Physical Damage 101: Bread and Butter Attacks

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Blackhat Vegas 2015

IOActive
Hardware | Software | Wetware
SECURITY SERVICES

ICS Village

- Lately I've had complaints that I only talk about chemical and haven't done a cool power talk lately
- This will be mostly chemical and manufacturing
- Power guys go to the ICS Village try to crash the east coast grid with Shaw and Culliss

"Software exploitation can be described as *unexpected computation*"

–Sergey Brattus

"CyberPhysical exploitation can be described as *unexpected physics*"

–Jason Larsen

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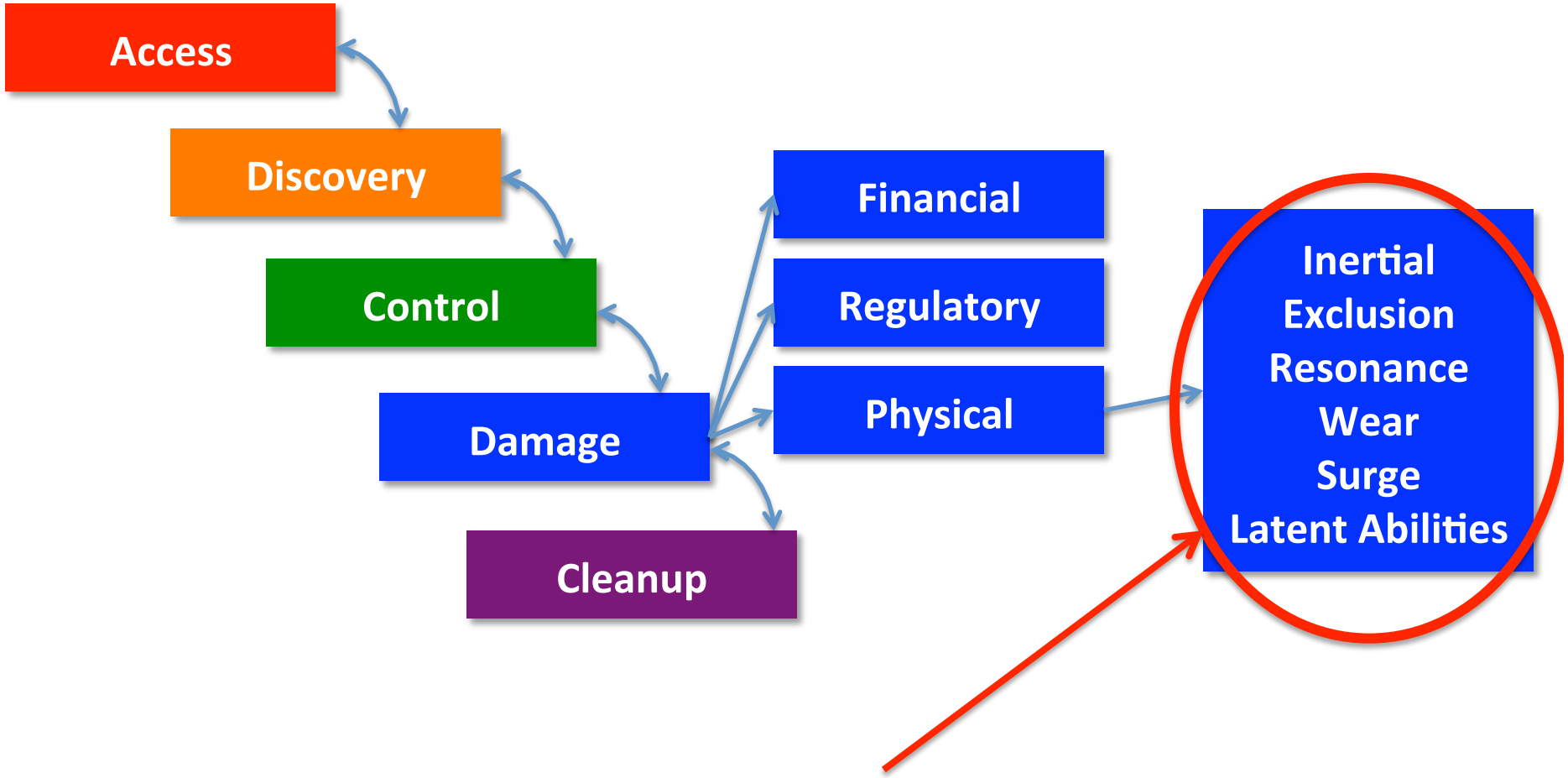
Stages of OT Hacking



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Parents Just Don't Understand

Me – "I have full control of the process"

Them – "OK, blow it up"

Me – "Ummmm… Give me a few weeks…"

Them – "I thought you said you had full control"

Me – "There's no big red self destruct button"

Them – "I thought you said you had full control"

Aaaaaarrrrrggggg!!!!!

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Why Study Physical Damage

- For an attacker compromising a process is only the start of the work
  - The physics are much more challenging
- Luckily the defender mostly just gives you free reign once border defenses are defeated
  - Maybe defenders should study attack?
- Also, destroying stuff is just fun

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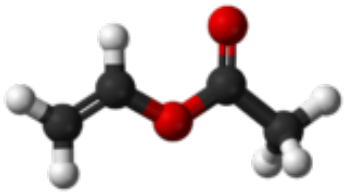
Process Specific Attacks



- There are more process specific attacks than there are generic ones
- Today we're going to cover as many of the generic ones as I have time

"The process constraints must be maintained …..

- The peak reactor temperature along the length of the tube must remain below 200◦C to prevent mechanical damage ….
- Liquid levels in the vaporizer, separator, absorber base, distillation column base, and decanter must operate within …
- Reactor inlet temperature and the hot side exit temperature form the heat exchanger must remain above 130◦C ….

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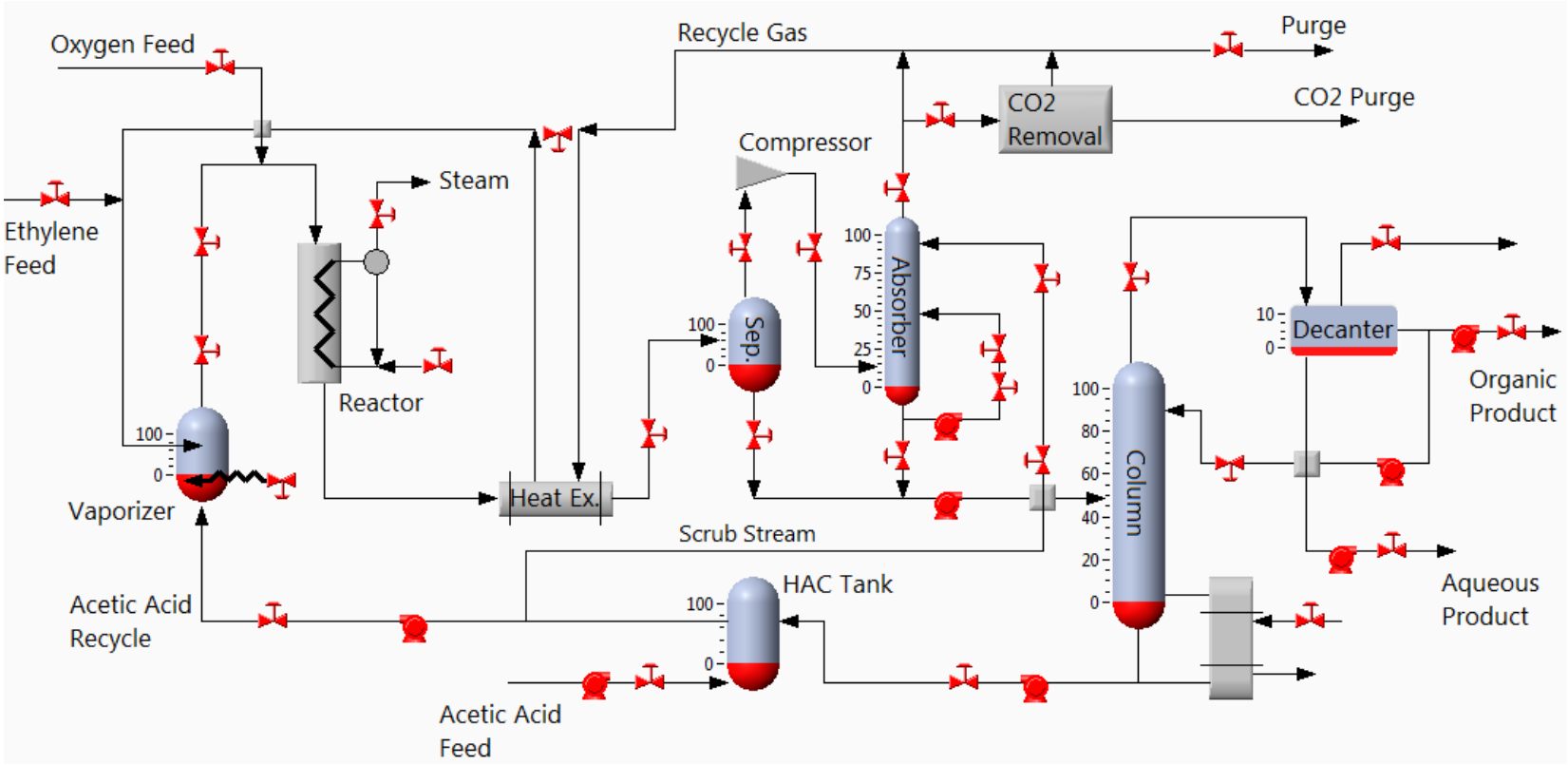
Oxygen Feed
Recycle Gas
Purge
CO2 Removal
CO2 Purge
Compressor
Steam
Ethylene Feed
Reactor
Absorber
Sep.
Decanter
Organic Product
Vaporizer
Heat Ex.
Column
Scrub Stream
HAC Tank
Acetic Acid Recycle
Aqueous Product
Acetic Acid Feed

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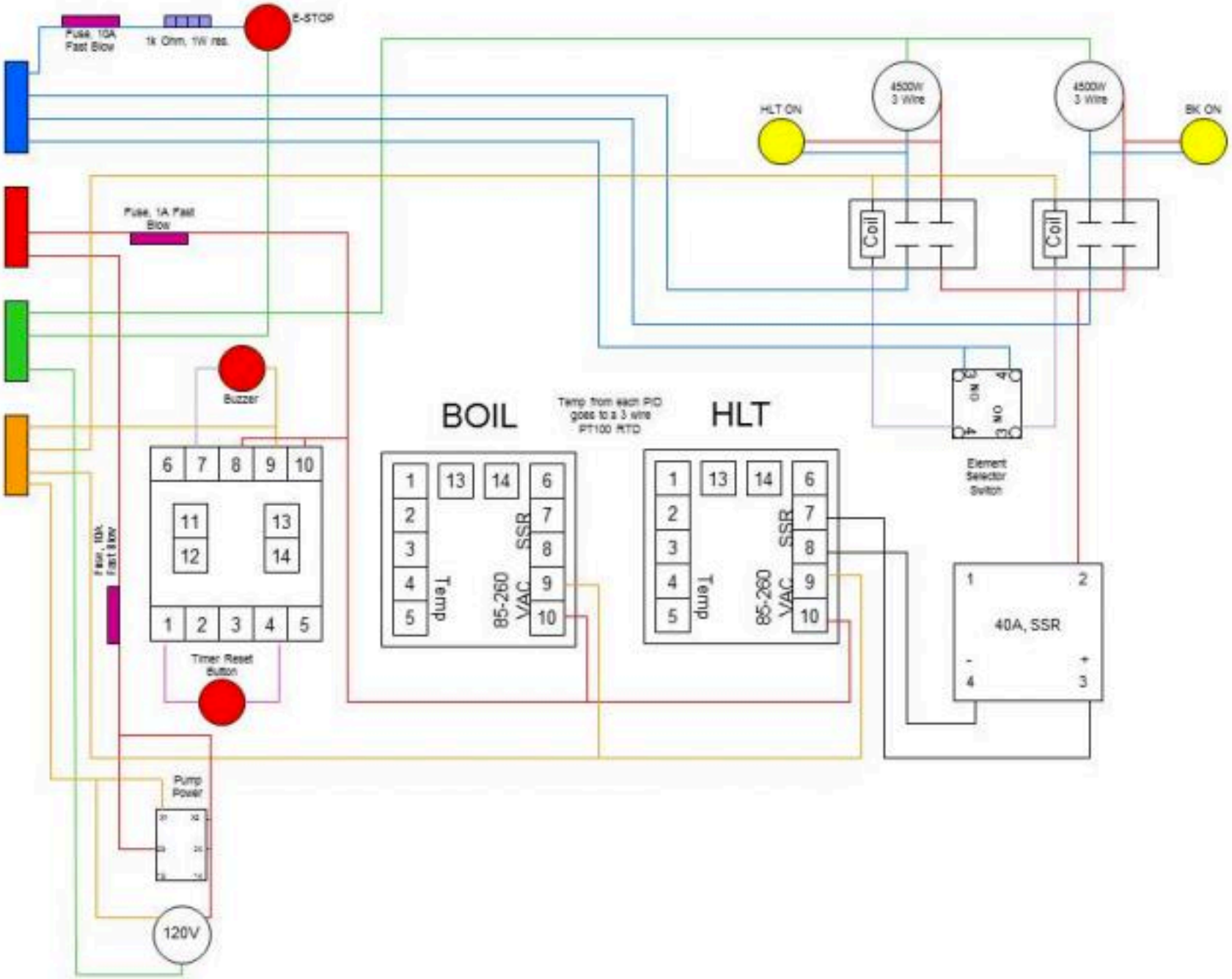
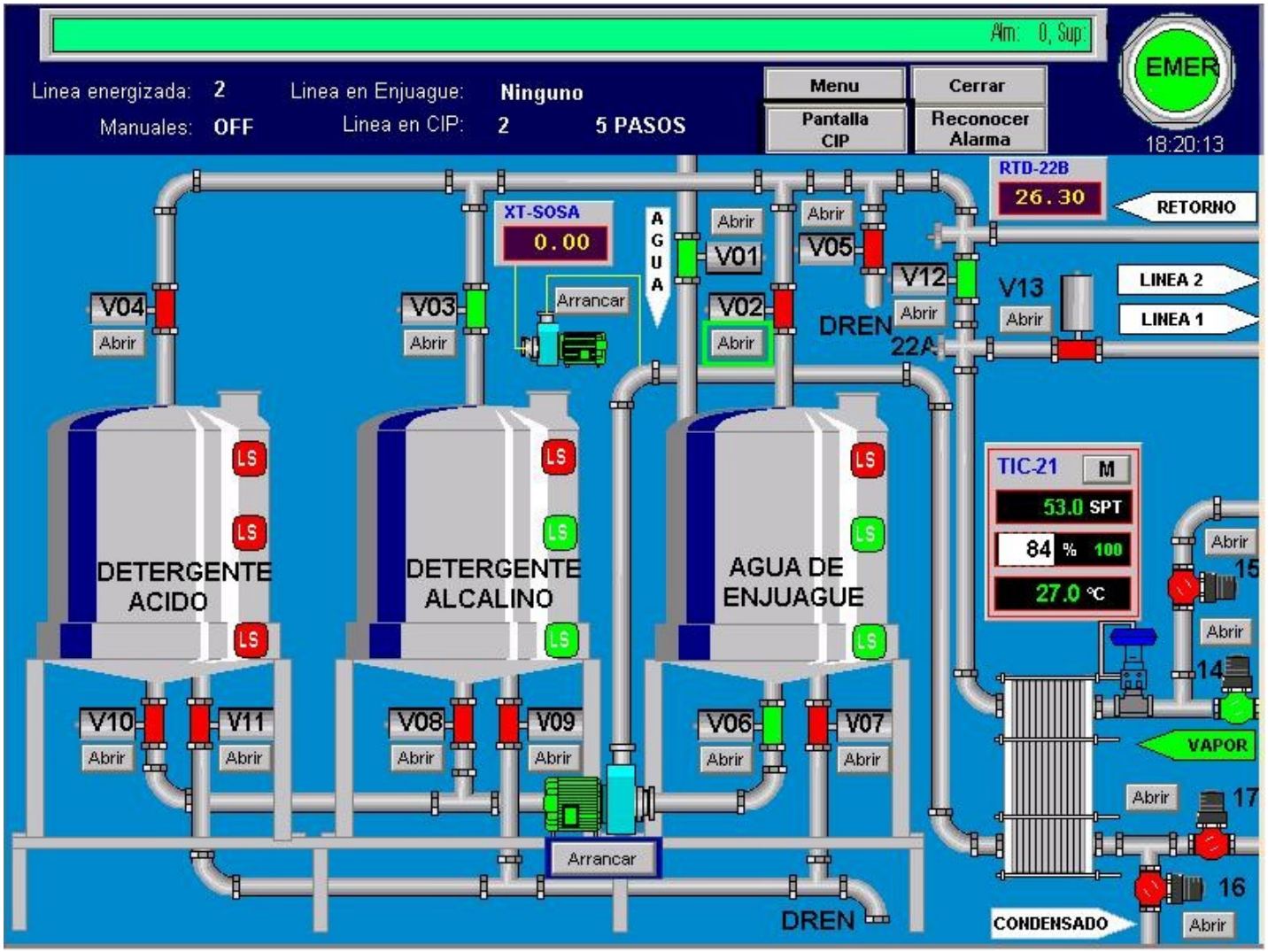

E-STOP
Fuse, 10A Fast Blow
1k Ohm, 1W res.
HLT ON
4500W 3 Wire
4500W 3 Wire
BK ON
Coil
Coil
Fuse, 1A Fast Blow
Buzzer
BOIL
Temp from each PID goes to a 3 wire PT100 RTD
HLT
Element Selector Switch
6 7 8 9 10
11 12 13 14
1 2 3 4 5
Timer Reset Button
Fuse, 10A Fast Blow
1 13 14 6 7 8 9 10
2 3 4 5
Temp
85-260 VAC
SSR
40A, SSR
1 2
- +
4 3
Pump Power
120V



Consider this…….

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Starting Demo

Screen shot of final HMI

When the reaction happens in that other place

Place Shifting Chemical Reactions

The chemical reaction is supposed to take place in here

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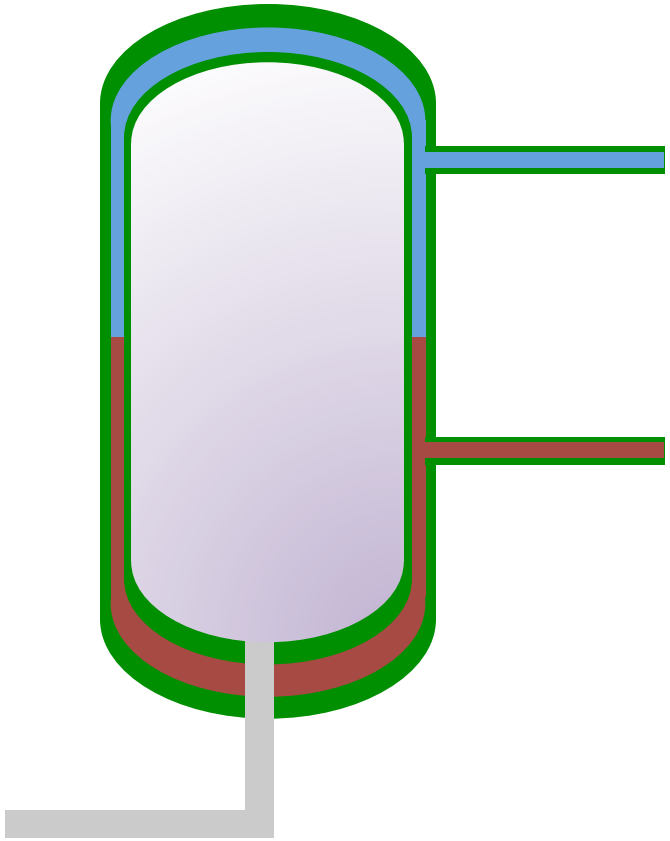

Pressure Relief Valve

Burst Disc

Catch Basin

ASME Rating

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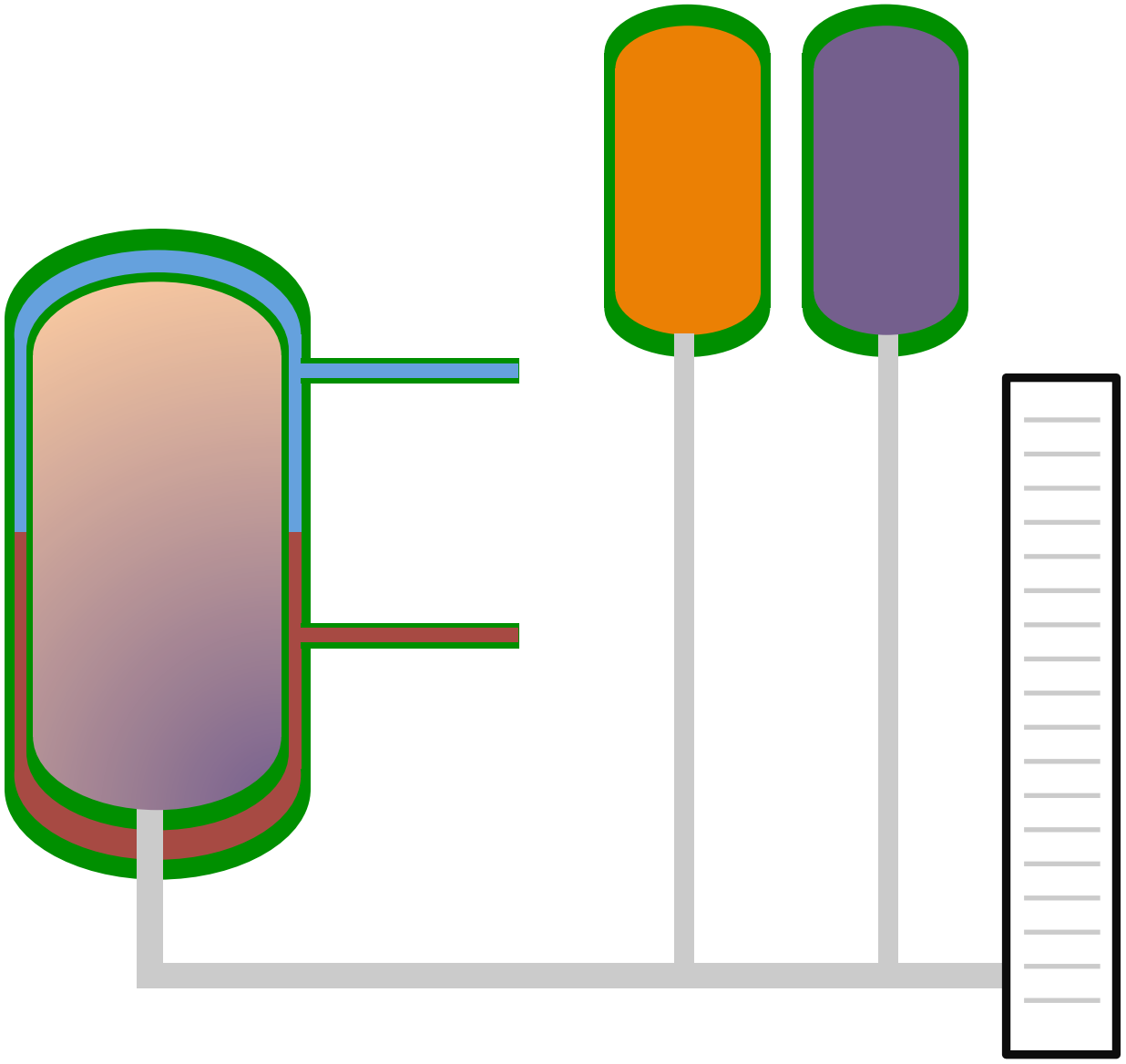

Where and when is almost complete under cyber control

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Place Shifting Chemical Reactions

- The problem is the heat
  - Most reactions have an activation temperature
  - The attacker has to find a way to heat the reactants in some other part of the plant

When water doesn’t stop suddenly

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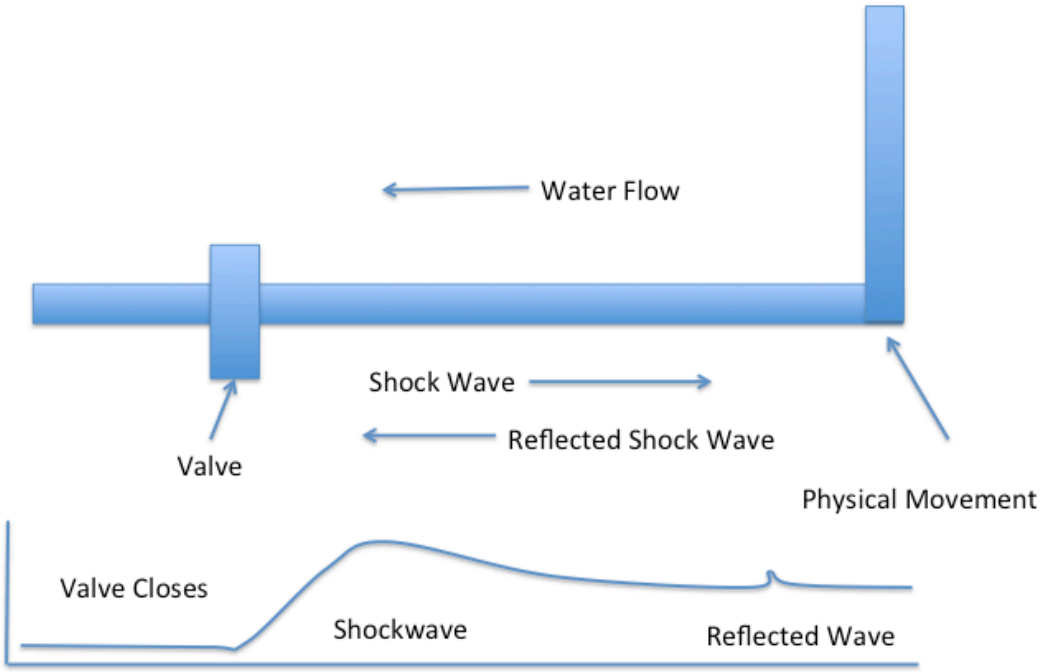
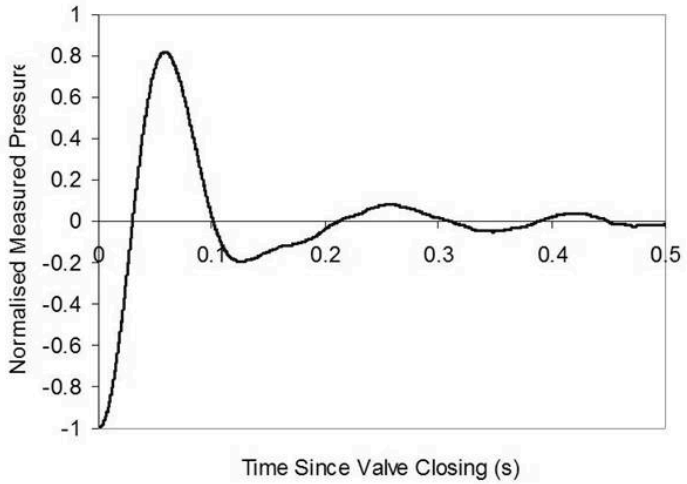
Pressure Transients

- Pressure transients are the basis for most attacks on piping infrastructure





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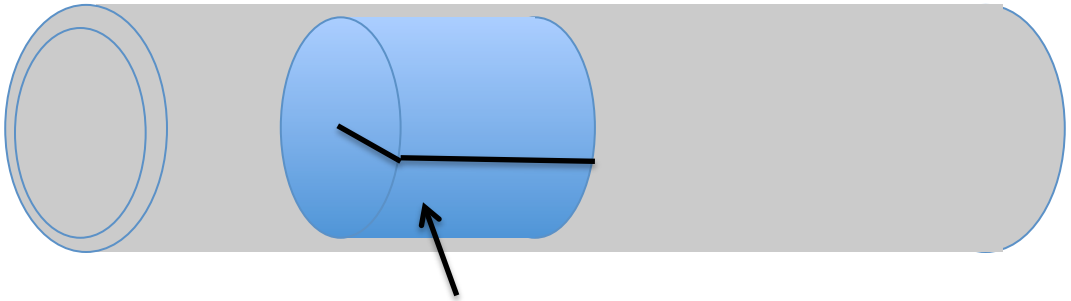
Water Hammer

- When liquid in a pipe suddenly comes to a stop, the energy has to go somewhere
- The energy involved increases exponentially with pipe size



$PI*r^{2}*h$

4 inch pipe 60 feet long = xxx pounds
12 inch pipe 60 feet long = xxx pounds

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Water Hammer

- Whether the hammer forms depends solely on the speed of the valve closing
- Large industrial valves often have electronic controls for valve speed and profile
- The speed of the transient is equal to the speed of sound in the liquid
  - Roughly the speed of a bullet for water

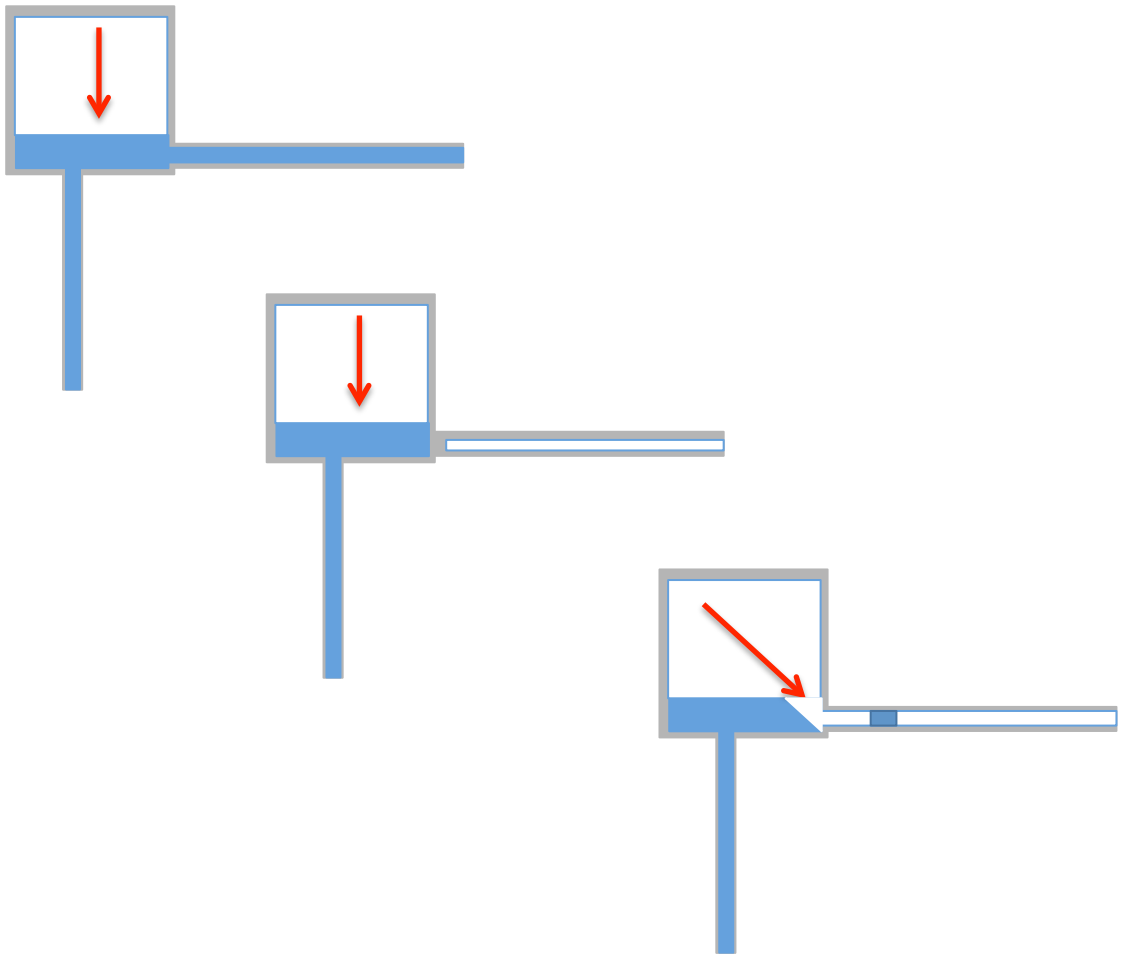
Column Separation

- If the stop is energetic enough, water can be turned into steam on the surface of the valve
- This steam pressure pushes back on the water
- An instant later, the steam turns back into water creating a vacuum
- This creates a huge pressure transient

Water Hammer Heating

- Water hammers produce heat
- All that energy has to go somewhere and most of it is turned into heat
- A hammer can be used to heat water
- Remember this during place-shifting chemical reactions

Level Boundary Slug



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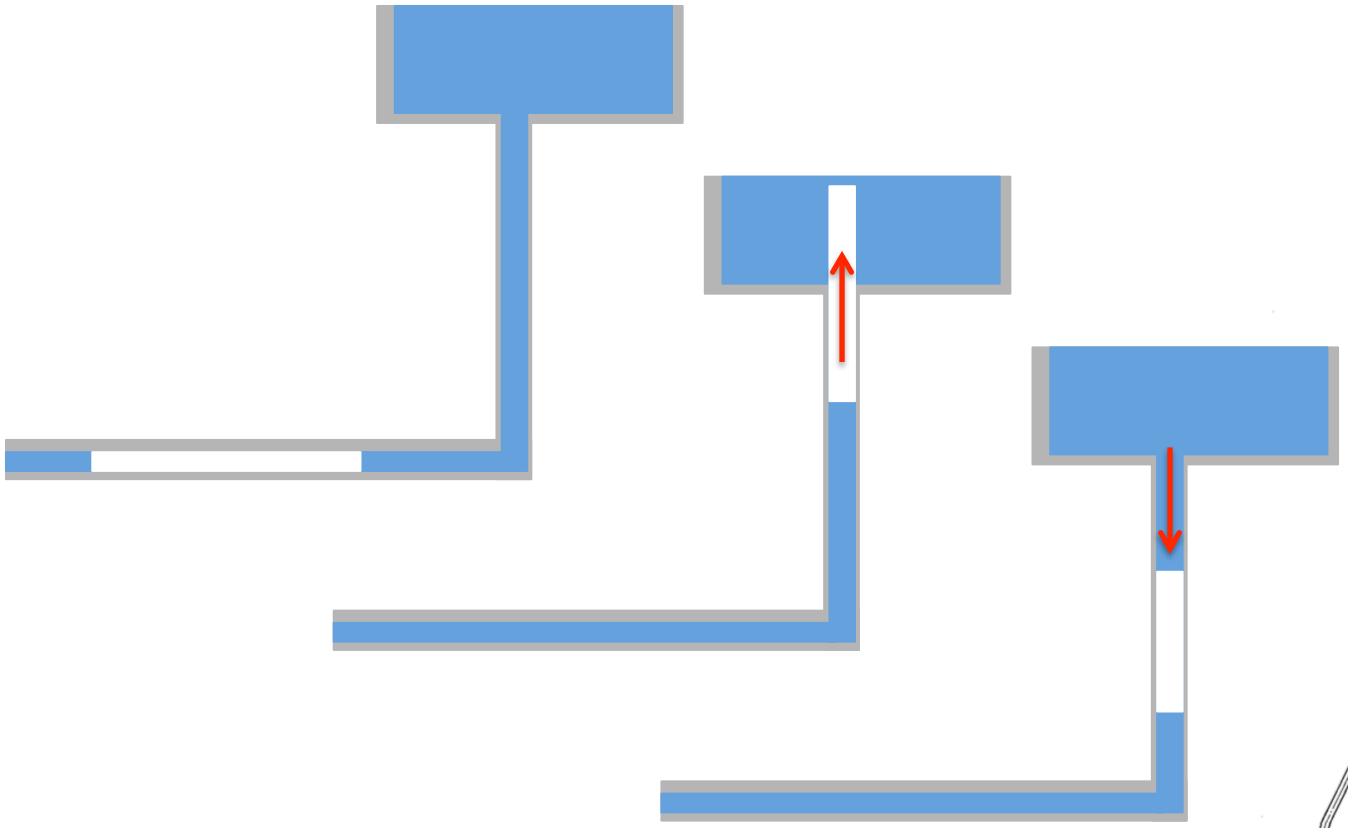
Gravity Hammer
Steam Void Collapse



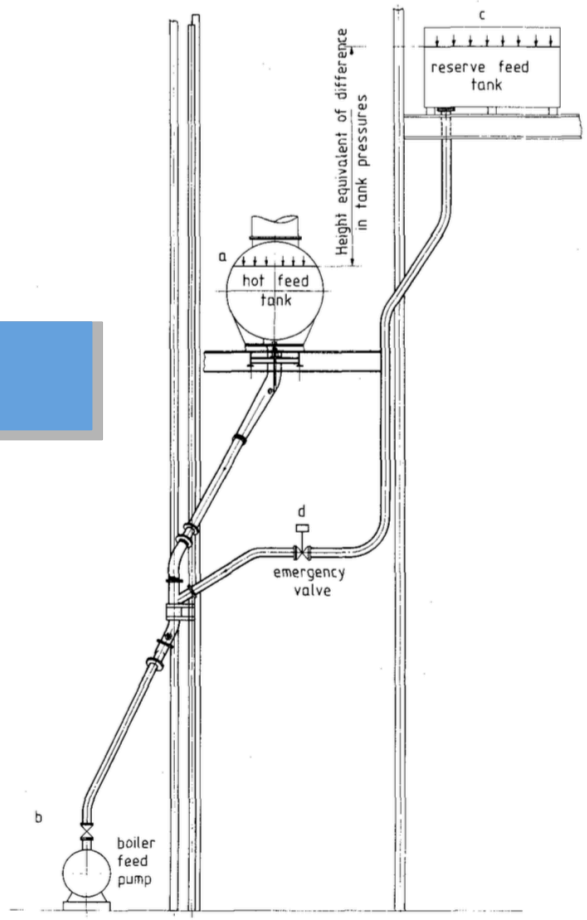


Fig. 3. Feed pump suction system at Nottingham Power Station

Proc Instn Mech Engrs Vol 194

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When gas and liquid move at different speeds

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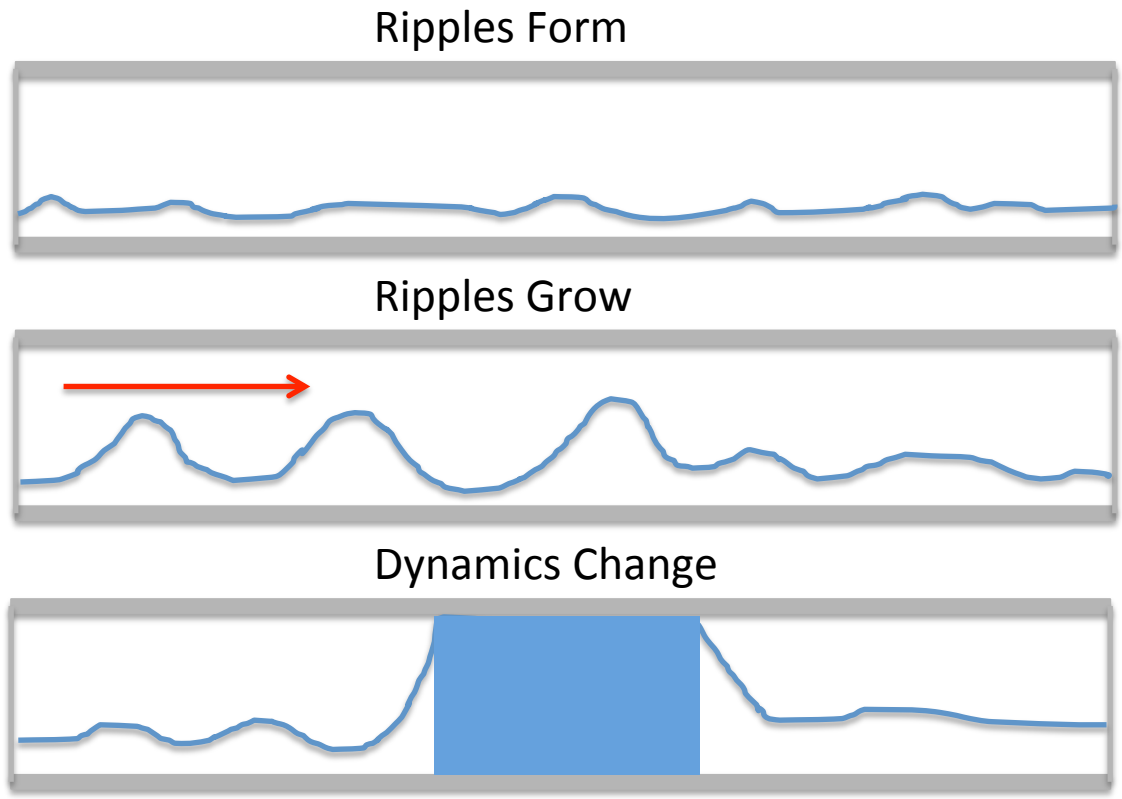
Biphase Slug



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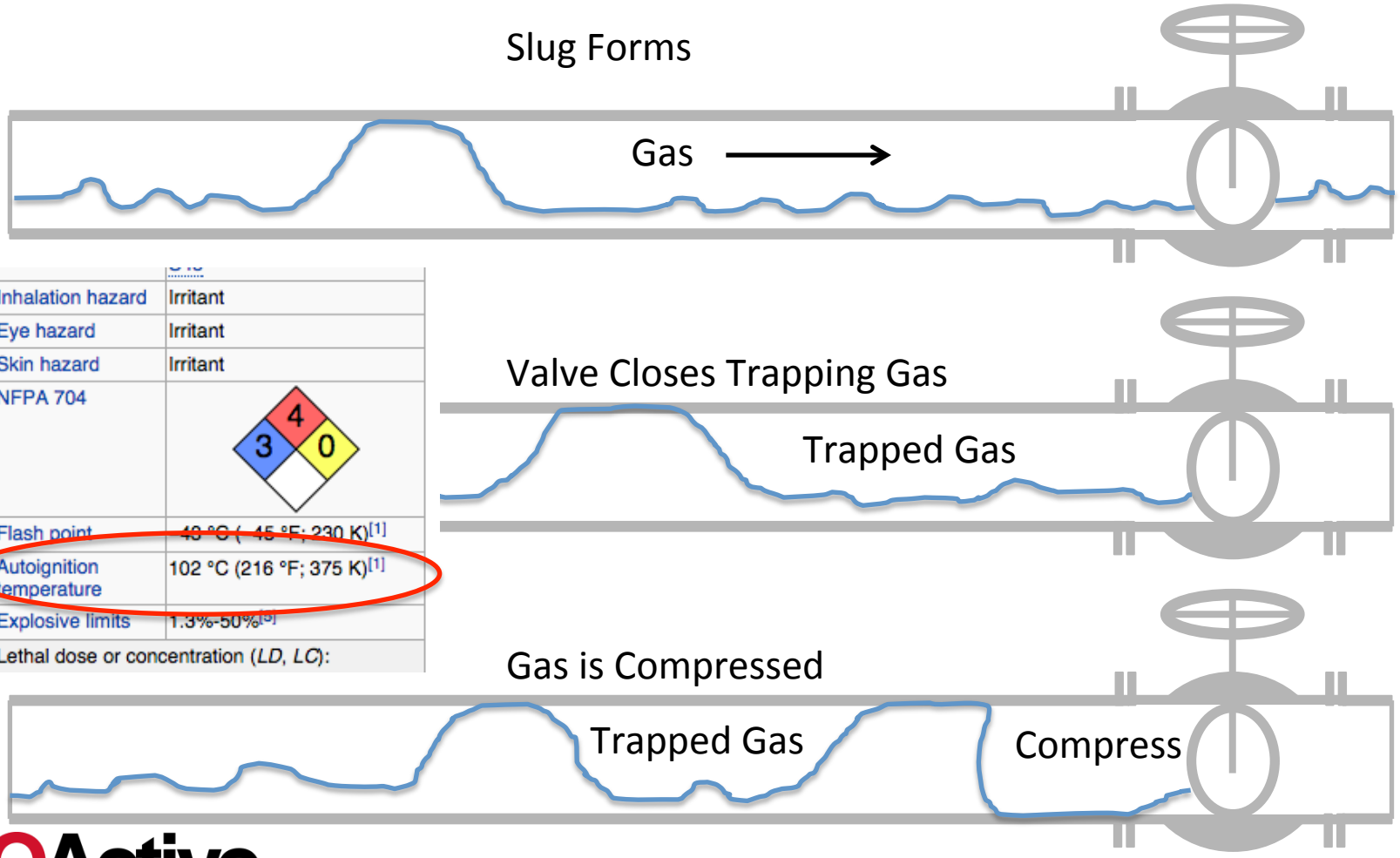
Biphase Slug with Piston Effect



Inhalation hazard	Irritant
Eye hazard	Irritant
Skin hazard	Irritant
NFPA 704	4 / 3 / 0
Flash point	43 °C (−45 °F; 230 K)[1]
Autoignition temperature	102 °C (216 °F; 375 K)[1]
Explosive limits	1.3%-50%[3]
Lethal dose or concentration (*LD*, *LC*):	

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When the pressure drops below zero

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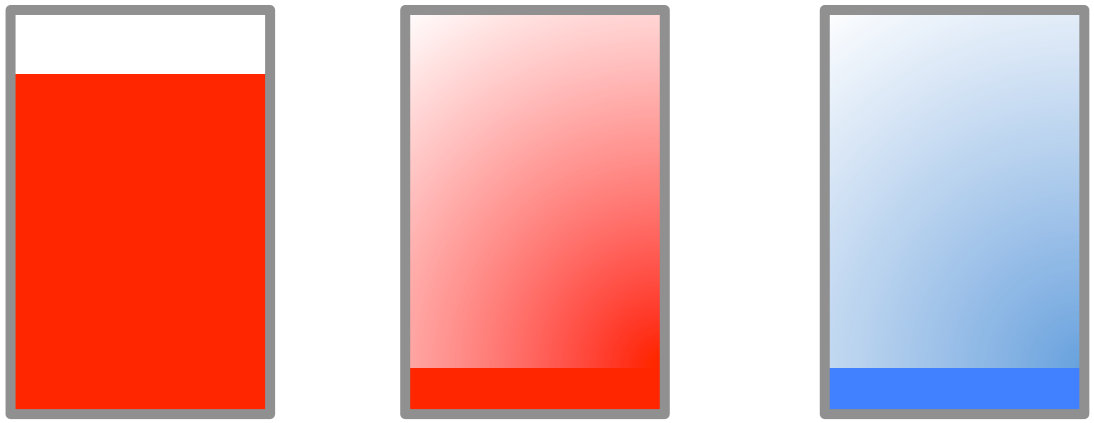
Vacuum Collapse

- Lots of structures can take very high positive pressures but can only take small negative pressures
- As we replace metal pipes with new types of plastic piping, this is becoming more common

-14.7 PSI = True Vacuum (on earth at least)

Steam Collapse



Ideal Gas Laws

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

1. Fill a space with hot stuff or hot gas
2. Remove the hot liquid
3. Let it cool down

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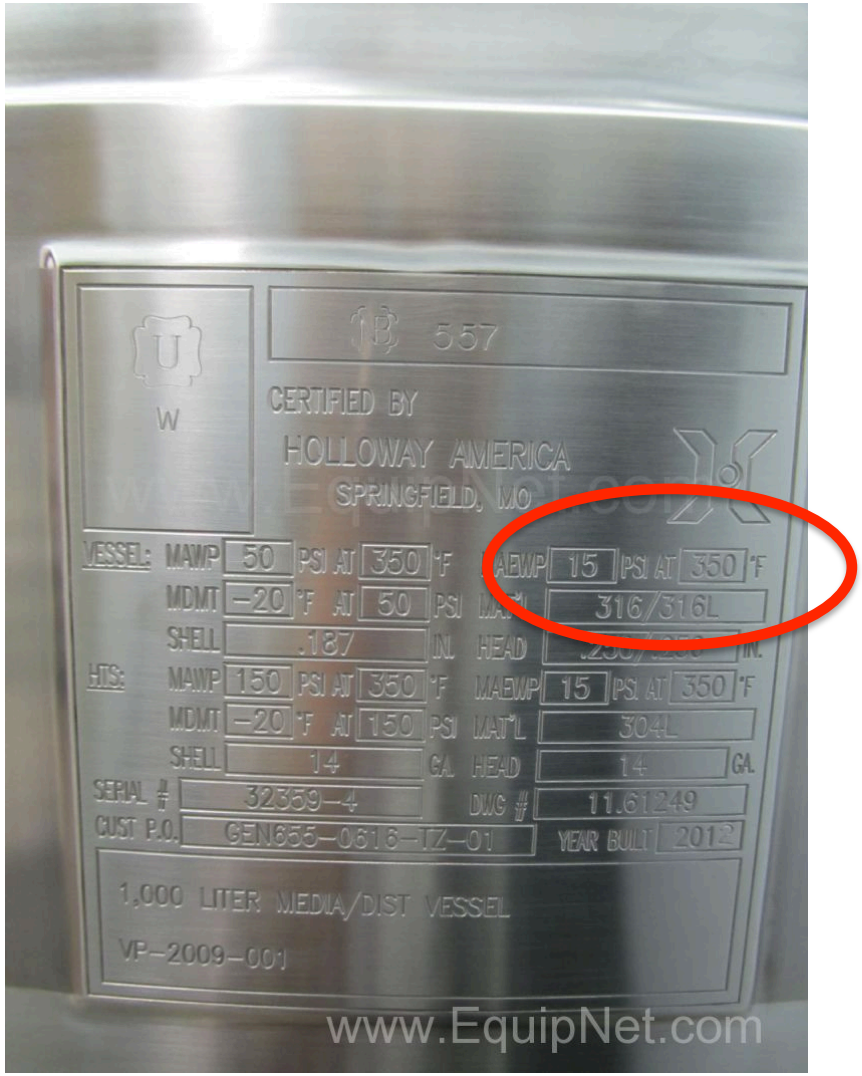
Steam Collapse



- Most pressure vessels can take a true vacuum
- The interesting part comes from all the external stuff we bolt on to the pressure vessel

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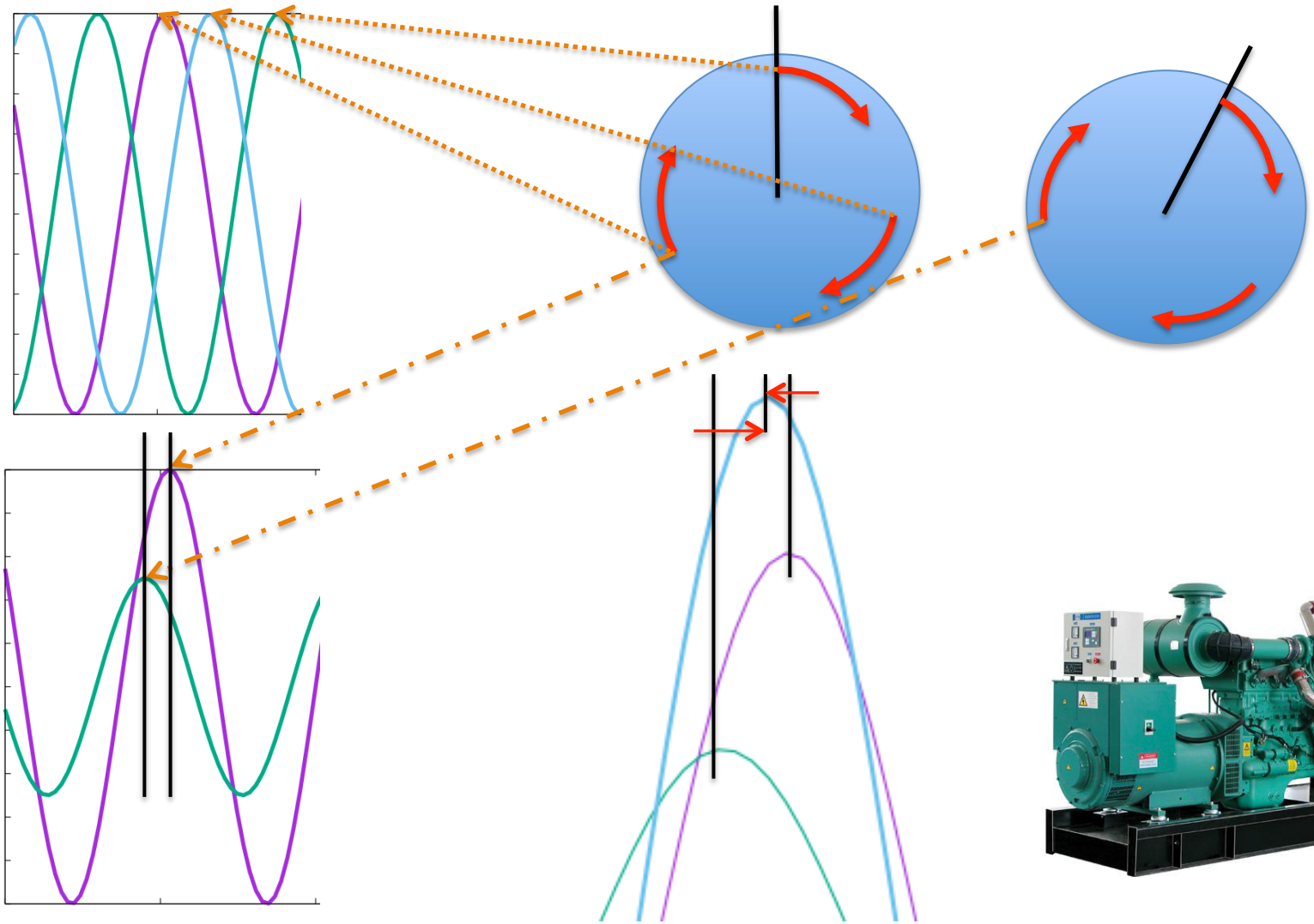
When you bring something in out of phase

Three-Phase Attacks



Newtonian Mechanics

- Speed of light in copper
- Rubber band effect
- It's all about the torque
- Big guys get to beat up little guys
- Far away guys are the same a little guys

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Combining

- Power outages caused the rupture of a water line

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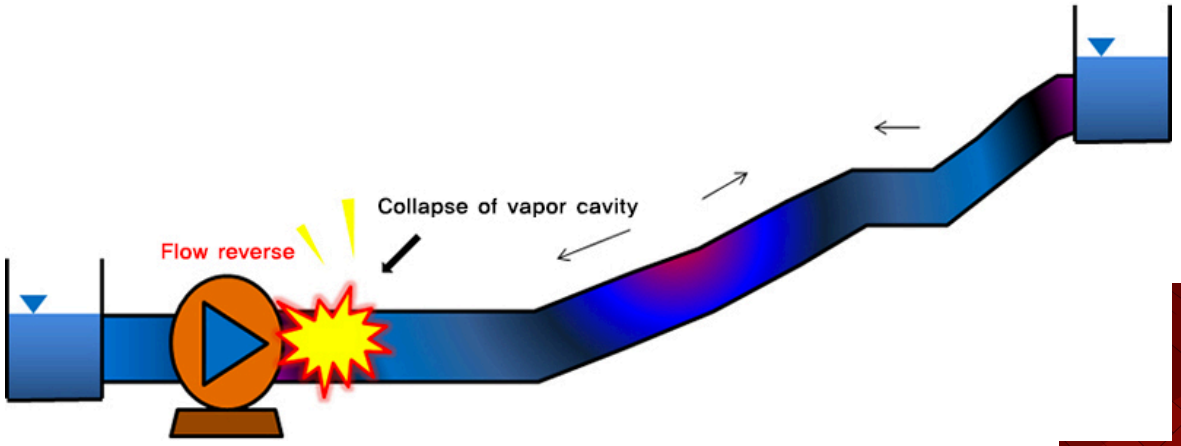
Multi-Adaptive

- Last non-constant derivative of a polynomial



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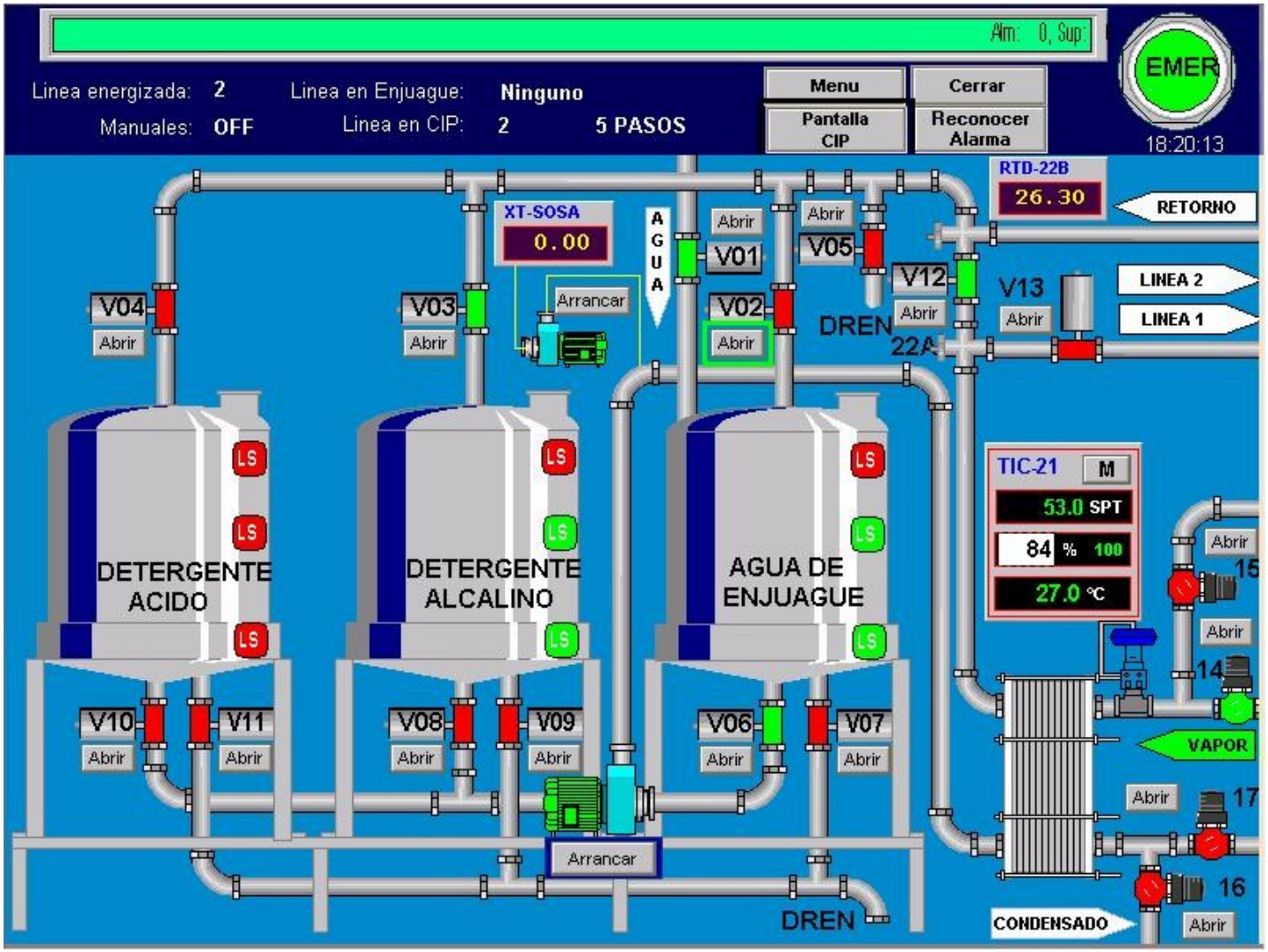

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Questions

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