Impedance Matching for Wave Driven Desalination Systems

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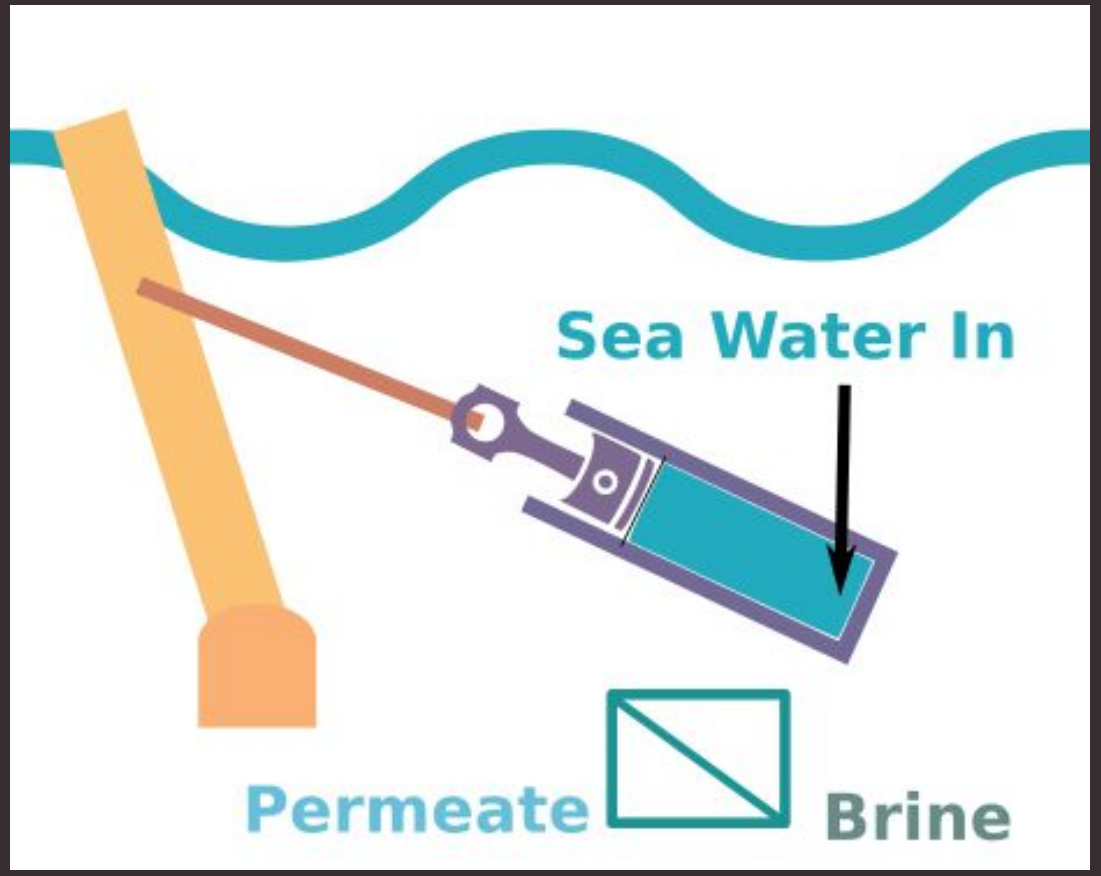
Agenda

- Background
  - **Wave Driven Desalination**
  - Impedance Matching
- Overview of Dynamics
- **DesalOptTool**
  - Current Issues
  - Future Steps
- Anticipated Impacts

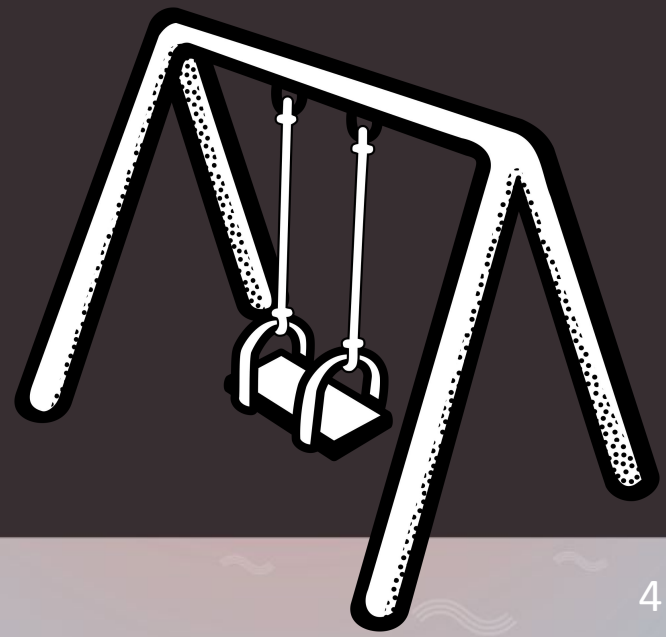
Wave Driven Desalination

- Clean water access is a growing concern [1]
- Direct Drive Desalination [2,3]
  - Wave Energy Converters (**WEC**s) **harness mechanical energy**
  - Desalination **needs mechanical energy**
- Potential niche market where WECs can develop [4]



Impedance Matching

- **Impedance = “Effort”/“Flow”**
- Impedance of WEC & Power Take Off (**PTO**) “matches” the excitation [5]
- 22% improvement in WEC performance for electricity generating PTOs [6]
- Can we apply to wave driven desalination?



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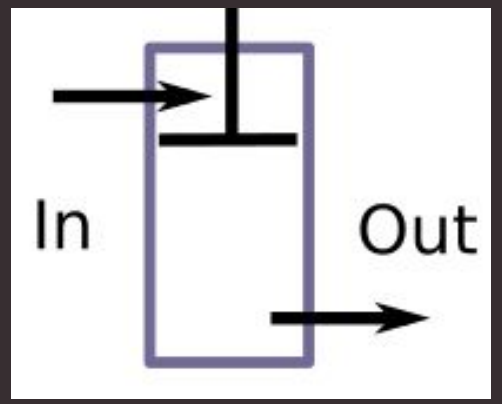
Dynamics (Piston)

$$A|v| = Q_{in}$$

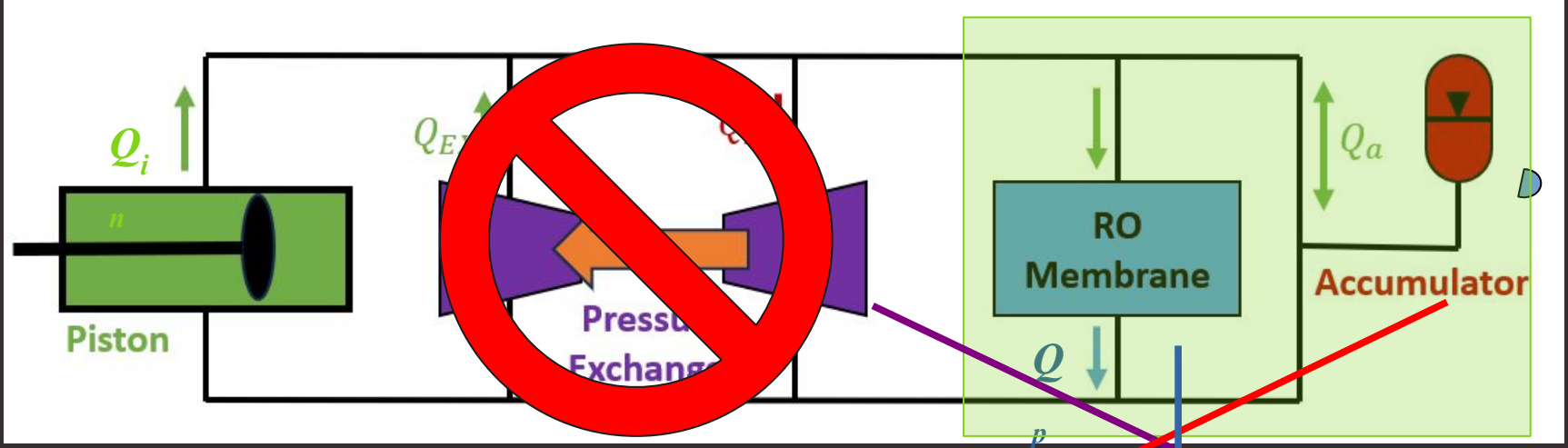
$$|F_{PTO}| = AP$$

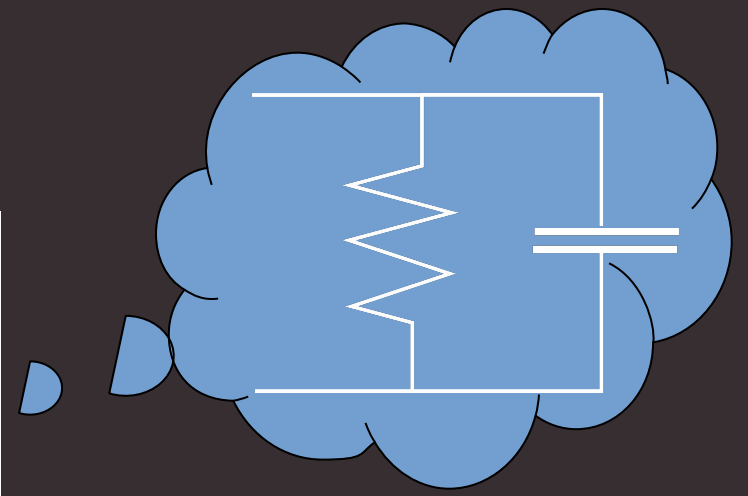


Force always opposes velocity

A	Piston area
v	Piston velocity
Q_{in}	Seawater flow rate into hydraulic circuit
F_{PTO}	Force on WEC due to PTO
P	Pressure of fluid in hydraulic circuit

Dynamics (Hydraulic Circuit)





$$0 = Q_{in} - C_a \frac{dP(t)}{dt} - \frac{P(t)}{R_m} - \frac{P(t)}{R_t}$$

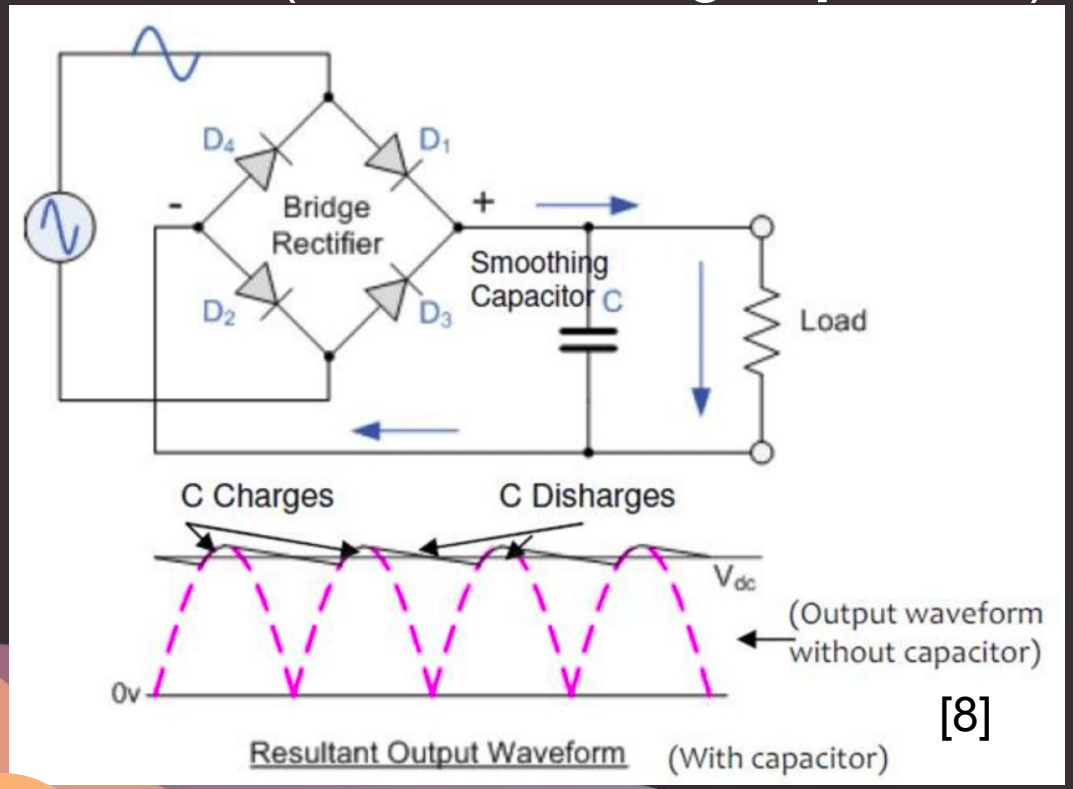
$$\mathbb{Z}_h(j\omega) = \frac{\mathbb{P}(j\omega)}{\mathbb{Q}_{in}(j\omega)} = \frac{1}{j\omega C_a + \frac{1}{R_m} + \frac{1}{R_t}}$$

Q_{in}	Seawater flow rate from Piston
C_a	Accumulator Capacitance
P	Pressure of fluid in hydraulic circuit
$R_{m/t}$	Resistance of Membrane/Brine valve
Z_h	Hydraulic Impedance

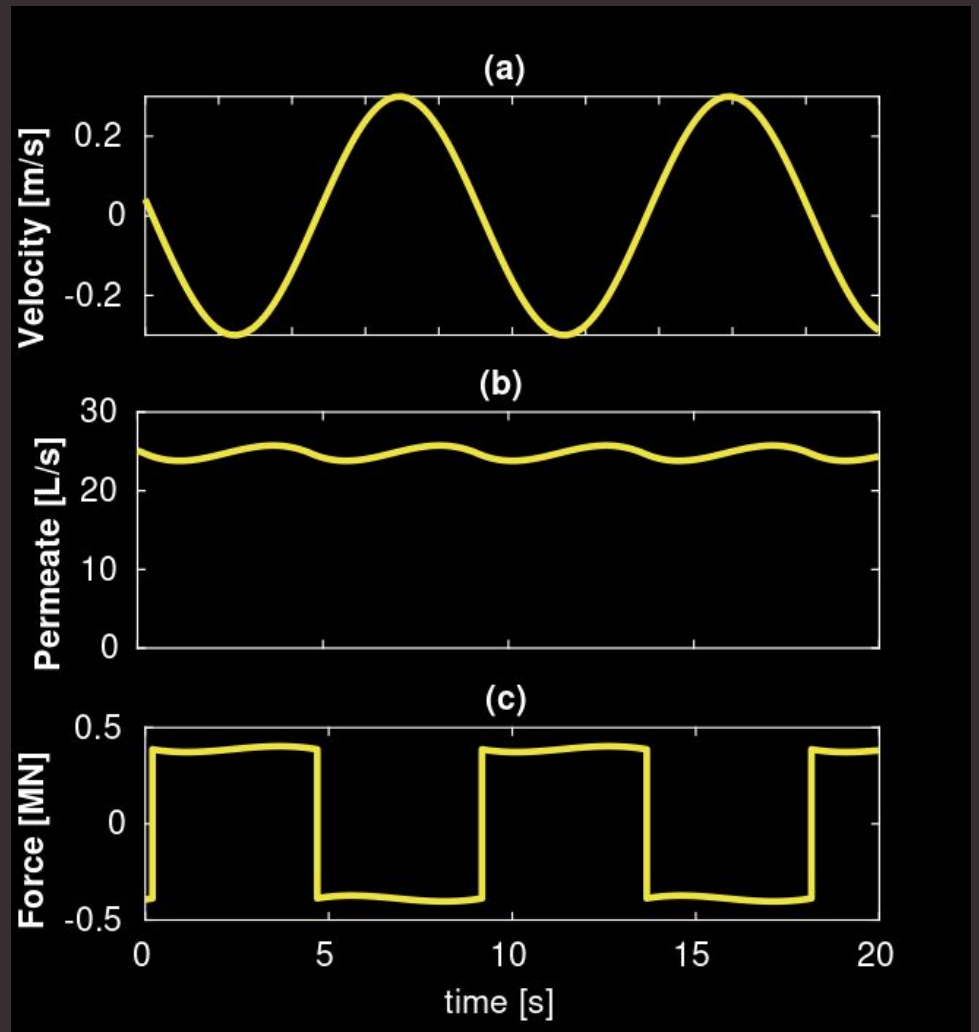
[7]

Dynamics (Combined)

Dynamics are similar to a **full wave bridge rectifier** (with smoothing **capacitor**)



[8]



Notice the force signal **discontinuities**

DesalOptTool (Overview)

- Add-on package for **WecOptTool**
  - Pseudospectral domain [9]
  - Control co-design (CCD) [6]
- Expand ideas in wave driven desalination
  - CCD
  - Impedance matching
  - Wave to water Multidisciplinary Design Optimization (MDO)

DesalOptTool (Current Issue)

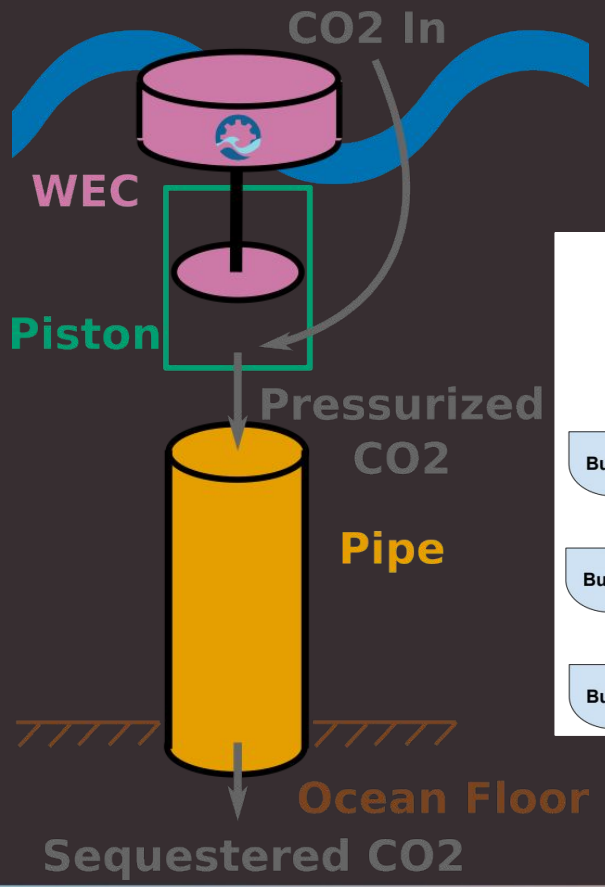
- Challenging dynamics
- Force is **discontinuous**
- **Check valves** cause PTO force to sometimes behave like static friction
  - **When excitation force is below PTO force –> velocity = 0**

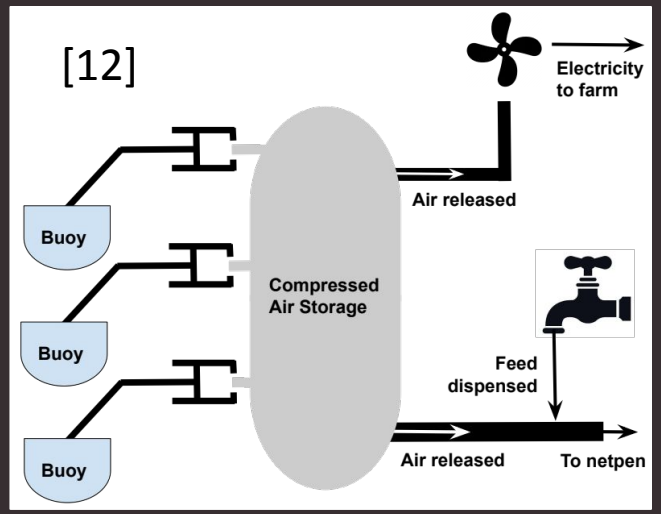
DesalOptTool (Future Work)

- Fix dynamics issue
  - Will likely require adjustment of core module
- Add in multiple DOF functionality
- Model other hydraulic components
  - Bladder style accumulator
  - Pressure exchanger
  - Fluid inertia
- Improve packaging

DesalOptTool (Anticipated Impacts)

- Tool for **MDO** in Wave Driven Desalination
  - CCD
  - **Wave to water** analysis
- Dynamics for other PTOs
  - Hydraulic drivetrains [10]
  - **Carbon sequestration** [11]
  - **Aquaculture** feeding system [12]





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Summary

- **Dynamics** involved in Wave Driven Desalination
  - Piston
  - Accumulator
  - **Discontinuous** Force
- **DesalOptTool**
  - Potential tool for **Wave to water MDO**
  - Dynamics pose problem
- Extensions of this work to **other applications**

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Questions?

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