

MacArthur Maze and Newhall Pass Fires and their Implications for Spent Fuel Transport



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Outline

- **Introduction**
- **Accident Description: MacArthur Maze**
 - Post Accident Analysis
 - Samples Collected
 - Material Analysis Results
 - Thermal Exposure Tests
 - Analysis of Tanker Truck Materials
 - Conclusions
- **Accident Description: Newhall Pass**
 - Samples Collected
 - Materials Analysis Results
 - Conclusions
- **Future Work**



Introduction

- **10 CFR Part 71 – Packaging and Transportation of Radioactive Materials**
 - **Section 73: Hypothetical Accident Conditions**
 - **30 Minute fire: Average Temp. 800° C (1475° F)**
- **Evaluate real world accidents against this standard**
- **Do the regulations mesh with the real world?**

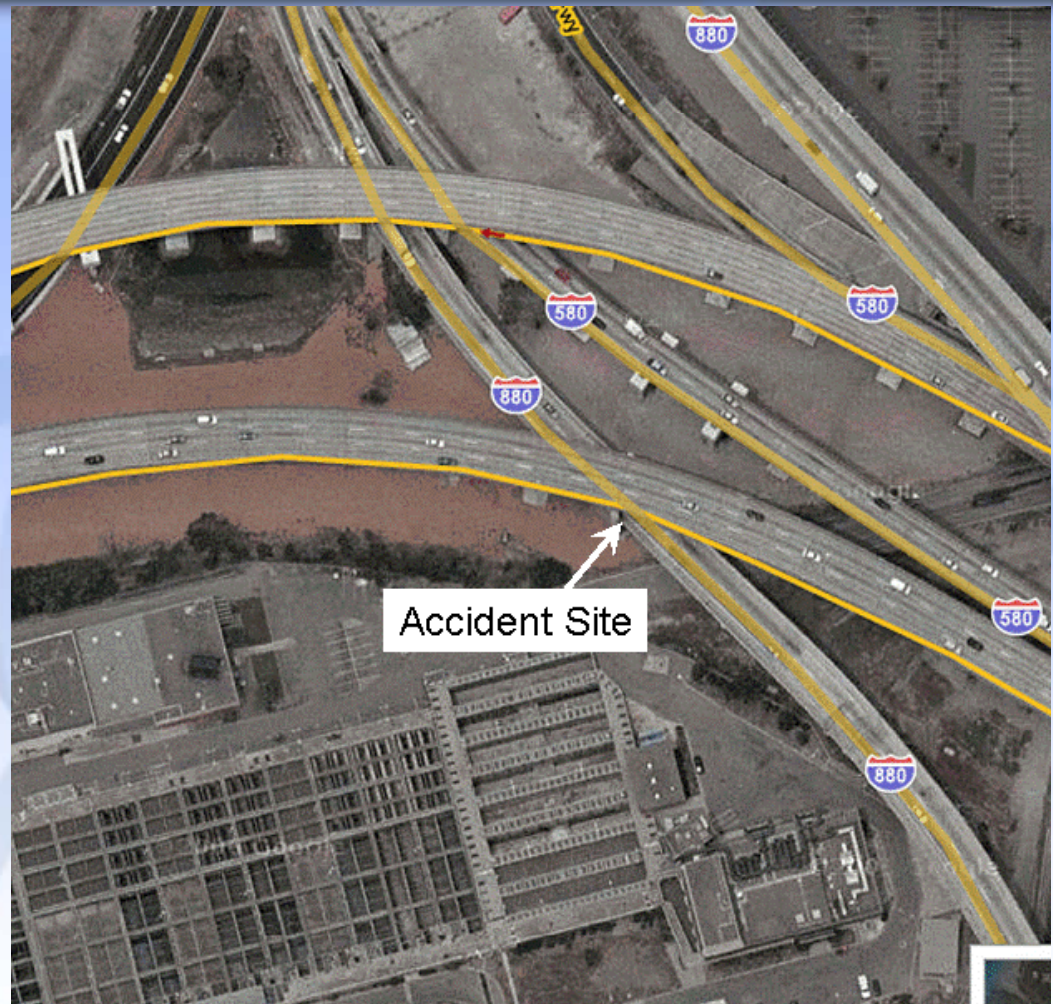
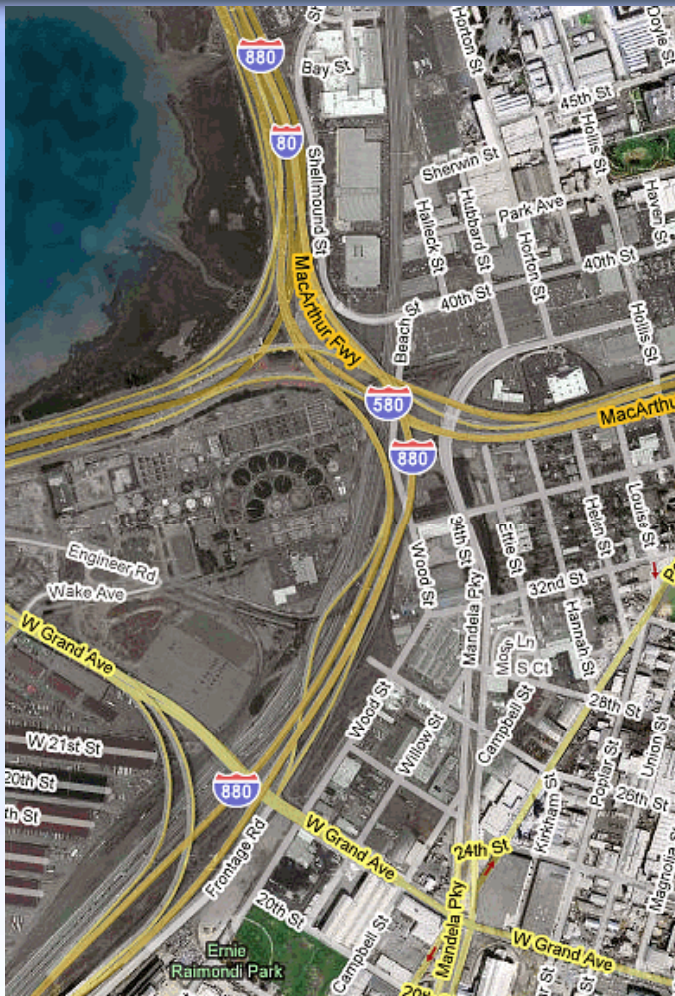


MacArthur Maze Fire

- **Accident and fire occurred April 29, 2007 at about 3:45 AM**
- **Gasoline double tanker truck**
 - 32,500 liters [8,600 gallons] of gasoline
- **Traveling south along Interstate 880 in Oakland, California**
- **Accident occurred in the MacArthur Maze, an interchange connecting I-80, I-580, and I-880**
- **The I-580 overpass directly above I-880 collapsed approximately 17 minutes after the fire started**



Accident Location





Fire Damage





















Post Accident Analysis

- **NRC and SwRI staff collected samples to determine temperature witnessed by the girders during the fire**
 - **Samples were collected after demolition and reconstruction**
- **Caltrans tested structural steel and concrete to determine mechanical properties**
- **Fire damage to the concrete structures was documented by CalTrans**



Overpass Demolition



Girder cutting after concrete removal



Remnants of tanker truck



Fire Damaged Girders





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PG 12
mb 18

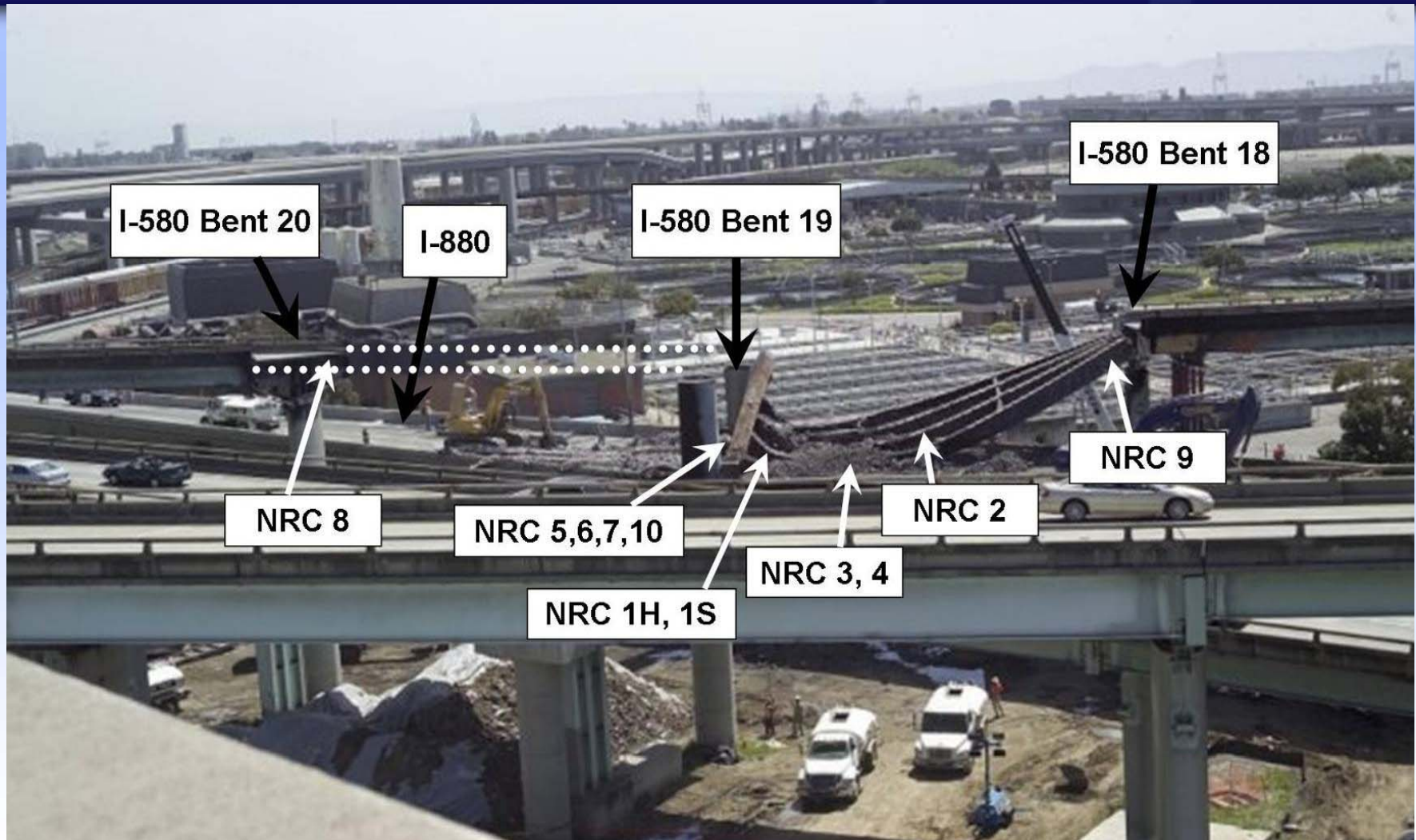


Samples Collected

<i>Sample Number</i>	<i>Girder</i>	<i>Location (Bent)</i>	<i>Weld Metal?</i>	<i>Description</i>
NRC 1H	Plate # 3	19	No	Plate Girder with rivet holes
NRC 1S	Plate # 3	19	Yes	Plate Girder with stiffener
NRC 2	Plate # 4	18 – 19	Yes	Plate Girder with butt weld
NRC 3	Plate # 5	18 – 19	Yes	Plate Girder with stiffener - heavy distortion
NRC 4	Plate # 5	18 – 19	Yes	Plate Girder stiffener - medium distortion
NRC 5	Box # 7	19	Yes	Box Girder lower plate with side and weld
NRC 6	Box # 8	19	No	Plate Girder segment attached to Box Girder
NRC 7	Box # 8	19	No	Rivet head
NRC 8	Plate # 10	20	Yes	Plate Girder Web and plate with weld
NRC 9	Plate # 12	18	Yes	Plate Girder with stiffener
NRC 10	Box # 8	19	No	Paint Flakes



Sample Locations





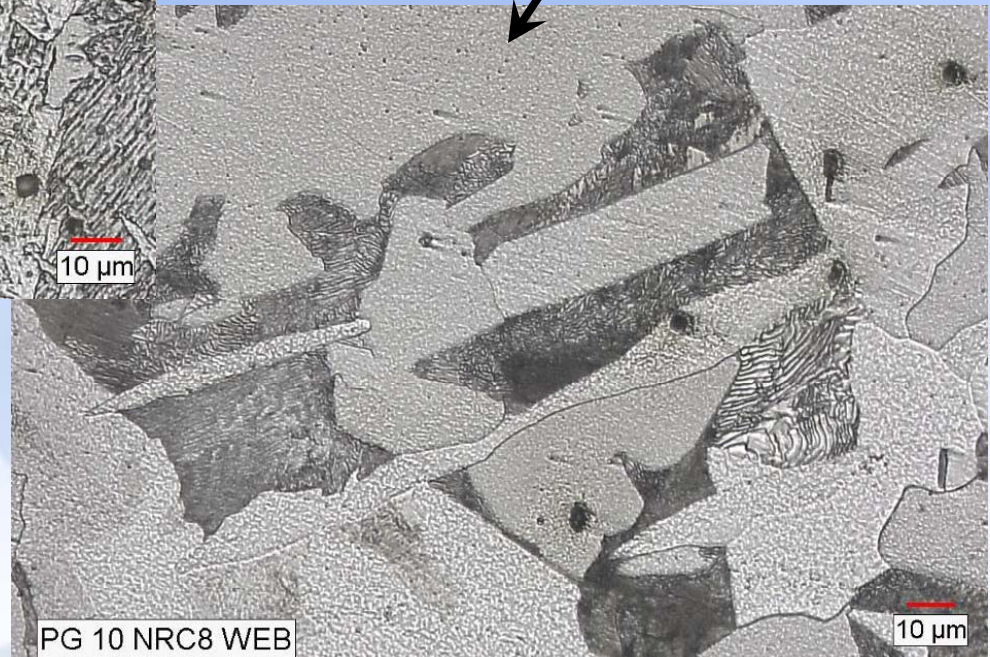
Possible Microstructures



PG 10 NRC8 WELD

As deposited weld metal – dendritic and equiaxed ferrite with some carbides

Equilibrium microstructure – ferrite (light gray) and pearlite (dark gray)



PG 10 NRC8 WEB



Analysis Results

<i>Sample Number</i>	<i>Girder</i>	<i>Location (Bent)</i>	<i>Weld Metal?</i>	<i>Weld Microstructure</i>
NRC 1S	Plate # 3	19	Yes	Dendritic Ferrite (as-deposited weld metal)
NRC 2	Plate # 4	18 – 19	Yes	Pearlite and Ferrite
NRC 3	Plate # 5	18 – 19	Yes	Pearlite and Ferrite
NRC 4	Plate # 5	18 – 19	Yes	Pearlite and Ferrite
NRC 5	Box # 7	19	Yes	Dendritic Ferrite with some Pearlite (partial transformation)
NRC 8	Plate # 10	20	Yes	Dendritic Ferrite (As-deposited weld metal)
NRC 9	Plate # 12	18	Yes	Dendritic Ferrite (as-deposited weld metal)



Thermal Exposure Tests

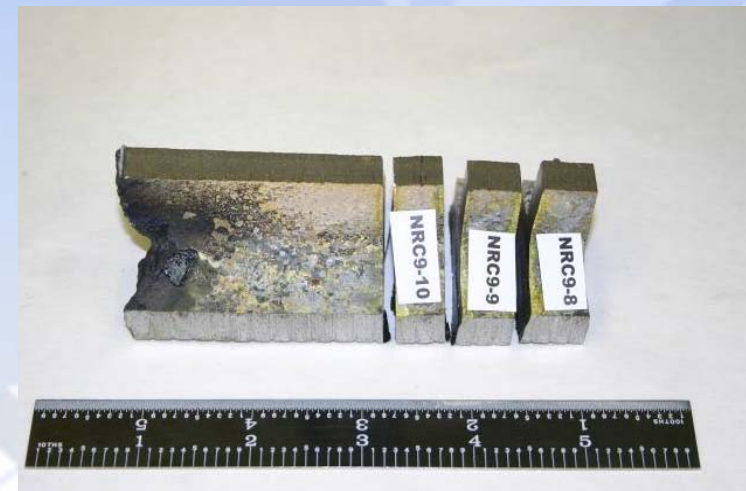
- **Isothermal exposures of unaltered specimen (Sample NRC 9) to determine weld transformation temperature**
 - 550 to 900 C [1,022 to 1,652° F]
 - 3 hours and allowed to cool in laboratory air (i.e. the samples were not quenched)
- **Metallurgical analysis conducted after isothermal exposure**



Specimens From NRC 9



- Specimens contain material from the plate girder, stiffener and plate-stiffener weld
- Thermal exposure according to prescribed matrix
- Large specimen collected for this purpose



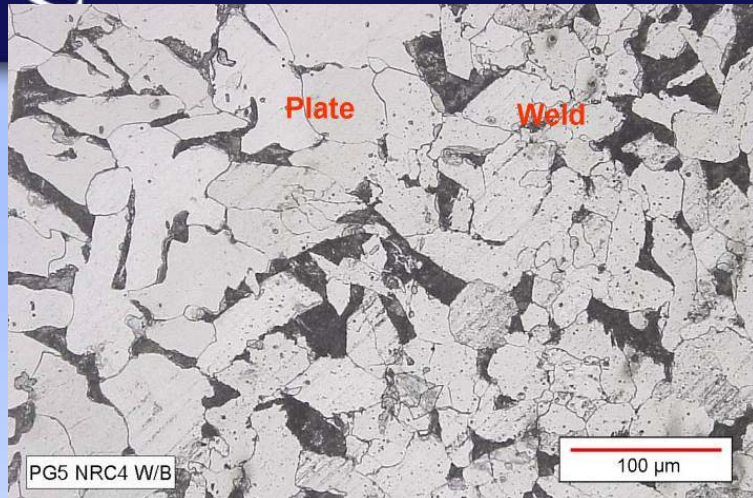


Thermally Treated Sample Results

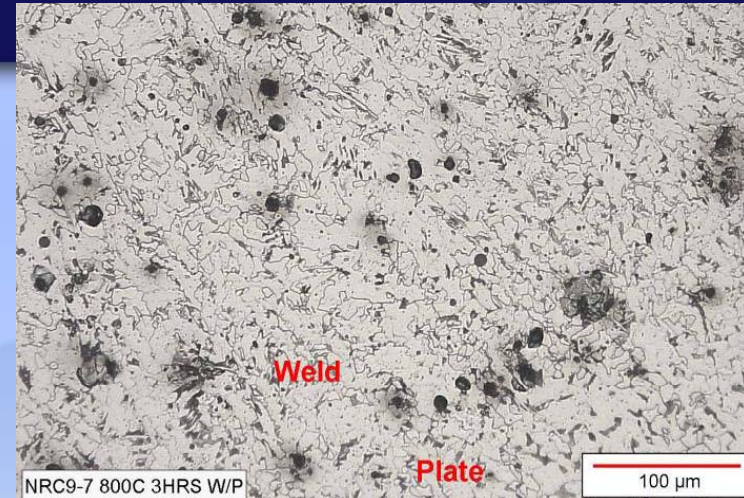
<i>Sample Number</i>	<i>Thermal Exposure Temperature</i>	<i>Microstructure</i>
NRC 9-1	None	Dendritic Ferrite (as-deposited weld metal)
NRC 9-2	550° C [1,022° F]	Dendritic Ferrite (as-deposited weld metal)
NRC 9-3	600° C [1,112° F]	Dendritic Ferrite (as-deposited weld metal)
NRC 9-4	650° C [1,202° F]	Dendritic Ferrite (as-deposited weld metal)
NRC 9-5	700° C [1,292° F]	Dendritic Ferrite (as-deposited weld metal)
NRC 9-6	750° C [1,382° F]	Dendritic Ferrite (as-deposited weld metal)
NRC 9-7	800° C [1,472° F]	Dendritic Ferrite with small regions of pearlite
NRC 9-8	850° C [1,562° F]	Ferrite and Pearlite with some dendritic Microstructure
NRC 9-9	900° C [1,652° F]	Ferrite and Pearlite (complete transformation)



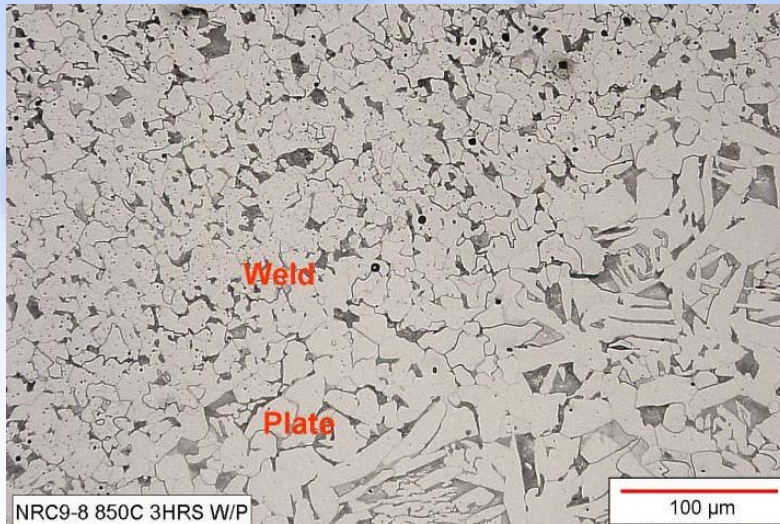
Sample Microstructures



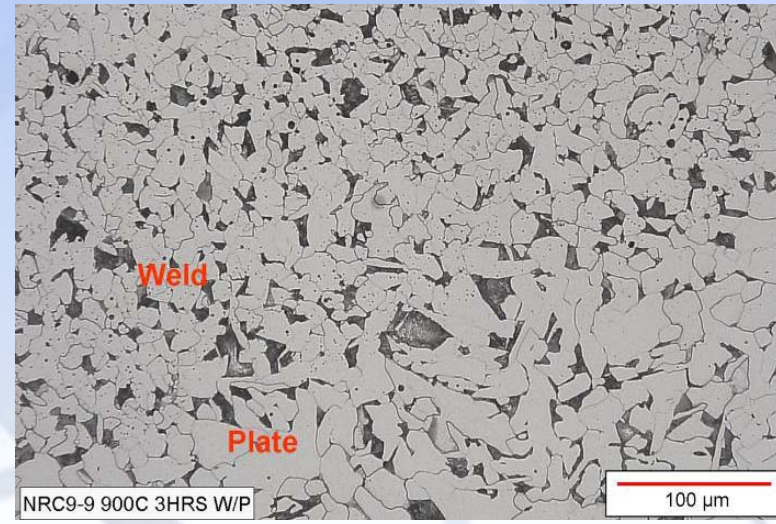
NRC 4



800° C – 3hrs



850° C – 3hrs



900° C – 3hrs



Tanker Truck Materials



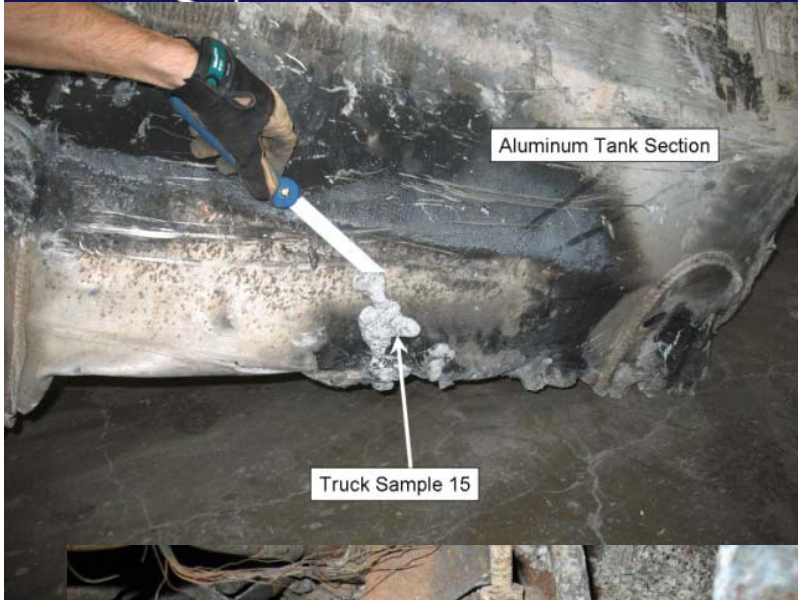


Truck Samples Collected

<i>Sample Identification</i>	<i>Description</i>
Truck Sample 1	Front tire cord from left side of vehicle
Truck Sample 2	Tire cord from #5 axle on right side of vehicle
Truck Sample 3	Brake pad located near rear of vehicle
Truck Sample 4	Rim component sample from #5 axle
Truck Sample 5	Spring located near rear of truck
Truck Sample 6	Large bolts (3) located on frame and near engine
Truck Sample 7	Grade 5 bolt located on frame
Truck Sample 8	Copper wire ground strap located on frame
Truck Sample 9	Copper wire battery cable
Truck Sample 10	Copper wire electrical system wiring located on frame and melted aluminum
Truck Sample 11	Fitting with brass located on engine
Truck Sample 12	Bolt from engine passenger side with steel wire and melted aluminum
Truck Sample 13	Aluminum screen from radiator
Truck Sample 14	Aluminum rim from dual wheel axle
Truck Sample 15	Aluminum tank section
Truck Sample 16	Glass mirror from passenger side
Truck Sample 17	Stainless steel mirror support bracket

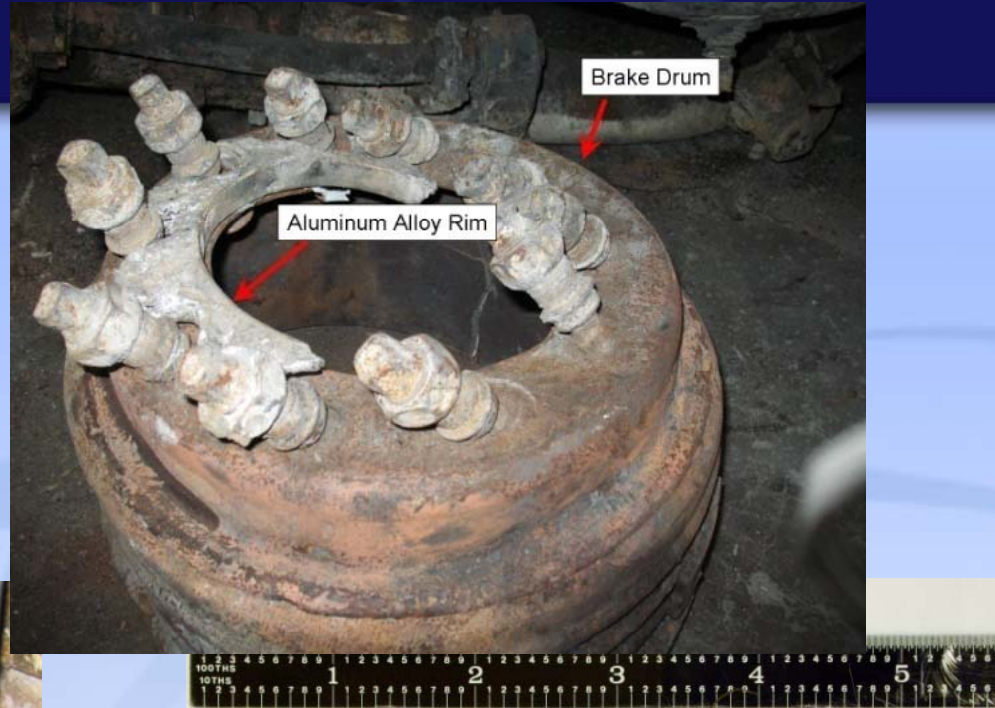


Sample Photos



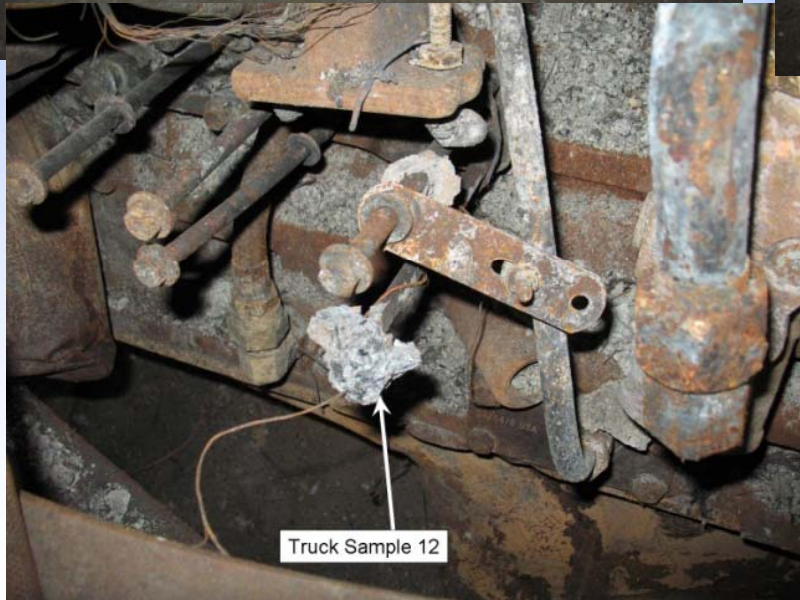
Aluminum Tank Section

Truck Sample 15



Brake Drum

Aluminum Alloy Rim



Truck Sample 12



Truck Sample 10



Tanker Truck Samples Analyses Description

- **Aluminum Alloys (Partial Melting)**
 - Tank sections, wheel rim, radiator screen
 - Analyzed to determine composition and melting points
- **Copper Alloys (No Melting)**
 - electrical wiring, battery cables
 - Analyzed to determine composition
- **Iron Based Alloys (No Melting)**
 - Vehicle frame, stainless steel brackets, bolts
 - Frame exhibited scaling
 - Rearview mirror bracket was not sensitized
 - Fasteners tested for yield and tensile strength

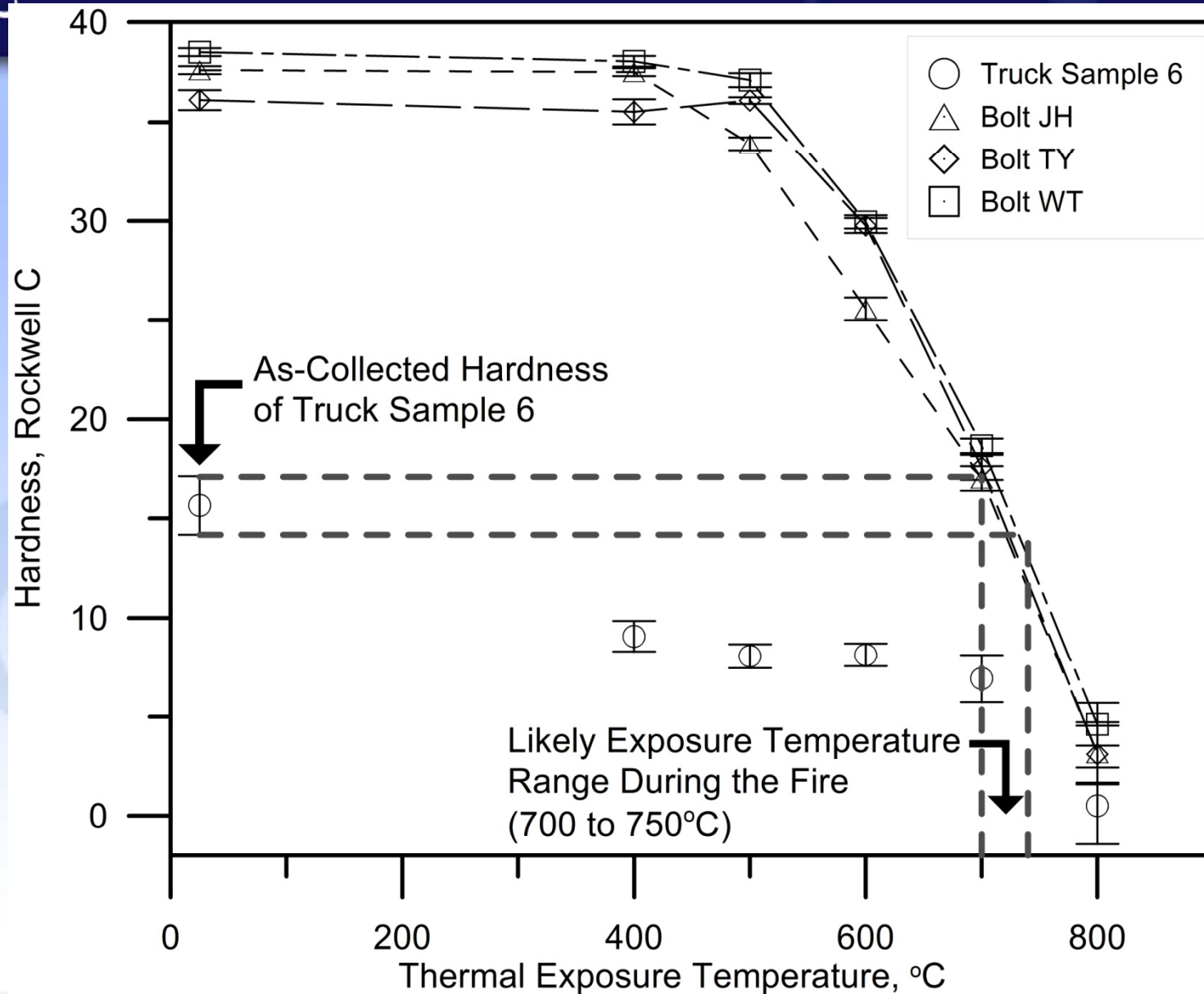


Steel Fastener Analysis

- **Grade 8 Hardware (new)**
 - Minimum 130,000 psi yield
 - Minimum 150,000 psi tensile
 - Rockwell hardness C33 to C39
- **Truck Sample 6 (as exposed)**
 - 98,000 psi tensile
 - Rockwell C16
- **Testing indicated a exposure of 700 to 750° C**



Exposure Temperature vs. Hardness





MacArthur Maze Fire: Conclusions

- Based on the samples collected and the results of thermal exposures, the temperature of the I-580 overpass is estimated to range from 850° C [1,562° F] to approximately 1,000° C [1,832° F].
- Near the truck, the maximum exposure temperature is estimated to be at least 720° C [1,328° F] and less than 930° C [1,706° F].
- The hottest gas temperatures during the fire were located above the I-880 roadway near the steel girders of the I-580 overpass.



Newhall Pass (I-5) Fire October 12, 2007

- 24 Tractor trailer rigs and 1 car involved
- Severe fire lasting several hours
- 3 deaths
- 1/10 mile (550 ft) tunnel (truck bypass)

- **NRC Actions**

- Met with CHP MAIT team to review accident information and data
- Retrieved and analyzed material samples to determine temperature exposures
- Developing fire model to characterize the fire





Newhall Pass Fire: Tunnel Exit



Photo by Gene Blevins/LACOFD/Photo



Newhall Pass Fire: Tunnel Exit



Photo by Gene Blevins/LACOFD/Photo



Newhall Pass Tunnel: Post-Fire



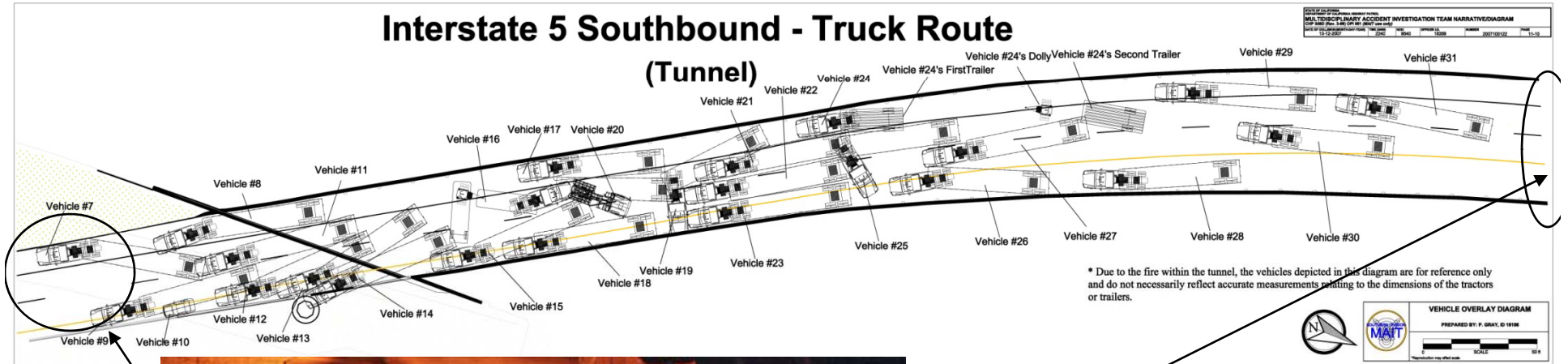


NHP Tunnel: Post-Fire Damage





Newhall Pass Accident



39

Photos by Gene Blevins/LACOFD/Photo; Diagram Courtesy of CHP

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Samples Collected

Sample Identification	Description
Truck Sample 9-01	Melted aluminum and Grade 5 bolt from trailer wheel
Truck Sample 9-02	Brass Schrader valve from trailer wheel
Truck Sample 14-01	Aluminum bracket holding steel cable
Truck Sample 14-02	Copper wire from rear lighting of the trailer with some melted aluminum
Truck Sample 14-03	Brass clamp holding a copper wire from the driver's side engine compartment
Truck Sample 14-04	Melted aluminum and Grade 5 bolt from rear driver's side wheel of trailer
Truck Sample 14-05	Melted aluminum flooring with imbedded steel screw
Truck Sample 14-06	Melted aluminum from the grill of the tractor
Truck Sample 17-01	Partially melted rear brake brass compression fitting
Truck Sample 18-01	Brass clip containing copper electrical wire
Truck Sample 18-02	Melted aluminum and Grade 5 bolt from wheel
Truck Sample 18-03	Melted aluminum and Grade 5 bolt from wheel
Truck Sample 27-01	Melted aluminum and Grade 5 bolt from wheel
Truck Sample 27-02	Melted aluminum from rear of trailer
Truck Sample 27-03	Brass ID tag from axle housing

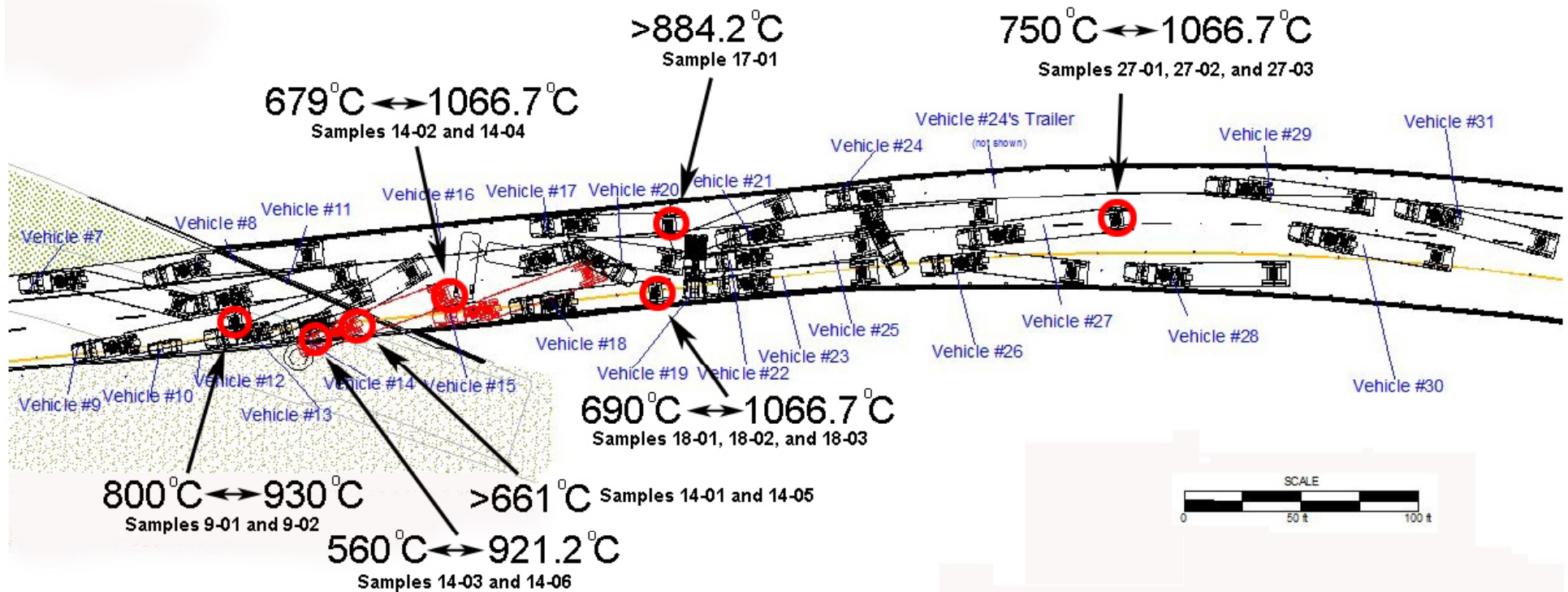


Material Analyses Results

Vehicle Number	Component/Sample	Condition/ Analysis	Temperature Bound	Temperature Range
9	Graded Bolts	hardness and microstructure	lower	880-930 °C [1,472-1,706 °F]
	Brass Schrader Valve	unmelted	upper	
	Aluminum	melted	lower	
14	Aluminum from Grill of Tractor	melted	lower	560 – 920 °C [1,040-1,690 °F]
	Brass Clamp from Engine Compartment	unmelted	upper	
	Aluminum Flooring (Trailer Front End)	melted	lower	> 660°C [>1,220°F]
	Aluminum Wheels (End of Trailer)	melted	lower	680-1,070 °C [1,256-1,958 °F]
	Copper Wiring (End of Trailer)	unmelted	upper	
17	Brass Compression Fitting Ferrule	melted	lower	> 880 °C [>1,616 °F]
18	Aluminum (at Wheel Level)	melted	lower	690-1,060 °C [1,274-1,940 °F]
	Brass/Copper	unmelted	upper	
27	Graded Bolt	hardness and microstructure	lower	750-1,070 °C [1,382-1,958 °F]



Sample Locations in Tunnel





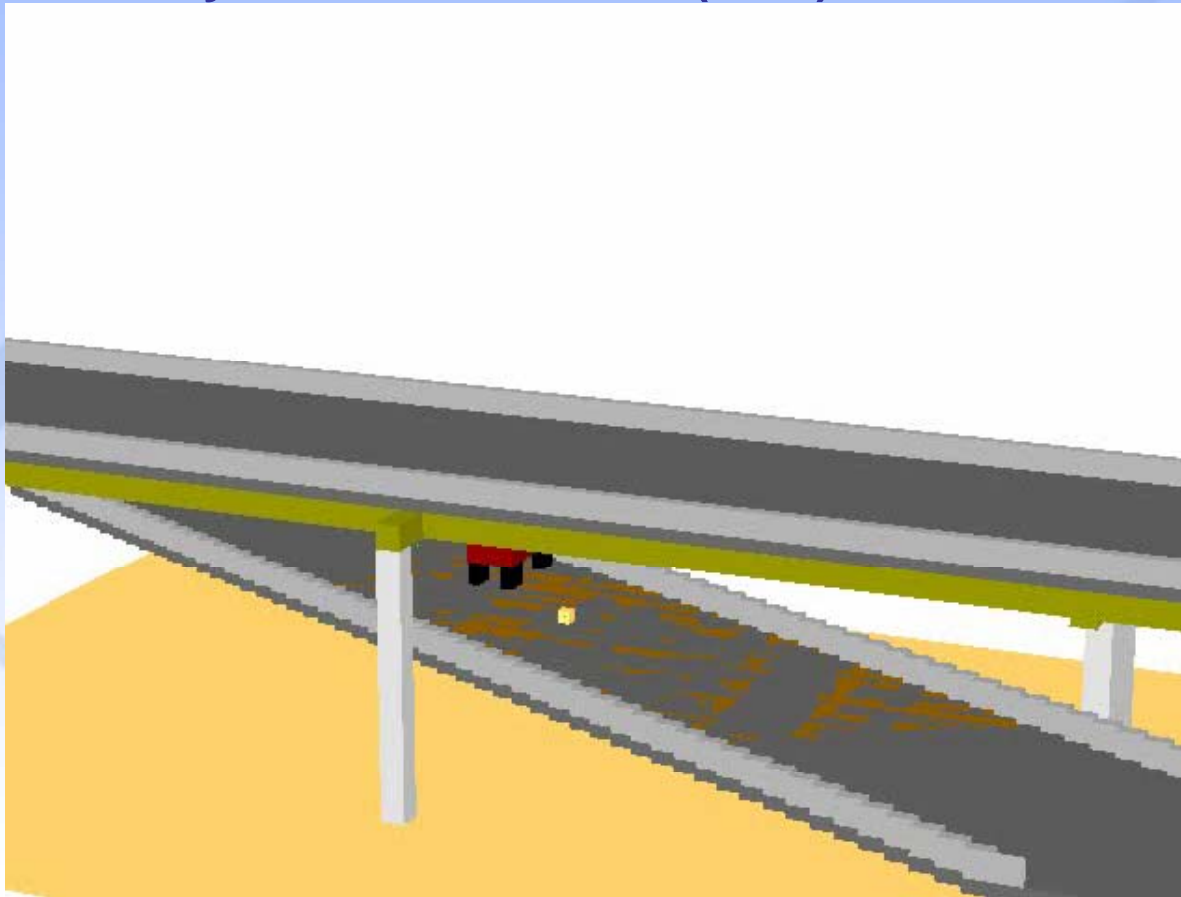
Newhall Pass Fire: Conclusions

- **Temperature in the tunnel reached levels high enough to melt aluminum.**
 - greater than 560° C [1,040°F]
- **At the location of truck 17, a higher temperature was observed based on a melting point analysis.**
 - greater than 884° C [1,623°F]
- **Hardness data (from bolts) indicated temperatures between 400 and 800 °C [750 and 1,470 °F].**
- **Based materials analyses results, gas temperature varied with time and location and exceeded 884° C [1,623°F] in at least one location.**



Future Work

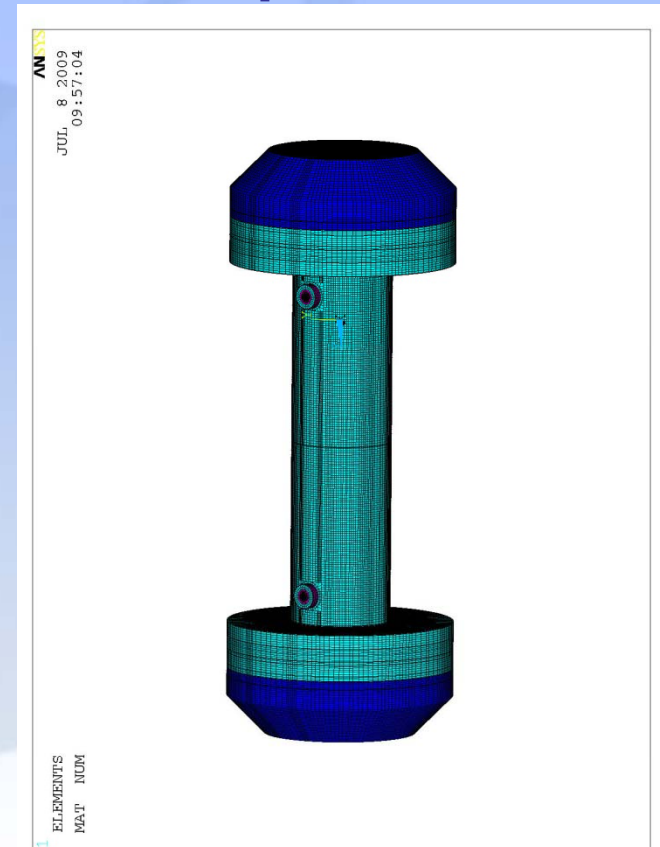
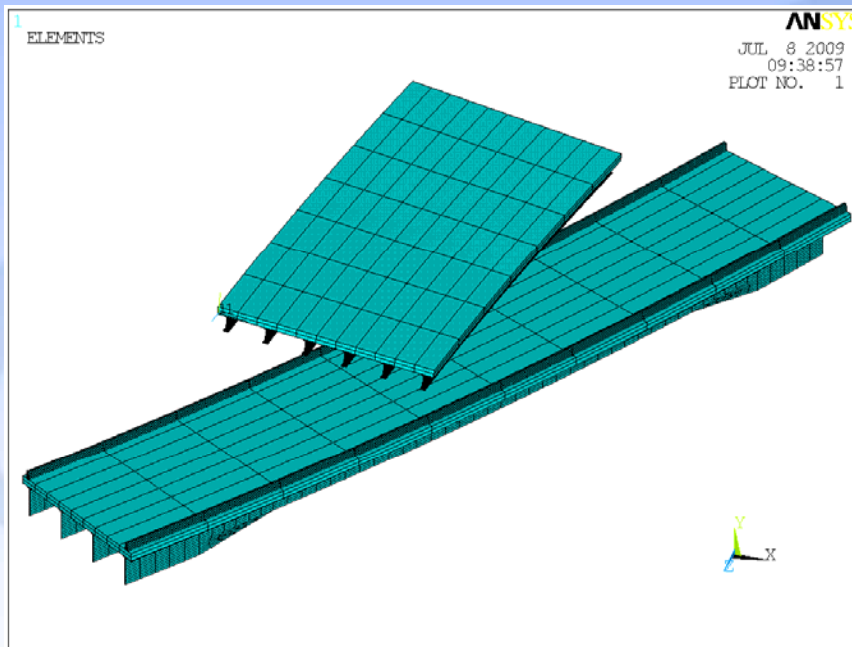
- **Modeling the MacArthur Maze Fire**
 - Fire Dynamics Simulator (FDS) code





Future Work, cont.

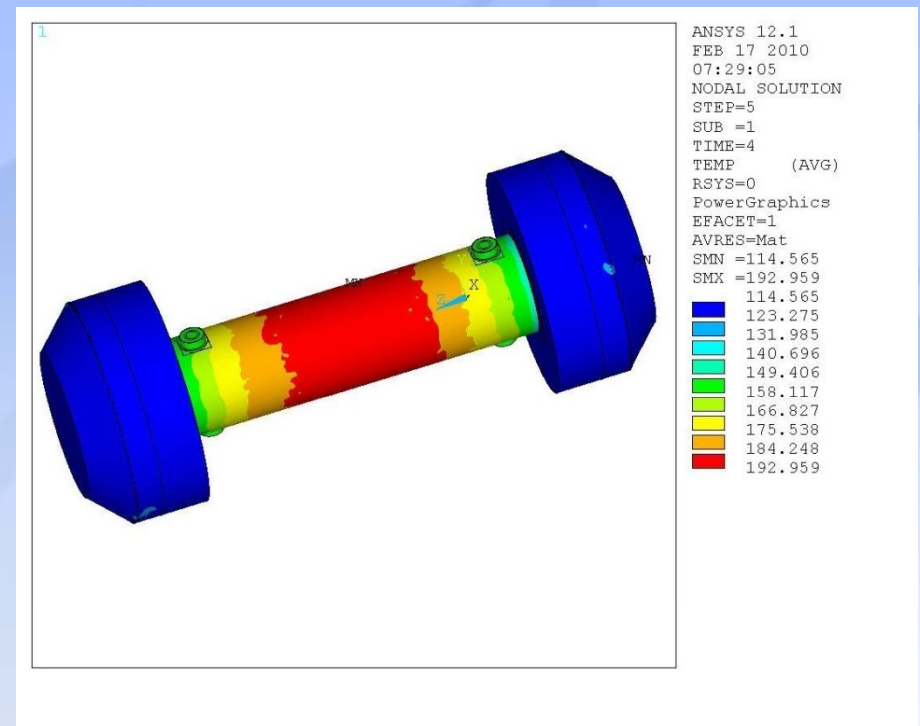
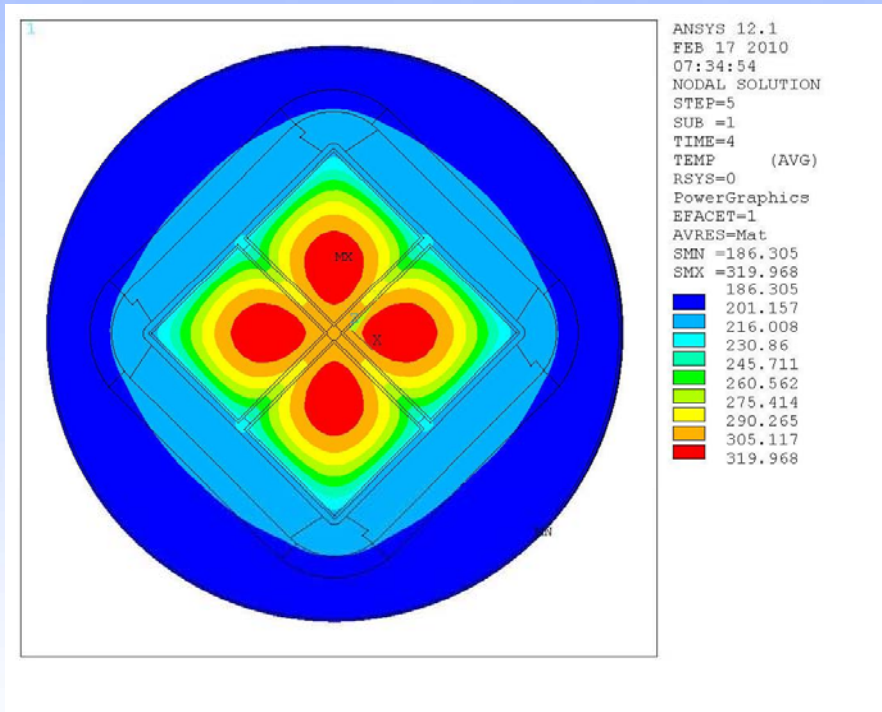
- **Modeling of Transportation Cask Response**
 - Finite element model of bridge and transportation package





Future Work, cont.

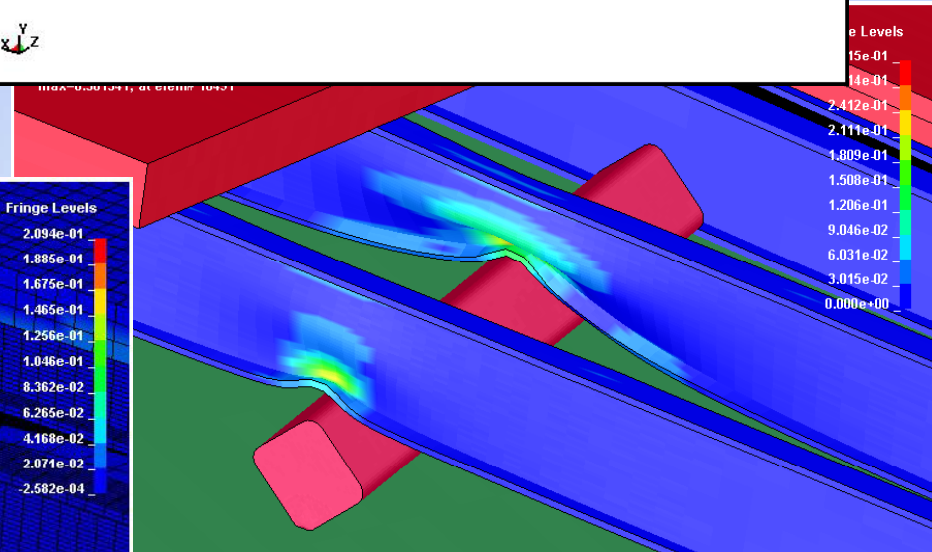
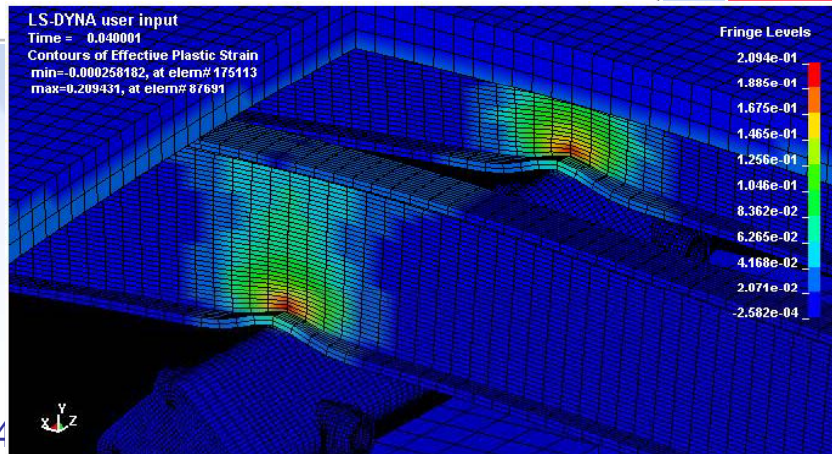
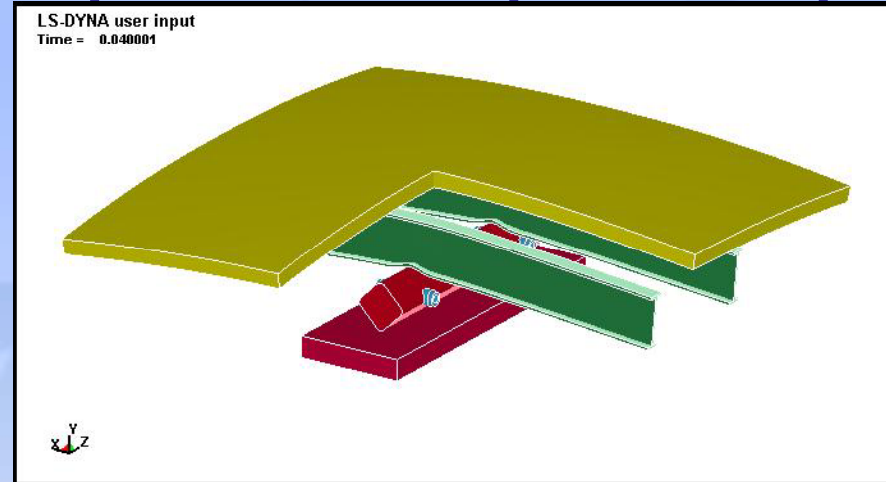
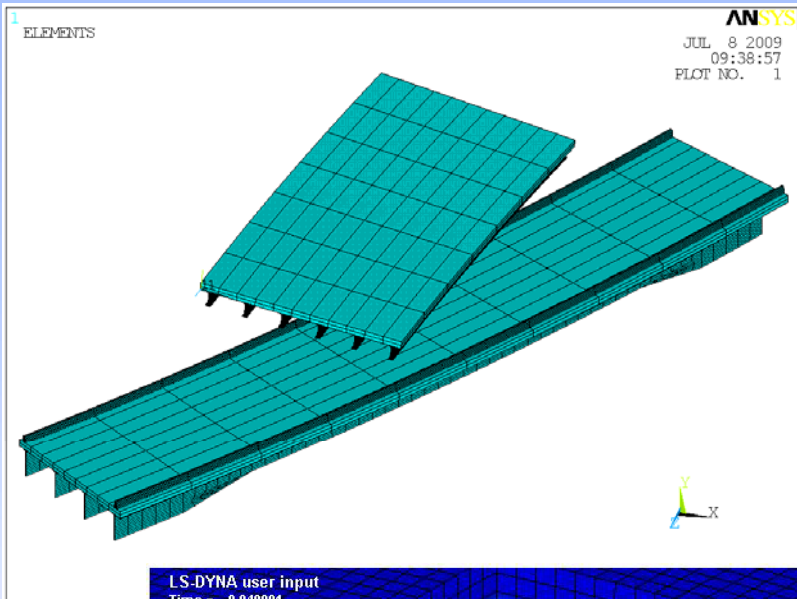
- Modeling of Transportation Cask Response
 - Fire effects (thermal)





Future Work, cont.

– Modeling of package response to overpass collapse



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Communications

- **Reports (NUREG/CR)**
 - **Materials analyses (NUREG/CR 6987)**
 - <http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6987>
 - **Fire Modeling Report(s)**
 - MacArthur Maze fire model
 - NHP to be a combined report
 - **Transportation package response**
 - For truck transport SNF package



Acknowledgements

- California Department of Transportation
- California Highway Patrol
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- Center for Nuclear Waste Regulatory Analysis
- National Institute of Standards and Technology



