



# FEATURES AND PERFORMANCE OF THE HPP SMOKING MACHINE

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# Introduction

The testing of tobacco burning cigarettes is governed by the testing methods set forth in ISO 3308 and the Canadian Intense Regime (CIR). These both call for a two second “puff” that is taken once (FTC) or twice (CIR) minute in the amounts of 35 and 55 ml respectively. Electronic cigarettes or e-cigarette vapor generation methods are likely to be covered by guidelines defined by CORESTA. This calls for a 3 second puff of 55 ml volume taken twice per minute.

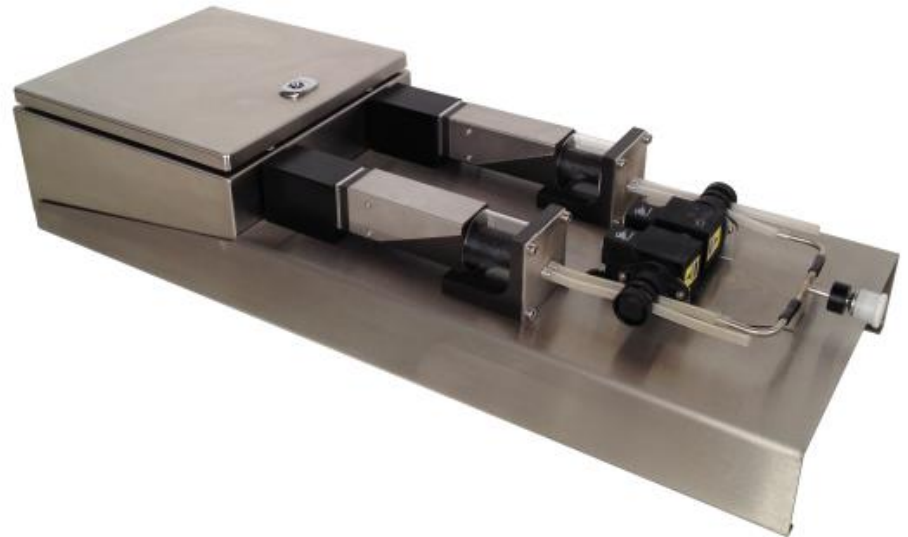
While vapor and aerosol toxicology studies need to be conducted for Modified Risk Tobacco Products (MRTP), the availability of equipment suitable for the reliable, precise and accurate generation of eCigarette vaporization aerosols has yet to be addressed in the industry.

The piston pump of the Human Puff Profile (HPP) Smoking Machine, was tested to determine if it had the combination of reliable, accurate and precise characteristics that would allow it to be used for such determinations.

The following presentation reports on these observations for this purpose. The integration of this device with analytical instruments or inhalation exposure systems is proposed.

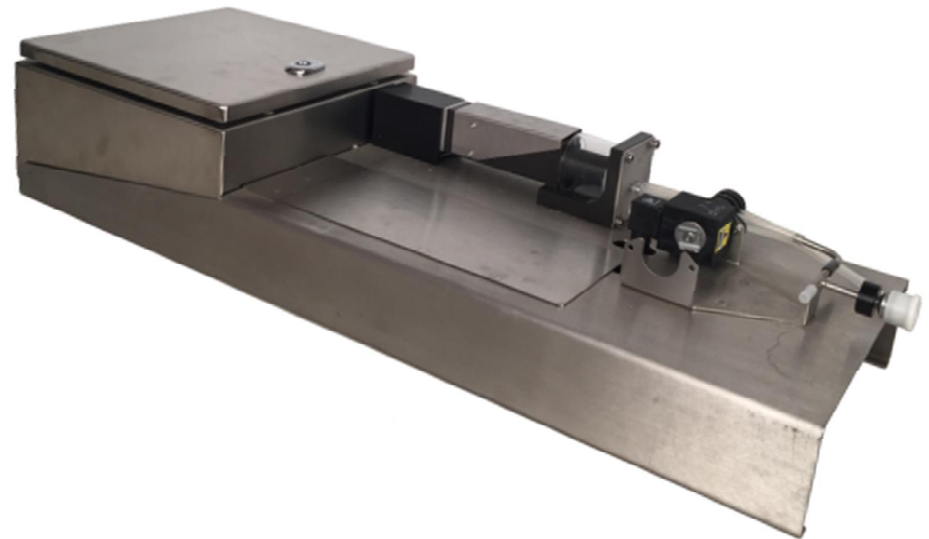
# HPP Smoking Machine Series - Dual

- ❑ Two 100 ml high precision glass cylinders
- ❑ Pumps operated independently or in sync
- ❑ Pinch valves synced with piston movements
- ❑ Very fast Maxon motors
- ❑ Puff volumes up to 200 ml
- ❑ Human puff profiles



# HPP Smoking Machine Series - Single

- ❑ Single 100 ml high precision glass cylinder
- ❑ Pinch valves synced with piston movements
- ❑ Very fast Maxon motor
- ❑ Puff volumes up to 100 ml
- ❑ Human puff profiles



# Main Features of the Proposed HPP Smoking Machine – Double E-HPP

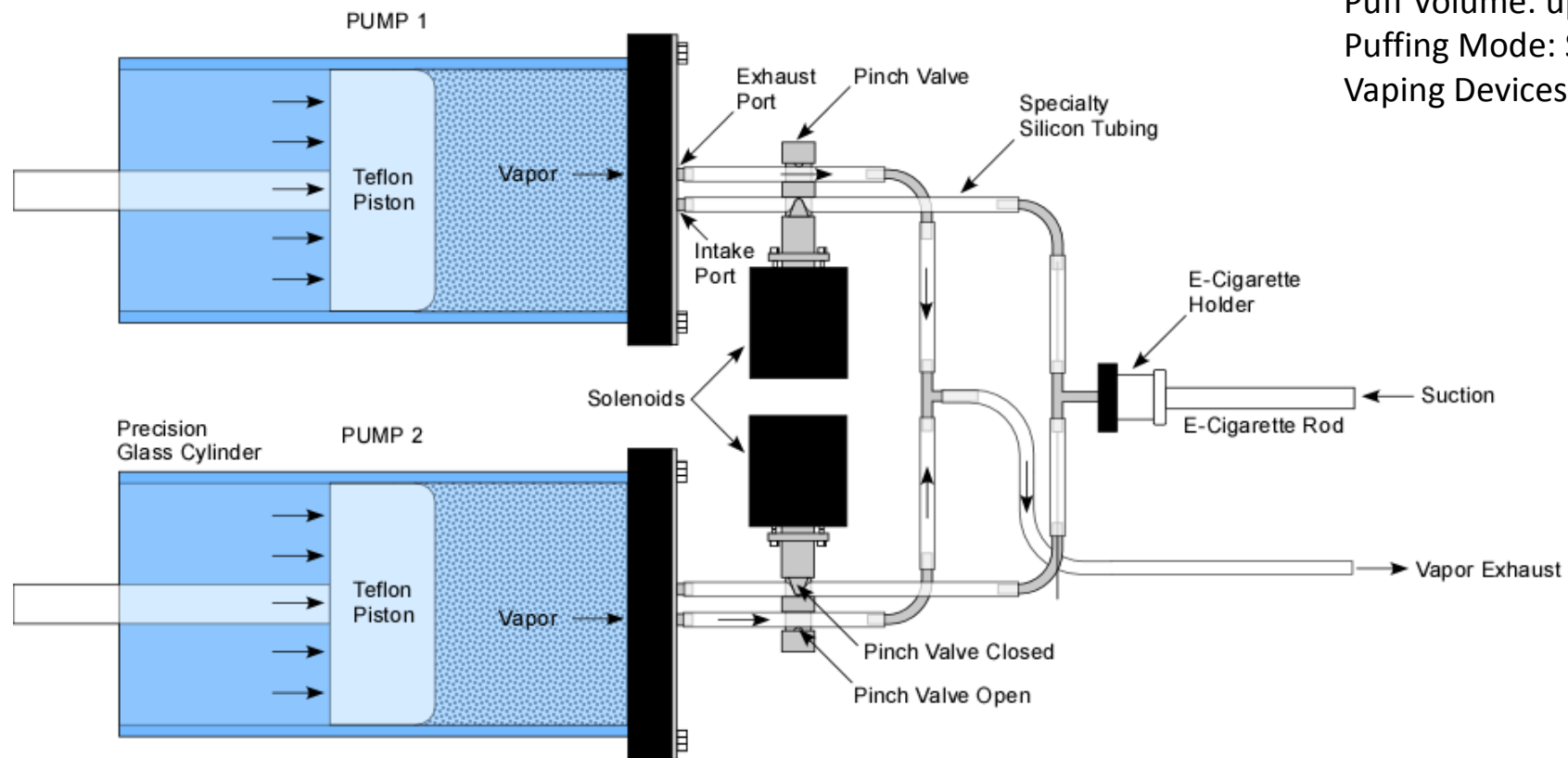
## Current

- Can deliver puffs with very large volumes (up to 200 ml)
- Can be used with a virtually unlimited number of standard and user-defined puffing regimen, including real human puff profiles (within the operational limits of the machine)
- Can vape one or two devices at a time

## Proposed Upgrades

- Can puff e-vaping devices in both suction mode or positive pressure (push) mode
- Can optionally control voltage to e-vaping devices if the user choose to do so
- Can be used with a variety of vaping devices (with custom designed adaptors)

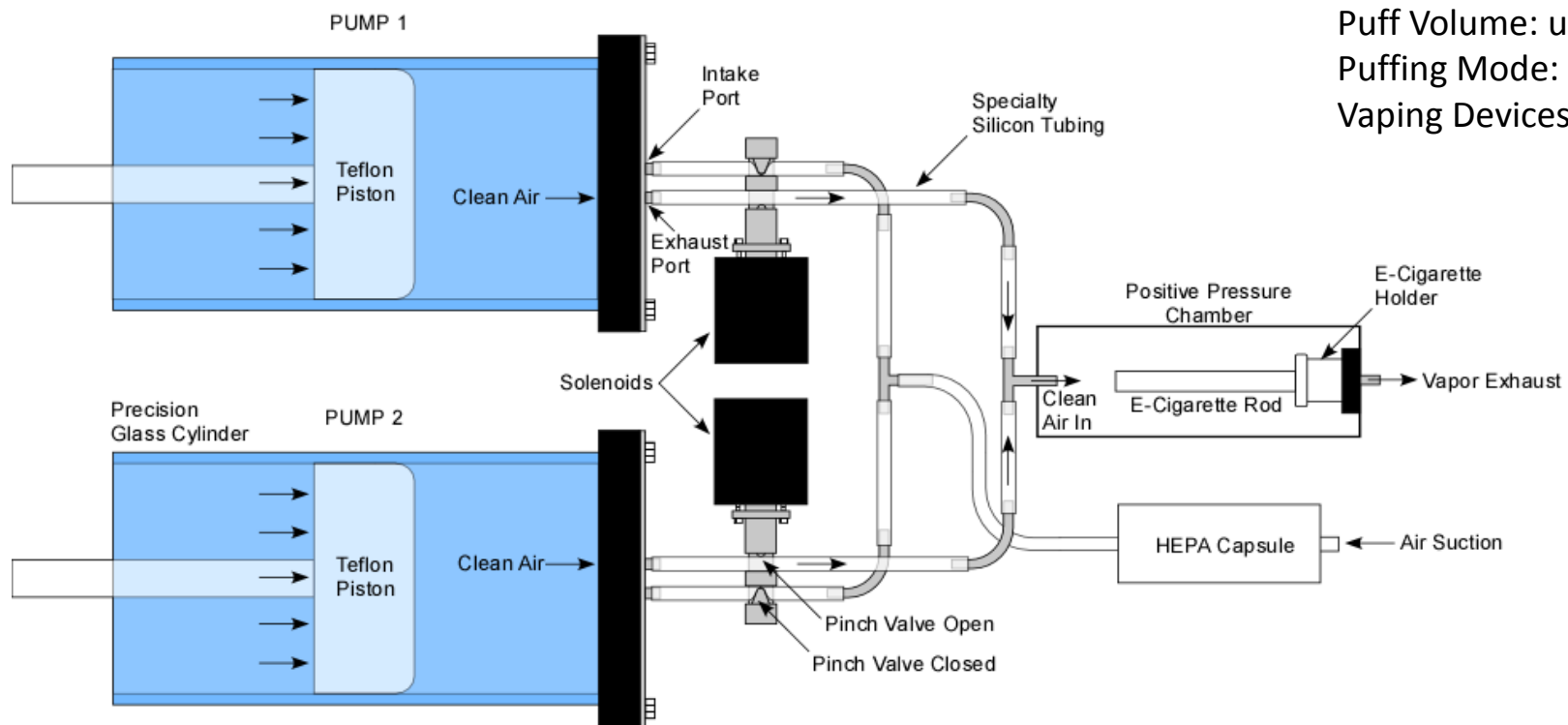
# Double E-HPP Operation: Mode 1



Puff Volume: up to 200 ml  
Puffing Mode: Suction  
Vaping Devices: Single



# Double E-HPP Operation: Mode 3

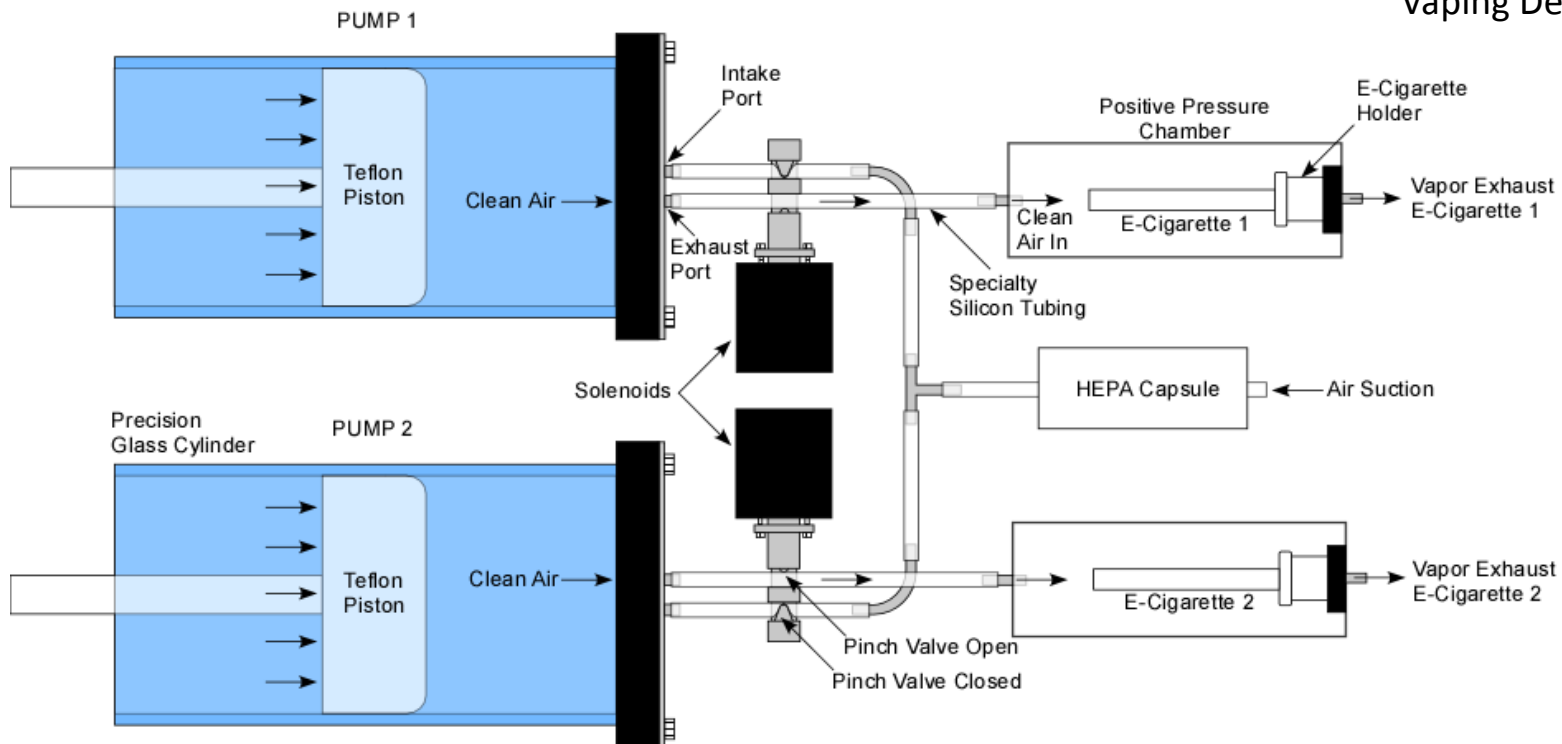


Puff Volume: up to 200 ml  
Puffing Mode: Positive Pressure  
Vaping Devices: Single

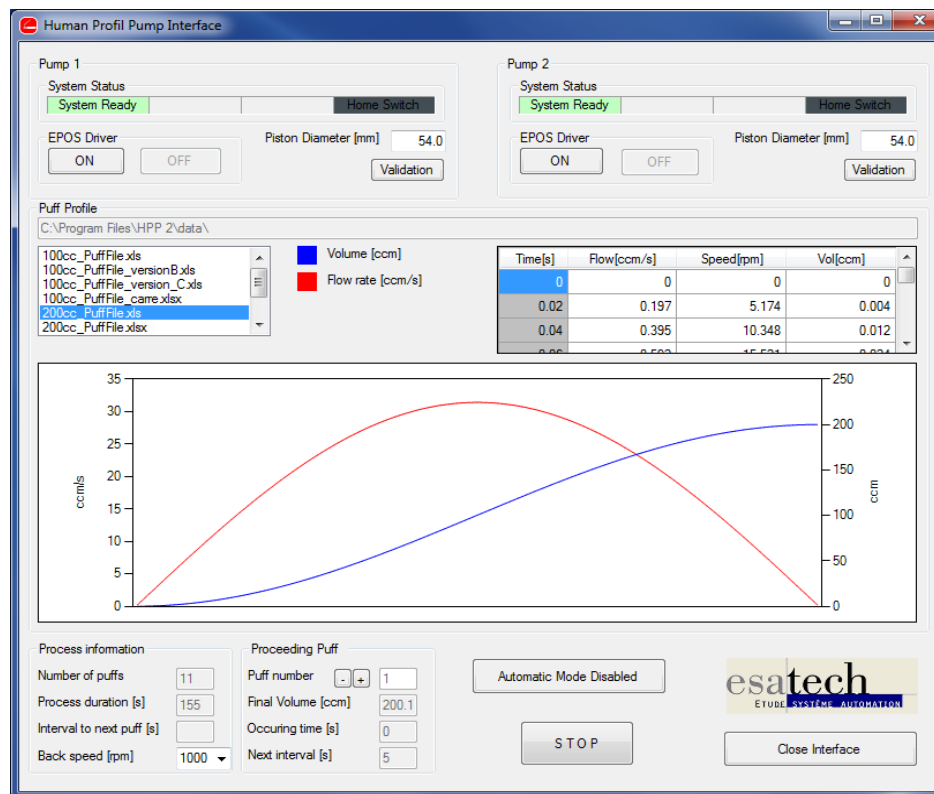


# Double E-HPP Operation: Mode 4

Puff Volume: up to 100 ml  
Puffing Mode: Positive Pressure  
Vaping Devices: Two

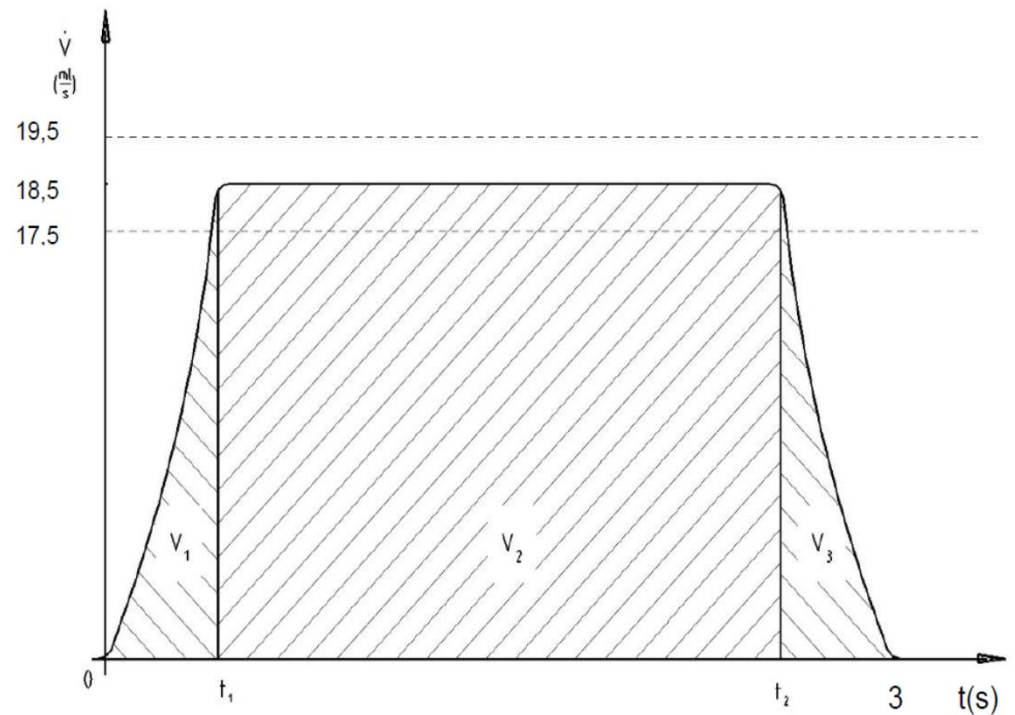


# Double E-HPP GUI



# CORESTA-Recommended Protocol for E-Cigarette Testing

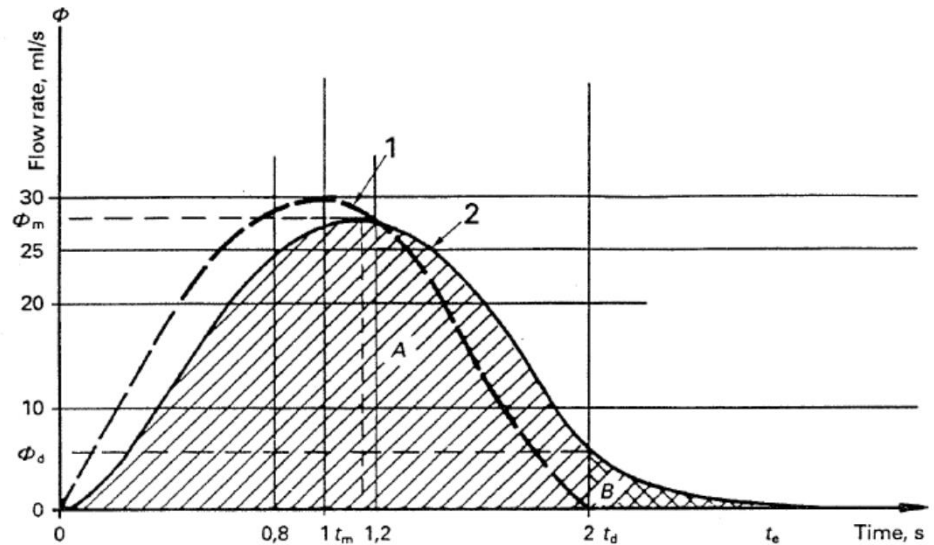
- Puff Duration:  $3 \pm 0.1$  s
- Puff Volume:  $55 \pm 0.3$  ml
- Puff Frequency:  $30 \pm 0.5$  s
- Puff Shape:
  - Top: Flat
  - Sides:  $V_1 + V_3 \leq 5$  ml
- Avg. Max. Flow:  $18.5 \pm 1$  ml





# Standard Protocols for Tobacco Cigarette Testing

Parameter	ISO	CIR
Puff Duration	$2 \pm 0.02$ s	$2 \pm 0.02$ s
Puff Volume	$55 \pm 0.1$ ml	$35 \pm 0.3$ ml
Puff Frequency	$60 \pm 0.5$ s	$30 \pm 0.5$ s
Puff Shape	Bell	Bell
Max Flow Rate	$25 \text{ ml/s} \leq \Phi_m \leq 30 \text{ ml/s}$	-
Peak Time	$0.8 \text{ s} \leq \Phi_m \leq 1.2 \text{ s}$	$0.8 \text{ s} \leq \Phi_m \leq 1.2 \text{ s}$





# Data Analysis Methodology

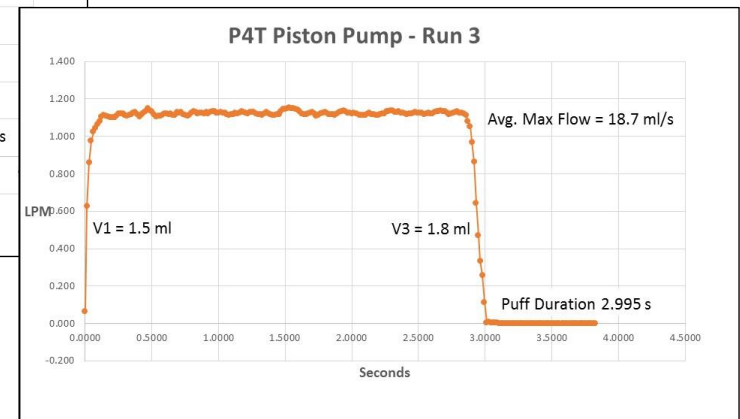
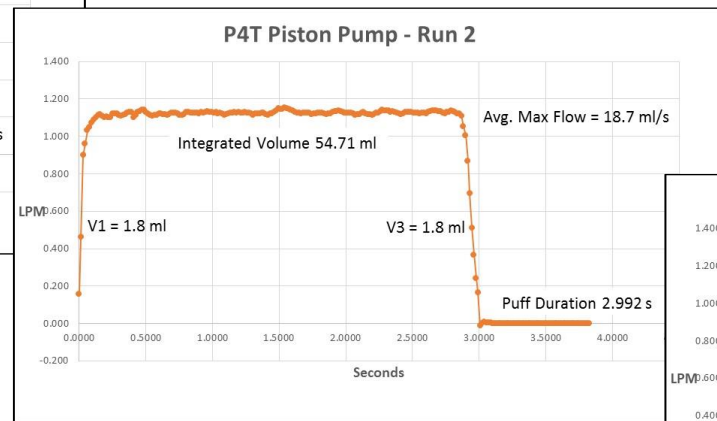
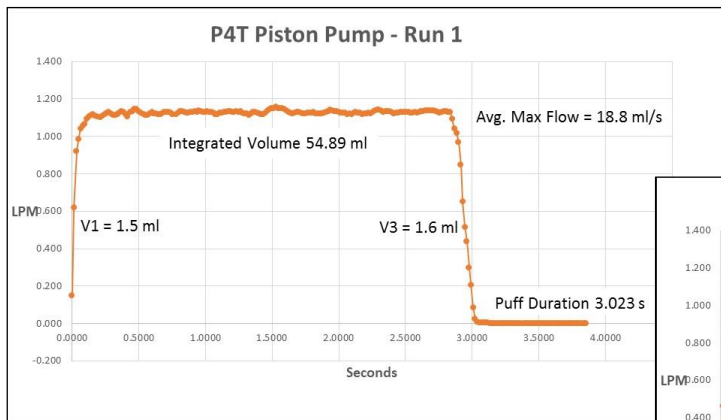
- Determination of the threshold flow rate to mark the beginning and end of each puff. A value of 0.020 L/min was used to demarcate puff duration.
- Each analysis is an average result of at least 5 puffs in a row. An Excel spreadsheet to identify and analyze the puffs based on the threshold flow rate criterion.

# HPP Pump Test Results

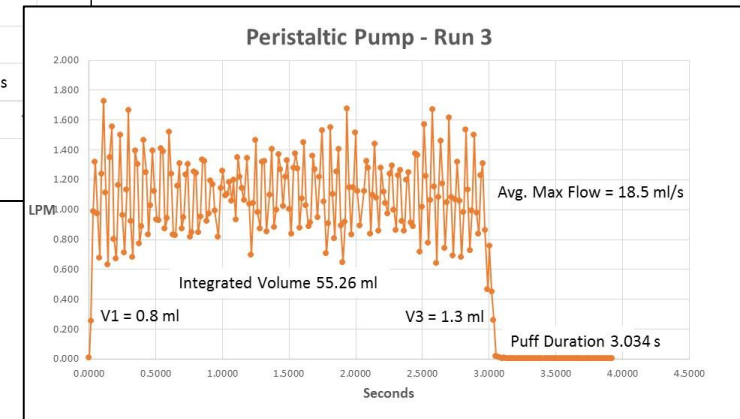
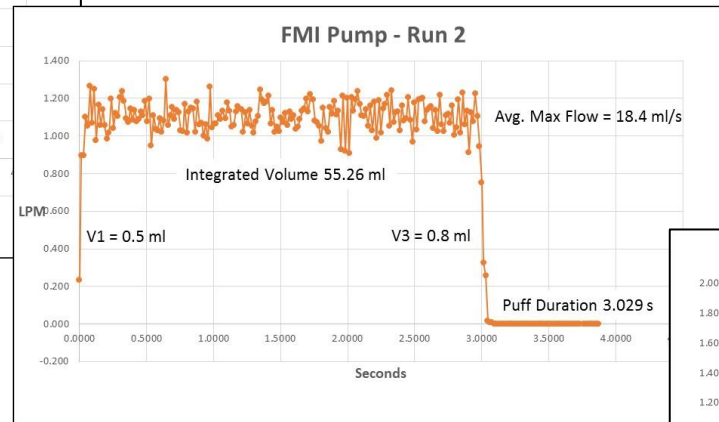
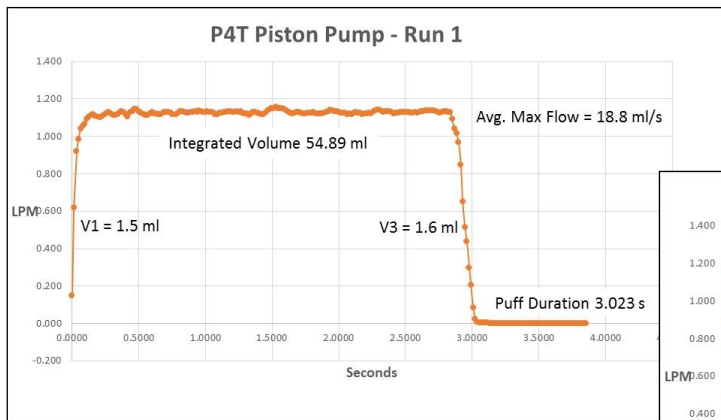
Run #	Puff Duration (s)		Puff Volume (ml) V1 + V2+ V3		Avg. Max Flow Rate (ml/s)		V1 + V3 (ml)	
	Target	Measured	Target	Measured	Target	Measured	Target	Measured
1	3 ± 0.1	3.023	55 ± 0.3	54.89	18.5 ± 1	18.8	< 5.5	3.1
2	3 ± 0.1	2.992	55 ± 0.3	54.71	18.5 ± 1	18.7	< 5.5	3.6
3	3 ± 0.1	2.995	55 ± 0.3	54.64	18.5 ± 1	18.7	< 5.5	3.3
AVG		3.003		54.75		18.8		3.3
SD		0.017		0.13		0.0		0.3



# CORESTA Profiles Generated with HPP Pump



# Comparison of Measured Puff Profiles Shapes \*

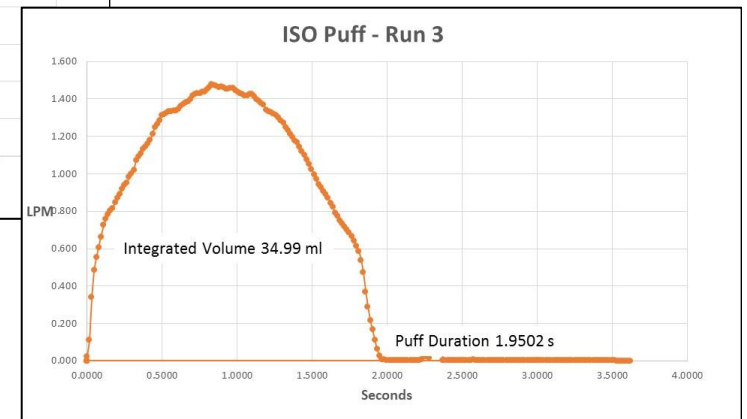
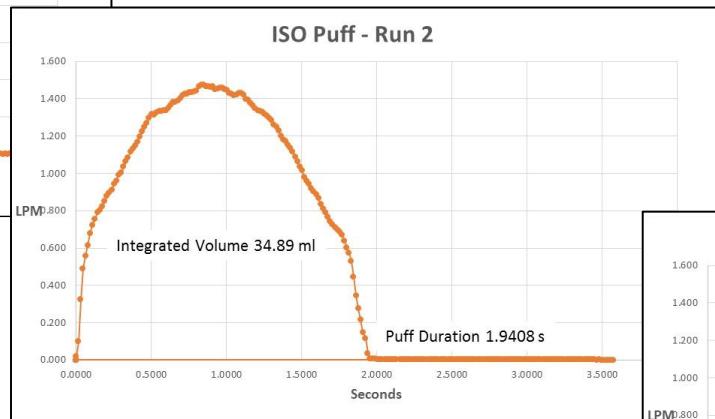
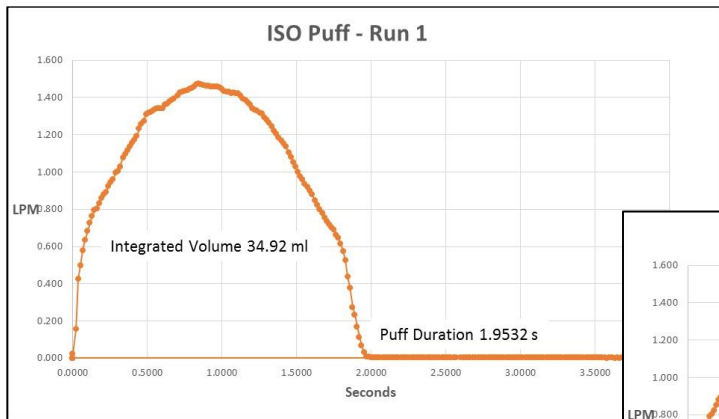


\*Best Performing runs for each type of pump

# ISO Protocol Test Results

	Target Puff Duration (s)	Measured Puff Duration (s)	Target Volume (ml)	Measured Volume (ml)
Run 1	2 ± 0.02	1.953	35 ± 0.3	34.99
Run 2	2 ± 0.02	1.941	35 ± 0.3	34.89
Run 3	2 ± 0.02	1.975	35 ± 0.3	34.92
AVG	2 ± 0.02	1.948	35 ± 0.3	34.93
SD		0.006		0.05

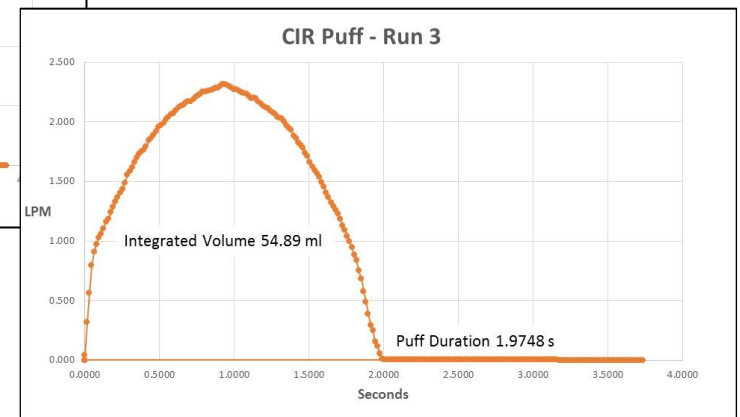
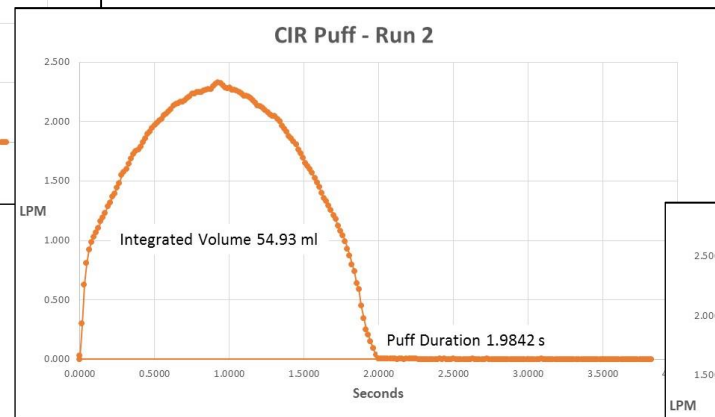
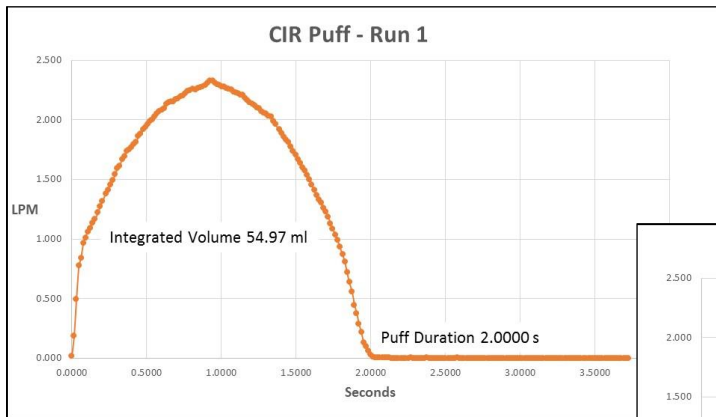
# ISO Profiles Generated with P4T Pump



# CIR Protocol Test Results

	Target Puff Duration (s)	Measured Puff Duration (s)	Target Volume (ml)	Measured Volume (ml)
Run 1	2 ± 0.02	2.000	55 ± 0.3	54.97
Run 2	2 ± 0.02	1.984	55 ± 0.3	54.93
Run 3	2 ± 0.02	1.975	55 ± 0.3	54.89
AVG	2 ± 0.02	1.986	55 ± 0.3	54.93
SD		0.013		0.04

# CIR Profiles Generated with HPP Machine



# Conclusions

- ❑ The proposed E-HPP Smoking Machine satisfactorily meets all the requirements set by the CORESTA recommended method for e-cigarette testing, including puff duration, puff volume, puff shape and inter-puff interval. HPP can deliver smooth and consistent puff profiles.
- ❑ E-HPP can be operated in suction or positive pressure mode, with a single or two independently vaped devices
- ❑ The HPP also offers outstanding performance with CIR, ISO and other standard smoking protocols for standard tobacco burning cigarettes
- ❑ Paired with appropriate analytical instrumentation, the HPP smoking machines could be highly effective when used for e-cigarette toxicity testing or as an R&D tool for assessment and evaluation of Modified Risk Tobacco Products (MRTP)