College of Engineering
LAMAR UNIVERSITY

Department of Mechanical Engineering

Mechanical Design and Testing of Event Recorder used in Locomotives

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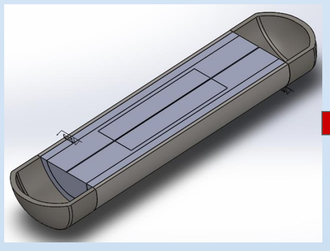
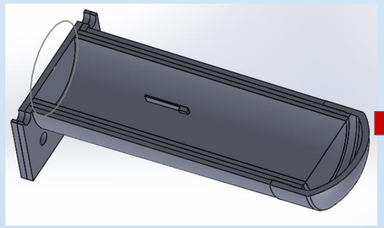
Abstract

Event Data Recorders (EDR) used in the transportation industry are an integral part of accident investigation. Event recorders, commonly known as black boxes, allow for the determination and evaluation of crash events. An event recorder must be armored and well mounted to survive so that the information they contain can be recovered. One type of armor is a thermal insulation to protect the memory module inside in the event of a fire after an accident. Typically, in addition to standard insulation, another material that is part of the thermal protection is one that changes phase and absorbs significant heat in the process. A common one is boric acid, which while incredibly effective, is also used as rat and roach poison making it incredibly environmentally unfriendly. The goal is to replace these phase changing materials with more modern materials, while maintaining the thermal integrity of the electronics inside. Currently, in accordance with Federal Railroad Administration and IEEE guidelines, thermal and structural modeling and simulation has been completed and the initial physical testing has begun. With the overall end goal being a more environmentally safe and more reusable event recorder.

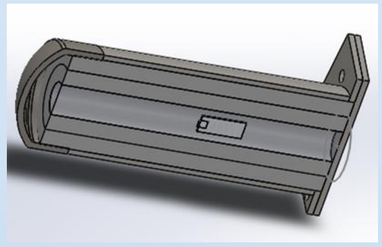
Design



Preliminary Design

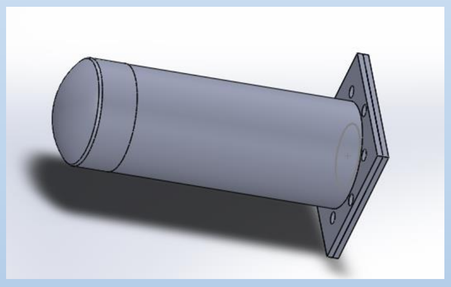


Ideal Design

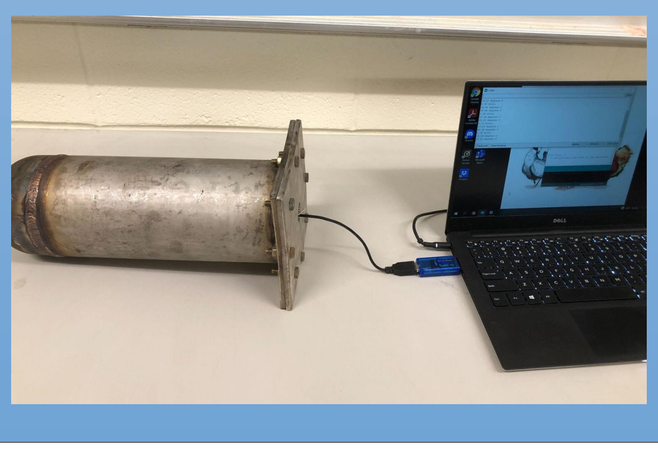


Prototype

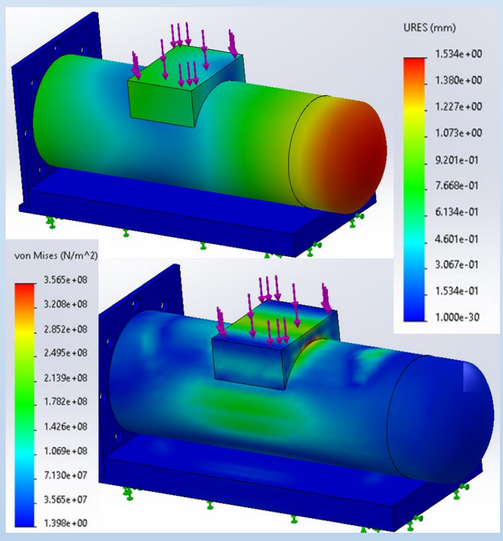
- Ideal design has our microtherm wrapping a firebrick and installed in steel shell
- Event recorder sits in center of firebrick to maximize protection and heat dissipation
- Flange was added in later designs to allow access to internal components
- Prototype circuit board was developed to do steady state testing
- During operational steady state 1 Watt of power is generating heat that must be dissipated by the innermost insulation



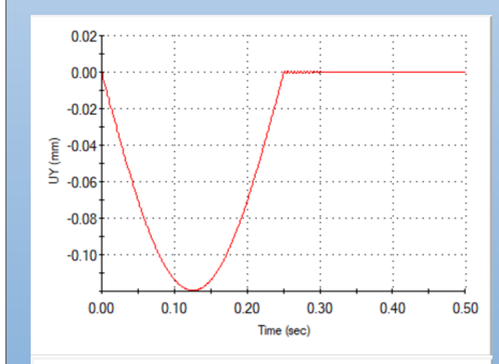
- The system would have two conditions:
  - operating: pre-crash when electrical components are active
  - non-operating: post-crash when electrical components are offline
- Operating temperature is not to exceed 100°C, this would shut off the electrical components
- Non-operating temperature is not to exceed 180°C, this would melt the solder and component materials and prevent the data on the circuit board from being extracted

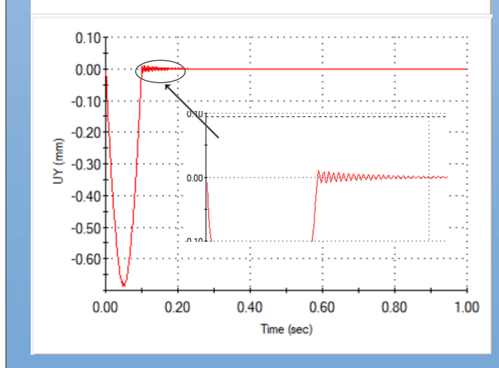


Simulations – Static Crush, Impact Shock, and Transient Thermal Analysis



- Static Crush simulation results for the 111 KN test provided a max stress of 365 MPa which caused a deformation of 1.5mm



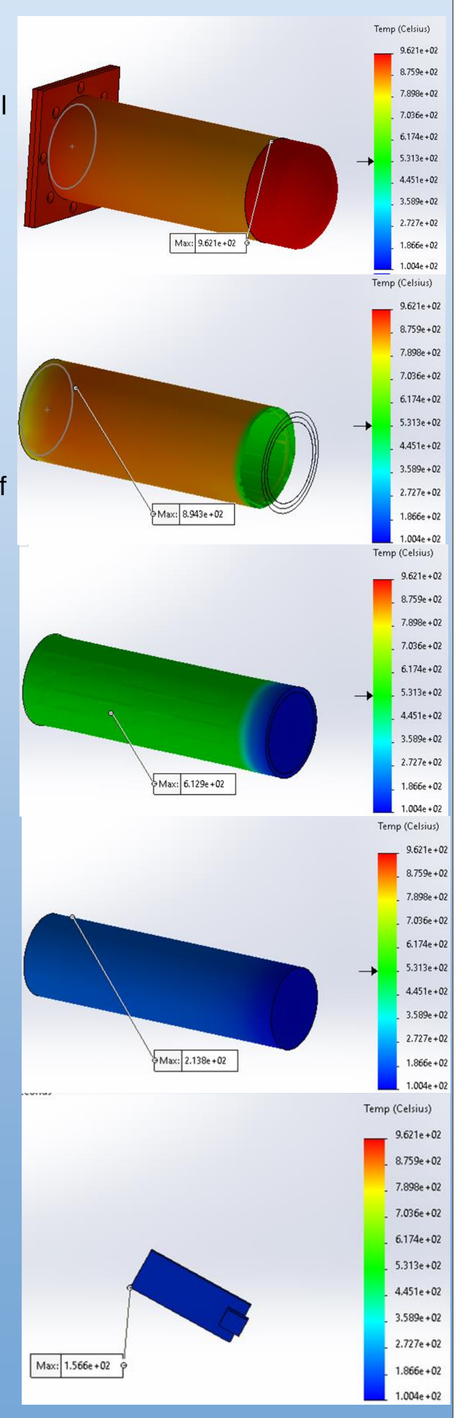


External Shell
962.1°C

Two Layers of Microtherm
894.3°C
612.9°C

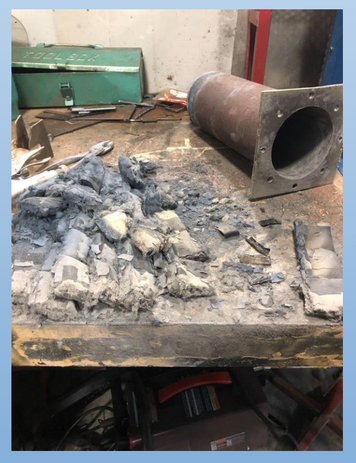
Firebrick
213.8°C

Internal PCB
156.6°C



- The impact shock simulation test results show minimal deformation to the casing
- Awaiting repair of Lamar's universal testing machine for physical testing

Experiments – Static Crush Test and Furnace Test



Temperature Monitoring Strips

Methods

- Static crush performed on Lamar's Civil Engineering Humboldt tester with half length model
- Furnace test performed in Lucas's material science lab

Results

- No major deformities were present after testing
- Temperature strips were burnt inside event recorder
- In upcoming weeks we will conduct furnace test at 500°C

Criteria and Insulators

FRA Performance Criteria for Event Recorder

Parameter	Value	Duration	Remarks
Fire, High Temperature	1000 °C (1832 °F)	60 minutes	Heat source: Open flame.
Fire, Low Temperature	260 °C (500 °F)	10 hours	Heat source: Oven.
Impact Shock—Option 1	23gs	250 ms.	
Impact Shock—Option 2	55gs	100 ms	½ sine crash pulse.
Static Crush	111.2kN (25,000 lbf) 44.5kN (10,000 lbf)	5 minutes. (single "squeeze")	Applied to 25% of surface of largest face.
Fluid Immersion	#1 Diesel, #2 Diesel, Water, Salt Water, Lube Oil, Fire Fighting Fluid.	48 hours *each*.	
Hydrostatic Pressure	46.62 psig (= 30.5 m. or 100 ft.).	48 hours at nominal temperature of 25 °C (77 °F).	

- The static crush and impact shock tests should identify any possible deformations or penetration points
- If there is noticeable deformation in the outer shell then it may crush the inside insulation which would reduce the thermal efficiency of the insulation
- If there is a penetration in the shell or any of the welds then it would later fail the fluid immersion tests

Comparing Insulators

	Min-K Mold	Excelblok DR	Microtherm Panel	McMaster Ceramic Fiber
Thermal Conductivity (W/m*K)	0.029~0.083	0.00202-0.0062	0.023~0.044	0.09368
Thermal Diffusivity (m2/s)	9.412e-8 ~ 2.3e-7	1.8e-3 ~ 3.73e-3	8.87e-5 ~ 1.028e-4	Specific Heat, Cp, required for analysis
Cost Availability	Not available in small orders	Not available in small orders	~$320 for 6 300x300x25 mm panels	$107.02 for 2in thick, 24in wide x 12.5ft long
Environmental Impact	Ceramic material, vendor information required for further analysis.	Ceramic powders have a medium environmental impact, Ceramic fibers are low	Glass cloth and Alumina both have med-high impacts due to their processing	Ceramic Fiber has a low environmental impact

Conclusions

- We believe the sealant is imperfect and eventually allows heat through the flange
- Microtherm listed thickness not accurate to received material
- We also believe the shell is simply not big enough and we do not have enough mass to dissipate the heat