

# Solar Thermal Adsorptive Refrigeration: Bihar, India

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## Abstract

A Solar Thermal Adsorptive Refrigeration (STAR) system was designed, tested, and constructed in Patna, Bihar in northern India. The non-government organization partner, Solar Alternatives and Associated Programmes (SAAP) provided the workshop, tools and local expertise. Ethanol and carbon are the working adsorption pair in the STAR system. The refrigeration effect occurs when the system is under vacuum, -30 in Hg for optimal performance; therefore, sealing methods were thoroughly researched and tested to ensure vacuum proof connections. The best performing sealing method was inserting non-threaded pressure gauges and valves into heated and remolded CPVC piping. Asian Paints knife putty, a locally sourced material, was the external sealant. A test system held a vacuum of -27 in Hg for four weeks until it was disassembled to be used in the final design.



Figure 1: ETHOS Patna Team

## Introduction

- 33-61% of vaccines spoil in India due to refrigeration issues, according to a UNICEF study
- Rural hospitals and clinics depend on unreliable, limited, or non-existent electricity from the grid
- Adopt SAAP's commitment to environmental protection and empowerment of the downtrodden through solar technologies to address vaccine spoilage

### STAR Project Objective:

- Develop alternative refrigeration technology driven by solar thermal energy and ethanol adsorption onto the surface of activated carbon
- Repeatedly achieve refrigeration temperatures between 2°C and 8°C



Figure 2: Solar Technologies in Patna

## Project Description

- Assembled prototype copy from University of Dayton and demonstrate refrigeration effect to prove the concept to SAAP workers in Patna
- Analyzed and evaluated 2012-2014 ETHOS design
- Redesigned and simplified ethanol-carbon STAR system without using corrosion prone metals or threaded connections
- Use locally available and affordable materials
- Built and tested 14 sealing methods



Figure 3: Construction of Final Design

- Successfully held vacuum for 4 weeks using a heated CPVC, non-threaded connection method with knife putty as an external sealant
- Built model sized solar thermal adsorption refrigerator using tested sealing method

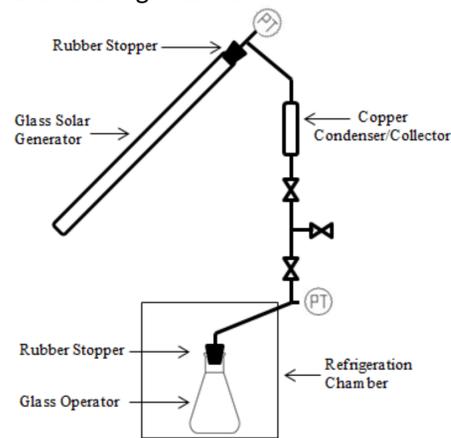


Figure 4: Final Design Schematic

### Side Projects:

- Distilled recovered ethanol to purify for recycled use
- Removed patina and copper oxide corrosion using available resources

## Results & Discussion

- Previous system exposed to the atmosphere and humid air was deteriorated and not functional
- Multiple pipe diameters and threaded connections made the system inefficient due to considerable pressure drop across its length
- The ambient temperature in Patna in June is 33°C which affects the pressure at which ethanol flashes
- A pressure less than -26 in Hg must be obtained for ethanol to flash and cool to any extent in Patna

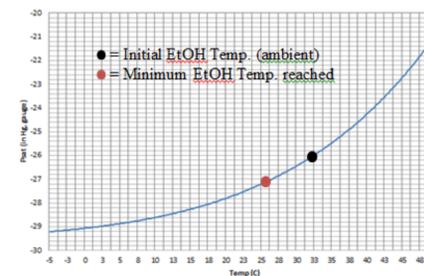


Figure 5: Prototype Data with respect to Patna-adjusted Antoine's PT Relationship

- The updated 2016 design reduced the number of connections from 47 to 21, eliminating multiple possible leaking sites
- Knife putty, heated CPVC, non-threaded connection was proven to be successful and was implemented in the final design
- GI pipes of generator were substituted by a glass pipe previously used in solar water heaters to avoid corrosion
- Aluminum tape and grease were used to prevent the knife putty from drying, cracking, and leaking



Figure 6&7: Final Updated System

- Final design held vacuum without increasing for 36 hours. A buckled CPVC to valve connection is the most probable cause of leaking

## Recommendations

- Threads were the most significant cause of pressure increase in the system. Continue and develop the idea of a non-threaded system
- Troubleshoot the updated design and look for possible sources of leaking
- Improve the assembly technique of the knife putty, heated CPVC, non-threaded sealing method to avoid buckling in the pipe
- Redesign the glass operator and reconsider the material selection with regards to heat transfer properties
- Research and test for different valve options
- Consider an alternative working pair that does not require ethanol. Alcohol is banned in the State of Bihar since May of 2016

### Cultural Recommendations:

- Do not be afraid to try new things and travel
- Make friends that make it feel like home
- Challenge yourself with spicy food
- Be grateful and enjoy your experience!



Figure 8: Our Indian Family

## Acknowledgements

The success of this project, the knowledge acquired throughout the immersion, and our personal growth could have not been possible without the hard work, support, and contribution of the following people:

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- SAAP
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