Celanese

The chemistry inside innovation™

CelFX™ Carbon Technology: Puff-by-Puff Profile

R. M. Robertson, J.N. Suthar. S. Basu

2015 Smoke Science and Product Technology Joint Study Group
Jeju Island, South Korea
4-8 October 2015

Outline

Objective:

Compare CelFX puff-by-puff smoke filtration vs. results for conventional filters.

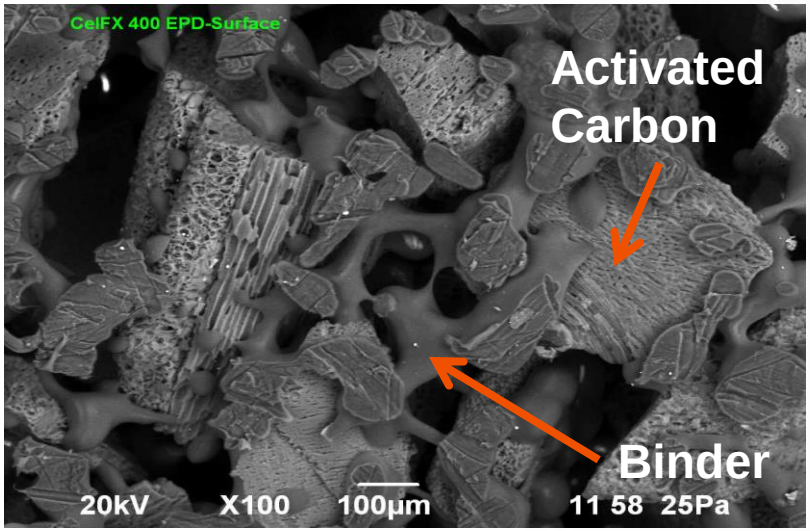
- CelFX technology overview
- Previous research overview
- Method and experimental setup
- CelFX puff-by-puff results
- Conclusions

CelFX™ Overview

Advanced Binder

CelFX Process

CelFX™ Matrix Technology

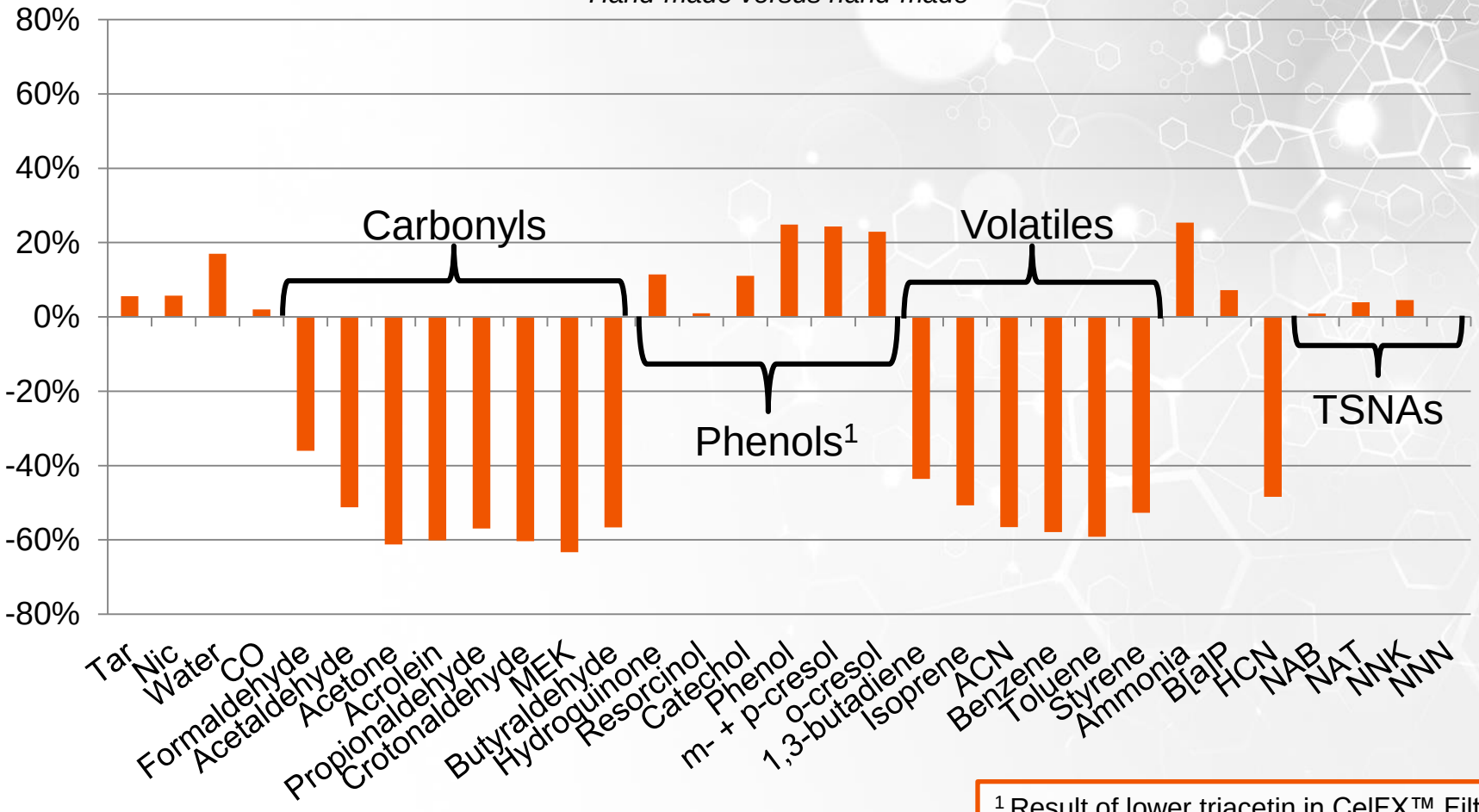


- Benefits
  - High carbon loading
  - Low carbon taste
  - Superior gas-phase filtration
  - Clean, low dust product
  - Firm filter feel
  - Tight control of quality parameters
  - Product design flexibility
    - Any pressure drop
    - Full range of sizes
  - Approved ingredients
- Commercialized technology, in use in commercial cigarettes today

Past CelFX™ Research

% Change with 12 mm CelFX vs Carbon-on-tow Control

Hand-made versus hand-made



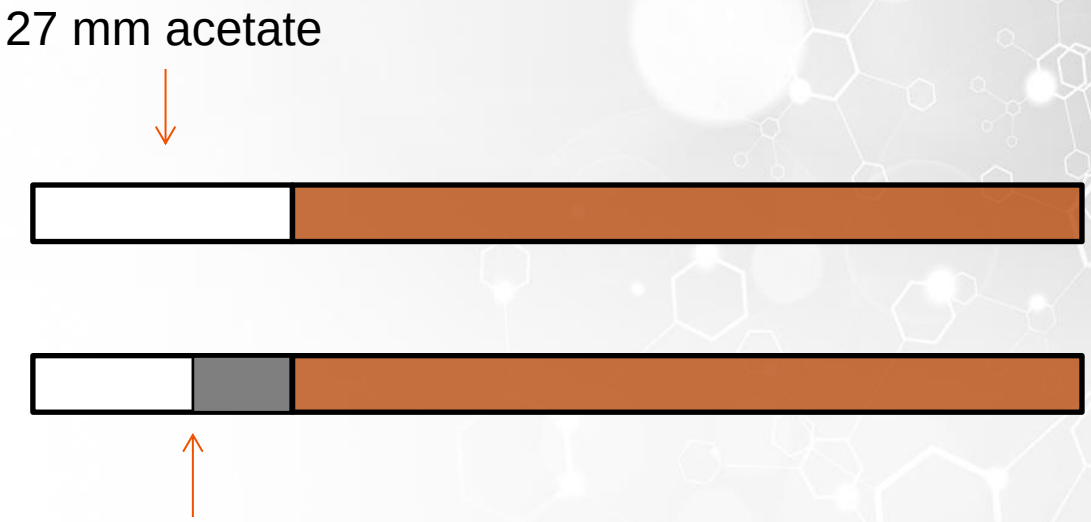
[1] Result of lower triacetin in CelFX™ Filter

Significant improvement in removal efficiency of gas-phase components vs. carbon-on-tow (40-60% improvement)

Experimental

- Cerulean CR 20i smoking machine
- Kentucky Reference 3R4F, matched pressure drop
  - Control 27 mm acetate
  - CelFX = 17 mm acetate + 10 mm CelFX (140 mg carbon)
- ISO 3088 Protocol with ventilation blocked
- Triplicate testing
  - Standard smoke analysis
    - 1-8 puff collected
  - Volatiles (CRM 70)
    - 1-4 puffs collected
    - 5-8 puffs collected
  - Carbonyls (CRM 74)
    - 1-8 puffs collected

Kentucky Reference 3R4F



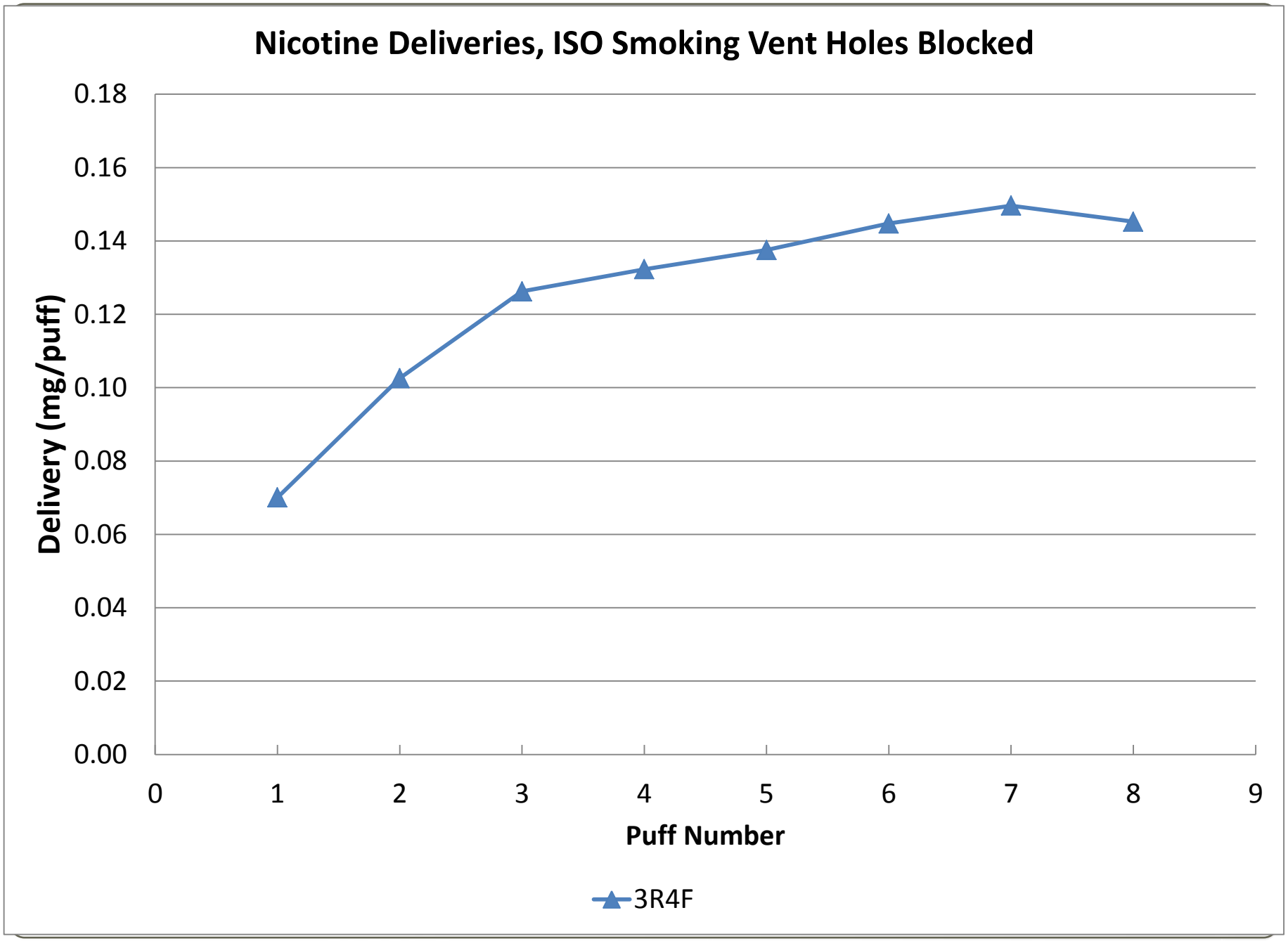
Carbon	Properties
Activity	60 %
Mesh	30 x 70
Surface Area	1000 meter^2/gram

Trapping Set-up

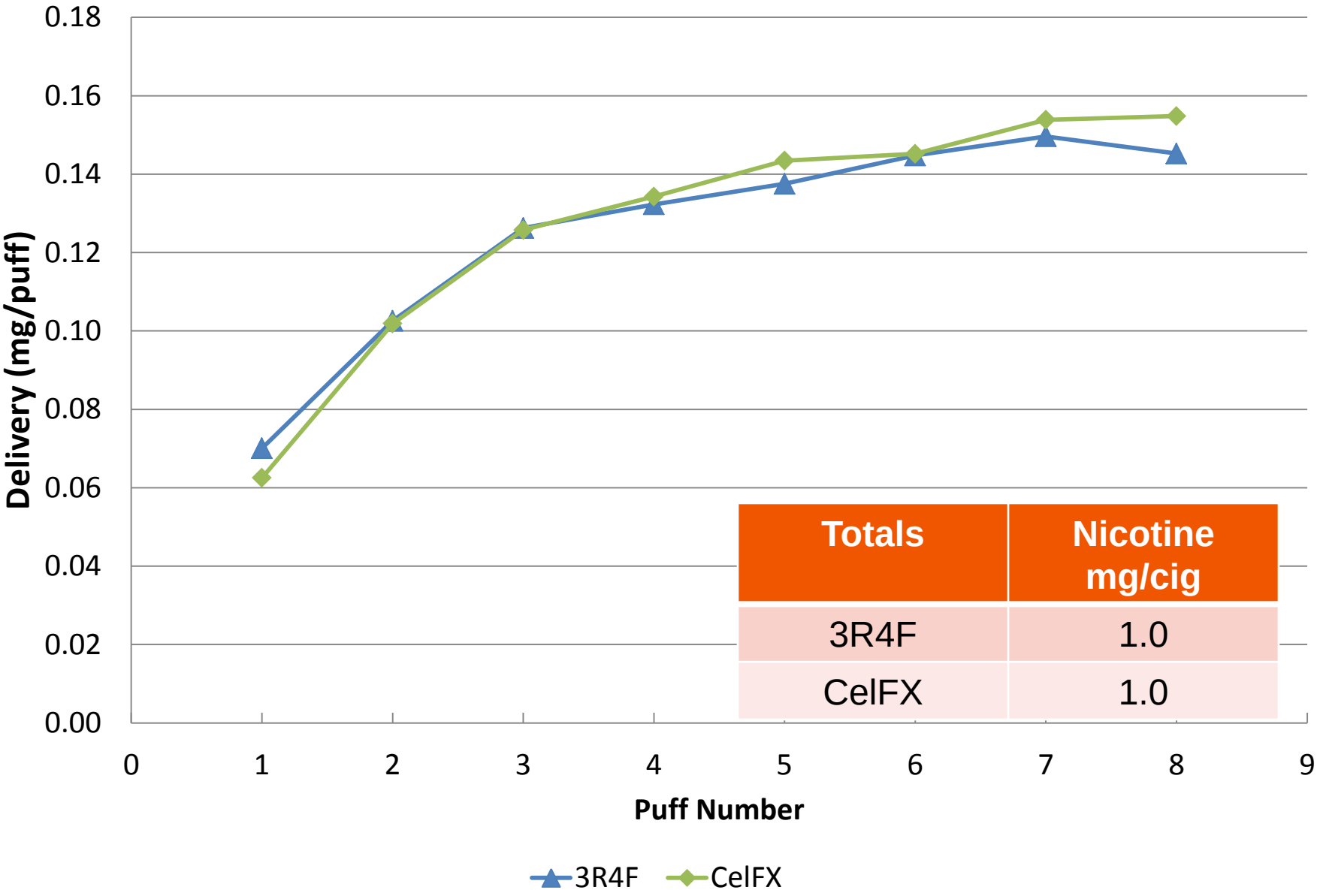
Celanese

The chemistry inside innovation™

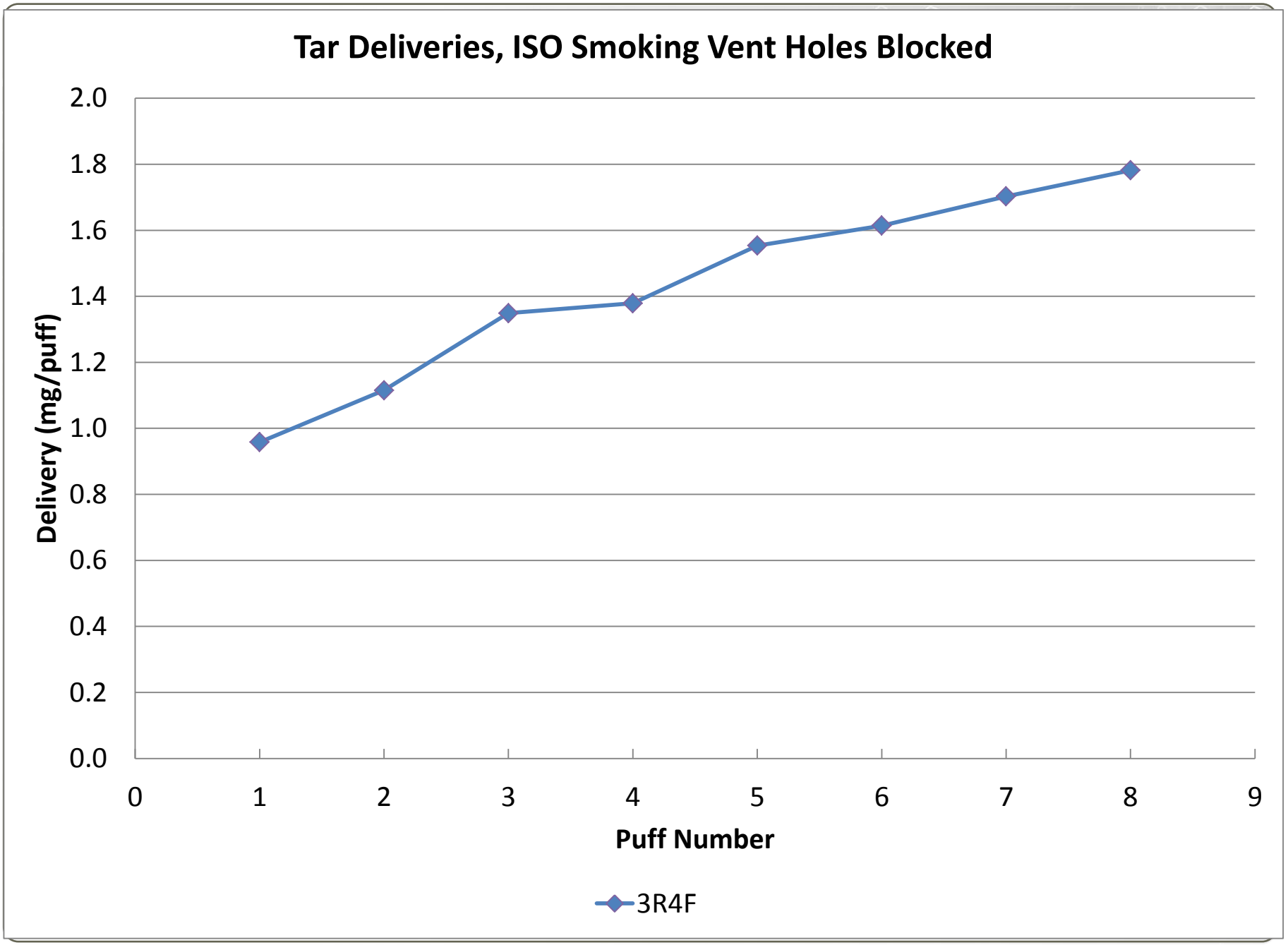
Standard Smoke: Benchmarking


Nicotine Deliveries, ISO Smoking Vent Holes Blocked
Delivery (mg/puff)
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
1
2
3
4
5
6
7
8
9
Puff Number
3R4F

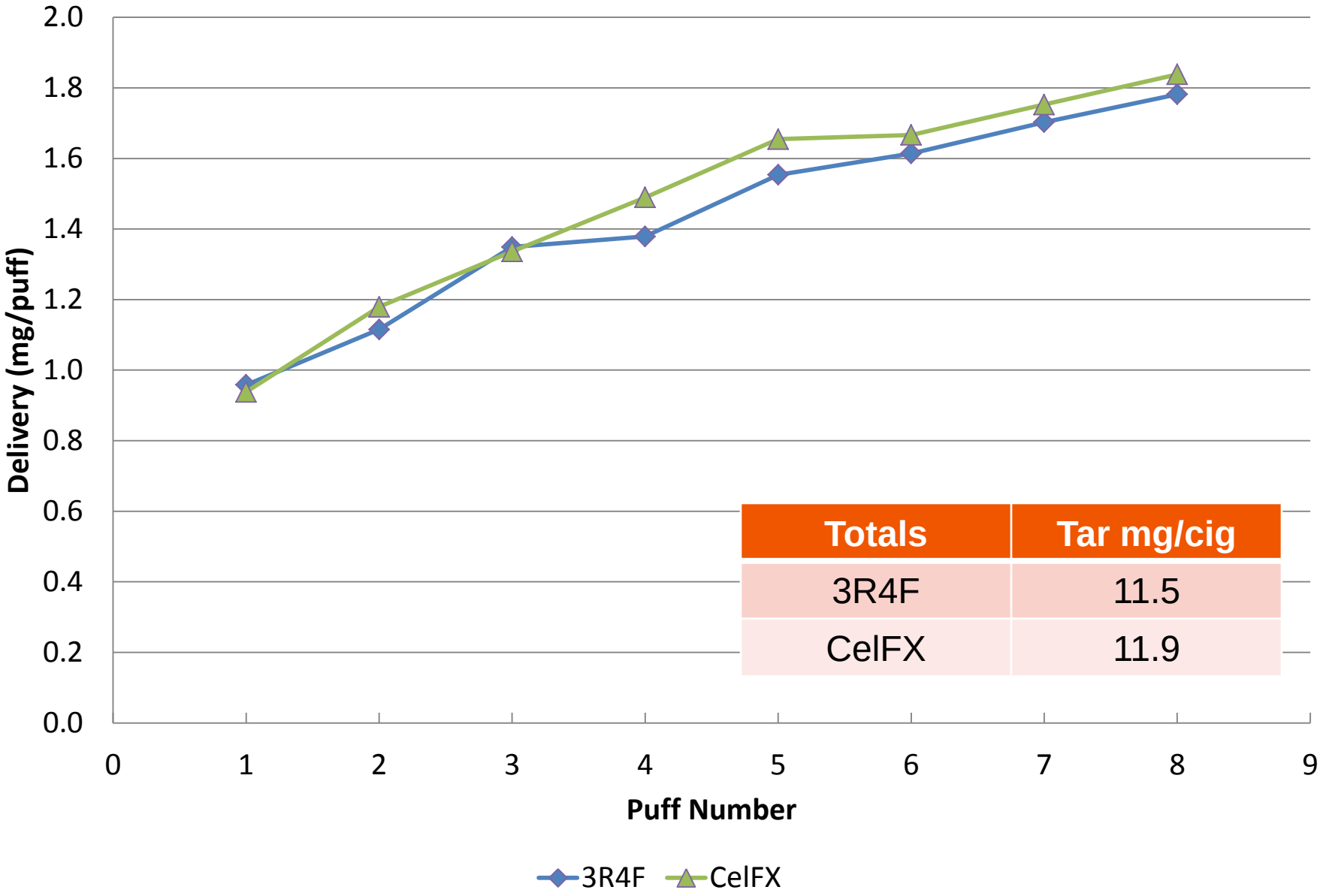
Nicotine Deliveries, ISO Smoking Vent Holes Blocked



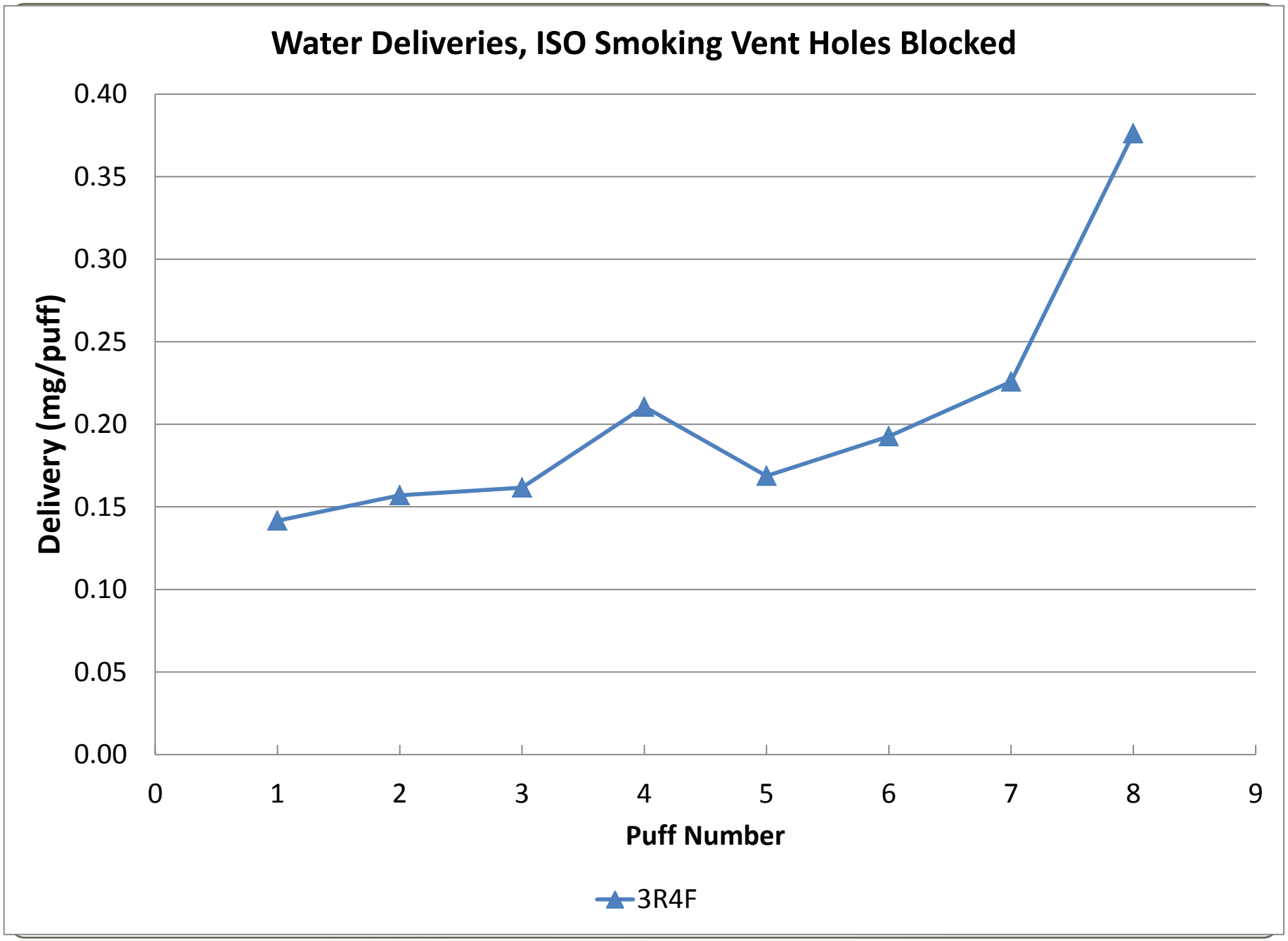
Totals	Nicotine mg/cig
3R4F	1.0
CelFX	1.0


Tar Deliveries, ISO Smoking Vent Holes Blocked
Delivery (mg/puff)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
8
9
Puff Number
3R4F

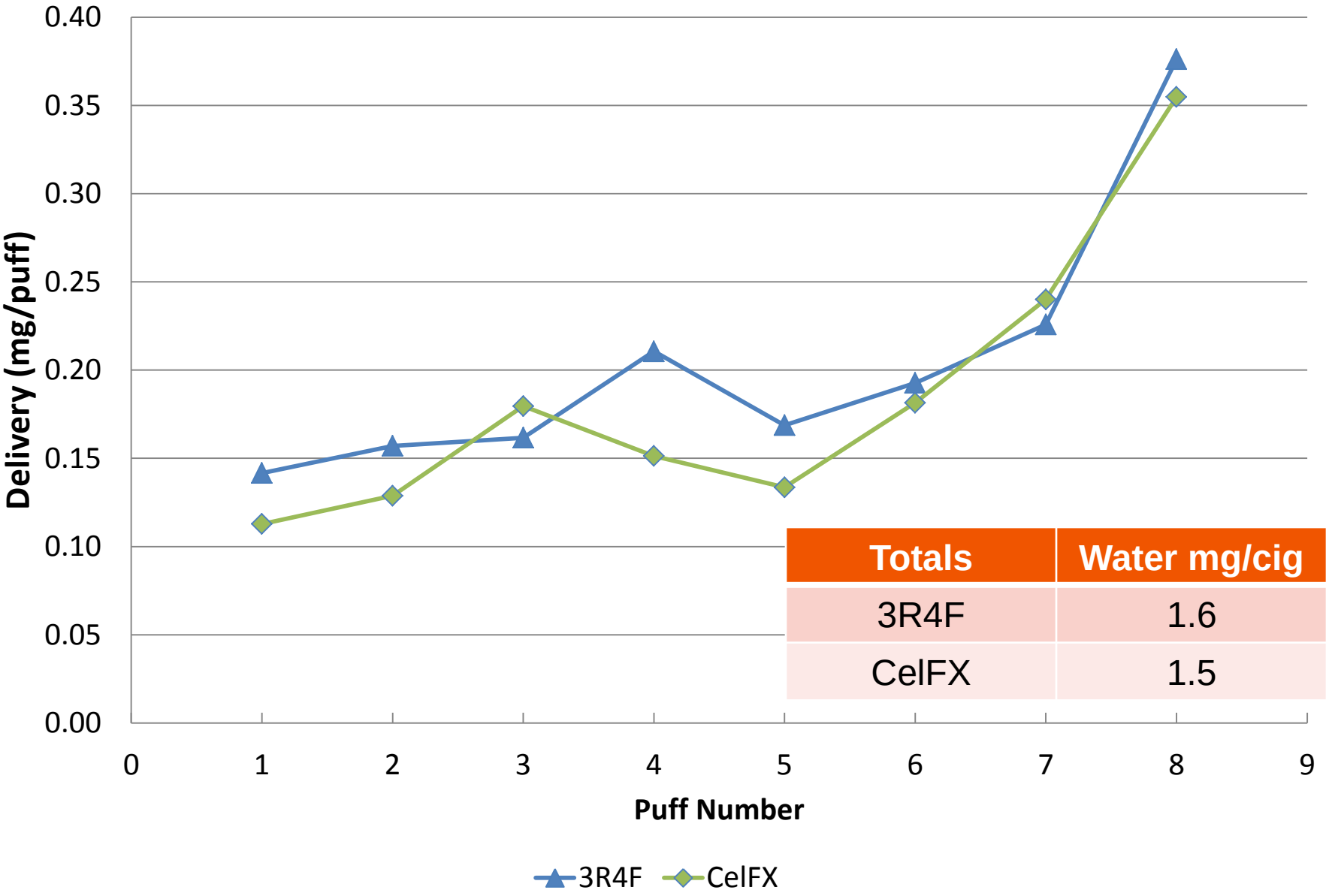
Tar Deliveries, ISO Smoking Vent Holes Blocked



Totals	Tar mg/cig
3R4F	11.5
CelFX	11.9


Water Deliveries, ISO Smoking Vent Holes Blocked
Delivery (mg/puff)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
1
2
3
4
5
6
7
8
9
Puff Number
3R4F

Water Deliveries, ISO Smoking Vent Holes Blocked



Totals	Water mg/cig
3R4F	1.6
CelFX	1.5

Observations

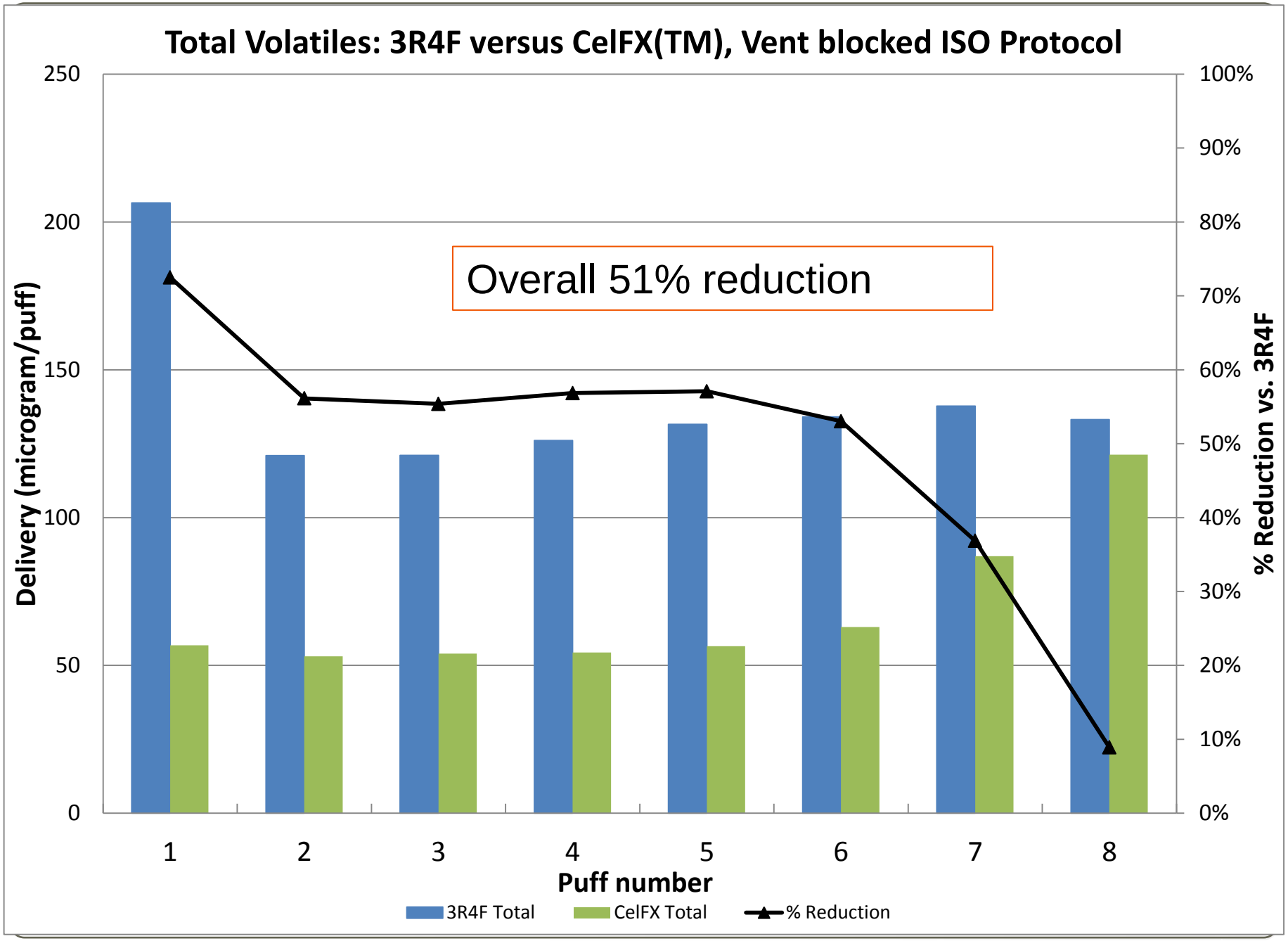
- Matched pressure drop
- No impact on deliveries
  - Nicotine
  - NFDPM
  - Water
- Profiles similar to published work[1]

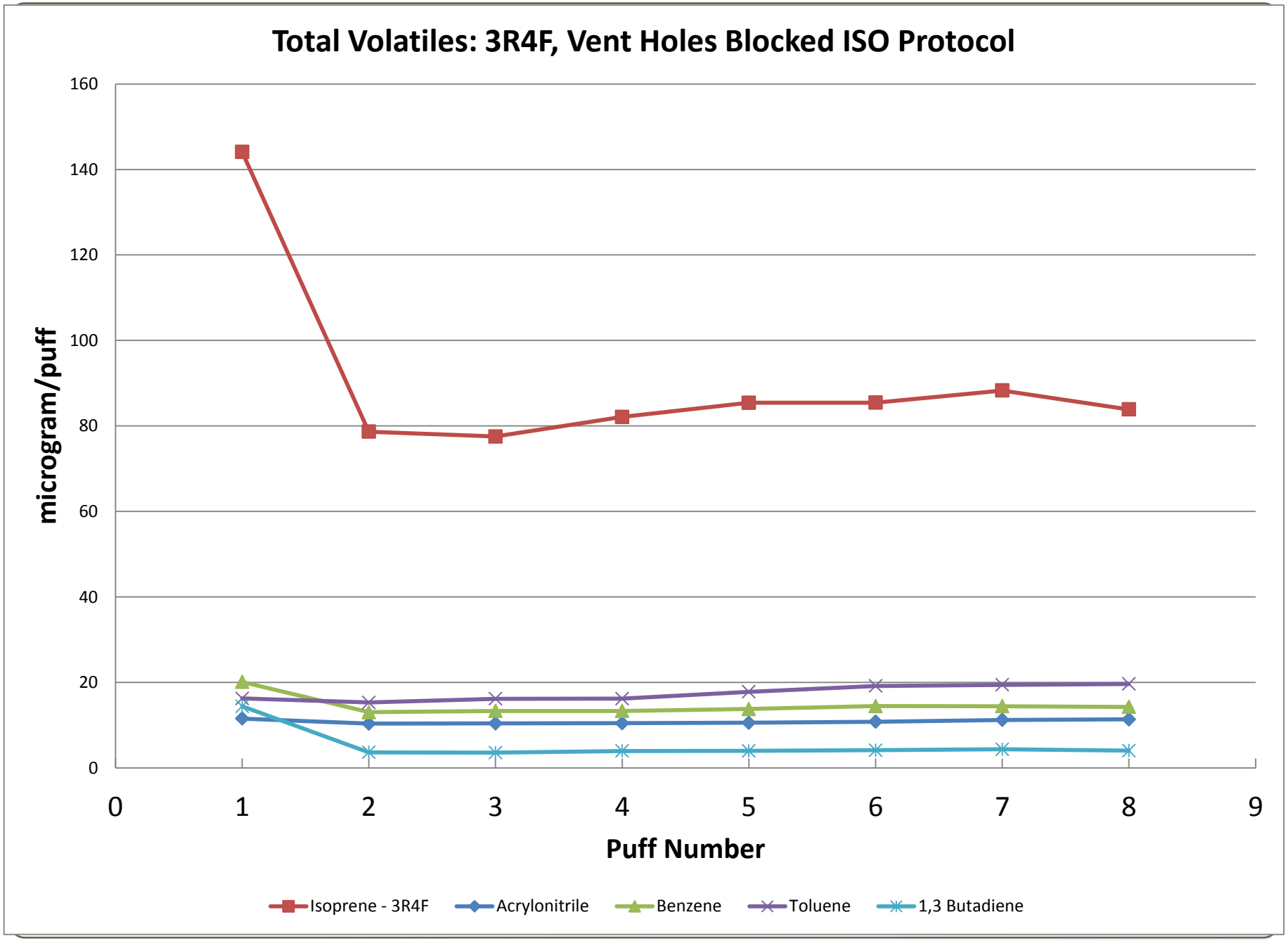
1. Wagner, K.A, Higby, R., Stutt, K., Puff-by-Puff Analysis of Selected Mainstream Smoke Constituents in the Kentucky Reference 2R4F Cigarette, Beiträge zur Tabakforschung International, Vol. 21, No. 5, (2005), 273-279.

Celanese

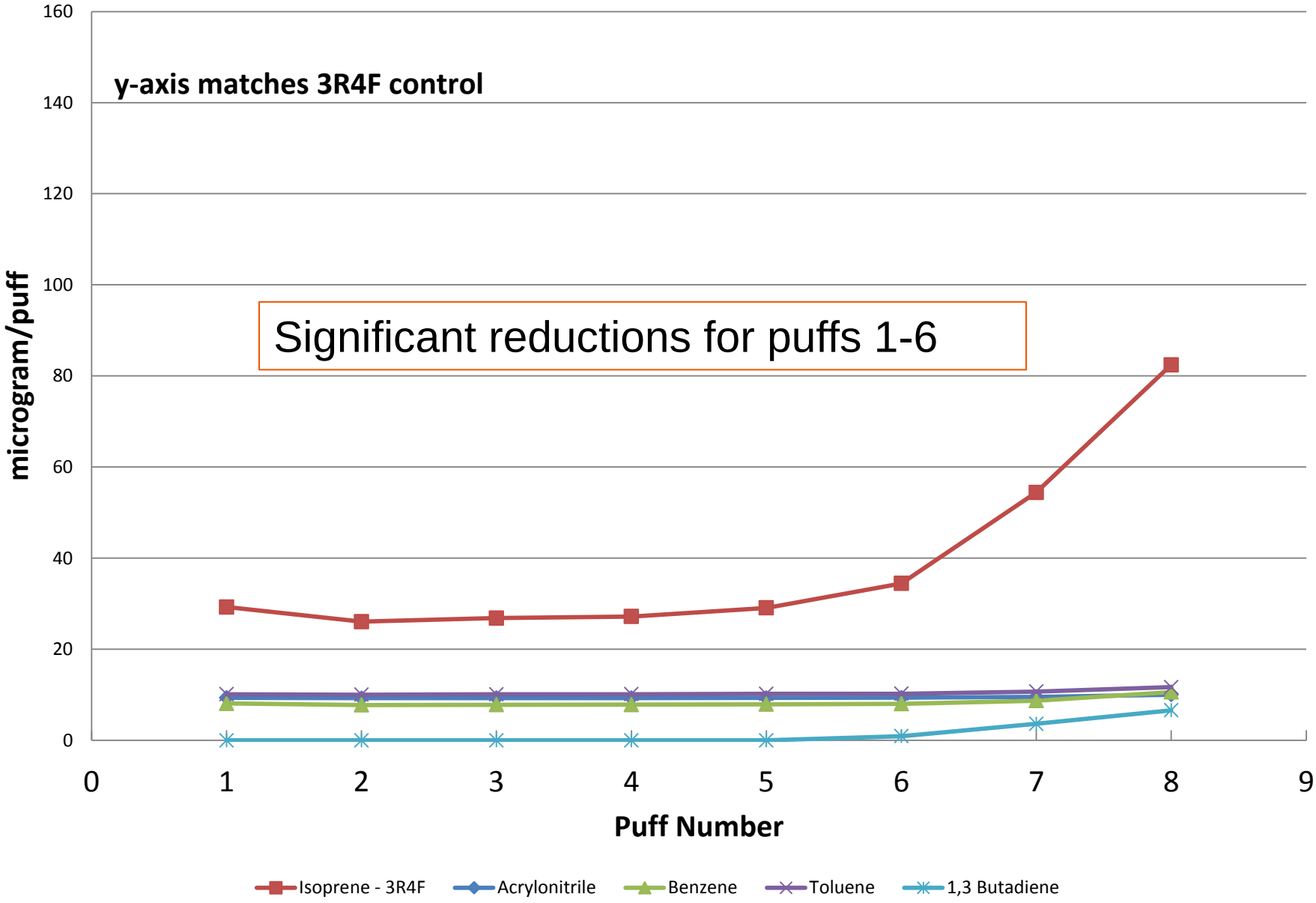
The chemistry inside innovation™

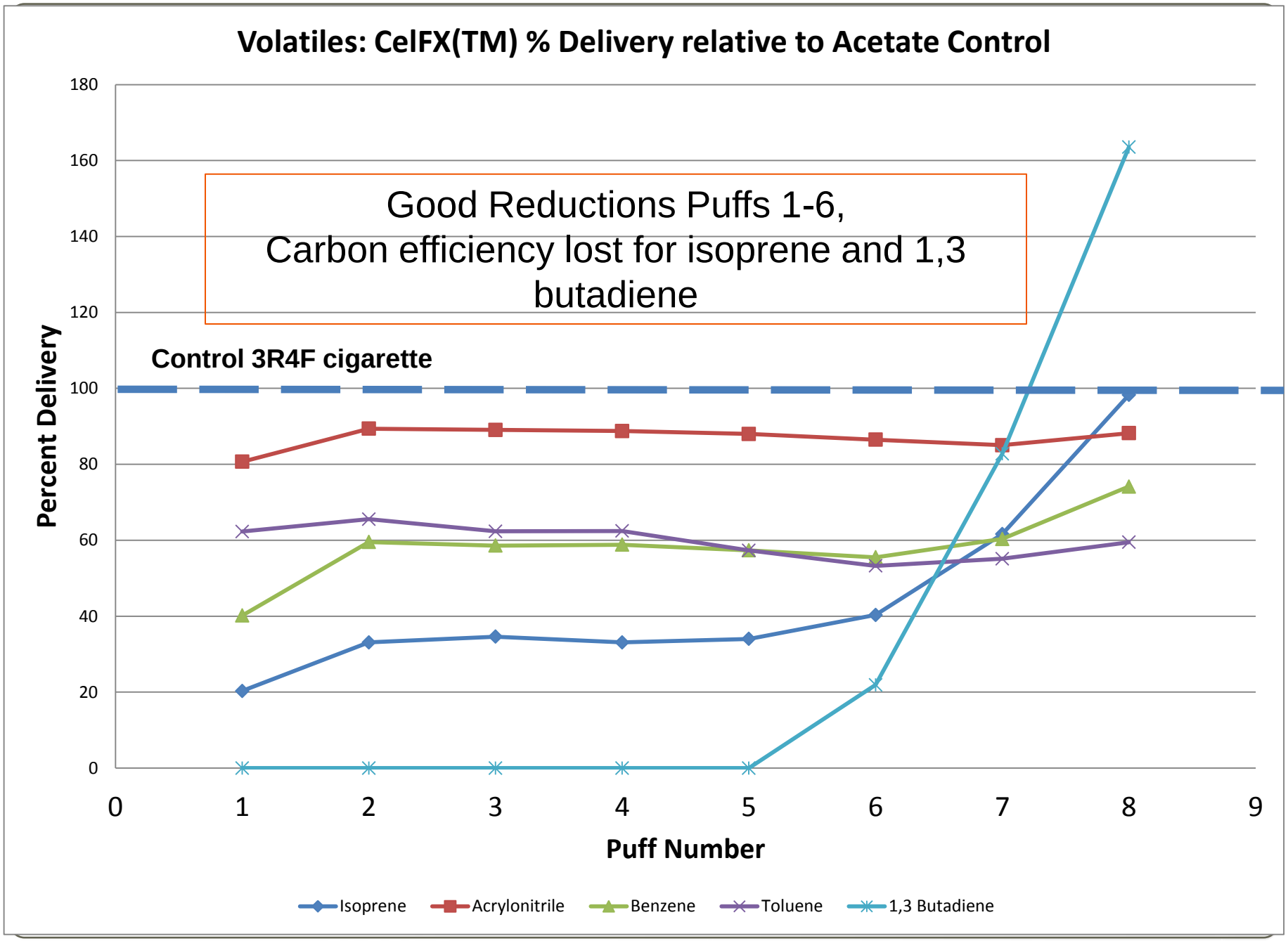
Volatiles


Total Volatiles: 3R4F versus CelFX(TM), Vent blocked ISO Protocol
Overall 51% reduction
Delivery (microgram/puff)
% Reduction vs. 3R4F
Puff number
250
200
150
100
50
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1
2
3
4
5
6
7
8
3R4F Total
CelFX Total
% Reduction


Total Volatiles: 3R4F, Vent Holes Blocked ISO Protocol
microgram/puff
160
140
120
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
9
Puff Number
Isoprene - 3R4F
Acrylonitrile
Benzene
Toluene
1,3 Butadiene

Total Volatiles: CelFX(TM), Vent Holes Blocked ISO Protocol

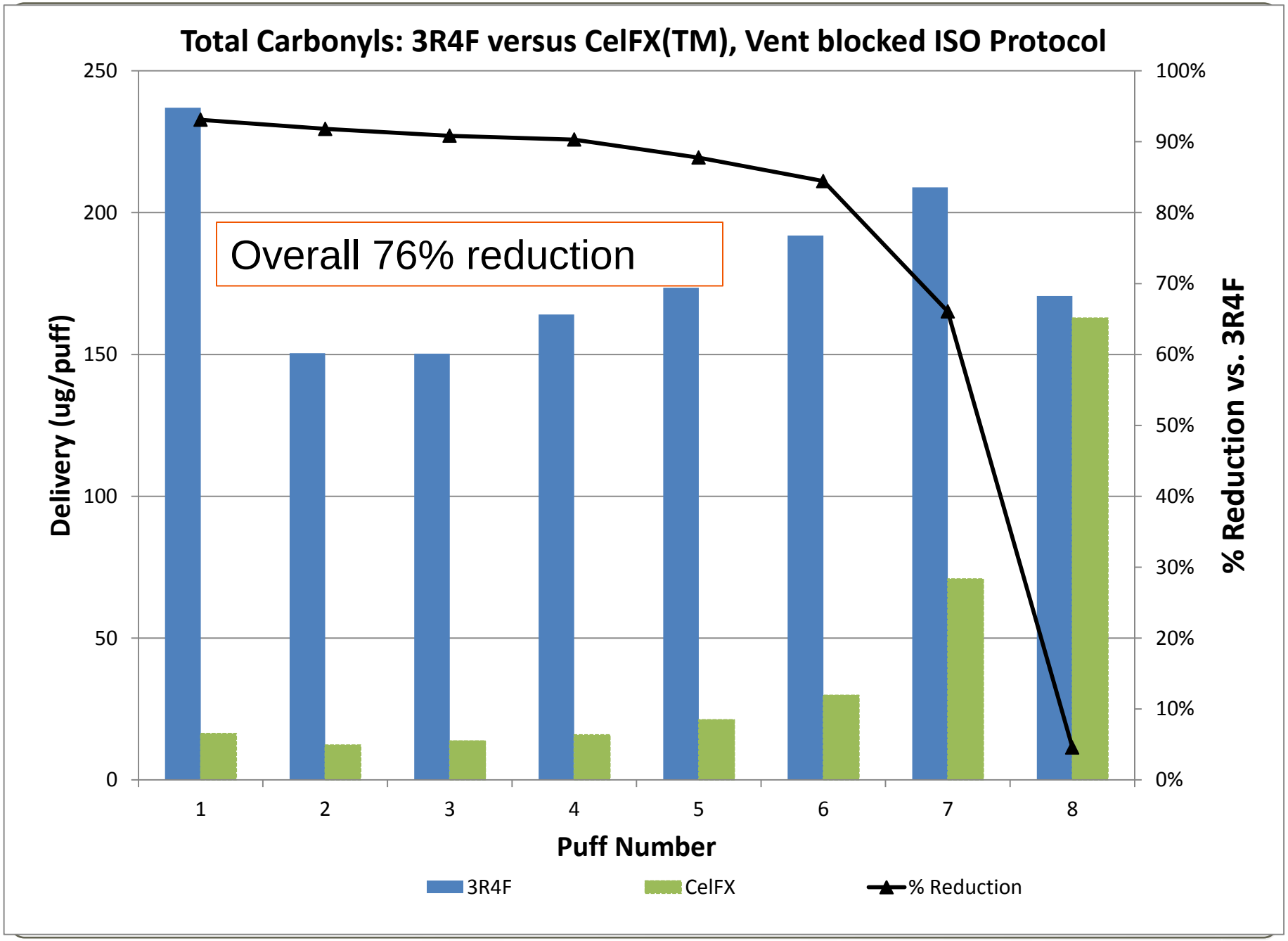


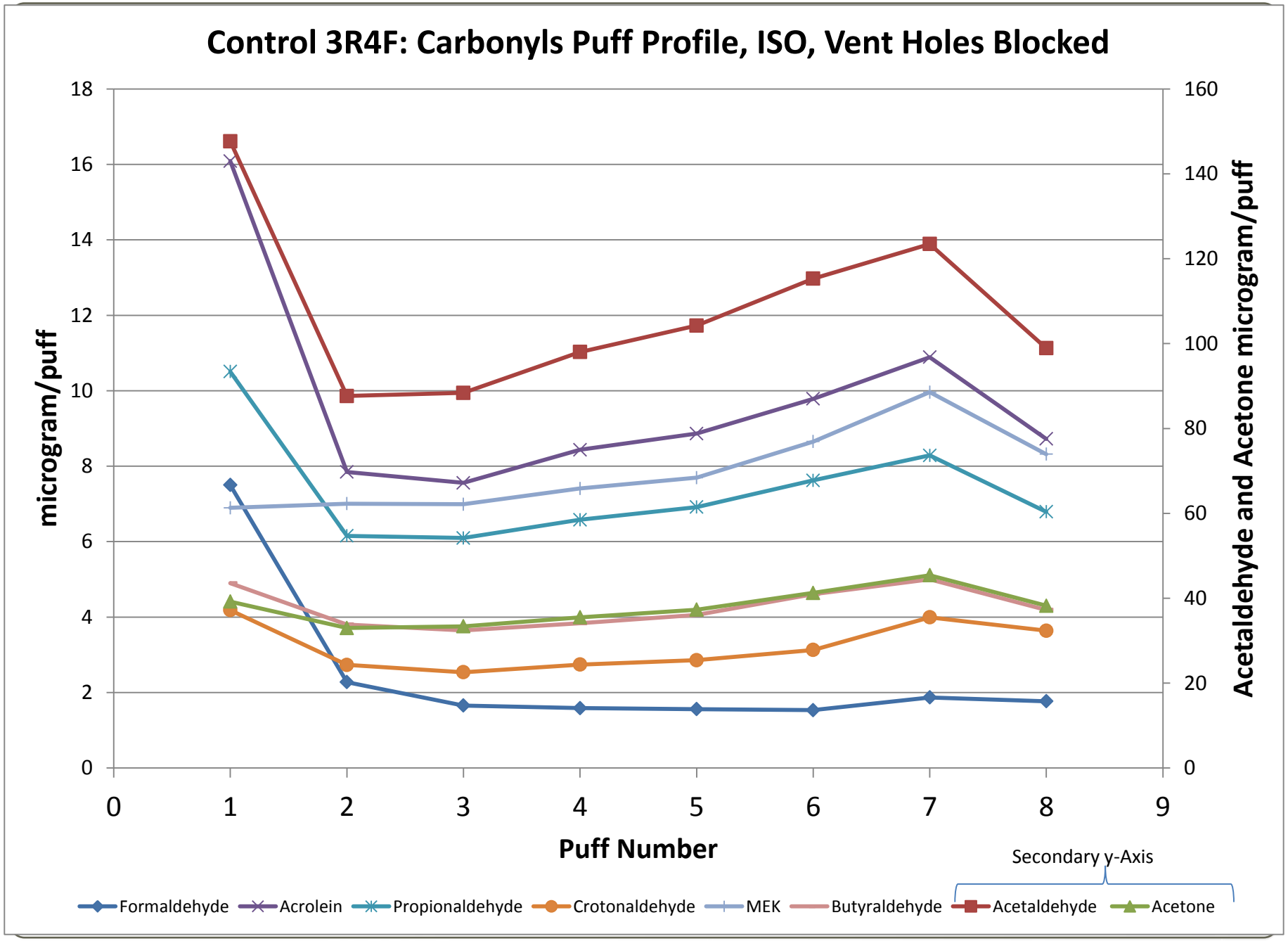

Volatiles: CelFX(TM) % Delivery relative to Acetate Control
Good Reductions Puffs 1-6,
Carbon efficiency lost for isoprene and 1,3 butadiene
Control 3R4F cigarette
Percent Delivery
180
160
140
120
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
9
Puff Number
Isoprene
Acrylonitrile
Benzene
Toluene
1,3 Butadiene

Celanese

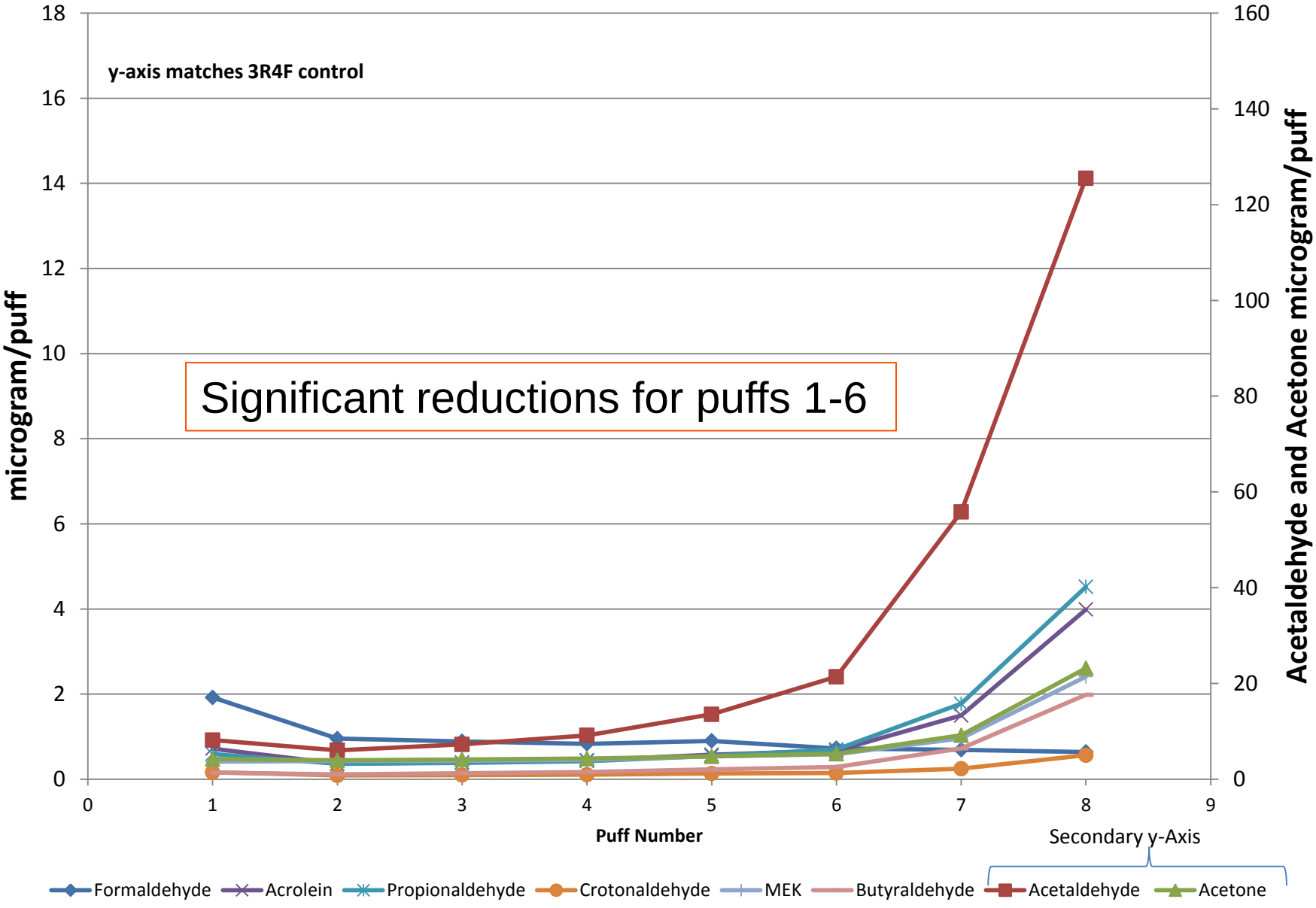
The chemistry inside innovation™

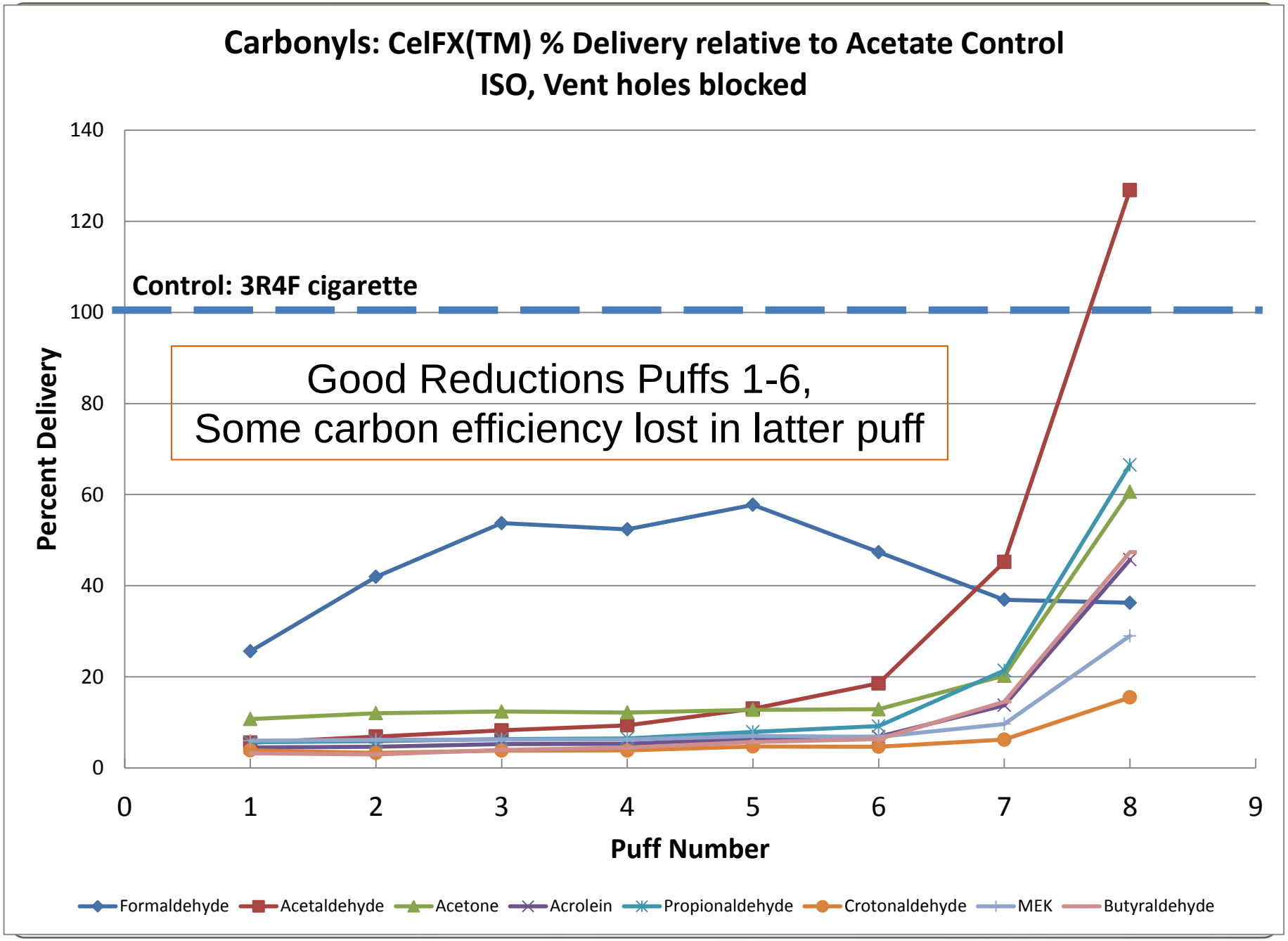
Carbonyls


Total Carbonyls: 3R4F versus CelFX(TM), Vent blocked ISO Protocol
Overall 76% reduction
Delivery (ug/puff)
% Reduction vs. 3R4F
Puff Number
250
200
150
100
50
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1
2
3
4
5
6
7
8
3R4F
CelFX
% Reduction

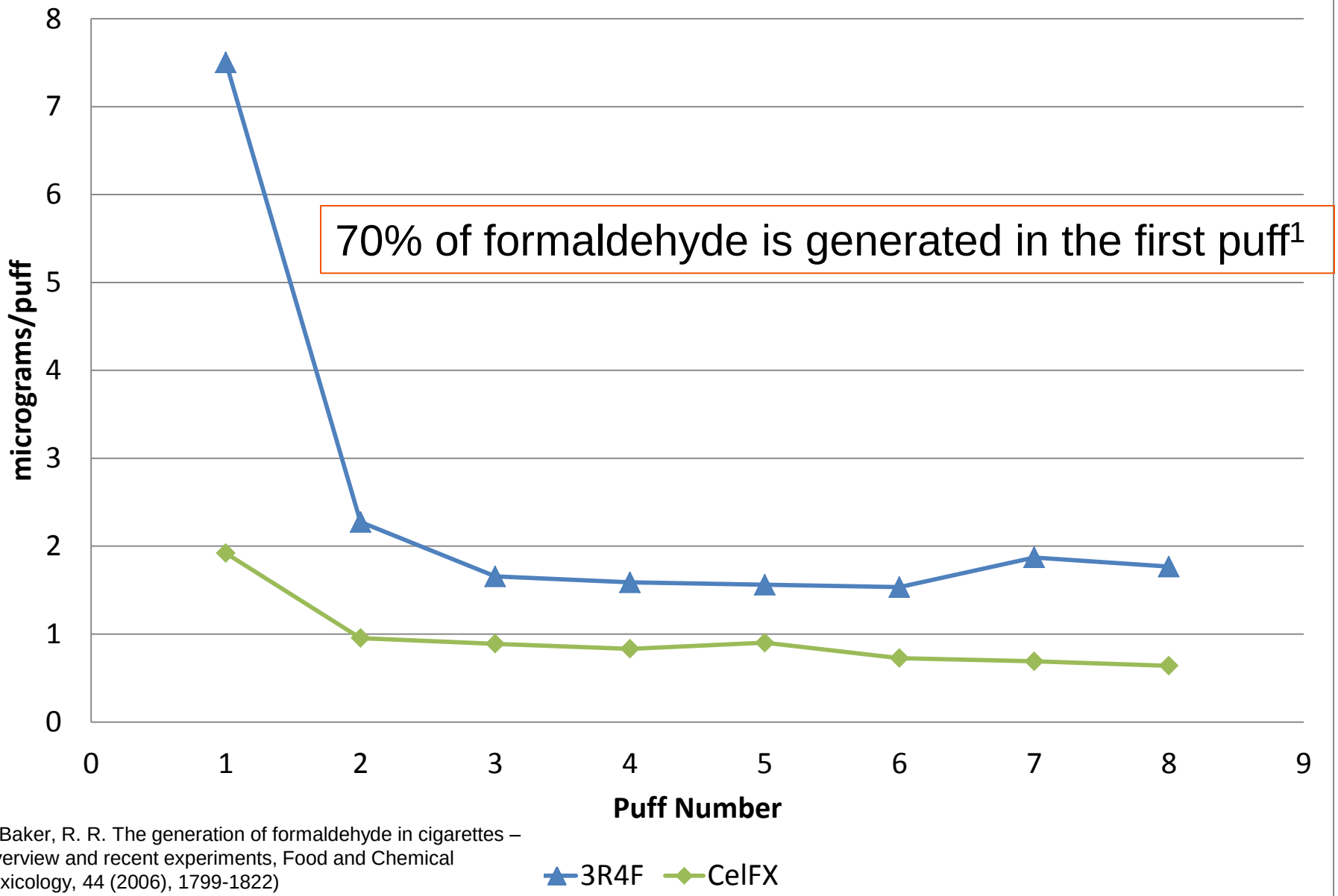

Control 3R4F: Carbonyls Puff Profile, ISO, Vent Holes Blocked
microgram/puff
Acetaldehyde and Acetone microgram/puff
Puff Number
0
1
2
3
4
5
6
7
8
9
0
2
4
6
8
10
12
14
16
18
0
20
40
60
80
100
120
140
160
Secondary y-Axis
Formaldehyde
Acrolein
Propionaldehyde
Crotonaldehyde
MEK
Butyraldehyde
Acetaldehyde
Acetone

CelFX(TM): Carbonyls Puff Profile, ISO, Vent Holes Blocked



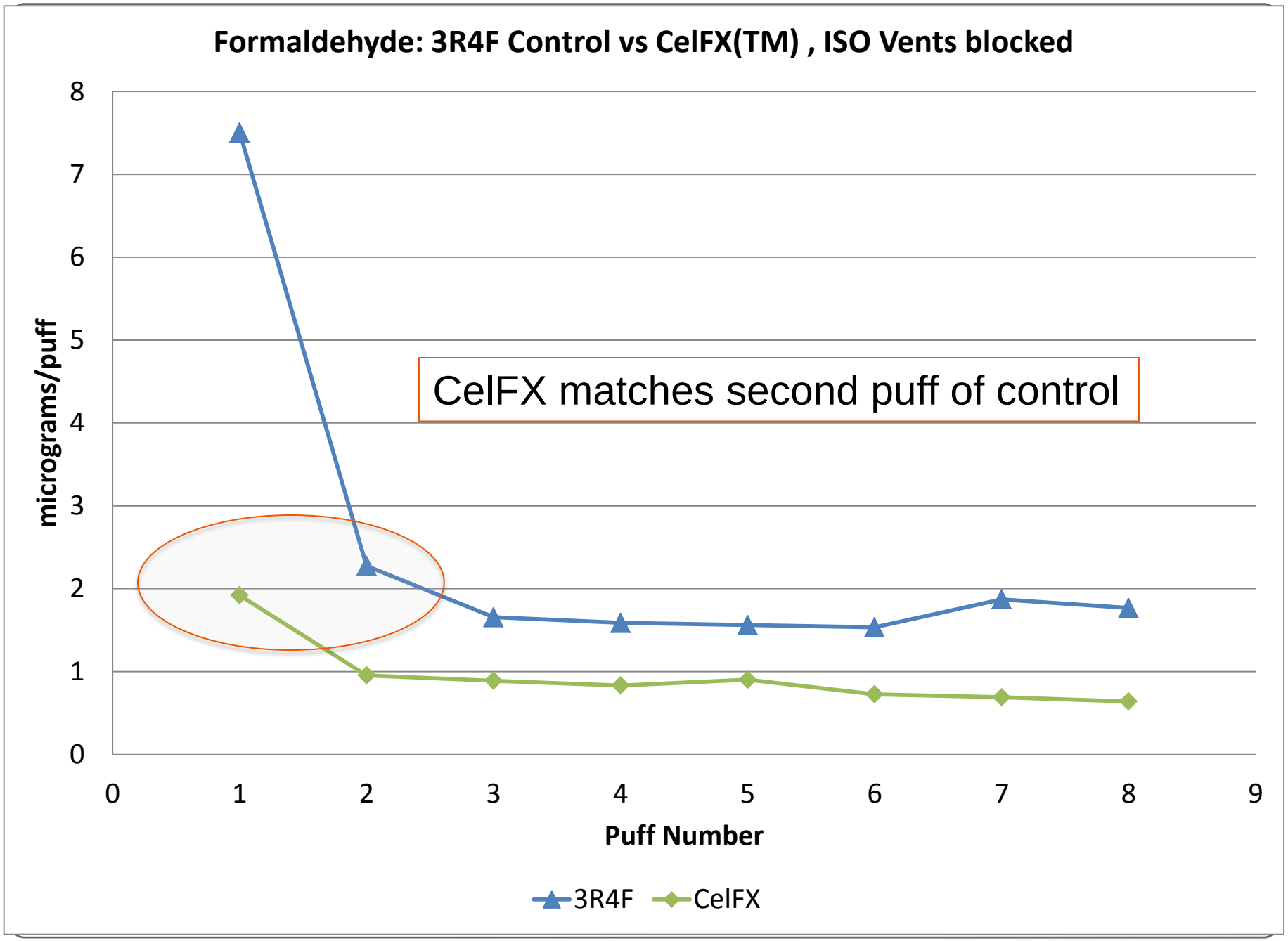

Carbonyls: CelFX(TM) % Delivery relative to Acetate Control
ISO, Vent holes blocked
Control: 3R4F cigarette
Good Reductions Puffs 1-6,
Some carbon efficiency lost in latter puff
Percent Delivery
Puff Number
0
20
40
60
80
100
120
140
0
1
2
3
4
5
6
7
8
9
Formaldehyde
Acetaldehyde
Acetone
Acrolein
Propionaldehyde
Crotonaldehyde
MEK
Butyraldehyde

Formaldehyde: 3R4F Control vs CelFX(TM) , ISO Vents blocked

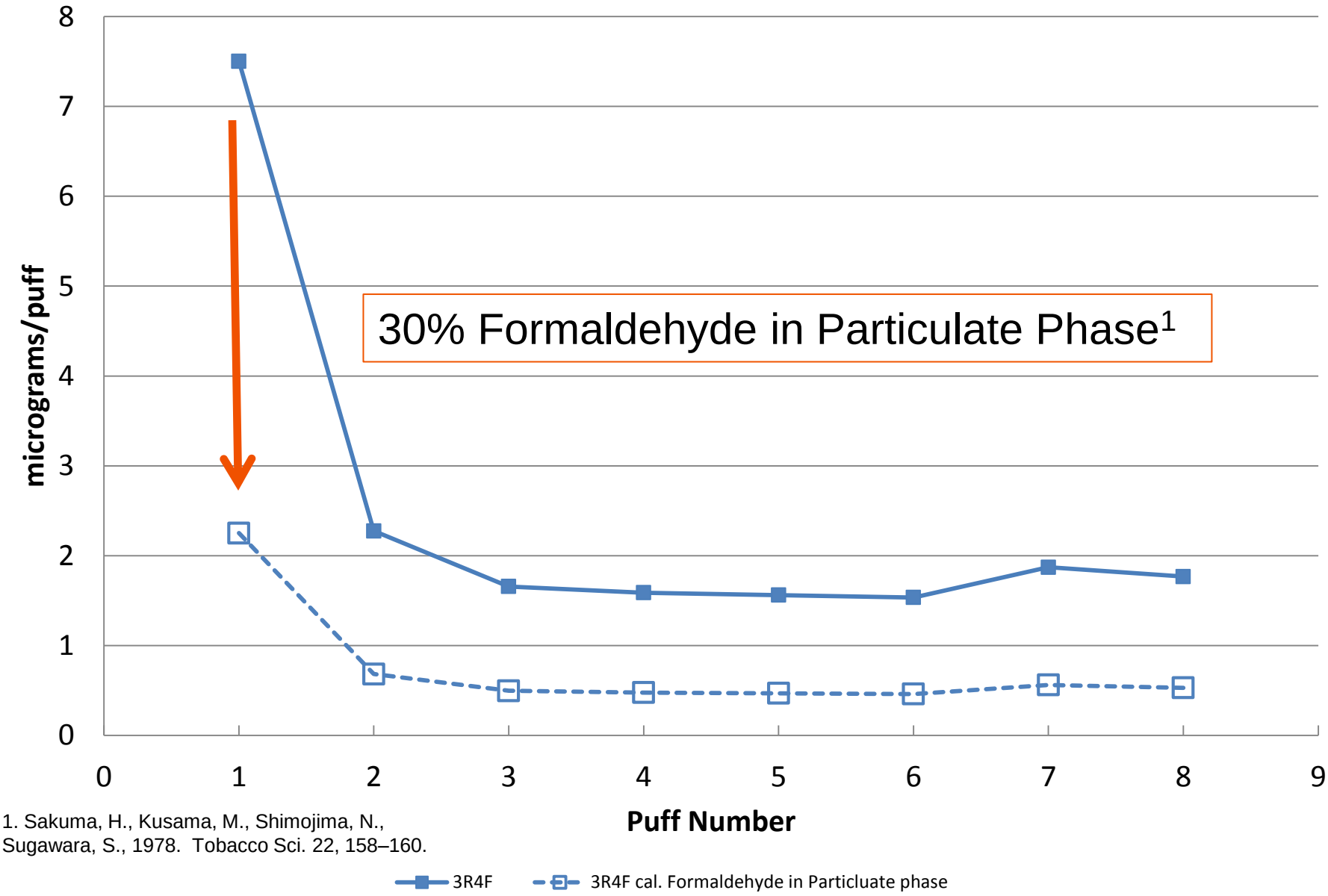


70% of formaldehyde is generated in the first puff[1]

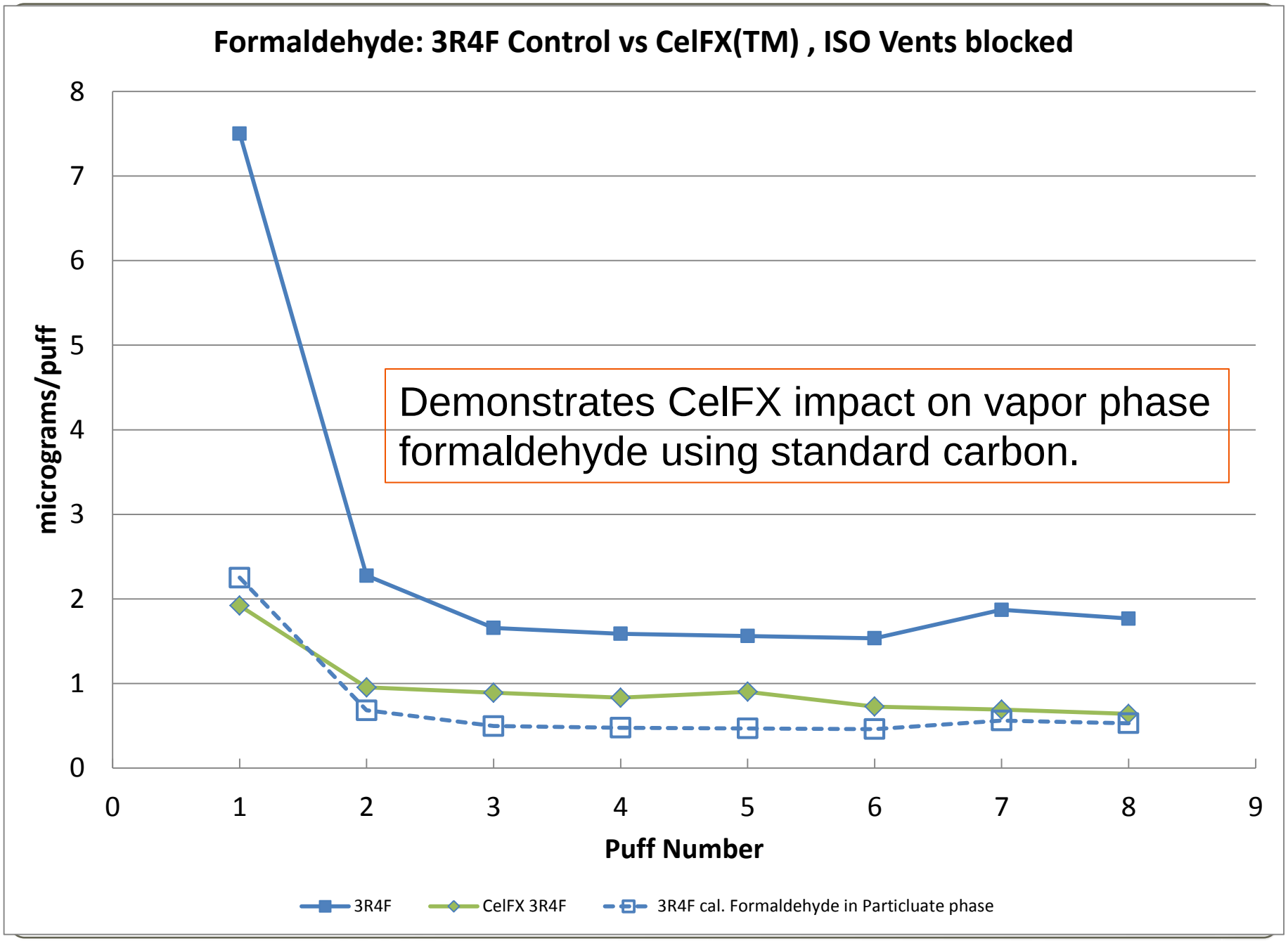
1. Baker, R. R. The generation of formaldehyde in cigarettes – Overview and recent experiments, Food and Chemical Toxicology, 44 (2006), 1799-1822)


Formaldehyde: 3R4F Control vs CelFX(TM) , ISO Vents blocked
micrograms/puff
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5
6
7
8
9
Puff Number
CelFX matches second puff of control
3R4F
CelFX

Formaldehyde: 3R4F Control vs CelFX(TM) , ISO Vents blocked



1. Sakuma, H., Kusama, M., Shimojima, N., Sugawara, S., 1978. Tobacco Sci. 22, 158–160.


Formaldehyde: 3R4F Control vs CelFX(TM) , ISO Vents blocked
micrograms/puff
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5
6
7
8
9
Puff Number
Demonstrates CelFX impact on vapor phase formaldehyde using standard carbon.
3R4F
CelFX 3R4F
3R4F cal. Formaldehyde in Particluate phase

Conclusions

- Standard Smoking
  - No impact – NFDPM, Water, Nicotine Delivery
- Carbonyls
  - Overall 76% reduction
  - 90% reduction, puffs 1-6
  - 38% reduction, puff 7-8
    - potentially diminished removal capacity in final puffs
  - Gas phase formaldehyde almost entirely removed
- Volatiles
  - Overall 51% reduction
  - 60% reduction, puffs 1-6
  - 23% reduction, puffs 7-8
- Overall
  - CelFX seems to significantly homogenize early puffs – no “spikes”
  - High reductions possible
- Future Work
  - Ventilation Impact
  - Constituent mitigation in latter puffs
  - Optimized filter designs to maintain reductions through final puffs
    - Longer CelFX, higher activity carbon, etc.

Thanks

- Jitendra Suthar
- Sayanti Basu
- Whitney Canterbury
- Melissa Aldrich-Welch