Failure due to improper cell controls

- Even the best battery cells will fail if they are abused
- "Bad things" to do to a cell include (internal) overcharge, undercharge, overtemperature
- Violating temperature, voltage specifications causes:
  - Electrolyte breakdown
  - Electrode plating
  - Penetration of separator
  - Gassing, swelling, venting
  - Overheating, thermal runaway
- Most of these conditions result in cell overheating, which ultimately kills it

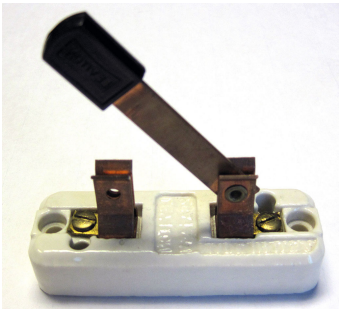
Failure due to physical abuse

- Physical abuse is also a "bad thing": may include:
  - Dropping
  - Crushing
  - Penetrating
  - Impact
  - Immersion in fluids
  - Freezing or contact with fire

  any of which could occur to an automotive battery
- Accepted that battery may not *survive* these trials; should still not itself cause an increased hazard

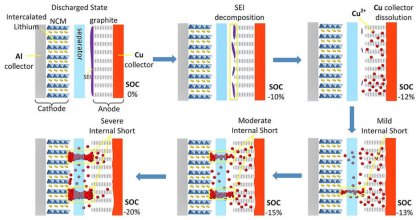
Failure modes (1)

- Several possible failure modes associated with complete cell breakdown; rarely possible to predict which will occur
- Depends very much on the circumstances:
  - ***Open circuit:*** This is a failsafe mode for the cell but maybe not for the application.
    - Once current path is cut and cell is isolated, possibility of further damage is limited
    - But, if one cell goes open circuit then whole battery will be out of commission



Failure modes (2)

- Several possible failure modes associated with complete cell breakdown; rarely possible to predict which will occur
- Depends very much on the circumstances:
  - ***Short circuit:*** If kept cool, other cells over-loaded but battery continues to provide power
    - Hard Short: Solid connection between electrodes, extremely high current flow, complete discharge, permanent damage
    - Soft Short: Localized contact between electrodes, possibly self correcting by melting separator



Failure modes (3)

- Several possible failure modes associated with complete cell breakdown; rarely possible to predict which will occur
- Depends very much on the circumstances:
  - ***Explosion and/or fire:*** Rate of chemical reaction tends to double for every 10 °C increase in temperature
  - If heat can't be removed as fast as generated, can set up self-sustaining uncontrolled positive feedback known as thermal runaway
  - Fire/explosion, which must be avoided regardless of difficulty or cost

Summary

- Cells can fail due to improper controls
- Can also fail due to physical abuse
- Failures manifest as open circuit, short circuit, and/or thermal runaway and fire
- Must take every precaution to avoid increased safety hazard

Credits (1)

Credits for photos in this lesson

- "Dead" cell on slide 1: Pixabay license (https://pixabay.com/en/service/license/), https://pixabay.com/en/dead-battery-leak-leakage-charge-1623377/
- Electric-vehicle accident on slide 2: By William James, [CC BY-SA 2.0 (https://creativecommons.org/licenses/by/2.0/)], https://www.flickr.com/photos/torontohistory/4624334211
- Open-circuit switch on slide 3: By AYL (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Open_knife_switch.jpg

Credits (2)

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- Short-circuit diagram on slide 4: Figure 2 from Guo, Rui, et al. "Mechanism of the entire overdischarge process and overdischarge-induced internal short circuit in lithium-ion batteries." *Scientific reports* 6 (2016): 30248 [CC BY-4.0 (https://creativecommons.org/licenses/by/4.0/)], http://dx.doi.org/10.1038/srep30248
- Fire on slide 5: Pixabay license (https://pixabay.com/en/service/license/), https://pixabay.com/en/fire-flames-wood-burning-yellow-184885/