

# NREL H<sub>2</sub> Electrolysis - Utility Integration Workshop



**TELEDYNE**  
ENERGY SYSTEMS, INC.  
A Teledyne Technologies Company

**Hydrogen Generation by Electrolysis**  
**September 2004**  
**Steve Cohen**

*Better Engineered Solutions.*  
*What Listening Generates.*



# Hydrogen Generation by Electrolysis

- ▶ Intro to Teledyne Energy Systems
- ▶ H<sub>2</sub> Generator Basics & Major Subsystems
- ▶ H<sub>2</sub> Generating & Storage System Overview
- ▶ Electrolysis System Efficiency & Economics
- ▶ Focus for Attaining DOE H<sub>2</sub> Production Cost Goals

Power  
Systems

Gas  
Systems





## Hunt Valley, Maryland

- ▶ State-of-the-art thermoelectric, hydrogen and fuel cell labs and manufacturing facilities
- ▶ Electrolysis & thermoelectrics R&D
- ▶ Manufacturing of all products
- ▶ Engineering, design and sales



## West Palm Beach, Florida

- ▶ Fuel Cell & Electrochemical R&D
- ▶ Fuel cell prototyping and analysis
- ▶ Test station control system design



# Teledyne Energy Systems' Product Lines

**Hydrogen  
Generation  
Systems**



*Gas  
Systems*

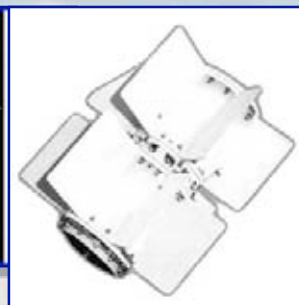
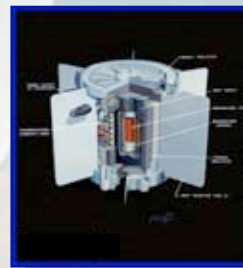


**Fuel Cell  
Test Stations**



**Fuel Cell  
Components  
and Systems**

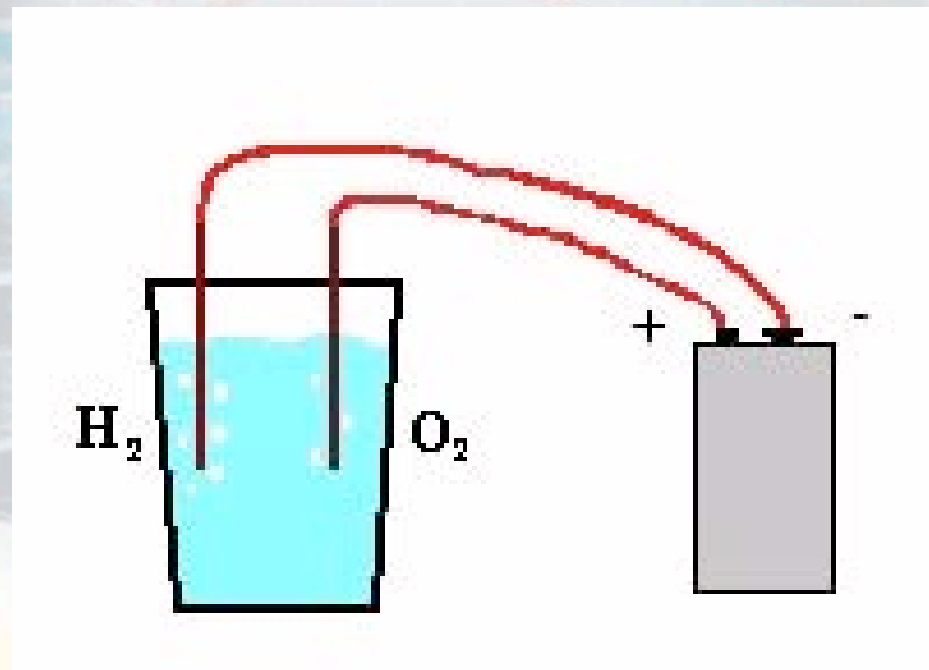
*Power  
Systems*



**Government  
and Advanced  
Power Systems**



# Water Electrolysis



- ▶ **Commercial Technologies**
  - ◆ Alkaline Water Electrolysis
  - ◆ Proton Exchange Membrane Electrolysis



# Water Electrolysis - Modules

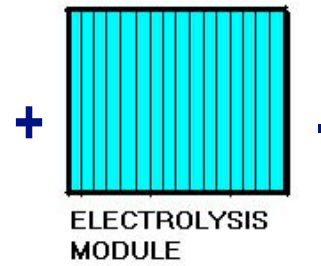


Power Systems



# H<sub>2</sub> Generator

## HYDROGEN GENERATOR BASICS

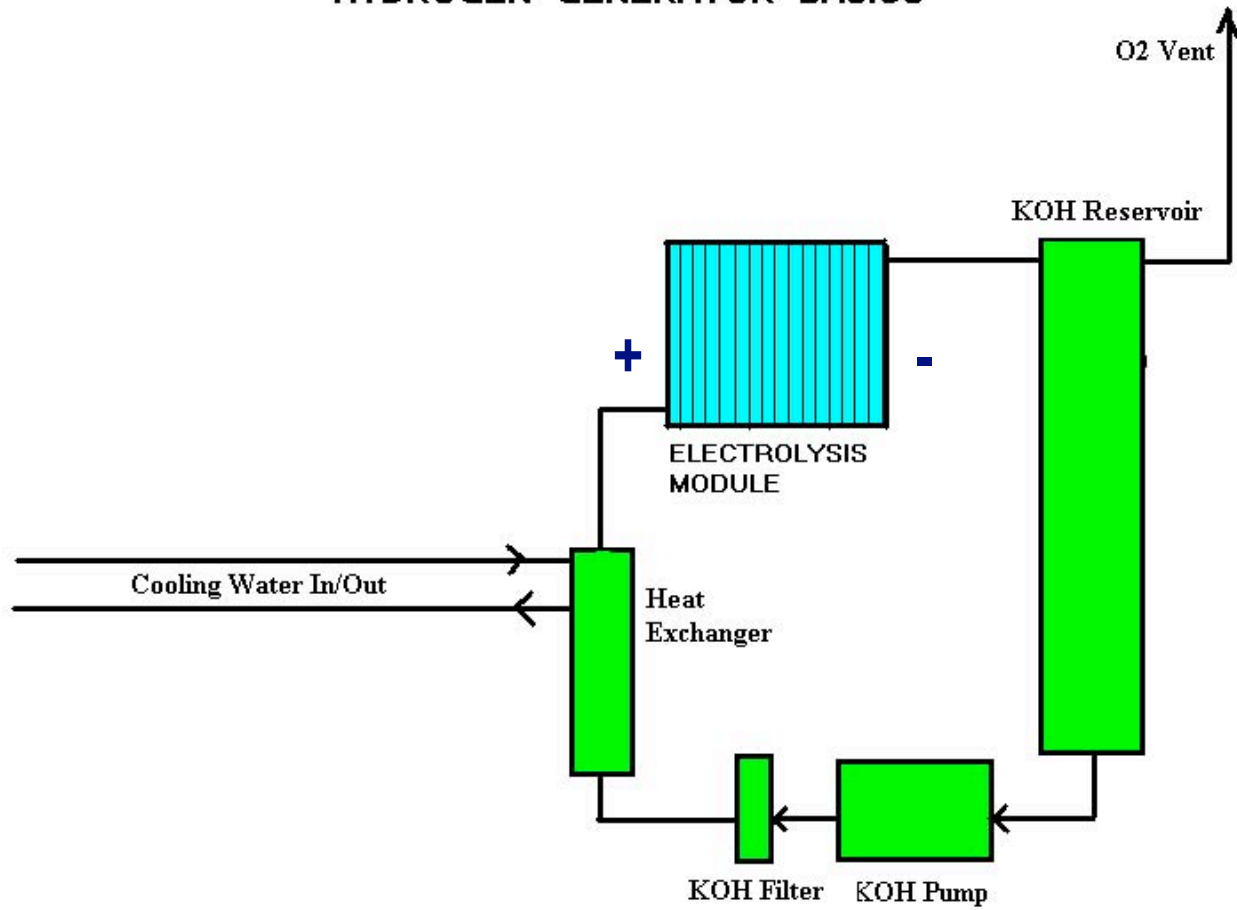


Power  
Systems



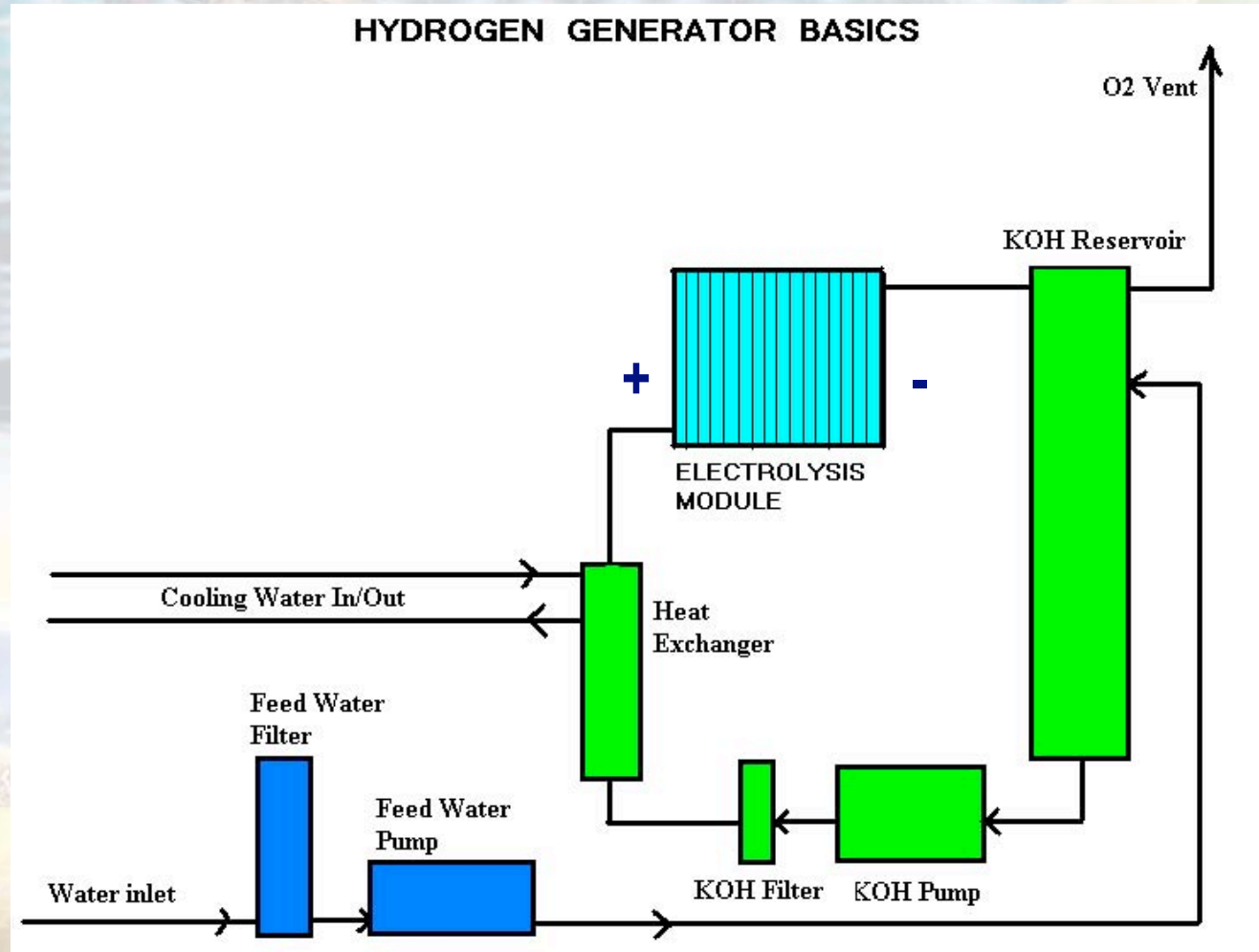
# H<sub>2</sub> Generator – Single Irriguous

HYDROGEN GENERATOR BASICS

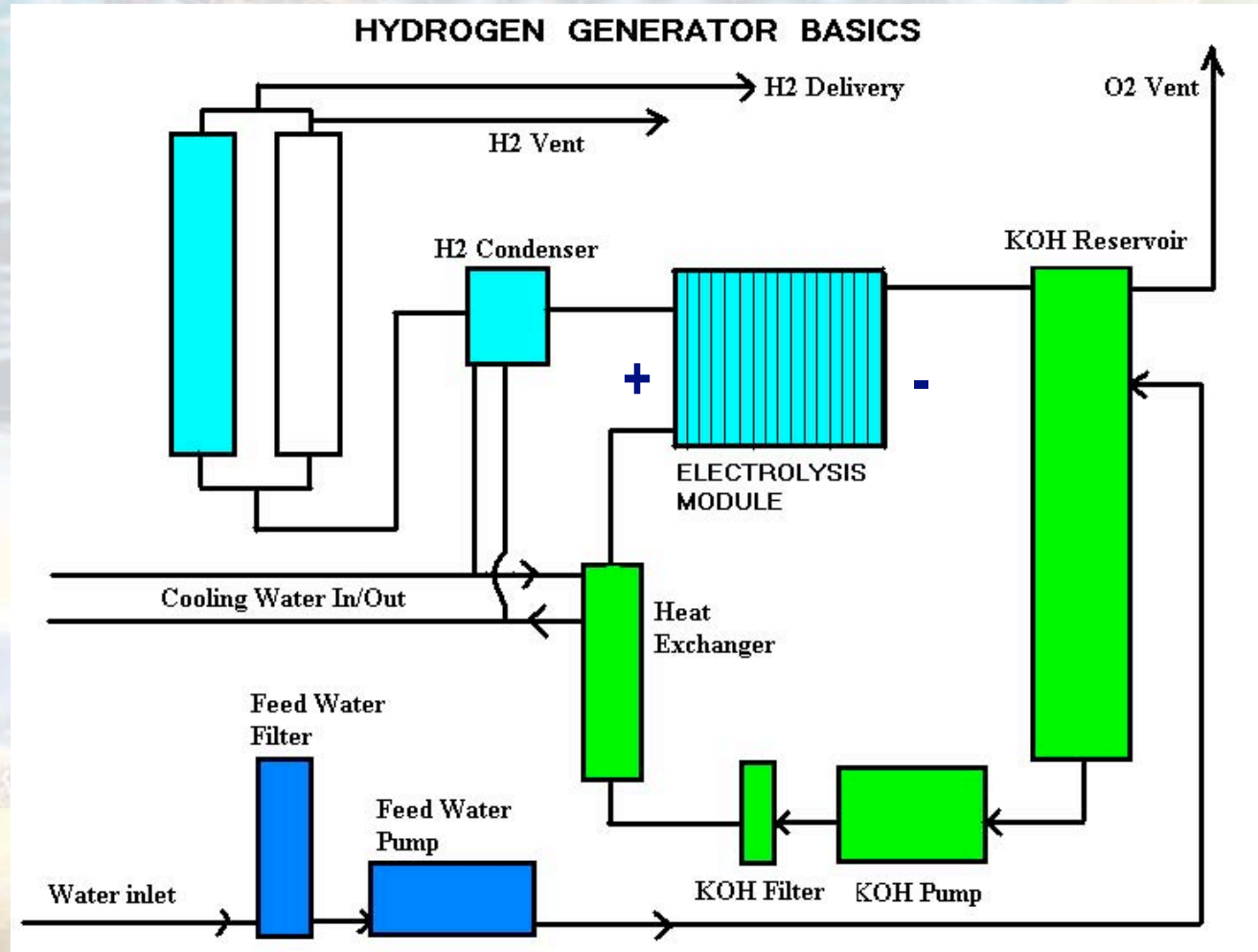




# H<sub>2</sub> Generator – Single Irriguous



# H<sub>2</sub> Generator – Single Irriguous



# Hydrogen Generator Controls

**TESI H<sub>2</sub> Generator are Completely Automatic Utilizing PLC Controls to provide:**

- ◆ **Normal operation and control of system**
- ◆ **Display of system status (touch-screen)**
- ◆ **Sequence and timing functions**
- ◆ **Continuous system surveillance and warning or system shutdown when conditions are out-of-tolerance**
- ◆ **Record shutdowns for diagnostic purposes**



# TESI Gas Systems Products

## PRODUCT PORTFOLIO

1 SLM

**HL  
GENERATOR SERIES**

20 slm, ~2.5 kg/d

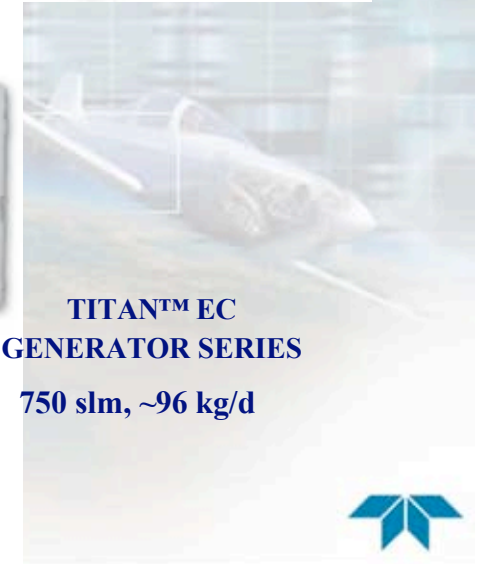


**TITAN™ HM  
GENERATOR SERIES**  
200 slm, ~25 kg/d



**TITAN™ EC  
GENERATOR SERIES**

750 slm, ~96 kg/d



Power  
Systems

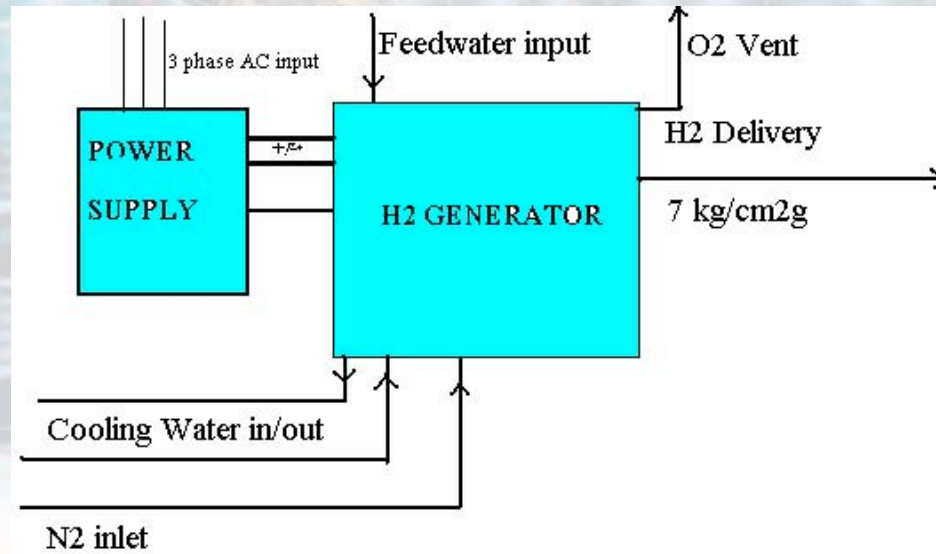
# Power Supply for H2 Generator

## ► Power Supply

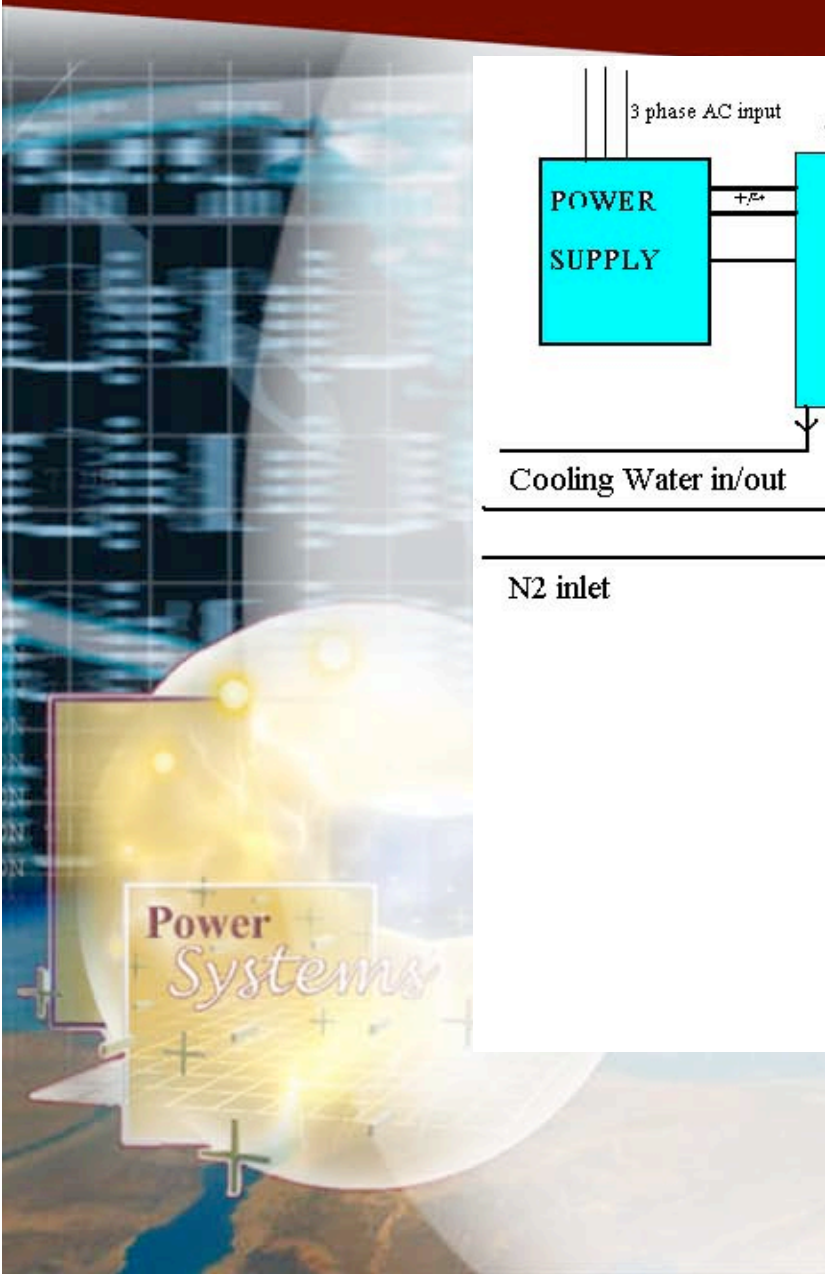
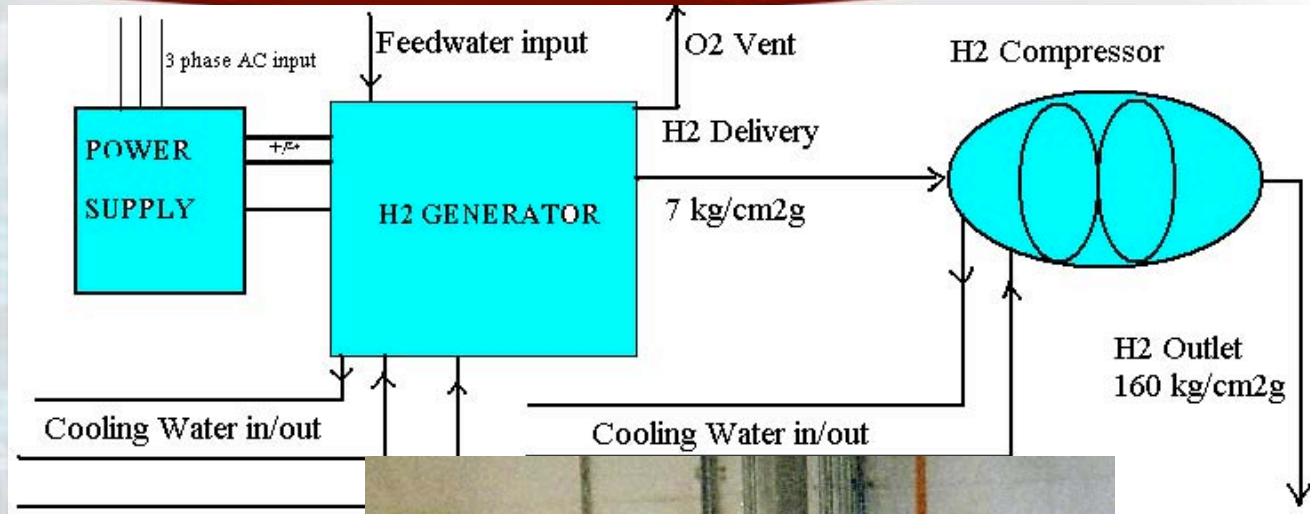
- ◆ Rectifies AC to DC needed for electrolysis
- ◆ Provide control voltages



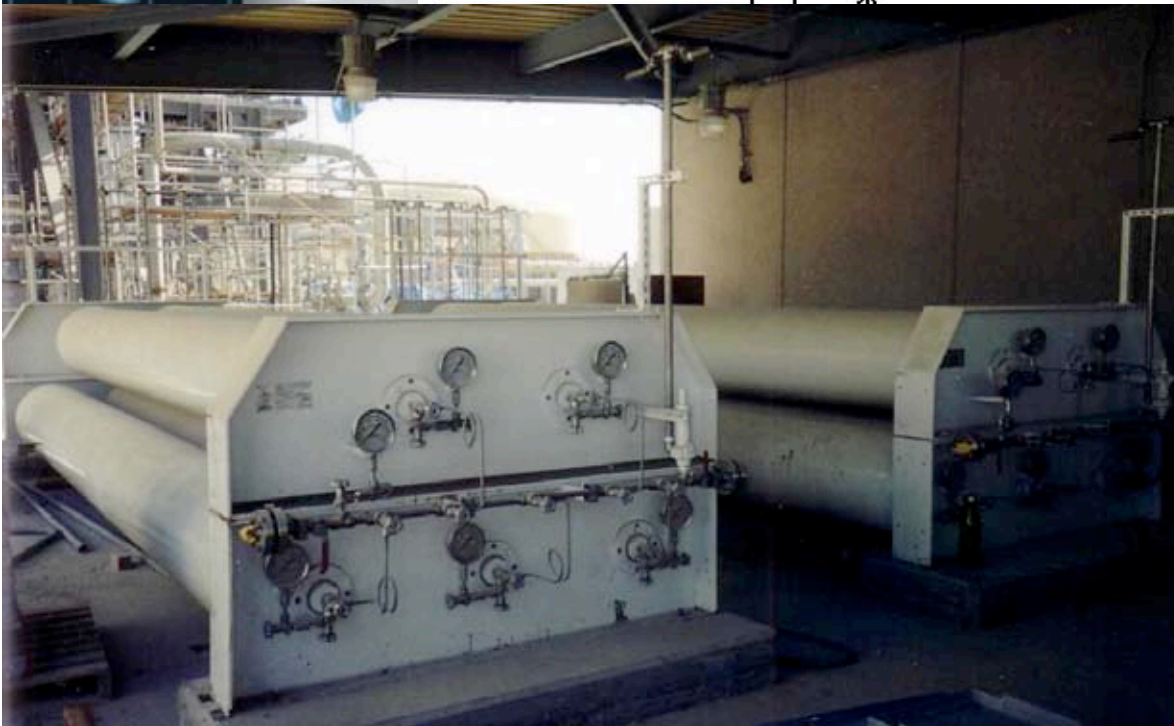
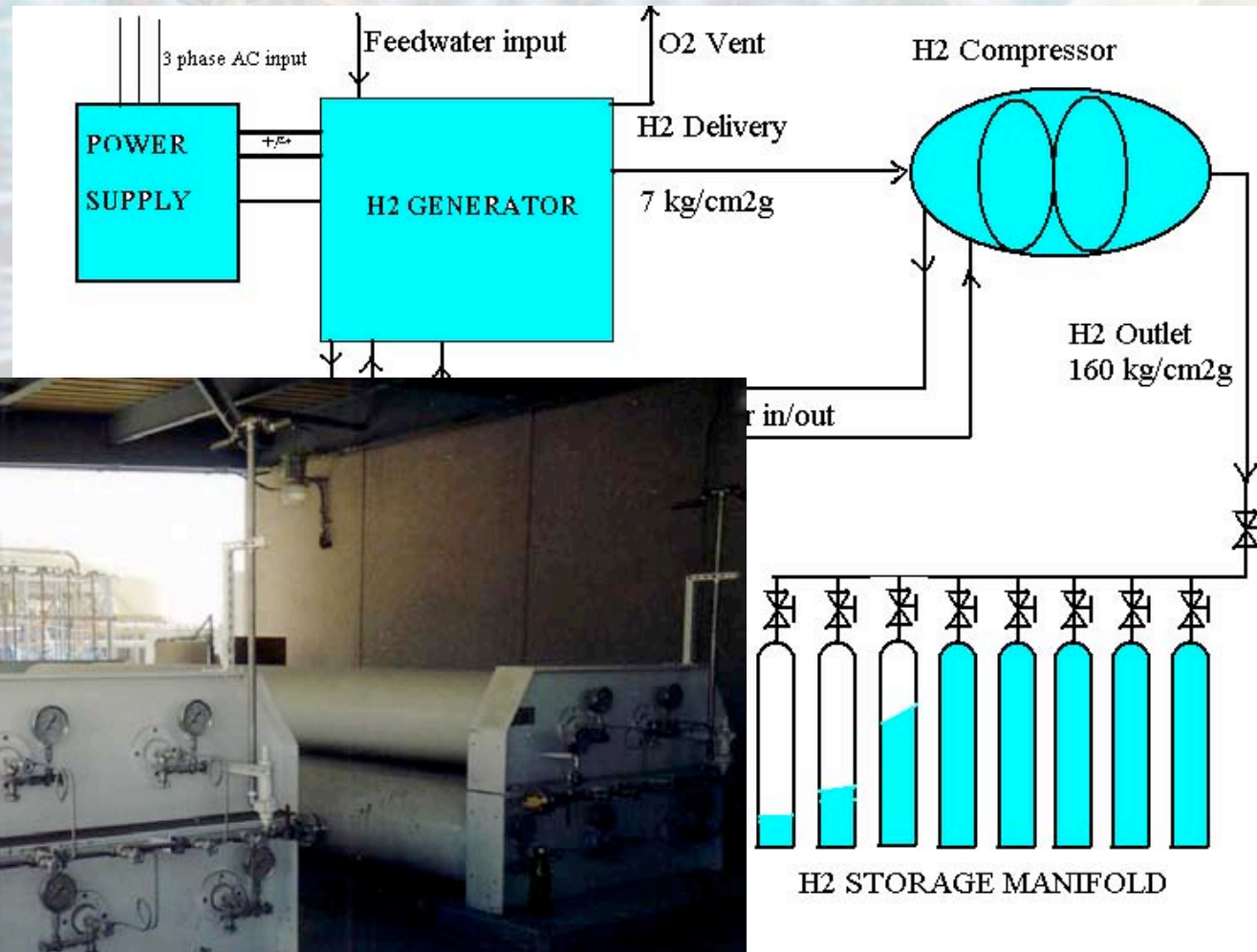
# Simple H<sub>2</sub> Generation System Schematic



# Simple H<sub>2</sub> Generation System Schematic

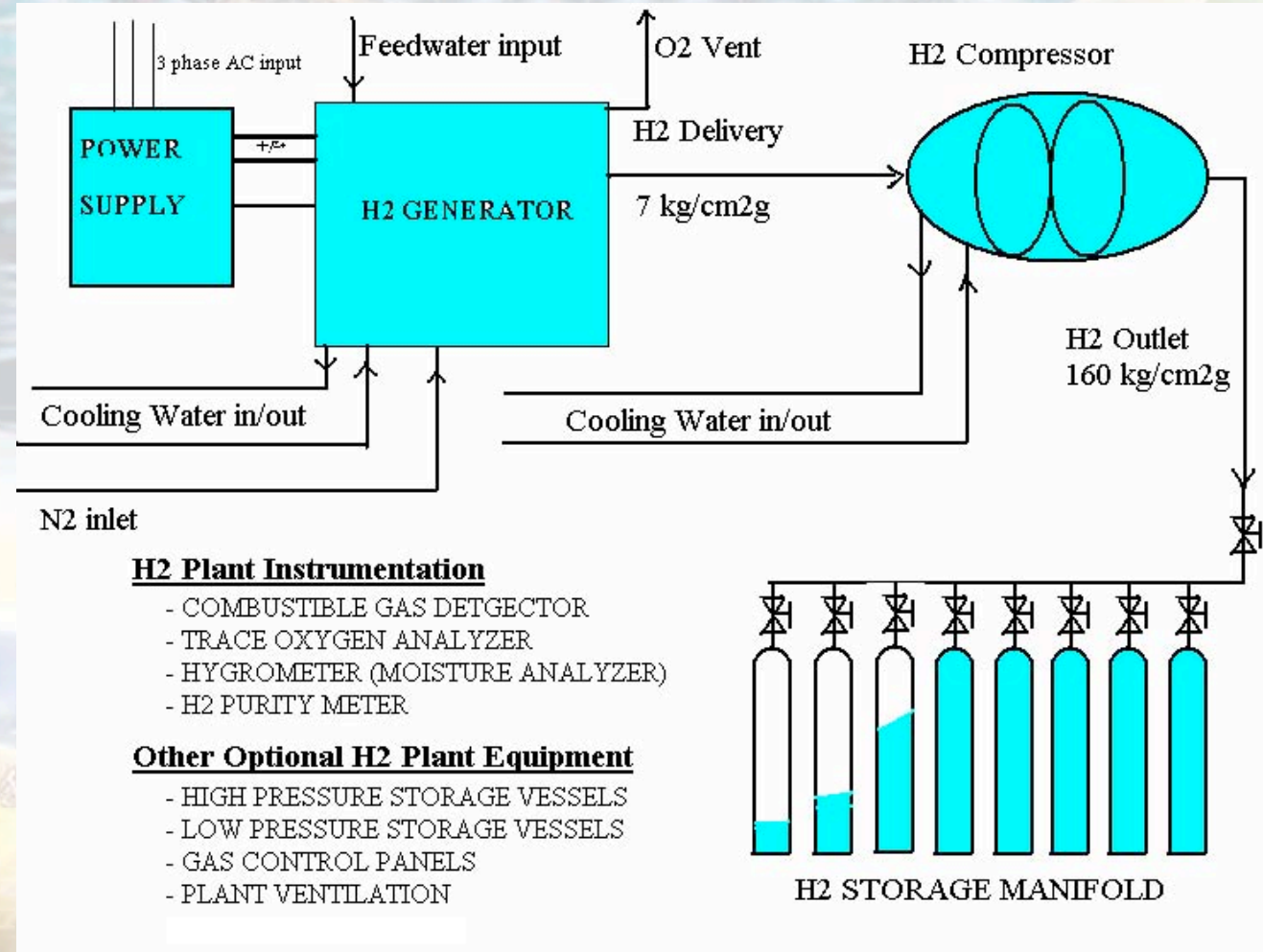


# Simple H<sub>2</sub> Generation System Schematic





# Simple H<sub>2</sub> Generation System Schematic



# Teledyne Titan™ H<sub>2</sub>/O<sub>2</sub> Generators – 30 Year Legacy

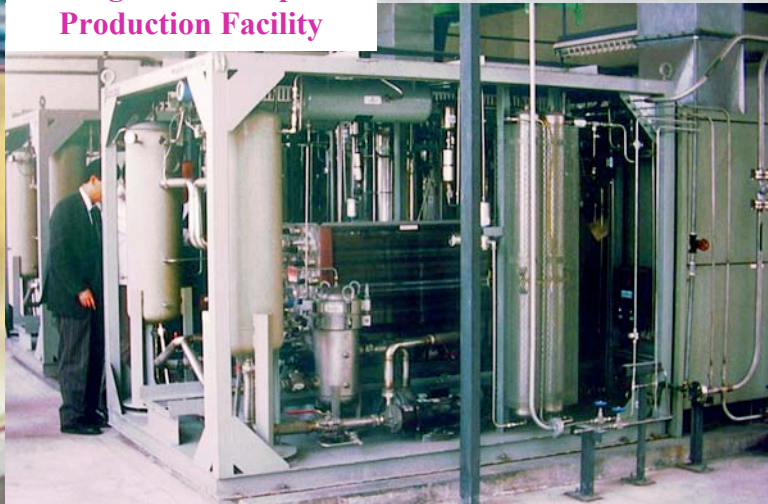
**China National Power  
Installation**



**Hesfibel  
Fiber Optics  
Turkey**



**Yangtze Fiber Optic  
Production Facility**



**PP-9  
Power Plant  
Saudi Arabia**



# Titan™ Hydrogen Systems with Fueling In Mind

20 Nm<sup>3</sup>/hr to 150 Nm<sup>3</sup>/hr Modular Hydrogen Facilities  
High Pressure Class 1/Div 2

Titan H<sub>2</sub>Oasis



Titan HP



# Schatz Hydrogen Generation Center – TESI Systems



Hydrogen Generator:	Teledyne Energy Systems Altus 20 Electrolytic Hydrogen Generator 20 slm
Hydrogen Dryer:	Teledyne Energy Systems Altus 20 dries gas to less than 1 ppm water content
Hydrogen Compressor:	Pressure Dynamic Consultants PDC-4 2-stage, triple diaphragm compressor 3600- psig discharge
Hydrogen storage:	(6) DOT certified cylinders each 300 scf @ 3600 psig
Control system:	Pentium PC running Windows NT and custom control software written in LabVIEW® (National Instruments Corporation)

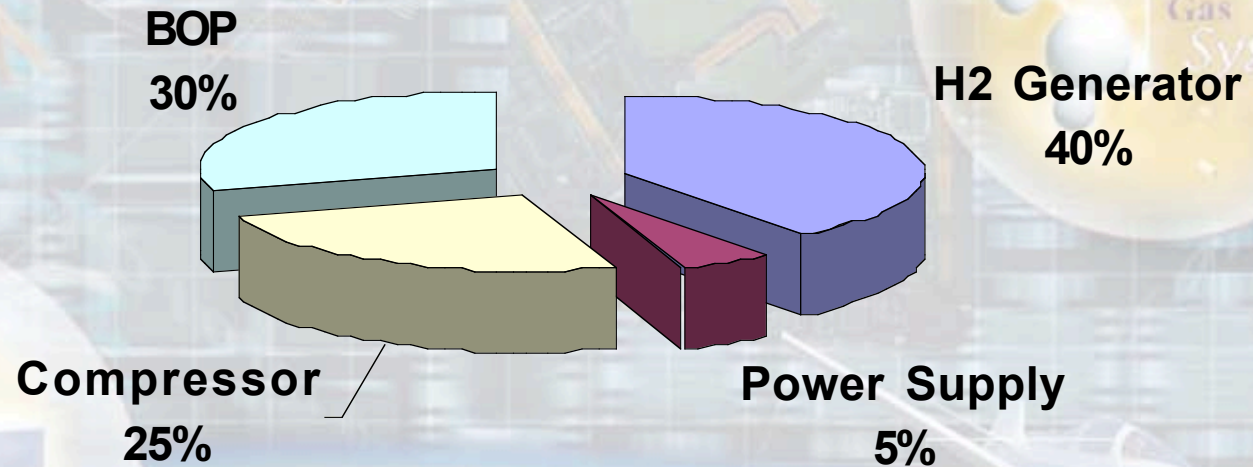


# H<sub>2</sub> Generation Facility at Power Plant



# Relative System Costs - Typical

## Hydrogen Generation & Compression (no storage)



**Storage can be a very significant cost factor dependent on volume**



# Electrolysis System Efficiency

- ▶ Rectification
- ▶ Electrolysis
  - ◆ Voltage Efficiency – minimum theoretical voltage = 1.48 Volts/cell
    - Separator resistance
    - Electrolyte type & concentration
    - Electrolyte temperature
    - Electrode materials
    - Catalysts
    - Current density



# Electrolysis System Efficiency

- ▶ **Current Efficiency (Faraday – the hydrogen produced is directly proportional to the current applied to the cell)**
  - ◆ Losses from due to stray currents
  - ◆ Gas loss in purification
- ▶ **Parasitic Processes – e.g. pumps, heat for dryer regeneration, and I&C**
- ▶ **Pressurization/compression**





# Focus for Attaining DOE H2 Cost Goal

- ▶ Reduce capital costs by:
  - ◆ DFMA
  - ◆ Integration of electrolysis & compression systems
- ▶ Improve Electrical Conversion Efficiency by Improving Cell Efficiency
  - ◆ Reduce cell separator resistivity
  - ◆ Anode & Cathode materials & electrocatalysts



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