

Gravity-Independent Laundry System

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Problem

- Laundry in Space
 - Traditional laundry methods inapplicable
 - High expense
 - Volume taken up by clothing
 - Hygiene and comfort
 - Removal of Lunar Dust

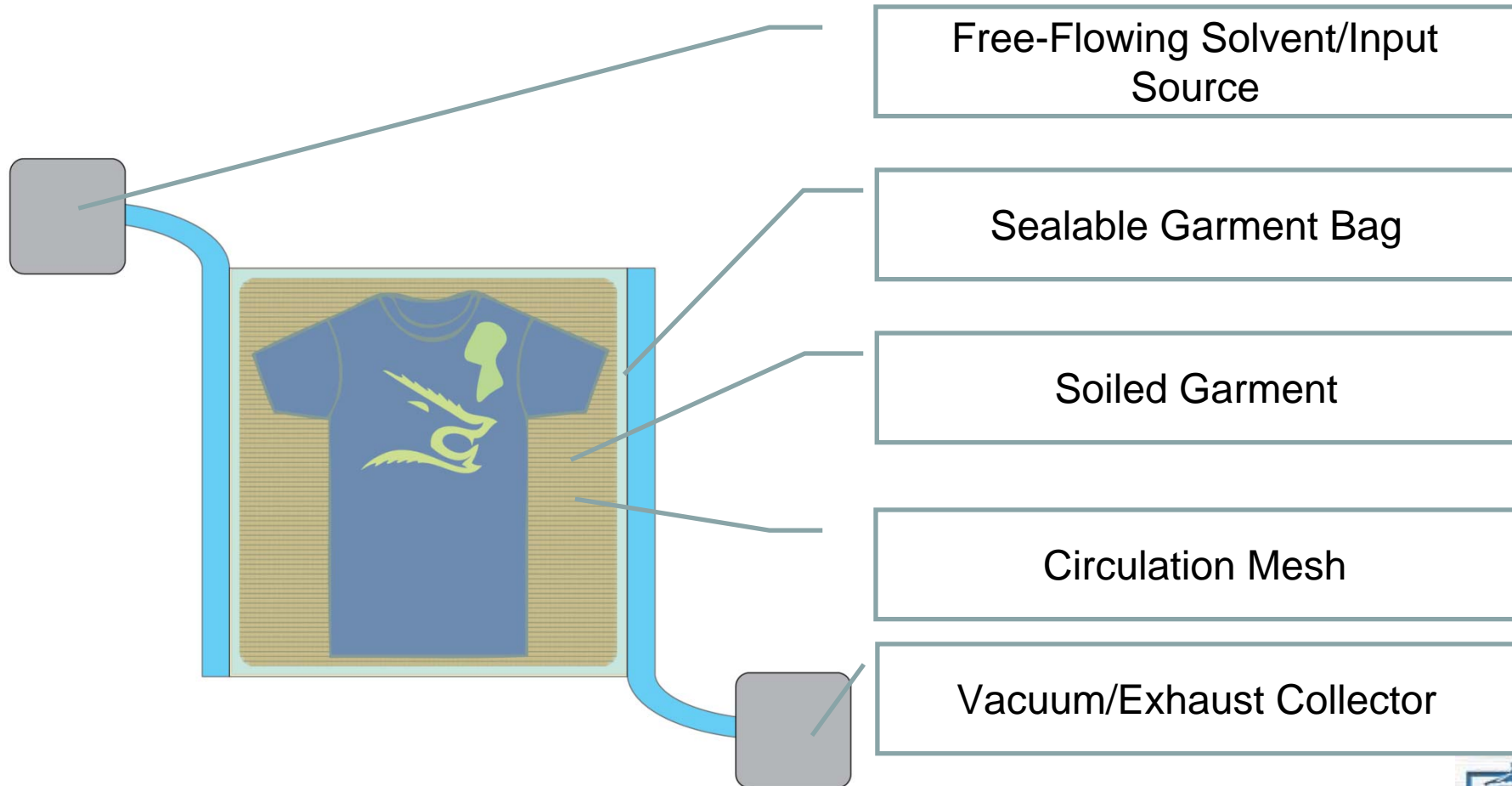


Objective & Design Goals

- **Proposal**
 - Design a process to wash, disinfect, and dry lightly soiled clothing in the micro-gravitational environment of a space station and future lunar base
- **Desired Attributes**
 - Efficient as regards to resources
 - Able to filter and reuse solvent, H₂O, etc.
 - Use minimal power to operate
 - Consume little actual space
 - Ease to operate
 - Minimal maintenance
 - Lightweight
 - Safe
 - Closed system in accordance to NASA policy
 - Safe to the sterile environment of a space station/craft
 - Implementation of non-toxic materials



Original Vacuum Bag Design



Previous Work

- Generations I-V
 - Generation I
 - Base for all proceeding generations
 - Results
 - Closed system essential
 - Materials needed improvement
 - Generation II
 - Observe water retention of system
 - Results
 - Plastic fittings were problematic
 - Needed a way in which to measure pressure



Previous Work Cont'd

- Generation III
 - Improve on leakage of system
 - Focus on water extraction
- Results
 - Cleaning the garment was not a priority at this point
 - Instead drying should be the main focus

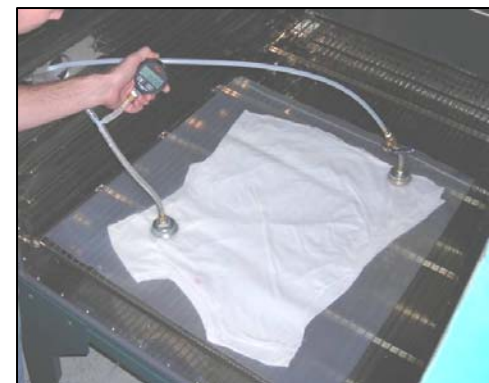


Generation IV

- Generation IV
 - Series of smaller trials each with different configurations
 - Eliminated the intake of water
 - Compared configurations by their efficiencies
- Results
 - Addition of heat improved efficiency
 - Air flow improved efficiency
 - Pinhole leaks proved problematic



Config. 1, 3 & 4



Config. 2, 5



Generation V

- Generation V
 - Series of smaller trials each with different configurations
 - Complete mesh coverage
 - Compared configurations by their efficiencies
- Results
 - Using single and dual layer mesh configurations proved promising
 - It is possible that the mesh acted as an channel for the water to escape
 - Further testing with mesh configurations is needed



Current Work - Generation VI

- Goal
 - Test shirt in rigid apparatus (dessicator)
- Procedure:
 - Test if water can be boiled out and extracted by vacuum alone.
 - Shirt was wrapped with mesh to facilitate extraction

Initial (Dry Shirt) Mass (g)	Damp Shirt Mass (g)	After 30 min. Mass (g)	Efficiency (%)
Baseline 1 – Adult Cotton T-shirt			
128	313	301	6.4
Baseline 2 – Cotton Blend Child’s T-shirt			
79	200	191	7
Vacuum Pressure >28 in Hg for both tests			



Baseline Test Discussion

- Small amounts of water can be extracted via desiccator
- Not as effective at removing water as vacuum bags, using same vacuum pump.
- Vacuum caused shirt/water temperature to decrease, reducing efficiency.



Water Removal Comparison

Generation IV	Efficiency (%)
RT/ no air	7.56
Hot / no air	25.61
RT/ input air	15.15
RT / input hot air	15.03
Hot /input hot air	39.16
Generation V	Efficiency (%)
1 Mesh, RT	26.97
2 Mesh, RT	32.60
Generation VI	Efficiency (%)
Baseline 1	6.4
Baseline 2	7

RT=Room Temp



Solvent Research

Positive Azeotropes

- A mixture of two or more liquids in such a ratio that the boiling point of an azeotrope is less than the boiling points of any of its constituents.

- Typically, the only common azeotropes that might work are light hydrocarbons such as acetone and isopropyl alcohol. All such substances are banned from the ISS. Currently, this approach has been shelved.

Liquid Carbon Dioxide

- Currently, liquid Carbon Dioxide has slowly transitioned into dry cleaning processes.

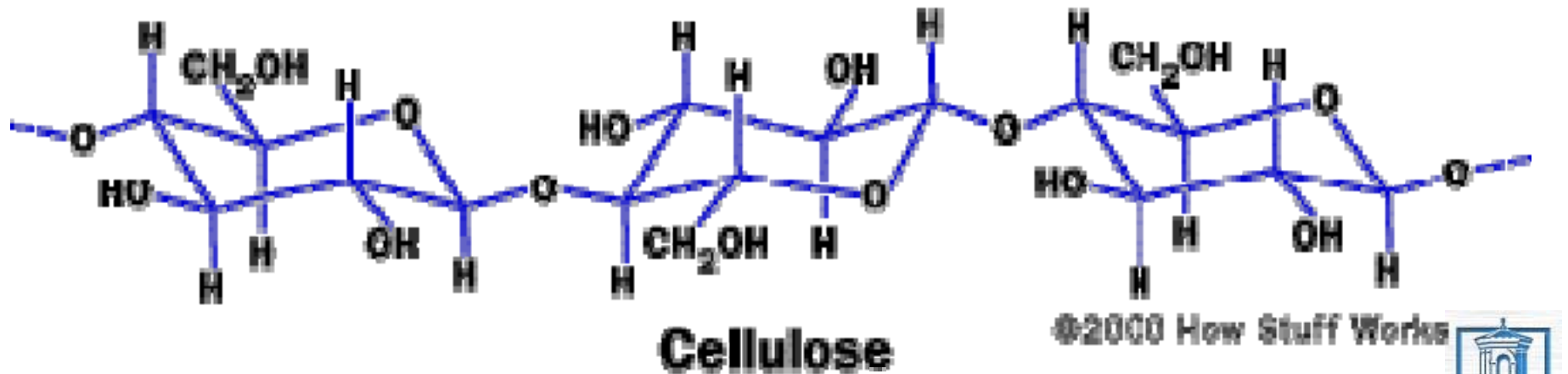
- Because liquid Carbon Dioxide solely is not a good surfactant, Carbon dioxide-compatible surfactants are being researched to add into the cleaning system.



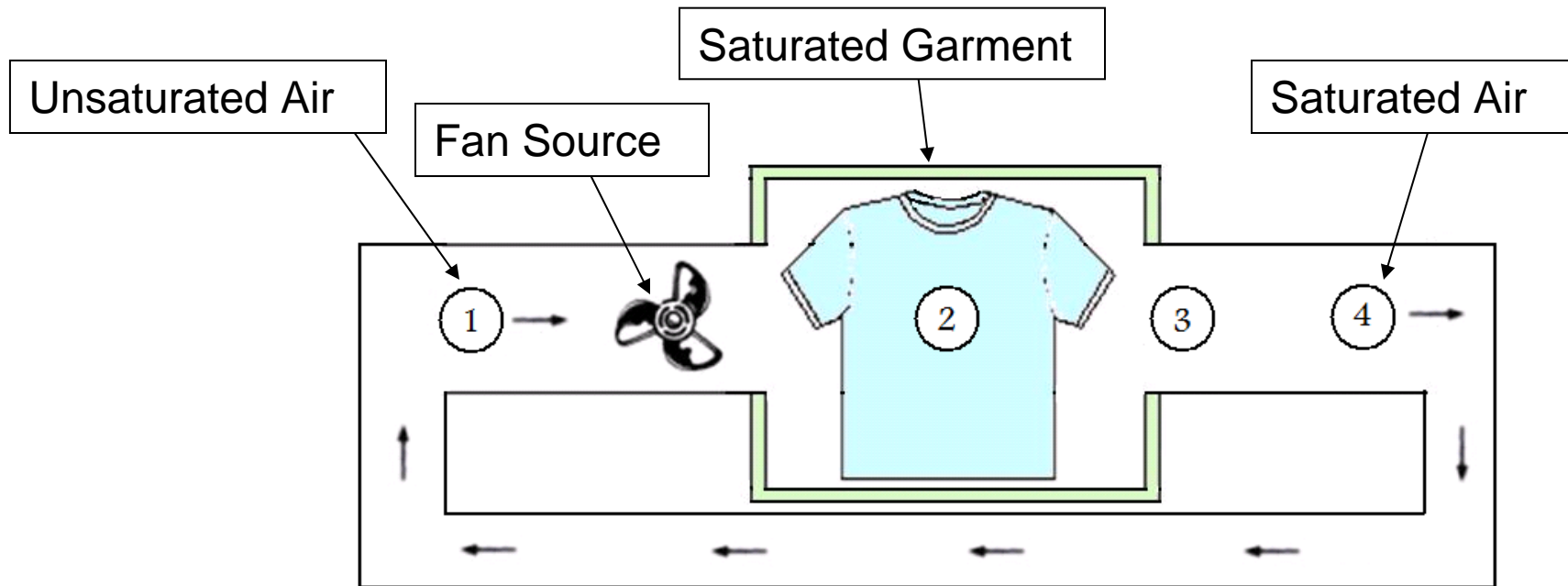
Fabric Research

Cotton

- Worst case scenario
- Molecular structure has tendency to attract water
- Can hold up to 27 times its weight in water



Adiabatic Conceptual Design



Point 1

- Temperature is elevated and humidity lowered

Point 2

- Dry air is blown across garment

Point 3

- Energy is radiated to space

Point 4

- Dew point is reached, water condensates and is collected



Conclusion/Future Work

Conclusions

- Water extraction via desiccator not as effective as vacuum bag apparatus
- Compression of garment in vacuum more effective in extracting solvent than mere exposure to vacuum

Future Work

- Continuing research into different solvents/surfactants
- Adiabatic Saturation Process
- Semi rigid structure may be necessary to remove lunar dust



Acknowledgements

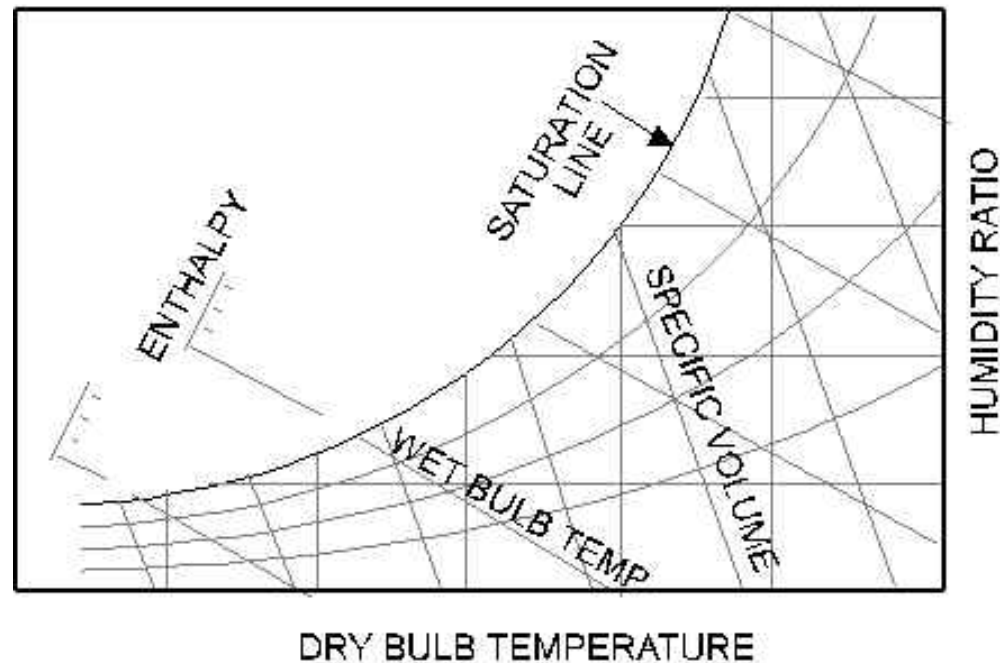
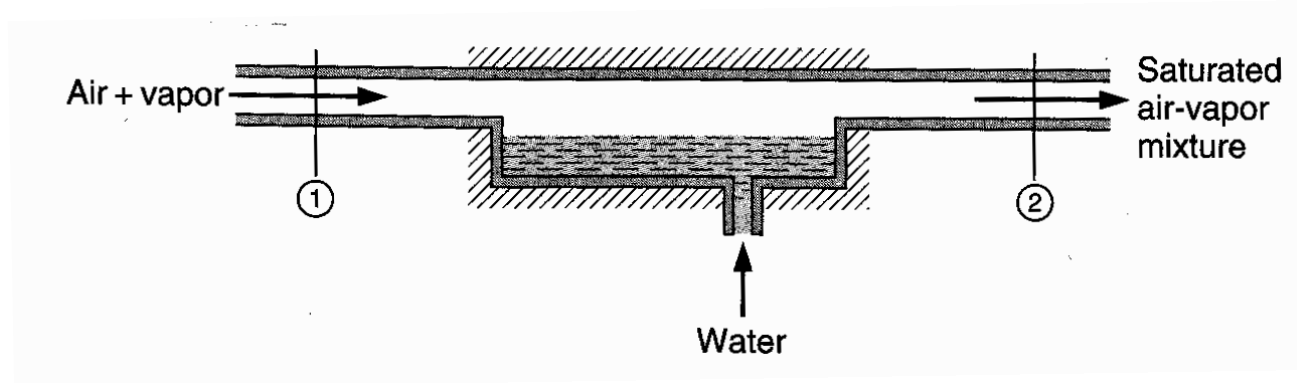
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Questions/Discussion



Adiabatic Saturation Process



Adiabatic Process

