



## Application of Multiphase Flow Computational Dynamics to Real Process Challenges: Thien Cyclone

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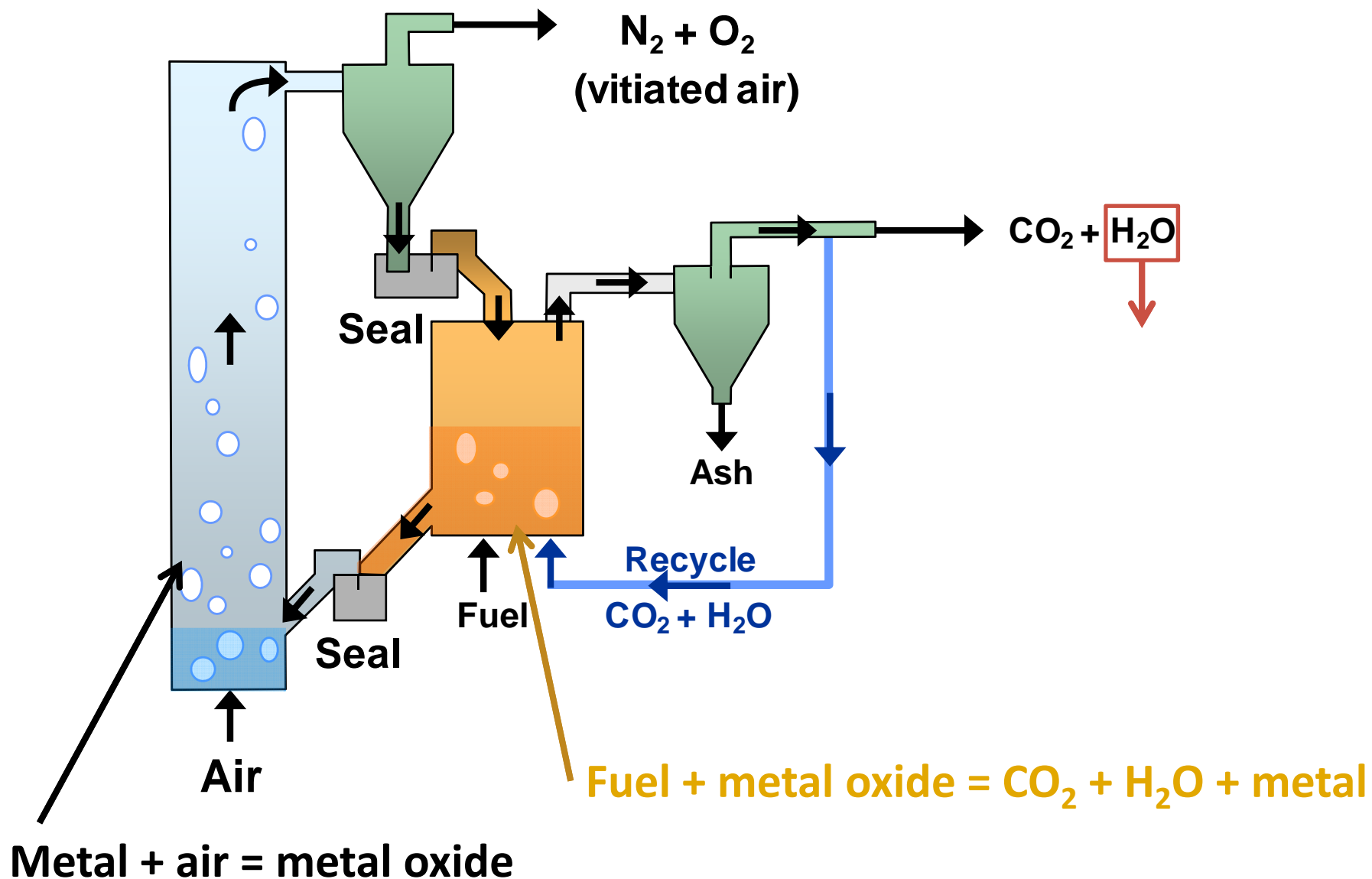
**2014**



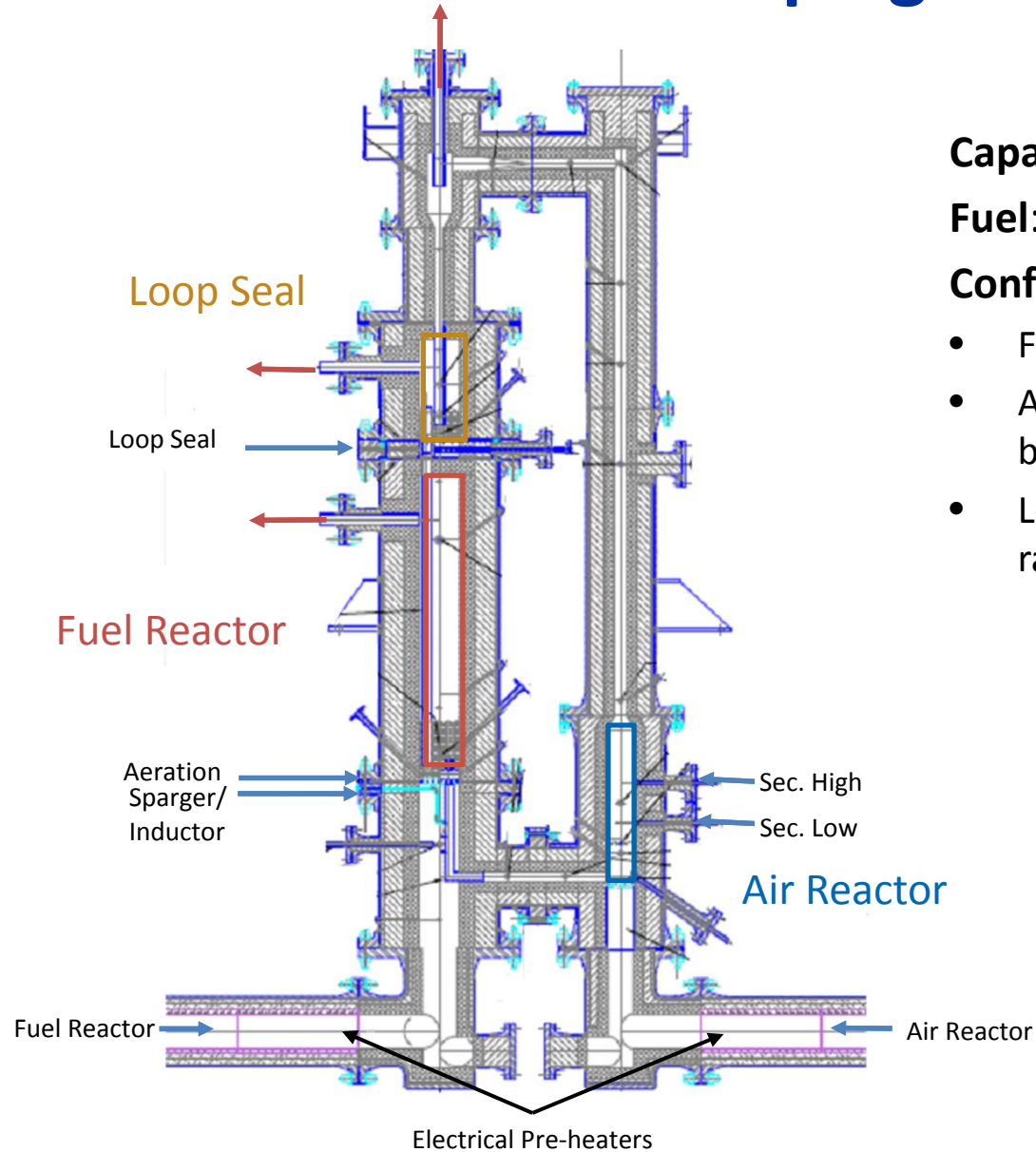
U.S. DEPARTMENT OF  
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# Chemical Looping



# Chemical Looping Reactor [CLR]



**Capacity:** 20-50kW<sub>thermal</sub>

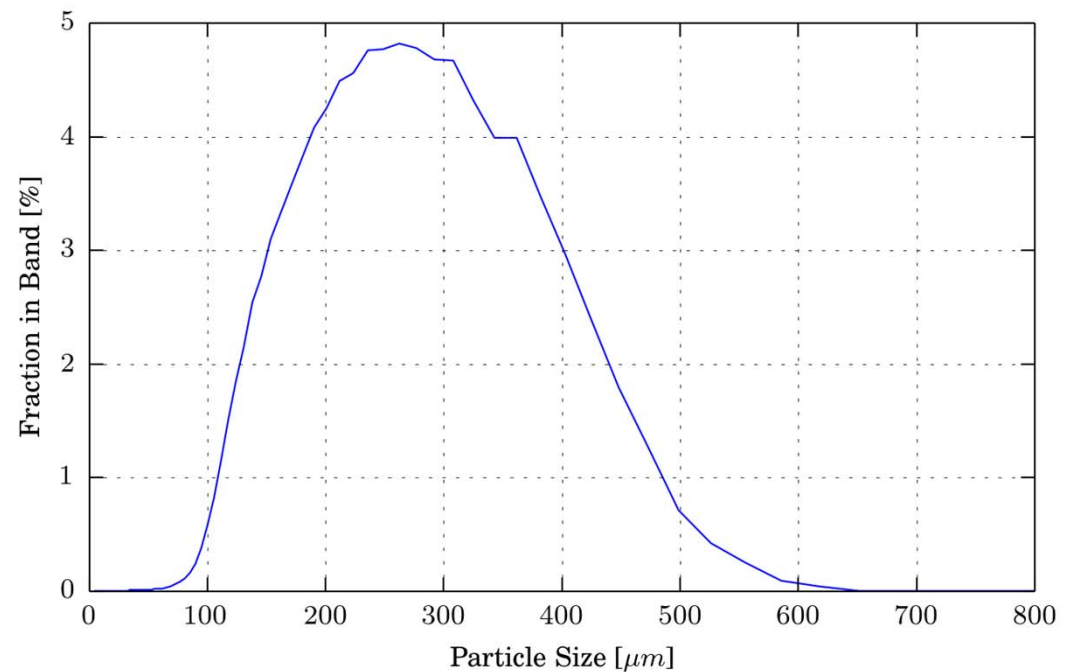
**Fuel:** Natural gas (CH<sub>4</sub>)

## Configuration:

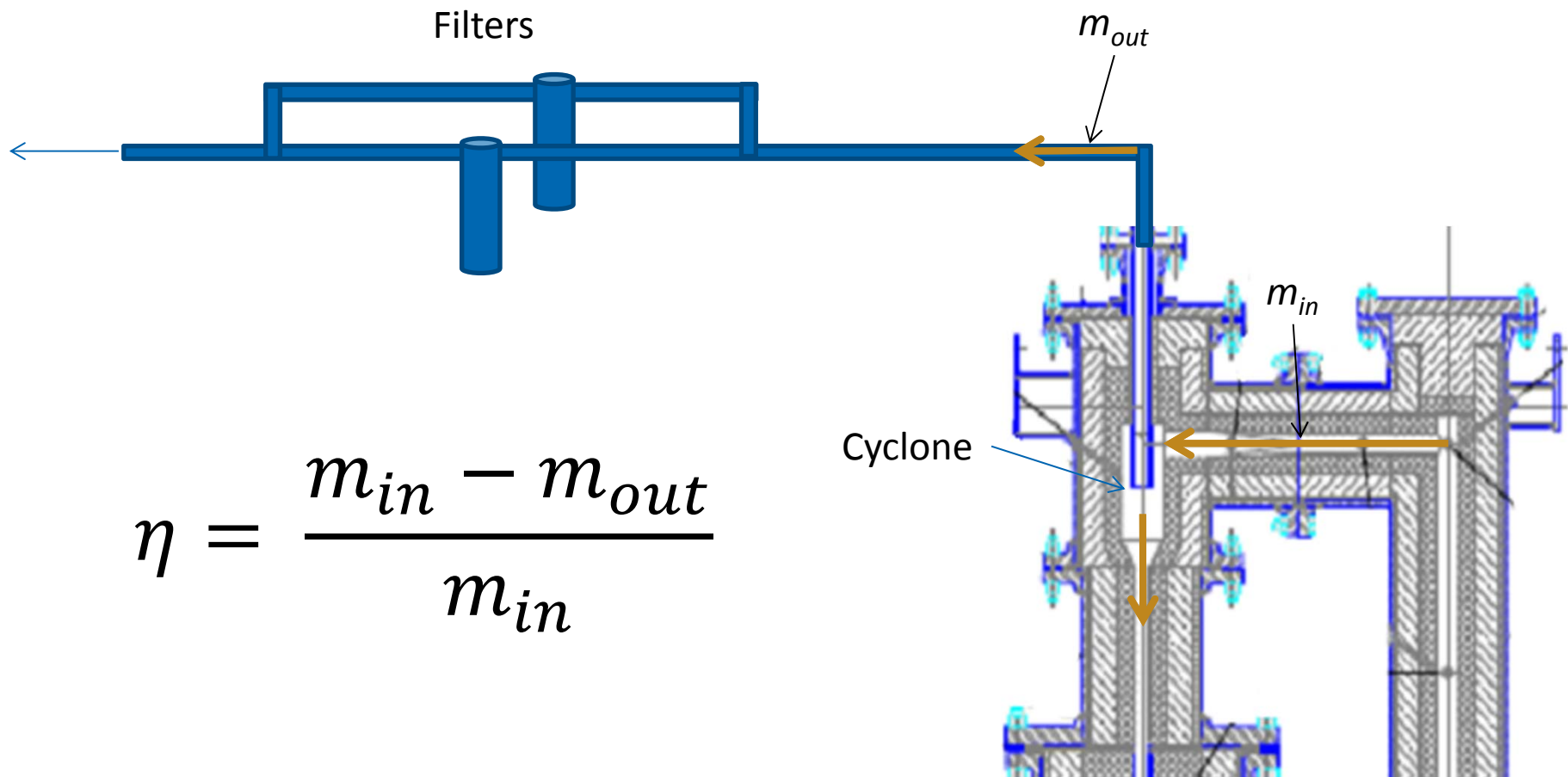
- Fuel Reactor – Bubbling Bed
- Air Reactor – Turbulent, transporting bed
- L-valve – to control solids circulation rate

# Hematite

- Mean Diameter: 234 $\mu\text{m}$
- Particle Density: 3.34 g/cm<sup>3</sup>
- Sphericity of 0.847



# Problem

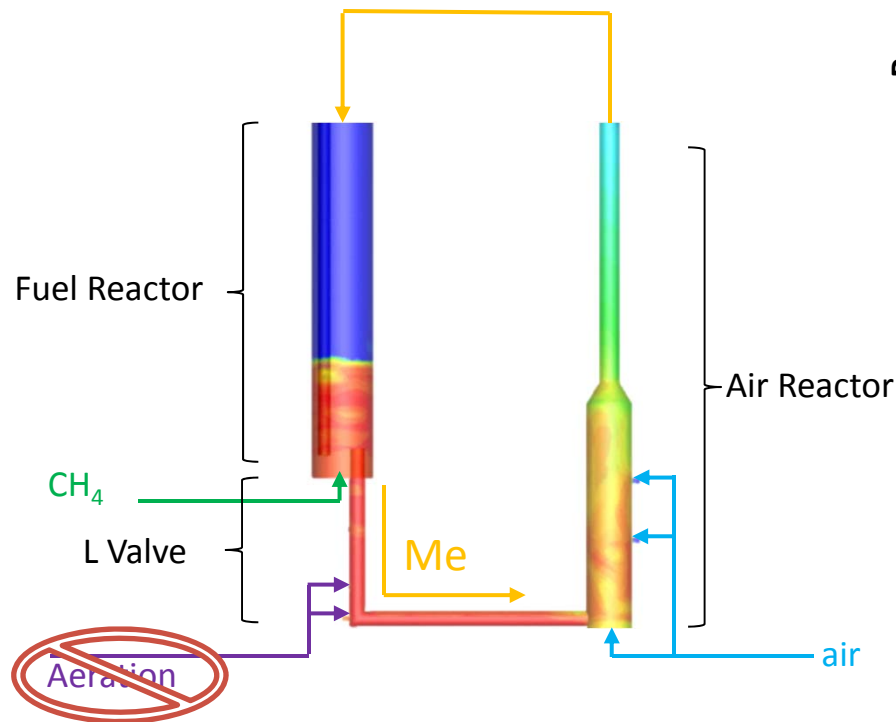


$$\eta = \frac{m_{in} - m_{out}}{m_{in}}$$

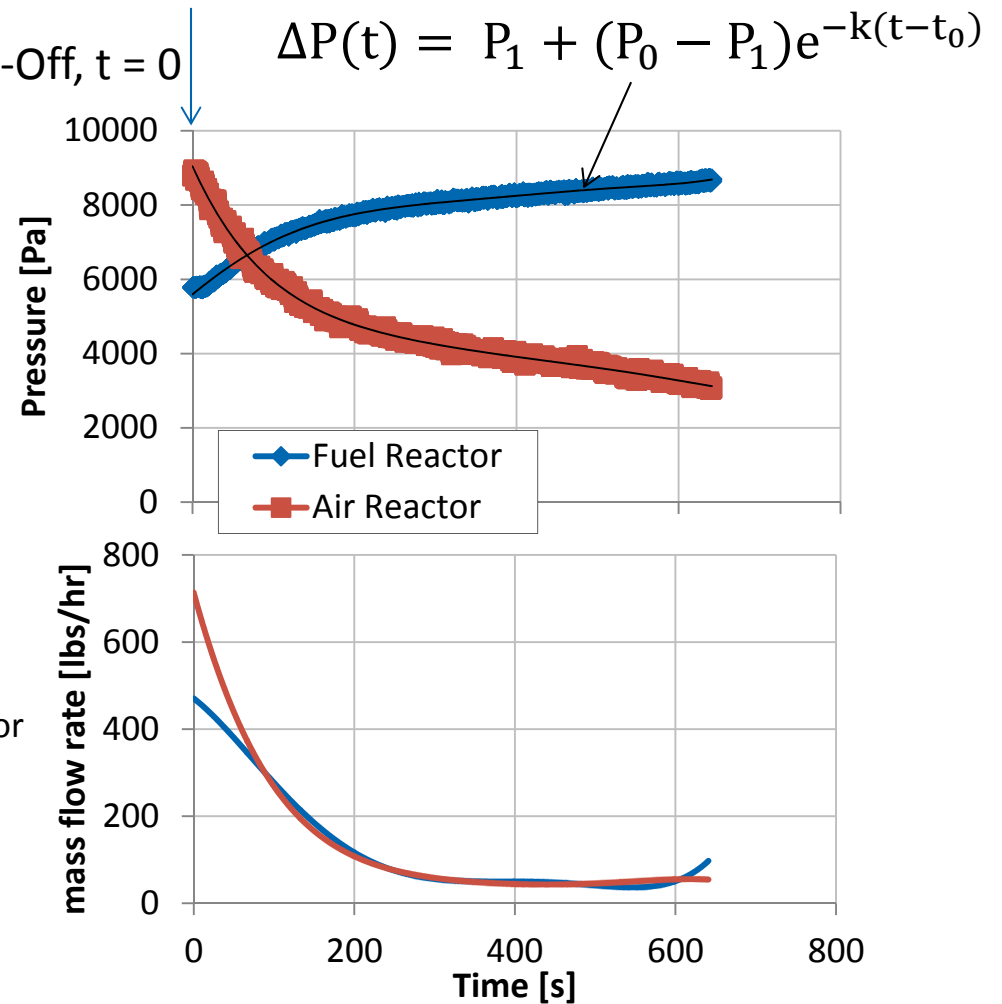
# L-valve Cut-Off Technique

$$\Delta P = \frac{mg}{A}$$

$$\frac{dm}{dt} = \frac{A}{g} \cdot \frac{dP}{dt}$$

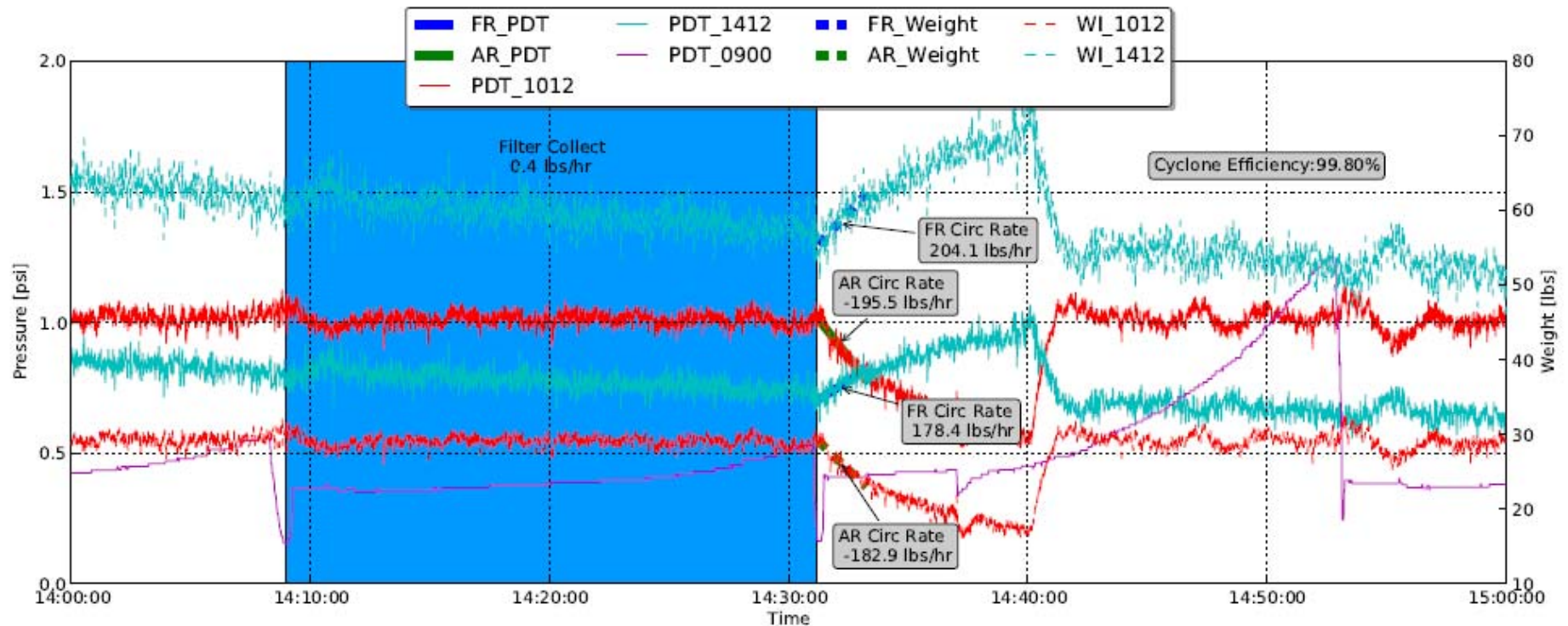


L-Valve Cut-Off,  $t = 0$





# Cyclone Efficiency



Cyclone: 98.3% to 99.8% Efficient

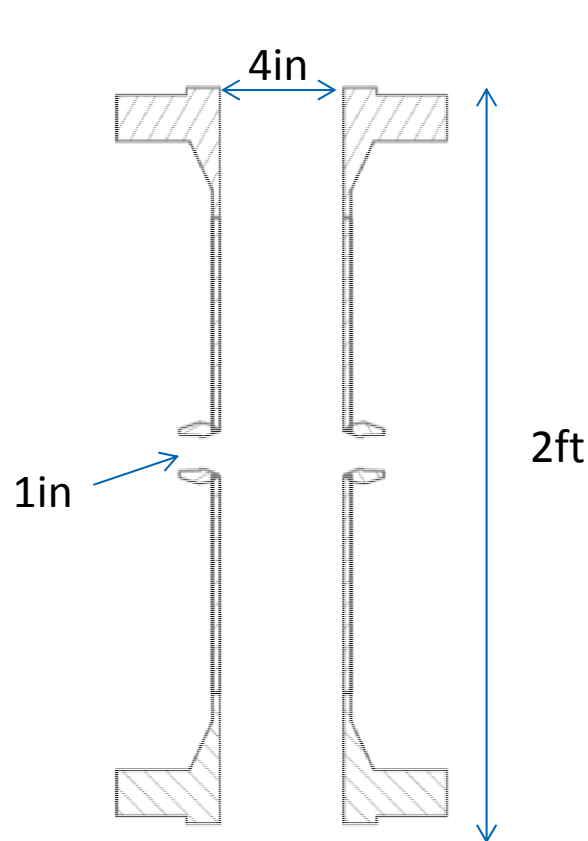
@ 800 lbs/hr, 99% efficient, lose-> 8lbs/hr

@ 150lbs inventory, lose all material in 18.75 hours!

**A Single Cyclone is not Efficient Enough!**

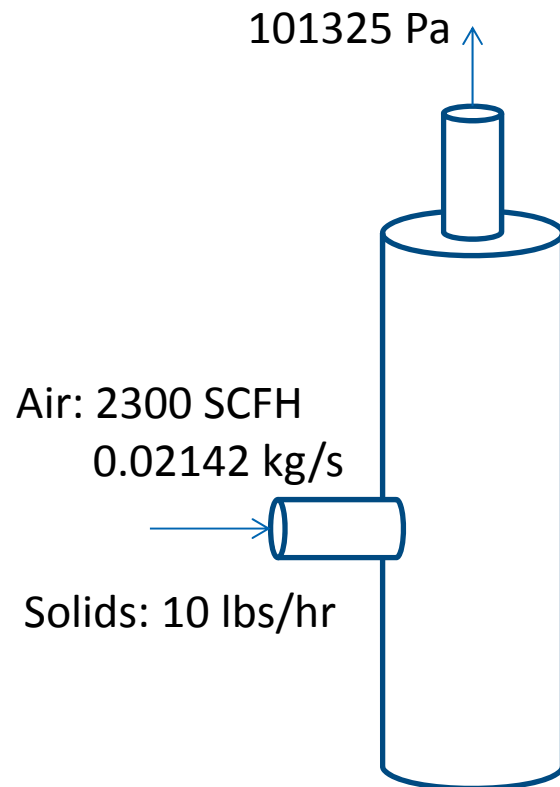
# The Challenge

- Design a solids separator for the chemical looping reactor that can be built out of existing materials/pipe





# Multiphase Flow CFD as a Design Tool?

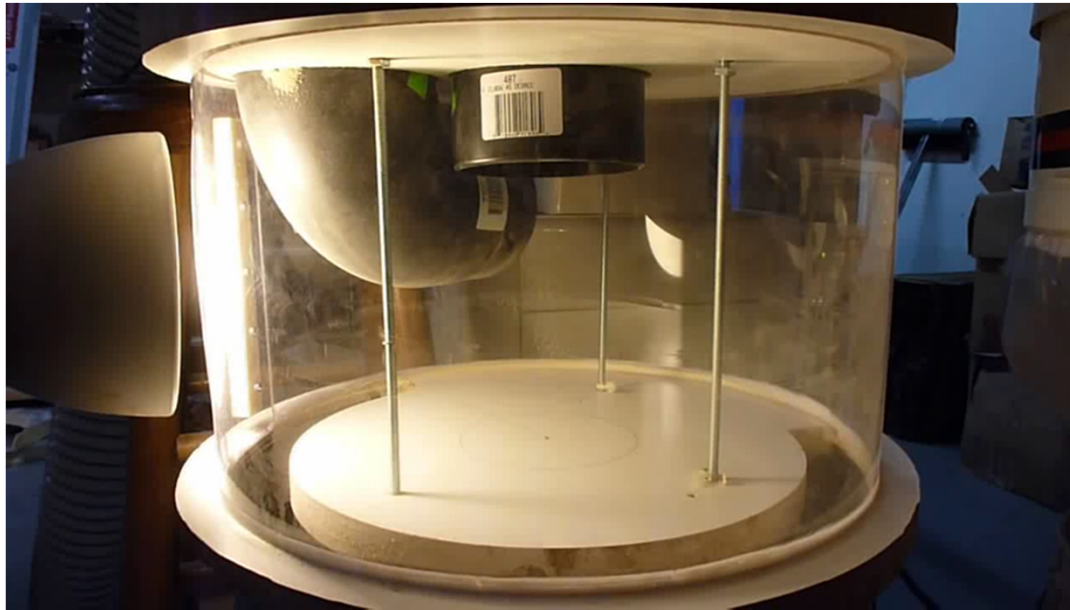


Falls outside of  
Cyclone design  
correlations

Isothermal: 477K

# DIY Wood Shop Community

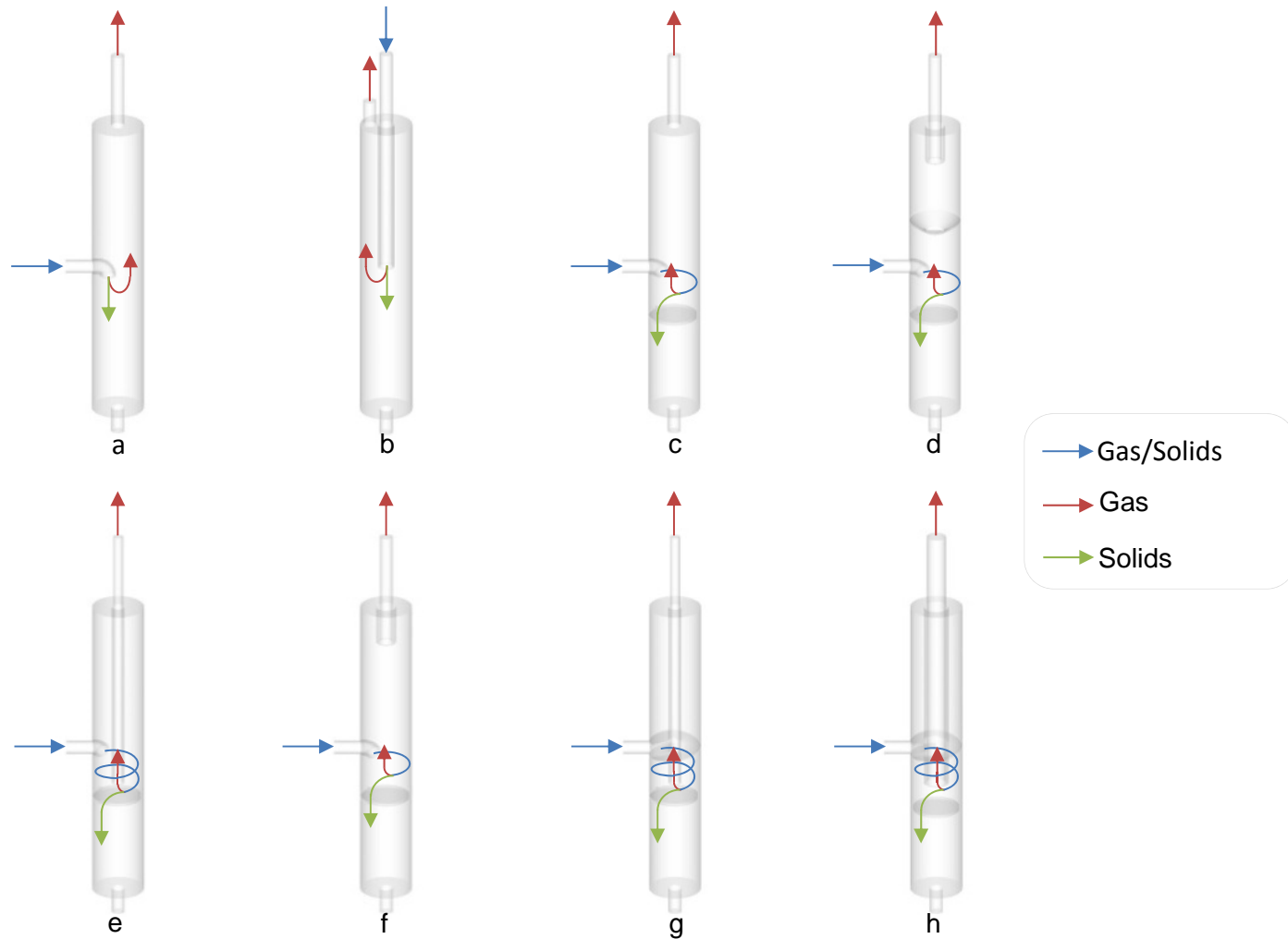
Thien Top Hat Dust Separator (J. Phil Thein)



<http://madebyjohn.blogspot.com/2011/11/my-thien-dust-collector.html>



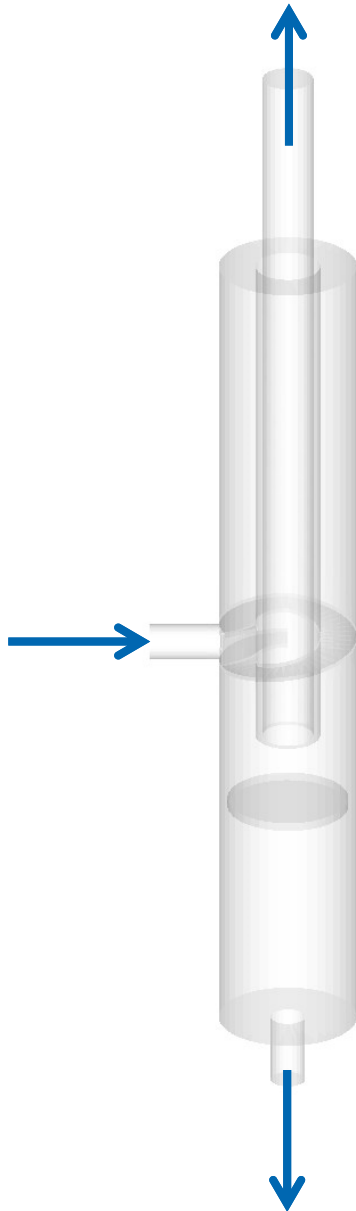
# Proposed Designs



# Run Details

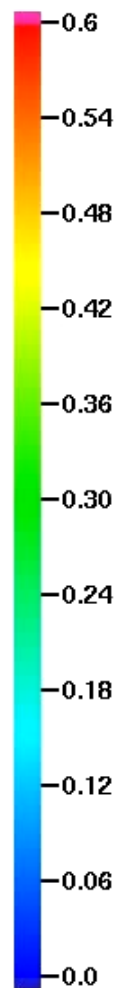
Model	Grid	Real Cells	Computational Time [s/day]	Average Time Step [s]
a	52x43x189	256,154	1.81	2.68E-005
b	42x43x187	258,943	1.41	2.25E-005
c	52x43x195	264,500	1.92	2.98E-005
d	70x43x217	417,823	0.83	2.55E-005
e	52x43x189	252,960	0.94	1.08E-005
f	42x43x189	253,640	1.98	2.98E-005
g	70x48x126	289,854	0.57	7.57E-006
h	70x48x126	286,008	0.58	7.70E-006

## Model Results



Model	Efficiency, $\eta$	$\Delta P$
	[%]	[Pa]
a	5.75	4267
b	5.53	3010
c	64.23	2818
d	80.41	3921
e	98.86	10824
f	87.54	3026
g	99.88	8667
h	99.75	2124

Particles VolFrac

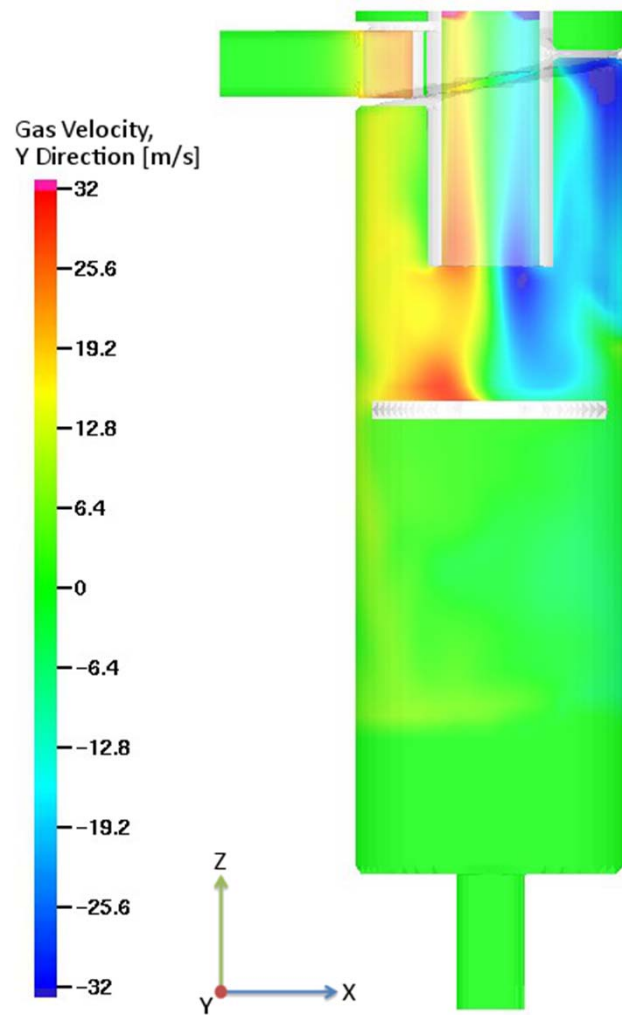


Gas + Solids

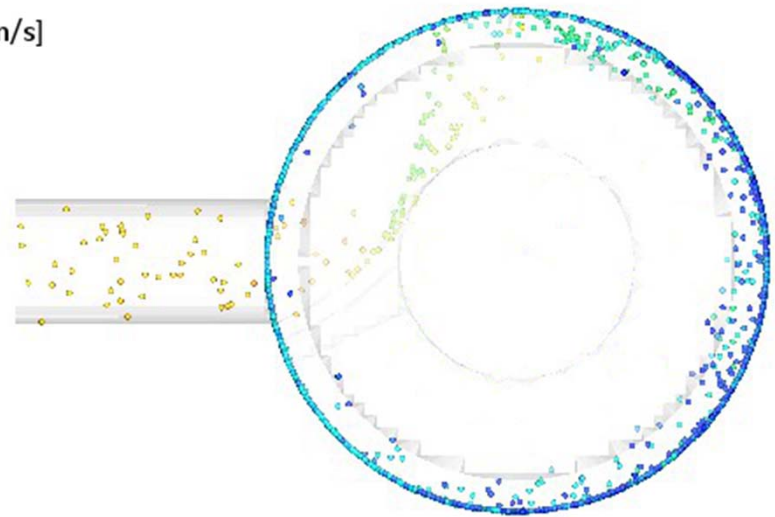
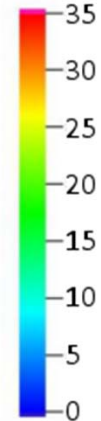
Gas

Solids

# Model Results: Case H

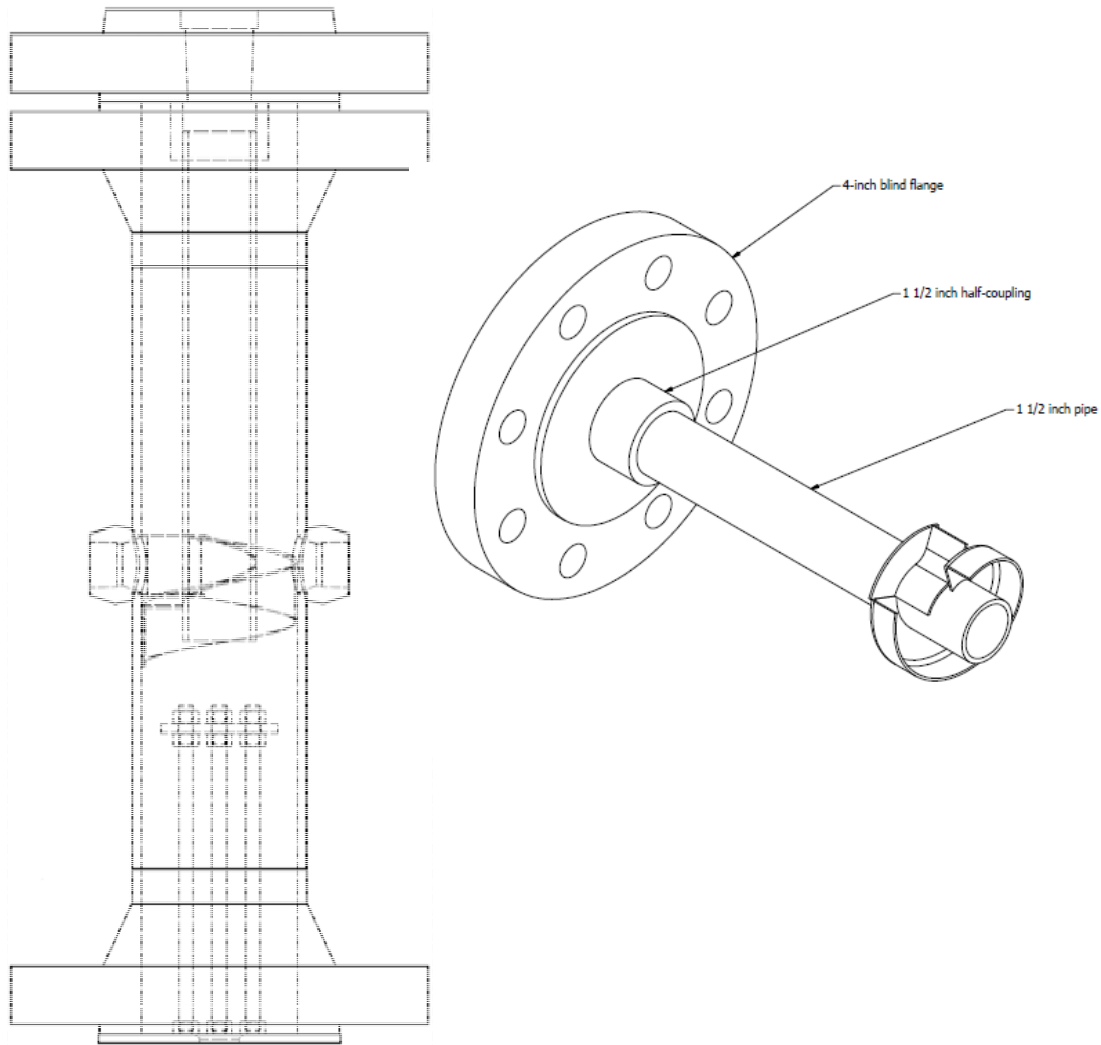


Particle Speed [m/s]

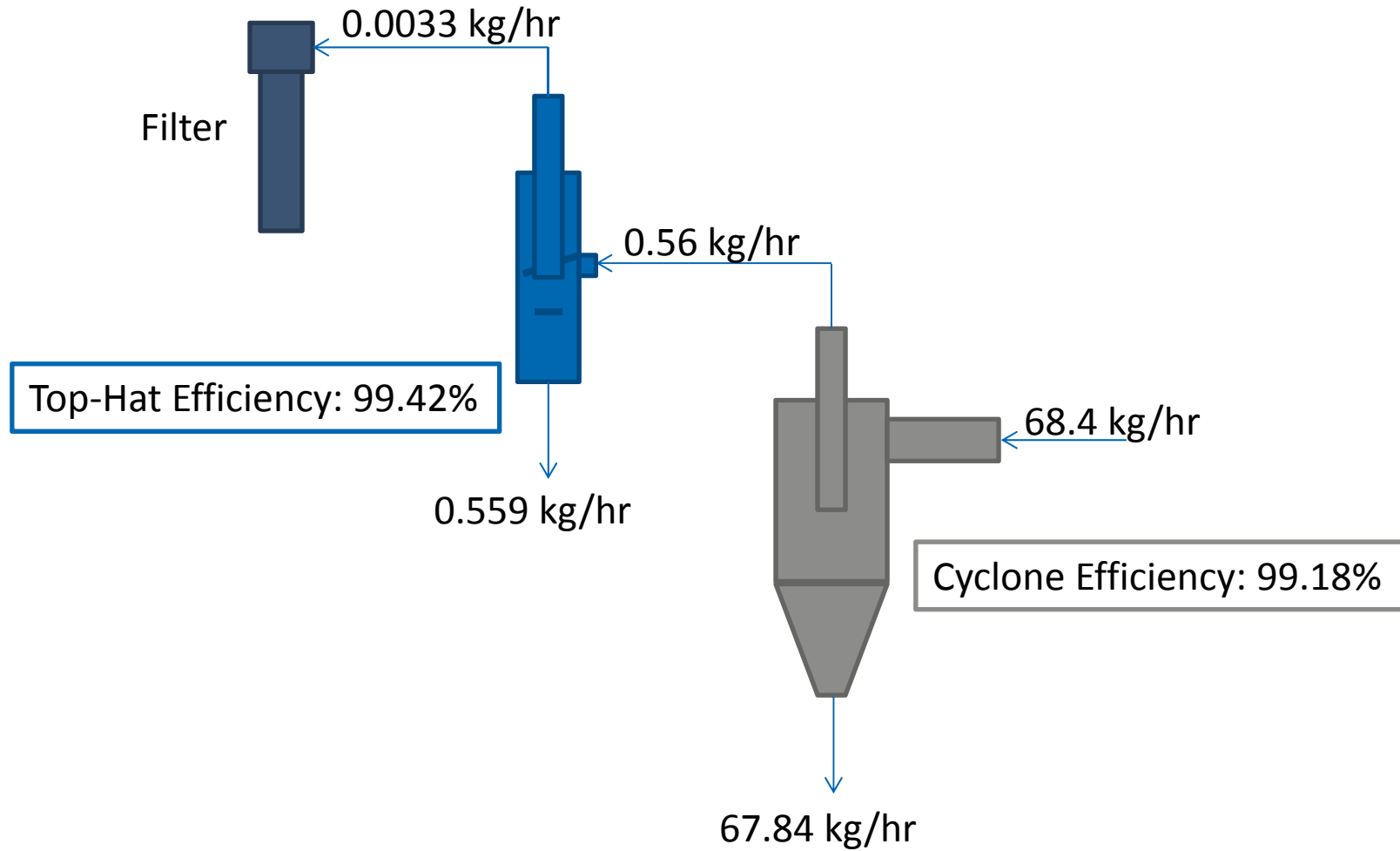




# Final Design



# Solids loss: Cyclone



**Combined Efficiency 99.995%**

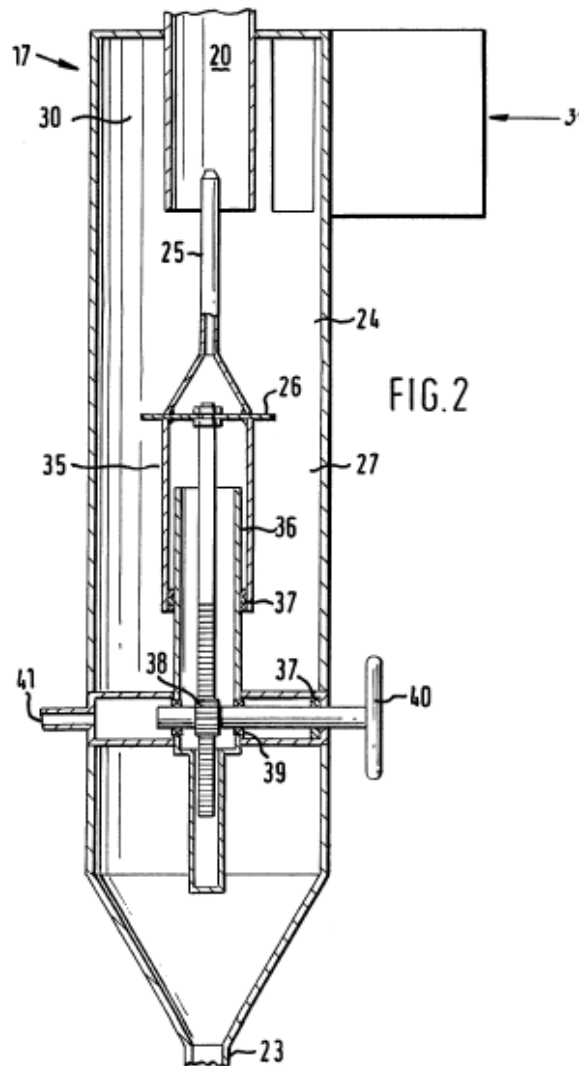
# Adjustable Cyclone?

## Adjustable Cyclone Separator

CA 1259573

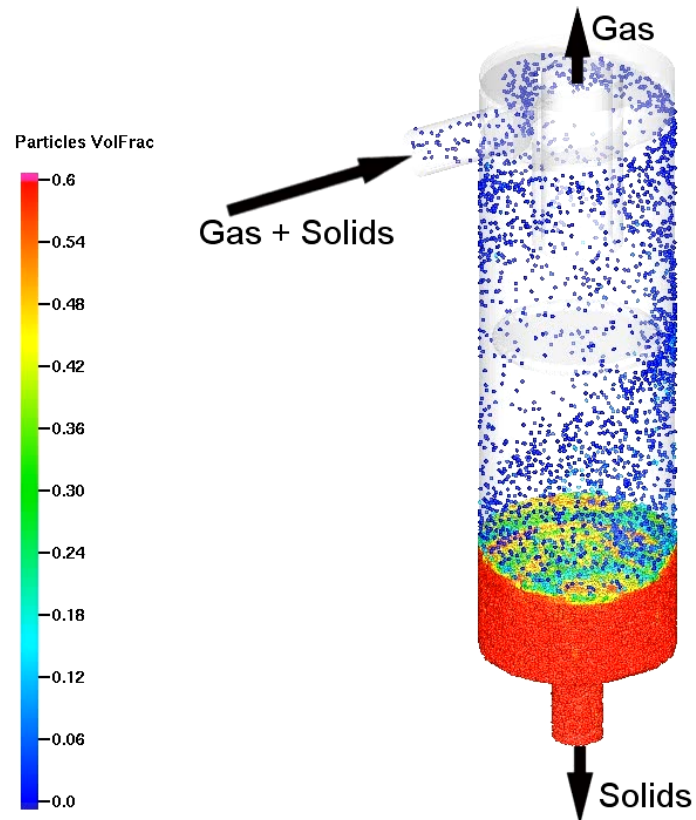
Thomas Dewitz (Shell)

1985

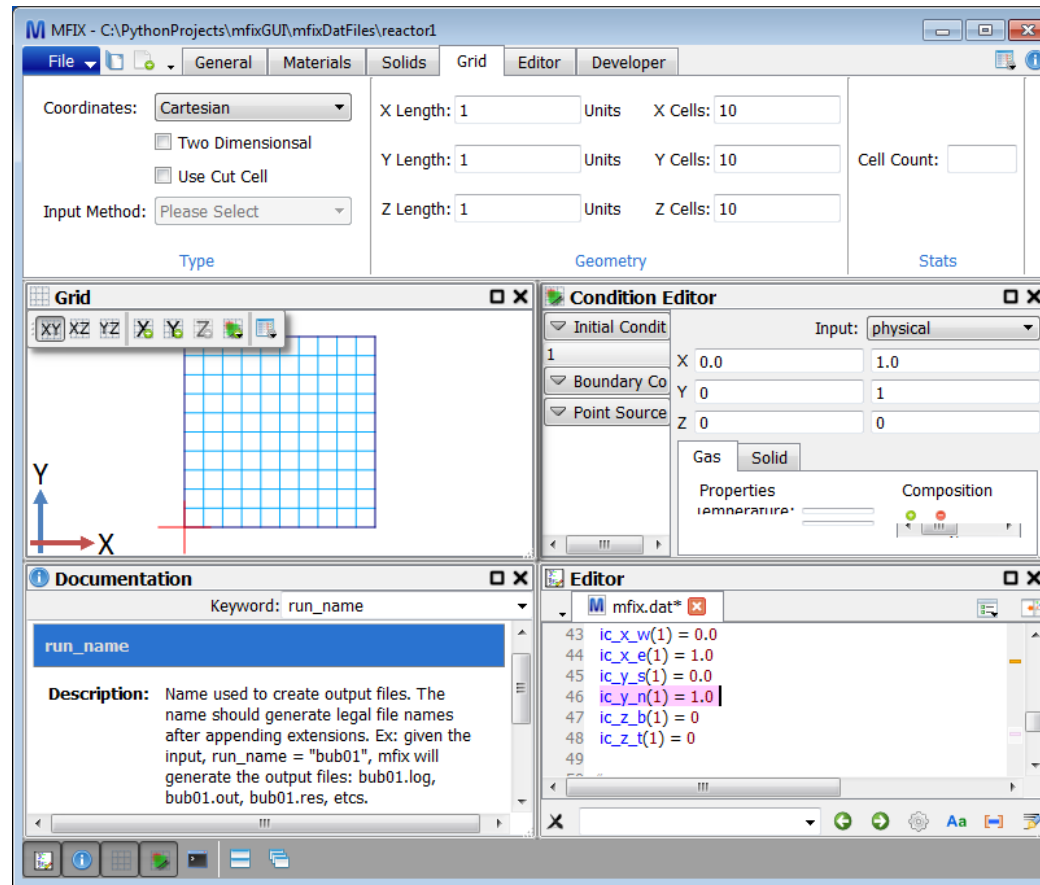


# Summary

- Needed to design a cyclone
- Used CFD to iterate on design
- Built Cyclone
- Performed well



# Questions?



MFIX GUI Beta Testers: [justin.weber@netl.doe.gov](mailto:justin.weber@netl.doe.gov)