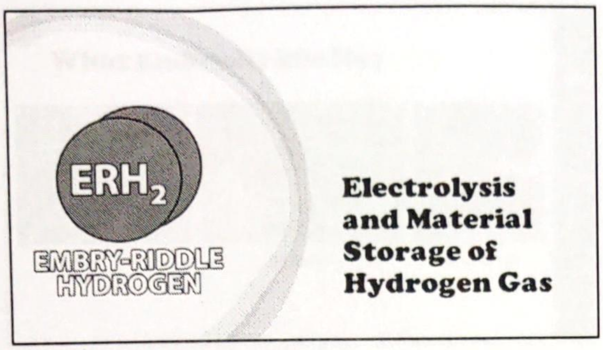
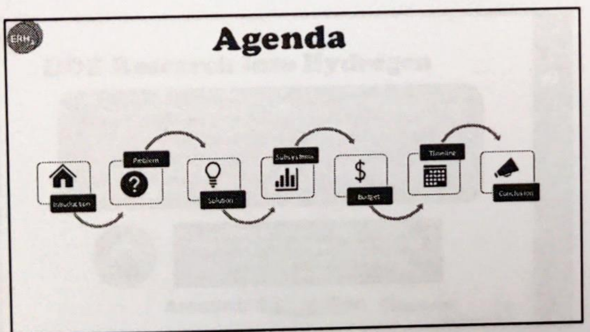


12:08 start
12:39 stop

Hannah

All

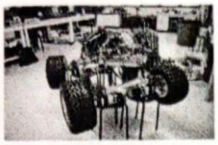


Don't read agenda items

Hannah

What Embry-Riddle Has

Wind Tunnel



Robotics Lab

Propulsion Lab

Jacob

Embry-Riddle does *not* have

Energy Labs

Energy Classrooms

Viewable Demonstrations

Jacob

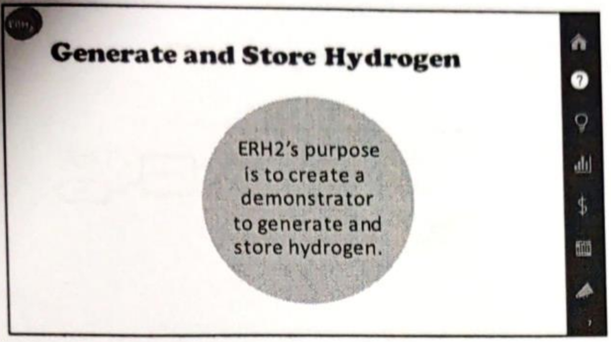
DOE Research into Hydrogen

The DOE is researching multiple uses for hydrogen gas, producing the need for more hydrogen. This creates interest within Embry-Riddle to create an alternative energy demonstrator that teaches the general public about hydrogen fuel and storage.

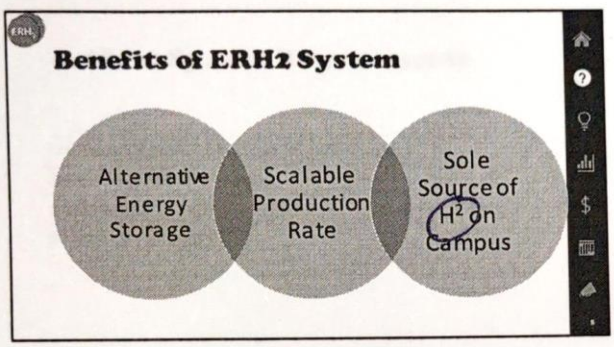
Funding Notice: Clean Hydrogen Production, Storage, Transport and Utilization to Enable a Net-Zero Carbon Economy

Amount: $32 million Seems small

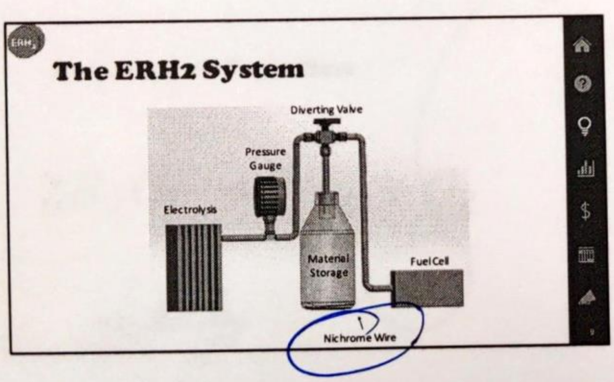
Tesla



Dylan



Dylan

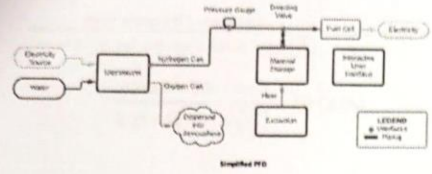


Brief overview

Need Modes of Operation.

Tesla

Process Flow Diagram



Simplified PFD

· Numbers to describe operation.
· Operating modes.

Jacob

Critical System Requirements

Produce 0.02 grams of hydrogen over 10 minutes
Store 0.04 grams of hydrogen
Safely extract hydrogen from system
Internal components visible

Hannah

Electrolysis Equation

$$2H_2O \longrightarrow 2H_2 + O_2$$

electricity

e

Show half reactions

Titan

Hydrogen Production Requirement

$$\frac{Power\ wanted\ (kW) * Time(sec.)}{Percent\ Eff\ of\ fuel\ cell * Lower\ heating\ value\left(\frac{KJ}{Kg}\right)} = Amount\ needed\ (g\ H_2)$$

$$\frac{.001kW * 600\ (sec.)}{0.25 * 120{,}000\left(\frac{KJ}{Kg}\right)} = .02\ (g\ H_2)$$

What equation? Why LHV?

why not Gibbs free energy?

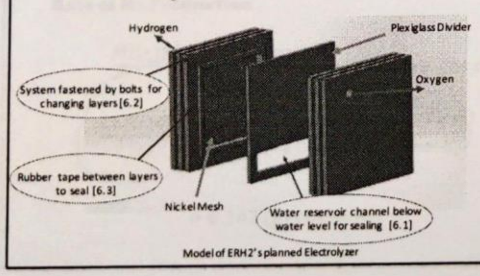
Titan

ERH$_2$

Electrolysis

Grant

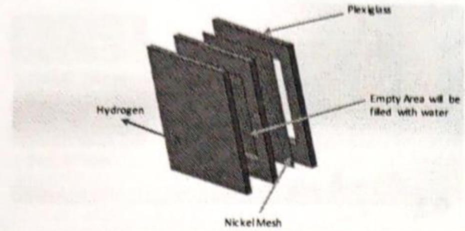
Electrolysis Breakdown



Model of ERH2's planned Electrolyzer

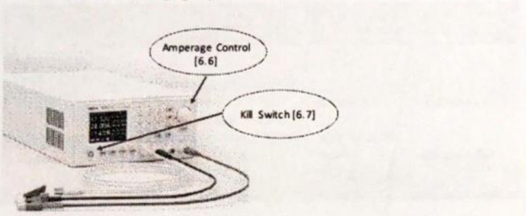
Grant

Mesh Section-View



Grant

Power Supply



20 amp limit?

Grant

Faraday's Law of Electrolysis

Rate of H2 Production

$$\frac{Max\ theoretical\ Current}{Valence} * Molar\ weight\ of\ H$$

$$\frac{22.89\,(C)}{1\,(s)} * \frac{600\,(s)}{96{,}485\,(C)} * \frac{1\,(mol\ H_2)}{2\,(mol\ e^-)} * \frac{2.007\,(g\ H_2)}{1\,(mol\ H_2)}$$

$$= 0.142\,(g/10min\ H_2)$$

Grant

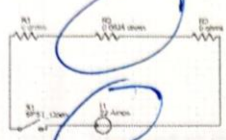
Electrolysis Power Circuit

R1 = R3

- Nickel Mesh

R2

- Salt Water



Dimension to set this R2

22 Amps vs 20

Grant

Electrolysis Summary

Requirement	Design	Expected Performance	Verification
6.1	The hydrogen and oxygen will be separated at creation	100%	Fuel Cell Runs
6.2	The system was designed to be sandwiched together into different layers making it replaceable	Life of bolts used	It will come apart
6.3	Ability to bolt together	The life span of seals	It will come apart

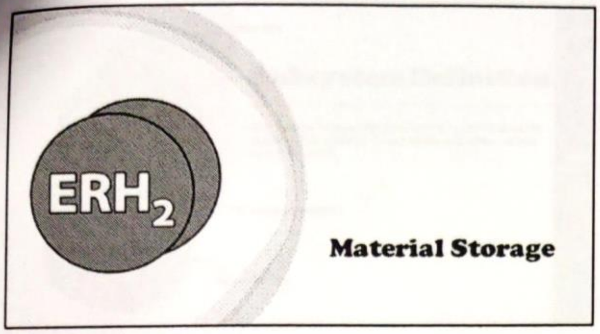
Grant

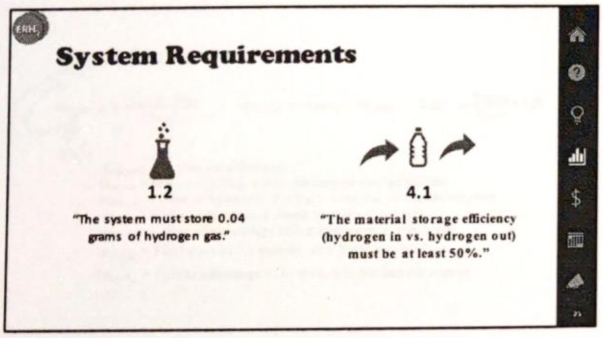
Talk through

Electrolysis Summary

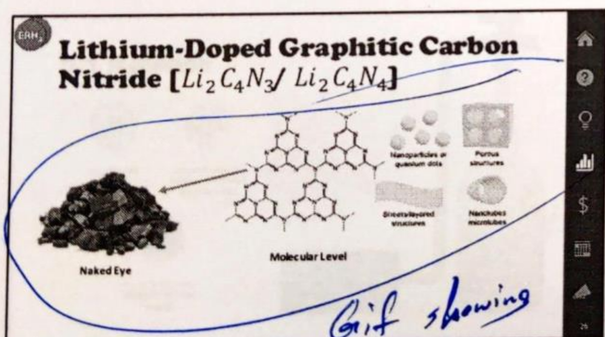
Requirement	Design	Expected Performance	Verification
6.4	Will be made of plastic	Nonconductive	Voltmeter
6.5	Will use 12-gauge wire	Rated for 20 amp	National Electrical code
6.6	Will set power supply to max 20 amps	Max 20 amps	Power supply read out
6.7	Have and on off switch	100%	System turns off

Grant



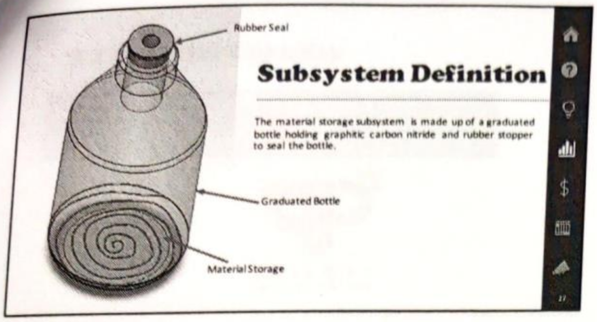


thanks



Gif showing H_2 getting trapped.

Is this a surface-only phenomenon?



Hannah

Equations

$$E_{Material} = \frac{m_{H_2 out} - m_{H_2 in}}{m_{H_2 in}} \qquad m_{Stored} = m_{initial} - m_{final} \qquad \%wt_{H_2} = \frac{m_{Stored}}{m_{final}} * 100$$

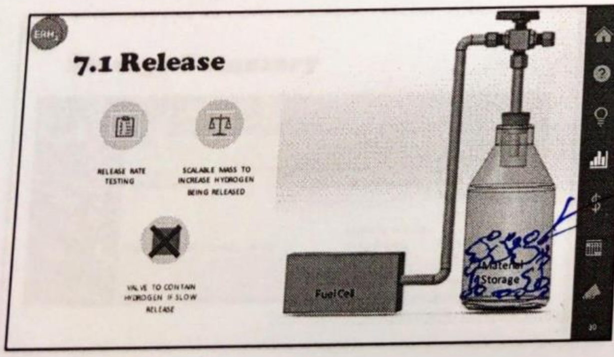
η ?

Where:

$E_{Material}$ = Material Efficiency
$m_{H_2 in}$ = Mass of hydrogen into the material storage system
$m_{H_2 out}$ = Mass of hydrogen leaving the material storage subsystem.
m_{Stored} = Mass of hydrogen stored in material storage
$m_{initial}$ = Mass of the storage before hydrogen is introduced
m_{final} = Final mass of the material after hydrogen loading
$\%wt_{H_2}$ = Weight percentage of hydrogen in the material storage

19

Hannah



show material (or show how small it is)

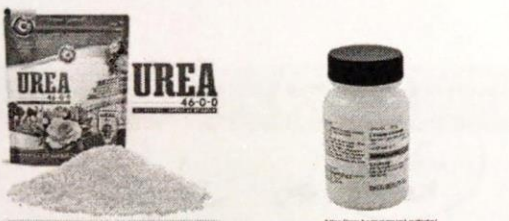
7.2 Material Capacity

…it was found that the gravimetric and volumetric densities of …drogen in both $Li_2C_4N_3$ and $Li_2C_4N_4$ were greater than 10 wt% …d 100 g/L respectively" [Wu et al.]

Hannah

7.3 Material Needed

4% yield Urea to Graphitic Carbon Nitride



Can be done on campus.

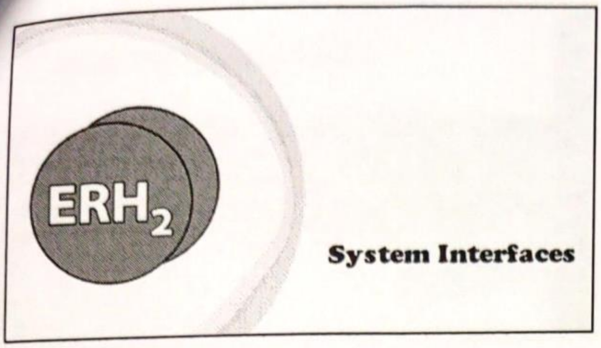
What's needed / process?

Pyrolysis

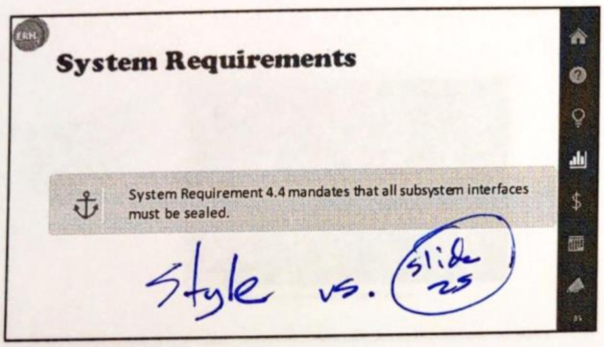
Hannah

Storage Summary

Requirement	Design	Expected Performance	Verification
7.1	Extraction heats material to release temperature	Releases at least 0.02 grams per 10 minutes	Runs the fuel cell
7.2	Doped graphitic carbon nitride	Capacity of 10% wt hydrogen	Numerically, Greater than 2% Testing
7.3	2 grams of Graphitic Carbon Nitride	Synthesize 50 grams for 4% yield	Greater than 2 grams

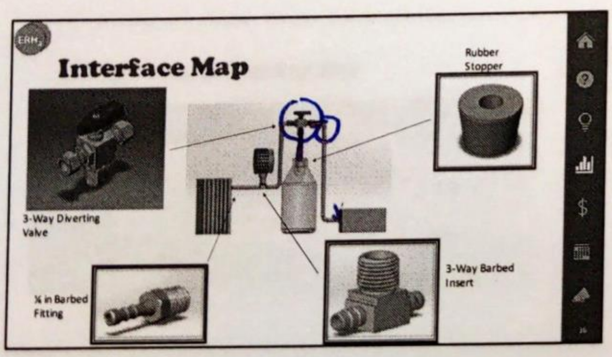


Titan



Style vs. slide 25

Titan



Specs on interfaces.

"PTFE tubing" ⟸

Material specs for use w/ H_2?

Titan

More barbed fittings.

Misc. Interfacing Table

Type of Interface	Name	Price	Interface Point
Plastic Epoxy	Plastic Epoxy Putty	$5.83 per 2 ounces	Electrolyzer to piping connection
Electrical Epoxy	Fire Barrier Sealant	$11.28 per 10.3 ounces	Electrical Epoxy for Electrolyzer
Gasket Tape	NEMA 12	$15.55 per 10 feet	Internal Electrolyzer Interfaces
Pipe Gasket	Gasket	$0.79 each	Threaded Connections
Plastic Epoxy	J-B Weld	$9.76 per 2 ounces	Electrolyzer Water Storage Casing
Threaded Connections	Made Inhouse	1/2 inch Aluminum Stock	To be Decided

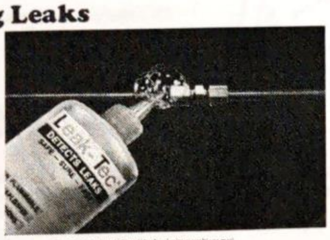
? carbon/element?

17

Titan

Detecting Leaks

ERH2 will follow ASHRAE Bubble Method under Chapter 29.9 Leak Detection in the 2017 edition ASHRAE Handbook.



18

Just ASHRAE

standard for use in HVAC systems.

Any H_2 reactions w/ soap? → w/ or w/o H_2

Titan

Integration Summary

Requirement	Design	Expected Performance	Verification
8.1	The electrolyzer fitting moves hydrogen gasfrom the electrolyzer to the piping.	No leaks	Bubble Test
8.2	The pressure gauge fitting moves hydrogen gasfrom the piping to the pressure gauge.	No leaks	Bubble Test
8.3	The rubber stoper fitting moves hydrogen gasfrom the 3-way diverting valve to the material storage.	No leaks	Bubble Test

Titan

ERH$_2$

Extraction

Tesla

System Requirements

Style matches ✓

2.1

"The system must allow for safe extraction of hydrogen gas without risk of major leaks."

4.3

"The material storage to fuel cell system must be able to run for 10 minutes."

Tesla

Heating Element – Nichrome Wire

- Type: Resistance Wire
- Material: Nichrome 80 Alloy (nom. 80% Ni, 20% Cr)
- Specification: ASTM B267
- Temperature Rating: 1177°C (2150°F)

[illegible] AWG	[illegible]	[illegible]

-Remington Industries

How much power?

Amp limits?

Tesla

Heat Loss Calculations

Energy Loss, 10ft. Of wire @ 300°C: 2.683W

$$Heat\ Rate\ Out = Conduction\ loss + Convection\ loss$$

$$Conduction\ loss = h_{air} A_1 \Delta T \quad Convection\ loss = -kA_2 \Delta T$$

h_{air} = 2.5 for still air

A_1 = .0038m^2 (50% surface area)

A_2 = .0019m^2 (25% surface area)

K= 11.3$\frac{W}{m \cdot {}^{\circ}K}$

ΔT = 280°

Tesla

Voltage Input Calculations

Voltage Requirement: 2.402V

$$Q = V^2/R$$

$$Q = 2.683W \qquad R = .705\frac{\Omega}{m} * 3.048m\ (10ft.)$$

> 1 Amp.

Tesla

Vessel Pressure

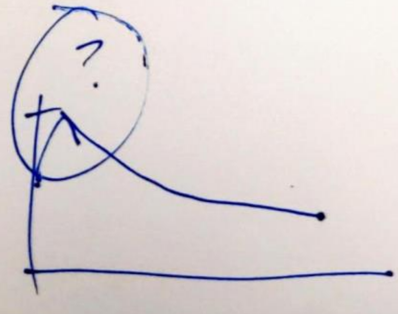
- Maximum Vessel Pressure: 40.43psia
  - Champagne Bottle: 90psia
  - Soda Can: 30psia

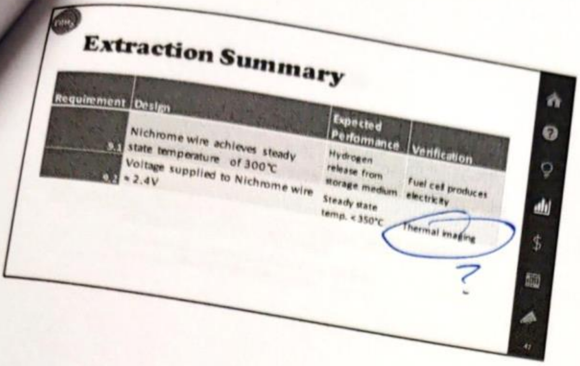
Based on what calc?

How much air? vs. H_2.

Tesla

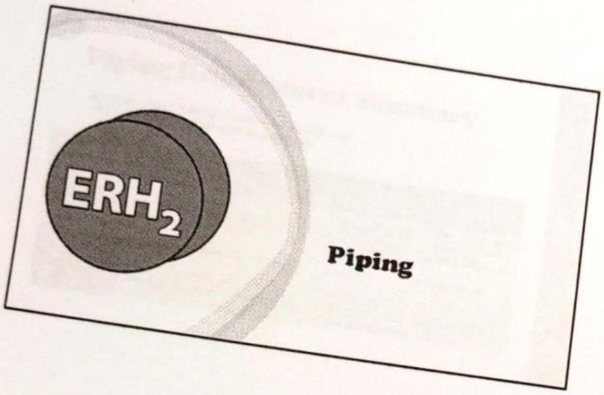
300°



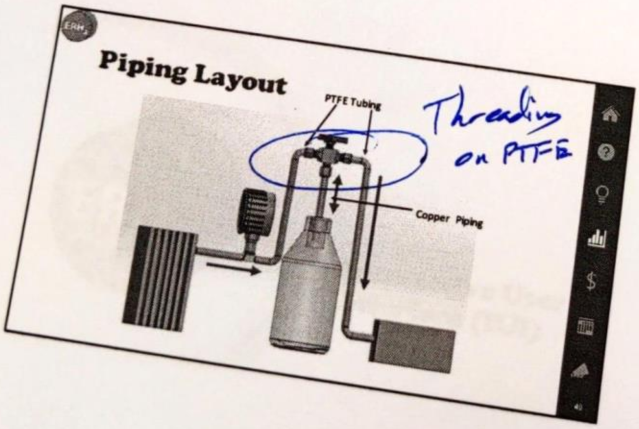


Requirement	Design	Expected Performance	Verification
9.1	Nichrome wire achieves steady state temperature of 300℃	Hydrogen release from storage medium	Fuel cell produces electricity
9.2	Voltage supplied to Nichrome wire ≈ 2.4V	Steady state temp. < 350°C	Thermal imaging

Tesla



Jacob



System Reqs?

Good animations. Should use much earlier w/ system overview.

Jacob

Heat Transfer Analysis

1. Use a 6in long pipe at constant 100°C that reduces internal gas temperature from 300°C to 150°C to determine flow regime.
2. Analyze 0.0001in long sections where pipe is average temperature of internal and external air.

R convection, inside	14.48	(K/W)
R convection, outside	20.35	(K/W)

To reduce the gas from 350°C to 80°C, the copper pipe must be 2.63 inches long.

Conduction through the pipe is negligible. Convection on the outside and inside of the pipe have similar magnitudes.

Jacob

Piping Requirement Summary

Hard Copper Pipe 0.5" OD x0.05" Wall Thickness x 2.63" Long
PTFE Tubing 0.31"ODx 0.03" Wall Thickness x2' Long

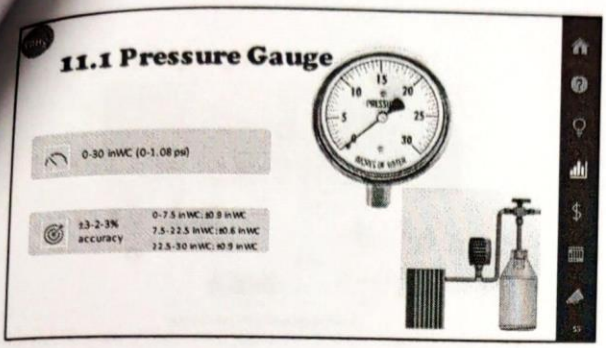
Requirement	Design	Expected Performance	Verification
10.1	PTFE tubing and copper pipe.	Transportation of hydrogen gas	Pressure gauge, mass of material storage, operation of fuel cell
10.2	Material chosen to withstand pressures.	No leaks	Bubble method
10.3	Copper piping sufficiently transfers heat.	Temperature reduced to 50°C at diverting valve	Thermal imaging

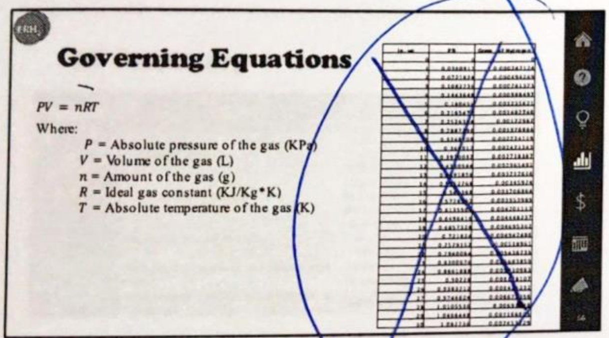
Jacob

ERH₂

Interactive User Interface (IUI)

Dylan

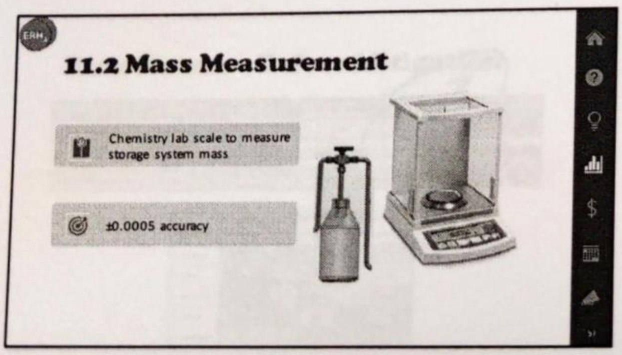




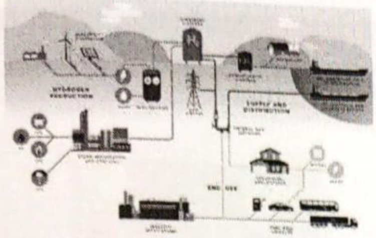
Any air?

T is also increasing.

Figure would be better.



11.3 Infographic



Dylan

IUI Summary

Requirement	Design	Expected Performance	Verification
11.1	0-30 inWC Pressure Gauge	Display accurate pressure of system	Visual Inspection
11.2	Chemistry lab digital scale	Display mass of hydrogen in storage system	Visual Inspection
11.3	Hydrogen Economy Infographic	Inform about hydrogen economy	Visual Inspection
11.4	Pressure gauge and scale have measurement displays	Display measurements	Visual Inspection
11.5	Pressure gauge and scale have English unit on the displays	English Units	Visual Inspection

Dylan

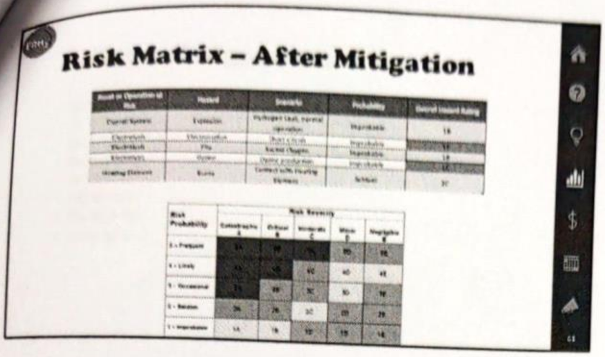
Risk Matrix – Before Mitigation

?

Asset or Operation at Risk	Hazard	Scenario	Opportunities for Prevention or Mitigation	Probability	Overall Hazard Rating
Overall System	Explosion	Hydrogen Leak, normal operation	Sealant	Likely	[illegible]
Electrolysis	Electrocution	Short Circuit	Insulator	Seldom	2C
Electrolysis	Fire	Excess Oxygen	Planned Dispersion	Likely	[illegible]
Electrolysis	Ozone	Ozone production	Capture	[illegible]	[illegible]
Heating Element	Burns	Contact with Heating Element	Warning Sign	Occasional	[illegible]

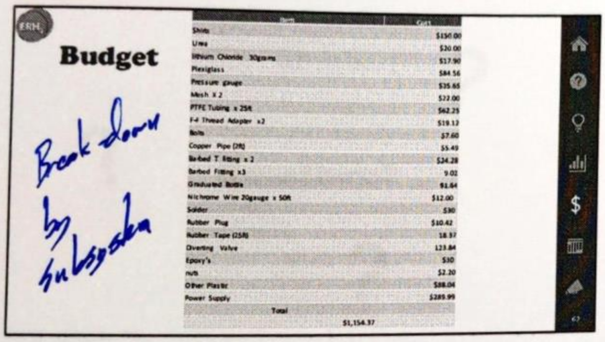
Risk Probability	Risk Severity: Catastrophic A	Critical B	Moderate C	Minor D	Negligible E
5 - Frequent	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4 - Likely	[illegible]	[illegible]	4C	4D	4E
3 - Occasional	[illegible]	3B	3C	3D	3E
2 - Seldom	2A	2B	2C	2D	2E
1 - Improbable	1A	1B	1C	1D	1E

Titan



What's the mitigation?

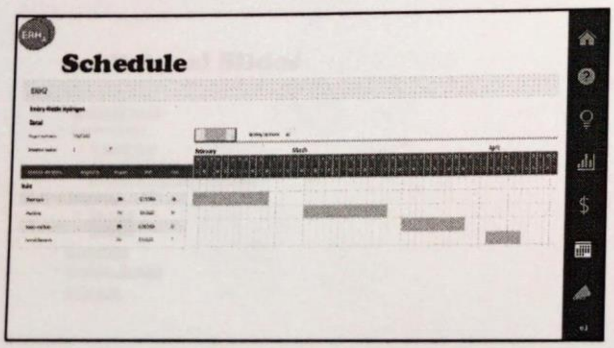
Wire insulation?



Item	Cost
Shirts	$150.00
Urea	$20.00
lithium Chloride 30grams	$17.90
Plexiglass	$84.56
Pressure gauge	$35.65
Mesh X 2	$22.00
PTFE Tubing x 25ft	$62.25
F-f Thread Adapter x2	$19.12
Bolts	$7.60
Copper Pipe (2ft)	$5.49
Barbed T fitting x 2	$24.28
Barbed Fitting x3	9.02
Graduated Bottle	$1.64
Nichrome Wire 20gauge x 50ft	$12.00
Solder	$30
Rubber Plug	$10.42
Rubber Tape (25ft)	18.37
Diverting Valve	123.84
Epoxy's	$30
nuts	$2.20
Other Plastic	$88.04
Power Supply	$289.99
Total	
	$1,154.37

Break down by subsystem

Pie chart



Storage - Testing?