NOVEMBER 9, 2023

WESTERN AUSTRALIA TRUCK EXPLOSION INVESTIGATION

CEAEC FALL MEETING – OTTAWA, CANADA

NOËL HSU

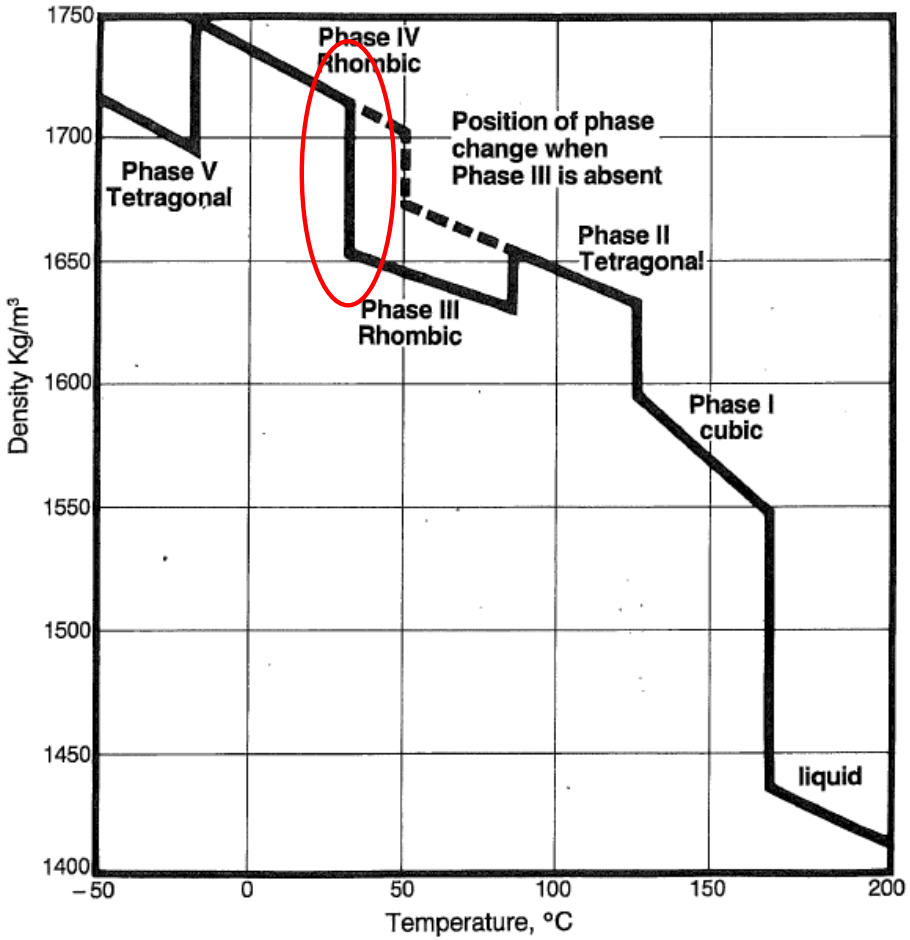

Fig. 1 Density changes in phase transitions of ammonium nitrate. (Data from Ref. 3.)

AN Phase transitions
(Presented by JF Grainger, 2009 ANNA Conference)

Thermal cycling effect on prills

Initial 6 cycles 12 cycles 18 cycles

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Thermal Behavior of Pure AN Solid (closed system)

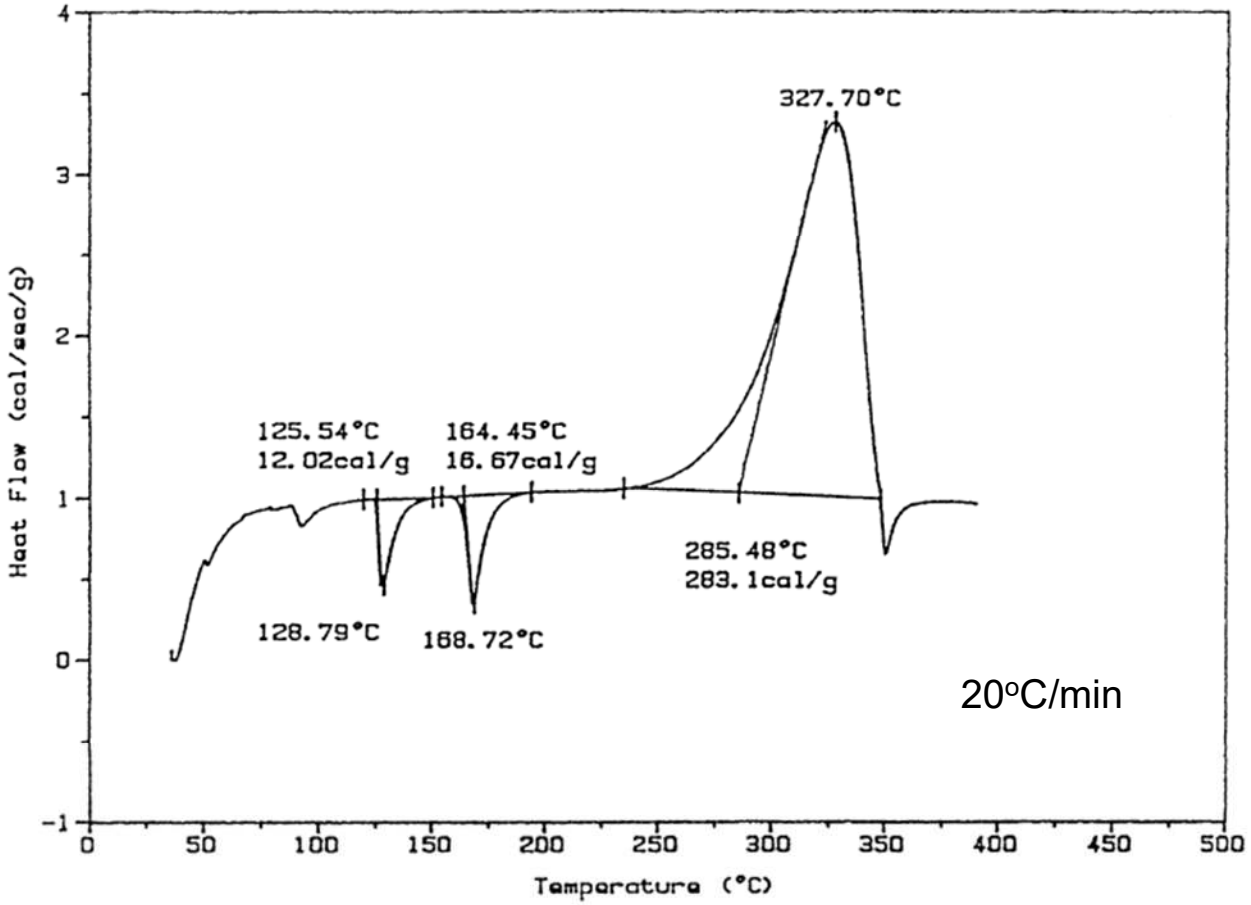
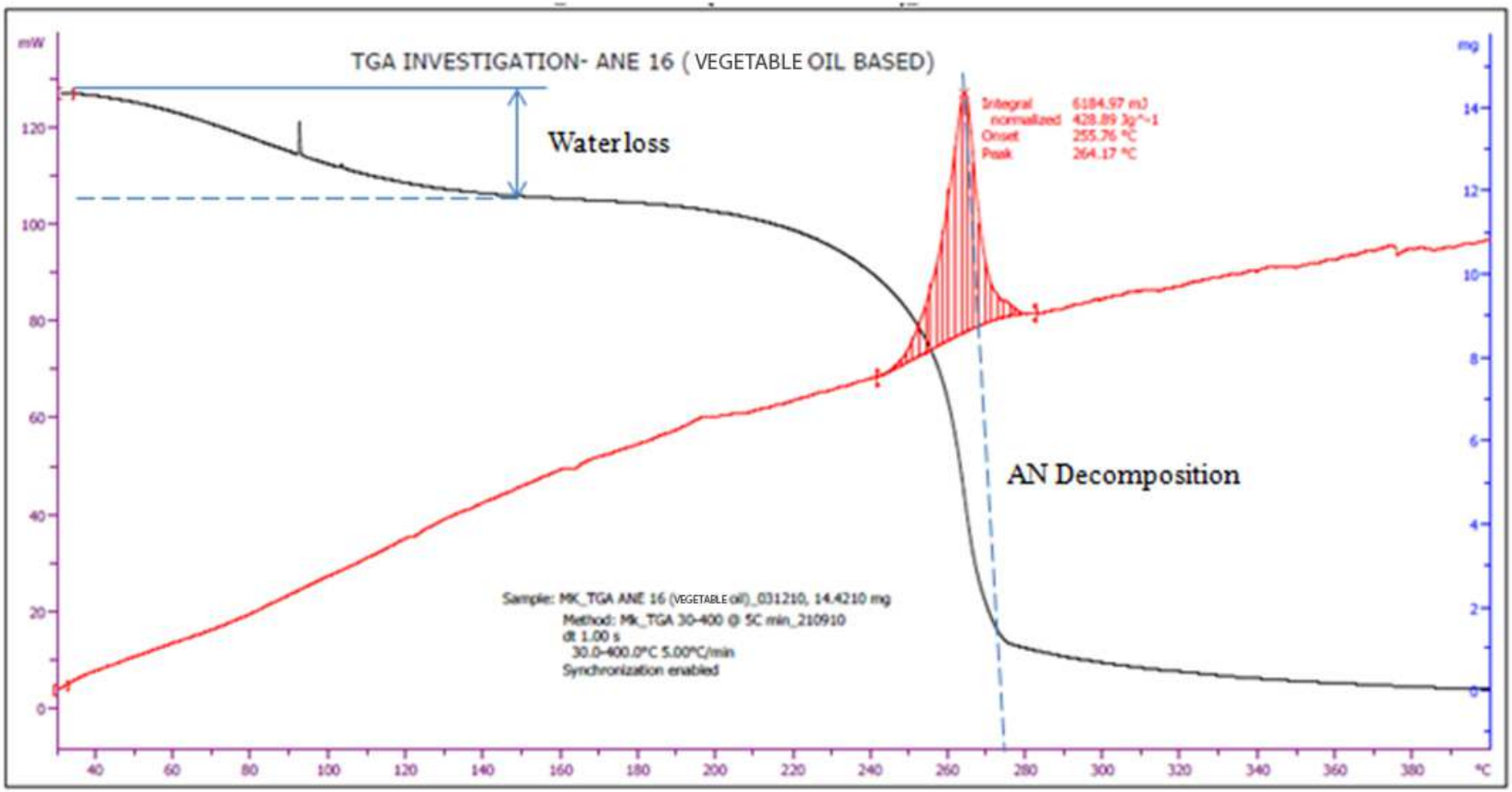


Fig. 1. DSC thermogram of neat AN.

Jimmie C. Oxley*, James L. Smith, Evan Rogers, Ming Yu, Ammonium nitrate: thermal stability and explosivity modifiers; Thermochimica Acta 384 (2002) 23–45

Thermal Behavior of an ANE



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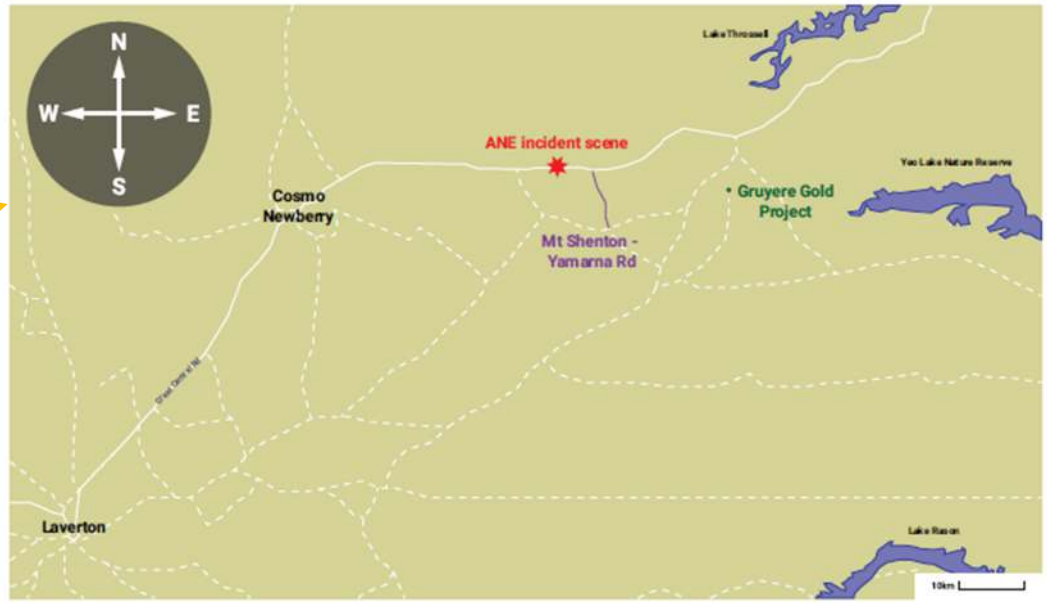

October 24, 2022

DMIRS Investigation Report – Key Points

- Ttri-axle rear tanker that was carrying 33.85 Te ANE
- Precursor event was a fire – common factor with other transport and storage events involving AN
- Fire persisted for ~2 hours before mass explosion
- TNT equivalence 1-3 Te = 3-10 Te AN (basis: only AN reacted)
- Proper evacuation procedures carried out; no injuries
- 16 recommendations: 7 were preventative and 9 mitigative
  - 14 directed toward carriers and vehicles
  - 2 addressing joint activities for explosives and transport industries

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Importance of AN-based explosives in WA

- “More than 99% of WA’s mining explosives are based on AN …”

- “ANEs have largely replaced the older AN water gels or slurry explosives technology. The reason for their large and growing market share is due to a combination of superior safety during transport, handling and use, high water resistance, ability to be safely pumped mechanically and the ability to be designed for a range of velocities of detonation.”

Schematic of Tractor-Trailer, and Trailer involved – from the report

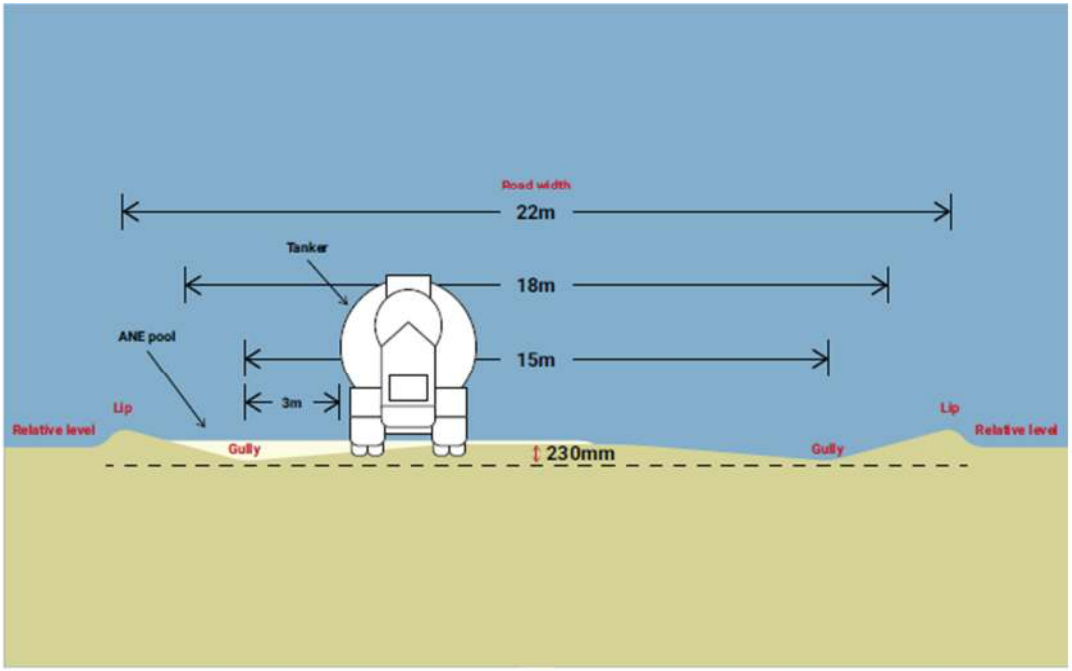
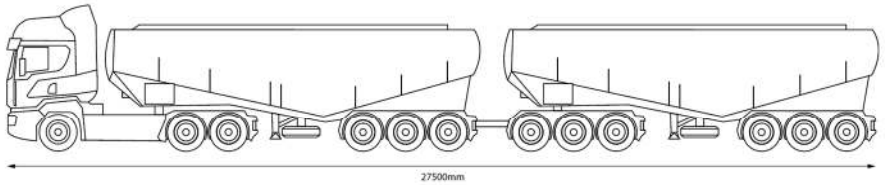


Figure 9.2 Schematic of the road and approximate location of the tanker trailer and dolly. The ANE pooled into a gully on the passenger-side and beneath the tanker trailer after a loss of containment occurred



Schematic of road train with two tanker trailers and dolly

Figure 4.5 Representation of the tanker trailer, demonstrating the four tyres on each axle (12 at the rear and 12 under the dolly at the front)

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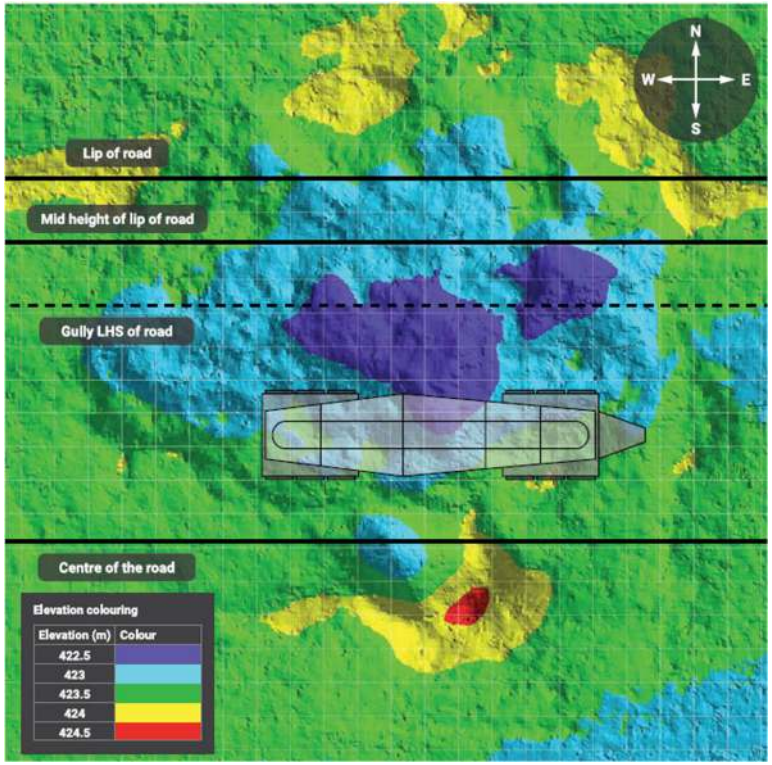
Topo of Crater overlaid on the photograph



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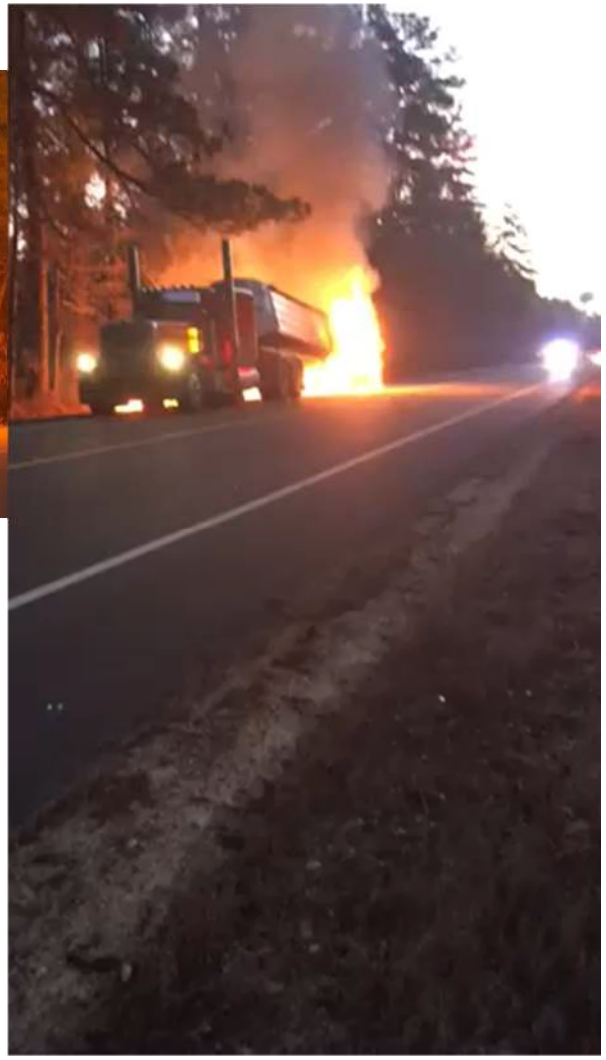
Crater from the WA event and that from the AN prill trailer explosion (March 28, 2019)

Aftermath: A crater sits on a portion of U.S. 278 west of Camden, caused by an explosion from a fertilizer truck on Wednesday. The driver of the truck was killed and the explosion could be heard miles away. Arkansas Democrat-Gazette/THOMAS METTHE

AN Prill trailer event Camden AR, March 28, 2019



Flames ‘appear’ to be on the ground

WA ‘ANE’ explosion

Camden, AR, AN prill explosion

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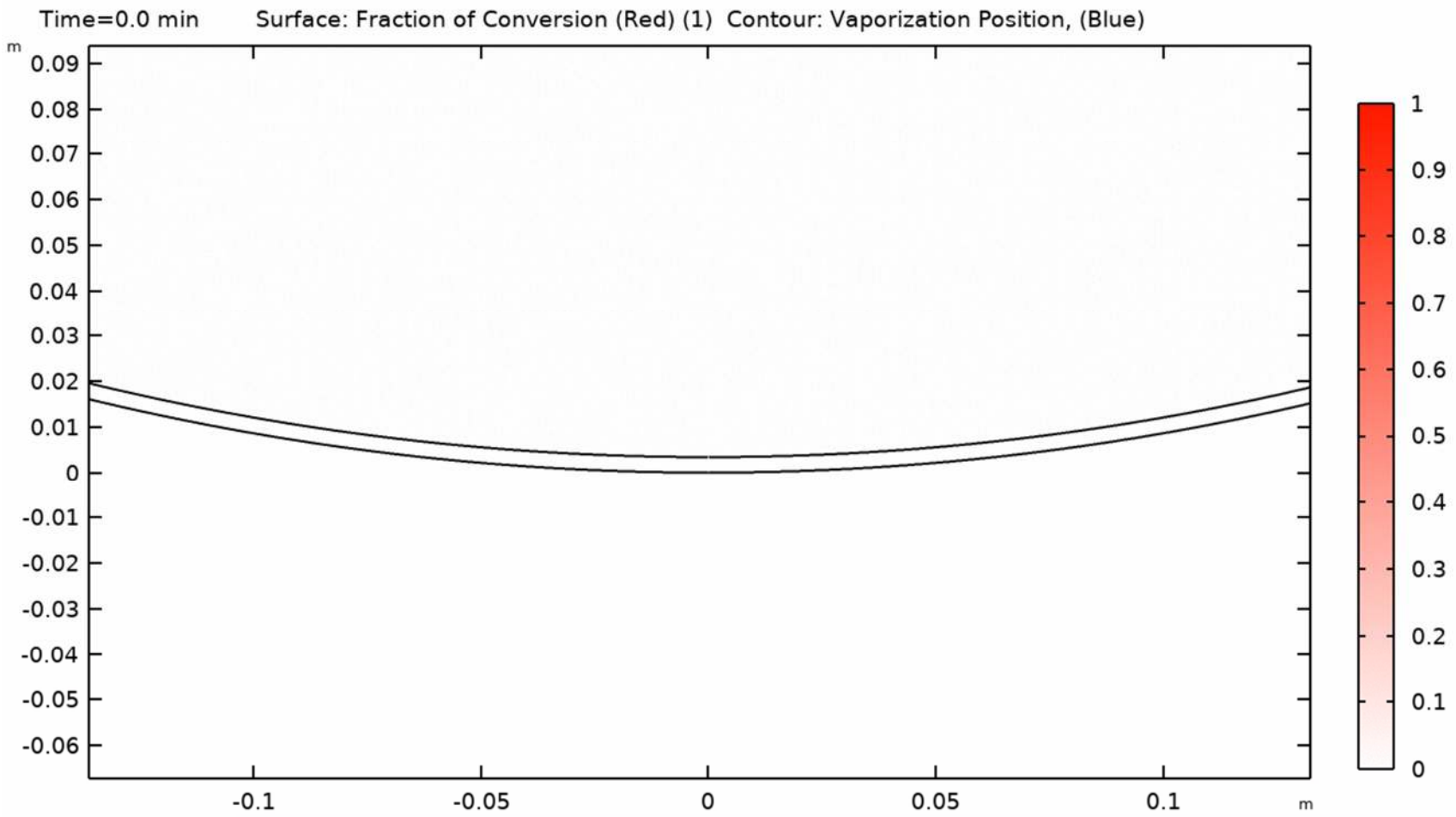
Schematic of Tractor-Trailer, and Trailer involved – from the report

Figure 4.5 *Representation of the tanker trailer, demonstrating the four tyres on each axle (12 at the rear and 12 under the dolly at the front)*


Time=0.0 min
Surface: Fraction of Conversion (Red) (1)
Contour: Vaporization Position, (Blue)
m
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.1
-0.05
0
0.05
0.1
m
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

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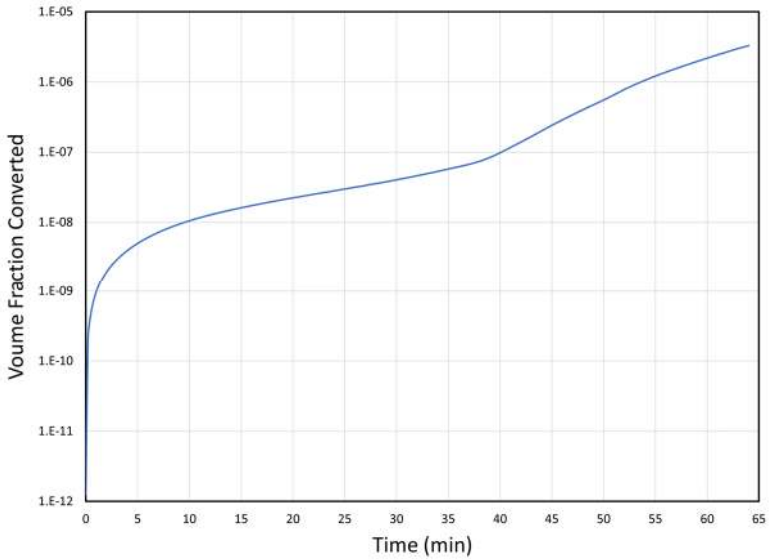
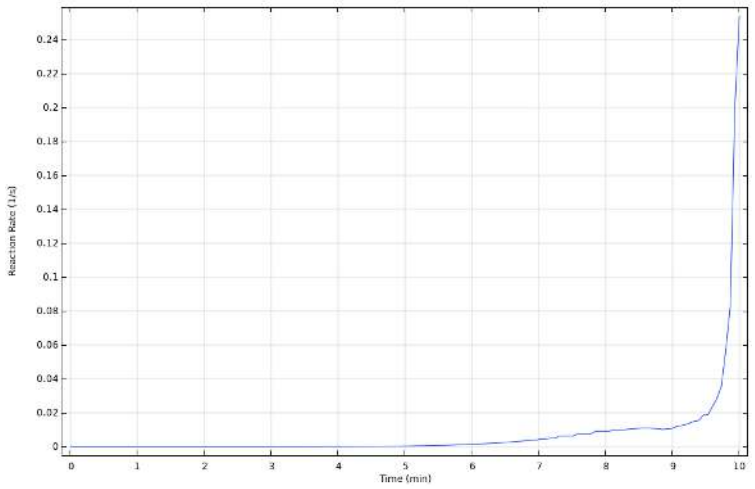
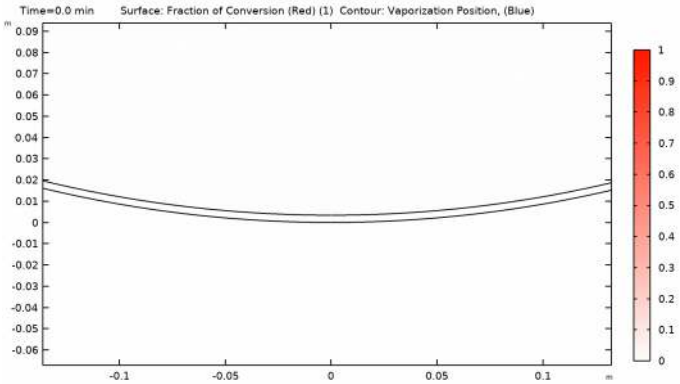
Reaction conversion for the 24 and 80kW/m^2 heat boundary flux







- For the 24kW/m^2 case, fraction converted is negligible
- For constant 80kW/m^2 case, reaction rates increase rapidly, and solver takes small timesteps at 10 min
  - Reactions are constrained to the crust phase
  - Emulsion ignites not propagates - other models to predict these physics
  - This flux is an unrealistic condition, only appropriate for large diesel fires and experiments
- This indicates that temperature profiles are dominated by formation of the crust and reaction rates
- Since the crust dimensions can be predicted by thermal diffusivity alone, the temperature profile is a function of physical properties, not scale and the MBP is the appropriate test

Kuosanen ANE Fire test in Al tank (2002)

Figure 10. One quarter o

Kuosanen ANE Fire test in SS tank (2007)

Figure 15, shows the ruptured stainless steel tank after the fire test. The rod is connected to the bottom valve and is a part of the tank.

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ANE TRANSPORT FIRE INCIDENT – USA

July 12, 2008
South Carolina

- Tractor pulling tanker trailer blew its front tire
- Driver lost control of vehicle crossing median striking three other vehicles en route.
- Cab caught on fire while crossing median.

- Minor injuries to driver and struck vehicles' occupants.
- Residents evacuated to 1-mile radius.
- ANE transferred to another tanker once fire was put out.
- ANE had 18.26% water

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ANE Transport Incident – USA; October 25, 2016

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ANE Transport Incident – Australia

March 12, 2018
Queensland

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7.5 Tanker trailer fire – New Norcia, Western Australia, 2023; from the report

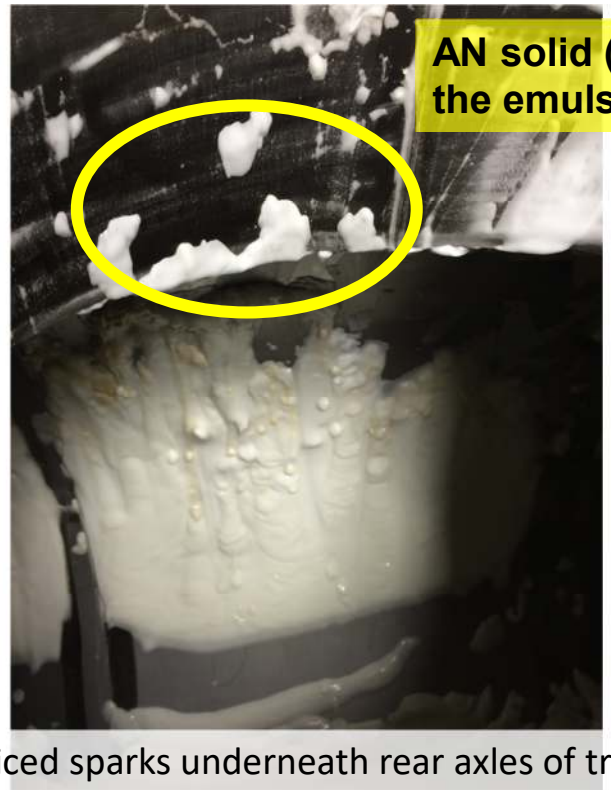
On the evening of 3 June 2023 the small monastery town of New Norcia was evacuated. The rear tanker trailer containing 30.97 tonnes of ANE of a 'C-train' (a B-train and a dog trailer) was noticed to be burning, 800 m from the town. The tanker trailers were purpose-built aluminium tankers for the transport of ANE.

When the hatch of the tanker was opened in the morning, the ANE within the tanker was approximately 40 °C, slightly discoloured and the viscosity had decreased due to the separation of some of the emulsion into its liquid components. When the product was transferred out of the tanker a thin layer (about 1 mm thickness) of solid AN was observed on the inner surface. The formation of solid AN was limited to where the ANE was in direct contact with the tanker shell and closest to areas that had received prolonged direct heating by the fire (Figure 7.4).

This is the third transport event supporting the modelling predictions

TRANSPORT FIRE INCIDENT – USA

December 12, 2014
Wyoming



- En route to mine site driver noticed sparks underneath rear axles of triple-axle tanker.
- Vehicle was stopped and on investigation flames were visible
- Three fire extinguishers were used but fire persisted
- Tractor was disconnected from trailer; traffic diverted from scene, and evacuations to 1-mile area carried out
- Fire consumed all six tires on the passenger-side, air-hoses, lights and wiring, and melted the aluminum rims.

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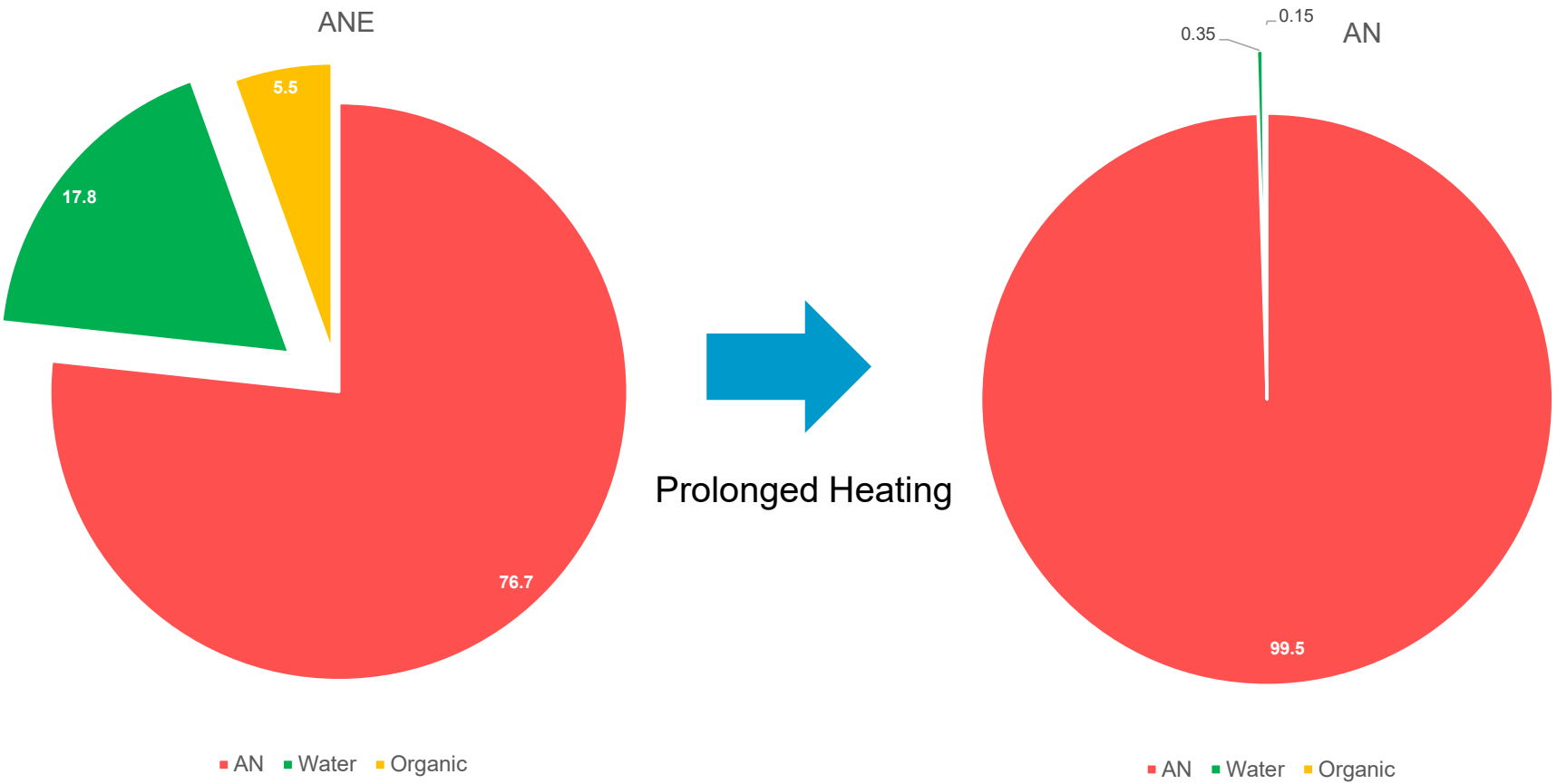
Comparison of ANE and AN prill compositions



DMIRS meeting with Industry

Will legislate:

- Driver training
- Tyre Pressure & Temperature monitoring systems; and
- Fire-fighting equipment, over and above ADG Code requirements.

Timing is mid-2024

Proposal

- Global industry develop an international Code of Practice/Good Practice Guide for ANE transport
  - Focus on preventative and mitigative measures, as recommended by the DMIRS investigation report

Note: The ANE involved in the event had passed the 8d test, and yet mass exploded. This raises the validity and value of requiring a bulk transport test for ANEs.

SAFEX ANE Good Practice Guide – WG members

- **AEISG** – Richard Bilman
- **AEL** – Kaylee Baker, Andre Pienaar
- **Austin** – King Wei Siew
- **BME** – Shivashkar Suthan
- **CSBP** – Wynand Grobler, Belinda Weggelaar
- **Dyno Nobel/IPL** – Kelly Ferguson, Jon Bowerman
- **CERL** - Shanti Singh
- **ENAEX** – Kirk Grant
- **EPC** – Bob Woolley, Johanne Della Rovere
- **Glencore** – Andrew Rose
- **IME** – Josh Hoffman
- **MAXAM** – Aaron Galt, Ignacio Madeira
- **MCS** – Alem Abdelkader
- **Nelson Bros** – Scott Blazek
- **Orica** – Steve Logan, Peter Skinner, Leslie Williams, Craig Johnson
- **Peddie Engineering Pty** – Ron Peddie
- **Riskom** – Ken Price
- **SSE** – Adam Marzec
- **WESCEF** – Lisa Fettis
- **Yara** – Francois Ledoux, Sami Lappi

Thank you