ENTHALPY ANALYTICAL

Do Temperature Regulated e-cigarettes Prevent The Formation Of Thermal Decomposition Products Under “Dry Wick” Conditions

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Definitions

- Dry wick conditions:
  - Occurs when either too much power or not enough liquid is supplied to the atomizer of an e-cigarette.
  - Characterized by an unpleasant, acrid taste in the aerosol and formation of thermal decomposition products.

- Temperature regulated e-cigarettes
  - Control coil temperature by measuring changes in coil resistance during heating. Typical coil materials are nickel, stainless steel or titanium. ~50% of the advanced devices sold in US include Temperature Regulation (TR) technology.

Temperature Regulated E-cigarettes

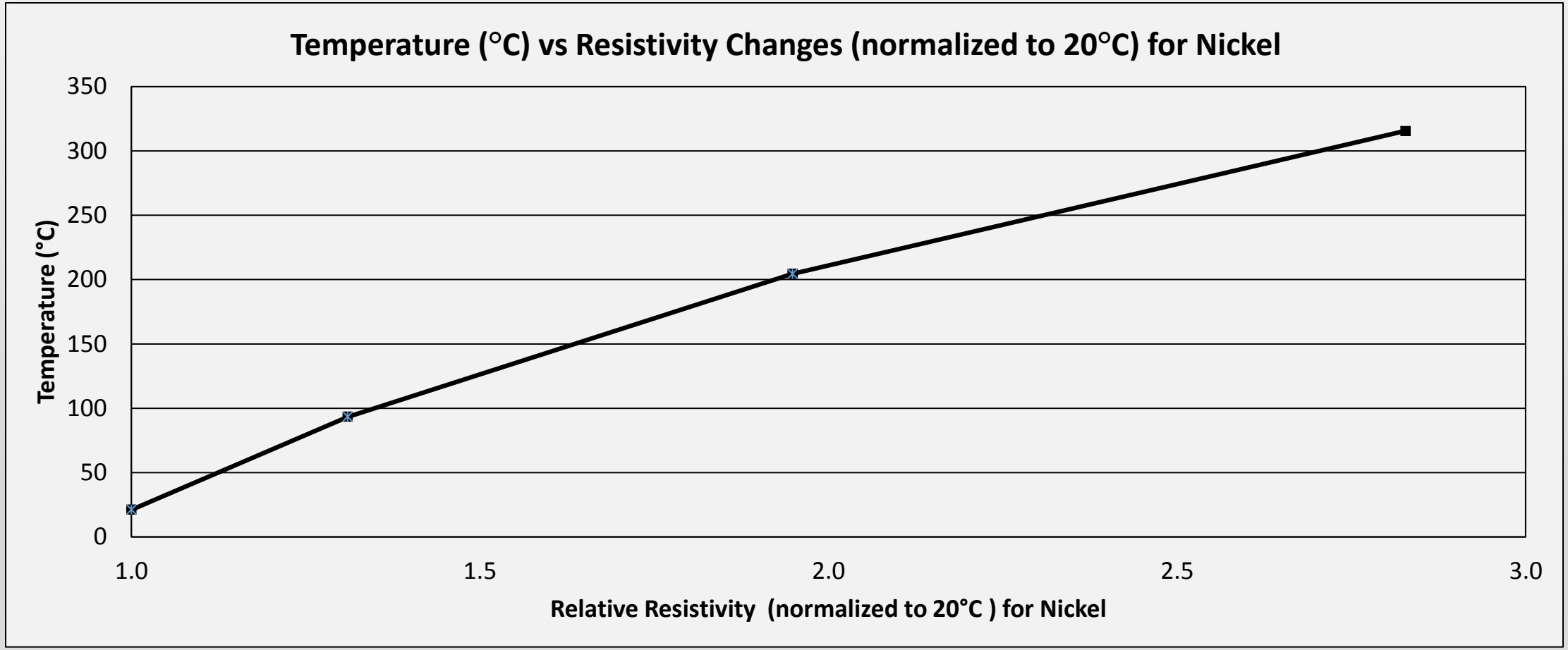
- Resistance values for conductors at any temperature can be determined by the formula:

  $R_{measured}=R_{ref}[1+\alpha(T_{actual}-T_{ref})]$

  where R_{ref} and T_{ref} are the resistance of the conductor material at a reference temperature

- The temperature coefficient of resistance, α, for the conductor is unique to each material. The measured resistance ($R_{measured}$) of the atomizer coil can be used to determine coil temperature (T_{actual})

Temperature Regulated E-cigarette

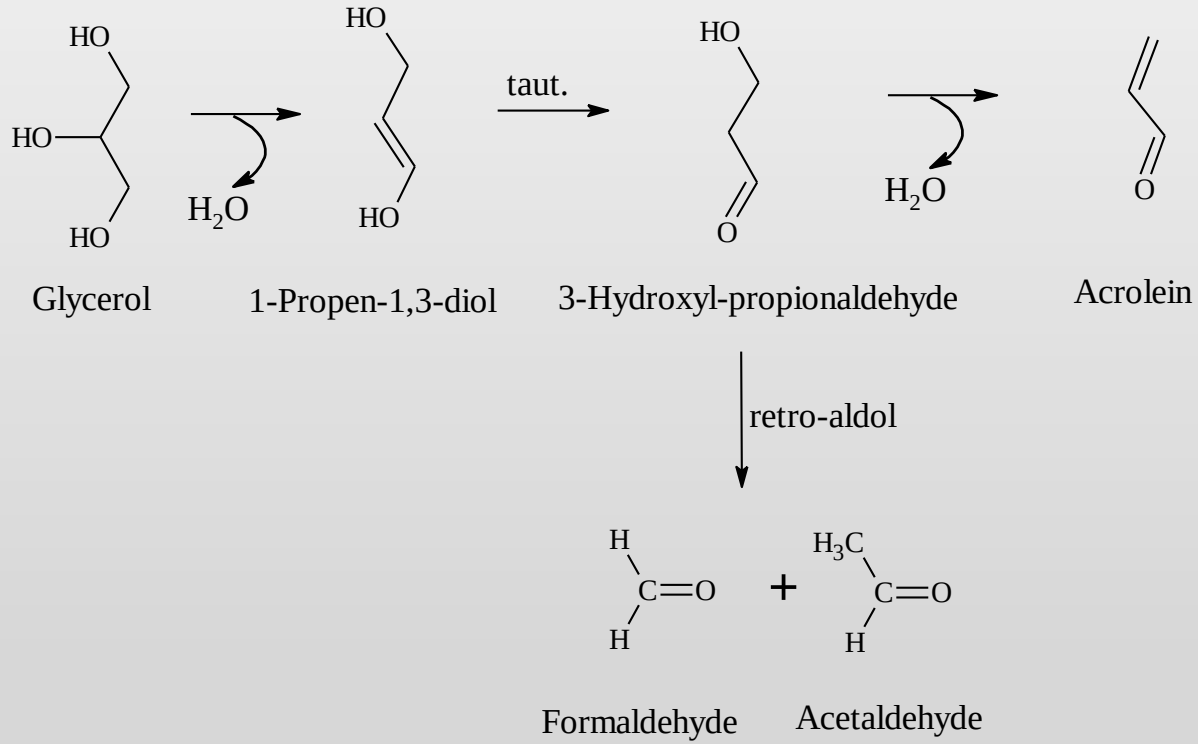


Experimental Design

- Aerosol was collected using an automatic “button pusher” using a 55 mL constant flow puff over 4 seconds every 30 seconds.
- 50:50 PG/VG liquid with 2% nicotine was used with all samples.
- Samples were collected using new coils, for each device.
- “Wet wick” samples were collected with a full tank
- ”Dry wick” samples were collected after tanks were drained, inverted, overnight.
- Aerosol samples were analyzed for aldehydes (formaldehyde, acetaldehyde and acrolein).

Formation of Decomposition Products

Heating of propylene glycol and glycerol may produce thermal decomposition products



Evidence of Coil Overheating, Non-TR

Unused Coil

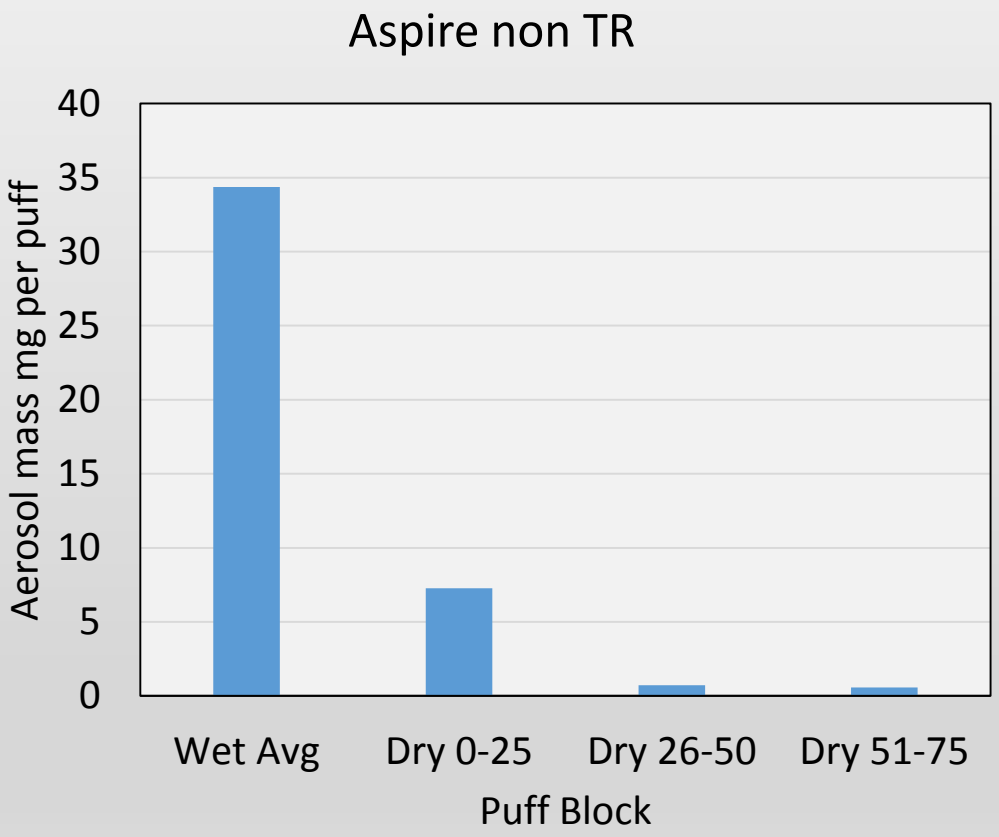
Used Coil

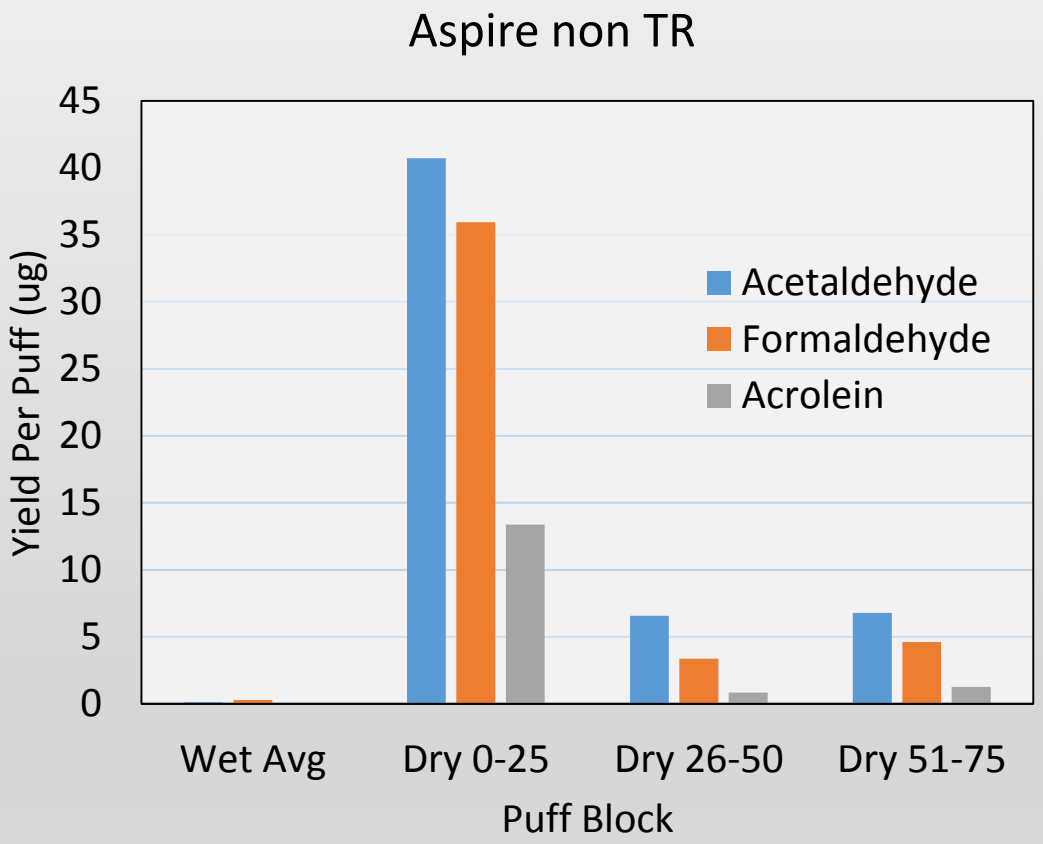
Evidence of charring on wick (example from CE4 tank)

Devices Tested

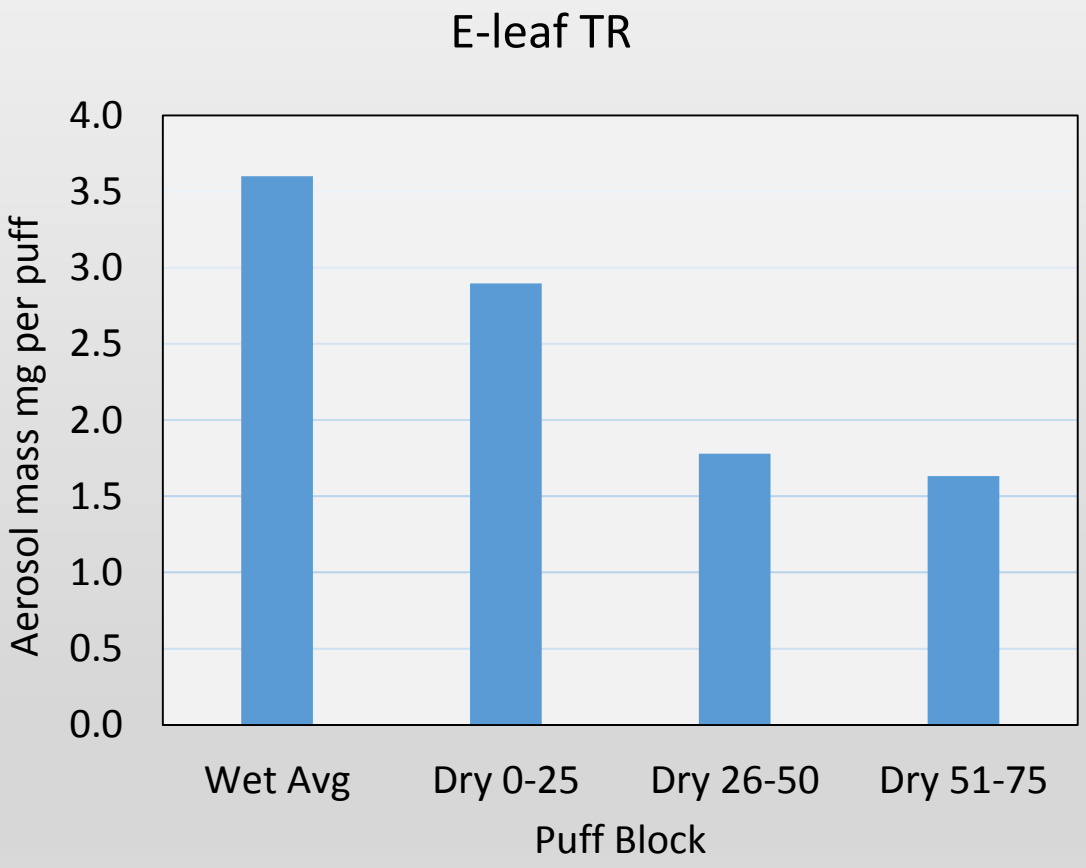
- Non-temperature regulated device (Control)
  - Aspire Atlantis V2
    - Sub-ohm Clapton Coil Niachrome Coil
    - Collected at 25 watts
- Temperature regulated devices
  - E-leaf iStick TC 40 (40 watt limit without preheat)
    - Sub-ohm nickel coil set to 215^{0}C
  - Evolv DNA 200 (40 watt limit with default preheat)
    - Sub-ohm nickel coil set to 215^{0}C
    - Kanger Subtank and Aspire Atlantis V2

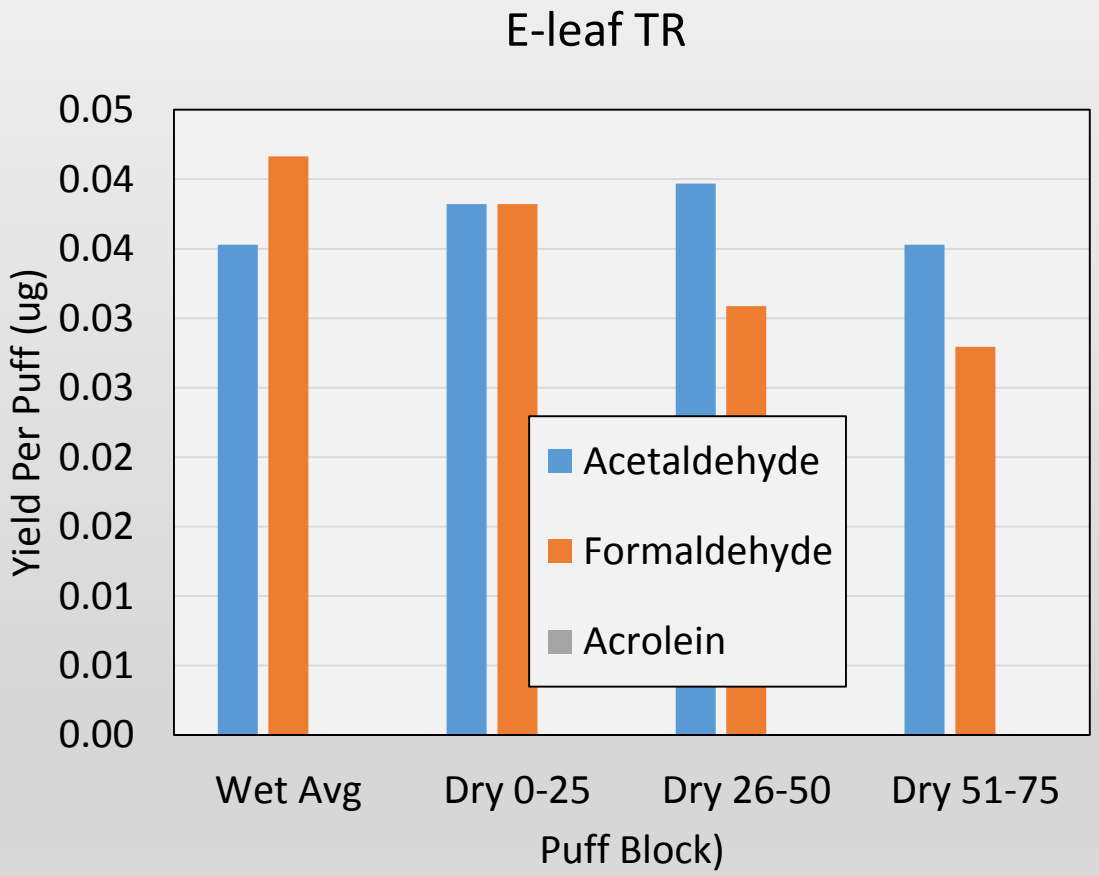
Aspire Atlantis V2 (Not Controlled)



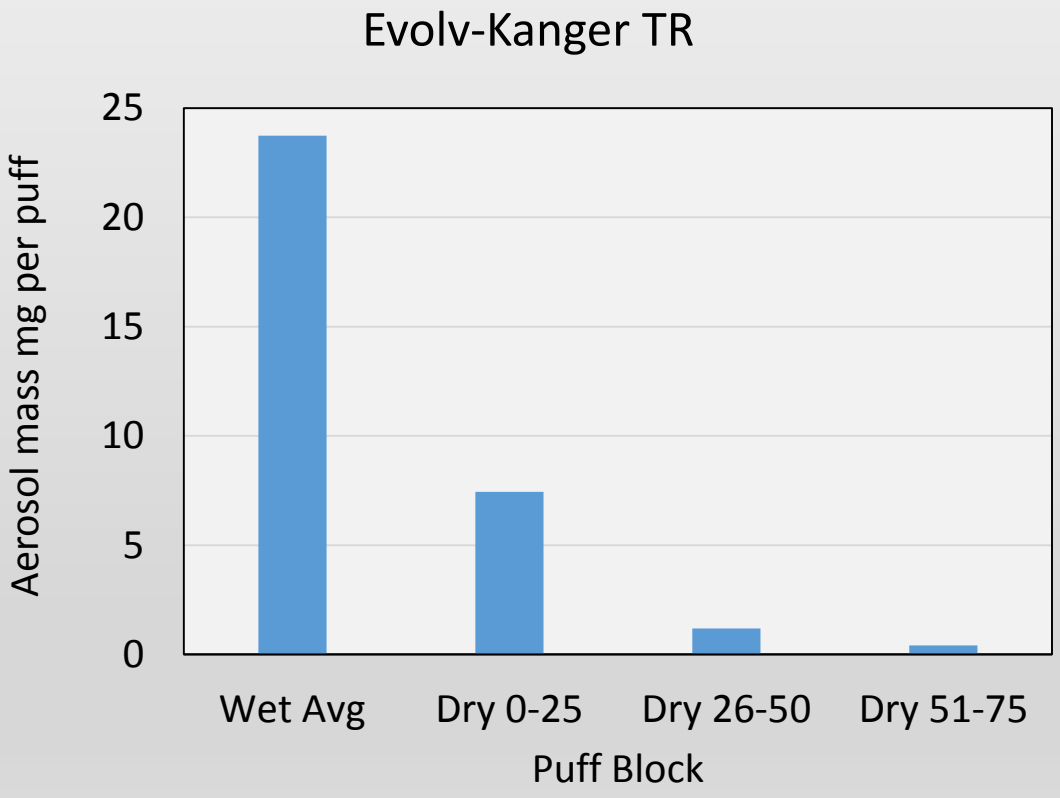


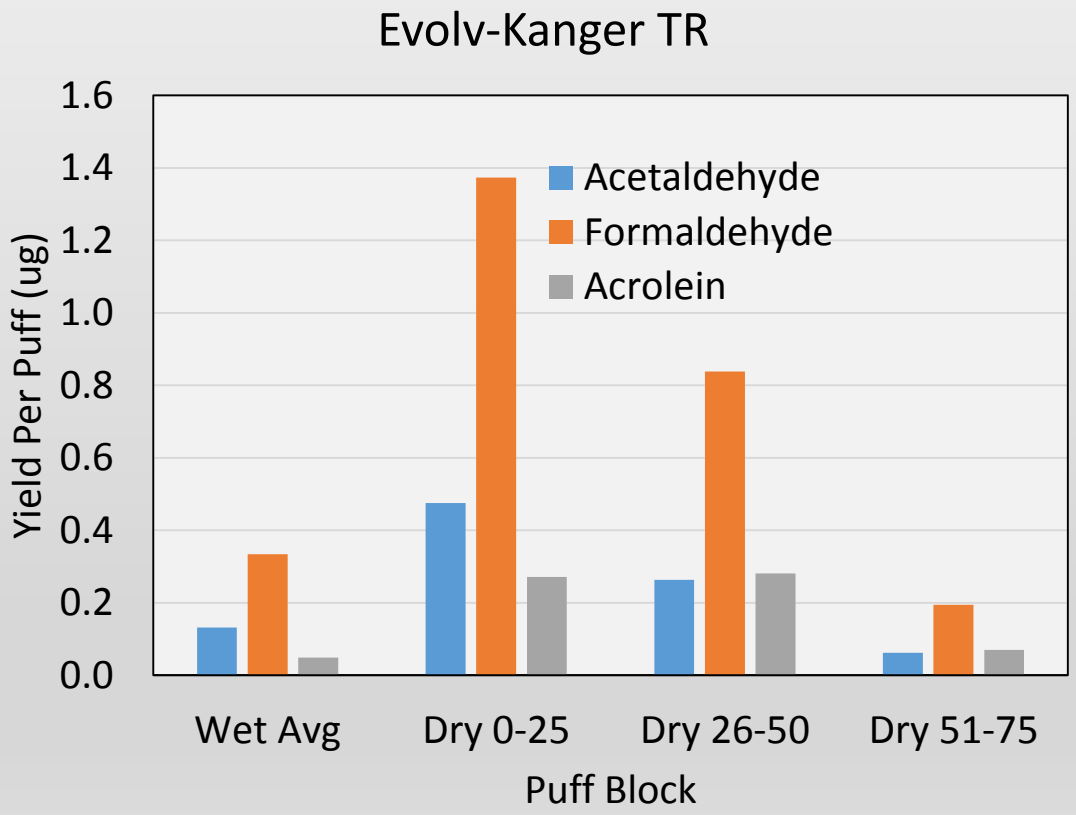
E-Leaf TR



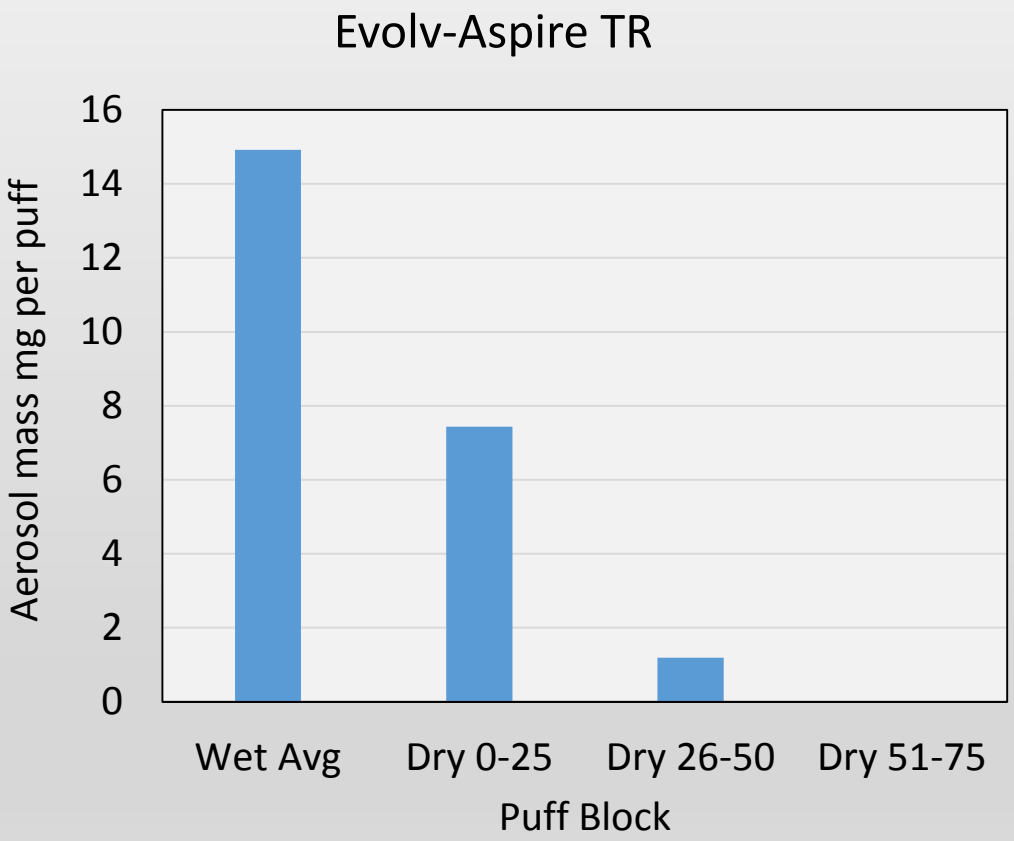


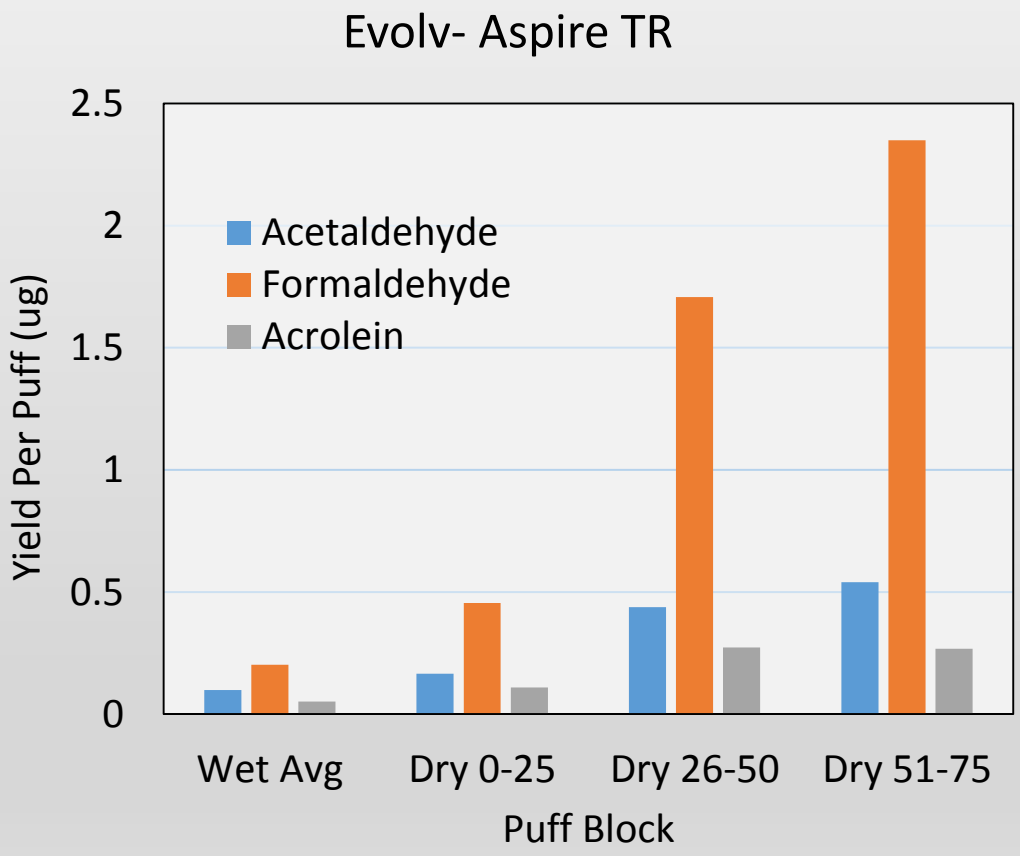
Evolv-Kanger TR



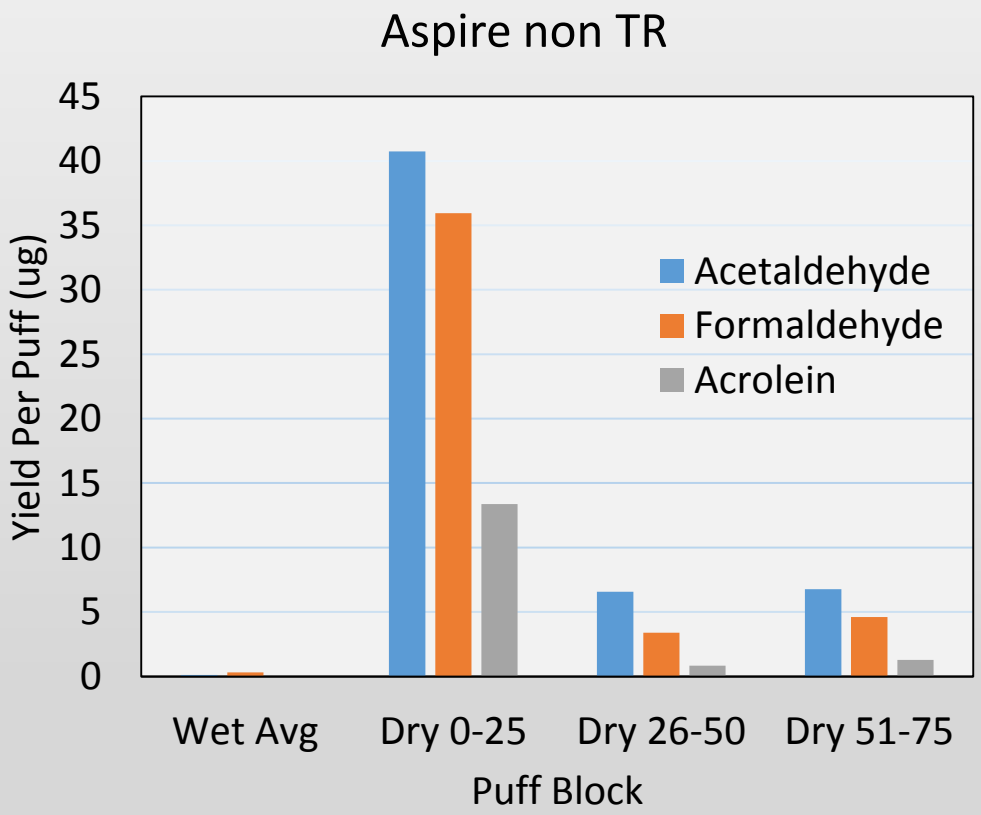


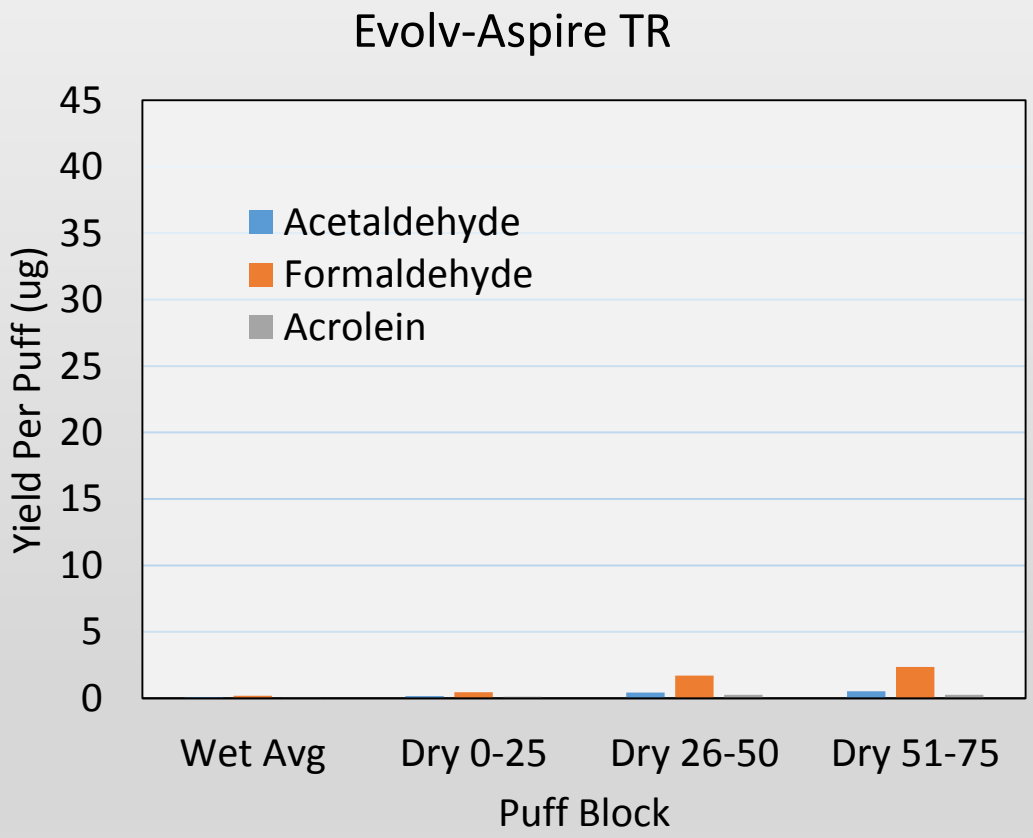
Evolv-Aspire TR





Comparison of Same Tank

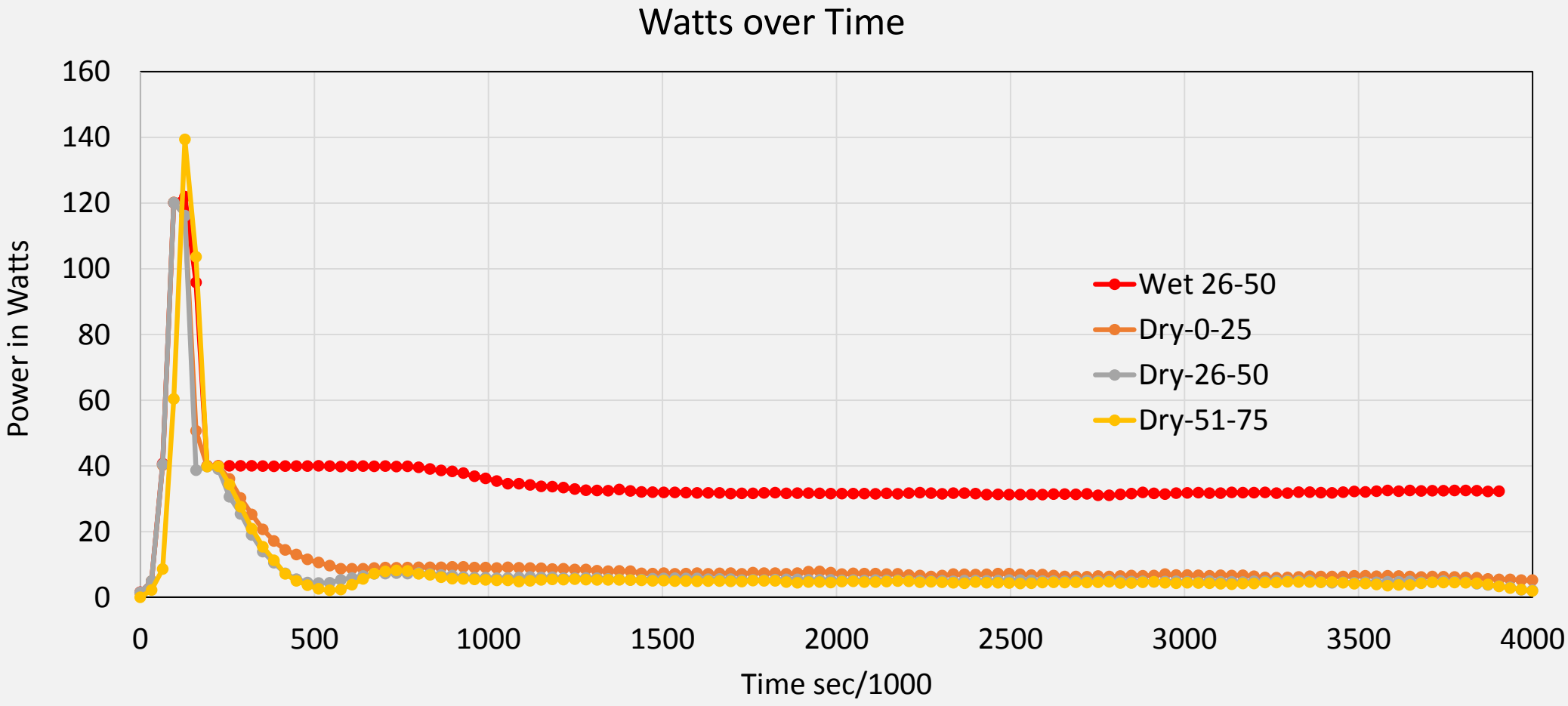




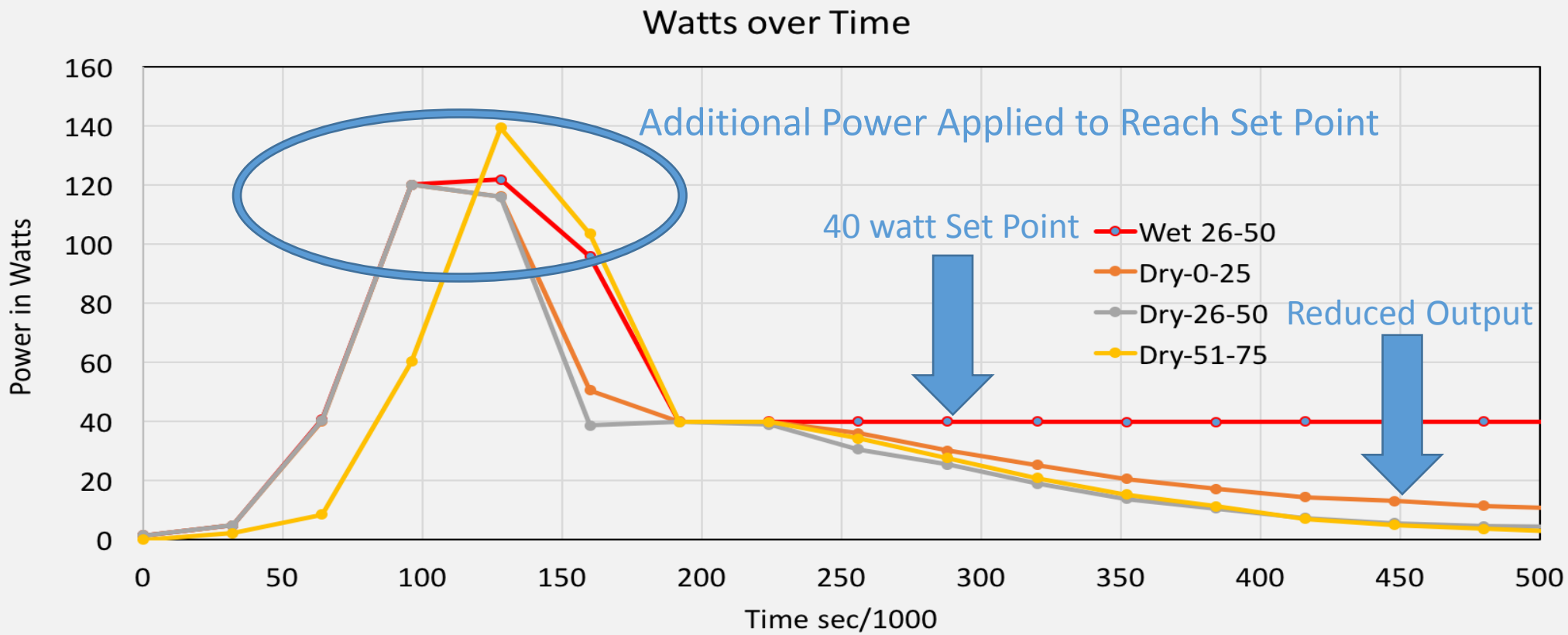
Data Logging During Puffing

- Some samples collected under “dry wick” showed an increase in thermal decomposition products over “wet wick” samples.
- The Evolv DNA 200 is equipped with USB interface that allows for collection of data during each puff. Data logging was not possible on the E-leaf device.
- Custom logging software was written to capture device information to a CSV file.
- Coil temperature and power applied to the coil was collected for a middle puff for each experimental condition.

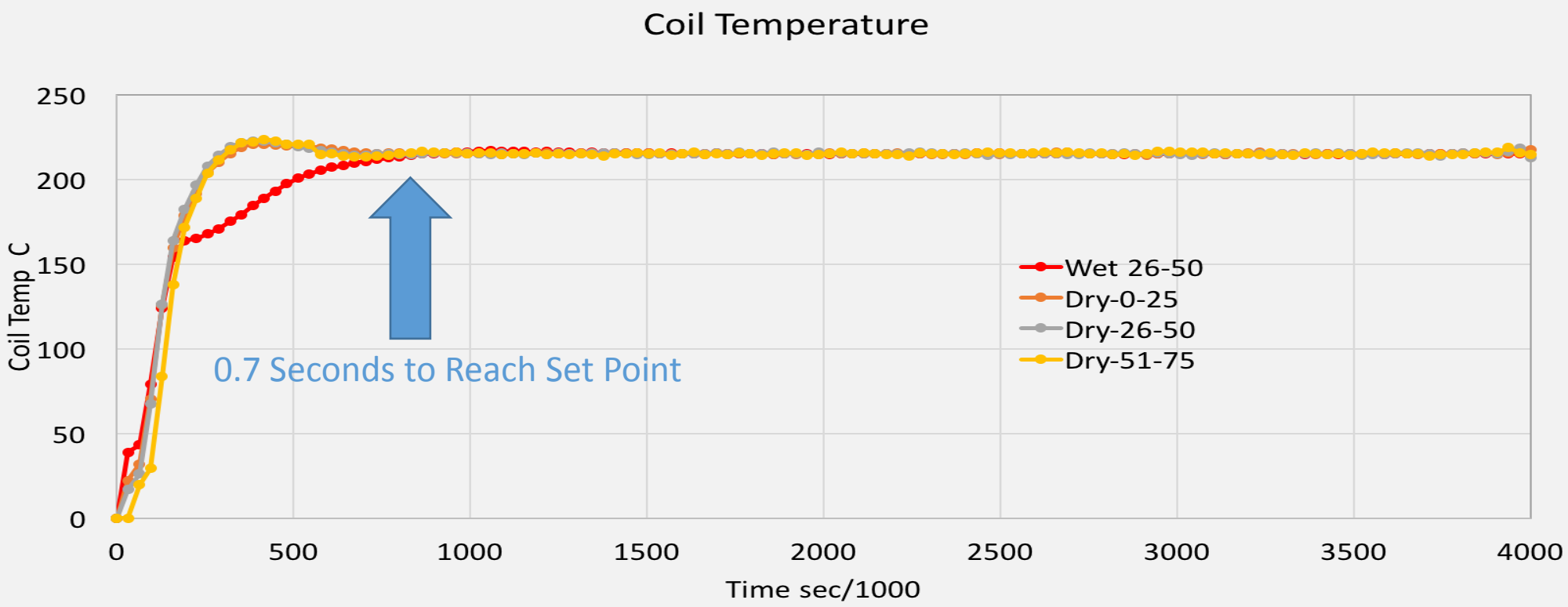
Power Logging



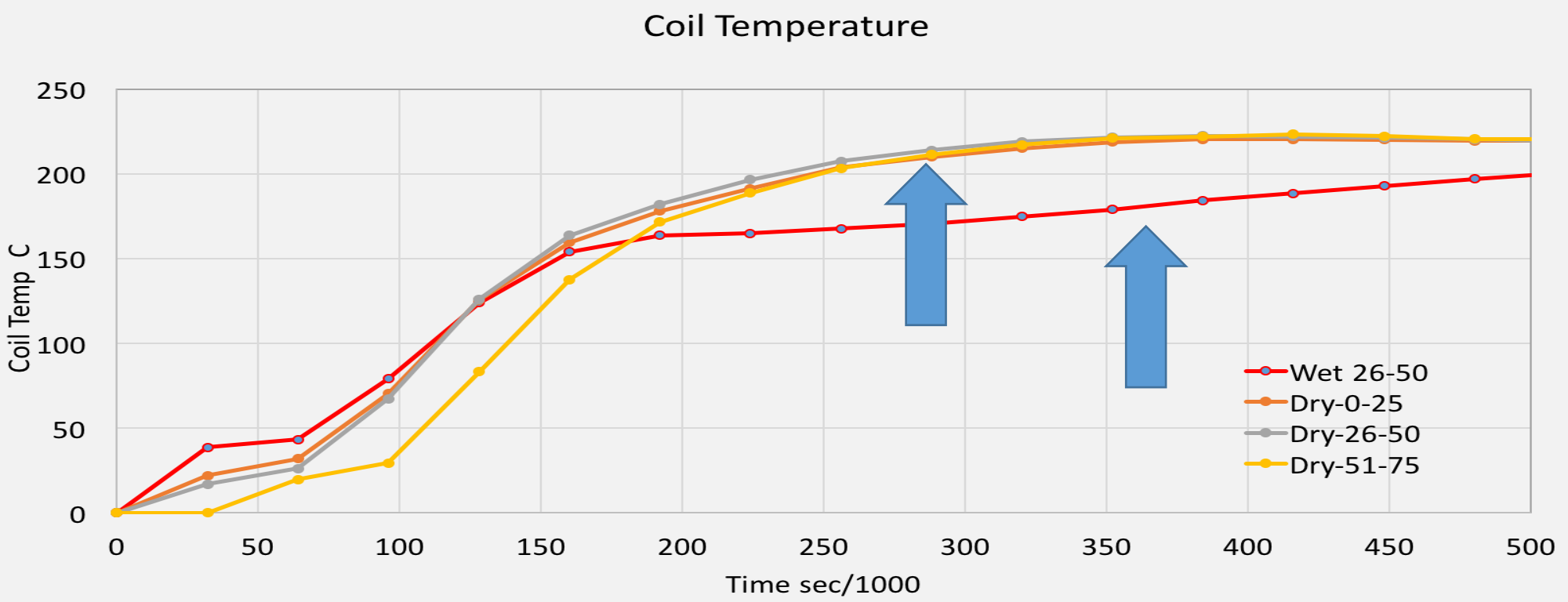
Power Logging



Temperature Logging



Temperature Logging



Summary

- The devices tested produced less aerosol mass under “dry wick” condtions as compared to full tank samples.
- Formation of aldehydes increased for all “dry wick” samples except the the E-leaf iStick.
- Aldehydes in the non TR devices, under “dry wick” conditions, increased by ~10,000% while the worst TR device increased by only ~400% (first 25 “dry” puffs).
- Some TR devices supply extra power during the beginning of the puff to quickly reach the temperature set point.

Conclusions

- TR technology reduces the formation of aldehydes under “dry wick” conditions as compared to non TR devices.
- Under “dry wick” conditions, TR devices with preheat may overshoot the temperature set point, leading to the formation of thermal decomposition products.
- Disclaimer:
  - Coil preheat is a user selectable option that may be disabled or modified.
  - The conditions used in study may not represent actual device usage.

Acknowledgments

- Kathy Humphries: Group Manager (EA Durham)
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