An Autonomous Wave-Powered Desalination System

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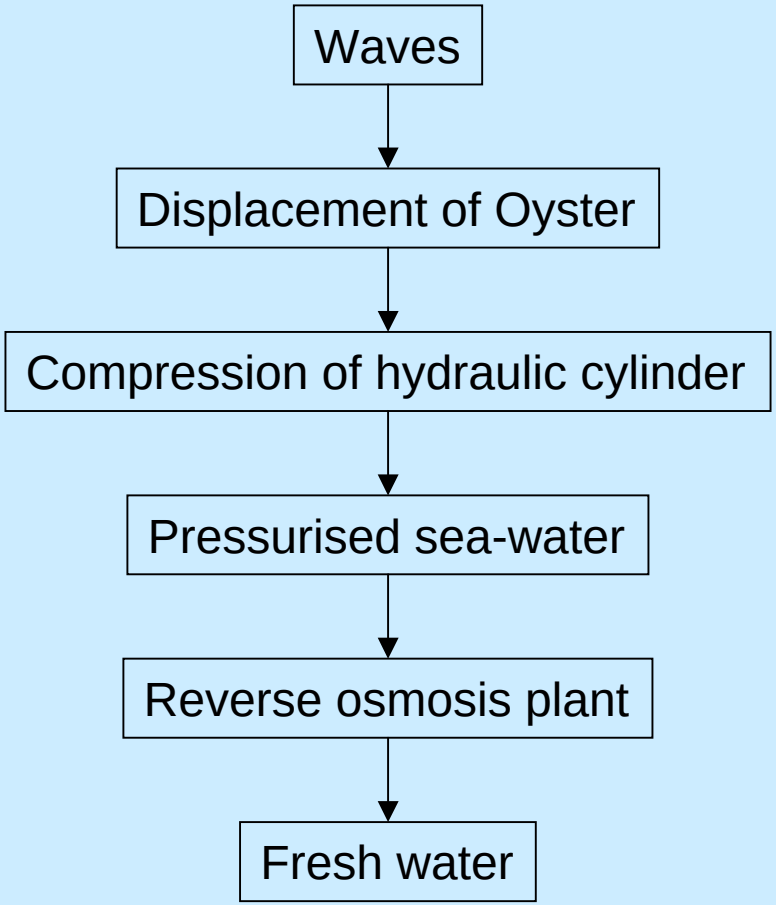
Gobierno de Canarias

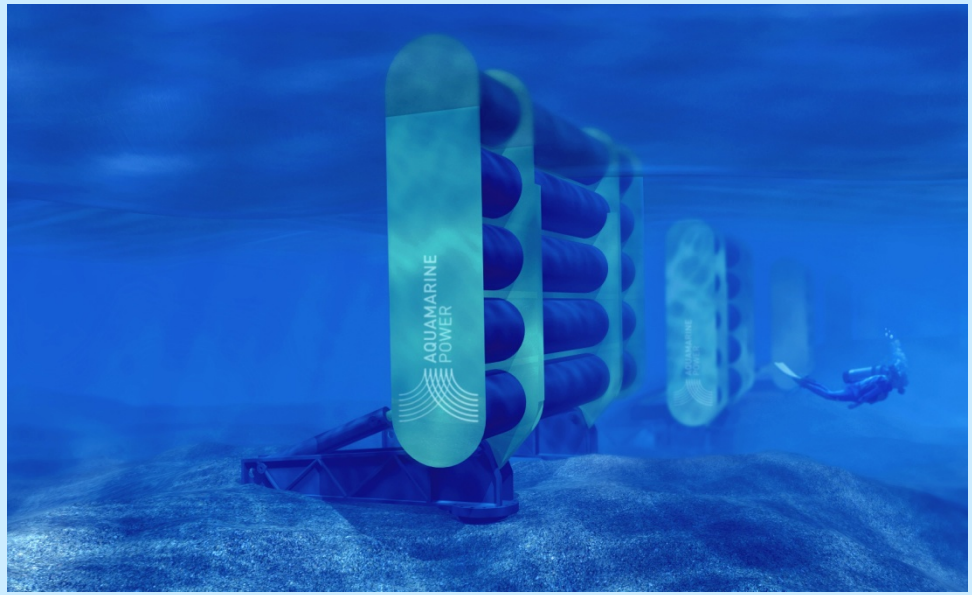
Wave-powered desalination

- **Indirect method**
  - **Generate electricity and use this to power a desalination plant**
    - **Vizhinjam plant, India**
- **Direct method**
  - **Mechanical vapour compression**
    - **Salter DUCK**
  - **Pressurised water hydraulics – Reverse osmosis**
    - **DelBuoy**
    - **McCabe wave pump**
    - **CETO**
    - **Oyster**

Energy flow

Oyster wave energy converter

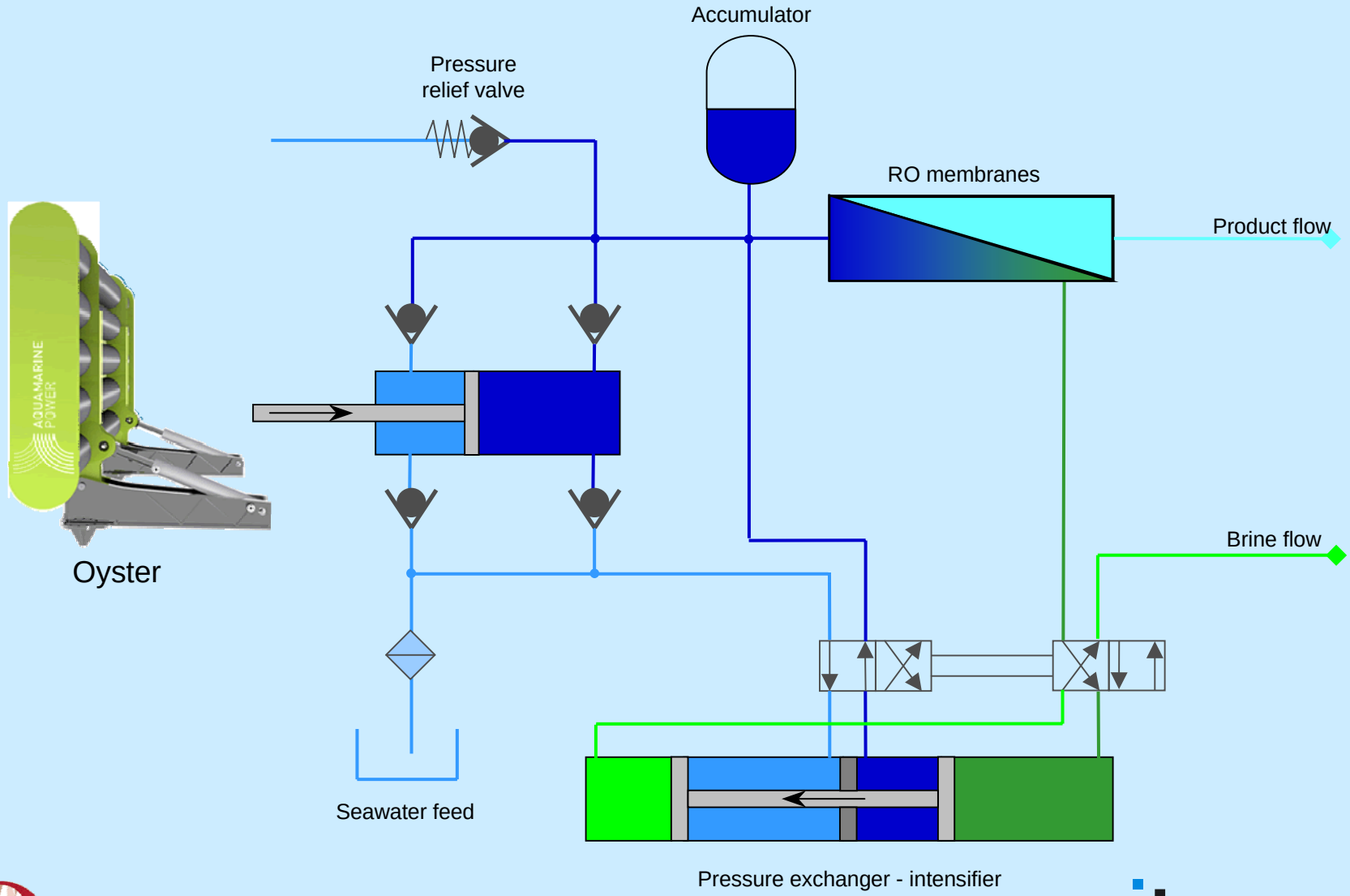




No conversion to electricity

- **Reduction in components**
- **Increased reliability**
- **Increase efficiency**

The wave-powered desalination plant



Modelling the desalination plant

- Characteristics of RO membranes derived from manufacturer's software – ROSA 6.1
- Quasi-steady state assumption
  - Instantaneous change of direction in pressure exchanger-intensifier
  - Product flow and salinity change instantaneously with feed pressure and flow
- System modelled using Simulink®

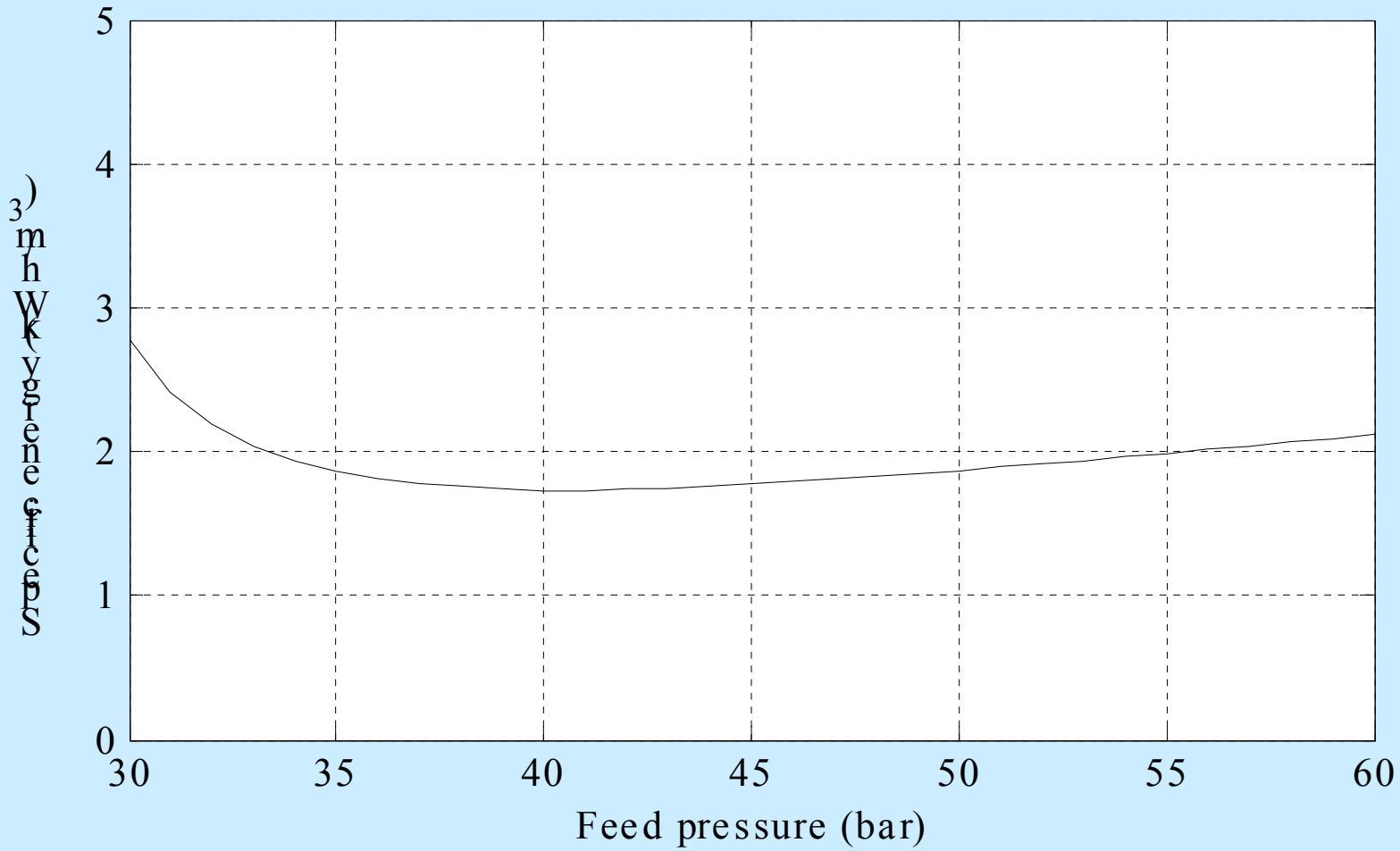
Modelling of pressure exchanger-intensifier

- Piston assumed to be inertia-less
- Quadratic loss function used to model the pressure drop across valves
- Quadratic loss function used to model the pressure drop across intake filter
- Leakage flow is assumed to be laminar and thus proportional to pressure difference
- A constant drag force is assumed to resist the motion of the piston

RO plant characteristics

- Number of membranes = 3
- Feed salinity = 37,000 ppm
- Membrane type = Filmtec SW30XLE-400i
- Product back pressure = 1.0 bar
- Minimum brine flow rate = 3.41 m^3/h
- Maximum feed flow rate = 14.1 m^3/h
- Maximum product flow rate = 1.14 m^3/h (per membrane)
- Maximum recovery ratio = 25%
- Maximum product salinity = 500 ppm

Specific energy consumption



Summary of RO plant performance

- Specific energy consumption less than 2.0 kWh/m^3 for large pressure range
- Pressure > 37 bar to maintain quality of product
- Pressure < 55 bar to limit recovery ratio
- Ratio of maximum : minimum power consumption
  - 3.5 : 1.0 if pressure maintained between 37 – 55 bar (product salinity < 500 ppm)
  - 11.3 : 1.0 if pressure maintained between 28 – 55 bar
- Manufacturers recommended feed conditions maintained without modification to plant

Oyster wave energy converter

- Dynamics suited to generation of high-pressure hydraulics
- Nearshore location minimises length of water pipe
- Rigid connection to seabed simplifies connection of water pipe
- Sufficient space on-board for desalination plant
- “Disposal” of brine at the device, away from shoreline

Oyster wave energy converter characteristics

- Width = 18 metres
- Water depth = 12 metres
- Initial accumulator gas volume = 2.5 m^3
- Accumulator charge pressure = 28 bar
- Pressure relief valve setting = 55 bar
- Number of RO pressure tubes = 55 (165 membranes)

Incident wave characteristics

- Bretschneider spectrum
- Significant wave height = 1.9 m
- Energy period of waves = 11.0 secs
- Incident wave power = 20 kW/m

Results of simulation

- Average water production = 102 m^3/hr
  - Production of electricity in equivalent plant = 175 kW
- Average product salinity = 288 ppm
- Peak product salinity = 471 ppm
- Maximum recovery ratio = 25 %
- Average specific energy consumption for whole plant = 2.1 kWh/m^3
- Average specific energy consumption of RO plant only = 1.85 kWh/m^3

Conclusions

- Directly-fed autonomous wave-powered desalination would appear to offer a promising and exciting potential for the coupling of renewable energy sources with desalination technology
- The pressure exchanger-intensifier ensures that the required operating conditions of the RO membranes can be maintained whilst accommodating changes in the input power due to the inherent variability of wave power
- Further work to determine the effect of variable pressure and flow on reverse osmosis membranes is required and for water production and plant life optimisation