TANN GROUP

Effect and Influence of Perforation Methods for Tipping Paper on the Control of the Thermal Energy of Smoke from Tobacco Products

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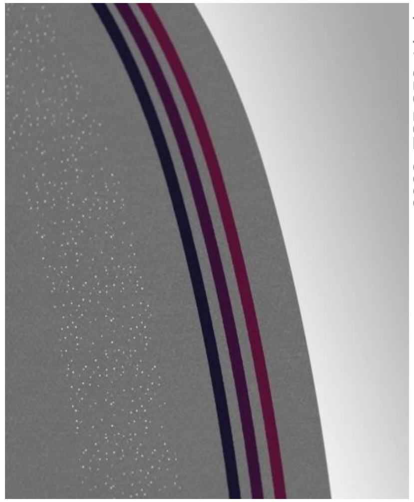
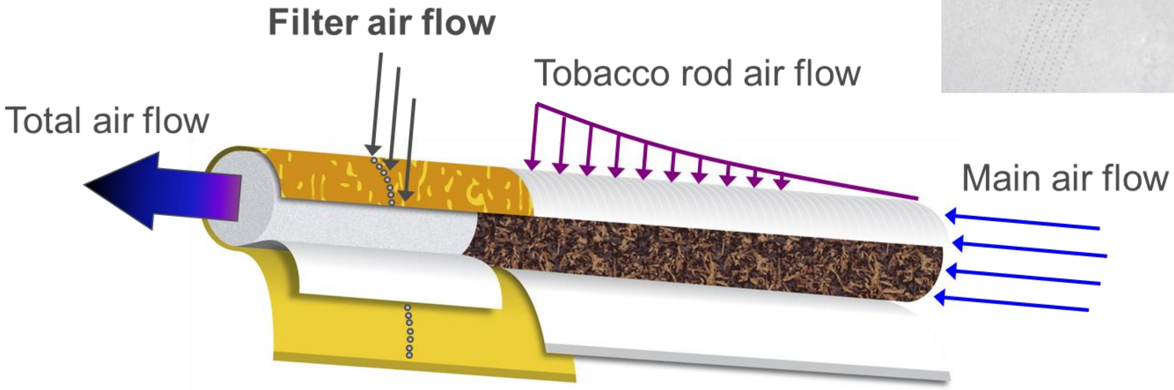
INTRODUCTION

- Definitions:
  - Factory made cigarettes (FMCs): Traditionally combustible filter cigarettes
  - Heated tobacco products (HTPs): Aerosol formed by evaporation and distillation with an electronic heating device (“Heat-not-Burn” products)
- FMCs and HTPs require Tipping Paper:
  - Connection of the tobacco rod with the filter plug
  - Perforation for specific filter ventilation and smoke yields

PERFORATION METHODS

- Electrostatic perforation (EP) by electrostatic discharges
- Laser perforation (LP) with a CO_2-laser
- Plasma Perforation (PP): Generation of invisible perforation holes by means of material evaporation due to low-temperature plasma and inert gas
- Main purpose of perforation: Reduction of gas and particulate yields through dilution





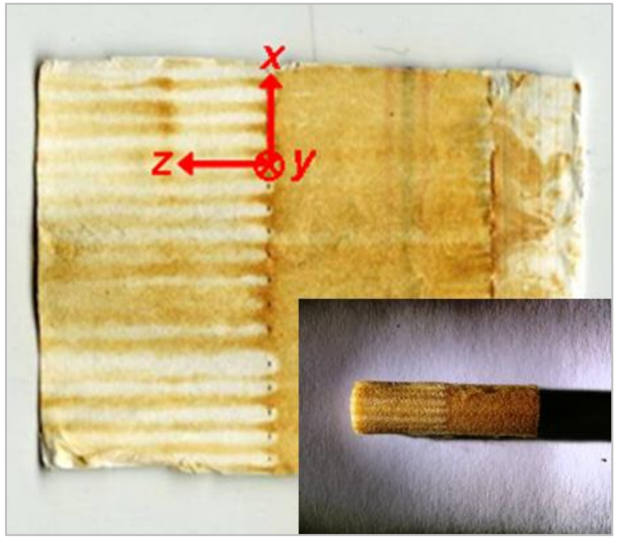
OBJECTIVES

- Influence of different types of Tipping perforation on the thermal energy of mainstream smoke generated by FMCs
- Dynamic smoke flow simulation model for the correlation between the measured smoke temperature and the smoke flow characteristics
- Possible conclusions for the optimization of the aerosol temperature of HTPs

DYNAMIC SMOKE FLOW SIMULATION MODEL

- Introduced in 2011 for evaluating the influence of perforation methods on the sensory properties of cigarette smoke
- Different smoke flow behavior underneath the Tipping Paper / inside the filter:
  - Impact on the taste of smoke → confirmed ✓
  - Impact on the temperature of smoke → open ?
- Based on the Laplace equation → distribution of the air flow intensity *I(x)* after the perforation holes:

$$I(x) = e^{-(\alpha x+\beta)^2} + e^{-(\alpha x-\beta)^2}$$



DYNAMIC SMOKE FLOW SIMULATION MODEL

- α, β… empirical model parameters depending on the physical and geometrical perforation properties:
  - Electrostatic perforation: $\alpha = c_{PW} c_{EP} \cdot \frac{\sqrt[4]{P}}{n_t^2}$ $\beta = \frac{1}{c_{PW}} \frac{\alpha d}{2}$ $c_{EP} = \frac{P^{0,74}}{v}$
  - Offline laser perforation: $\alpha = c_{PW} c_{LP} \cdot \frac{\sqrt{h_t}}{\sqrt[3]{n_t}}$ $\beta = \frac{1}{c_{PW}} \frac{\alpha d}{2}$ $c_{LP} = \frac{P^{0,64}}{v}$
  - Plasma perforation: $\alpha = c_{PW} c_{PP} \cdot \frac{\sqrt[4]{P}}{n_t^2}$ $\beta = \frac{1}{c_{PW}} \frac{\alpha d}{2}$ $c_{PP} = \frac{P^{0,74}}{v}$
  - c_{PW}… pressure drop / flow relationship of air flow through the porous plug wrap paper with its air permeability P_{PW}: $C_{PW} = \frac{P_{PW}^{0,31}}{v}$
  - h_t… number of perforation holes per track, n_t… number of tracks, d… average hole distance, P… air permeability, c_{EP}, c_{LP}, c_{PP}… pressure drop / flow relationship of air flow through the Tipping vents, v… air flow velocity: $v = \frac{VG_f}{100} \cdot \sqrt{\frac{2(p_{appl} - 9,81 \cdot p_{open})}{\rho}}$, VG_f… degree of filter ventilation, p_{open}… open pressure drop, p_{appl}… applied pressure difference, ρ… mass density of air

SAMPLE PREPARATION

- Cigarette samples produced by C.I.T. MONTEPAZ S.A. in Uruguay

Sample Number	Perforation Type	Number of Tracks	Number of Holes / Track	Permeability [CU]	Open Pressure Drop [mm H_2O]	Filter Ventilation [%]
1	Electrostatic	1	NA	150	107	21
2	Electrostatic	1	NA	300	96	34
3	Electrostatic	1	NA	450	85	42
4	Electrostatic	1	NA	800	71	58
5	Offline-Laser	4	34	150	106	23
6	Offline-Laser	4	38	300	97	34
7	Offline-Laser	4	42	450	84	43
8	Offline-Laser	4	52	800	70	59
9	Plasma	1	NA	150	112	20
10	Plasma	1	NA	300	100	31
11	Plasma	1	NA	450	92	39
12	Plasma	1	NA	800	80	50

- American blend tobacco, 24000 CU PWP, 50 CU non-LIP CP
- Mainstream smoke temperature & mathematical evaluation

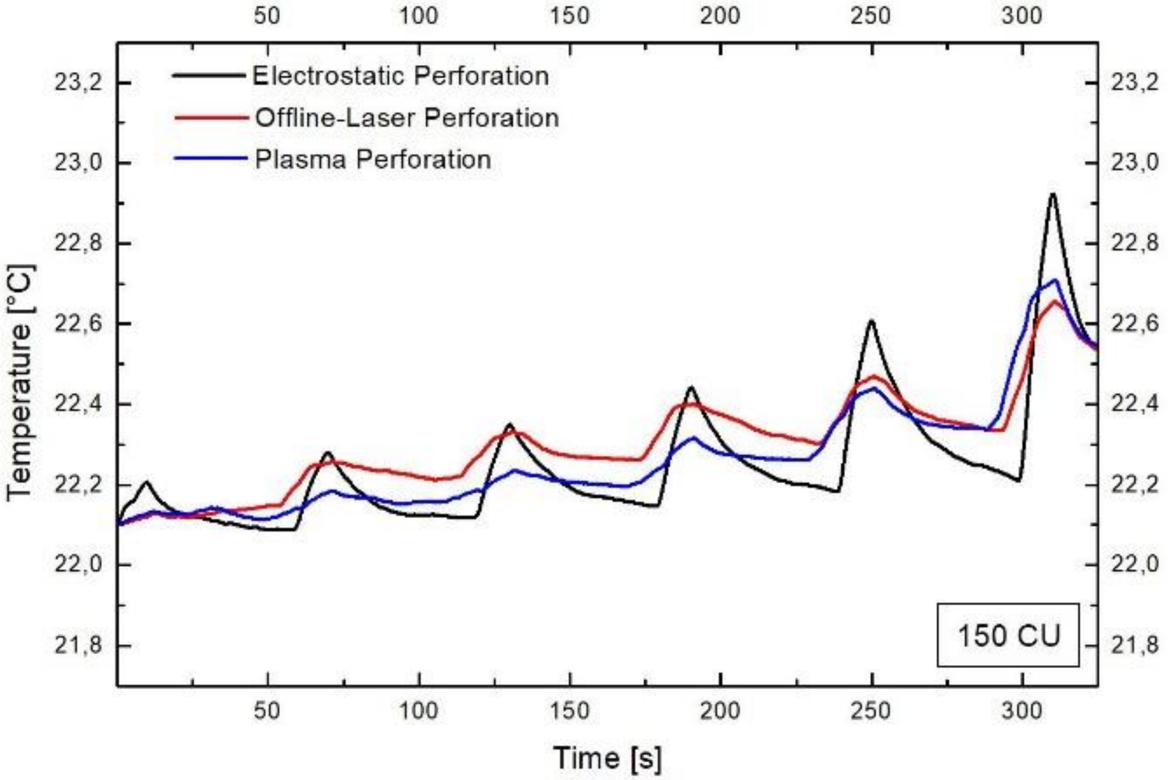
TEST METHOD

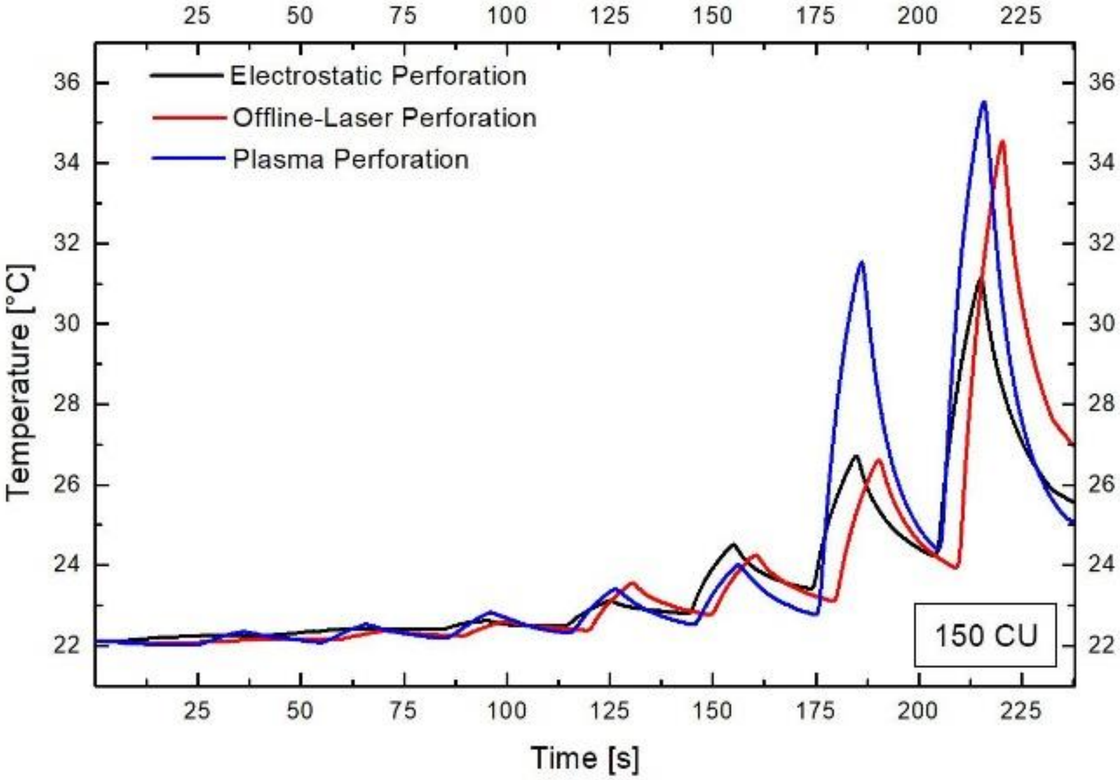
- Analysis of the mainstream smoke temperature: Linear smoking machine SM450 from Cerulean
- Determination of the time-dependent smoke temperature inside the Cambridge filter (full consumption of cigarette samples)
- 2 smoking regimes:
  - ISO 3308 smoking
  - Intense smoking (ISO 20778) with unblocked vents

EXPERIMENTAL RESULTS:

COMPARISON BETWEEN PERFORATION METHODS AT SPECIFIC PERMEABILITY LEVELS

- **150 CU:** Mainstream smoke temperature vs. combustion time



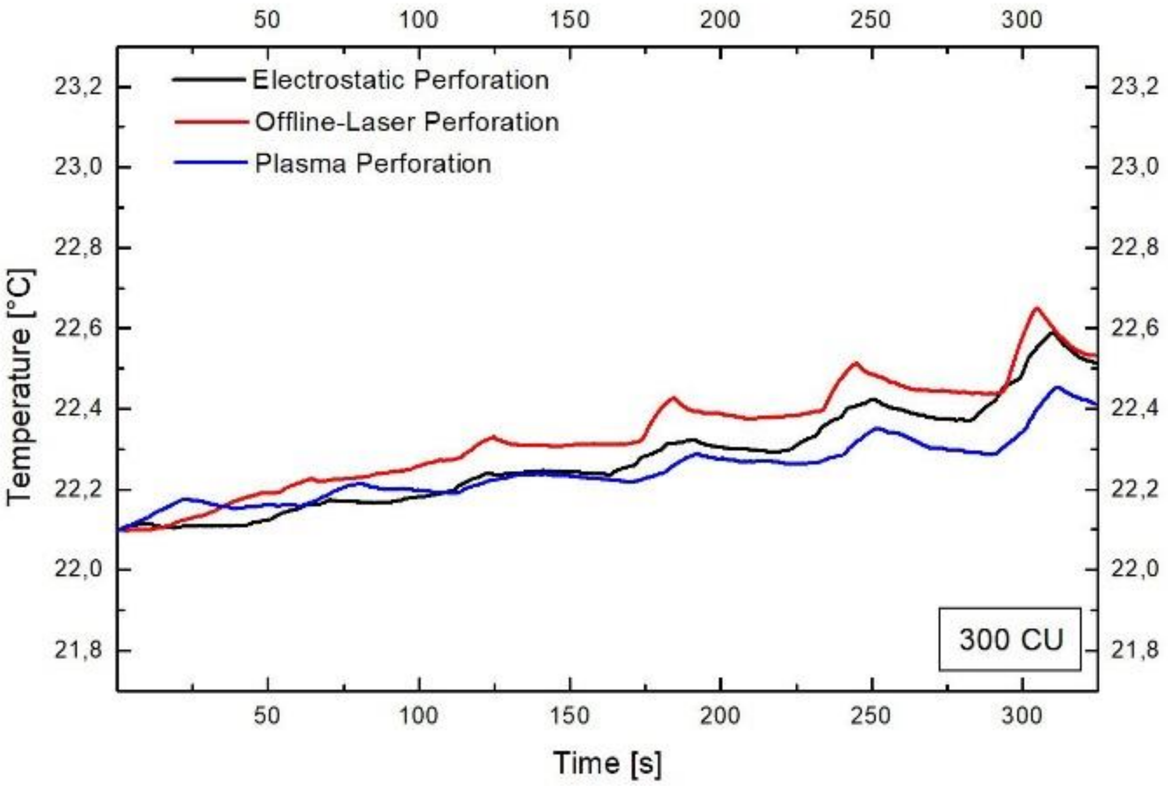


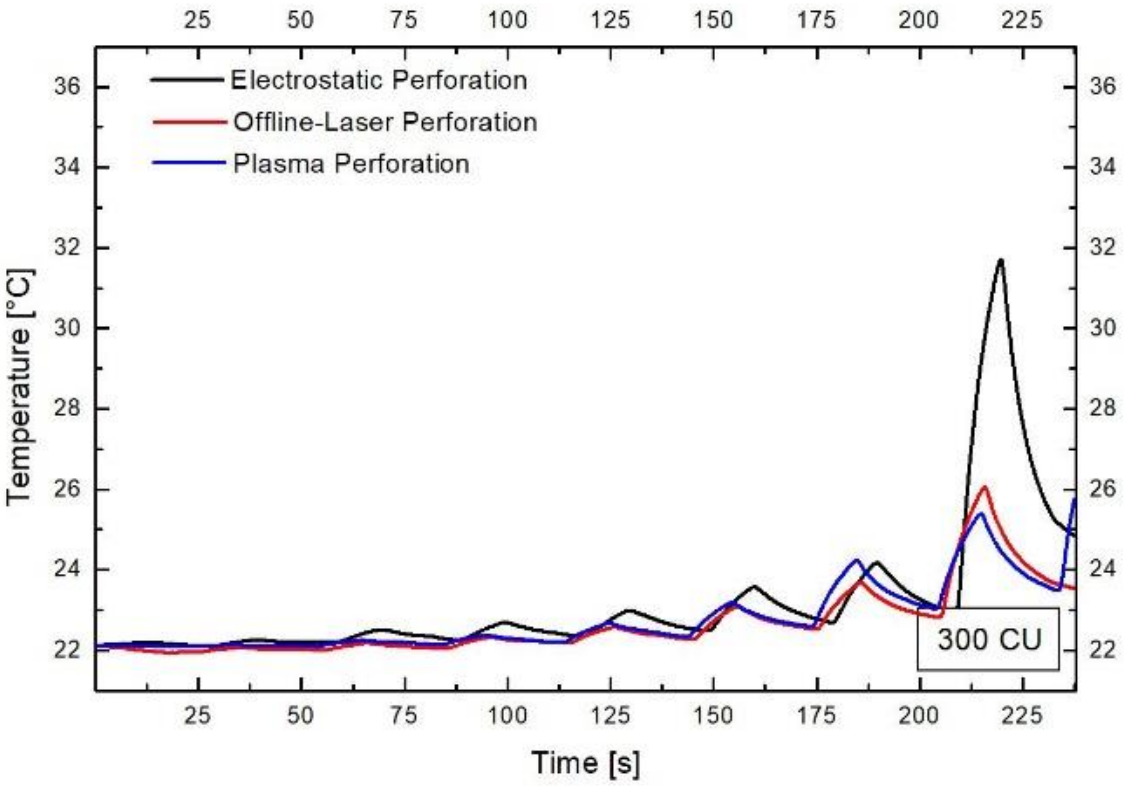
ISO 3308 smoking:
EP = Strong amplitudes
LP / PP = Lower peaks

Intense smoking:
EP / LP / PP = High peaks
EP = Weakest last amplitude

EXPERIMENTAL RESULTS:
COMPARISON BETWEEN PERFORATION METHODS AT SPECIFIC PERMEABILITY LEVELS

- **300 CU:** Mainstream smoke temperature vs. combustion time



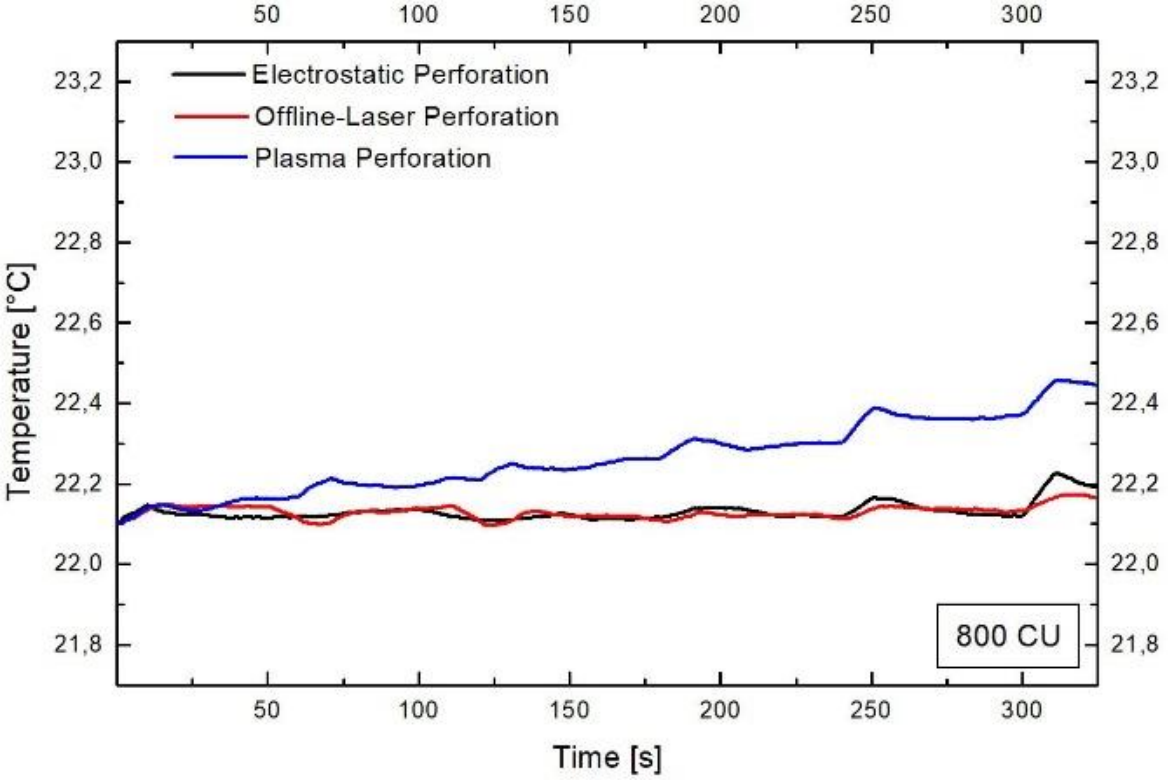


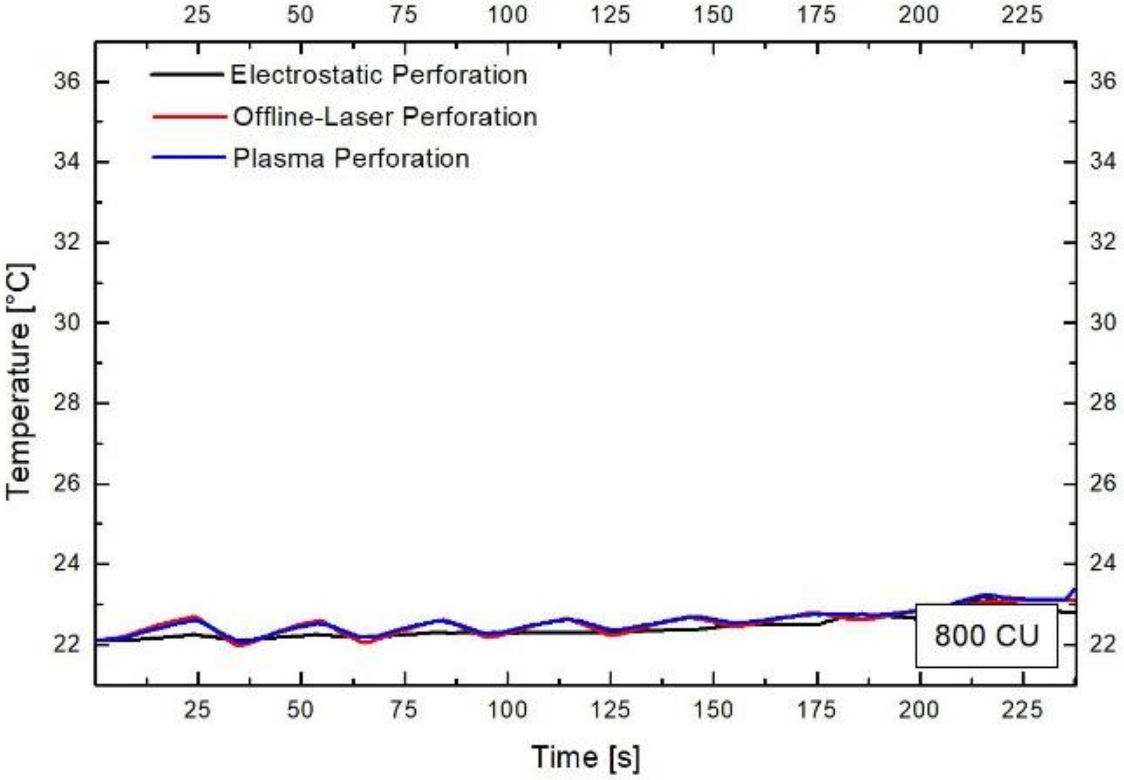
ISO 3308 smoking:
EP / LP / PP = Low peaks
No significant differences

Intense smoking:
EP / LP / PP = Low peaks
Last amplitude of EP = ?

EXPERIMENTAL RESULTS:
COMPARISON BETWEEN PERFORATION METHODS AT SPECIFIC PERMEABILITY LEVELS

- **800 CU:** Mainstream smoke temperature vs. combustion time



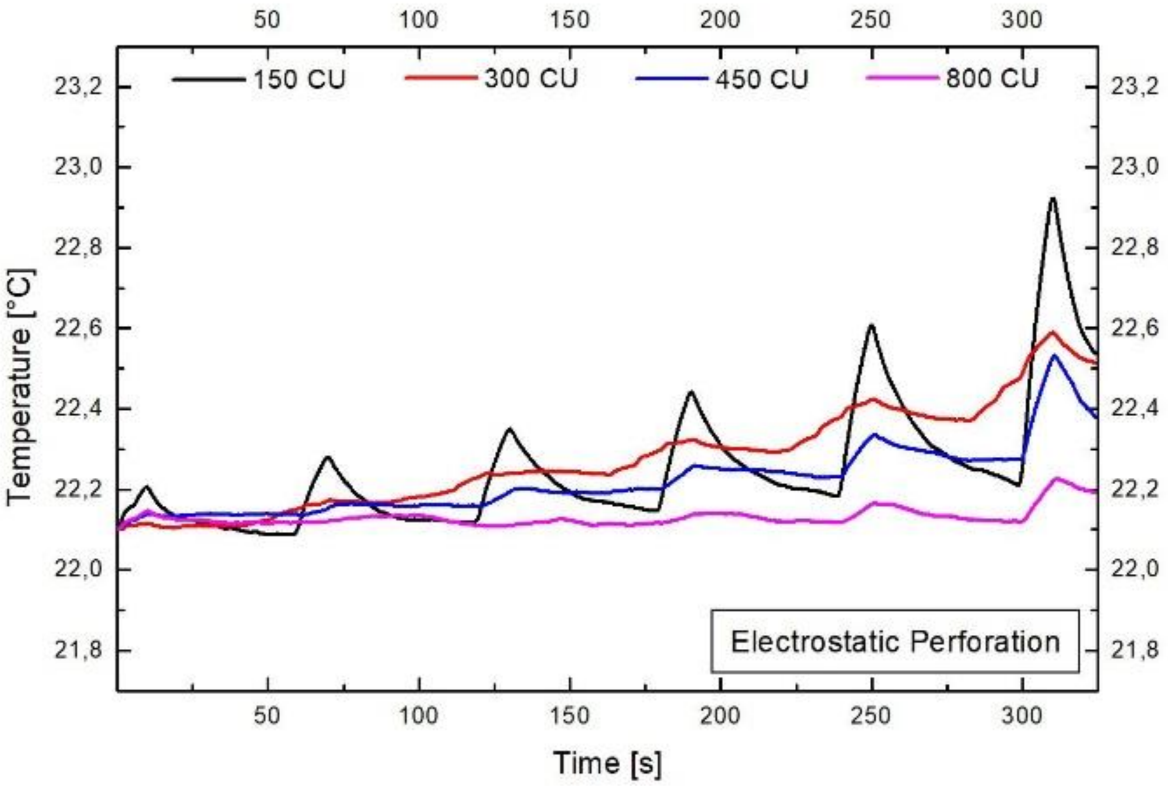


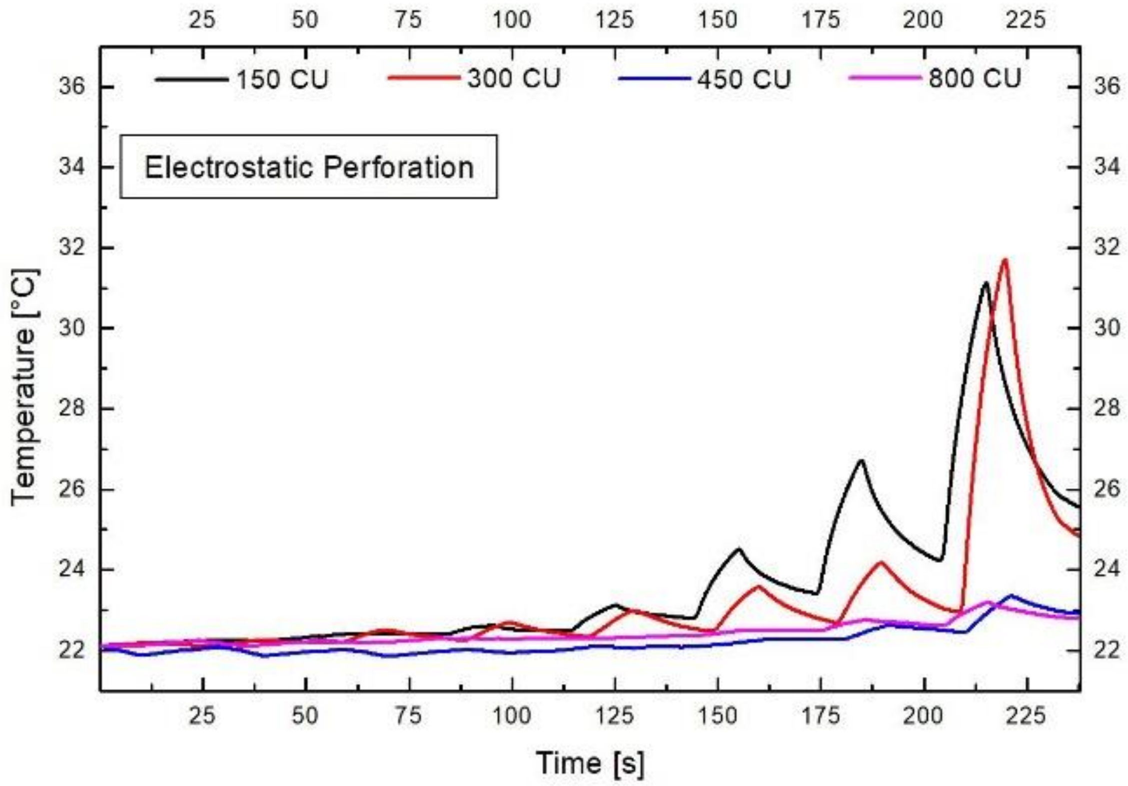
ISO 3308 smoking:
EP / LP / PP =
Very low peaks

Intense smoking:
EP / LP / PP =
Peaks disappearing

EXPERIMENTAL RESULTS:
COMPARISON BETWEEN DIFFERENT PERMEABILITY LEVELS FOR A SPECIFIC PERFORATION METHOD

- **EP:** Mainstream smoke temperature vs. combustion time





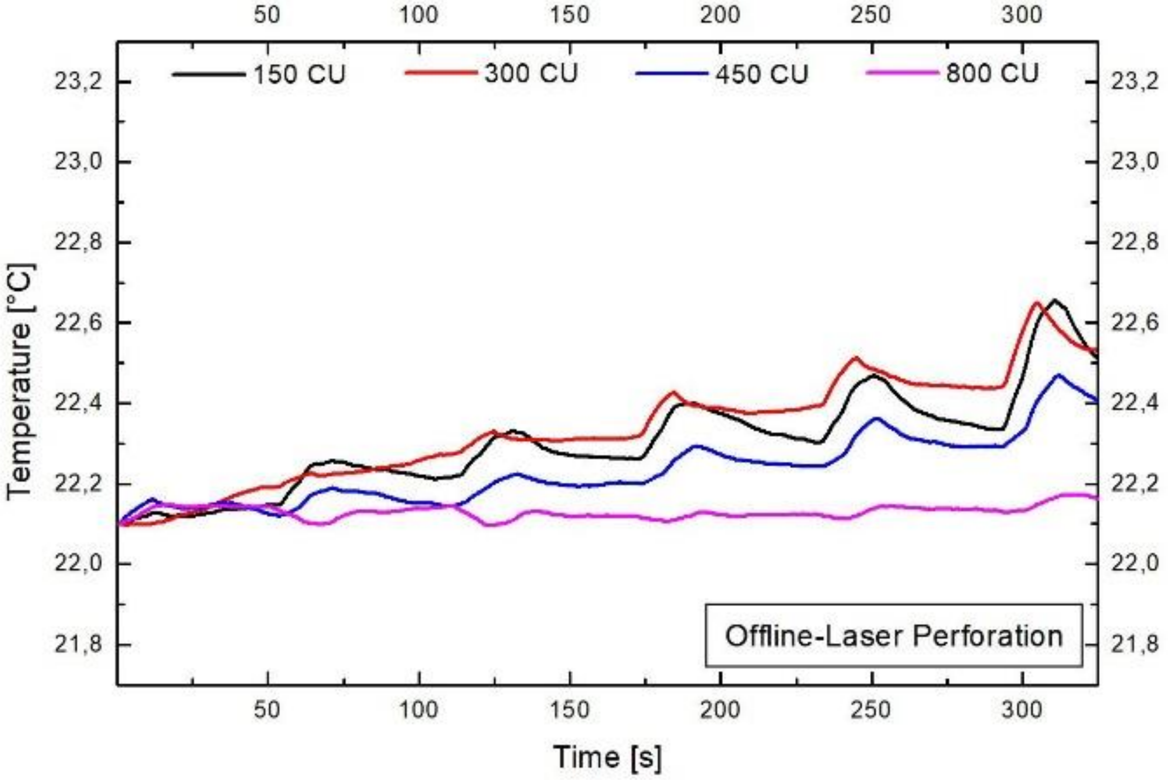
ISO 3308 smoking:
Uniform decrease of the peaks with increasing air permeability

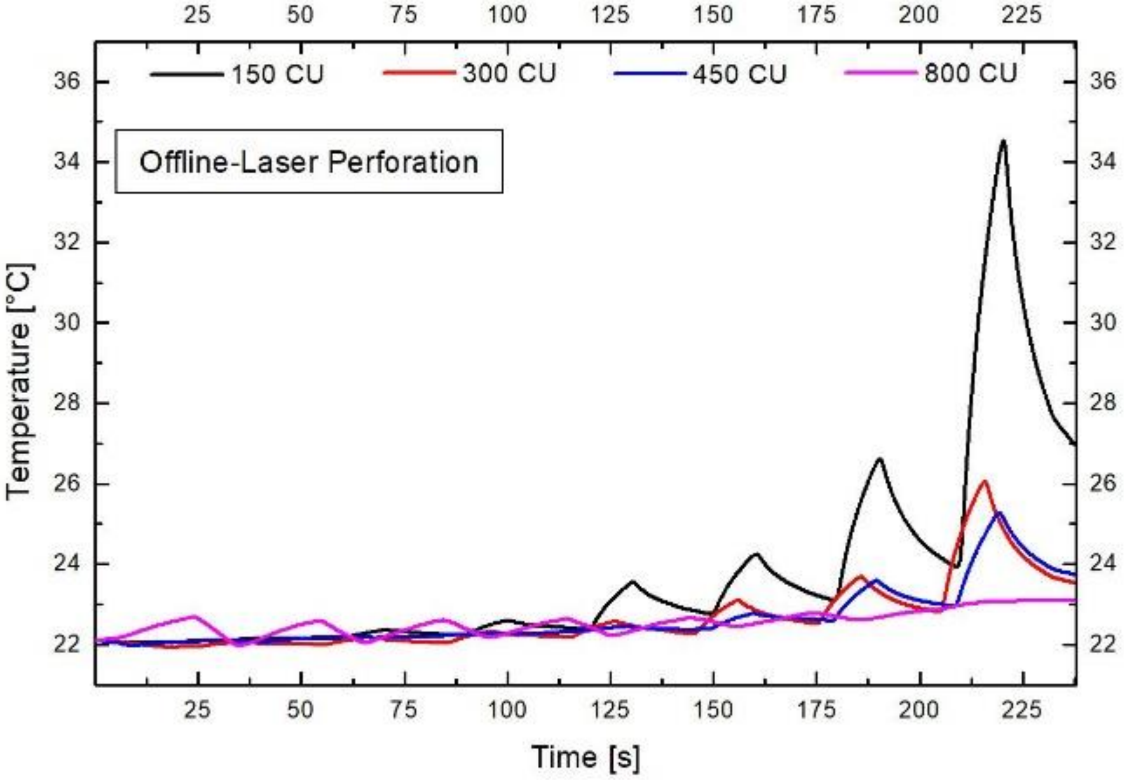
Intense smoking:
Drop of the peaks when switching from 300 to 450 CU

EXPERIMENTAL RESULTS:

COMPARISON BETWEEN DIFFERENT PERMEABILITY LEVELS FOR A SPECIFIC PERFORATION METHOD

- **LP:** Mainstream smoke temperature vs. combustion time





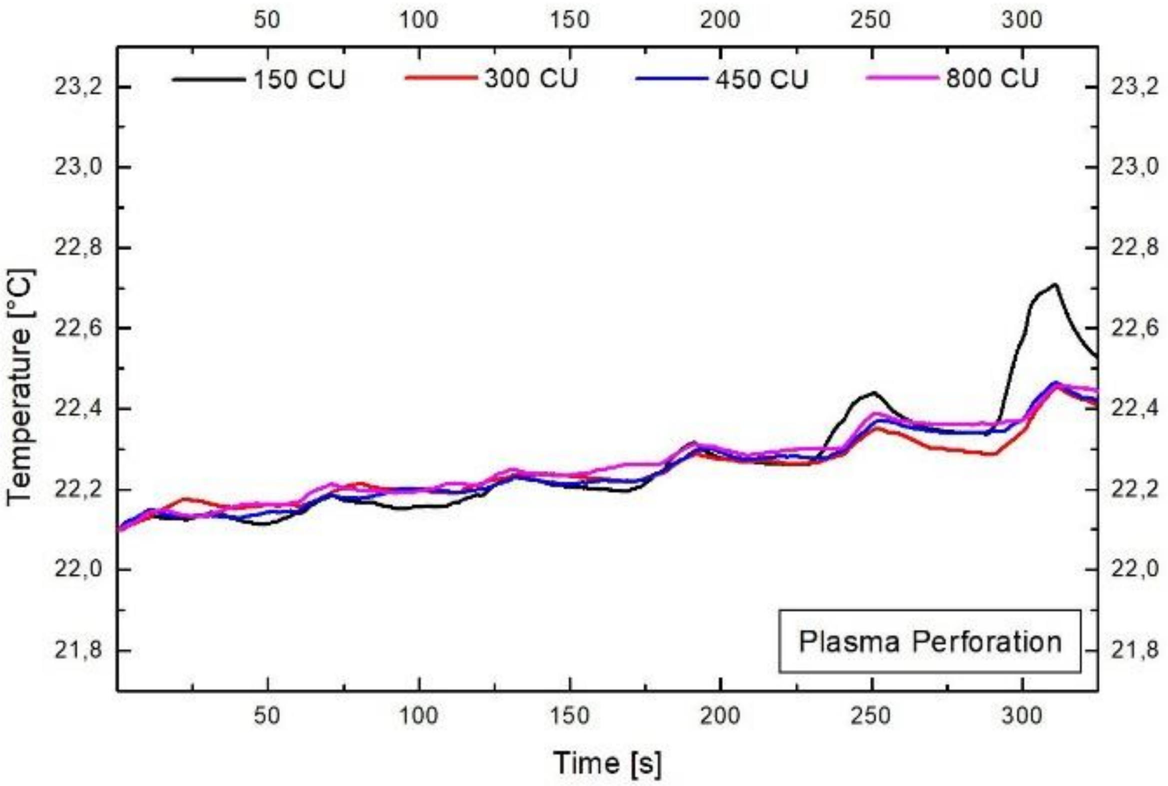
ISO 3308 smoking:
Uniform decrease of the peaks with increasing air permeability

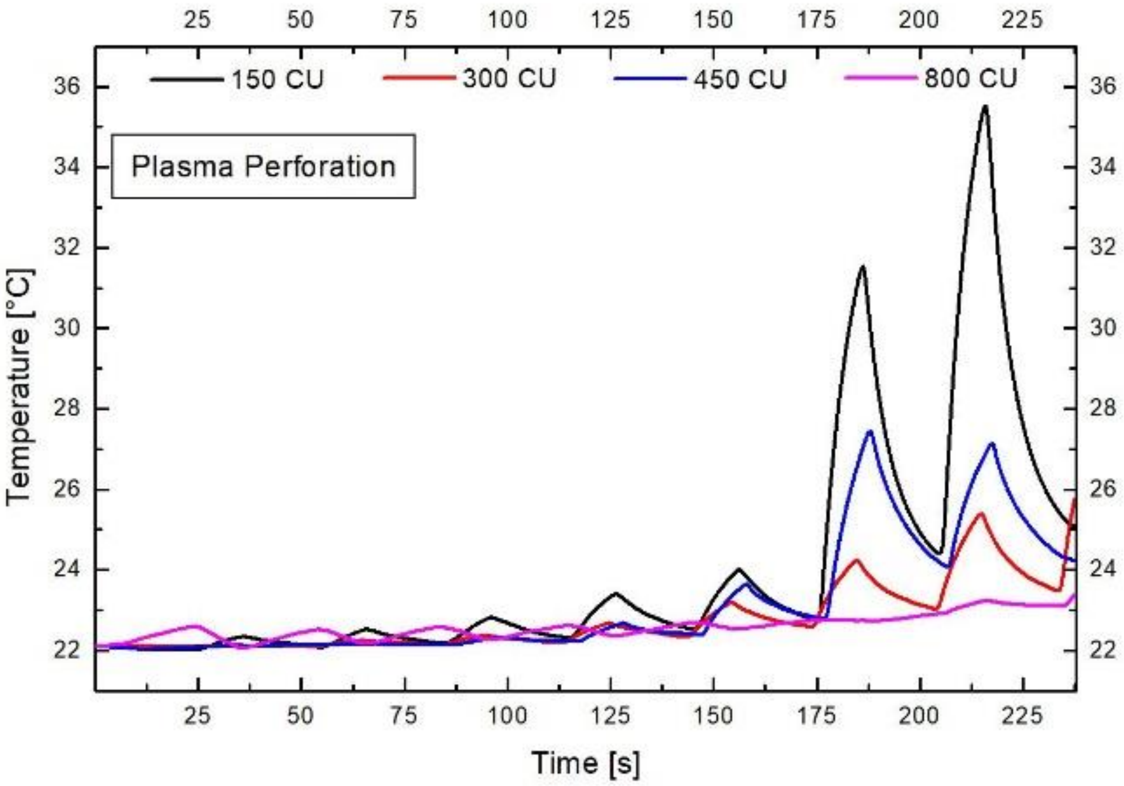
Intense smoking:
Drop of the peaks when switching from 450 to 800 CU

EXPERIMENTAL RESULTS:

COMPARISON BETWEEN DIFFERENT PERMEABILITY LEVELS FOR A SPECIFIC PERFORATION METHOD

- **PP:** Mainstream smoke temperature vs. combustion time





ISO 3308 smoking:
Uniform decrease of the peaks with increasing air permeability

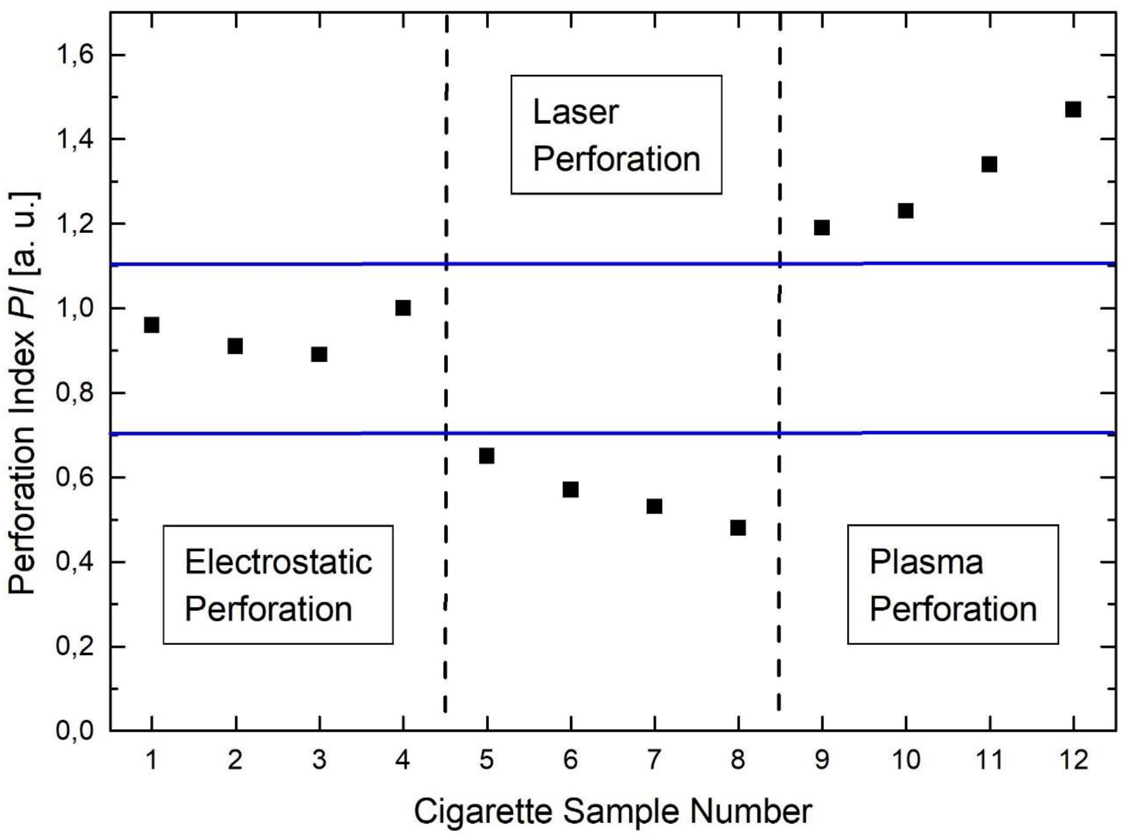
Intense smoking:
Drop of the peaks when switching from 450 to 800 CU

EXPERIMENTAL RESULTS:

CORRELATION BETWEEN THE SMOKE TEMPERATURE AND THE SMOKE FLOW CHARACTERISTICS (ISO 3308)

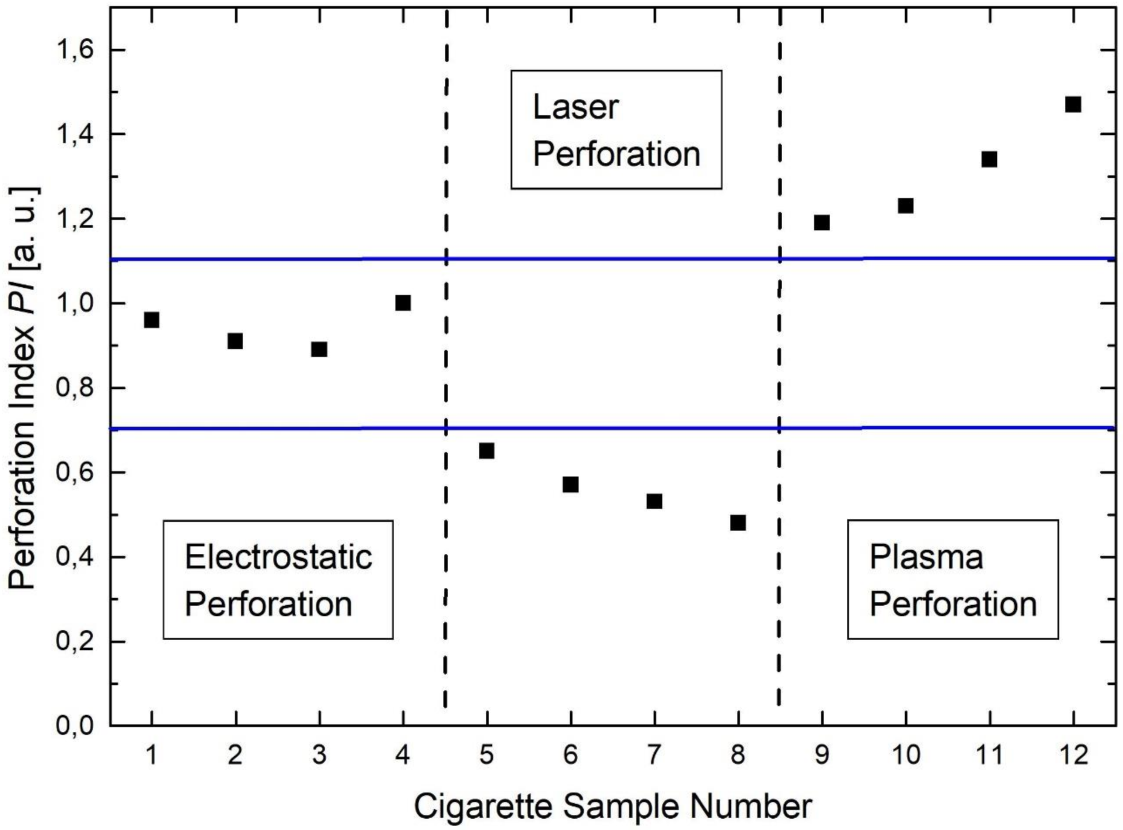
- Consideration of the dynamic smoke flow simulation model
- Calculation of the two model parameters α and β
- Relative complex experimental interpretation of the cigarette smoke temperature
- General rule for adjusting the perforation specifications → perforation index *PI*:

$$PI = \frac{\alpha + \beta}{2}$$



EXPERIMENTAL RESULTS:
CORRELATION BETWEEN THE SMOKE TEMPERATURE AND THE SMOKE FLOW CHARACTERISTICS (ISO 3308)

- Interpretation:
  - Samples 1 to 4 (EP):
    PI between 0,7 and 1,1
  - Samples 5 to 8 (LP):
    PI below 0,7
  - Samples 9 to 12 (PP):
    PI above 1,1
  - Guideline for perforation parameters for specific *PIs*
  - Impact on the thermal properties of cigarette smoke
  - Mainly applicable to ISO 3308 smoking



SUMMARY

- Correlation between the mainstream smoke temperature of combustible cigarettes and different Tipping perforation methods:
  - Experimental determination of the smoke temperature
  - Technical perforation parameters (EP, LP, PP) → dynamic smoke flow simulation model
  - ➢ All perforation types are suitable for reliable temperature control
  - ➢ Higher homogeneity of the air flow = more efficient temperature reduction (ISO 3308)
  - ➢ Correlation described with the perforation index
  - ➢ Potential application of the findings to HTPs

THANK YOU FOR YOUR VALUABLE QUESTIONS & FEEDBACK!

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