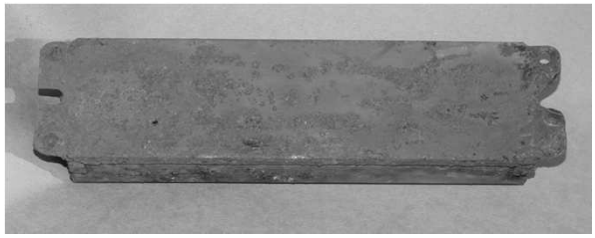

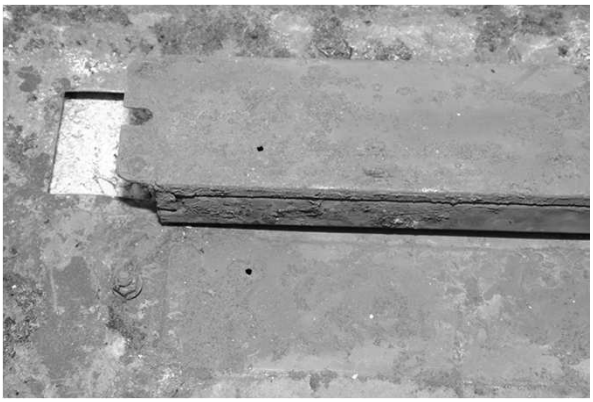

Multiple Arc Penetrations

Ballast Protection

- Between 1940's and early 1960's, most ballasts in heavy metal fixtures mounted away from combustibles.
- Around 1960, most manufacturers began to develop protection systems.
- First NEC code requirements in mid- 1960's

Ballast Protection History

- Originally fuses for each ballast recommended
- Single shot thermal protectors (~260F to 270°F) came next
- Self-resetting thermal protectors (~ 230°F) became common method of protection
- Internal capacitor protectors developed

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Thermal Protection History

- By 1961, most manufacturers had single shot thermally protected ballasts available
- In 1962, GSA required thermal protection in ballasts for government buildings
- In 1965, NEC required new fixtures to "incorporate ballast protection"
- The 1965 NEC requirement was postponed to 1967

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Thermal Protection History

- UL asked for NEC requirement to be moved back until 1968 - 1969
- UL begins "Class P" listing of thermally protected ballasts
- UL listing criteria favors self resetting thermal protectors in magnetic ballasts

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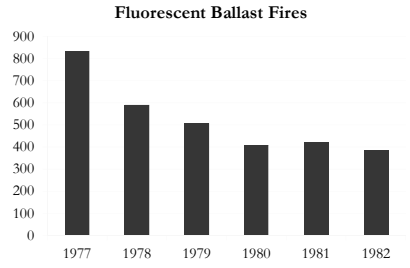
Thermal Protection History

- 1981 NEC states:
  - "Where fluorescent fixtures are installed indoors, the ballasts shall have thermal protection within the ballast. Replacements for these ballasts shall also be integrally protected"
- From 1968 to 1984, Non-thermally protected ballasts could be replaced with non-thermally protected units.
- 1984 NEC required all replacement ballasts to be thermally protected.

 106

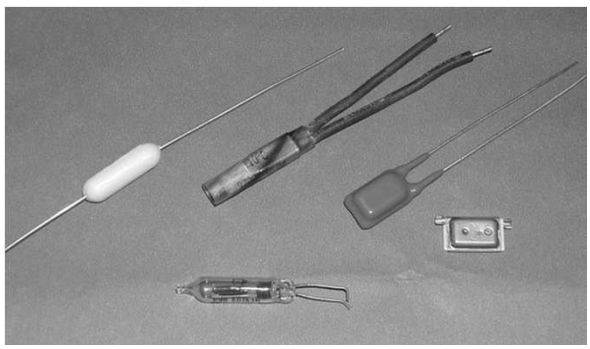
Fire History



Source: IAEI News 1978-1983

 107

Typical Thermal Protectors



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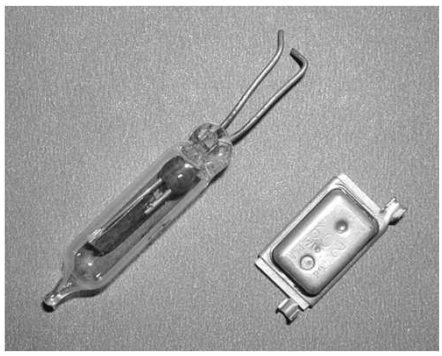
Self Re-setting Thermal Protectors



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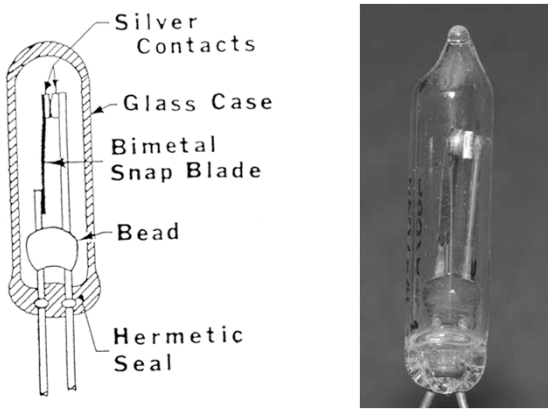

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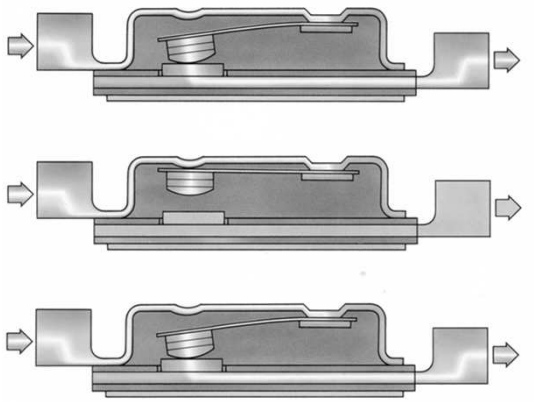

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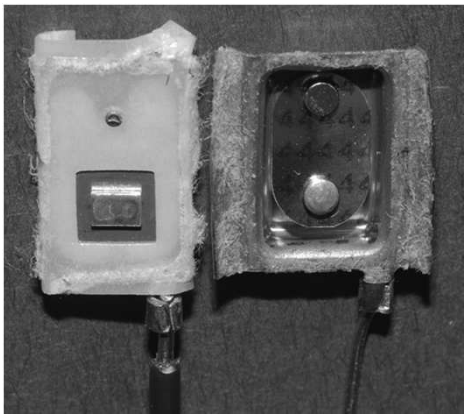


 113

Resetting Thermal Protectors

- Most set at 221°F to 239°F
- May not reset until cooled below 185°F
- Must be able to operate 10,000 times under load
- Most are able to operate about 14,000 to 16,000 times before failure
- Typical cycle is once every 30 to 45 minutes

 114

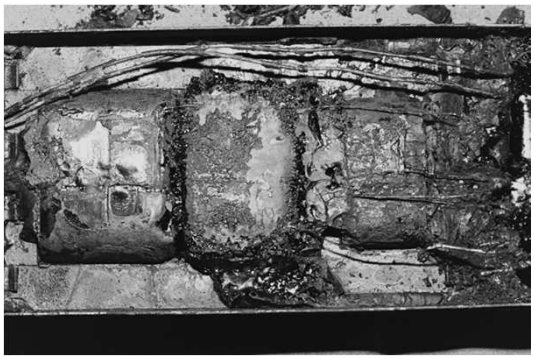
How Are Ballasts Evaluated After A Fire?

- **Post fire examination of ballasts is destructive in nature.**
- **Experts should perform the examination.**
- **Examination should be in laboratory setting**.
- **X-Rays are preferred before disassembly**.
- **Fairly well established protocols exist.**

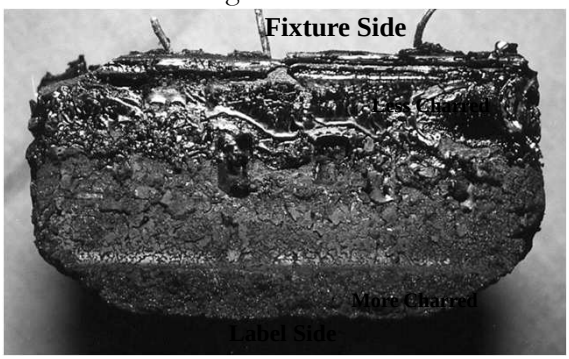
How Are Ballasts Evaluated After A Fire?

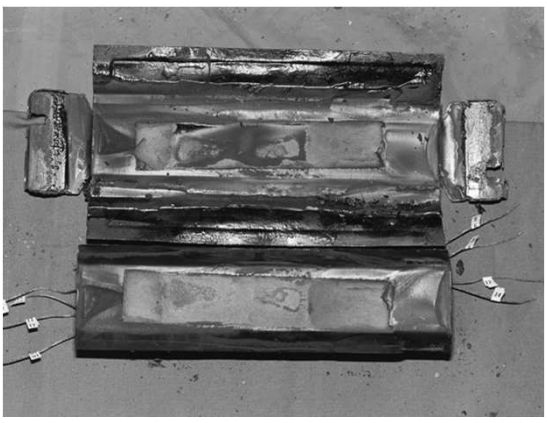
- Potting Compound Condition
  - Low heat - shiny black, soft
    - Can be re-melted
  - Medium heat - hard, tough dull black
    - Barely re-meltable
  - More Heat - hard, brittle, porous gray/black
    - Bubble size depends upon rate of heating
  - More heat - White powder (remains of sand)
  - Final stage - glass like fusing of sand

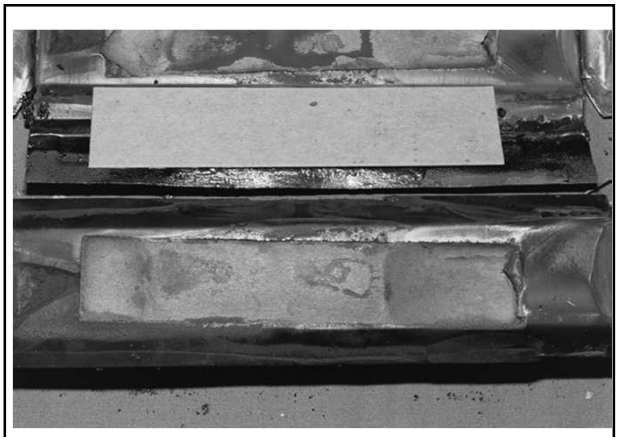
Coil Failure In Ballast



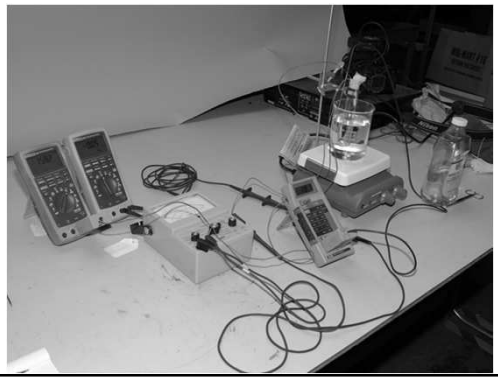
Cross Section of Ballast With Internal Overheating Due to Coil Failure





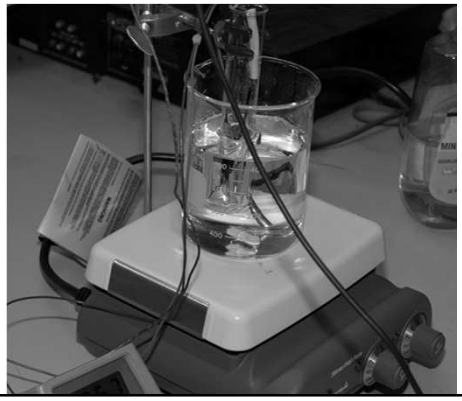


Thermal Protector Testing



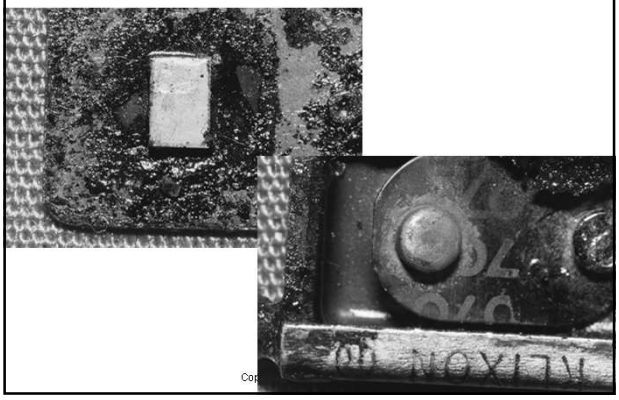
121

Thermal Protector Testing



122

Typical Fire Damaged Protector



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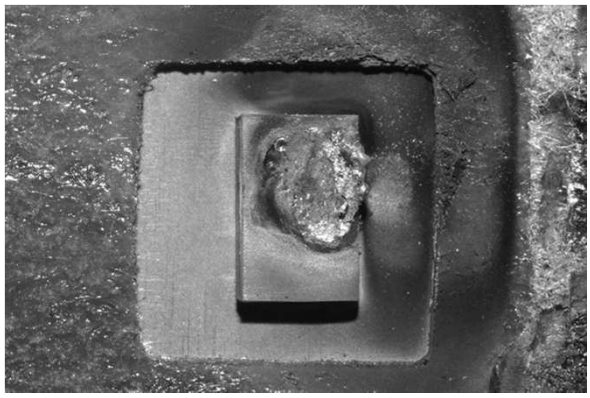

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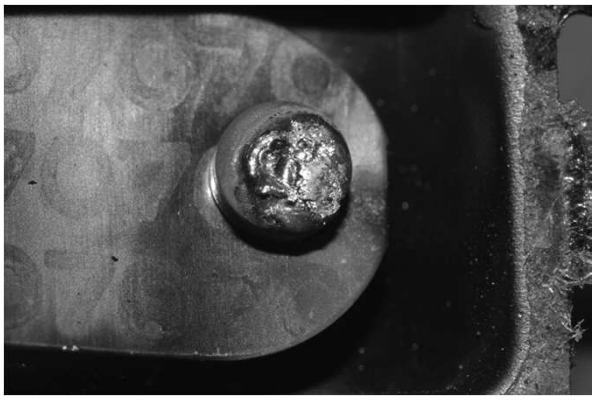

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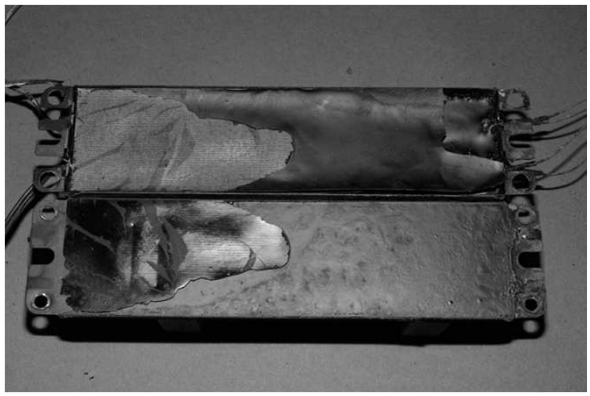
Analysis of Electronic Ballasts

- Does not have the "fire endurance" of a magnetic ballast.
- Do not have the general overheating like magnetic ballasts.
- Overheating is a component phenomena.
- Look for localized damage to the circuit board.
- Look for arc penetrations of the case.
- Examine the fuse.

 127



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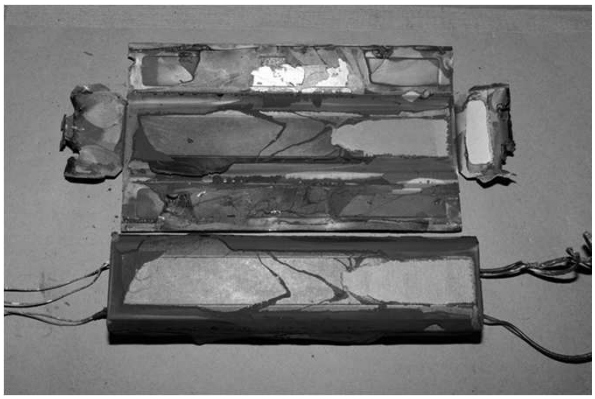

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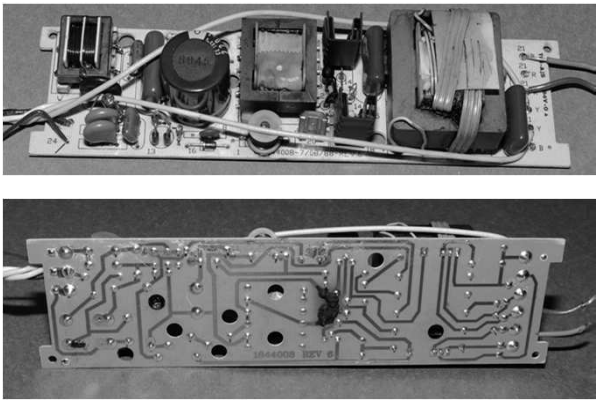

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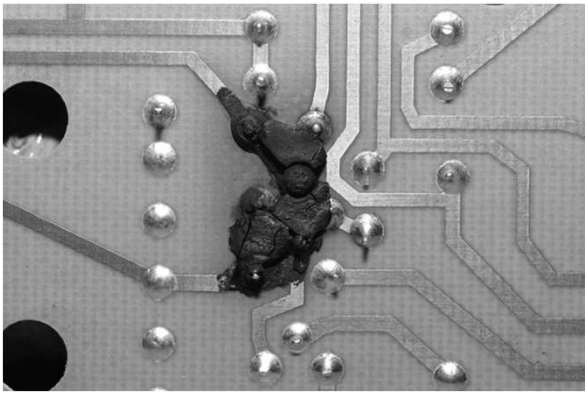

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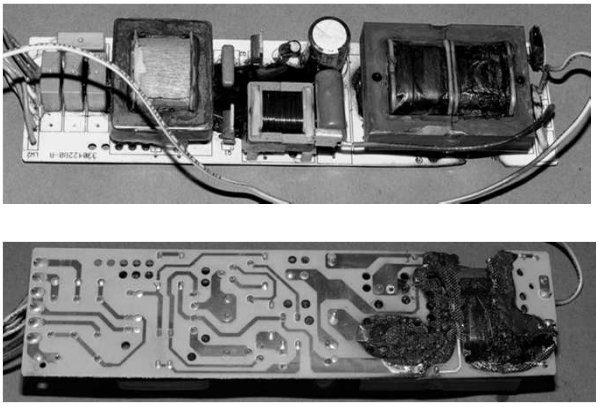

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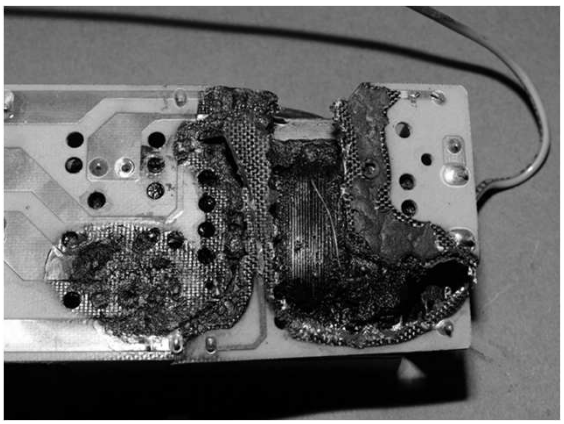

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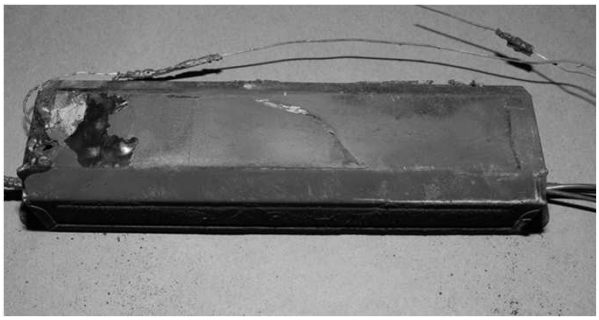

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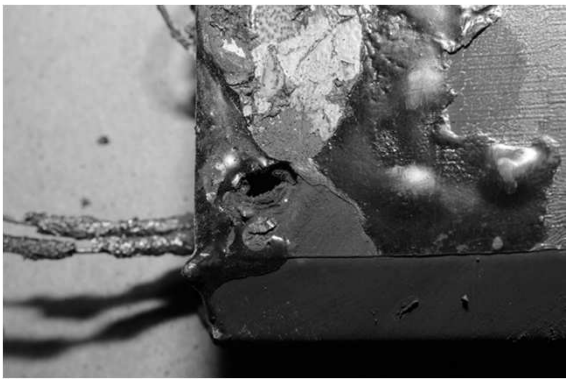

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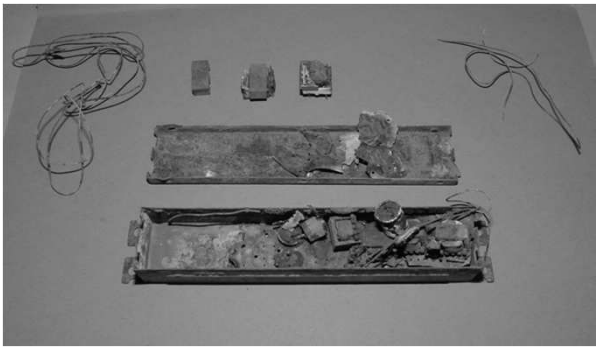

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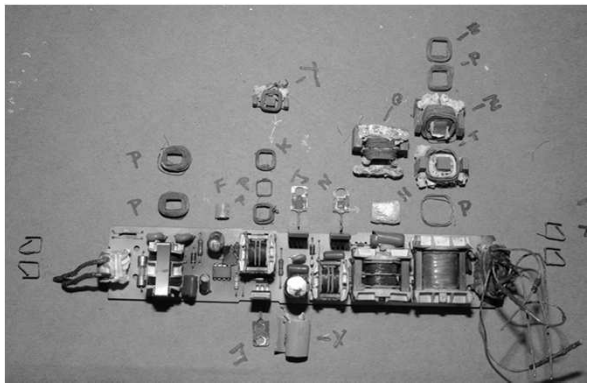
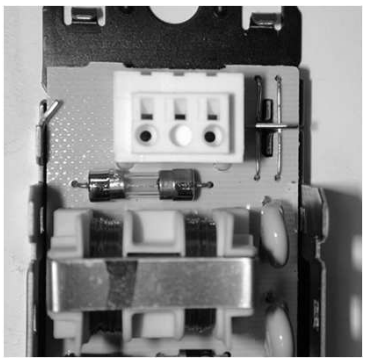
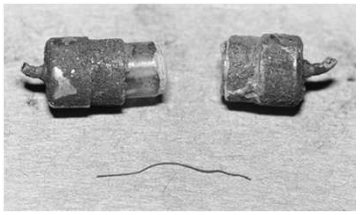


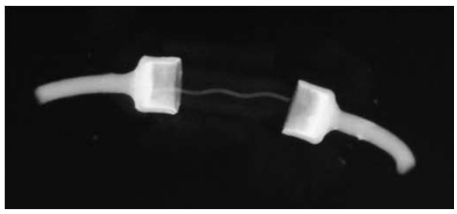
Protection of Electronic Ballasts

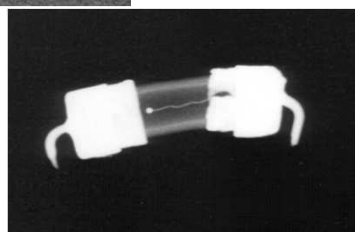
- Early electronic ballasts had resetting thermal protectors.
- Most electronic ballasts today use fuses instead of thermal protectors
- UL allows electronic ballasts to be listed as "Class P" with fuses

Typical Fuse









 145

Fixture Paint Condition

- Fixture paint condition often misleading
- Must be used with caution
- NFPA 921 warns "Care should be exercised when evaluating heat damage patterns on painted steel surfaces"

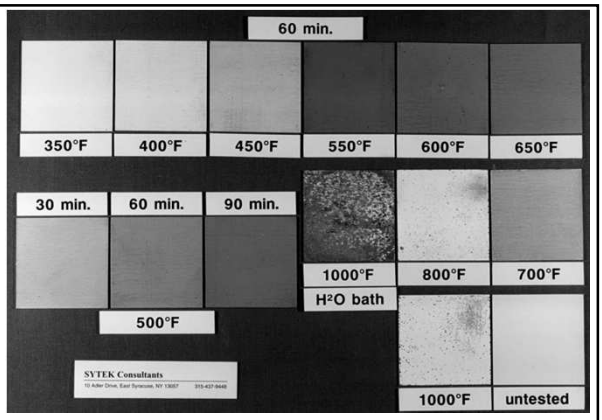
 146

Fixture Paint Condition

- Paints will
  - Discolor slightly by 400°F
  - Noticeably darken by 550°F
  - By 700°F will begin to lighten again
  - At 1000°F, paint will turn to chalky white powder

Thus, cooler locations may have darker color paint

 147



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Fire Heated Fixtures

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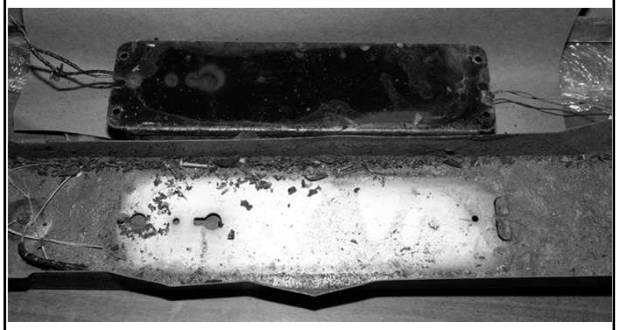
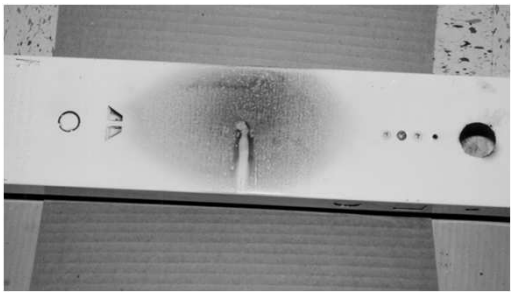


Over-heated Ballast Pattern



How Are Fluorescent Fixture Fires Investigated?

- Find point of origin first!
- Determine origin both horizontally and vertically
  - Was fire started above or below ceiling?
  - Was fire caused by drop down from above?
- Determine first fuel ignited
  - Was it in contact with fixture?
  - Is it combustible? Readily ignitable?

How Are Fluorescent Fixture Fires Investigated

It is not practical nor proper investigative technique to try to disassemble every ballast in a building to look for a cause of a fire. Identify any possible sources of ignition at the point of origin including light fixtures.

What To Do

- Document how fixture was mounted
- Document how the fixture was supplied with power
- Collect fixture, channel cover, wiring and lamp holders
- Leave ballast attached to fixture if possible
- Minimize damage to fixture
- Collect ceiling materials
- Gather exemplar fixtures

What NOT To DO

- **Dispose of fixture and channel cover**
- **Open or disassemble ballast**
- **Lose fixture wiring and lamp holders**
- **Remove and open thermal protector**
- **Energize the ballast**

 157

Common Myths

- The ballast that leaked the most potting compound caused the fire.
- The lightest ballast caused the fire.
- The ballast that rattles the most caused the fire.
- The fire burned inside the ballast can for an extended time.
- Ballasts can not cause fires.
- Arc penetrations mean the breaker was defective.

 158

Some Truths

- Ballast do cause fires.
- Lamp holders do cause fires
- Ballasts can "blow up"
- Some ballasts do contain PCB's in their capacitors.

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Example of Fluorescent Fixture Fire

Overheating and Arcing in Ballast Causes Low Density Ceiling Fiberboard Tiles to Ignite

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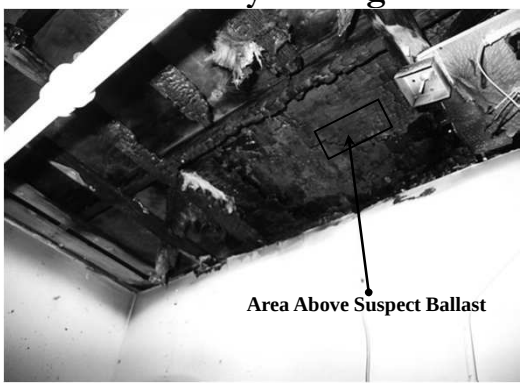
Low Density Ceiling Fire

 161

Low Density Ceiling Fire



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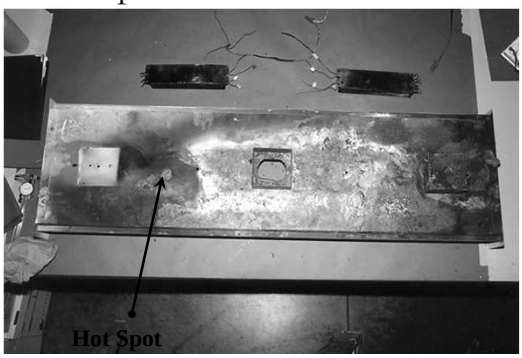
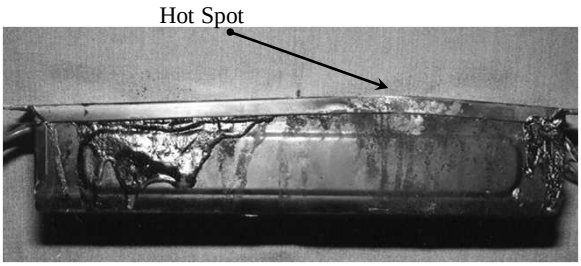
Top of Fixture After Fire



 163

Side of Ballast After Fire



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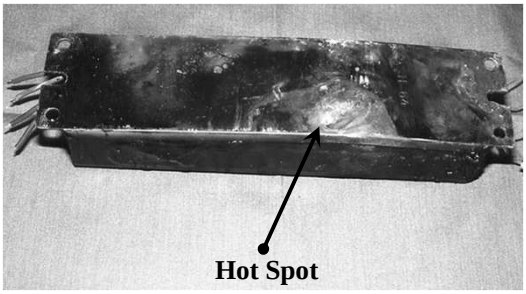
Base of Ballast After Fire



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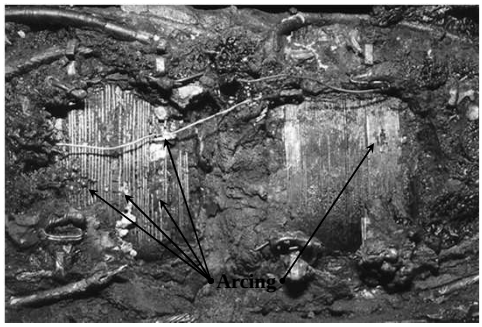
Ballast Coils



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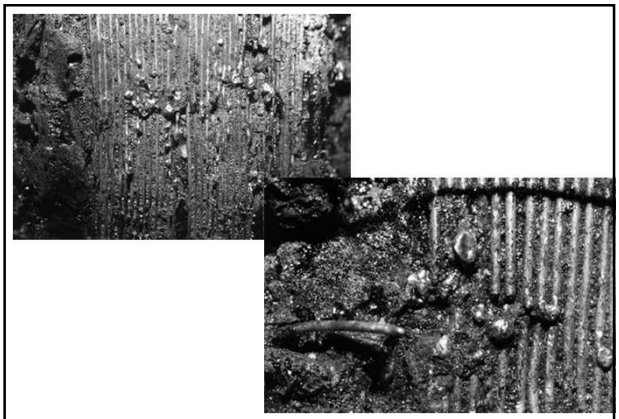

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Example of Long Term Overheating of Ceiling Material

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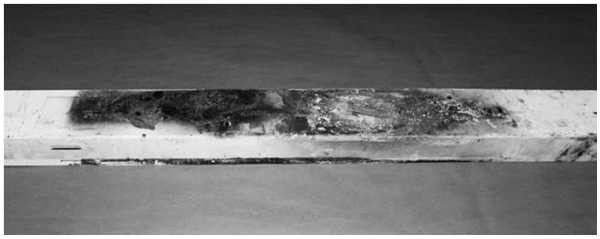
Photo by David Smith Copyright SYTEK Consultants 169

Photo by David Smith Copyright SYTEK Consultants 170

Photo by David Smith Copyright SYTEK Consultants 171

Photo by David Smith Copyright SYTEK Consultants 172



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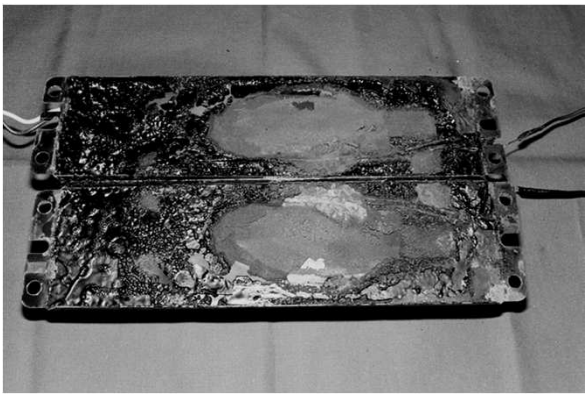
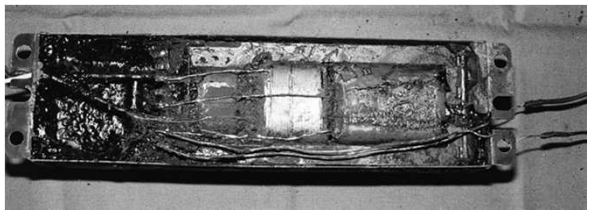
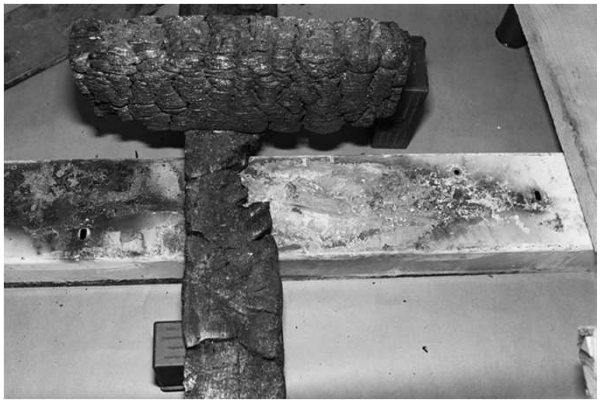
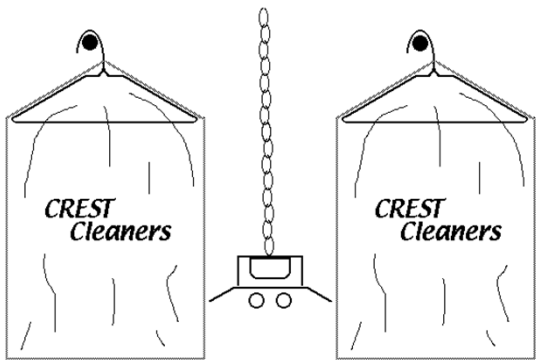




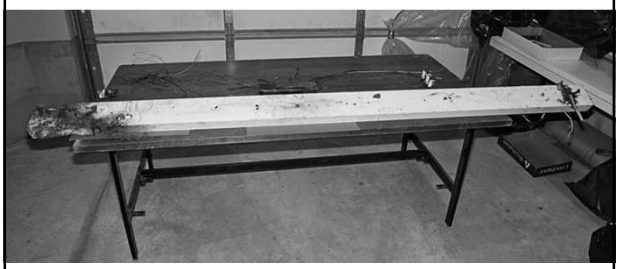


Example of Arc Penetration Causing a Fire

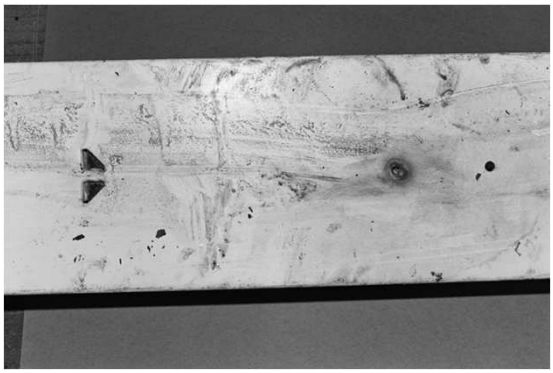
Fixture Position



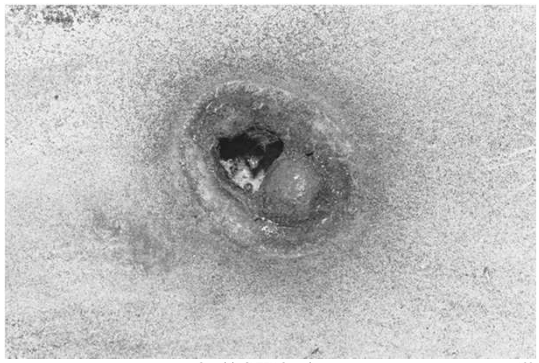
Top of Fixture



Top of Fixture



Top of Fixture



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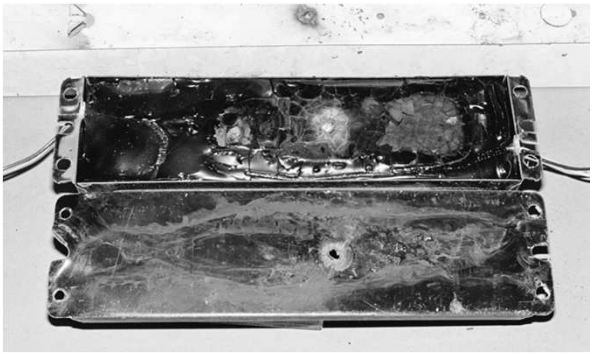
Ballast Interior



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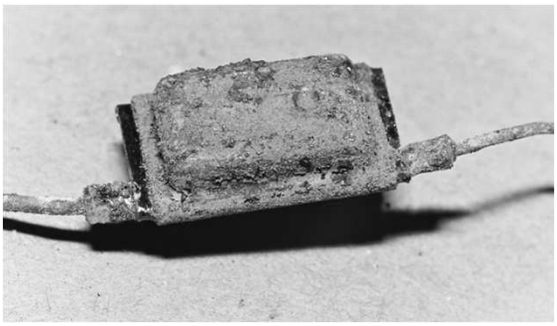
Ballast Interior

 184

Ballast Interior

Ballast Interior

Thermal Protector



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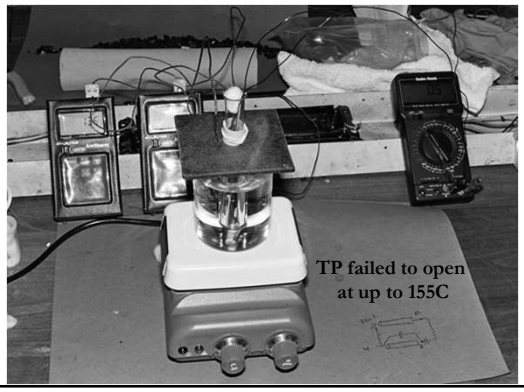
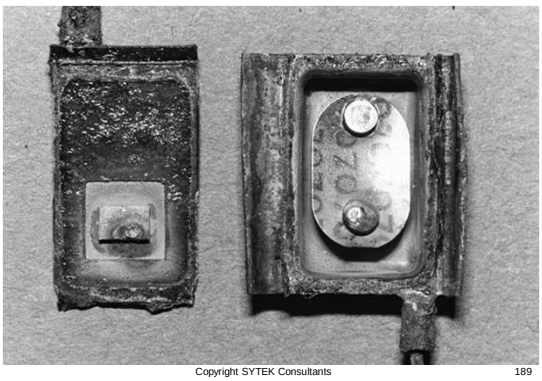
Thermal Protector



Thermal Protector



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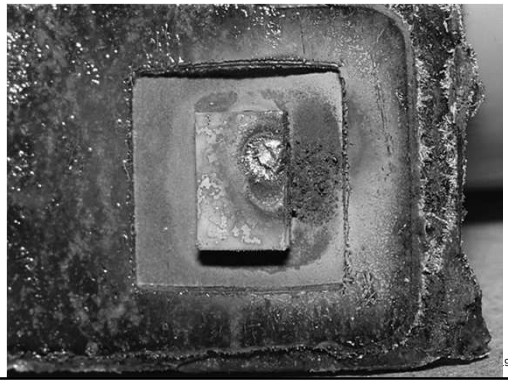
Thermal Protector



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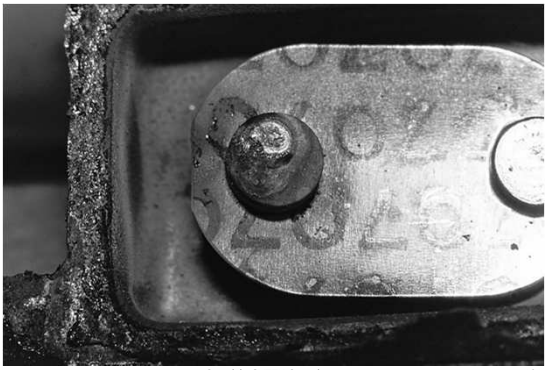
Thermal Protector



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