Temperature profiles of e-cigarettes and e-cigars during heating and thermal analyses of e-liquids

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Background – 1

- E-cigarettes of not long ago appeared to have two problems
  - Cartomizers of the time would often clog with charred e-liquid
  - E-cigarette aerosols would sometimes be hot and device surfaces would also be hot
  - Even today, some e-liquids will give aerosols with a “burnt” taste

Background – 2

- Good product stewardship requires knowledge of temperatures inside e-cigarettes
  - Are temperatures hot enough for pyrolysis of e-liquids?
  - Are temperatures hot enough for pyrolysis of materials used to fabricate e-cigarettes?
- Combination of temperature measurement and thermal analysis techniques could be useful

Objectives for research

- Determine interior temperatures for e-cigarettes, cartomizers, and e-cigars during puffing
- Determine if thermal analysis techniques can be used to differentiate thermally stable versus thermally unstable e-liquids

Temperature measurement

- Temperatures should be measured during human use or under machine puffing
- Apparatus for temperature measurement should have minimal effect on device performance
- Placement of temperature sensor should be close in area of highest temperature

Experimental systems – temperature

- Used Type-K micro-thermocouples (Amazon)
  - Digital readout on handheld device (Amazon)
  - Digital data acquisition using hardware and software from DAQami (mccdaq.com)
- Attempts to place thermocouples through device or cartomizer walls unsuccessful
- Thermocouple threaded through mouth-end of device or cartomizer to near heating point

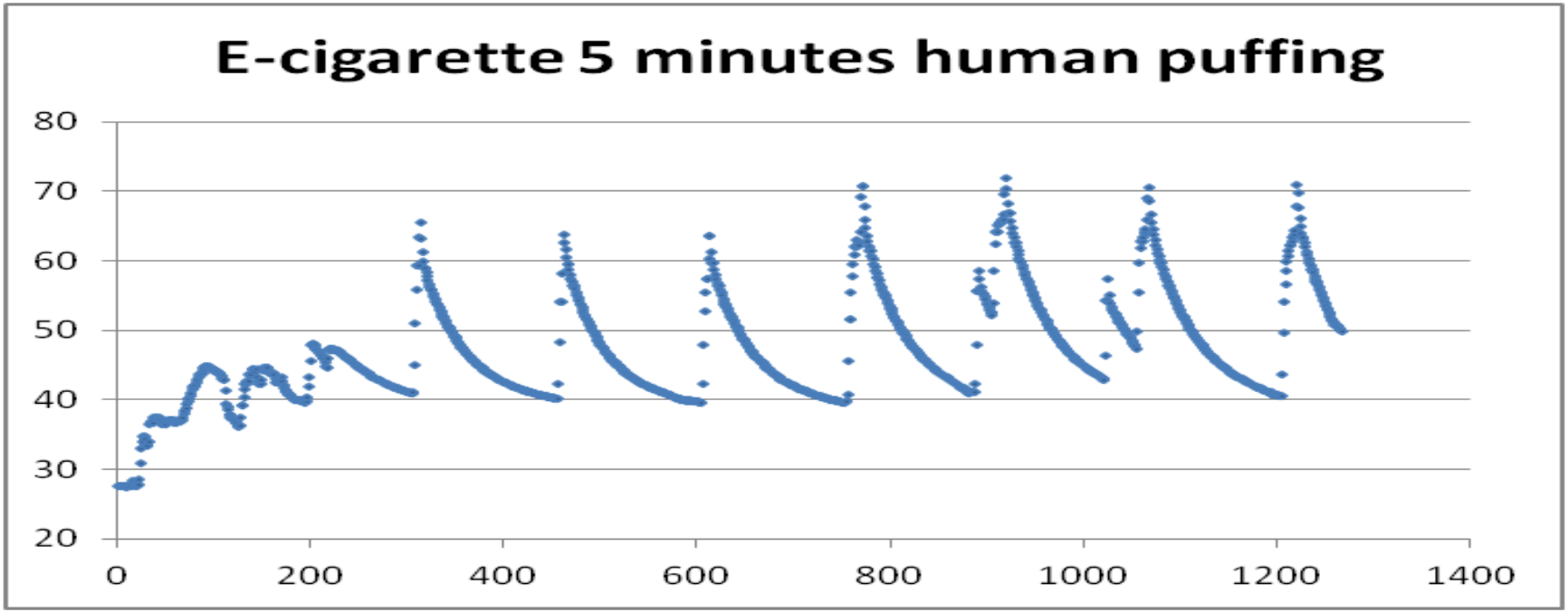
Experimental systems – puffing

- Human
  - Thermocouple leads affixed to side of device
  - Lips made seal around leads and device
  - Puff profiles
    - Natural versus frequent forced puffing
    - Frequent forced puffing gave higher temperatures
- Homemade smoking engine
  - Puff profiles 3/30 e-cig, 3/10 for large e-cig
  - Flow set to activate devices

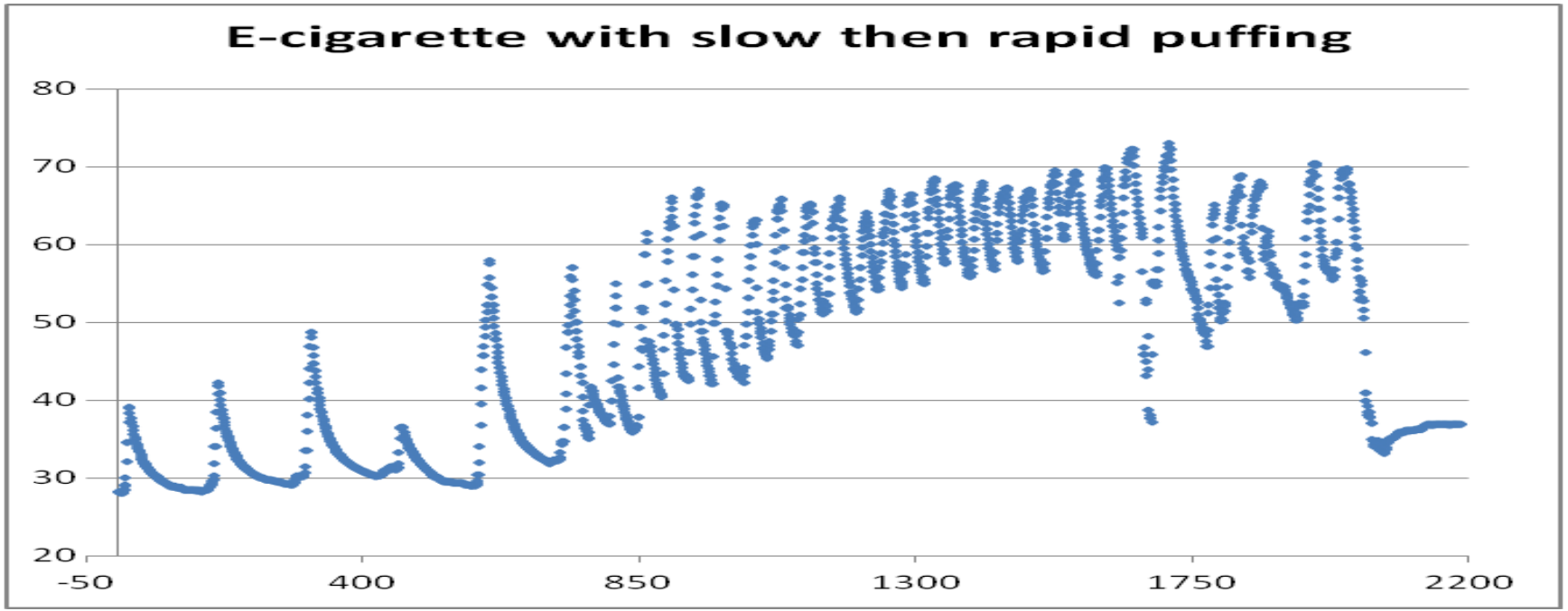
Homemade smoking engine

- Constant-vacuum design using two-stage rotary pump as vacuum source
  - "Square-wave" puff provided by Parker-Hannifin 12-volt solenoid valve
  - Solenoid valve controlled by SainSmart 4-channel relay board using SainSmart control software
  - Flow control at device set by needle valve attached to piece of clear PVC tubing

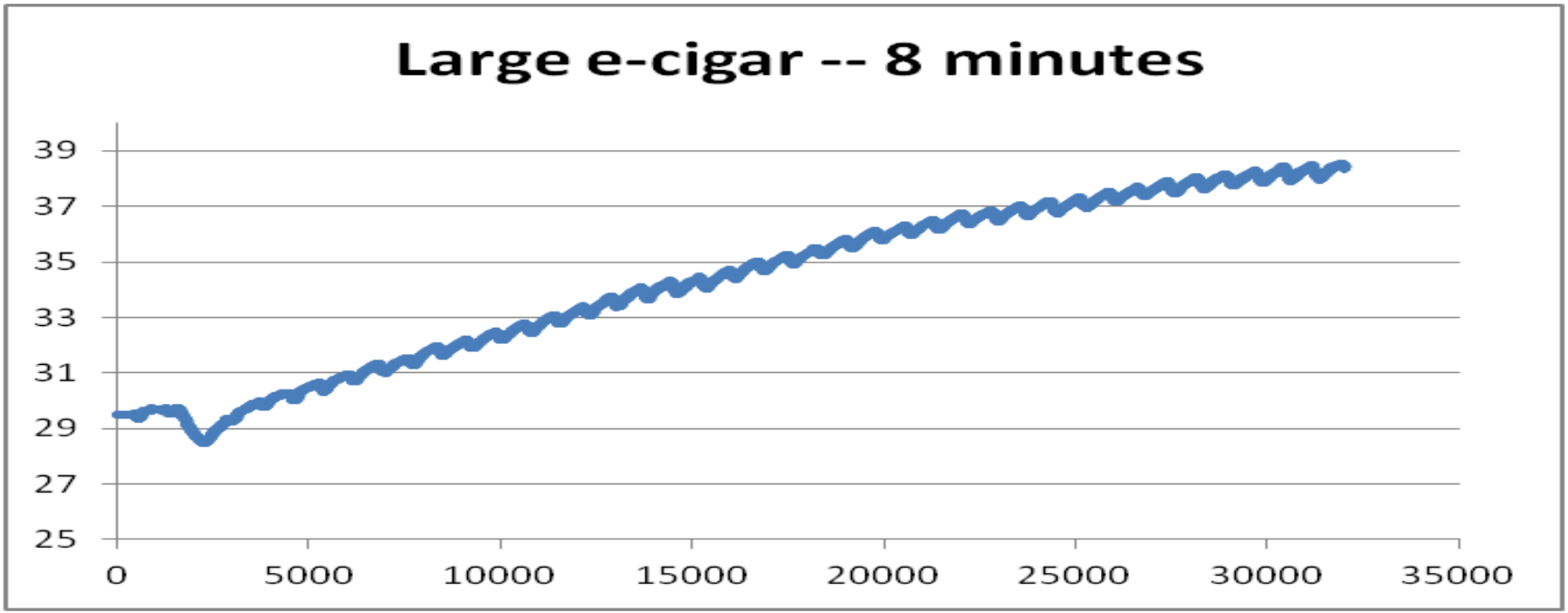
Human puffing – Example 1



Human puffing – Example 2

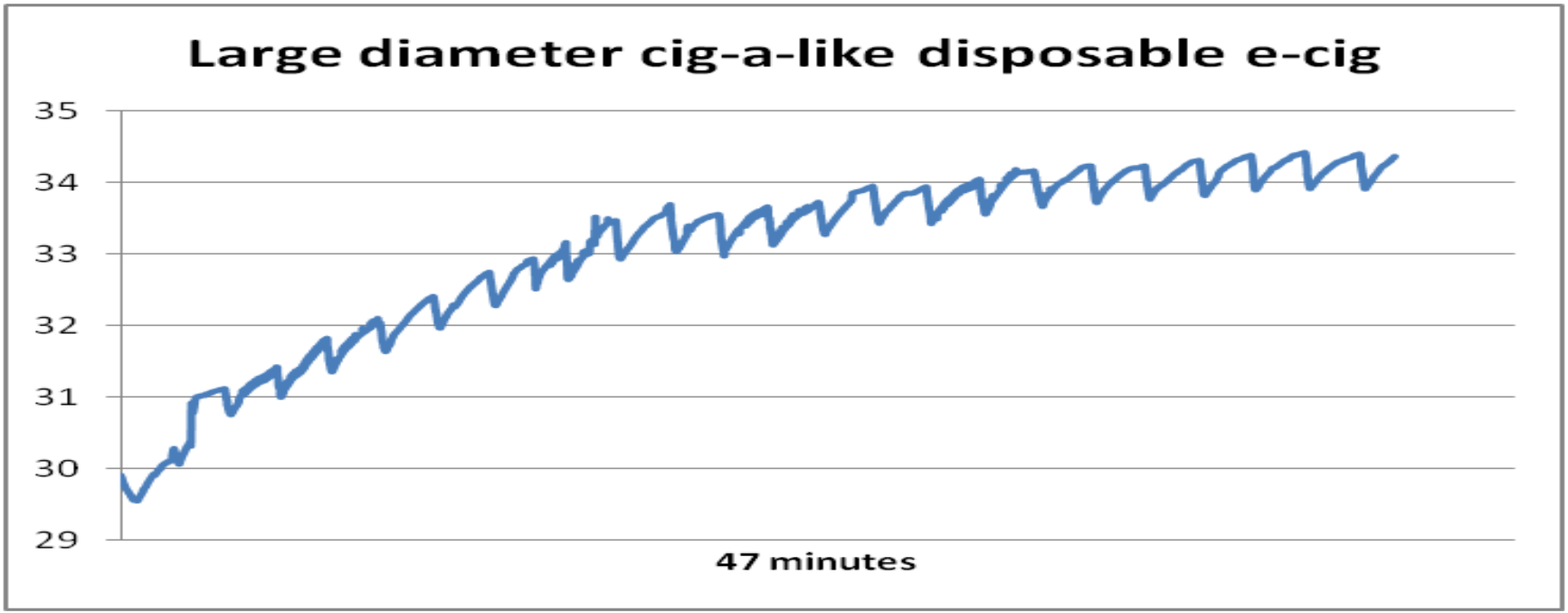


Machine puffing – Example 1

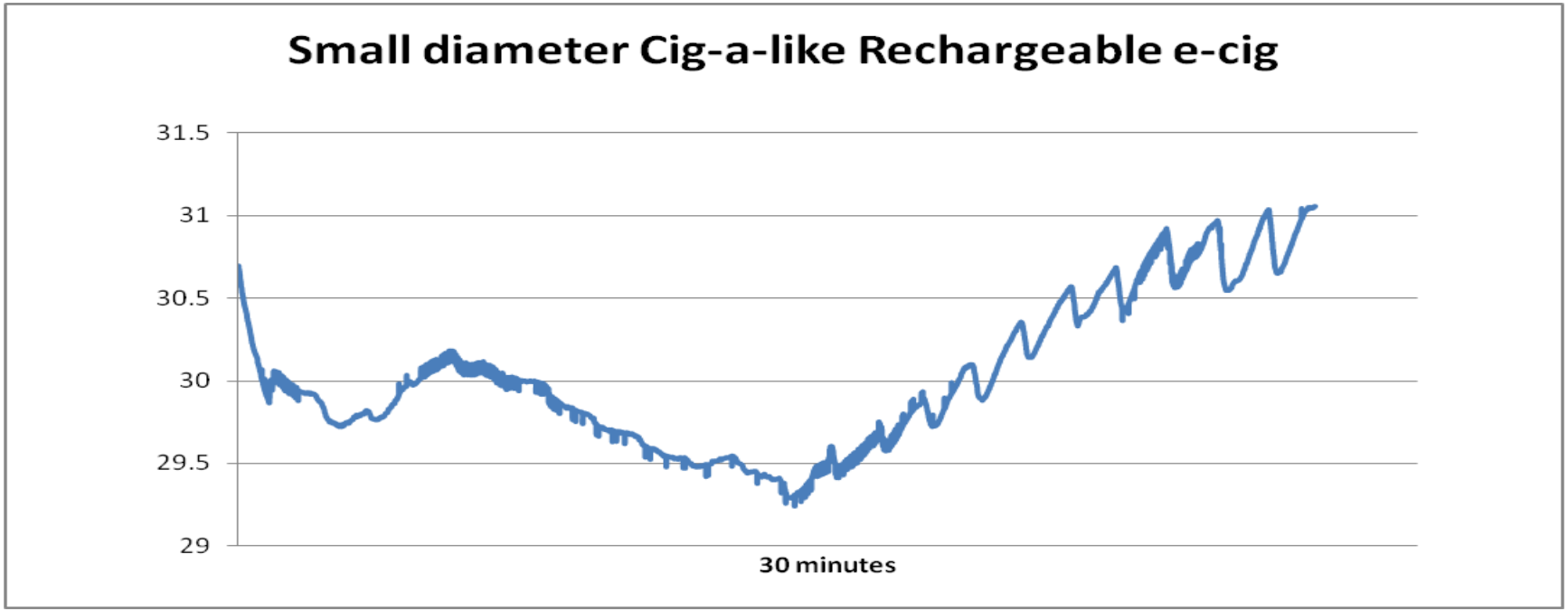


Machine puffing – Example 2

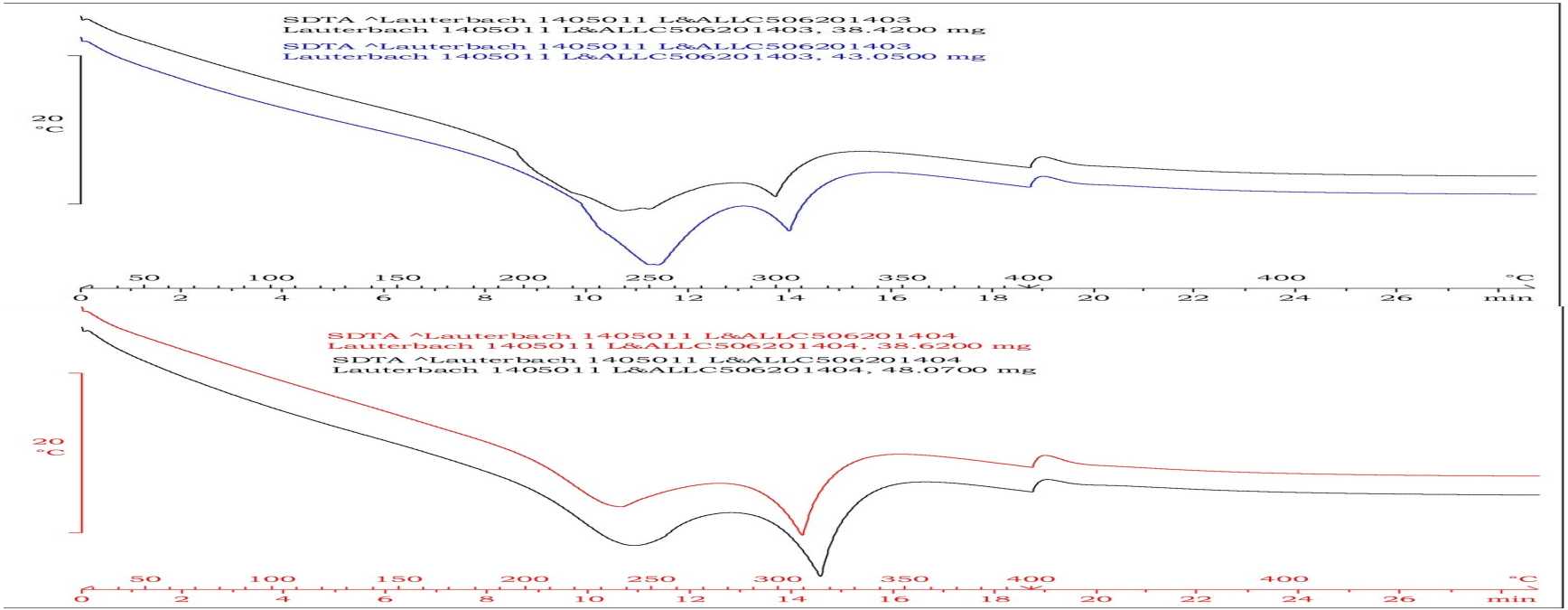
Machine puffing – Example 3



Machine puffing – Example 4



Thermal analysis – E-liquid vs. mix



Conclusions – 1

- Using convenience samples of e-cigars and e-cigarettes, we were able to obtain profiles of internal temperature versus puffing
- A puffing regimen of a 3-second puff every 30 seconds for cig-a-like e-cigs and a small e-cigar did not give excessive temperature rises
- A puffing regimen of a 3-second puff every 10 seconds showed greater rise with an e-cigar

Conclusions – 2

- Use of thermal analysis techniques such as thermogravimetric analysis (TGA) and differential thermal analysis (DTA) shows promise for characterizing e-liquids and components of e-cigarettes, but more research is needed to develop the instrumental parameters for such techniques