Practical Case Studies of Thermal Events in Buses

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Introduction

- Buses combine high occupancy loads, limited pathways for egress, and involvement of passengers with limited mobility
- Potential for injury, loss of life, and financial loss is significant in event of a fire
- Thoroughly investigating bus fires is critical to understanding ignition sources preventing future fires
- Case studies will be presented from each of the most common categories of bus fires: electrical systems, wheel level systems, and engine component failures

Introduction

- Between 1999-2003, an average of 6 bus fires per day in US
- Rate of bus fire claims at Lancer Insurance has risen since 2007
- Fatalities due to fire are rare
  - Estimated that 95% of incidents have no associated injuries/fatalities
- NFPA estimates between 2999-2003, bus fires resulted in an average of $24.2 million annual property damage
- Most origin locations are electrical systems, wheel level systems, and engine compartment failures
- Most contributing initiation factors could be addressed through pre-operation inspection and proper maintenance

Electrical System Failures

Electrical System Failures

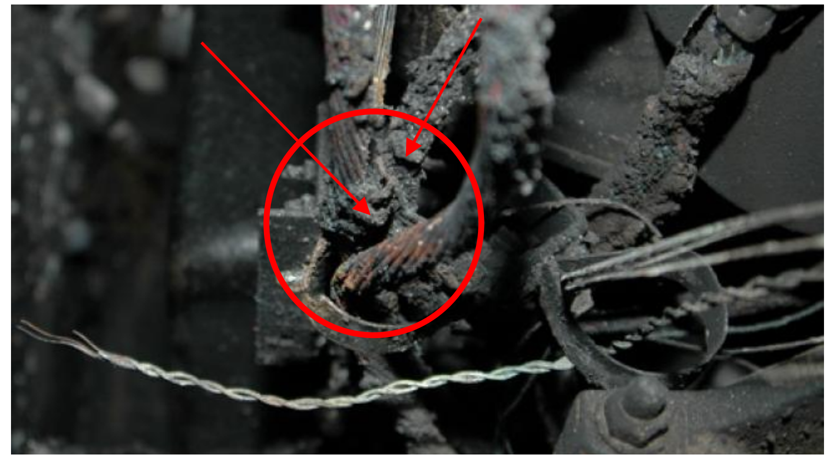
- Estimated to account for ~20% of fires reported between 1995-2008
- Typically due to:
  - Current Overload
  - High Resistance Connections
  - Electrical Arcing
- Commercial vehicles contain more wiring harnesses and therefore have more potential for electrical system failures

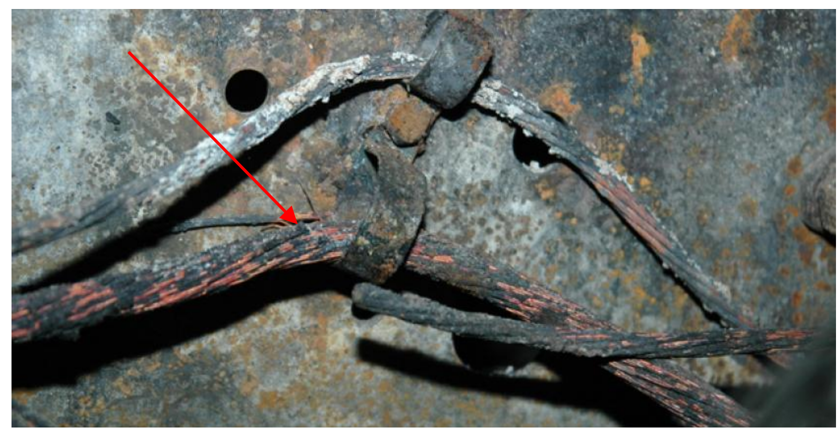
Case Study: Arcing Due to Chafing

- Six school buses involved in overnight fire
- Based upon relative damage and burn pattern, origin narrowed to buses 2-4
- Bus 2 and 4 had more significant suspension sagging on driver’s side and significant arcing/separation of primary power cables
- No evidence of primary battery cable faulting forward of battery box on buses 2 and 4

Case Study: Arcing Due to Chafing

- Bus 3:
  - Burn damage throughout engine compartment
  - Most considerable suspension sagging
  - Electrical activity observed where 3 power cables enter engine compartment near front left leaf spring
  - Arcing at primary power cable where it passed p-clamp on left hand side rail

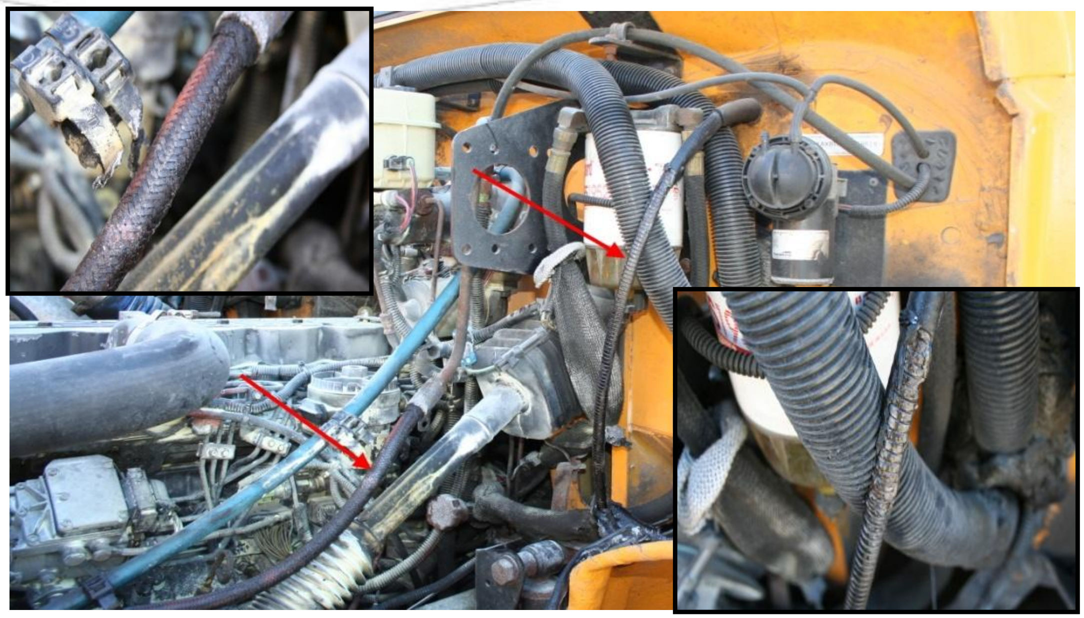




Case Study: Arcing Due to Chafing

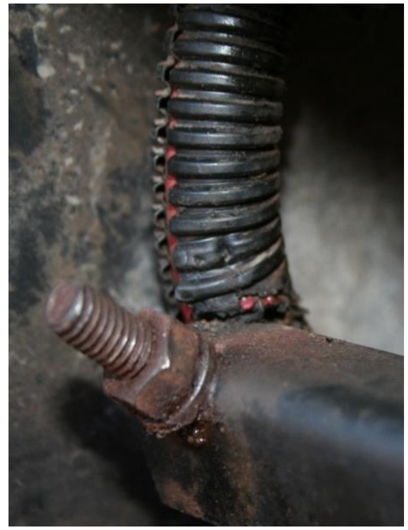
- Determine that fire resulted from electrical arcing of the power cables routed through the P-clamp of bus 3
  - Resulted in ignition of plastic/elastomers
  - No evidence of electrical arcing near battery box
- As a result, inspections of fleet were performed
- P-clamps on battery cable runs from the battery box to the engine were replaced with plastic blocks and zip-ties
- Changes resulted in significant reduction in reported fires due to chafing of the battery cables

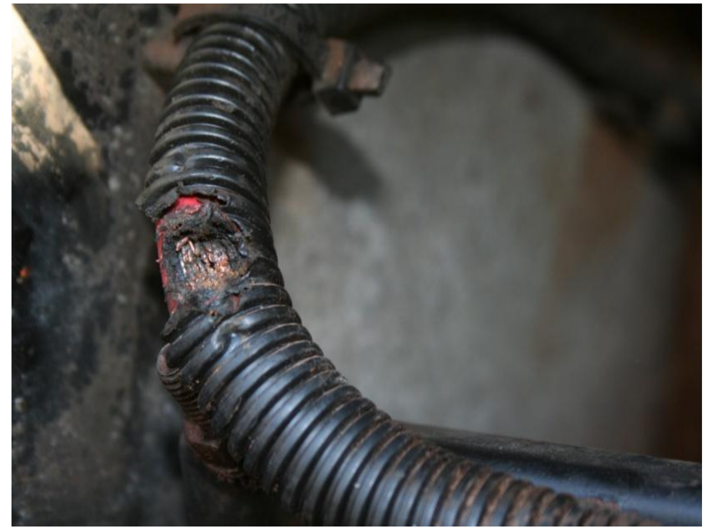
Case Study: Poor Ground Connection



- School bus in operation when driver lost engine power
- Fire observed on left side of engine compartment
- After the fire, the parking brake cable was inoperative
- Stainless steel high pressure power steering hose had signs of significant resistive heating

Case Study: Poor Ground Connection





- Parking brake cable melted from body to transmission-mounted parking brake
- B+ battery cable had evidence of fault activity
- B+ battery cable pinched at hold down bolt and insulation was chafed through

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Case Study: Poor Ground Connection

- Sufficient ground not achieved between body and primary ground at frame (highly corroded connection at ground stud on frame rail)
- Chafing of B+ battery cable resulted in significant fault current, which flowed through alternative paths to ground
- As a result, new procedures were established for inspecting and maintaining ground cables

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Wheel Level Systems

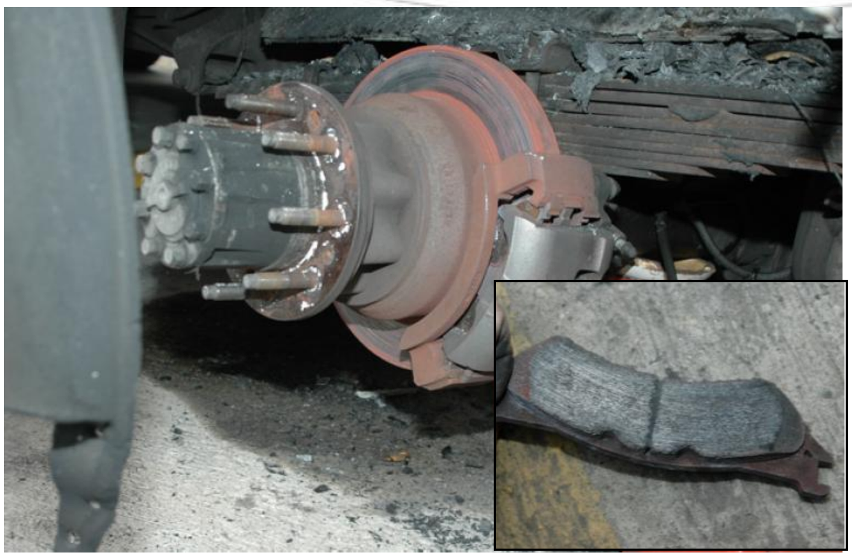
Wheel Level Systems

- Between 1995-2008, 20% of reported bus fires occurred at brakes, 16% at tires, 10% at bearings
- Typically due to:
  - Underinflated tires (duals)
  - Brake failures
  - Wheel bearing failures
- Commercial vehicles are subjected to more frequent operation in more severe conditions and are therefore more susceptible to failure

Case Study: Brake Failure due to Accessory Failure

- Paratransit in service when fire initiated at right rear wheel
- Bus equipped with wheelchair lift
- Bus in operation several hours before smoke
- Two days prior, bus was taken out of service for complaints of rear brakes dragging
  - Rear calipers and pads replaced, brake system bled

Case Study: Brake Failure due to Accessory Failure



- Left rear: rotor bluing, friction material degradation
- Right rear: tires partially consumed, more significant bluing of brake components and degradation of friction material
- Front brakes undamaged

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Case Study: Brake Failure due to Accessory Failure

- Bus was equipped with brake interlock system that applied the rear brakes when the wheelchair lift door was open
- Testing ruled out mechanical problem with brake interlock system
- Brake interlock system tested on similar buses
  - Door could be latched without completely closing
  - Door switch remained activated and brakes remained applied
- Determined that improperly closed door allowed door switch to remain active with brakes applied while bus was in operation
- As a result, all wheelchair lift doors and interlock systems were properly adjusted and are now inspected regularly

Engine Compartment Failures

Engine Compartment Failures

- Estimated to account for ~30% of fires reported
- Typically due to:
  - Failure of components
  - Failure of fluid or electrical routing
  - Lubrication or bearing failures
- Commercial vehicles with large engines and more accessories, and which are used for prolonged service in harsh conditions, are more susceptible to failure

Case Study: Compressor Clutch Bearing Failure

- Cut-away paratransit in service for ~6 hours
- Bus parked for 5 minutes, then restarted
- Driver lost ability to turn steering wheel and heard flapping noise under hood
- Driver then heard popping noise under hood
- Smoke observed from engine compartment, emanating from left side

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Case Study: Compressor Clutch Bearing Failure

- Circular melt pattern on air cooler charge
- Clutch bearing race fused to compressor
- Compressor body displayed incipient melting
- Clutch bearing completely destroyed due to friction

Case Study: Compressor Clutch Bearing Failure

- Air compressor clutch failure resulted in fire
- Bearing failure caused significant heat generation
- Thermal damage prohibited determination of first ignited material
- Prior to fire, bus was serviced for alternator and junction block replacement
  - Technician heard noise from air conditioning compressor
  - Technician placed out-of-service placard on bus but didn’t submit new work order prior to leaving for the day
  - Shop manager saw original work had been completed and no new work order was issued, so he released the bus with the failing clutch assembly

Rare Circumstance
Fire

Case Study: Bus Fire Due to Environment

- Two buses parked outside school in November (week following DST end)
- Seat began smoking and caught fire
- Another seat also smoldering
- Exemplar bus parked in same location, pyrometer indicated material temperature rose to 320F before bus was removed

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Case Study: Bus Fire Due to Environment

- School had added new tinting material to windows, which increased reflected intensity
- Sunlight concentrated onto buses, causing increase in temperature
- End of DST changed angle of sun at the time buses were parked
- Seat material confirmed to meet FMVSS 302
- Buses prohibited from parking in area impacted by reflection

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Conclusions

- Understanding how bus fires typically ignite can lead to methods of reducing contributing factors
- Most bus fires are avoidable
- Thorough inspection and proper maintenance can address potential issues before fire incidents occur
- A thorough inspection should include ensuring all components and auxiliary systems are adjusted and maintained properly
- Preventative measures will help ensure millions of passengers travel safely to their destinations