UiT The Arctic University of Norway

Designing and Optimizing a Sea-Spray Collector using CFD

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Multidisciplinary approach for spray icing modeling and decision support in the Norwegian maritime sector (SPRICE)

https://en.uit.no/project/sprice

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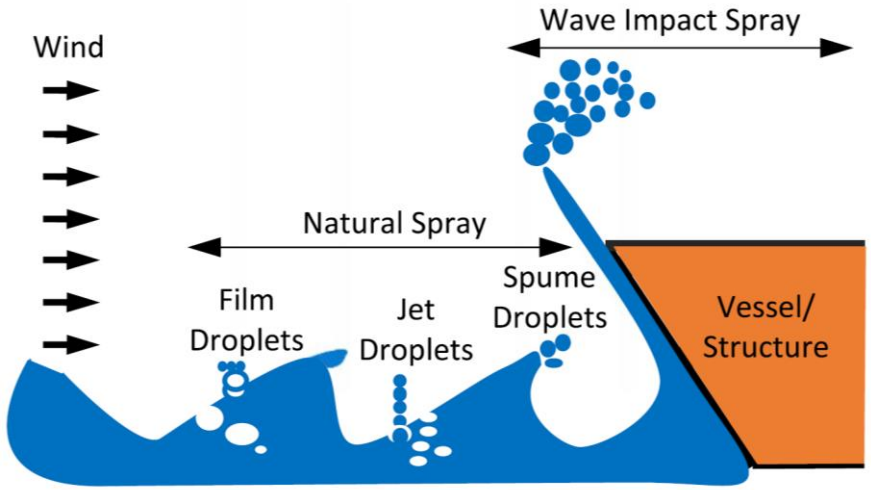
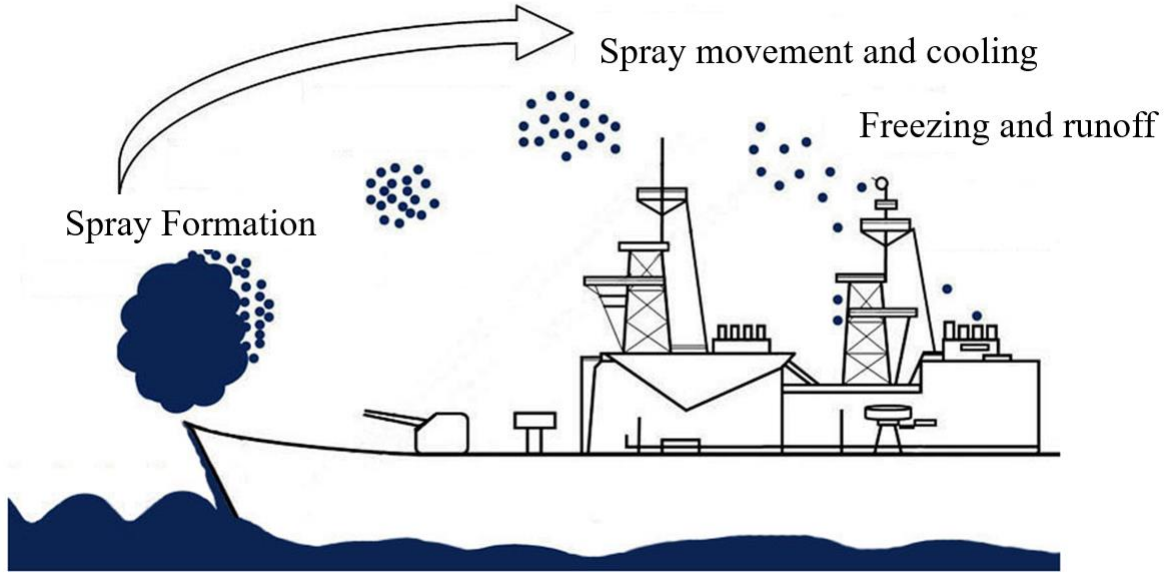
Sea spray icing



Mintu et al., 2020

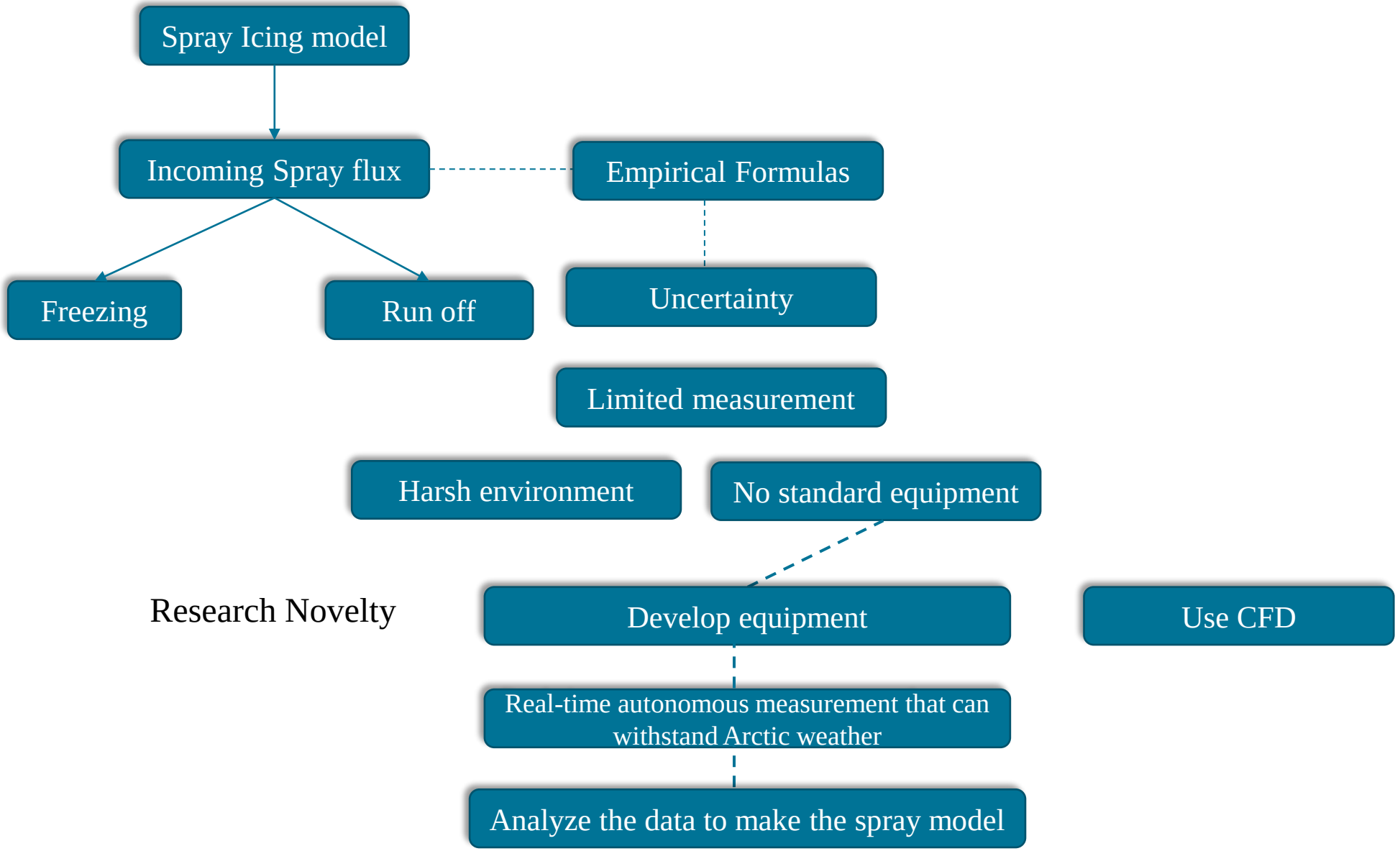


Dehghani et al., 2017

The sinking of the fishing vessel ONEGA, which led to the loss of 17 lives on 28 December 2020 while fishing west of Novaya Zemlya.

Dhar et al., 2022

Sea spray icing modeling



Stokes number: sea spray

- sea spray particle size: 1μm – 7.7 mm

$$\text{Particle Stokes number } (St_p) = \frac{Time\ to\ react\ to\ changes\ in\ fluid\ flow}{Time\ of\ changes\ in\ fluid\ flow}$$

k–ε RANS turbulence model

- We are not interested in the details of the turbulence
- Qualitative approach
- Faster computation

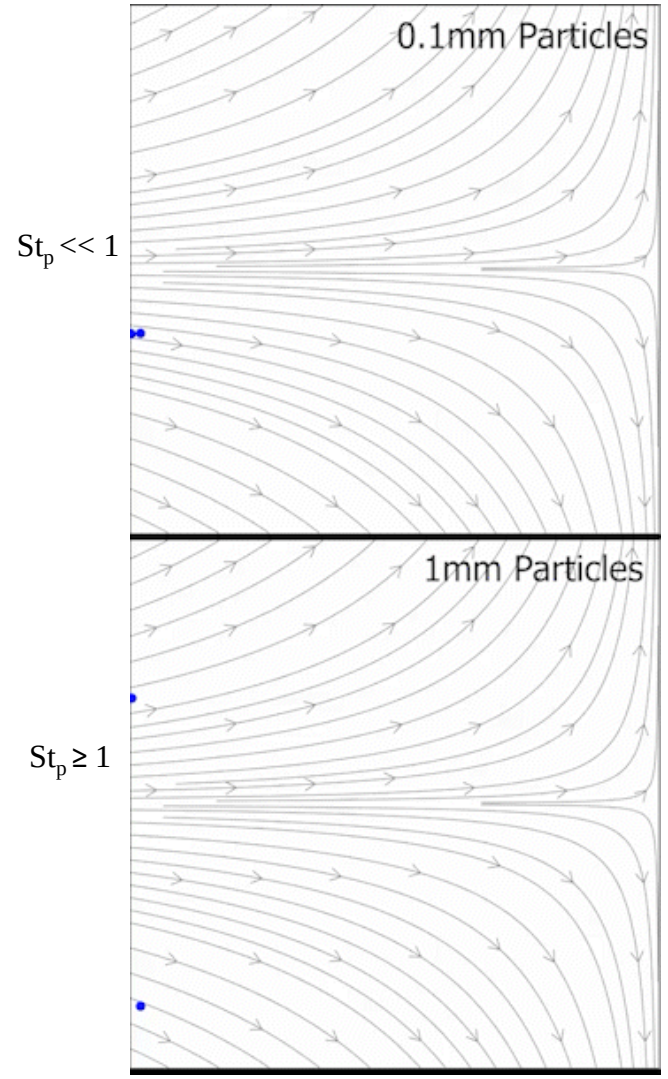
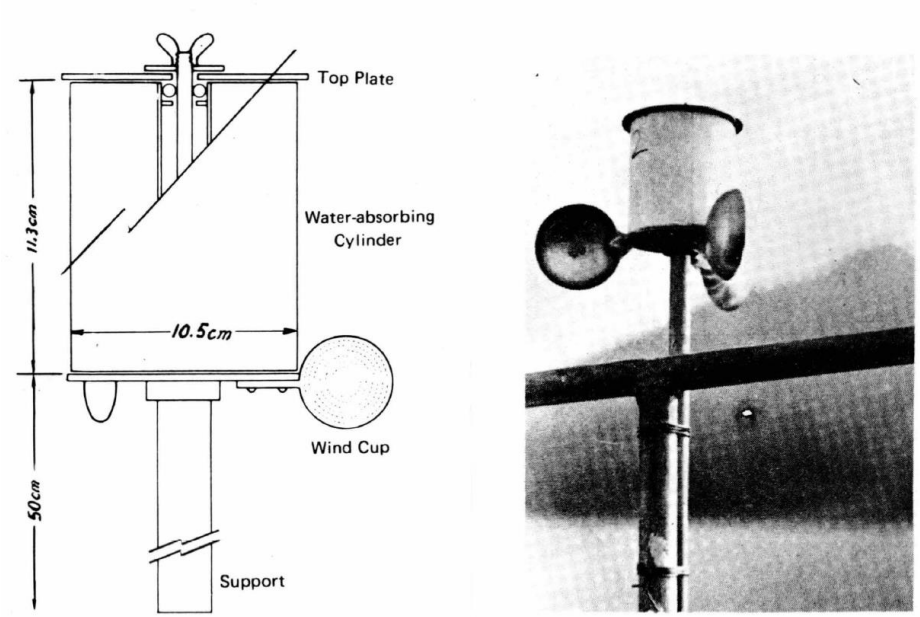


Fig. Comparison between two different particle sizes for tracking accuracy for PIV simulated particles in a stagnation point flow field (wiki commons)

Review and analysis of past sea-spray measurements

Toilet paper rolls



igure 10. Sea spray collector. (Tabata 1969) (Copyright, T. Tabata; reprinted by permission.)

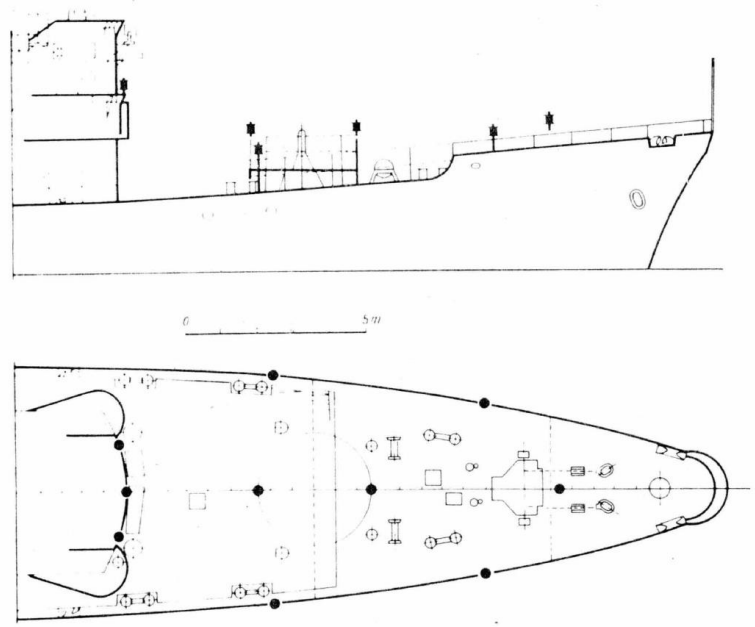
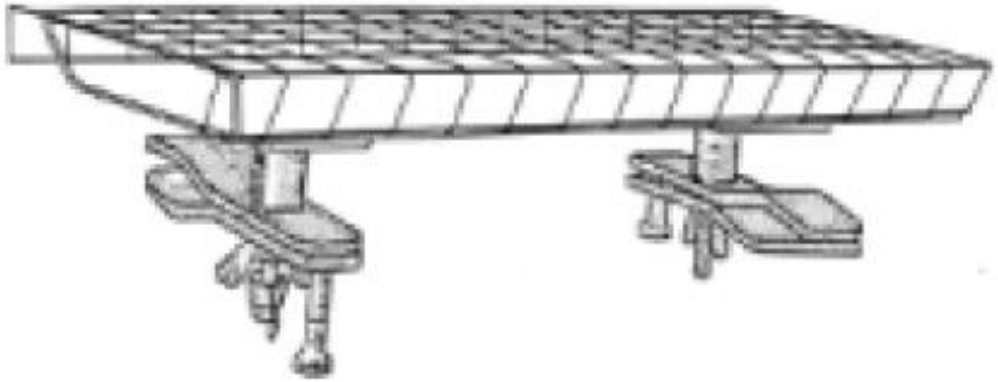


Figure 11. Distribution of sea spray collectors on board ship. (Tabata, 1969) (Copyright, T. Tabata; reprinted by permission).

Tabata, 1969

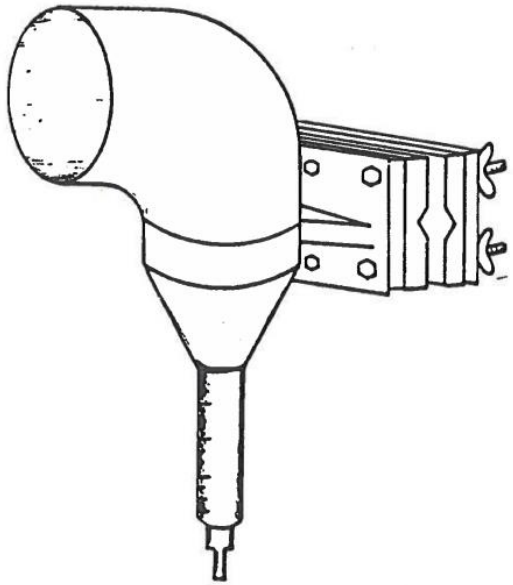
Review and analysis of past sea-spray measurements

Baby diapers



Measurements for ICEMOD (Jorgensen,1984, 1985, 1986)

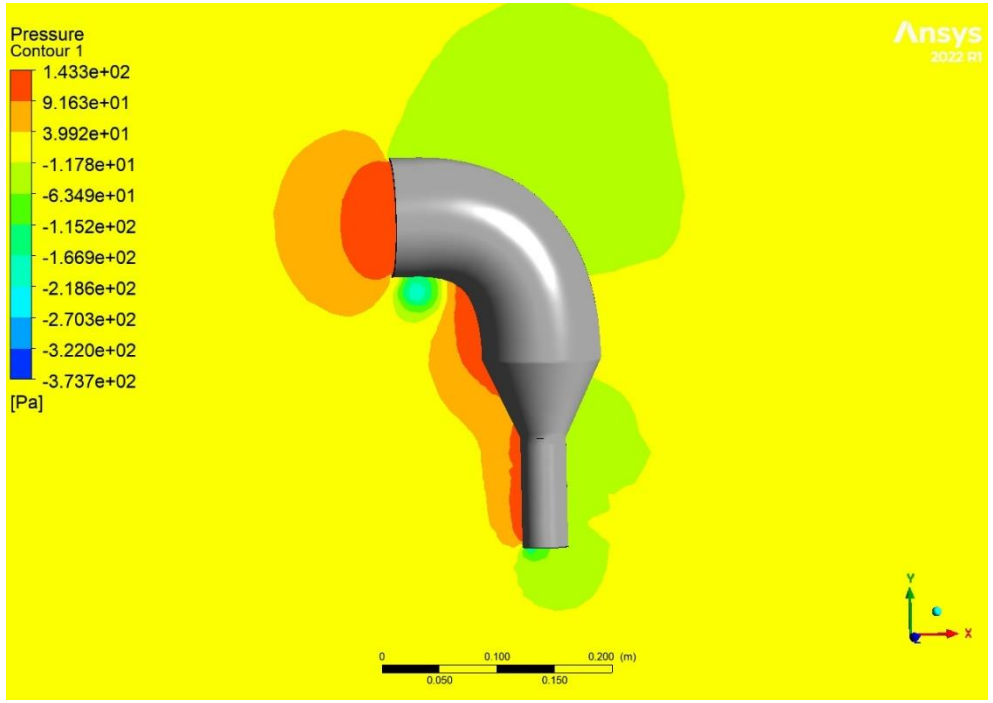
Bend pipe collector, 10 cm diameter

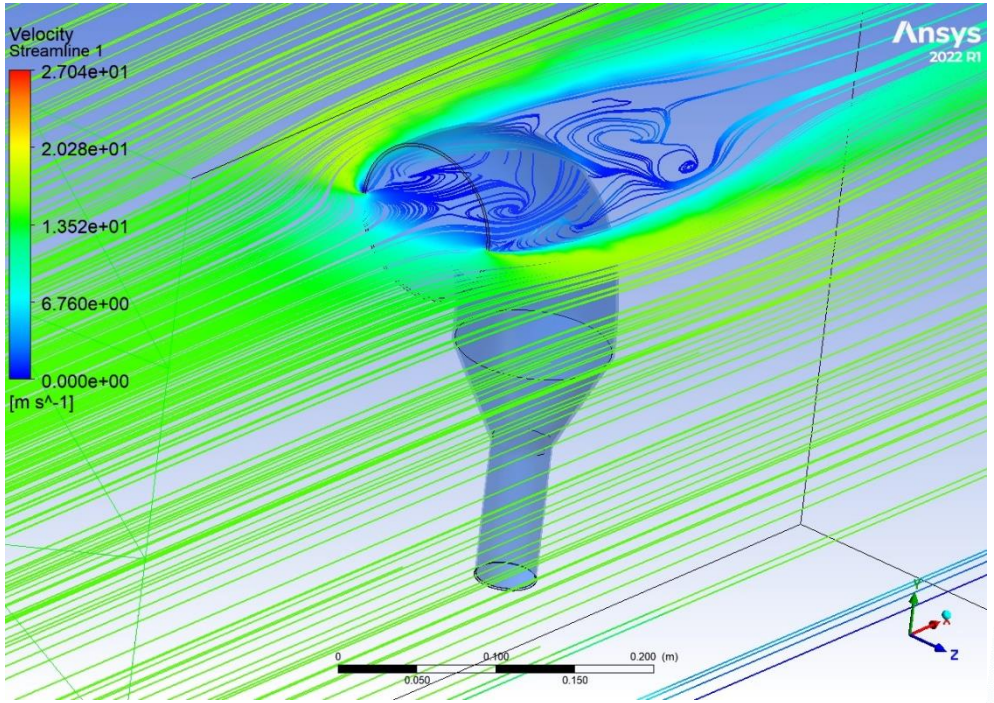


Horjen et al. (1986)

Review and analysis of past sea-spray measurements

Bend pipe collector, 10 cm diameter





CFD RANS simulation, wind speed 15 m/s

Review and analysis of past sea-spray measurements

45-gallon drums

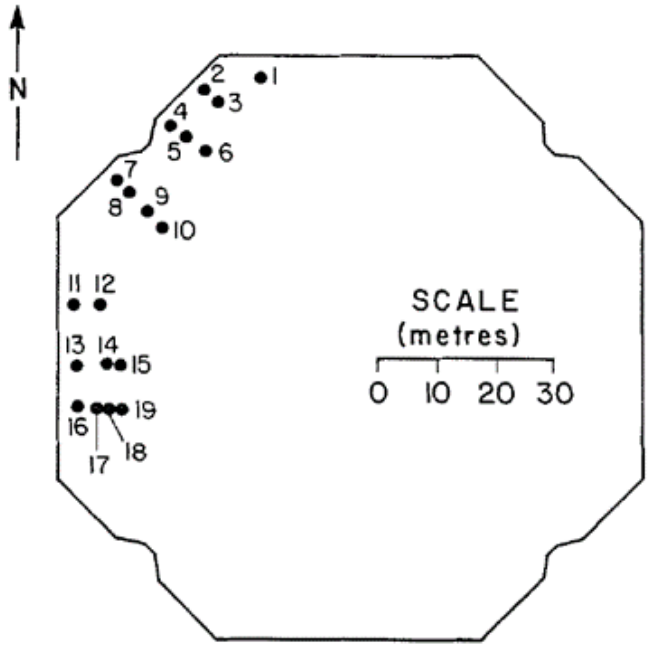


FIG. 5. Plan view of typical drum layout for the field study.

Tarsuit Island, an artificial caisson-based island in the Beaufort Sea

Measurements for RIGICE (Muzik, 1991)

Review and analysis of past sea-spray measurements

Counts spray particles 100 to 1,000 μm in diameter,

but sea-spray 1 to 7700 μm (Ryerson,1995)

Ozeki (2016)

FIG. 2. The DMT CIP and the Gill sonic anemometer/thermometer mounted on the foghorn platform on Mount Desert Rock.

Cloud Imaging Probe (Andreas, 2016)

Review and analysis of past sea-spray measurements

RigSpray design (Teigen et al., 2019)

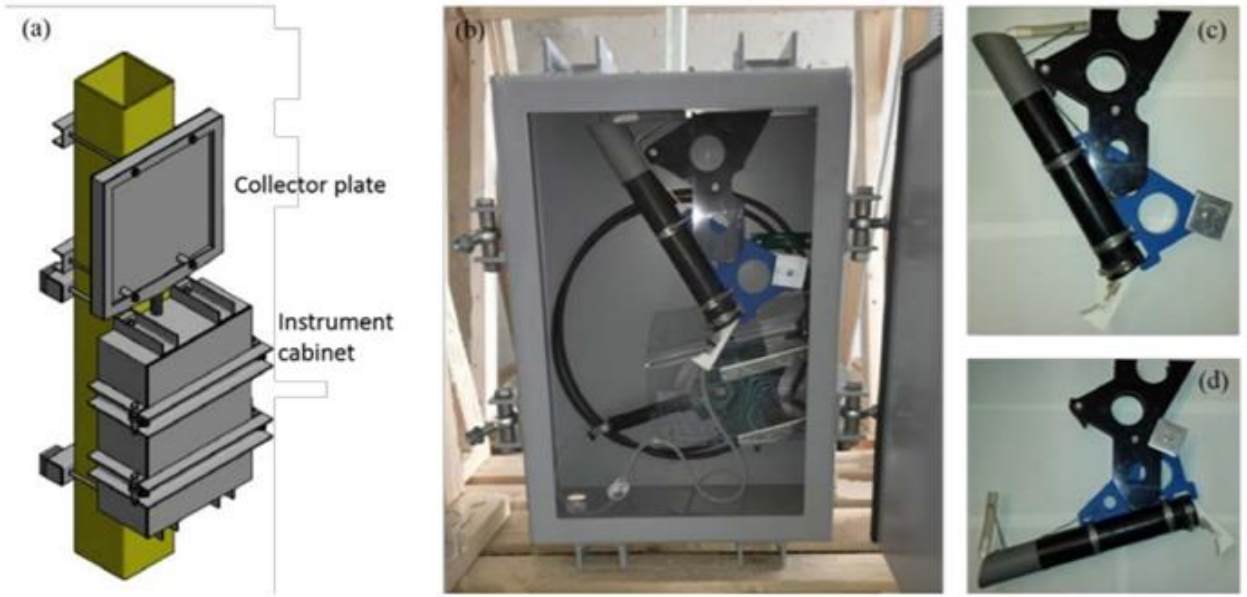
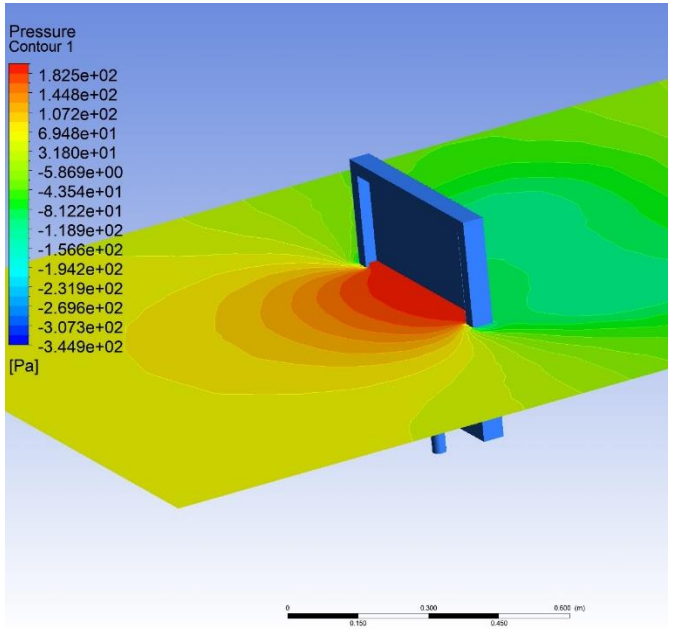
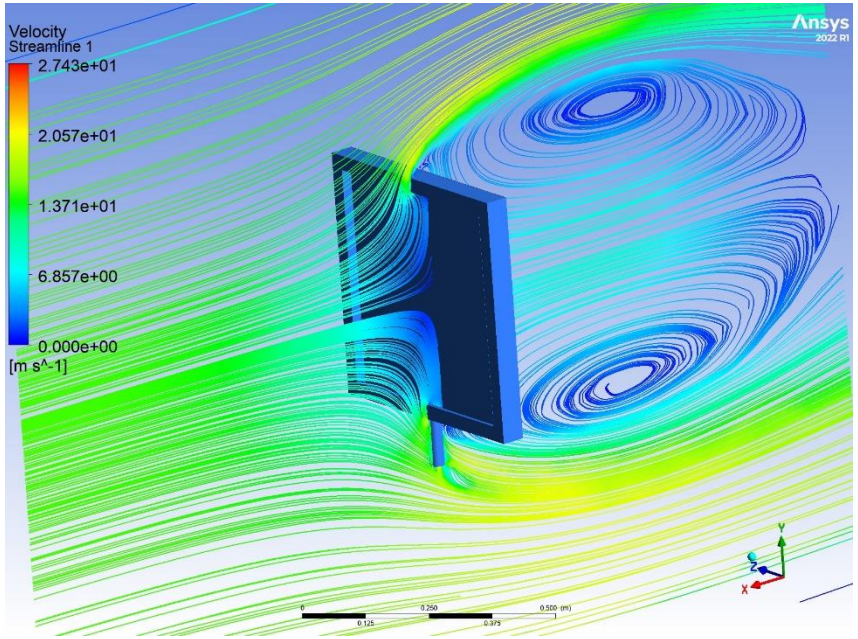


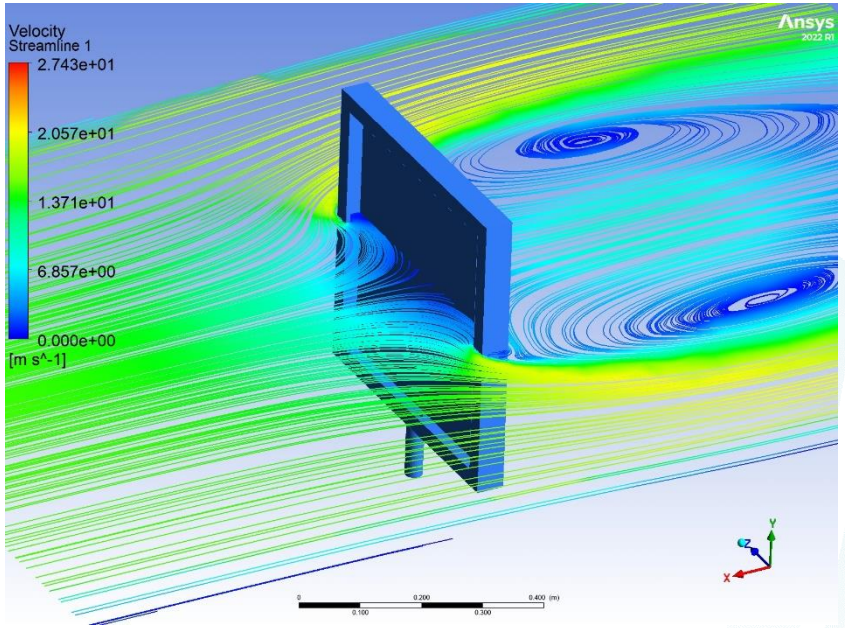
Figure 3. (a) Technical drawing of the collector plate and instrument cabinet assembly mounted on a vertical column, (b) Internal view of the instrument cabinet, (c) Close-up of tipping bucket in upright position, (d) Close-up of tipping bucket in tilted position.

Review and analysis of past sea-spray measurements

RigSpray design (Teigen et al., 2019)



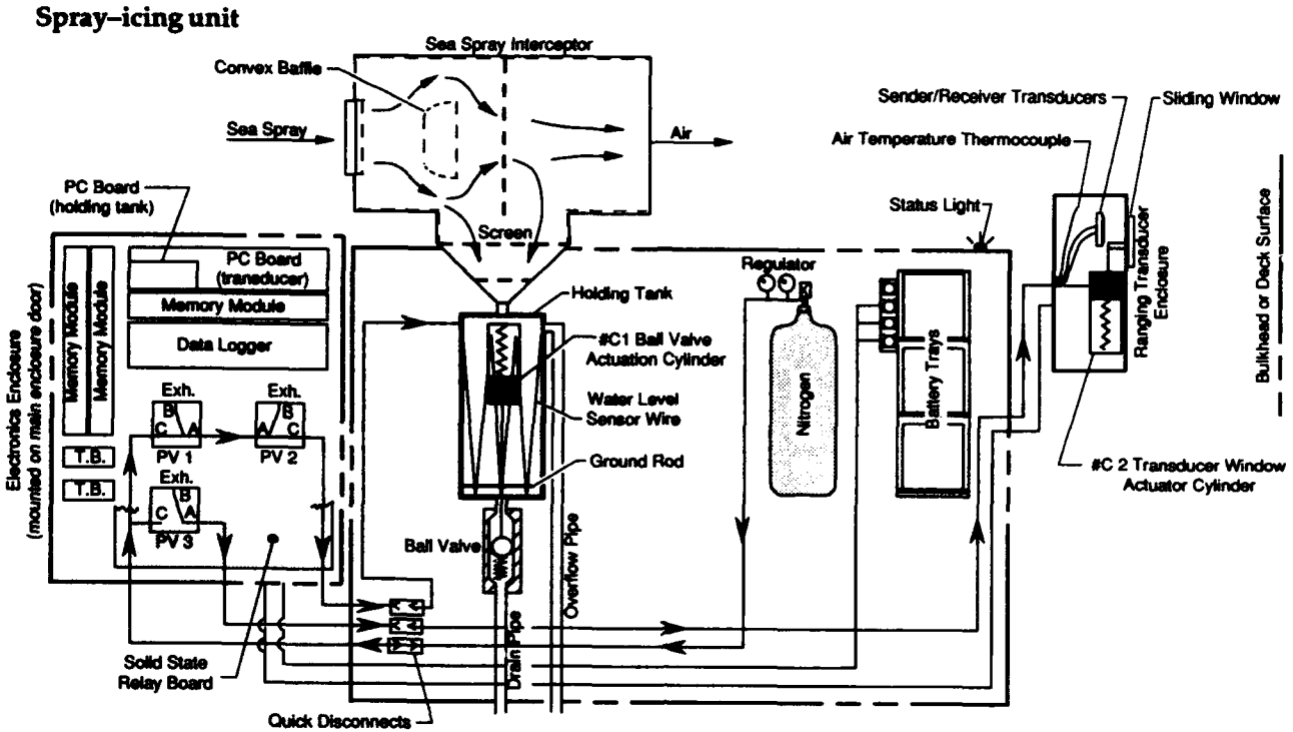




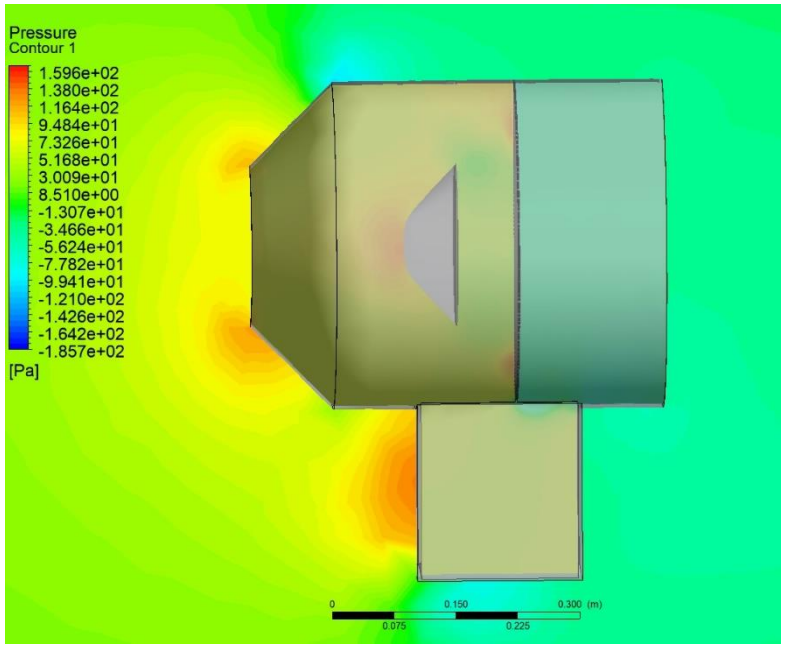
CFD RANS 15 m/s

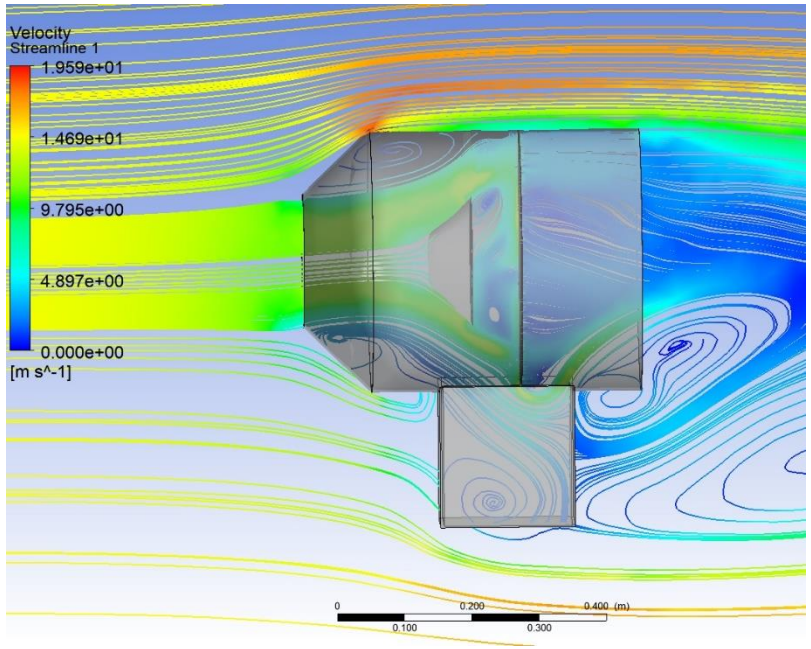
Review and analysis of past sea-spray measurements

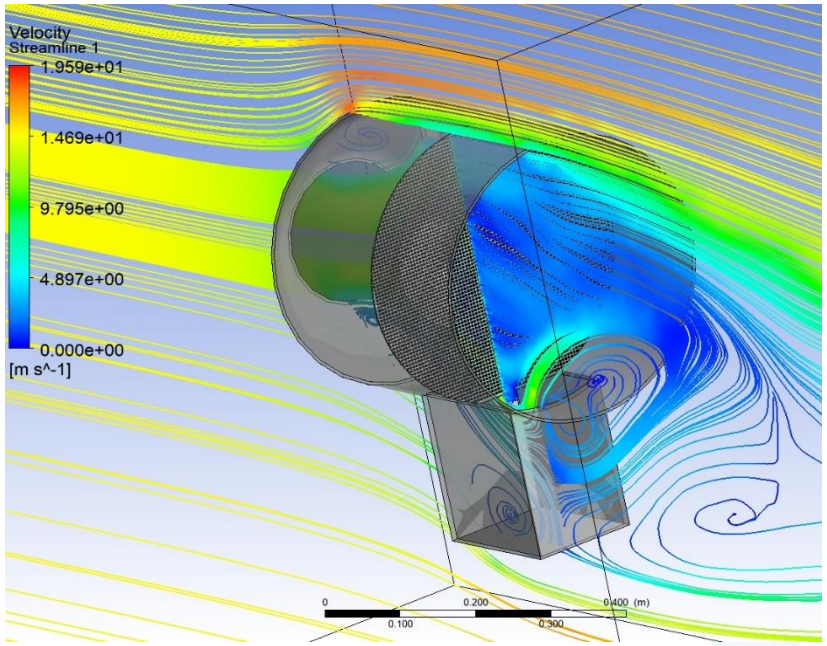
Ryerson (1992) Midgett design



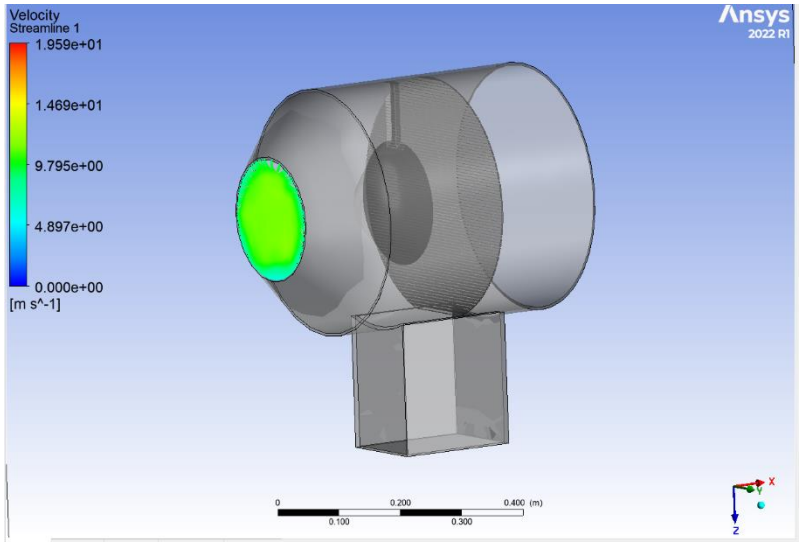
Review and analysis of past sea-spray measurements







CFD RANS 15 m/s



Ryerson (1992) Midgett design

Initial wind speed- 15 m/s
Average Velocity on the inlet plane of the collector - 10.7034 m/s
Average Pressure on the inlet plane of the collector - 79.3363 Pa

Efficiency = (Average velocity at the collector inlet plane / Initial wind speed) x 100
= **71.356%**

Review and analysis of past sea-spray measurements

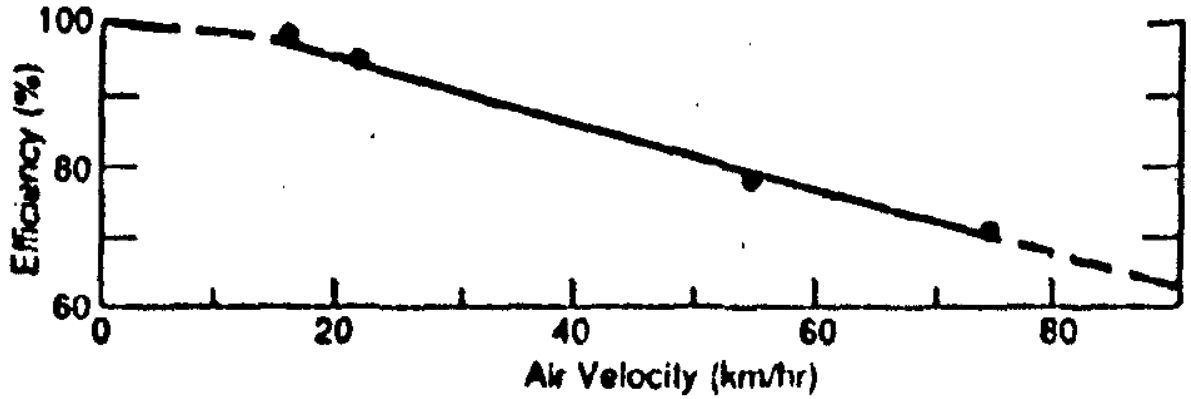
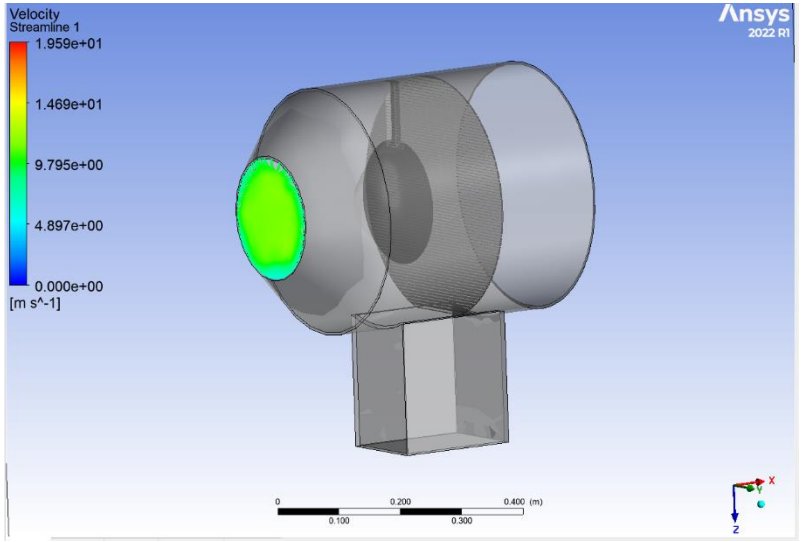


Figure 25. Efficiency curve for horizontal collector droplet interception (from Walsh et al. 1992).



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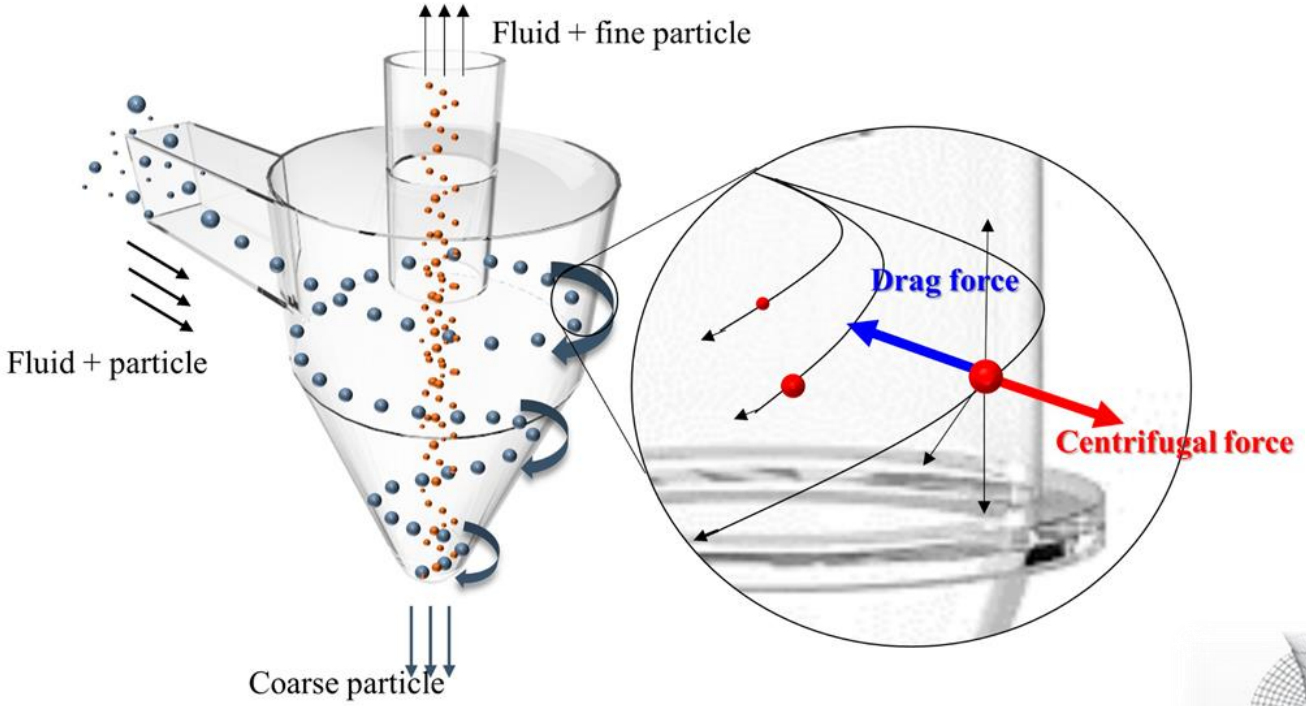
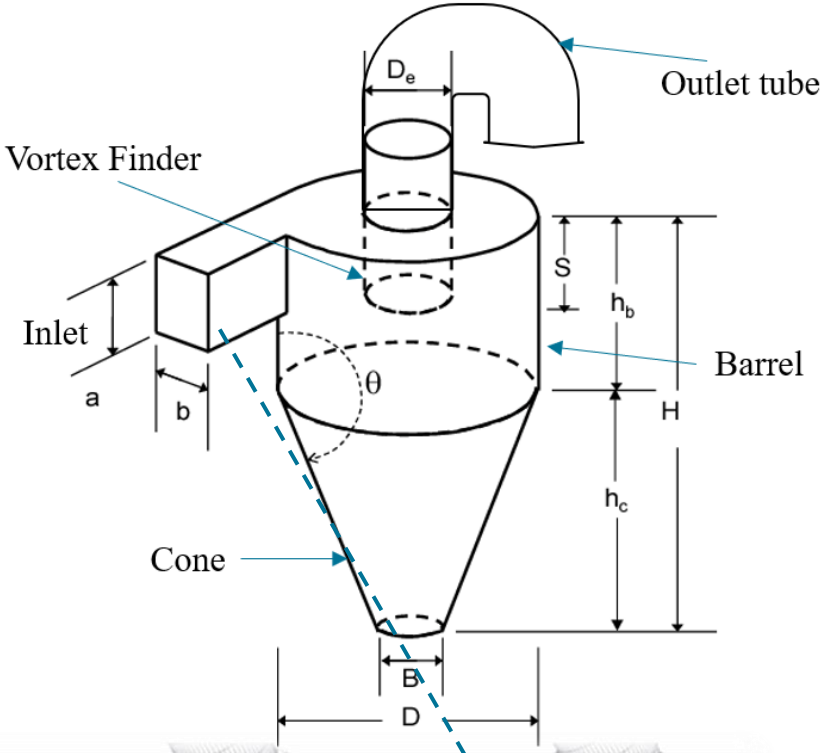
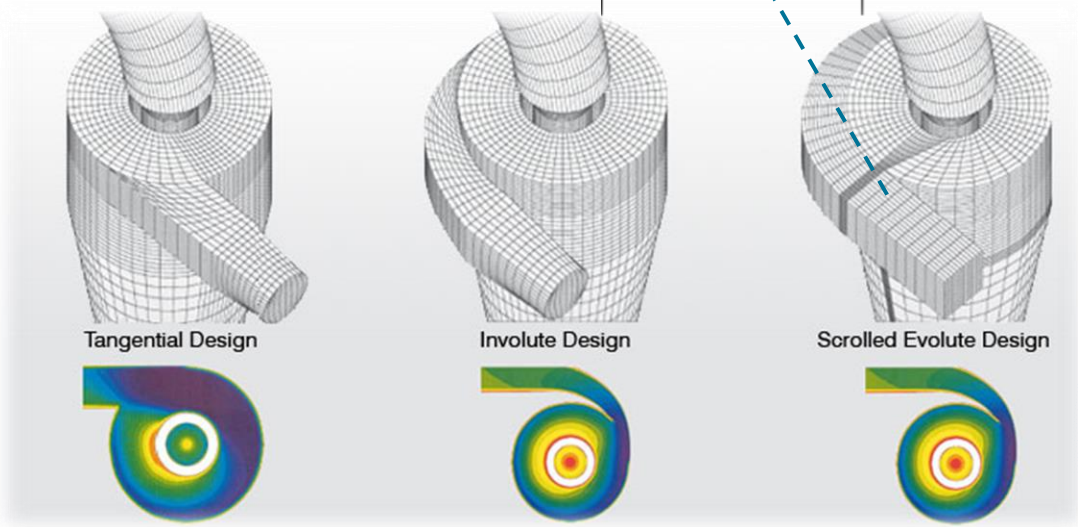
Cyclone separator

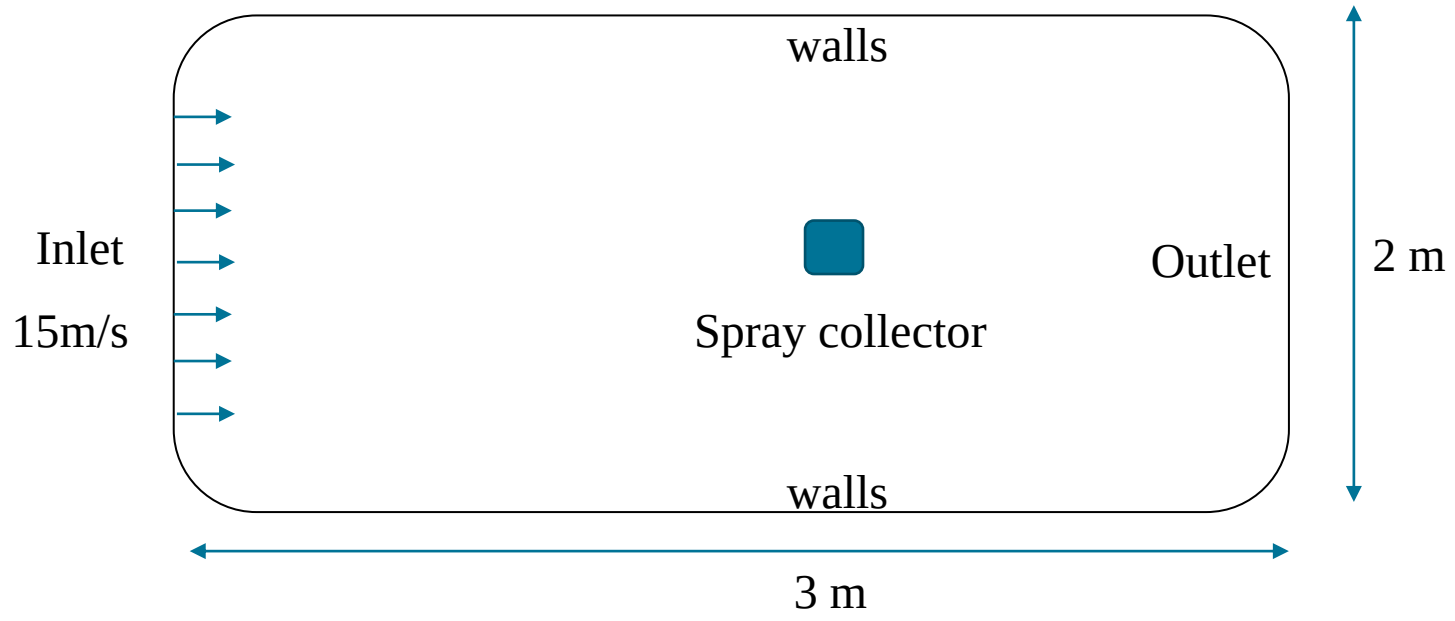


(Park & Go, 2020)

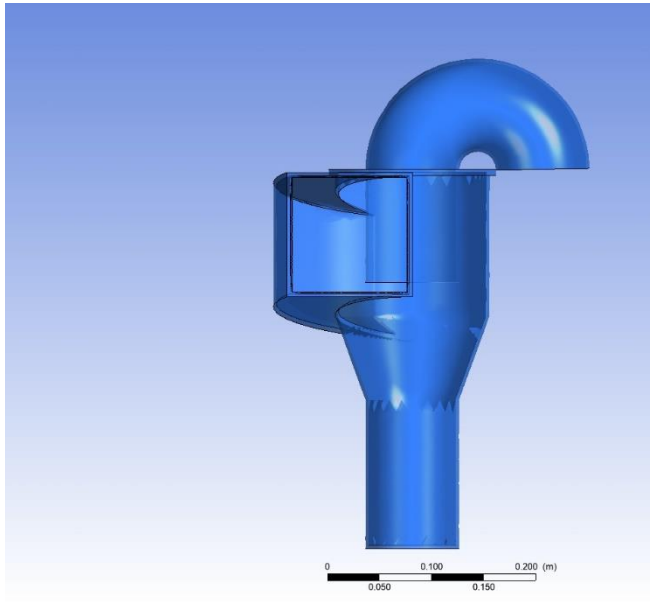


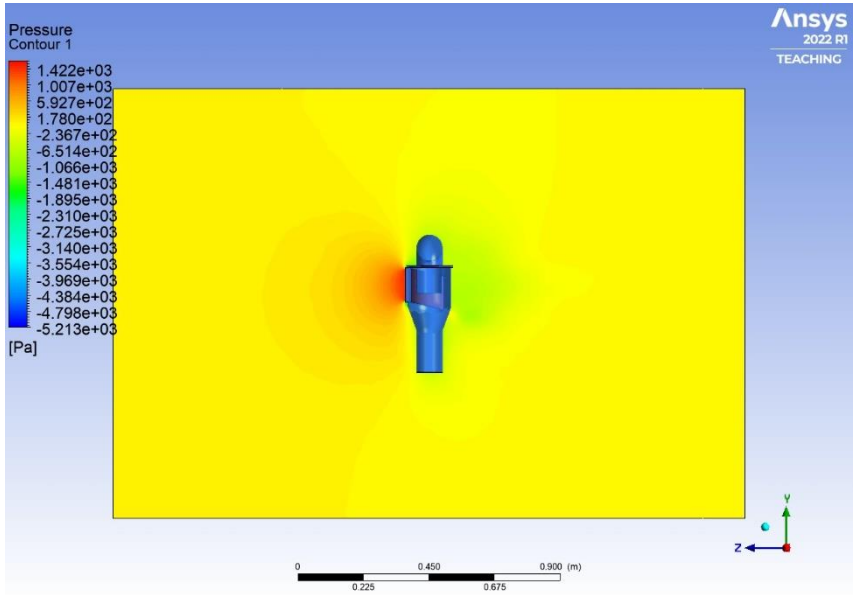


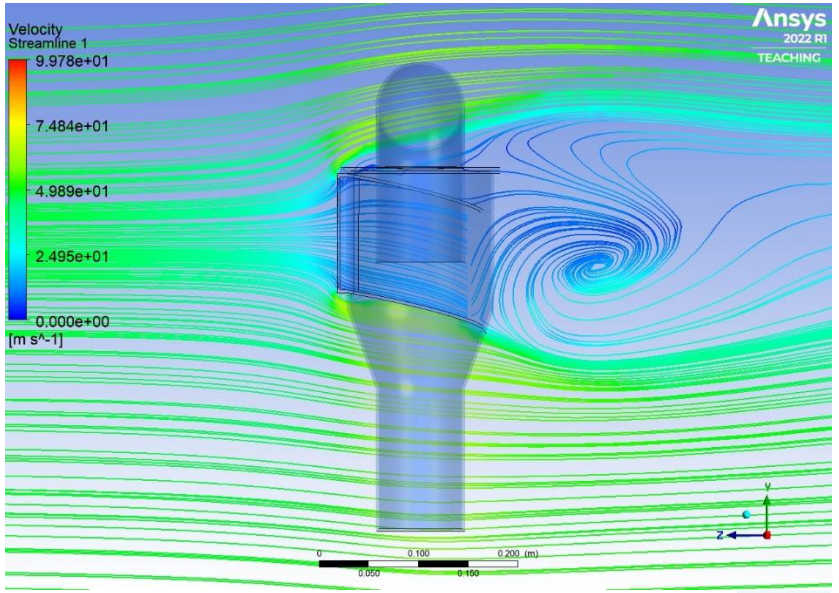
Wind tunnel Simulation



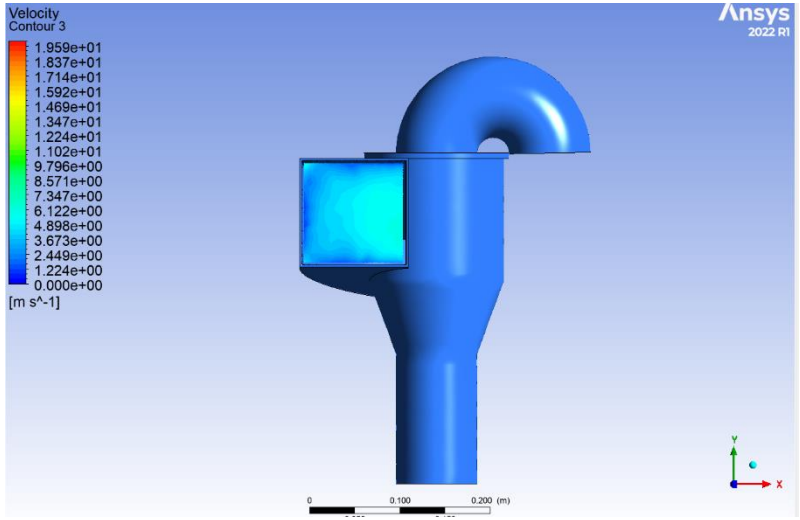
Attempt 1 – spray collector







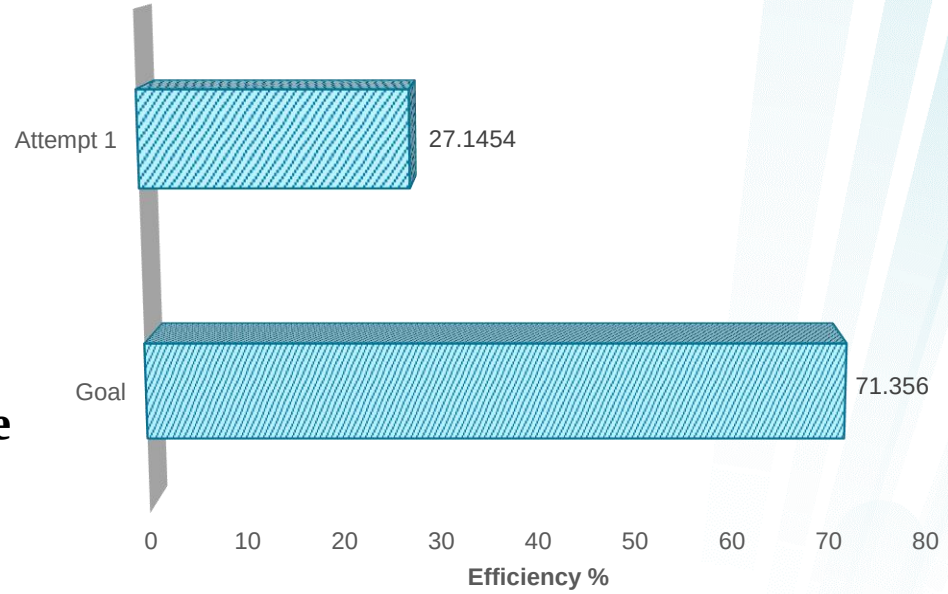
Short Nozzle



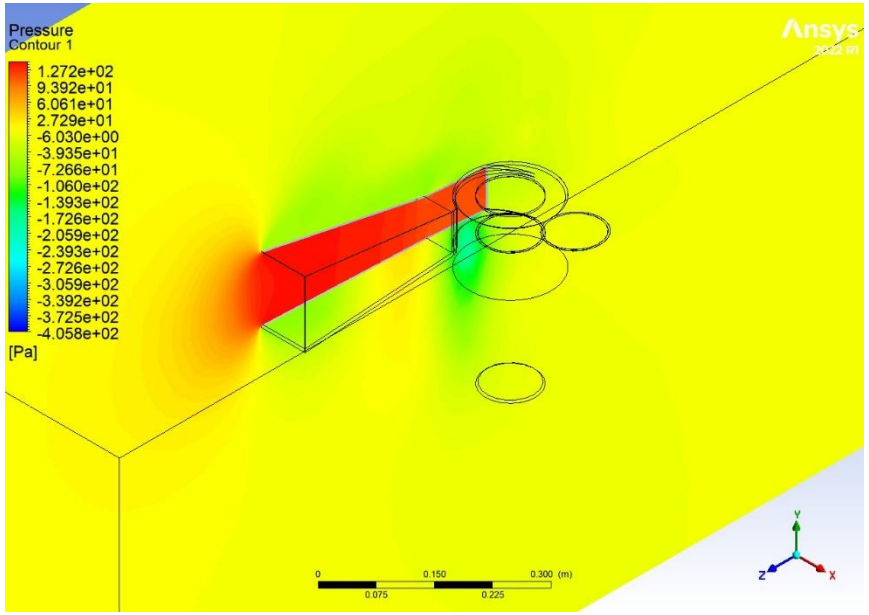
Initial wind speed - 15 m/s

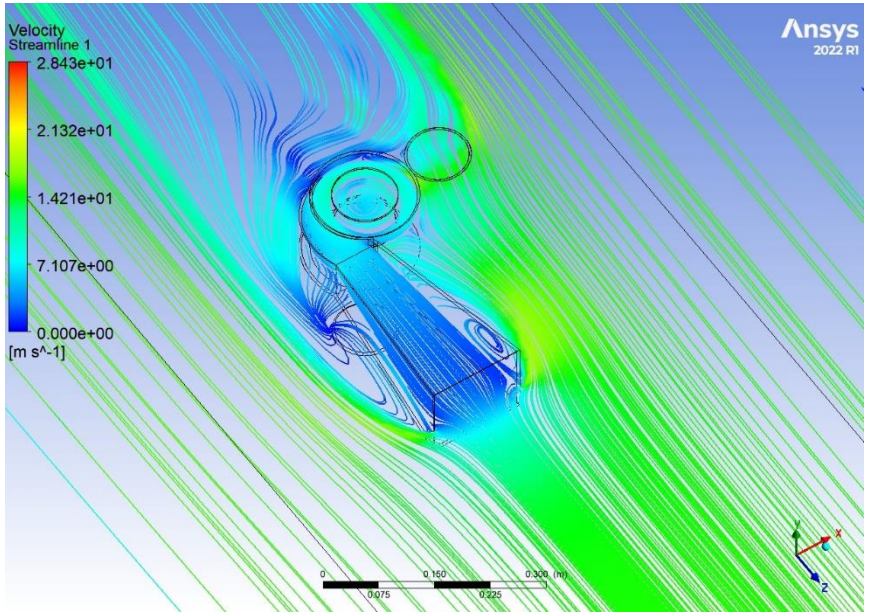
Average Velocity on the inlet plane of the collector - 4.07181 m/s

Average Pressure on the inlet plane of the collector - 132.563 Pa

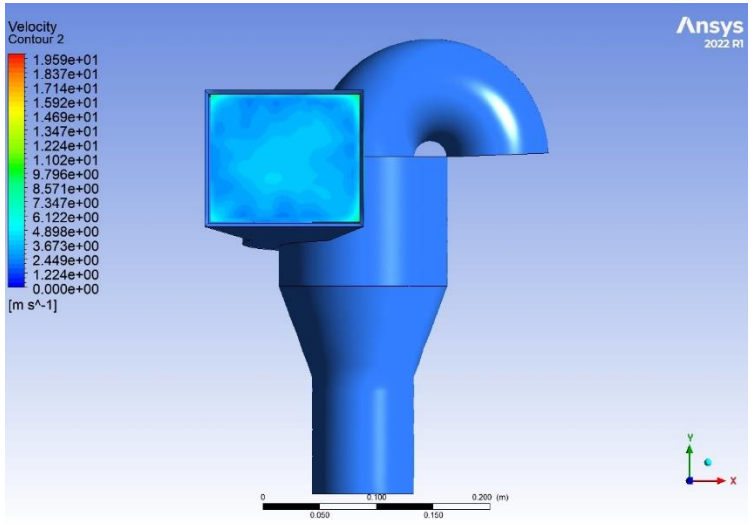


Attempt 2





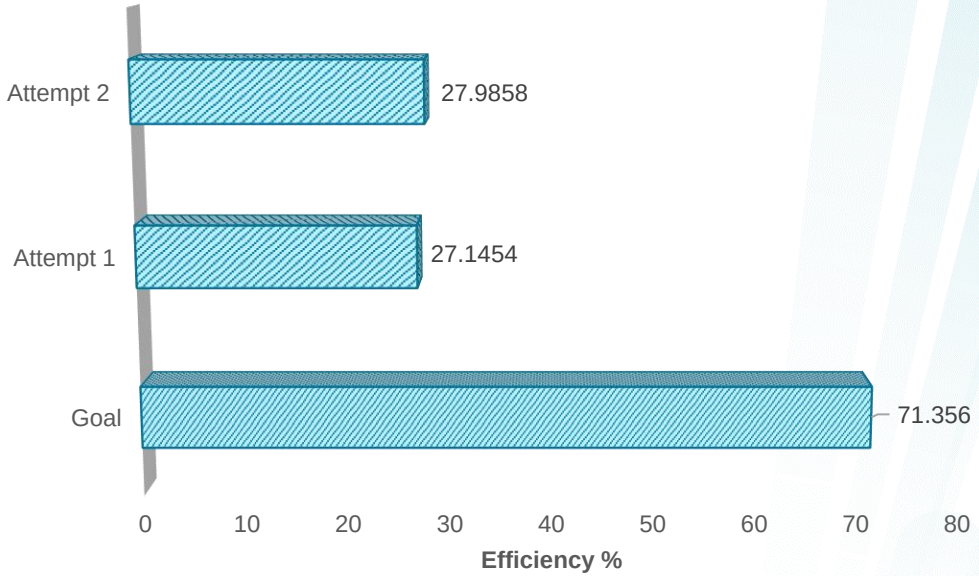
Long Nozzle



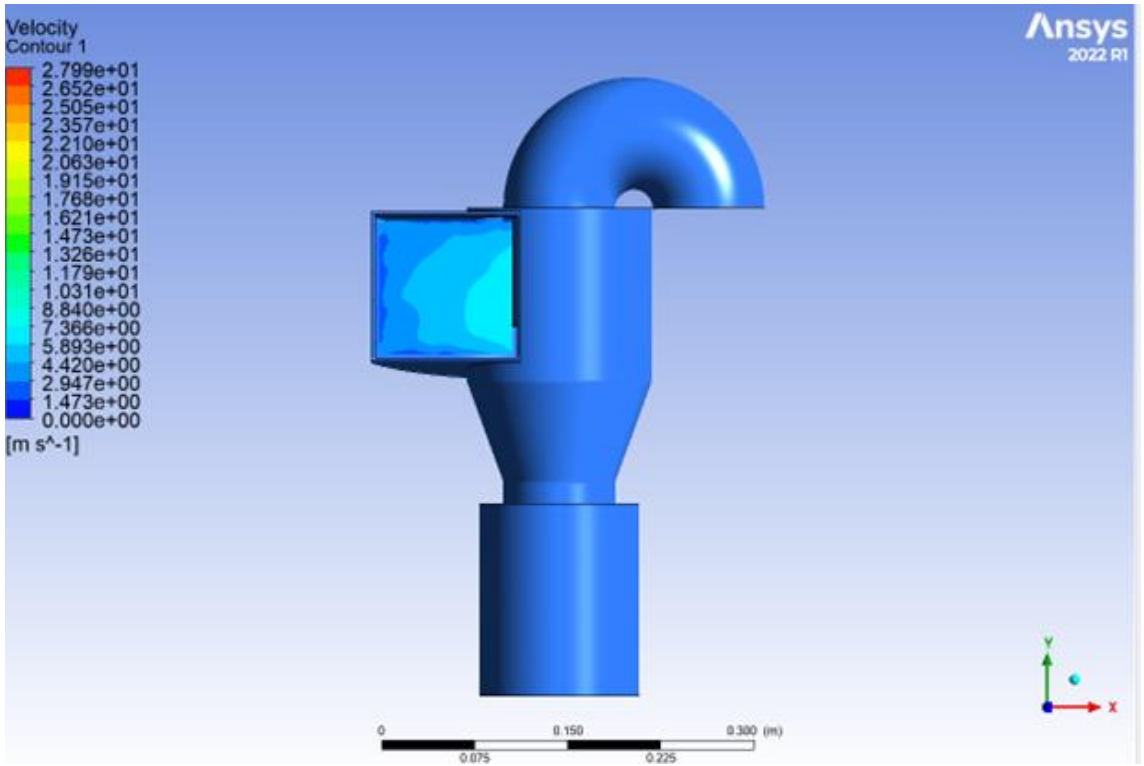
Initial wind speed - 15 m/s

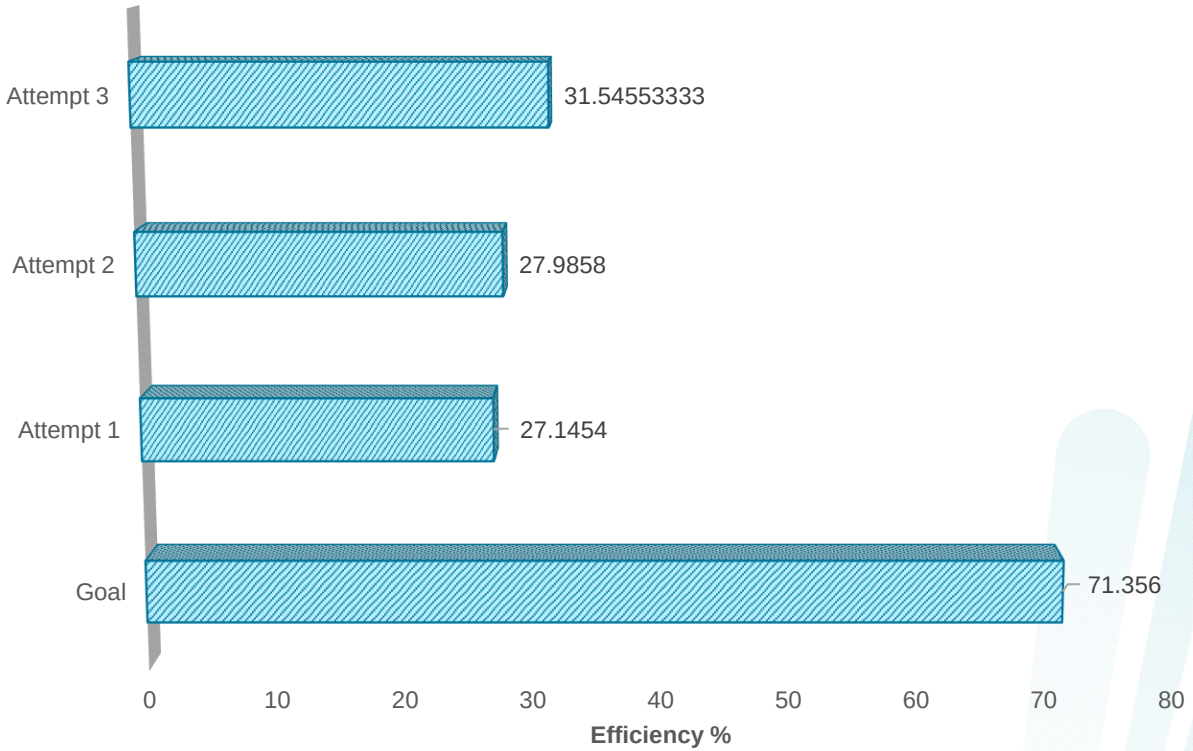
Average Velocity on the inlet plane of the collector - 4.19787 m/s

Average Pressure on the inlet plane of the collector - 130.426 Pa



Attempt 3





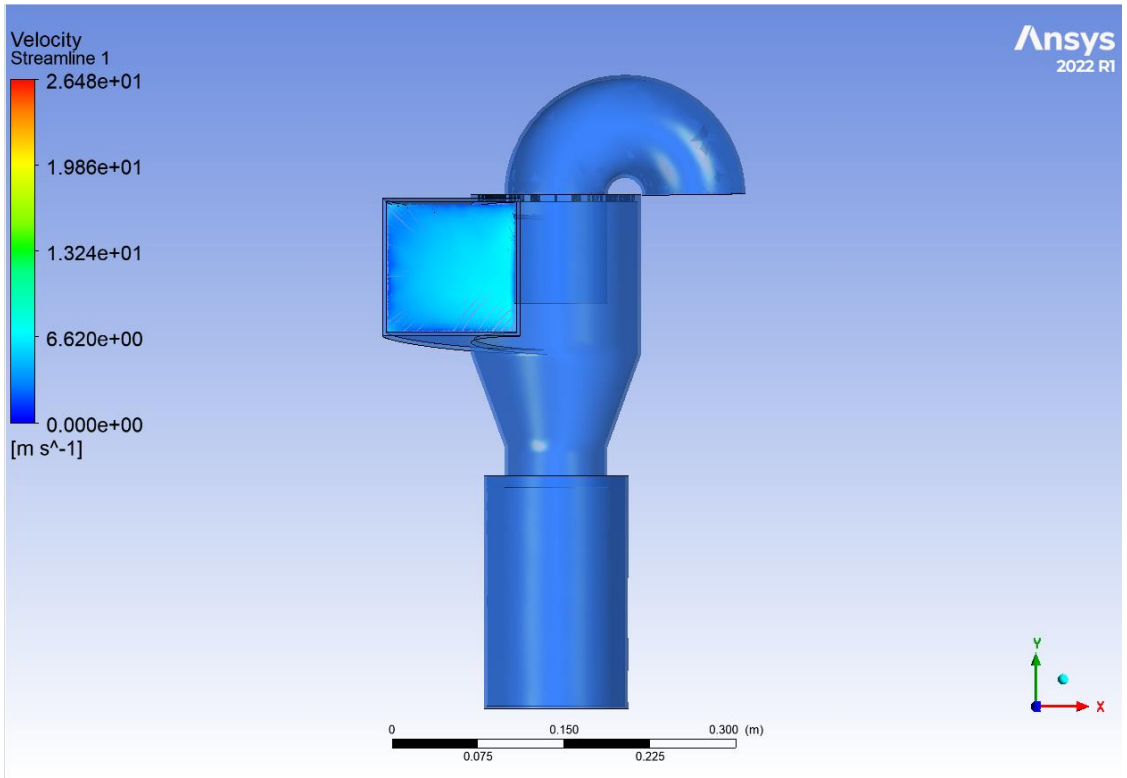
Short Nozzle disconnected base

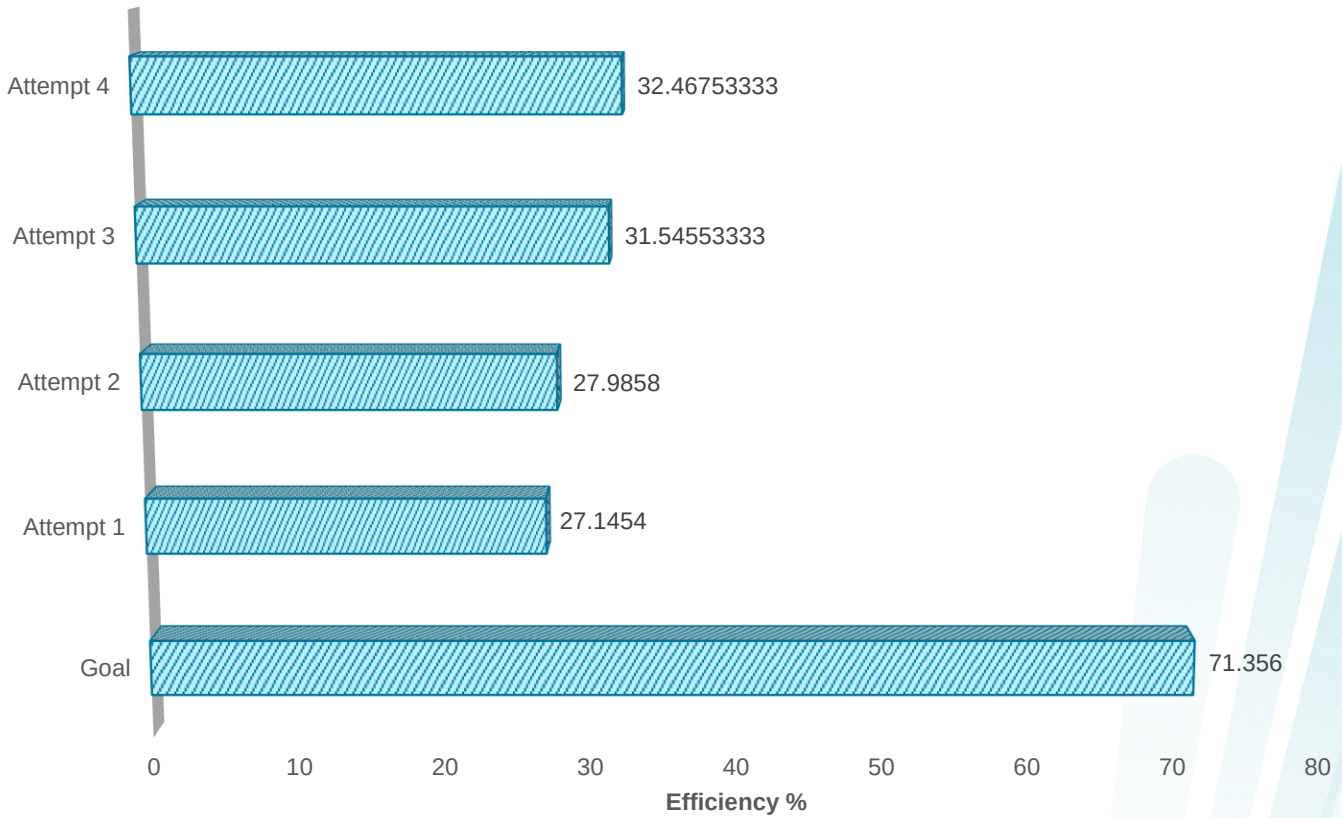
Initial wind speed - 15 m/s

Average Velocity on the inlet plane of the collector - 4.73183 m/s

Average Pressure on the inlet plane of the collector - 114.905 Pa

Attempt 4





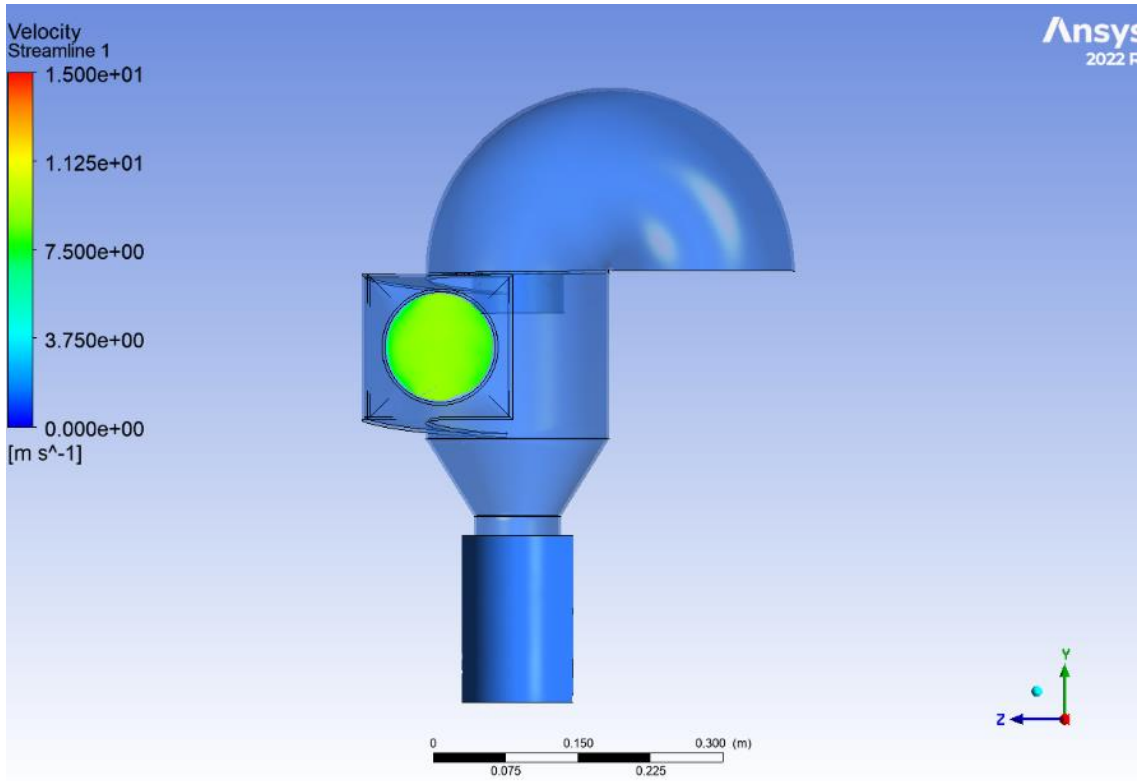
Short Nozzle disconnected base, perforated top

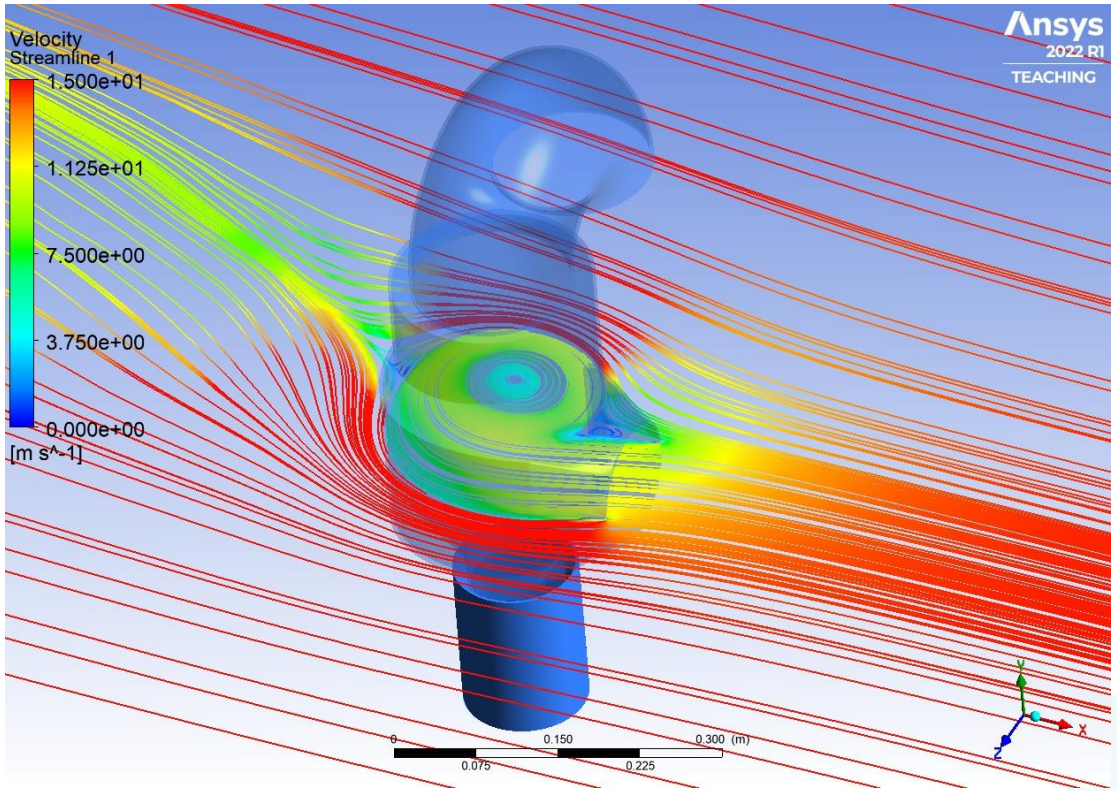
Initial wind speed - 15 m/s

Average Velocity on the inlet plane of the collector - 4.87013 m/s

Average Pressure on the inlet plane of the collector - 127.803 Pa

Attempt 5



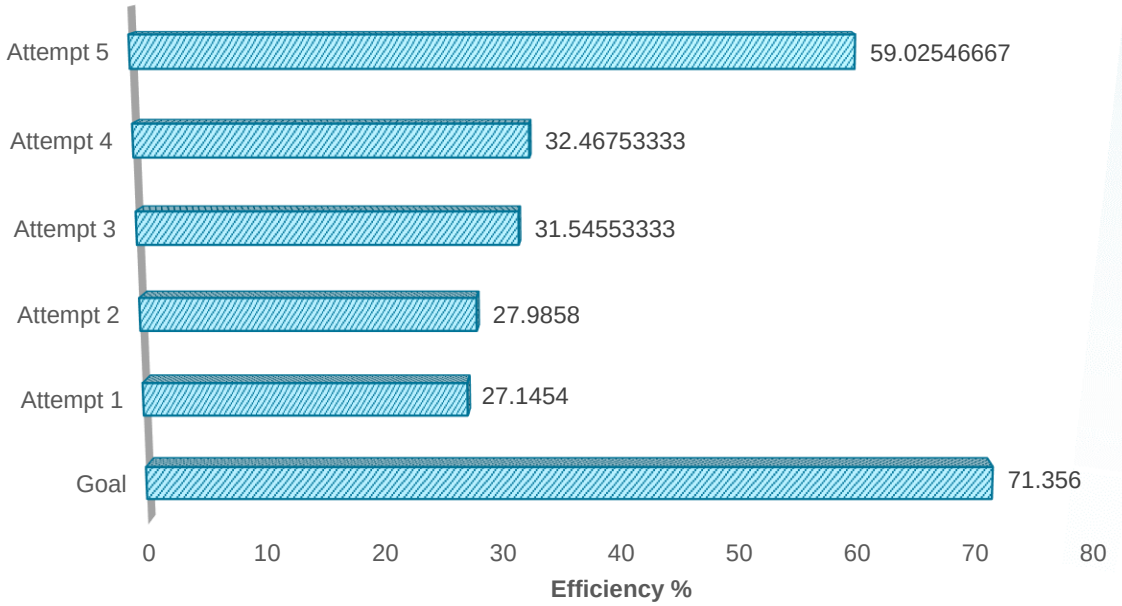


Conical Nozzle, disconnected base

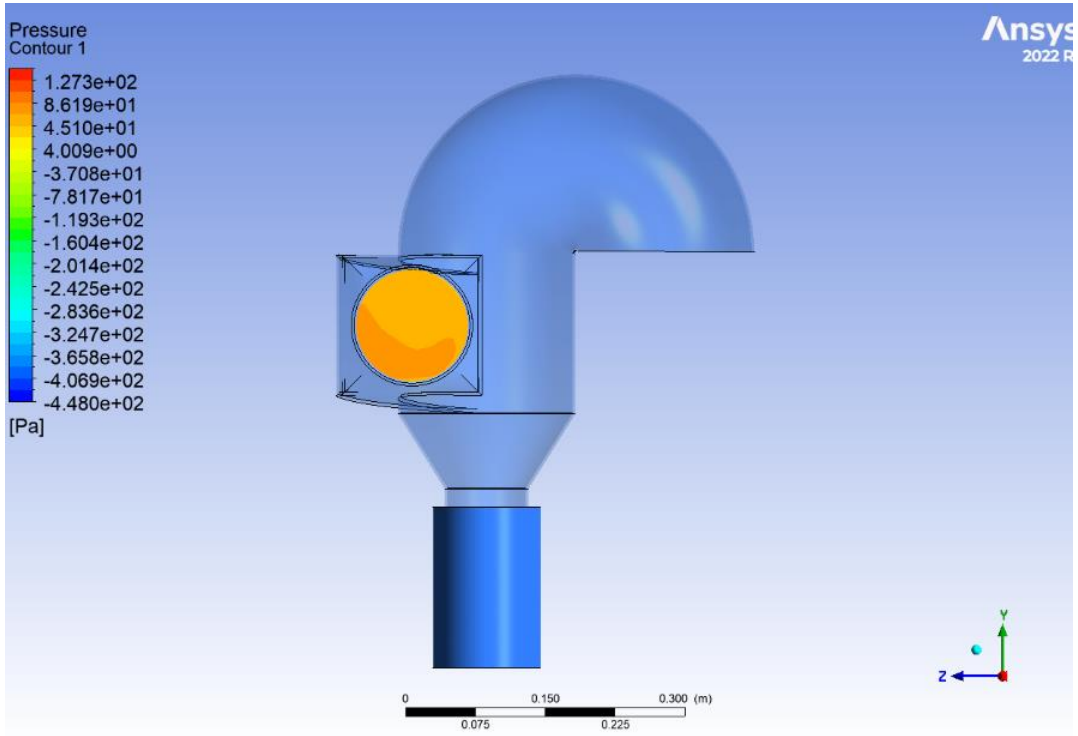
Initial wind speed - 15 m/s

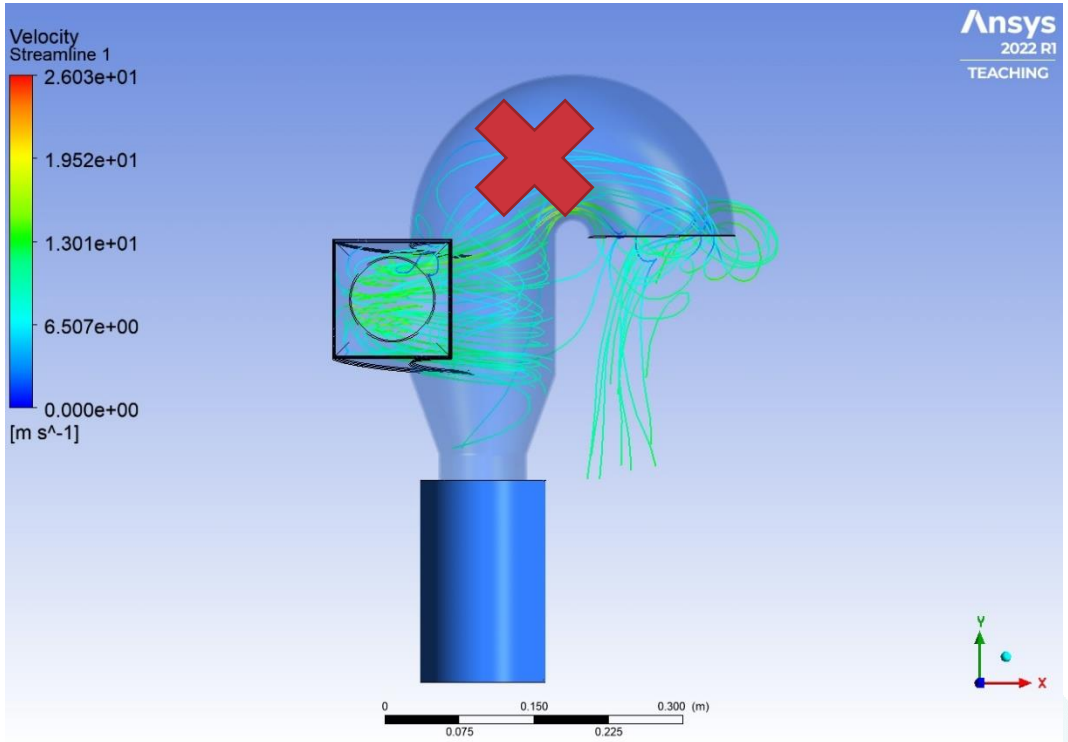
Average Velocity on the inlet plane of the collector - 8.85382 m/s

Average Pressure on the inlet plane of the collector - 99.5488 Pa



Attempt 6



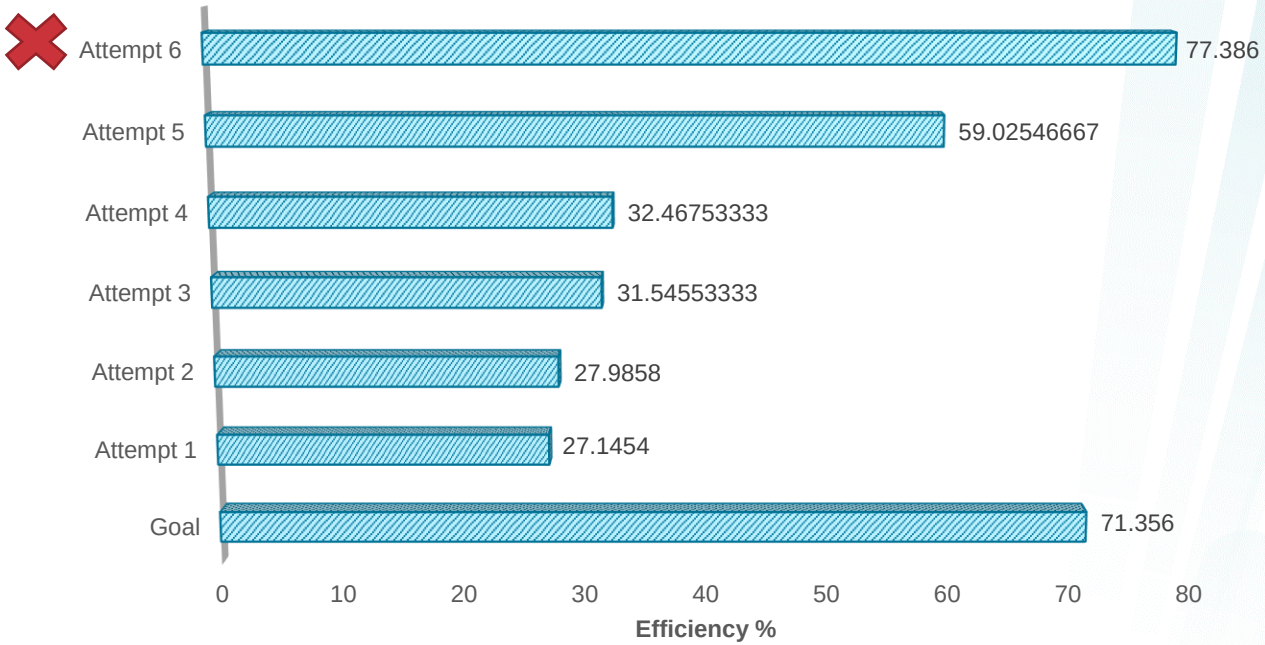


Conical nozzle, no vortex finder

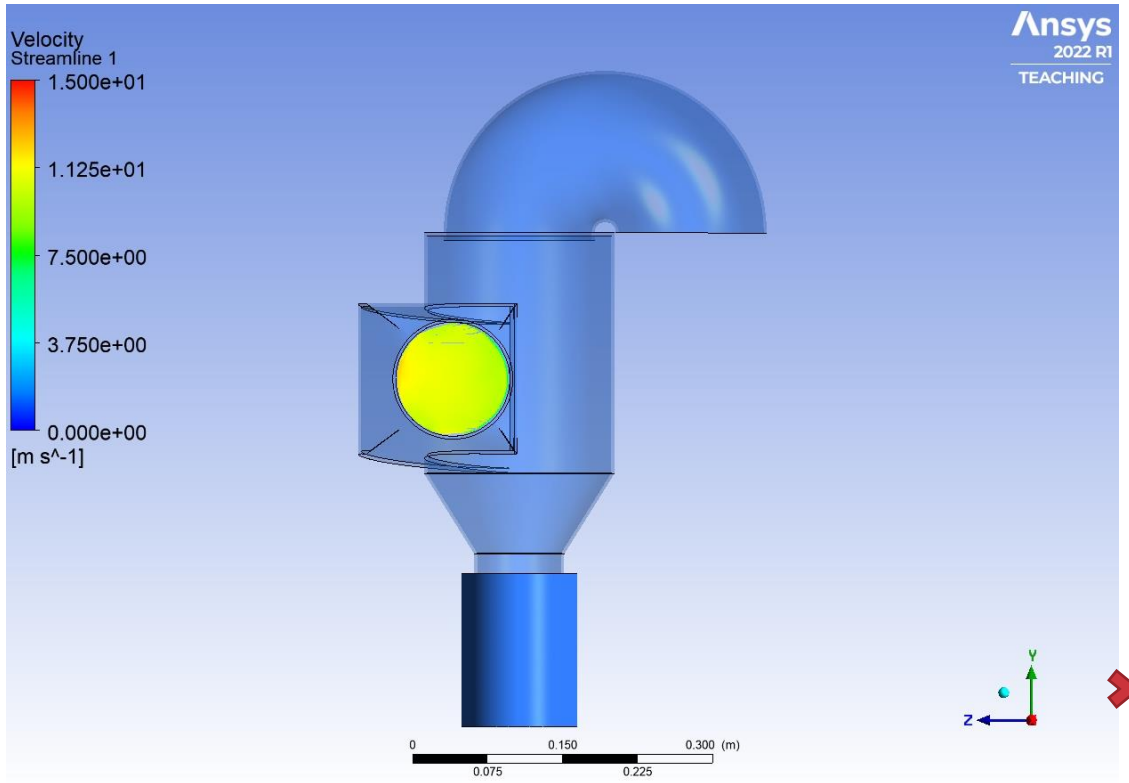
Initial wind speed - 15 m/s

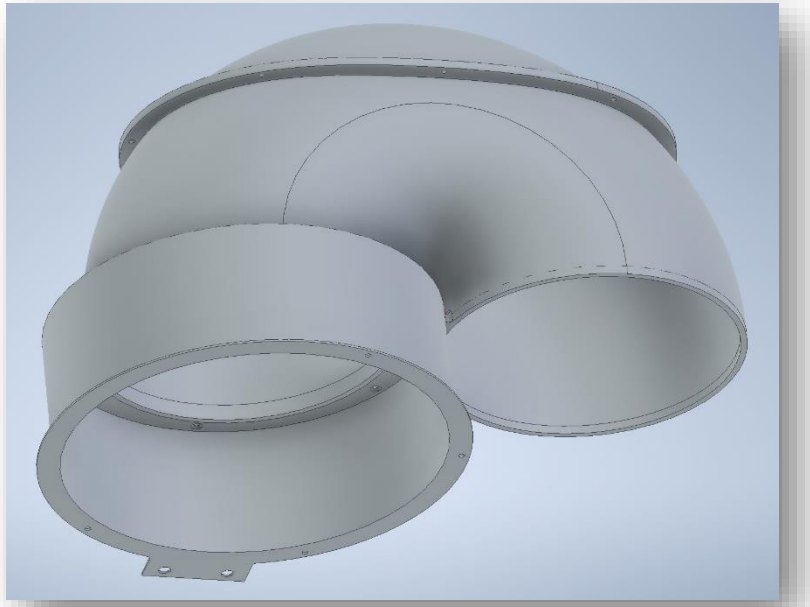
Average Velocity on the inlet plane of the collector - 11.6079 m/s

Average Pressure on the inlet plane of the collector - 63.6785 Pa



Attempt 7



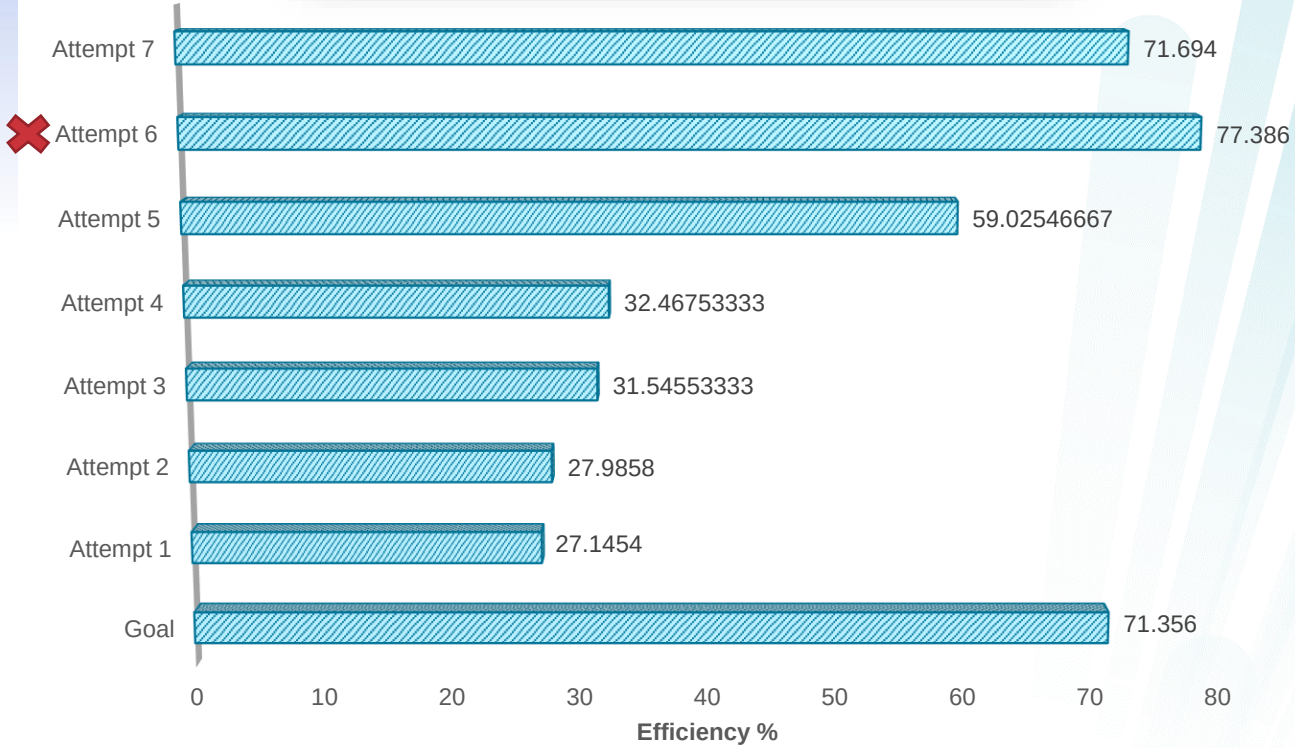


Conical nozzle, with a rim

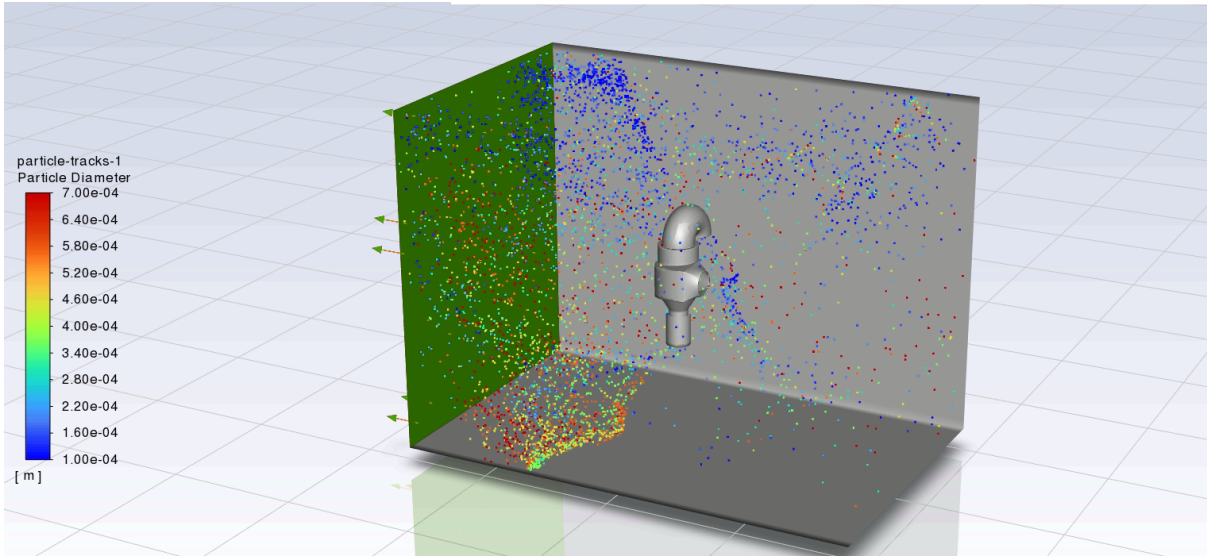
Initial wind speed - 15 m/s

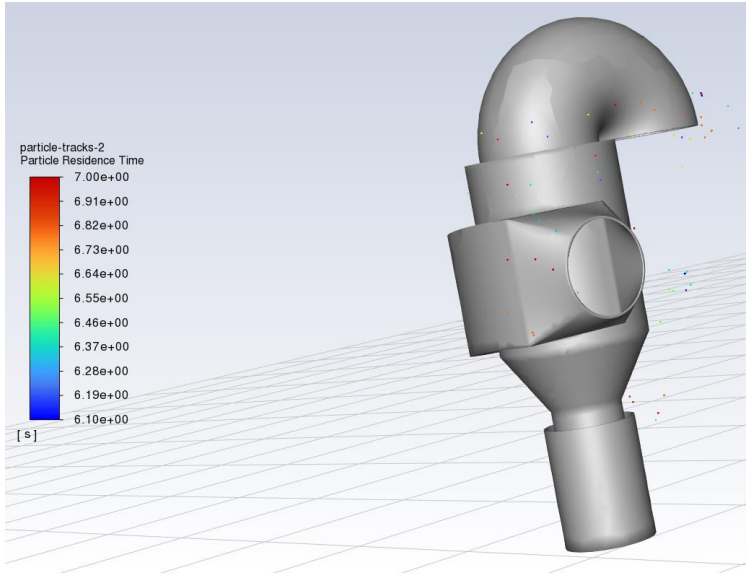
Average Velocity on the inlet plane of the collector - 10.7541 m/s

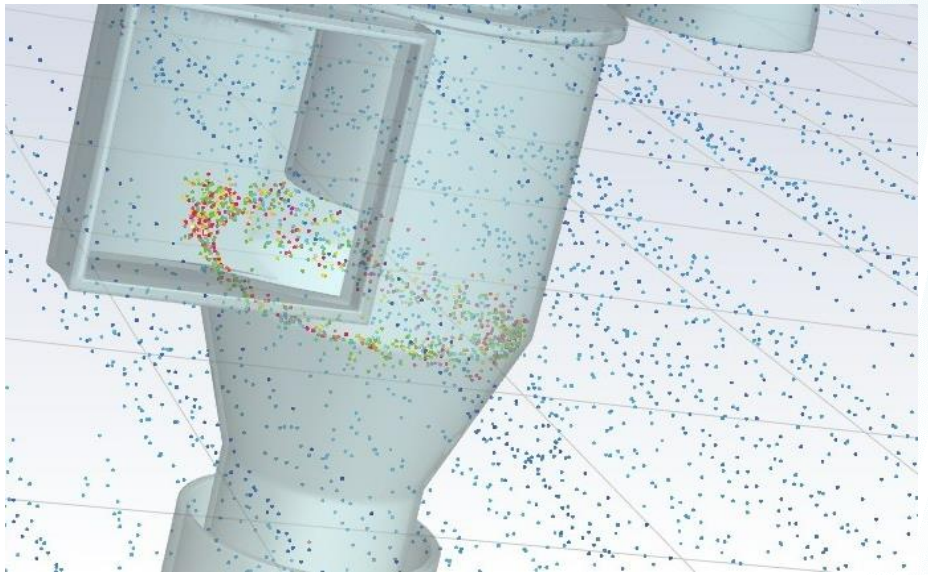
Average Pressure on the inlet plane of the collector - 75.4132 Pa



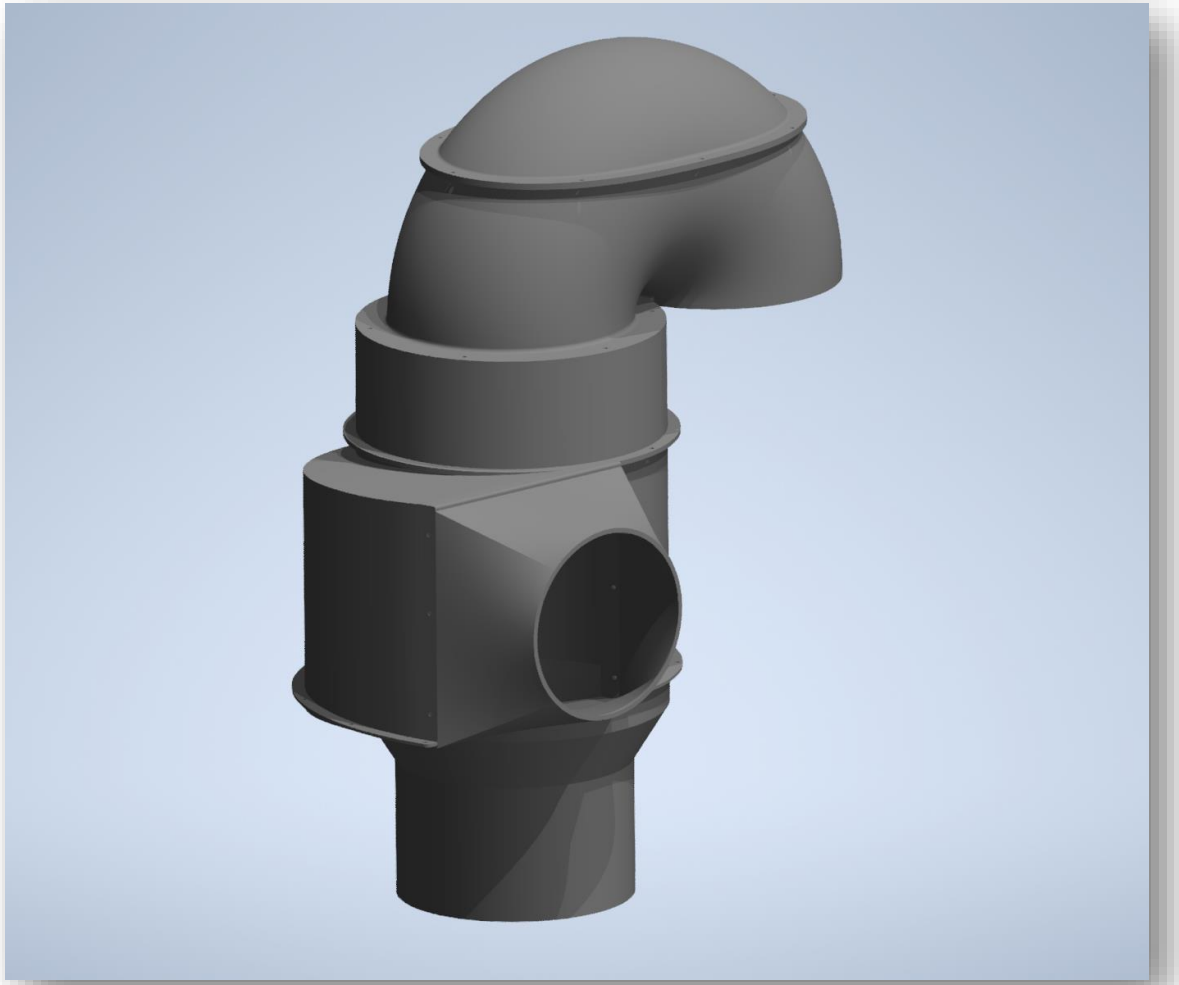
DPM (Discrete Phase Model)





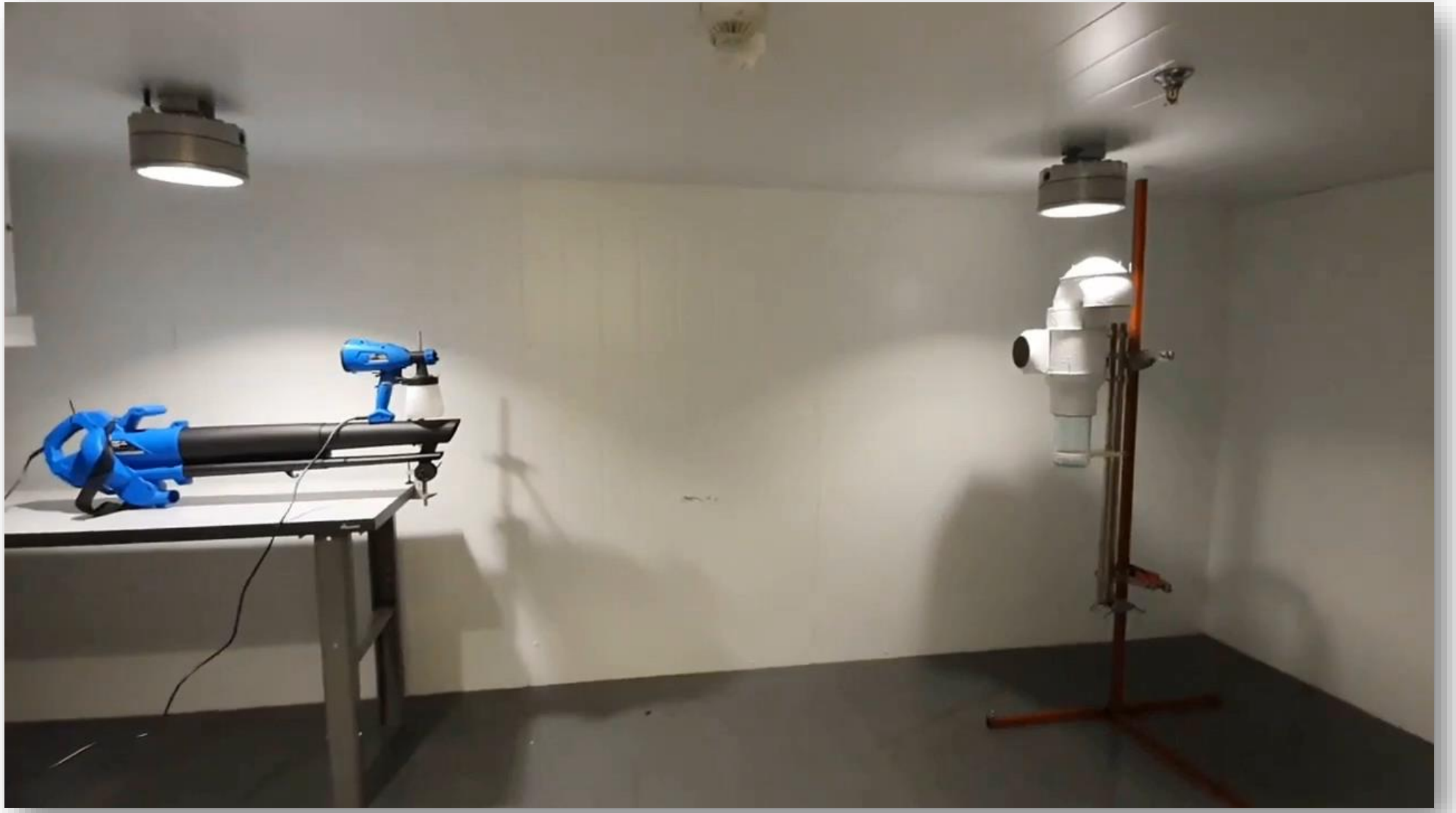


Final Design

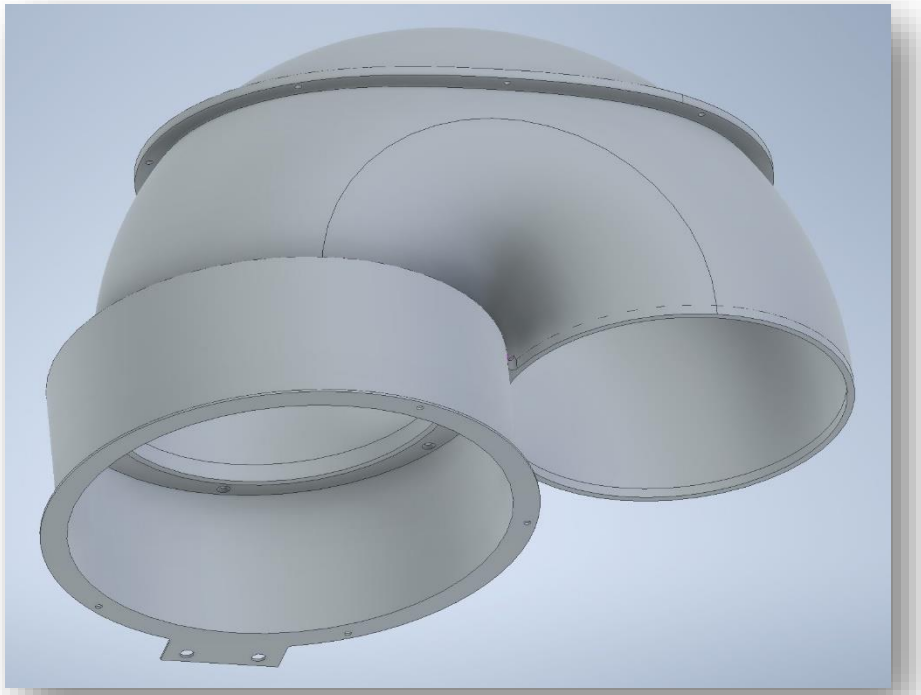


3D printed with Carbon fiber infused nylon filament

Lab Test



Lab Test



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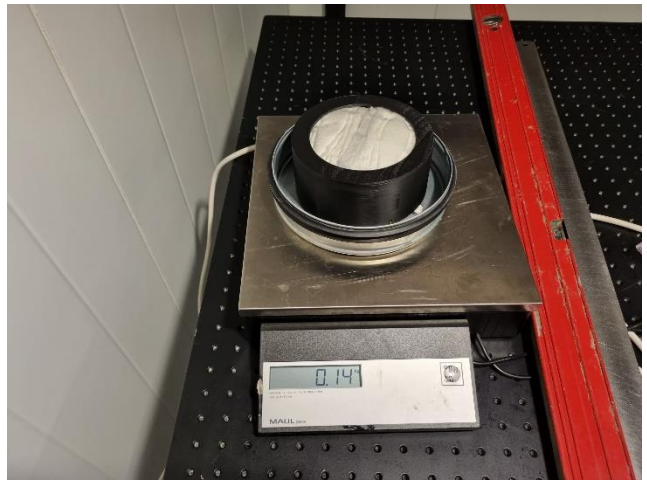
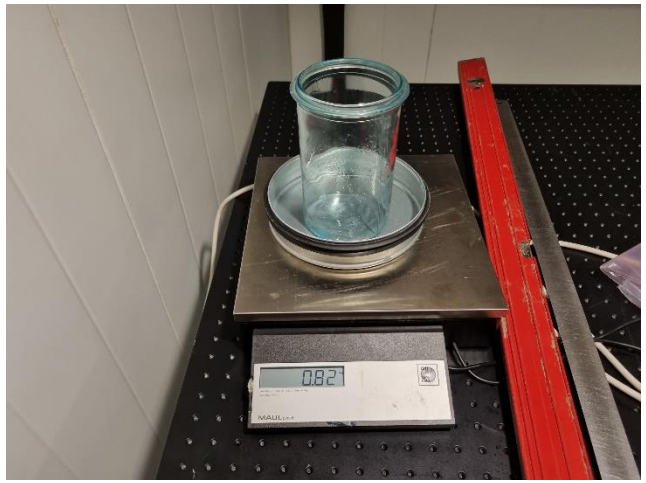




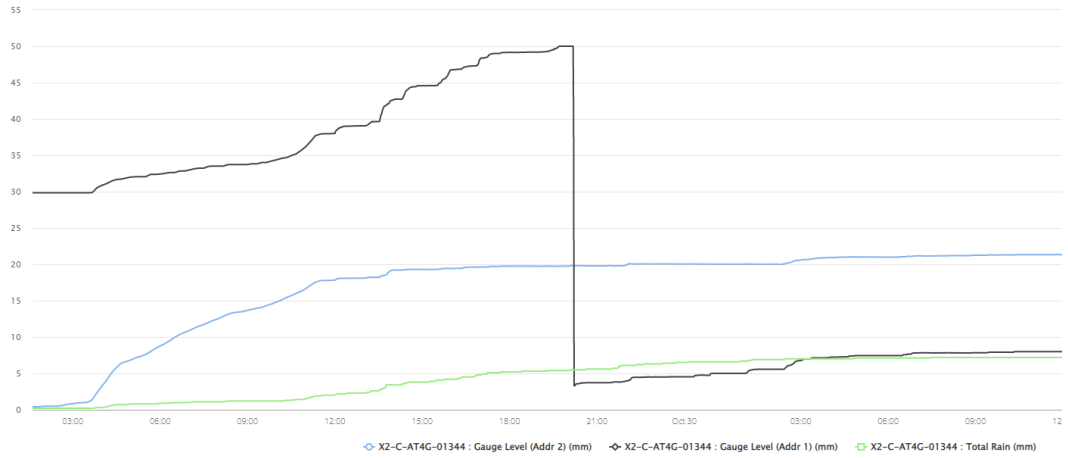
Field deployment

Gratanglaks

Real-time autonomous spray collector

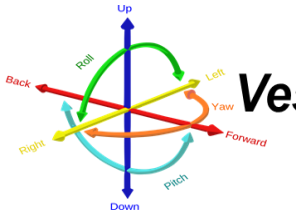
Field deployment, 7th October 2022

Real-time autonomous spray collector



Radiometer

Temperature, humidity and Precipitation



Vessel motion

Spray Measurement

Wave Parameters

3D Wind

Thanks for listening

https://en.uit.no/project/sprice