TELEDYNE ENERGY SYSTEMS
Everywhereyoulook™

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SYSTEM INTEGRATION CHALLENGES

TELEDYNE ENERGY SYSTEMS
Everywhereyoulook™

Teledyne Energy Systems

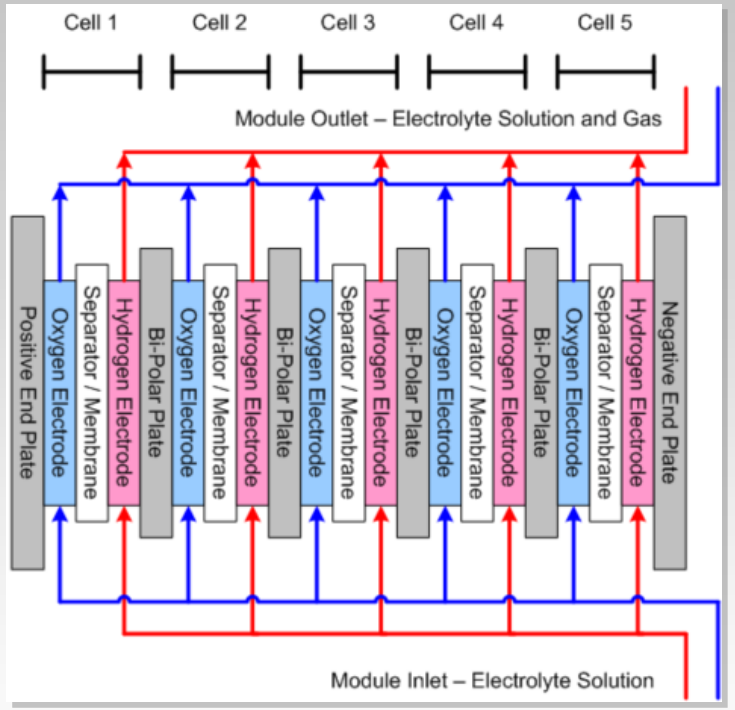
- Wholly Owned Subsidiary of Teledyne Technologies
- 122,000 ft^2 in two facilities
- Manufacturing, Engineering, Design, Sales & Service / Support
- State-of-the-art Thermoelectric, Hydrogen & Fuel Cell production
- 120 Employees

TELEDYNE TECHNOLOGIES:
Thousands Oaks, California

Hunt Valley, Maryland

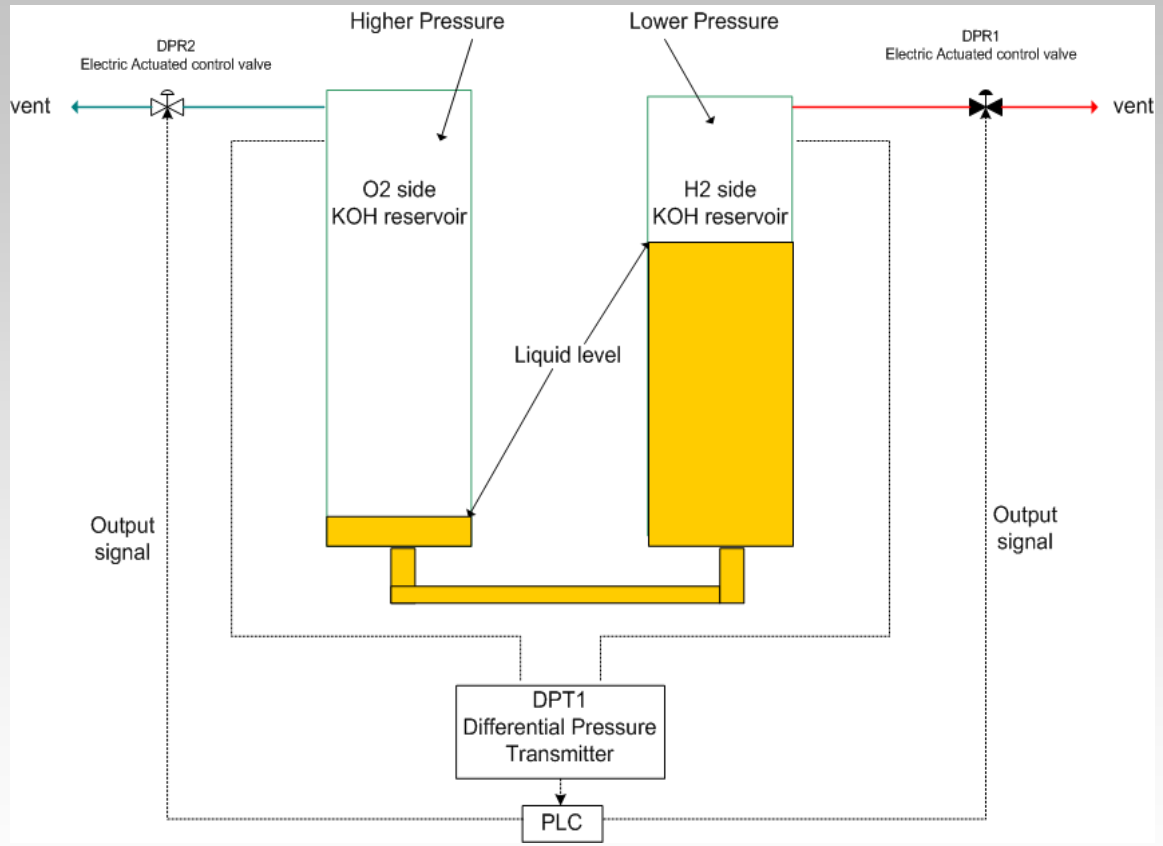
OPERATING INTERMITTENTLY

- Concerns of dropping below certain power levels
  - Manifold Electrolysis
    - Constant amount of Stray Current
    - Low level production, cannot dilute the opposite gas, combustible mixture
    - Must shut down current to the cell stack below that point
  - Auxiliary Power
    - Must have minimum power levels for control power
    - Some systems need power for electrolyte pumps
    - UPS for control power minimum, possibly for pumps for short periods
- Effect on Efficiency
  - Electrolyte Temp – Intermittent Operation may allow to cool



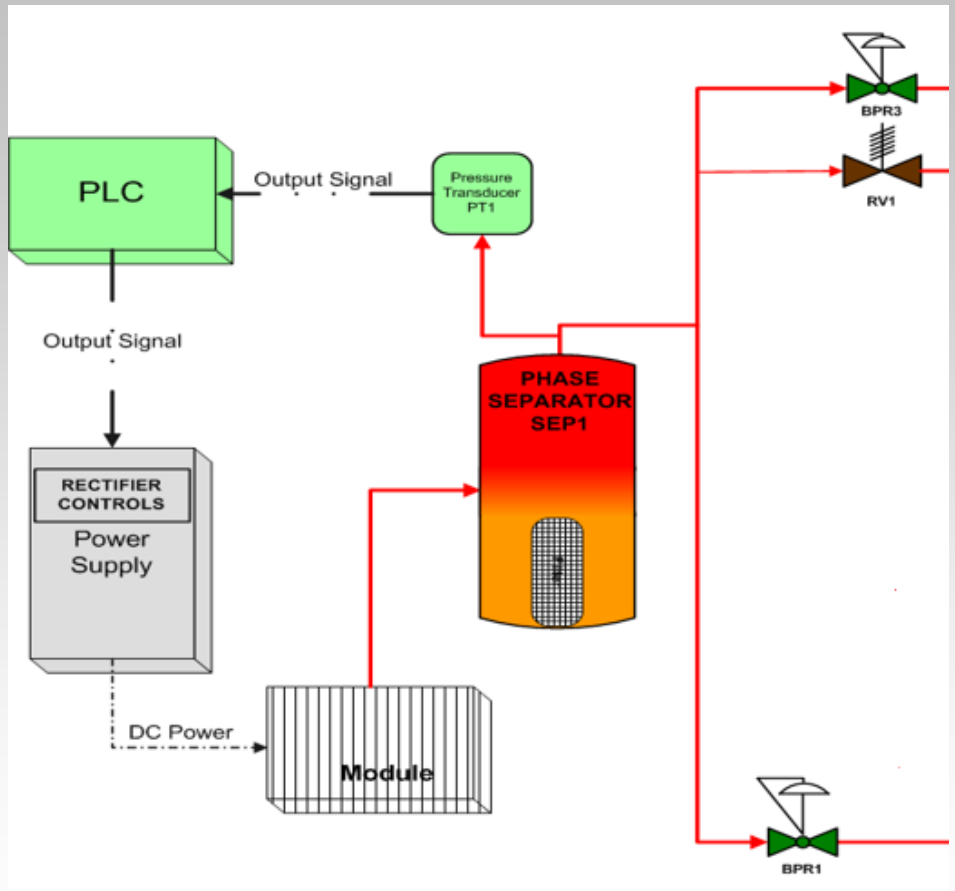
OPERATING INTERMITTENTLY

- Rapid changes in power level/gas generation could cause problems with
  - Differential Pressure control
  - Electrolyte Level control
  - System Pressure
    - need back pressure regulators to avoid dropping to low
- Power Level above maximum
  - Must Size the system properly for power input
  - Charge large battery

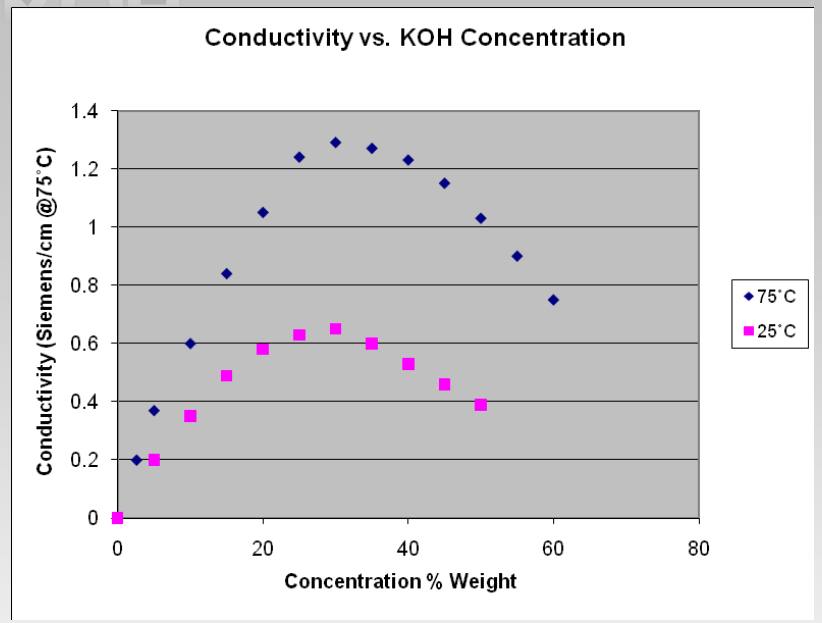


OPERATING INTERMITTENTLY

- Operational Mode
  - Industrial Applications – Demand Following
  - Renewable Energy Applications – Load Following
  - Different type of control is needed
  - Setting of Controls
- Maintenance
  - Continuous Operation – Less Stress on Mechanical Parts
  - Intermittent – More Pressure and Thermal Cycling, reduces Life of Parts



MANAGING CONCENTRATED KOH

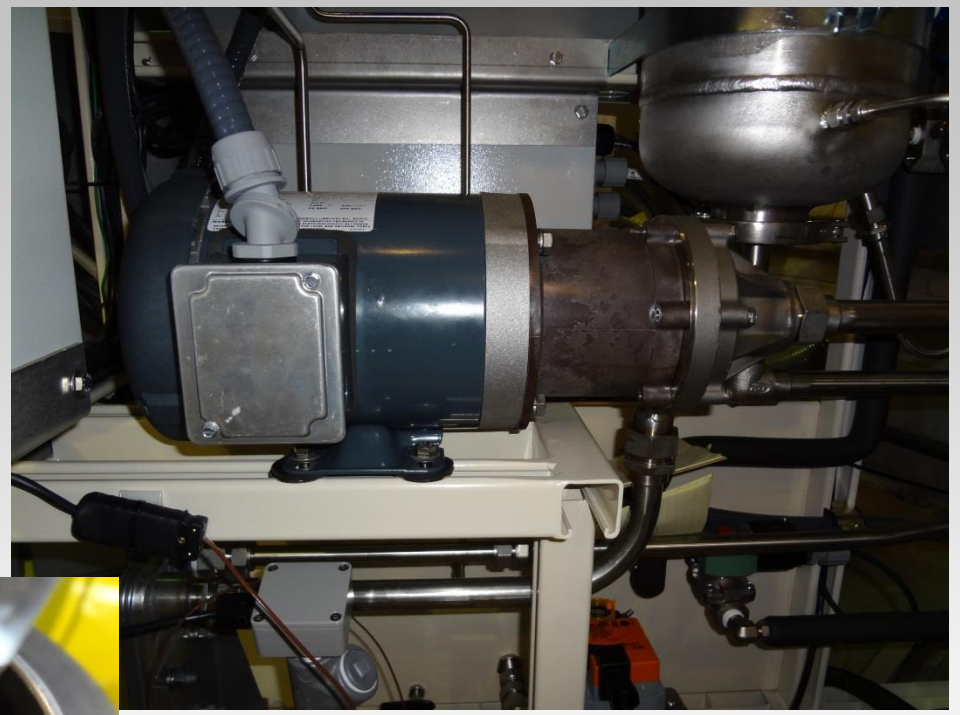


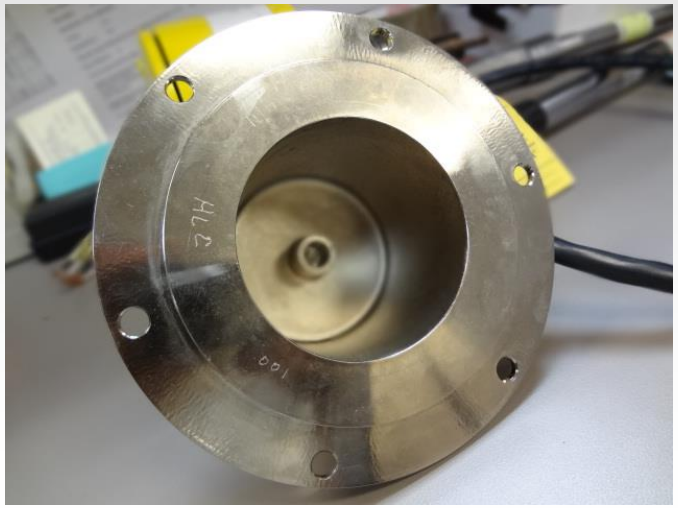
- Efficiency Balances
  - Higher Temperature – More Efficient but Faster Corrosion
  - Concentration Gradient
    - Too much concentration difference drives efficiency down
    - Too much mixing of electrolyte from both sides causes high h2-in-o2 and o2-in-h2

- Materials
  - Caustic, Higher Temperature, Oxygenated, Electrochemical Reactions – Prime for Corrosion
  - Must use materials that can withstand- Higher Cost
    - Low Carbon Stainless Steel
    - Nickel or Nickel Plated
    - Advanced Polymers
  - Instrumentation and Controls, Vessels, Piping more specialized

MANAGING CONCENTRATED KOH

- Must have special or complex sealing methods
  - KOH has a very low surface tension, it can leak through very small gaps
  - Cannot use NPT pipe thread in KOH loop
  - Careful around any electrical connections
  - Magnetically-Coupled Pumps
  - O-rings and Gaskets material must be compatible





MANAGING CONCENTRATED KOH

- Must ensure no high-pressure leaks and that the system is shielded for safety
- Must use care when handling for maintenance
  - PPE
  - Neutralizing solutions available
  - Proper Mixing - Water first

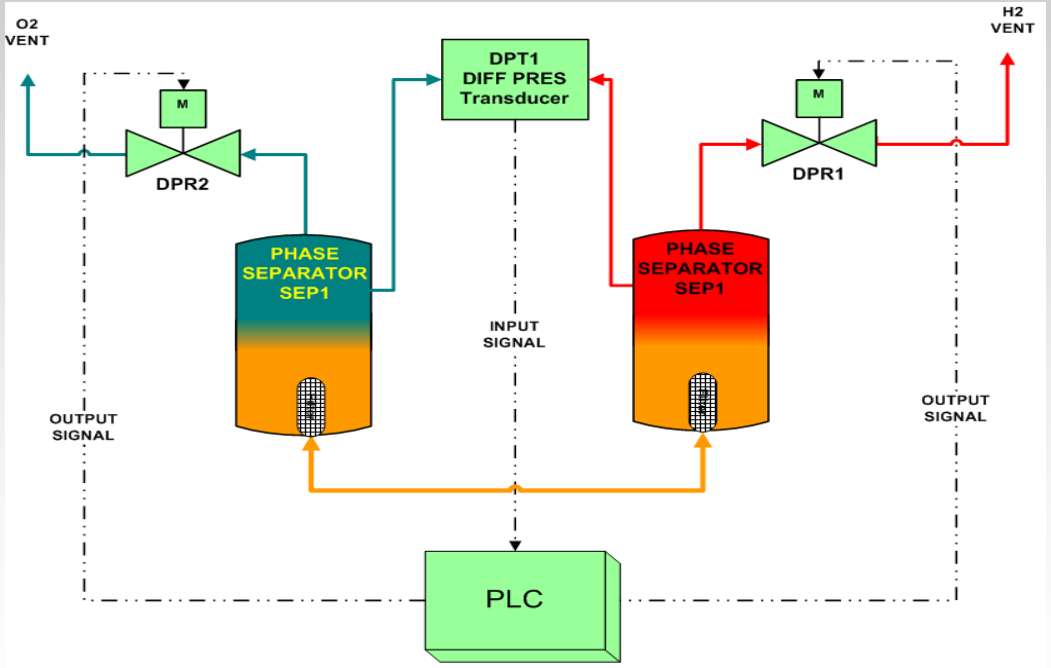
MANUFACTURING CHALLENGES

- Must Use 316L Stainless Threads and hardware gall easily
- Pressure vessels
  - ASME Stamped
  - Quality Control system
- Skilled welders

- Details must be cleaned very well
  - O2 Cleaning
  - Contamination
  - Welding Properly
  - Sealing Properly
- Skilled Assemblers
  - Precision work to avoid leaks
  - Proper swaging of compression fittings

OTHER CHALLENGES / OPPORTUNITIES

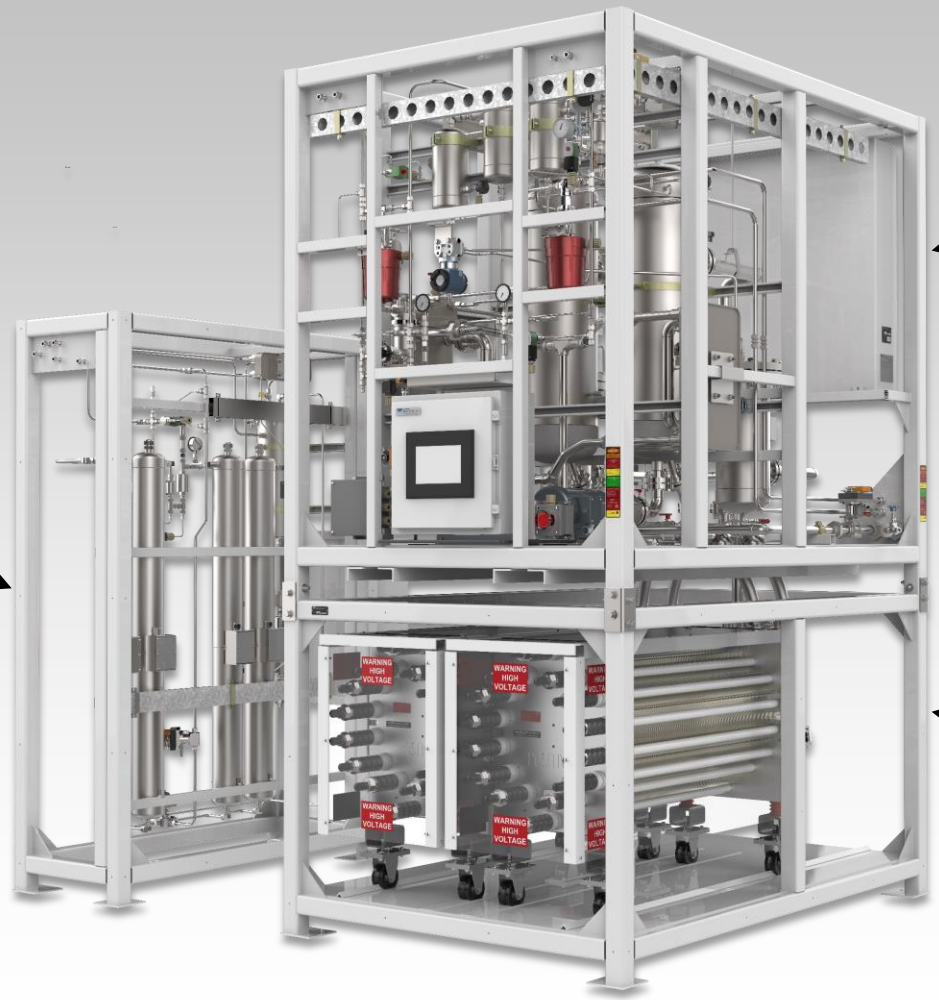
- Differential Pressure control system must be more complex
  - Must keep Hydrogen and Oxygen near same pressure
  - If Electrical, must use UPS



Differential Pressure Control System

- Configuration: Must keep cell stack flooded so phase separation best to be above
- Heat Control
  - Balance between current density/size and cooling method
  - Heat Exchangers
- DC Electrical bussing becomes more difficult with size
  - Bus Bars vs. Cable
  - More Space
  - Cost of Copper
- Water Purity Level not as high as PEM
  - Research into contaminated water, sea water

SYSTEM CONFIGURATION



Hydrogen Purification Module

Gas and Liquid Control Module

Cell Stack Module