Free Margin Masking of Capacitor Film by Flash Evaporation

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Outline

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- Motivation - conventional Free Margin Evaporator
- Requirements of the new FME
- Technology – Principle of Operation of new FME
- Experiments & Results
- Advantages of the new FME for Customers
- Cost Savings Calculation
- Summary

Motivation: Disadvantages of Conventional FME

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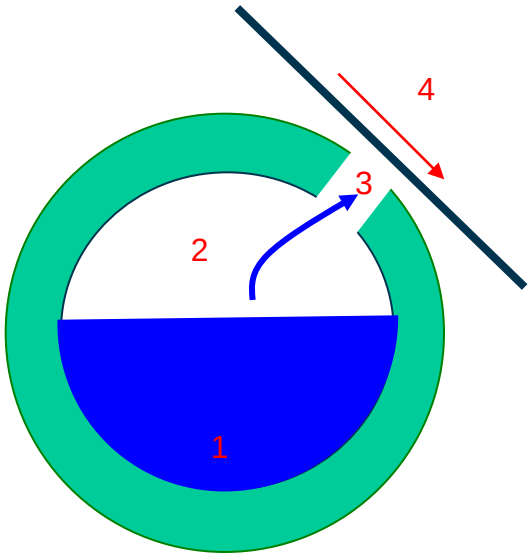
- **The Cylindrical Evaporator Tube**



- Large, excess amount of oil heated
- Degradation of excess oil during processing
- Unable to regulate oil temperature during process
- Temperature regulation dependent upon oil level
- Laborious refill
- Unable to refill during web coating
- Oil evaporation before start of web coating
  = contamination of chamber and waste of oil

1. Oil, **2.** Oil vapor, **3.** Nozzle, **4**. Substrate (web), and web direction

Requirements:

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Requirements of a new **F**ree **M**argin **E**vaporator (FME)

- Fast start, & stop of masking
- Optimum, constant amount of masking oil on film
- Fast regulation of oil thickness on film during process
- Minimum oil consumption (only amount needed for masking)
- No excess oil heated in machine (No degradation, No waste oil)
- Free margin edge steepness can be controlled
- No contamination of chamber & rollers during start & stop
- Easy refill of oil during process

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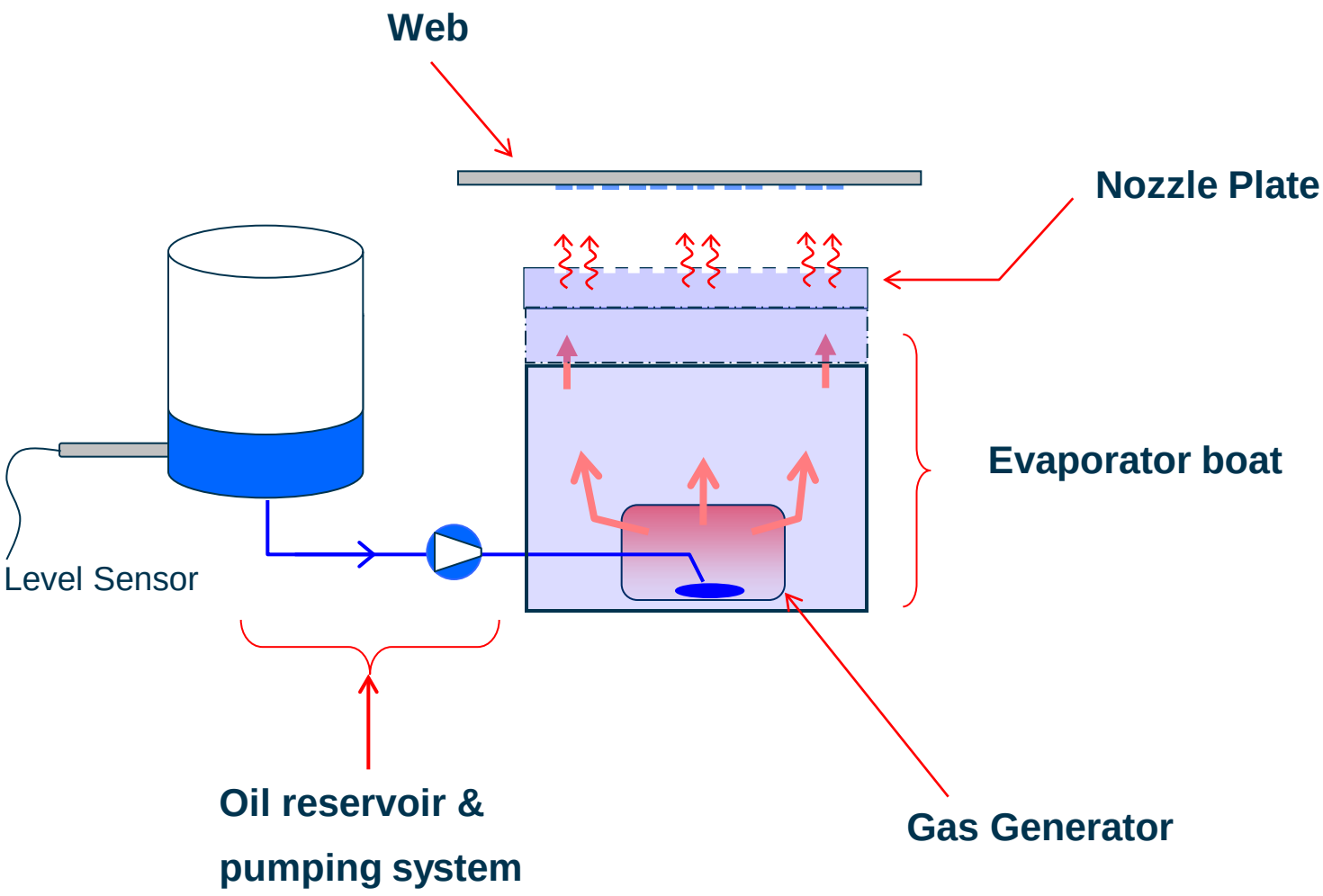
The Set-up: Schematic of the new FME Design



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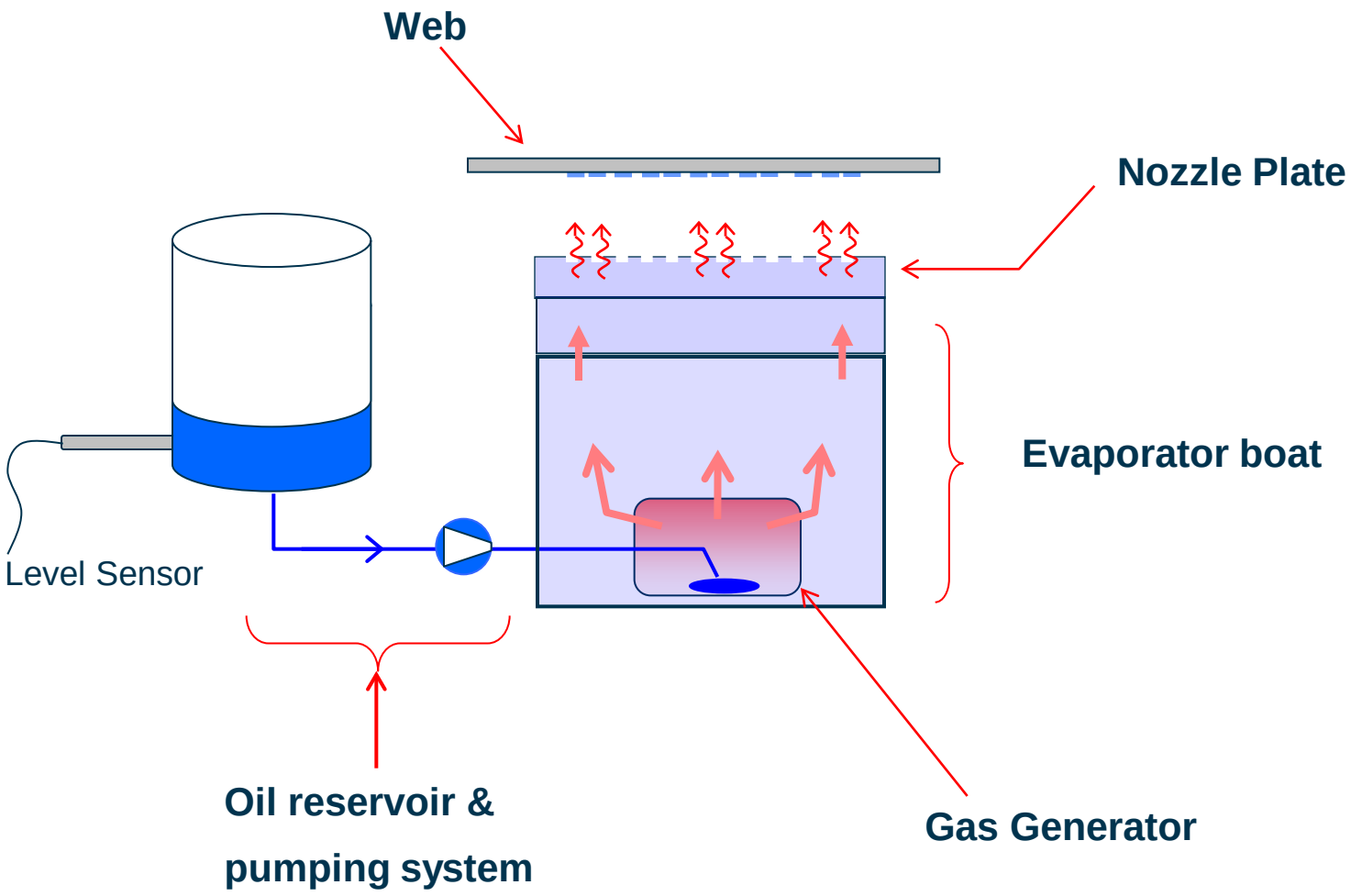
In process: Evaporation



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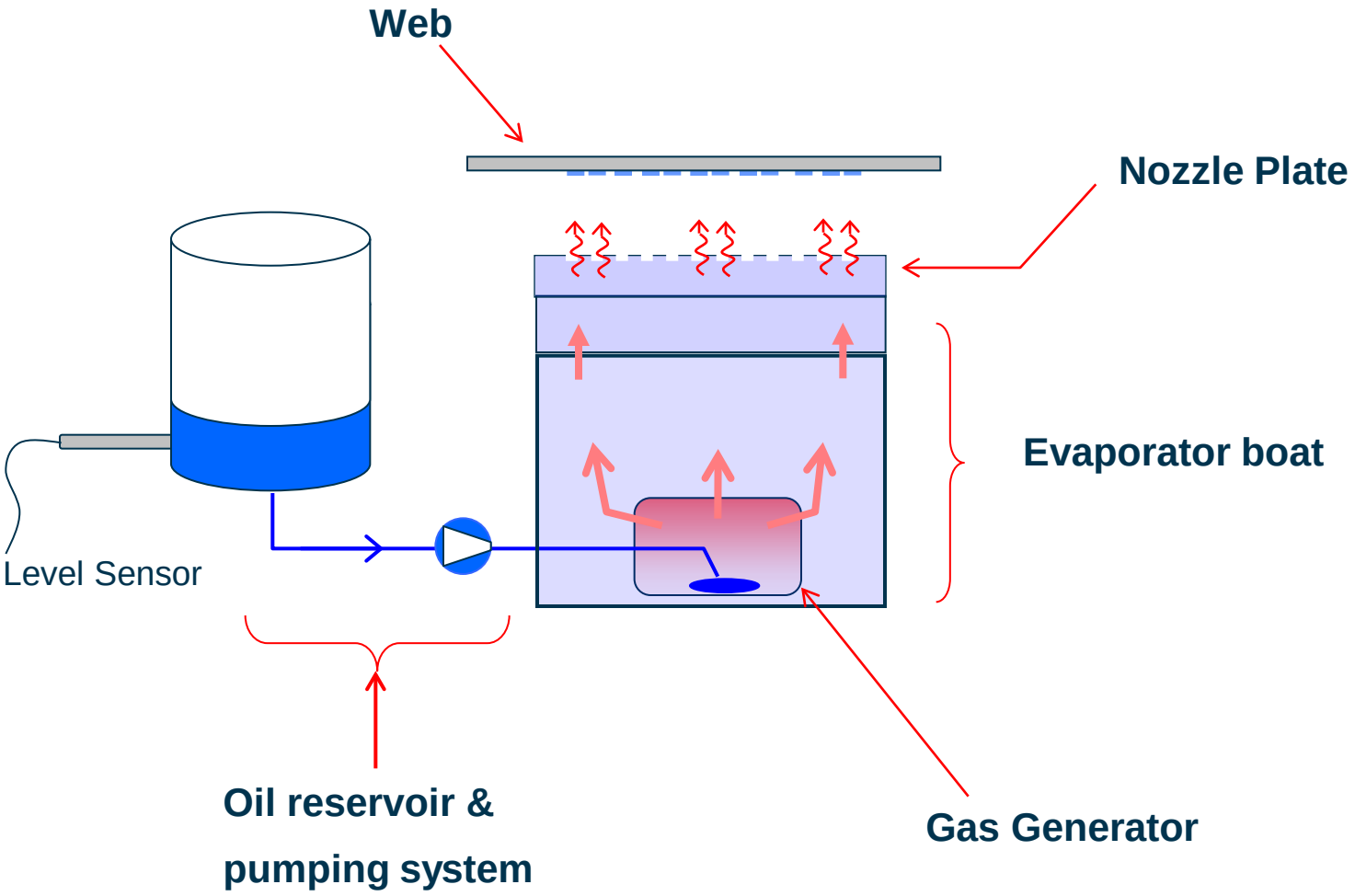
Increase Evaporation Rate



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EXPERIMENTS – The Main Parameters

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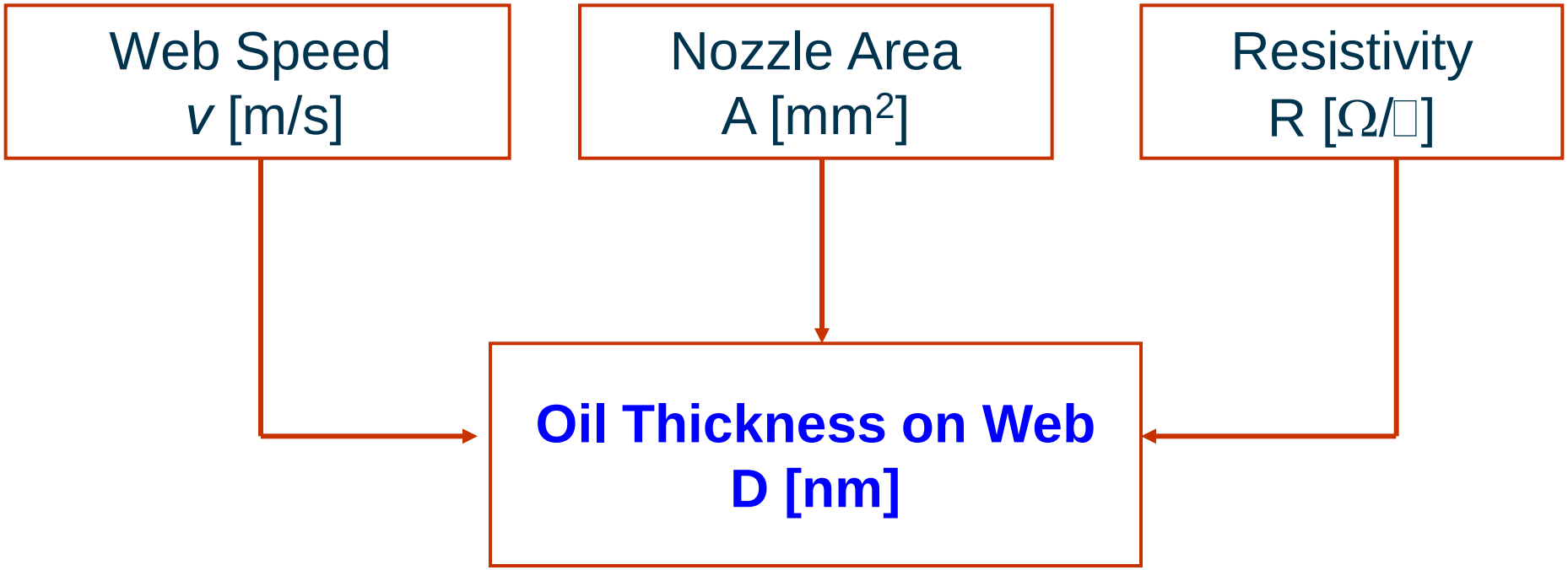
- Oil Consumption & Free Margin Quality mainly depend on three parameters:



Experiment: Oil masking thickness on web

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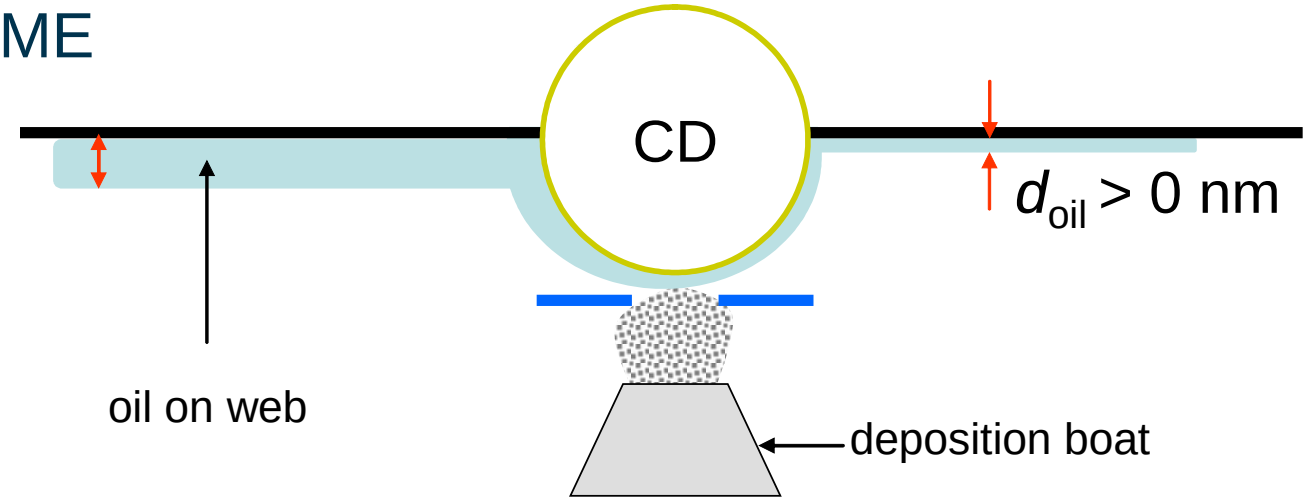
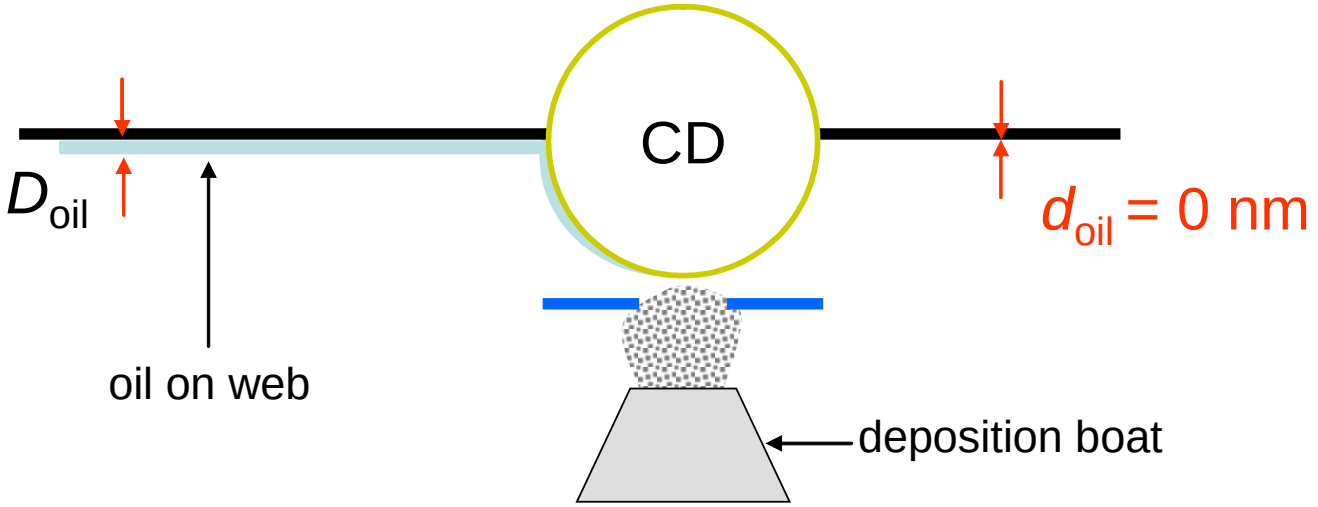
- Conventional FME



- The New FME



How can the D_{oil} be determined for all the variables?

Experiment: Oil masking thickness on web

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$$D_{oil(t)} \approx \frac{\dot{F}\,flow_{(t)}}{v_{(t)} \cdot w}$$

$$V_{oil} \approx \dot{F}\,flow_{(t)}$$

whereby;

$D_{oil} = oil\ thickness\ on\ web\ [m],$

$\dot{F}_{flow} = oil\ \ flow\ rate\ [l/s],$

$V_{oil} = total\ oil\ consumed\ [m^3],$

$w = nozzle\ width\ [m],$

$v = web\ speed\ [m/s],$

$t = coating\ duration\ [s].$

- Calculations are based on web speed, & volumetric flow rate and are not valid for the conventional FME (because flow rate cannot be regulated and slow heating rate during coating process)

Experiments – Parameters

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Web Speed

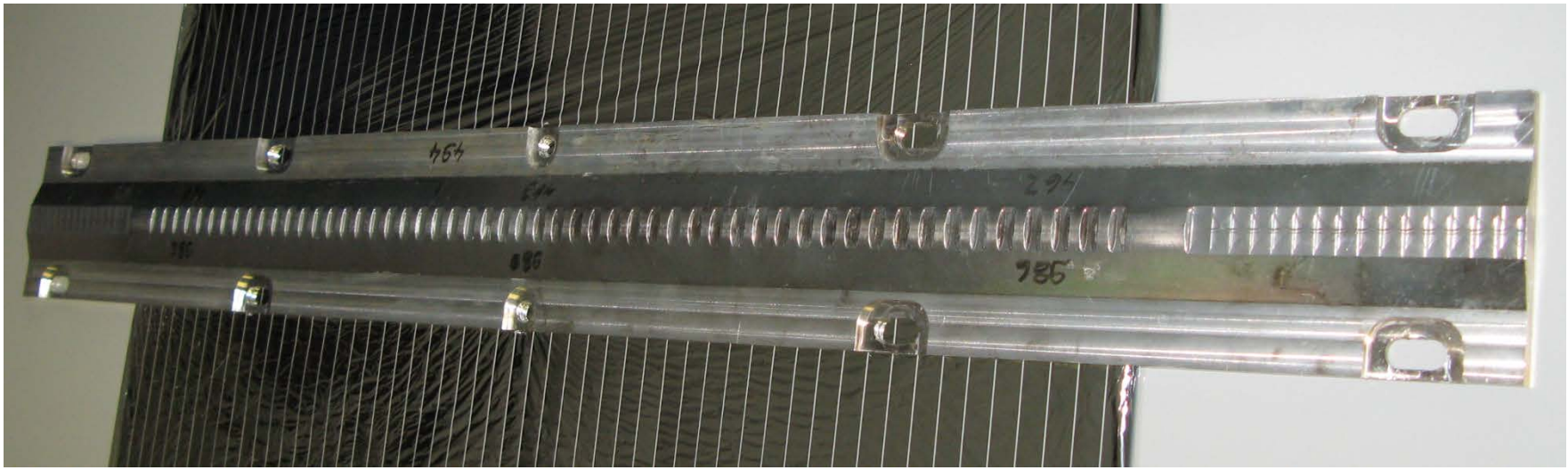
- 5 – 18 m/s

Nozzle types [% Free Margin]

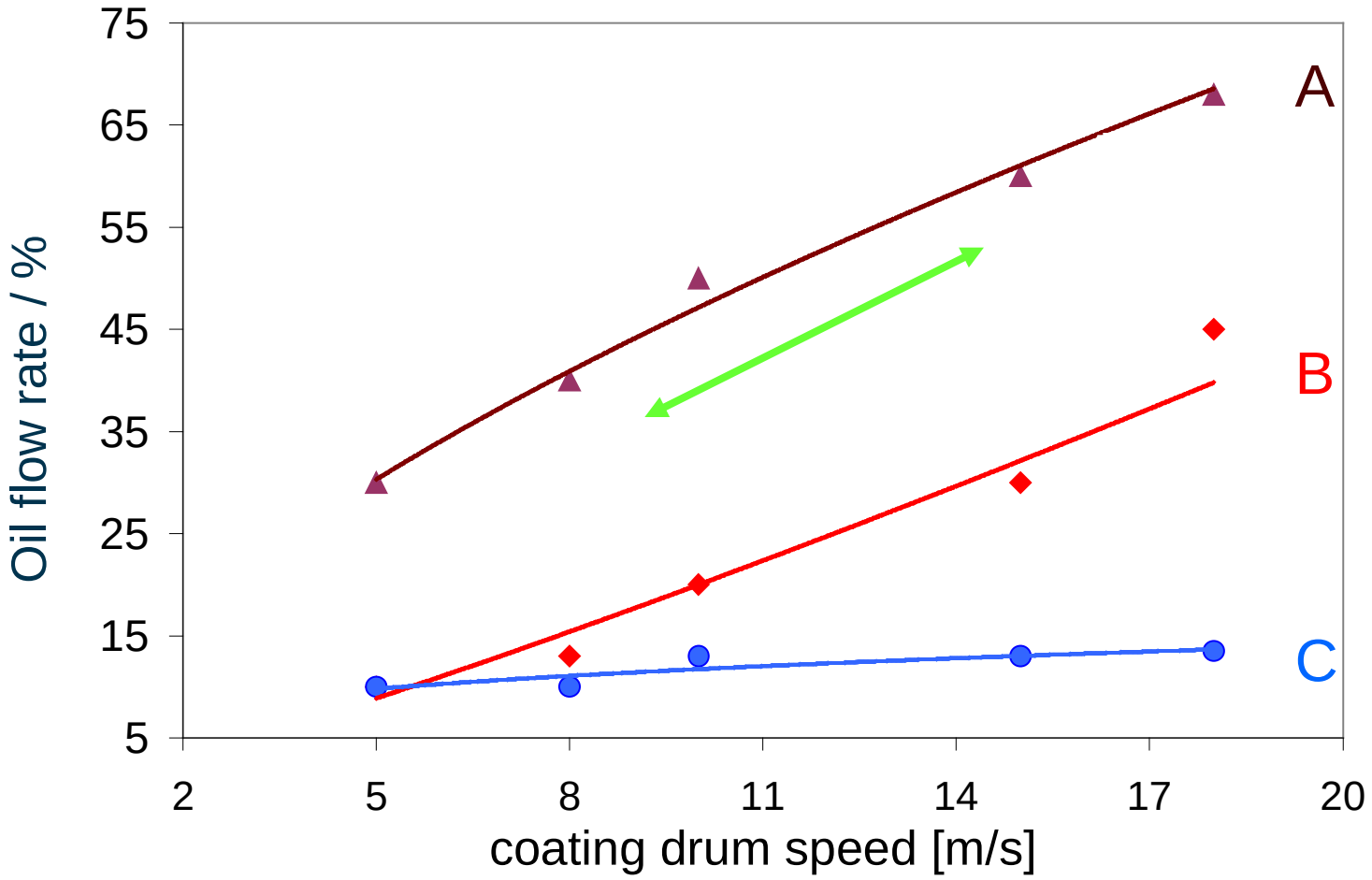
- 4.5%, 6%, 25%

Resistivity – Al, Al/Zn

- 1.5 – 7.5 Ohm /sqr

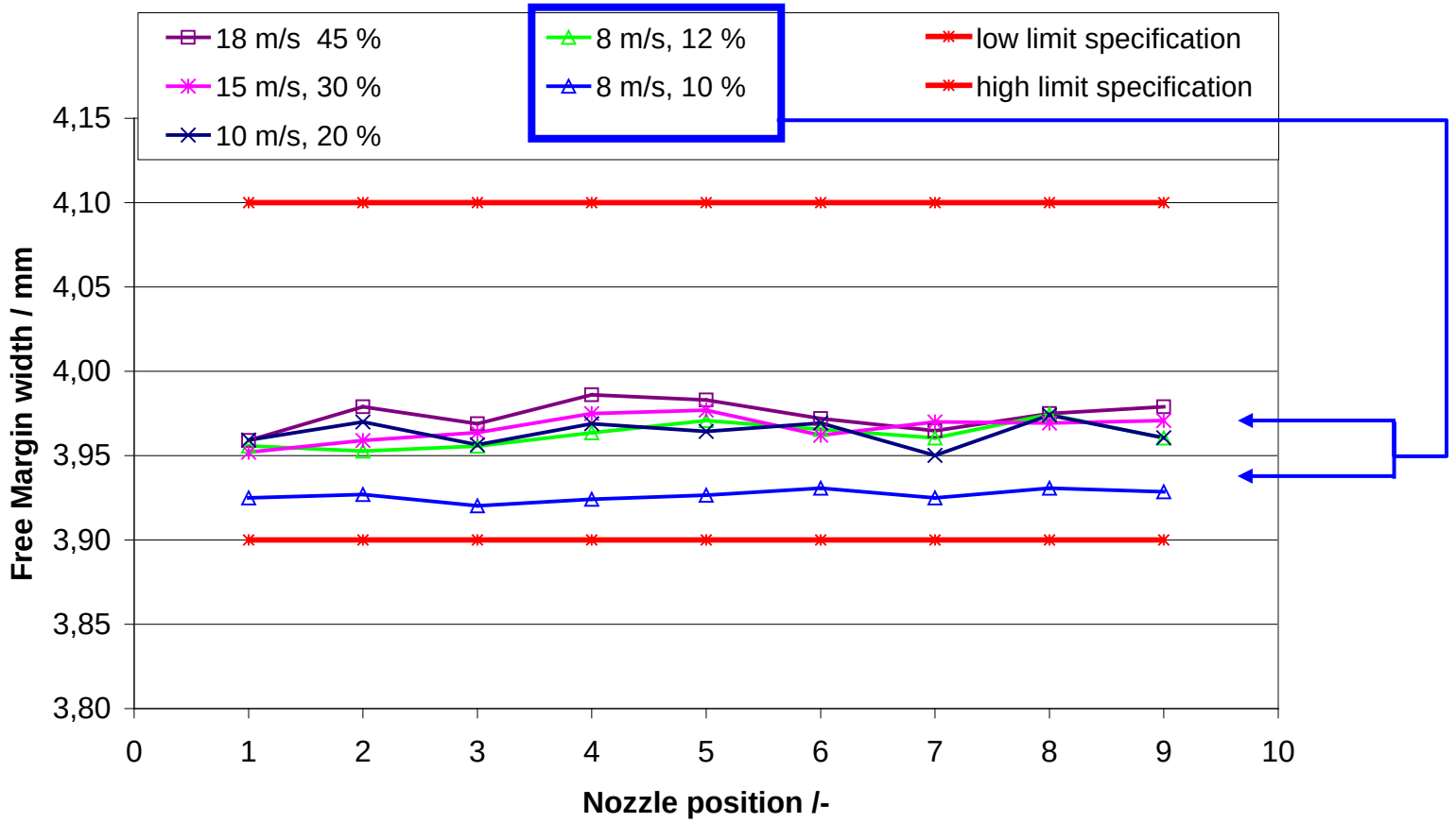


Results – Oil flow rate vs. Web speed



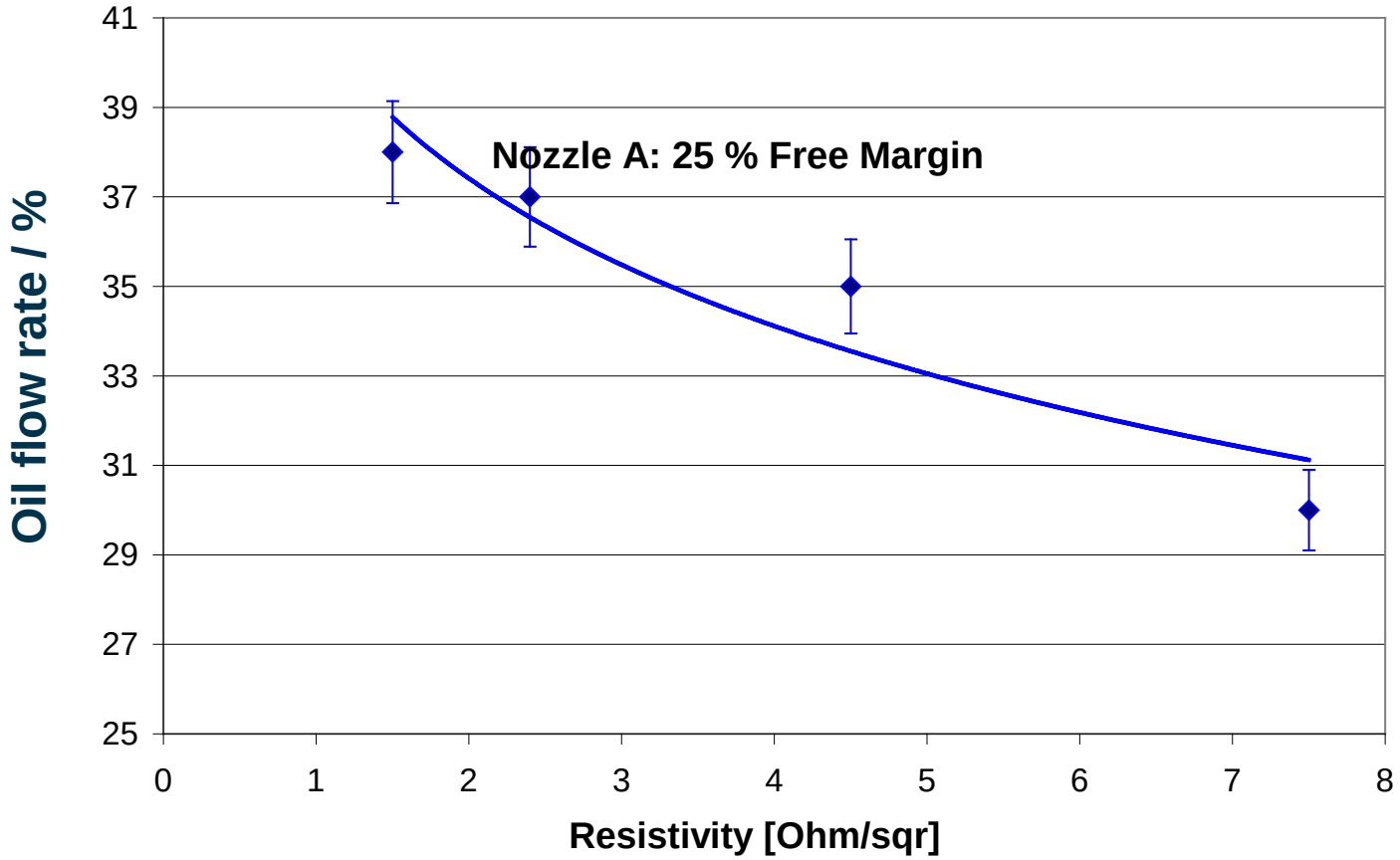
- Total oil for a defined process required increases with nozzle area and CD speed
- Oil flow rate is controlled during process (e.g. change in web speed)

Results: Free Margin Width vs. Nozzle position



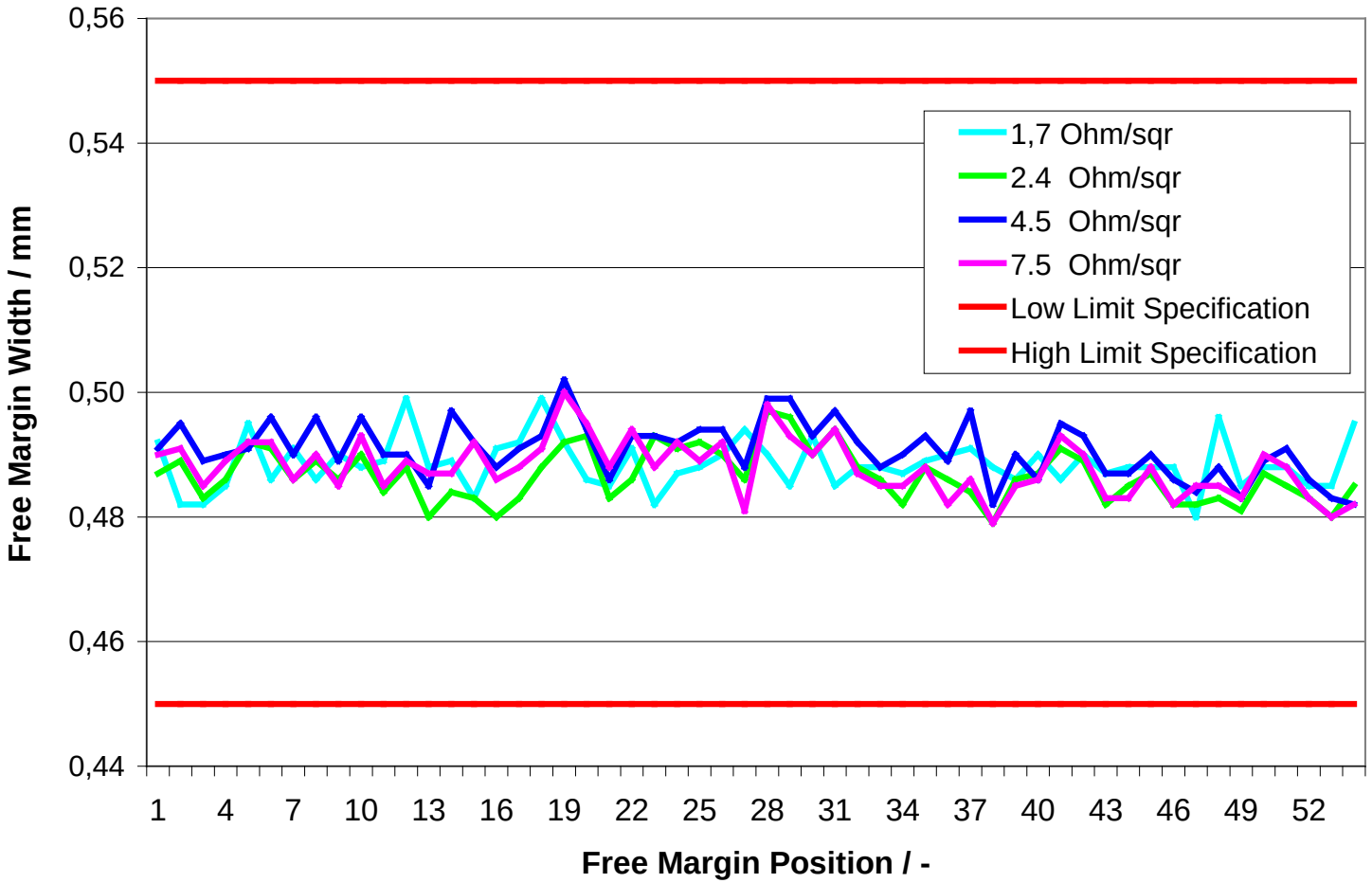
- Oil flow rate optimized at different web speeds
- Area Nozzle ***A***: 3.9 x 2 mm^2
- Oil amount influences the FM width [8 m/s @ 10 %, 12 %]
- Uniform FM width distribution for 54 & 64 nozzle openings (B&C)

Oil flow rate vs. Resistivity for Nozzle A



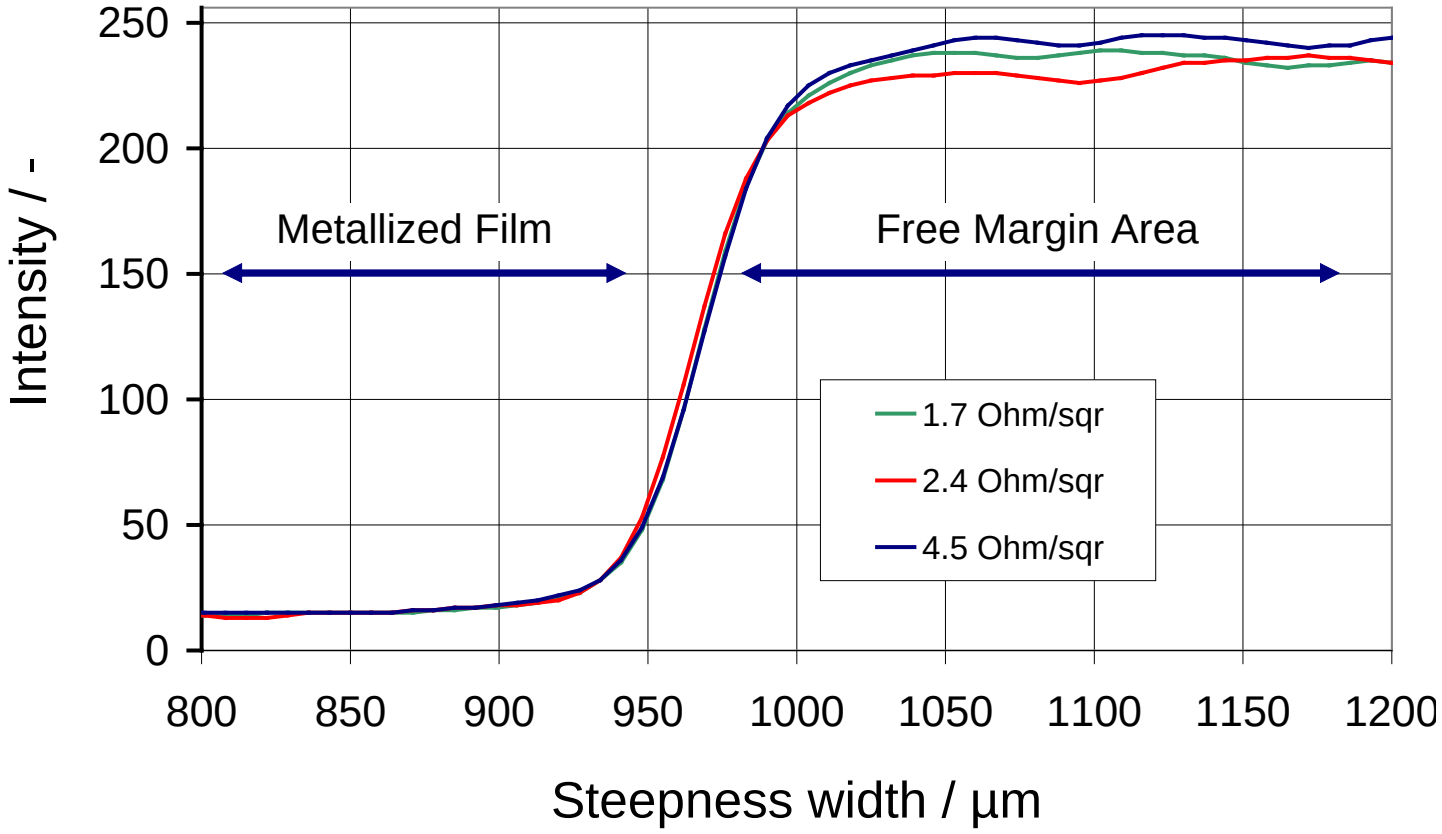
- Web speed: 8 m/s
- Oil thickness on web decreases with resistivity (for all other nozzles)
- Film thickness decreases with increasing resistivity
- Less oil required for the new FME (process regulated)

Free Margin Width: Film uniformity across Web



- Optimized oil flow rate for nozzle C (0.5 mm)
- Excellent uniformity of free margin at different resistivity across the web, due to optimized oil flow rate

Free Margin Width: Edge Steepness



- Transmission measurements Free Margin Measuring System (FMMS)
- Optimized pump performance for Nozzle C (0.5 mm)
- Oil thickness on web: 16 nm, CD speed: 8 m/s, performance: 10 %

Free Margin Evaporator built in CAP-M

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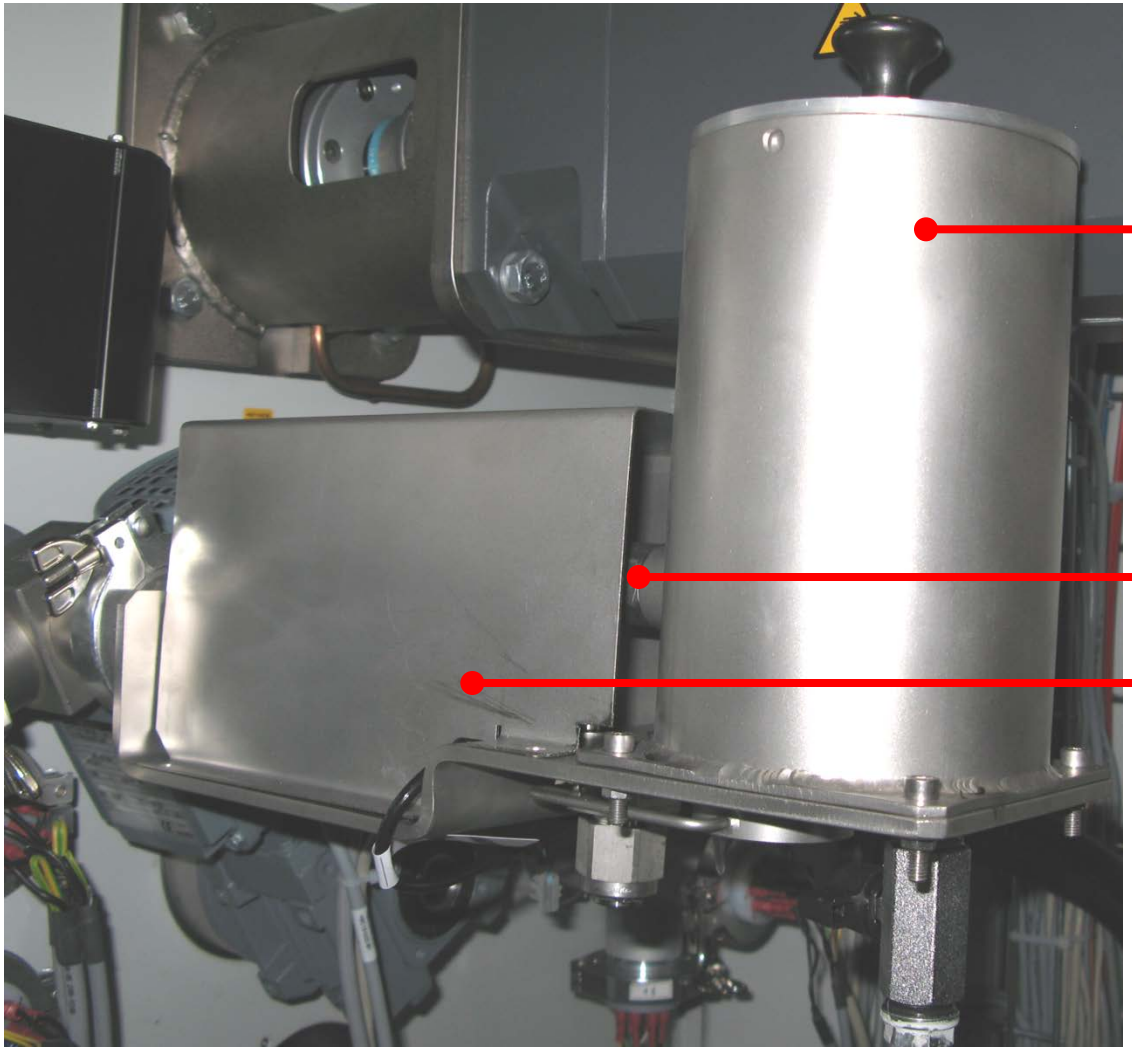
Oil Reservoir: outside the Winding Chamber



Advantages for the customer:

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- Cost savings
  - No wasted oil during start and stop
  - No degraded excess oil waste
  - Reduced time for cleaning and maintenance (No shutters)
- Constant, Improved Product Quality
  - Optimum, regulated amount of masking oil on web
  - FM width steepness can be regulated
  - No thermally degraded oil used in process
  - Amount of oil can be adjusted quickly and precisely during process

Advantages for the customer:

- Ease of operation
  - Oil reservoir in atmosphere (Easy refill any time)
  - No machine contamination during start and stop
  - Constant process temperatures
- Future proof technology
  - Backwards compatible to existing machines
  - Patented technology by Leybold Optics

Cost Savings Calculation for the FME

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Web length	**40 000 m**
Consumption per run	**17.3 ml**
Oil thickness on web	**16 nm**
Cost saving / year	**60 %**

Calculations based on:

- NO OIL REFILL
- NO WASTE OIL
- Consumption per run for conventional FME (26.7 ml)
- Optimized Oil thickness on Web, conventional FME (23 nm)
- Excellent Quality of Free Margin and Oil

Conclusion

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The key advantages of this development for the web coating customer are:

- **short start & stop times:** (no oil waste and chamber contamination),
- **optimum thickness of oil** for each product, even at varying web speeds, through closed loop regulation,
- **better free margins**, sharper, steeper edges of masked areas,
- **constant product quality** by use of 100 % of fresh masking oil,
- **ease of operation** (easy refill of oil reservoir in atmosphere even during process),
- **no oil waste** due to degraded oil and
- **significant cost savings:** thanks to regulated minimum applied oil film thickness and zero oil waste design.

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THANK YOU FOR YOUR ATTENTION

Photo: PET Film & Nozzle
Free Margin Width: 0.5 mm
2.0 Ohm/sqr

Cost Savings Calculation

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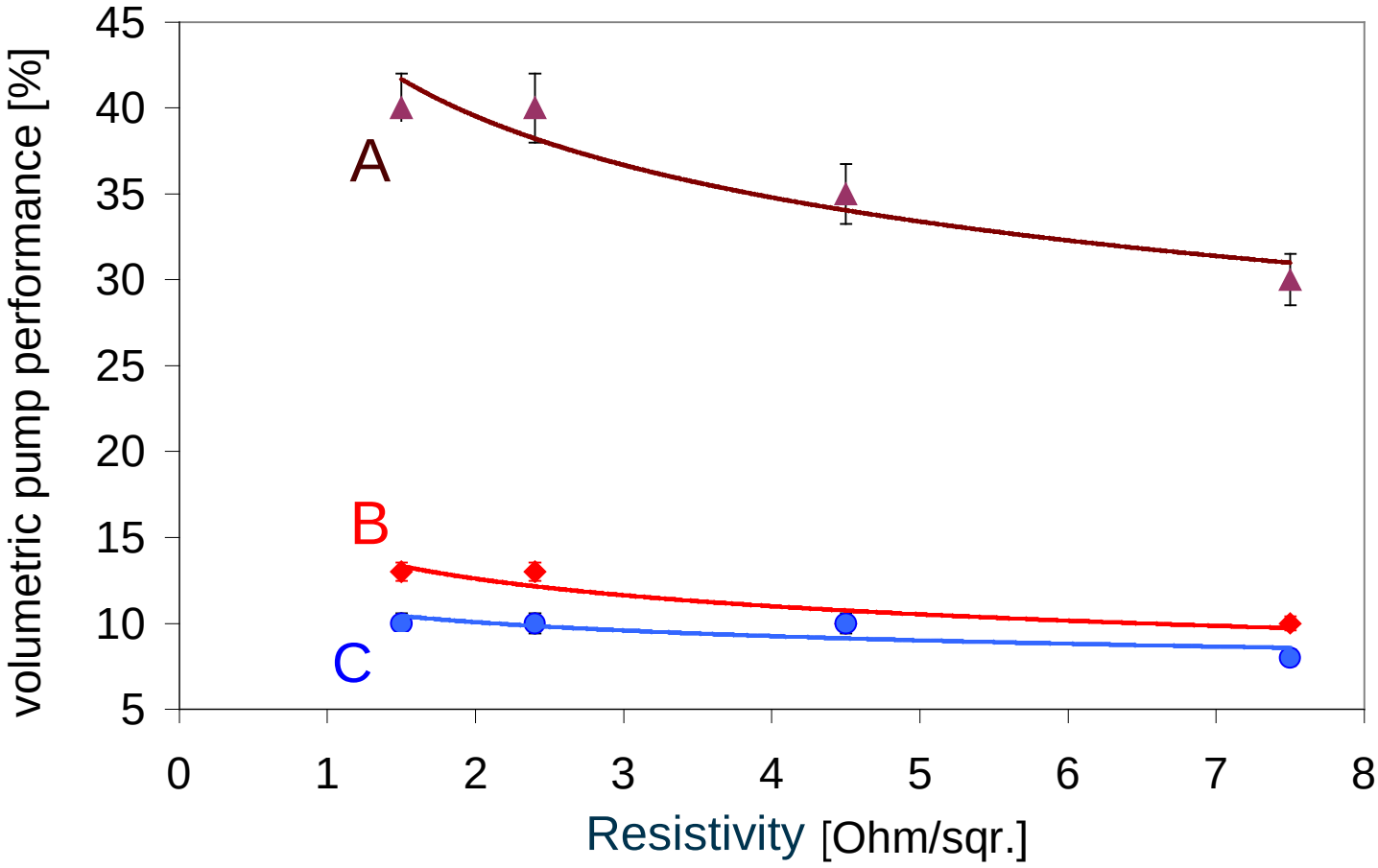
Parameter	unit	STANDARD	NEW
Web length	**m**	**40 000**	**40 000**
Price/liter	**€**	**250**	250
Consumption/run	**ml**	26,7	17,3
Filling	**ml**	500	0
Refills before oil change		30	0
Runs/day		18	18
Consumption/day	**ml**	480,6	311,4
Waste/day	**ml**	300	0
Cost of masking/day	**€**	120,15	77,85
Cost of waste/day	**€**	75	0
Working days/year		320	320
Cost of masking/year	**€**	38 448	24 912
Cost of waste/year	**€**	24 000	0
Oil thickness	**nm**	23	16
Less consumption (regulator)		0,00%	5,00%
Total cost per year	**€**	**62 448**	**24 912**
Saving/year	**€**		**37 536**

significant cost savings

Film Uniformity versus oil flow rate and nozzle area



- Oil thickness on web decreases with resistivity (film thickness increases)

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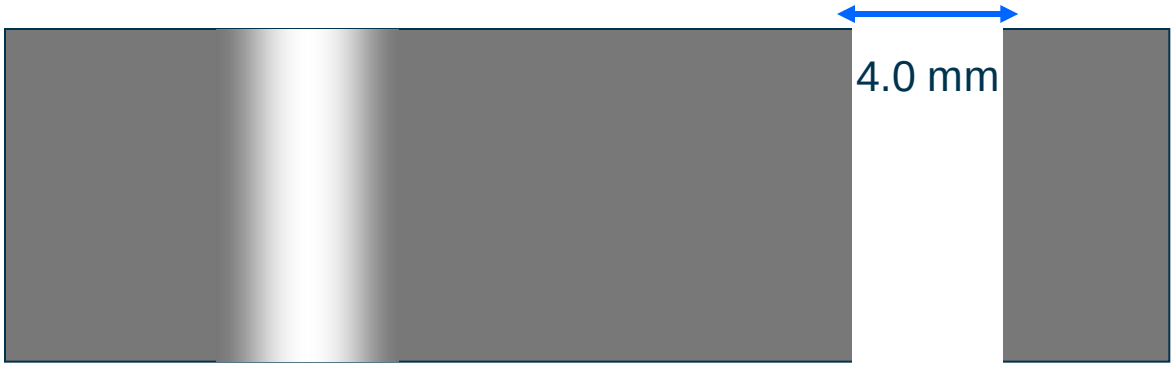
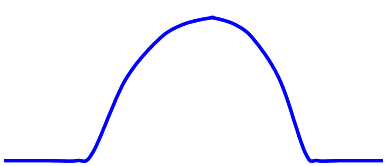
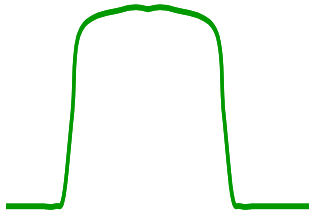
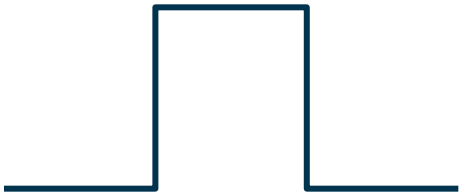
Schematic illustration: optimal masking oil thickness









oil thickness on film: 16 nm

Free Margin Profile