Particle concentrator

Final presentation – 14 December 2023

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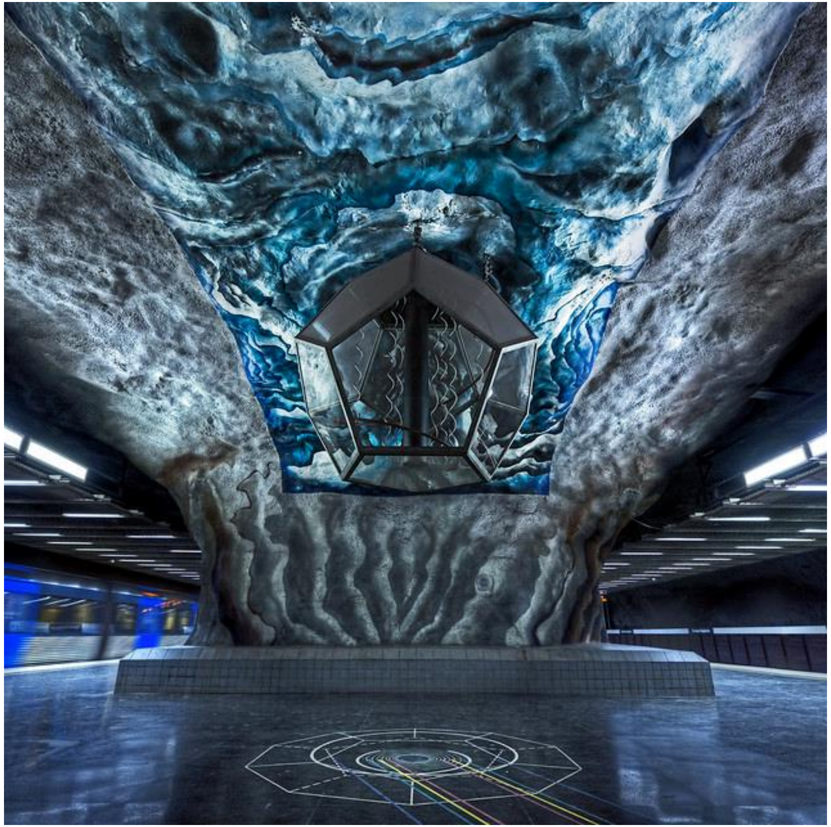
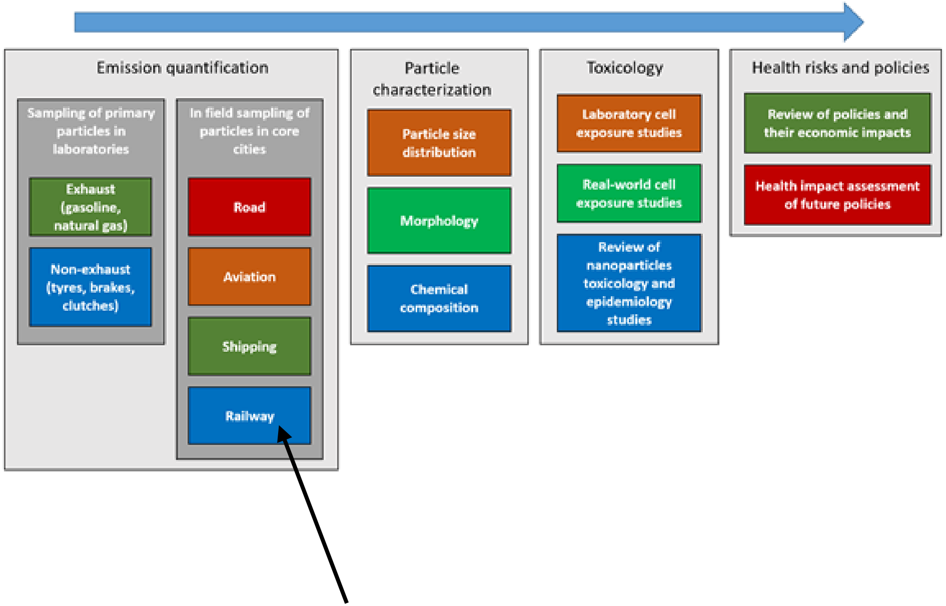
Outline

- Background
- Introduction
- Requirements
- Overview of system
- Final design
- Manufacturing
- Testing
- Future work
- Conclusions



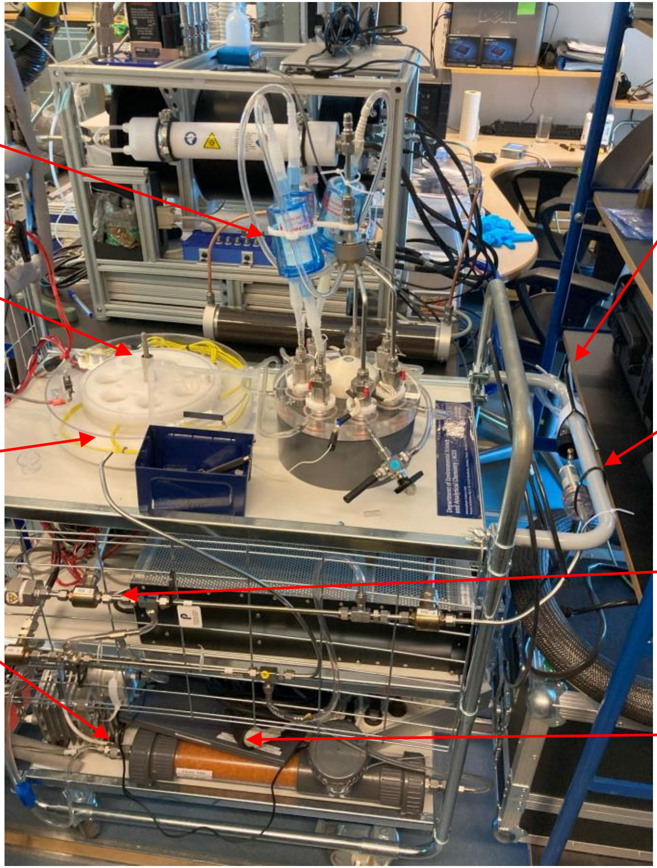
nPETS: Nanoparticle emissions in the transport sector

- Research project that assesses the emission of nanoparticles from all types of transport.
- Has received funding from the European Union.
- Develops innovative methods for quantification and monitoring of pollution levels
- The research that is being conducted at Stockholm university is also part of nPETS.



Our part in the project.

Air-Liquid Interface system



½ filtered (control)

lung cells

electrostatic charge

silica gel dryer

inlet from concentrator

2-stage cyclone + impactor

humidifier + sensor

computer

Introduction

Stakeholders

- Karine Ehlin at Stockholm University (SU)
- Ulf Olofsson at KTH

Scope

- Between air inlet and inlet to ALI system at SU
- Increase efficiency by concentrating particles

Requirements

No.	Requirement	No.	Sub-requirement
1	Performance	1a	The particle concentration factor should be $\geq 5\times$.
		1b	The particle sample size should be $\leq 1\mu m$.
		1c	The output flow of the device should be 1.5 l/min.
		1d	The particles exiting the device and entering the ALI system should be dried to its original size.
2	Working environment	2a	Should be able to withstand corrosion environment.
		2b	Should be able to withstand temperature range of -35 to +40 deg Celsius.
		2c	Should be able to withstand normal humidity outdoors.
3	Life in service	3a	Should have service life of xx years.
		3b	Components that are exposed to wear should be easy to replace.
4	Maintenance	4a	VI should be easy to assemble and disassemble for maintenance.
		4b	Easy access to part that are likely to require maintenance.
		4c	Need for special tools.
5	Target product cost	5a	Bench-marking.
6	Transport	6a	Should be able to transport with e-bike.
7	Quantity	7a	A single concentrator shall be produced.
8	Manufacturing facility	8a	IIP.
		8b	External workshop.
9	Size	9a	Should fit on an e-bike.
		9b	Should fit in existing cage in the metro.
		9c	One person should be able to lift it.
10	Weight	10a	One person should be able to lift it.
11	Appearance and finish	11a	It should match the existing aesthetic.
		11b	It should not draw to much attention.
		11c	It should not interfere with the particle chemistry.

No.	Requirement	No.	Sub-requirement
12	Materials	12a	It should not interfere with the particle chemistry.
13	Standards and specifications	13a	Follow standards for hoses and connections.
		13b	Follow standards for sensors.
		13c	Follow standards for framing and fasteners.
14	Ergonomics	14a	Should be able to read sensors clearly.
		14b	Non-slip carry handle on the frame.
		14c	Adjustments should be easily performed.
15	Process	15a	The concentrator shall use the virtual impactor principle.
16	Time-scales	16a	Concept generation and design should be finished during VT 2023.
		16b	Manufacturing and assembly should be finished during HT 2023.
17	Testing	17a	Should be finished during HT 2023.
		17b	Field test should be performed in subway and road tunnel.
		17c	Control test should be performed in a controlled environment.
		17d	Standard particle counter should be used.
18	Safety	18a	Emergency skill switch should be installed.
		18b	Hot water and pressurized water shuld not be able to contact the user.
19	Installation	19a	Should be movable.
		19b	Easy to connect to intake and ALI system.
20	Documentation	20a	Complete spare partlist and drawing. The machine should be able to be dissassembled and assembled from the documentation.
		20b	The project should be documented in a technical drawing.
21	Disposal	21a	Made from recyclale materials.
		21b	High material hygiene level.

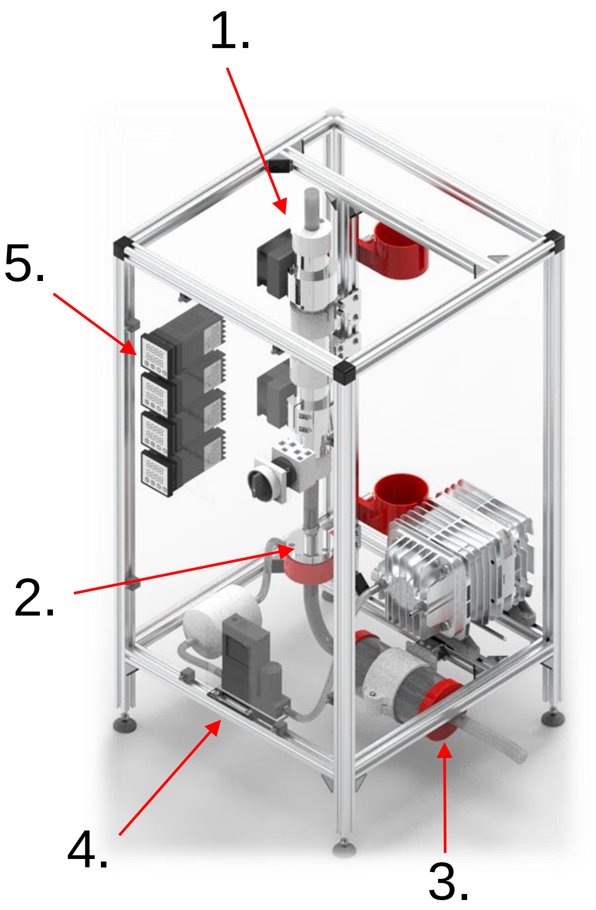
Performance and size requirements

No.	Requirement	No.	Sub-requirement
1.	Performance	1.a	Particle concentrator factor should be ≥ 5x.
		1.b	Particle sample size should be ≤ 1 µm.
		1.c	Output flow of the device should be 1.5 l/min.
		1.d	The particles exiting the device and entering the ALI system should be dried to its original size.
9.	Size	9.a	Should fit on an e-bike.
		9.b	Should fit in the existing cage in the metro.
		9.c	One person should be able to lift it.

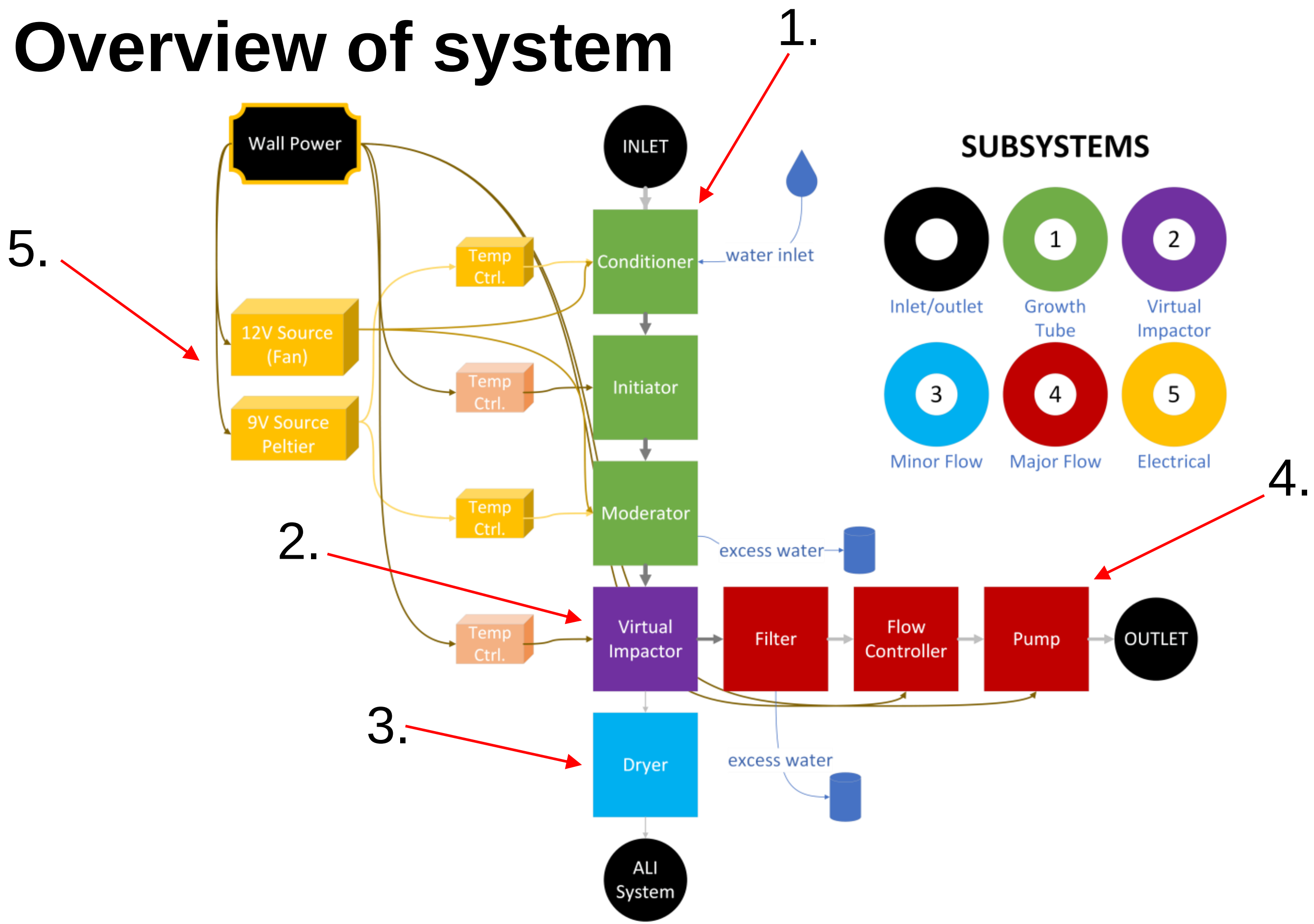
Overview of system

The device can be devided into five subsystems to include all the parts of the device.

1. Growth tube
2. Virtual impactor
3. Dryer
4. Major flow system
5. Electronics/controllers

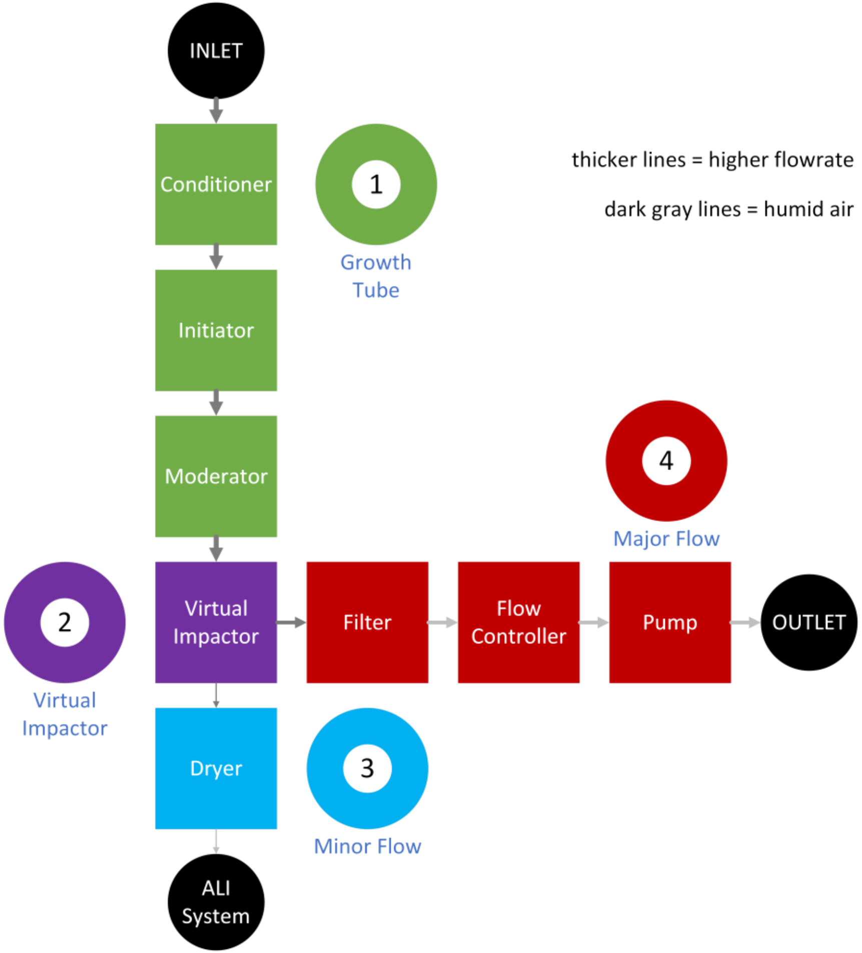


Overview of system



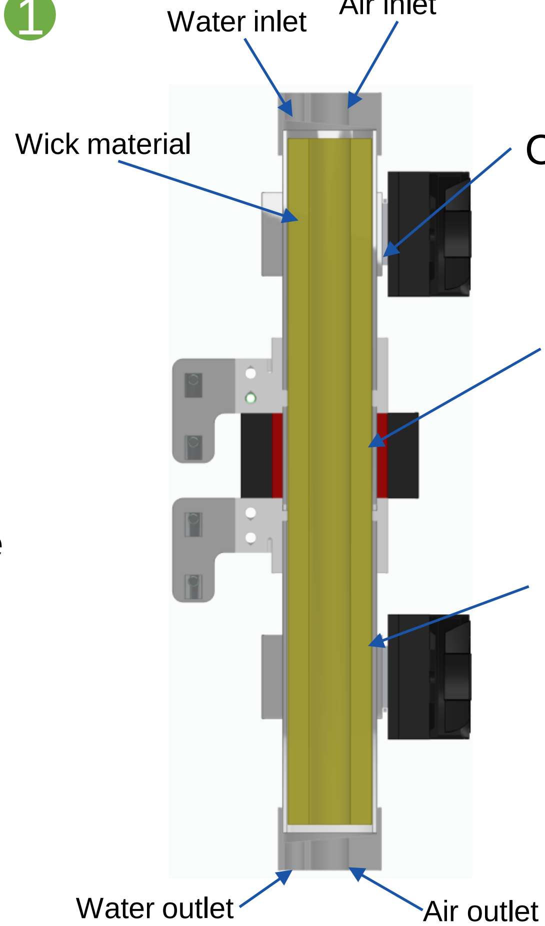
Flow system ❹ ❸

- Major Flow (7-15L/m):
  - Vacuum pump pulls air
  - Mass Flow Controller dictates the flow
  - Water filter protects the equipment
- Minor Flow (1.5L/m):
  - ALI system draws air
  - Dryer reduces the moisure level
- Combined Flow:
  - Flows intersect at the Virtual Impactor
  - Combined flow is hydrated in the Growth Tube



Growth tube ❶

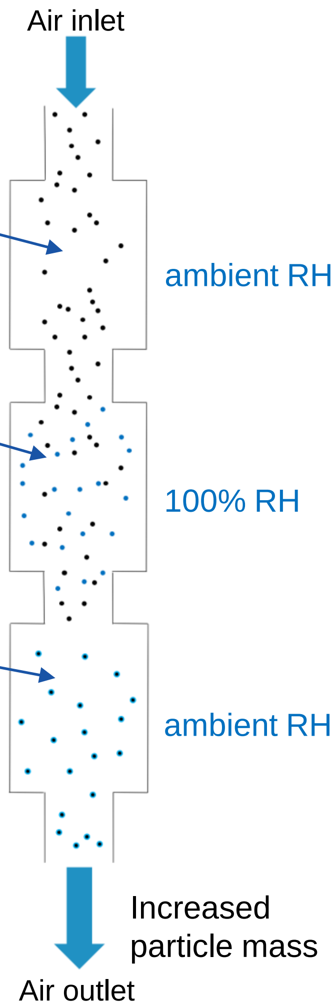
- Growth tube consists of three zones, two cold ones and one hot.
- The cold zones are created with a peltier module connected to a cooling block and a fan to remove heat from the peltier module.
- The hot zone with 100% relative humidity is achieved with a saturated wick material and heat tape surrounding the outside of the tube.



Conditioner
$T_1 = 15\ °C$

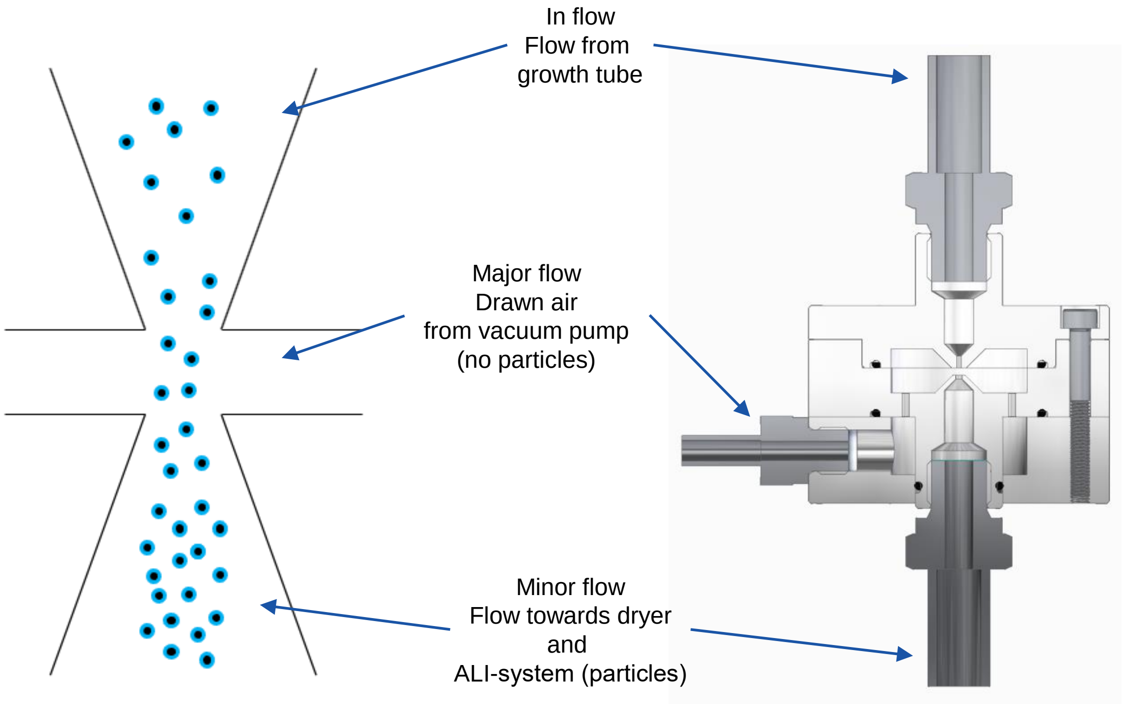
Initiator
$T_2 = 50\ °C$

Moderator
$T_3 = 5\ °C$

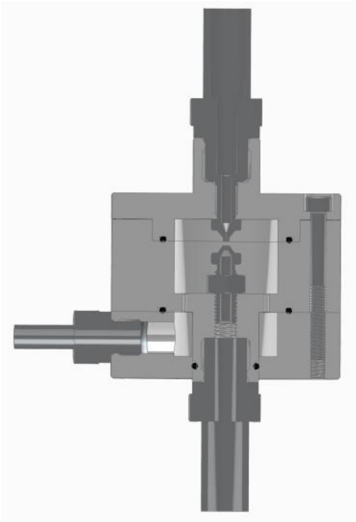


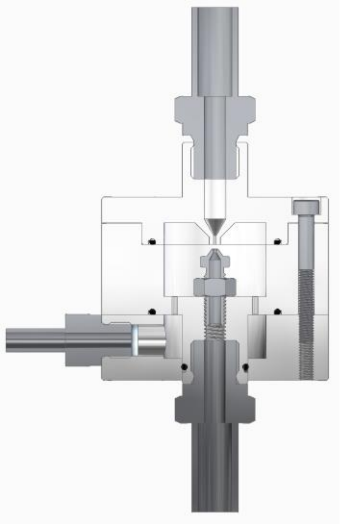
Virtual impactor ❷

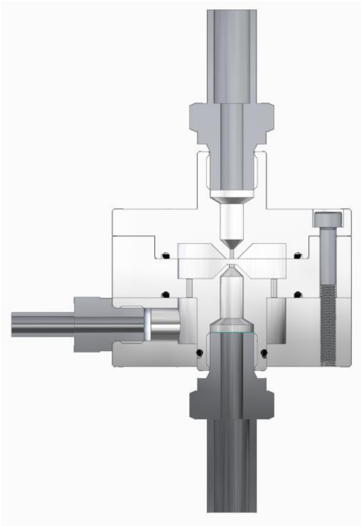
- Two different airflows
- One airflow is from the ALI system and is 1.5 L/min, it contains the particles. We call this the minor flow.
- The other flow is achieved using a pump and is approx 15 L/min, in theory it contains no particles. We call this the major flow.



Virtual impactor – Design Itereations ❷

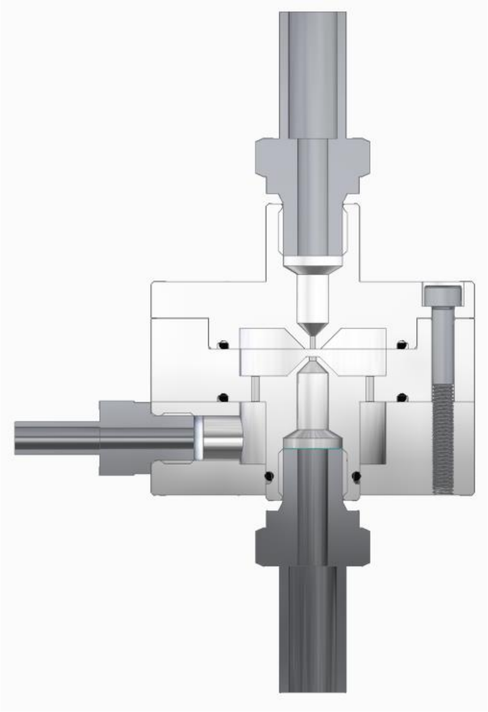

Mk. 1


Mk. 2


Mk. 3

- Mk. 1:
  - 2x removable nozzles
  - More adjustability
  - Less accurate (nozzle concentricity)
- Mk. 2:
  - 1x removable lower nozzle
  - Improved accuracy
- Mk. 3:
  - Built-in nozzles
  - Only nozzle gap is adjustable
  - Best accuracy

Virtual impactor – Final Design ❷

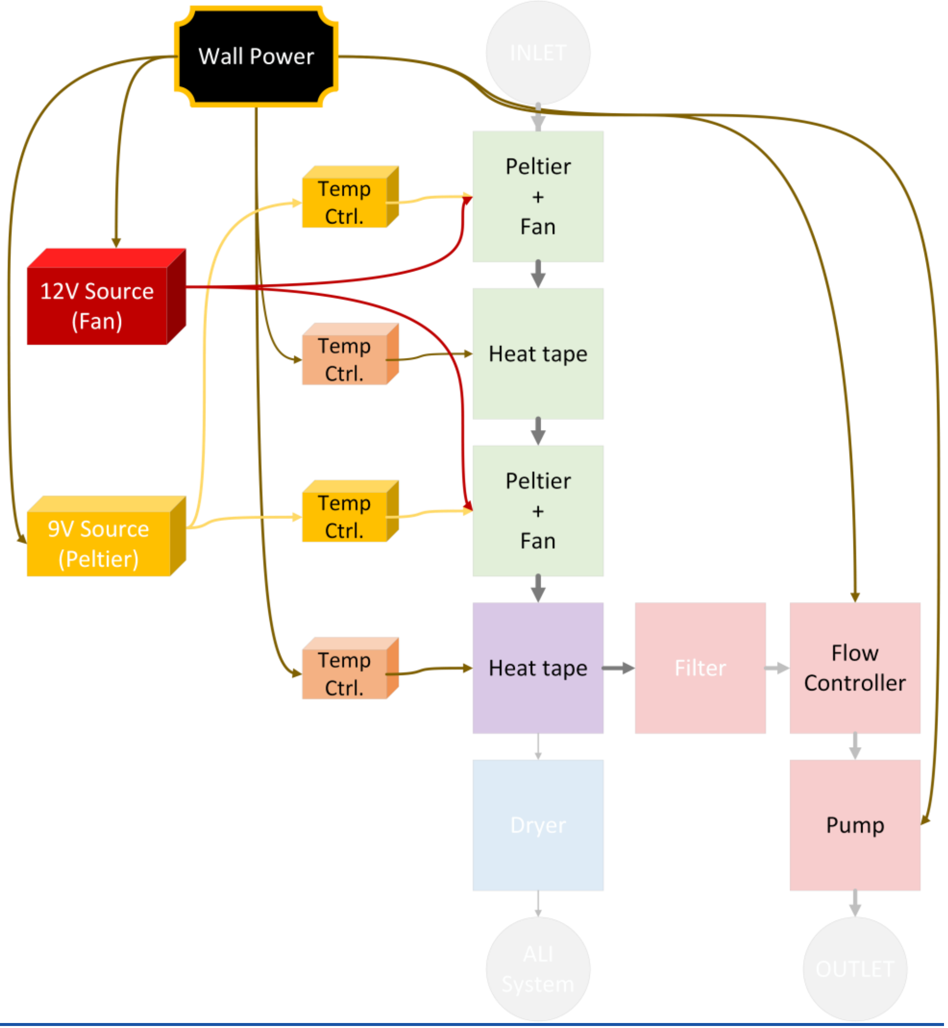


Mk. 4 (Final)

- Mk. 4 (Final version):
  - Built-in top & bottom nozzles
  - Nozzle geometry designed for manufacture (blunter cone angle)

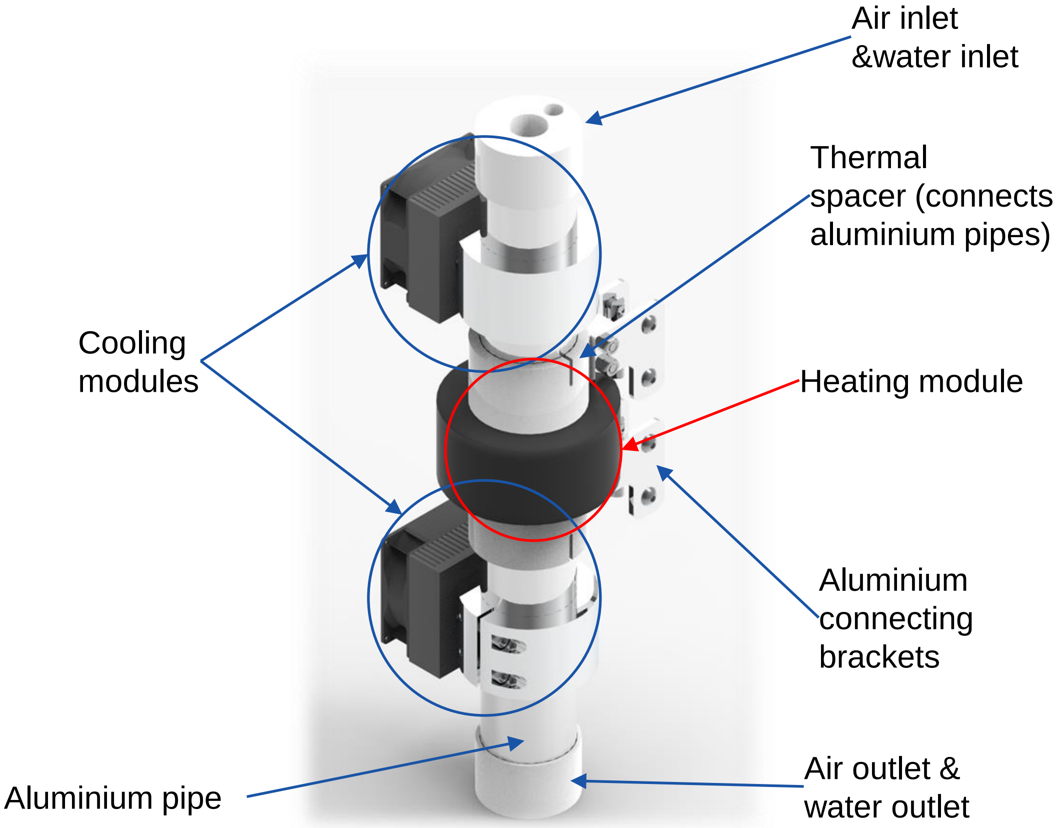
Electronics ⑤

- 230v (wall) system
  - Mass flow controller
  - Vacuum Pump
  - PID temp controller
  - Heating tape
- 12v system
  - Fan for peltier heat sinks
- 9v system
  - Peltier modules



Manufacturing - Growth tube ❶

- Aluminium pipe was purchased from CGT and cut to length.
- Cooling module and heating module are both a combination of bought parts and in-house manufactured parts
- Inlets and mounting parts were 3D printed and cut with a water jet.

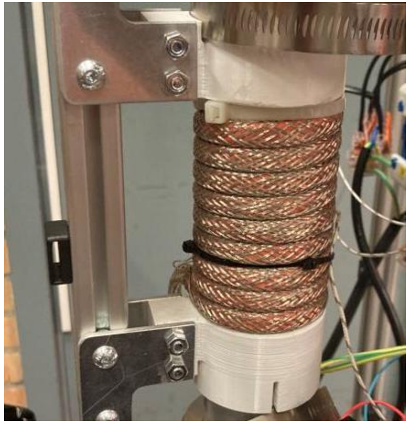


Manufacturing - Growth tube ❶

Cooling module

- Cooling block was manufactured in-house at KTH.
- Peltier module, thermocouple, heat sink and fan was purchased from RS components.
- Cooling block only has one slit to allow better thermal conductivity.

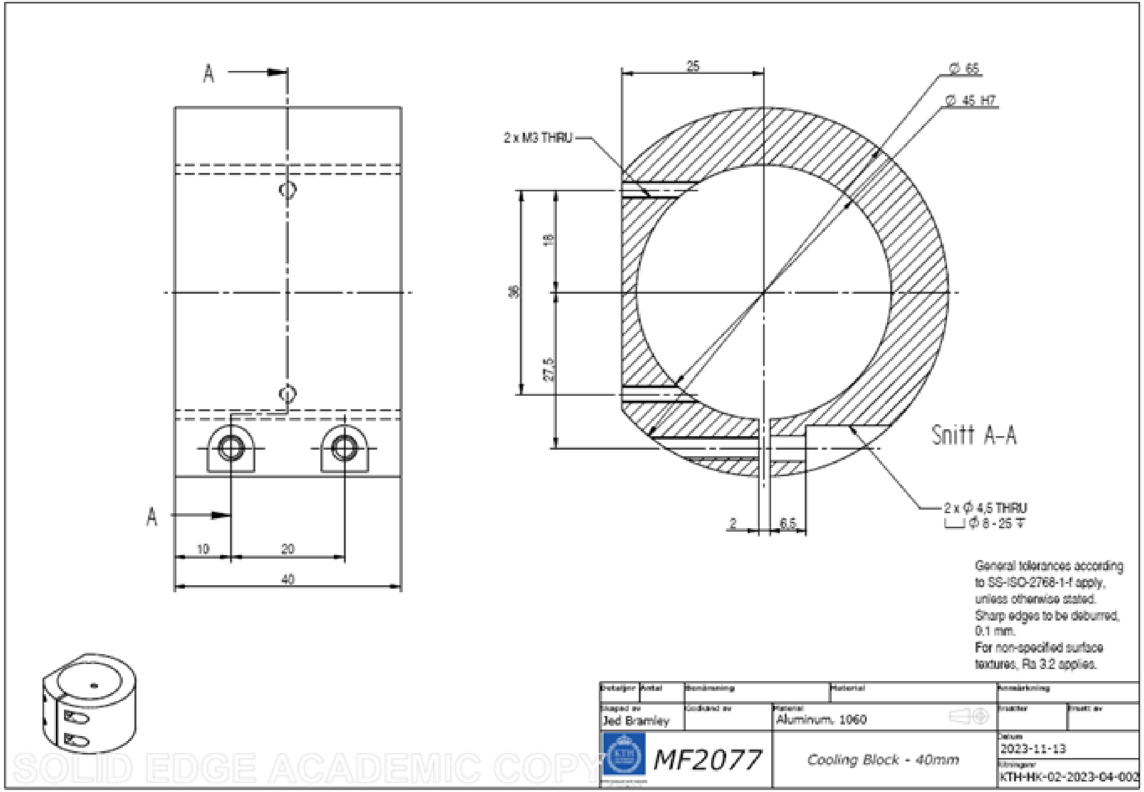
Heating module



- Heating tape/cord and thermocouple was purchased from RS components.
- Thermal insulation on the outside of the heating tape was purchased from Ahlsell

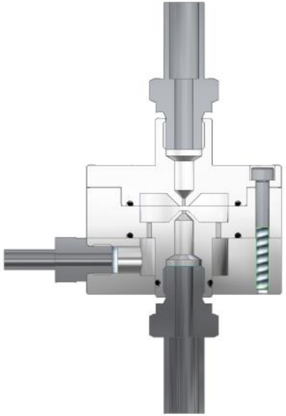
Manufacturing Drawings - Cooling Block

❶



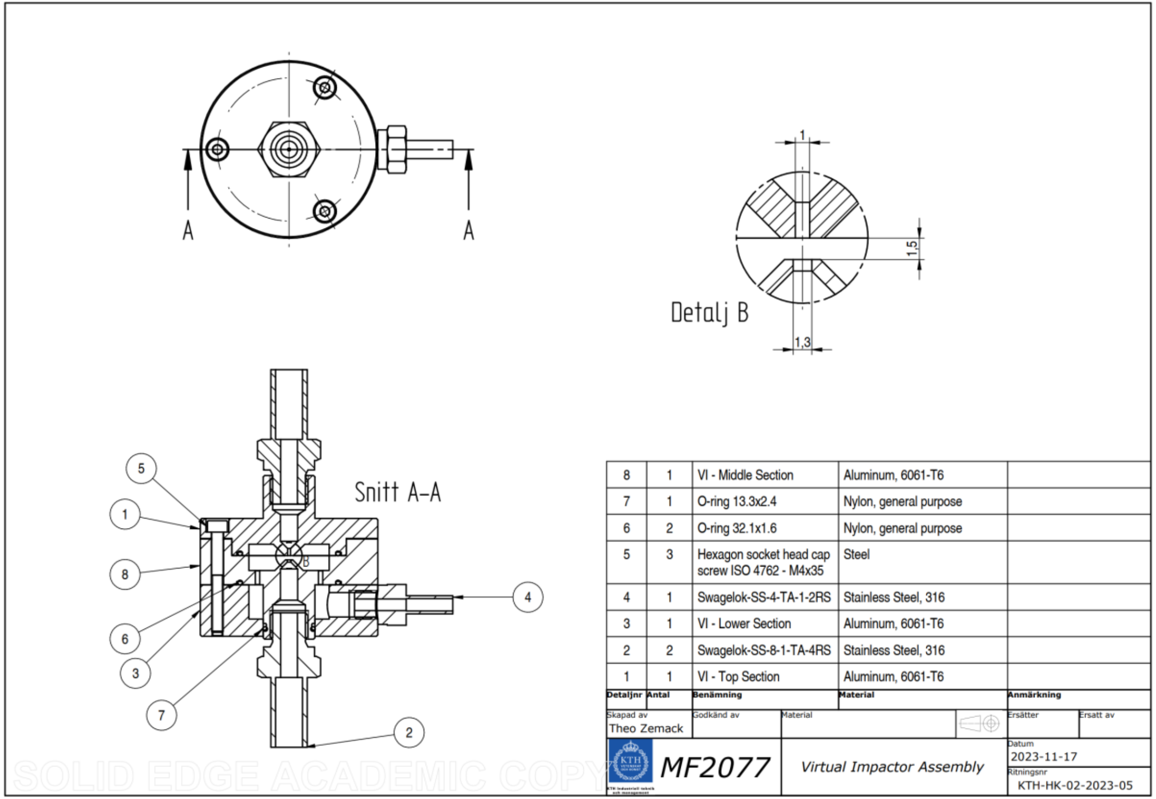
Manufacturing - Virtual impactor ❷

- Metallic AB
- Machined from aluminium alloy, AW7075
- Tolerances to ensure concentricity of nozzles
- O-rings to seal between compartments
- Swagelok fittings to connect the tubing



Manufacturing Drawings - Virtual impactor

❷

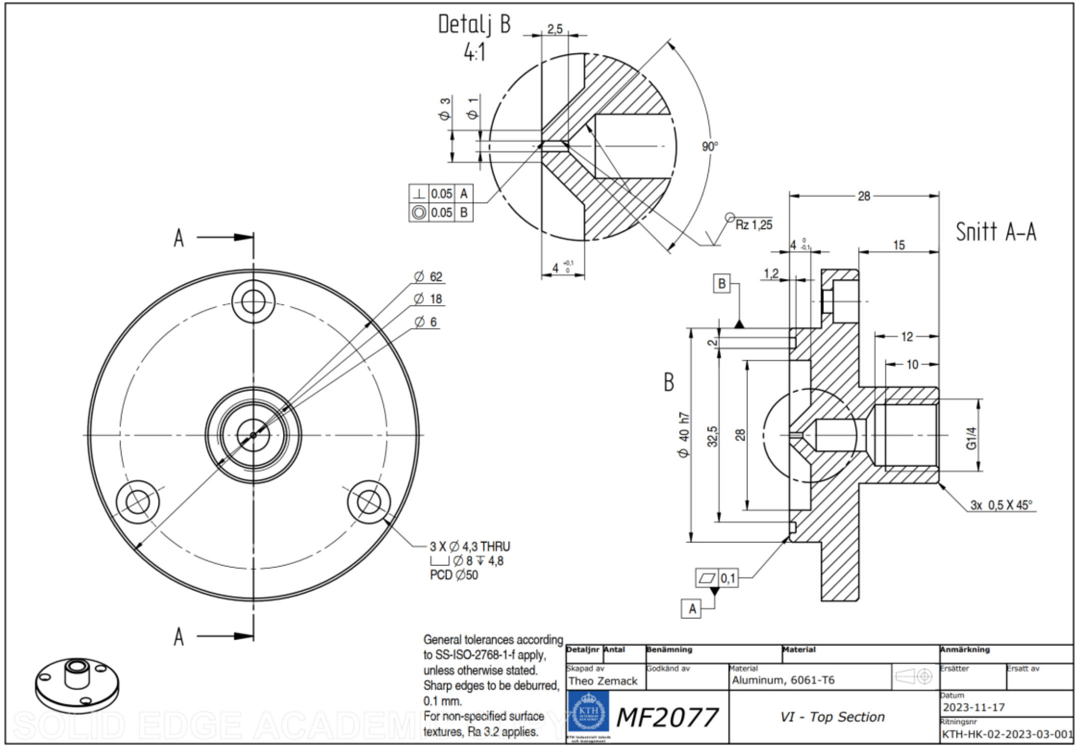


Detaljnr	Antal	Benämning	Material	Anmärkning
8	1	VI - Middle Section	Aluminum, 6061-T6	
7	1	O-ring 13.3x2.4	Nylon, general purpose	
6	2	O-ring 32.1x1.6	Nylon, general purpose	
5	3	Hexagon socket head cap screw ISO 4762 - M4x35	Steel	
4	1	Swagelok-SS-4-TA-1-2RS	Stainless Steel, 316	
3	1	VI - Lower Section	Aluminum, 6061-T6	
2	2	Swagelok-SS-8-1-TA-4RS	Stainless Steel, 316	
1	1	VI - Top Section	Aluminum, 6061-T6	

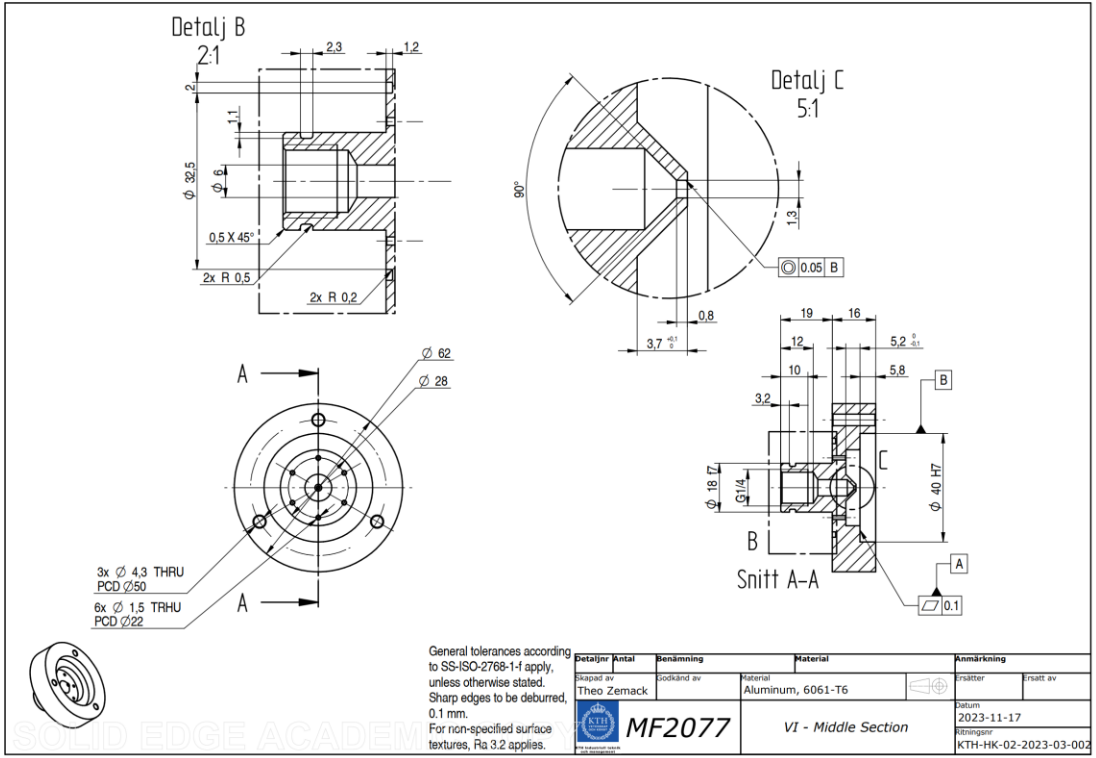
Skapad av	Godkänd av	Material	Ersätter	Ersatt av
Theo Zemack				

KTH	MF2077	Virtual Impactor Assembly	Datum 2023-11-17 Ritningsnr KTH-HK-02-2023-05

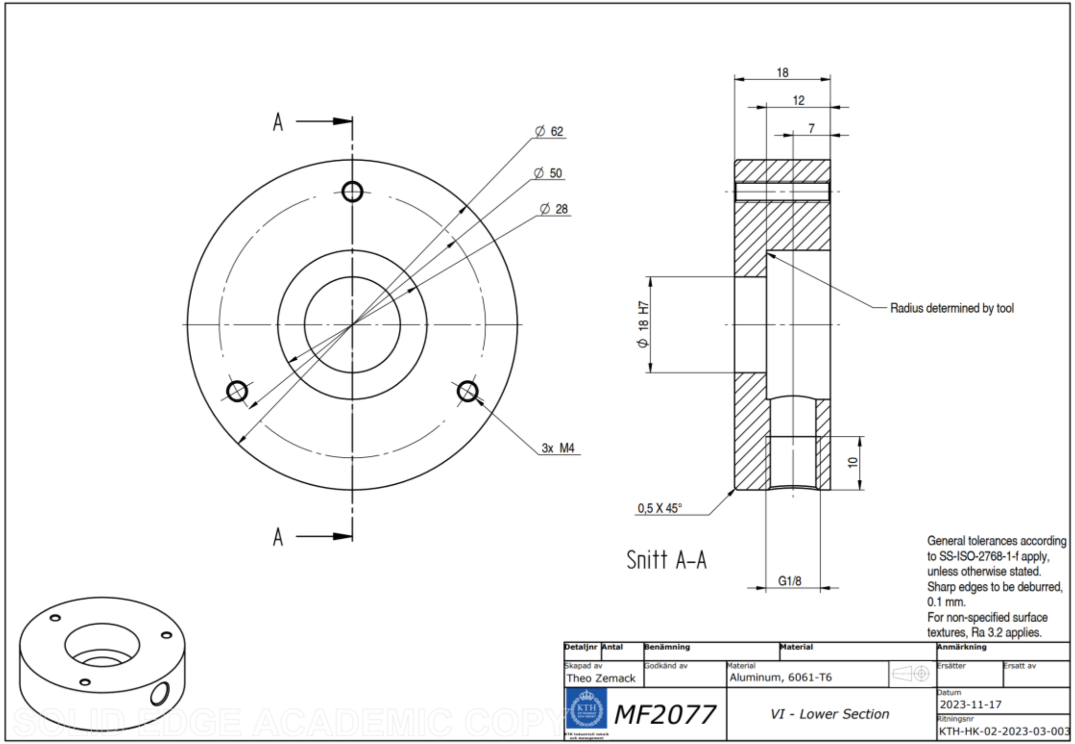
Manufacturing Drawings - Virtual impactor top ❷



Manufacturing Drawings - Virtual impactor middle ❷



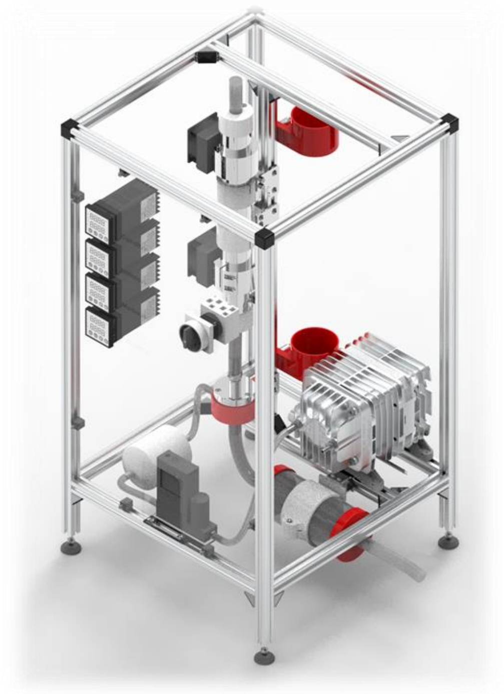
Manufacturing Drawings - Virtual impactor lower ❷

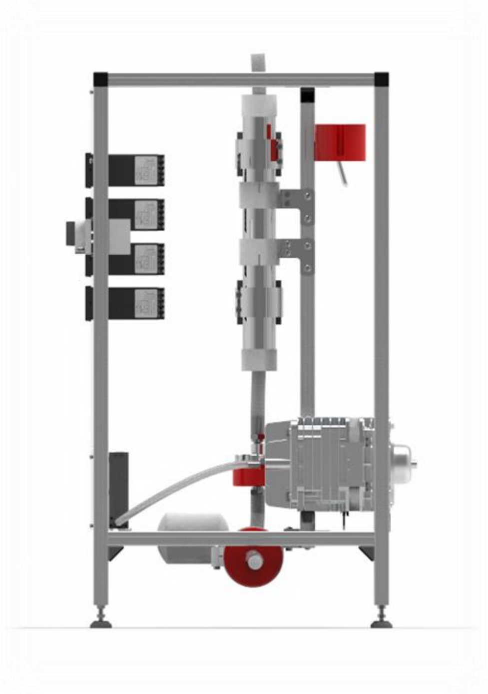


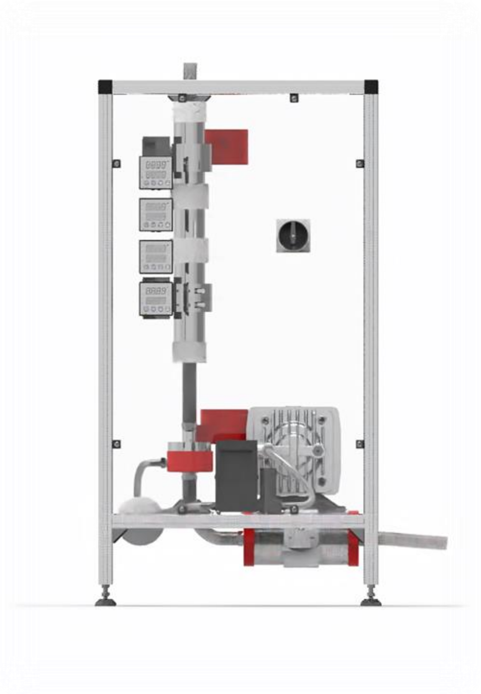
Manufacturing - Frame and misc

- Aluminium extrusion frame
- Adjustable feet
- 3D printed mounting brakets
- Water jet cut mounting plates

Final design

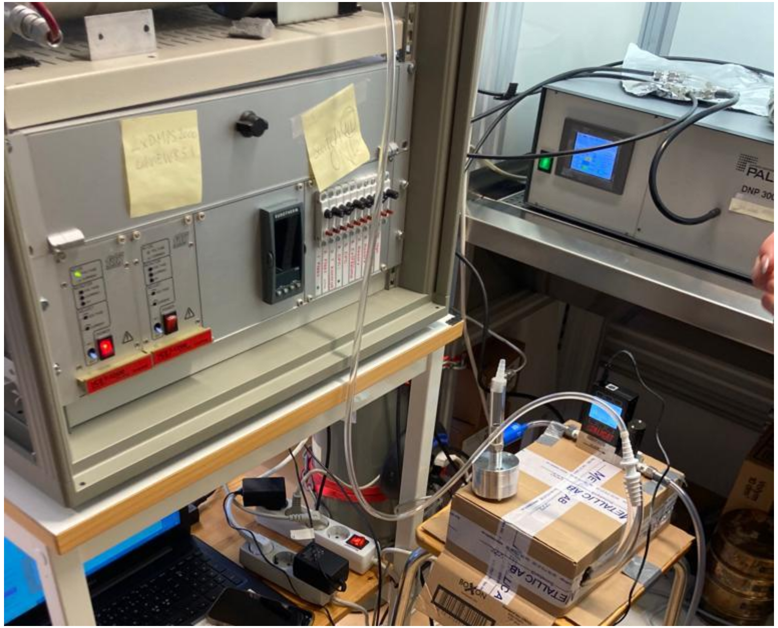






Final design

Testing: Spark Discharge + Condensation Particle Counter



- Spark Discharge:
  - ~ 60 – 154 nm
  - Metallic particles
- Condensation Particle Counter
  - 0.3 L/m
  - 16 nm – 600 nm
- Major flow
  - 0.5 L/m steps from 1 – 3 L/min

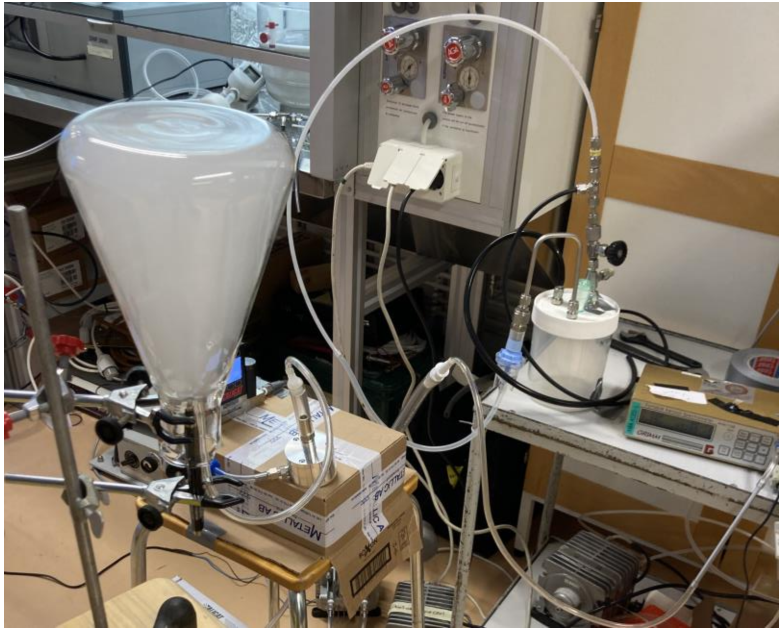
Comments: particle range 1-2 orders of magnitude too small – low flow

Testing: Particle Suspension + Optical Particle Counter

- Particle Suspension:
  - ~1, ~3, ~5 micron
  - Polystyrene particles
- Optical Particle Counter
  - 1.2 L/m
  - 0.25 – 32 micron
- Major flow
  - 12 – 15 L/min

Comments: dilution of particles – old suspension solution – weak OPC pump

Testing: Smoke Pen + Optical Particle Counter



- Smoke Pen:
  - Wide/unpredictable range
  - Soot particles
- Optical Particle Counter
  - 1.2 L/m
  - 0.25 – 32 micron
- Major flow
  - 7.5 – 15 L/min

Comments: small smoke volume – unpredictable dist. – weak OPC pump

Future work

- Electronics:
  - More/more powerful peltier coolers
  - Consolidate power supply
  - Custom circuit board to control the different systems
- Dryer:
  - Add access port to dryer
  - Test particle loss
- Testing:
  - Whole system – long term
  - On-site
  - Different VI nozzle gaps

Conclusion

- We have created a functioning first prototype for SU
- Sponsors at SU are satisfied
  - The dimension and weight requirements were followed with a focus on durability and modularity
  - Performance will be determined and summarized in report
- Our main obstacles involved the procurement and availability of specialty parts
- The main objective was to create a device that is easy to use, maintain, manufacture and modify

Thank You

Questions?