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2016 Purdue Conferences
Compressor Engineering
Refrigeration and Air Conditioning
High Performance Buildings

THEROELECTRIC MULTI-UTILITY WATER HEATER CUM AIR-CONDITIONER

TE_MUWHcAC

Paper # 2623

14/07/2016 15:30 to 17:30

214 C&D, Stewart Center, Purdue University

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OUTLINE OF PRESENTATION

22623, 14/07/2016 15:30 to 17:30 Rm# 214 C&D

Thermoelectric Multi-Utility Water Heater cum Air-Conditioner

- ***Conventional Residential Water Heaters***
  - » Electric resistance, LPG fired, solar based, heat pump assisted
- ***Thermoelectric Coolers***
  - » Working principle and heat transfer
- ***Performance Curves of TES-1 03139***
  - » dt_{hc}, Q_c, I, V_{dc}, COP_c
- ***Test Setup of TE_MUWHcAC***
  - » Assembly of heat source, sink, chips, thermal resistances
- ***Simulation Results Presented for***
  - » Effect of TE chips pitch on fin efficiency
  - » Temperature variation on cold and hot side of TE chips
  - » Variation of temperature in conditioned space
- ***Conclusions***

CONVENTIONAL WATER HEATERS

Advantages and Limitations

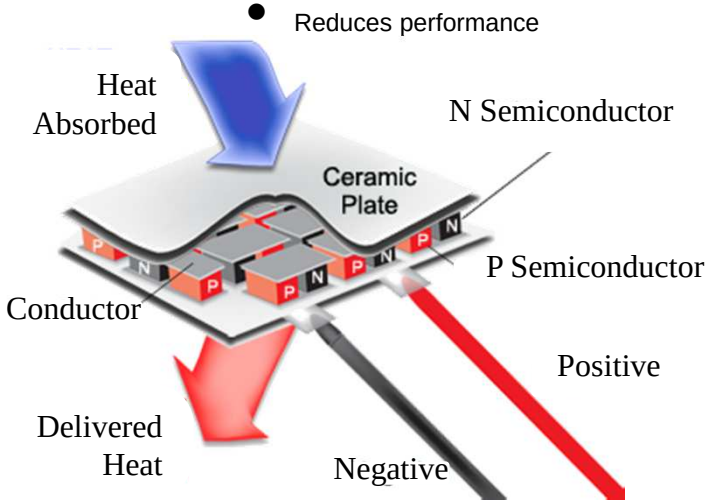
- ***Electric Resistance Water Heaters***
  - » Most common
    - – Simple, compact, no moving part, reliable
    - – 35 L water heated from 25 to 50^{o}C using kWh of electricity
- ***LPG Water Heaters***
  - » Popular in market
  - » Limitation due to space of gas storage
  - » High cost for non-subsidized gas
- ***Solar Water Heaters***
  - » Storage type solar operated water heater
    - – Space requirement is high
- ***Heat Pump Assisted Water Heaters***
  - » Thermoelectric Coolers are small capacity heat pump
  - » Refrigerant based systems are not serving as water heating in residences

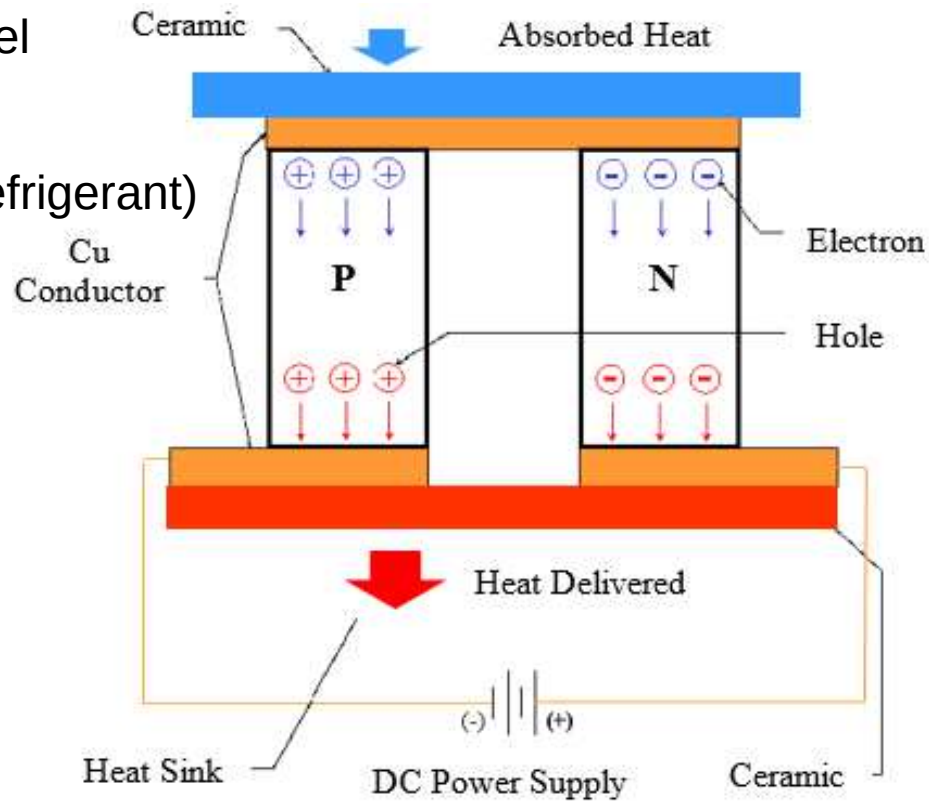
THERMOELECTRIC HEATER

Diagram from www.tellurex.com and modified further

Working Principle

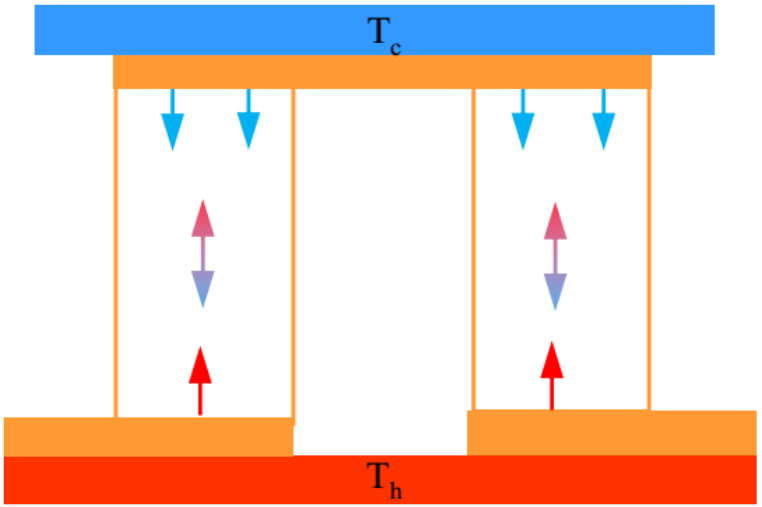
- ***Combination of P and N Semiconductor***
  - » Electrically series and thermally parallel
- ***Medium of Heat Transfer***
  - » Flow of free electrons and holes (as refrigerant)
    - – Due to direct current
- ***High Heat Flux***
  - » Requires heat sink on hot side
    - – About 25 kW/m^2, dt_{hc} increases
      - Reduces performance





THERMOELECTRIC HEATER

Heat Transfer



(Cheng and Lin, 2005)

Heat Flow Equations

$$Q_{Peltier} = \propto.I.T_c$$

$$Q_{Joule} = \pm \frac{I^2}{2A}(\rho.L + 2r_c)$$

$$Q_{Fourier} = - \frac{k.A.(T_h - T_c)}{L}$$

$$Q_c = N\left[\propto.I.T_c - \frac{I^2}{2A}(\rho.L + 2r_c) - \frac{k.A.(T_h - T_c)}{L}\right]$$

$$Q_h = N\left[\propto.I.T_h + \frac{I^2}{2A}(\rho.L + 2r_c) - \frac{k.A.(T_h - T_c)}{L}\right]$$

$$COP_c = \frac{Q_c}{Q_h - Q_c} = \frac{T_c - \frac{I}{2 \propto . A}(\rho . L + 2 r_c) - \frac{k . A . (T_h - T_c)}{\propto . I . L}}{T_h - T_c}$$

- ***Cooling Capacity***
  - » Increases with current flow
    - – Peltier cooling effect
- ***Heat Duty***
  - » Sum of Q_c and $P_{e.i}$
- ***Coefficient of Performance***
  - » Decreases with increase in dt_{hc}

PERFORMANCE CURVES TES1-03139

www.thermionic.com & 15 mm × 15 mm × 3.2 mm, 4.2 g/chip (including wires)

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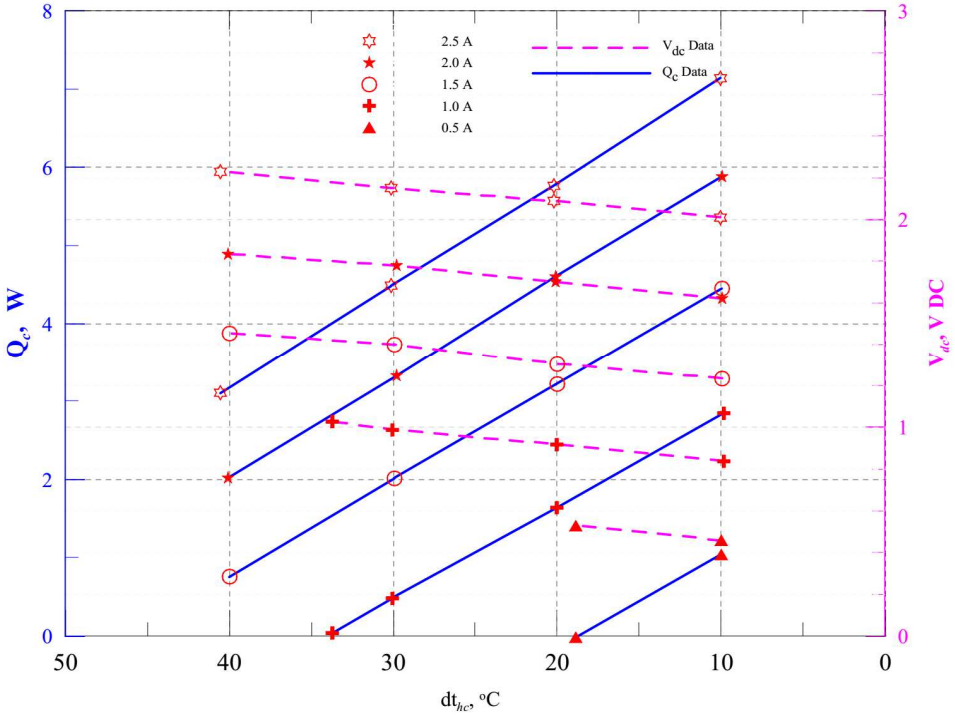
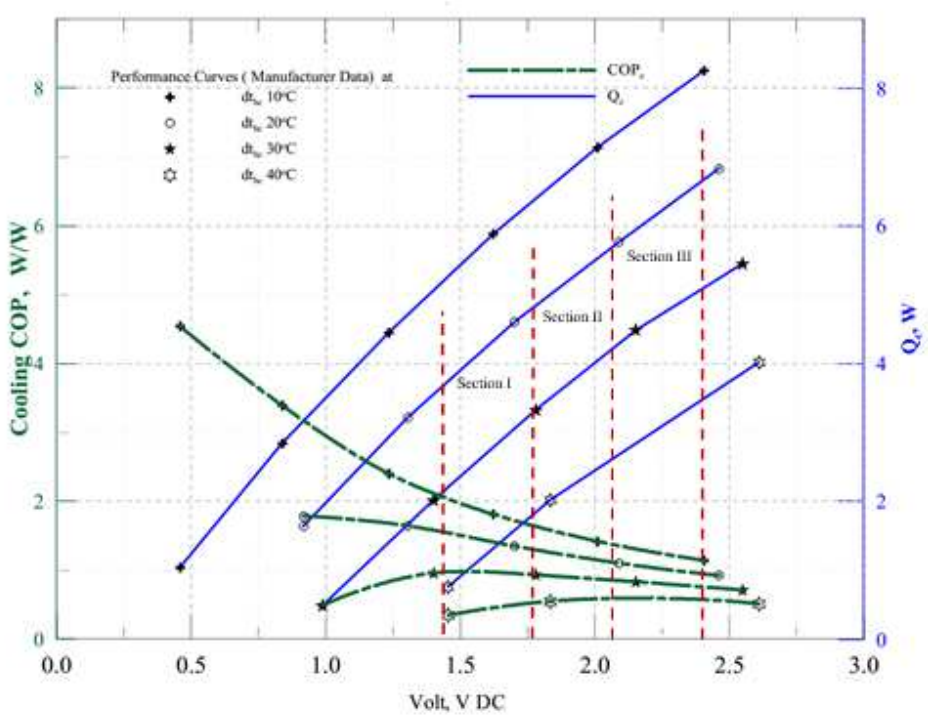
t_h 50°C, $Q_{c.max}$ 12.4 W, dt_{hc} 76°C, V_{max} 4.23 V, I_{max} 4.7 A, err < ± 3% $para_{act}$

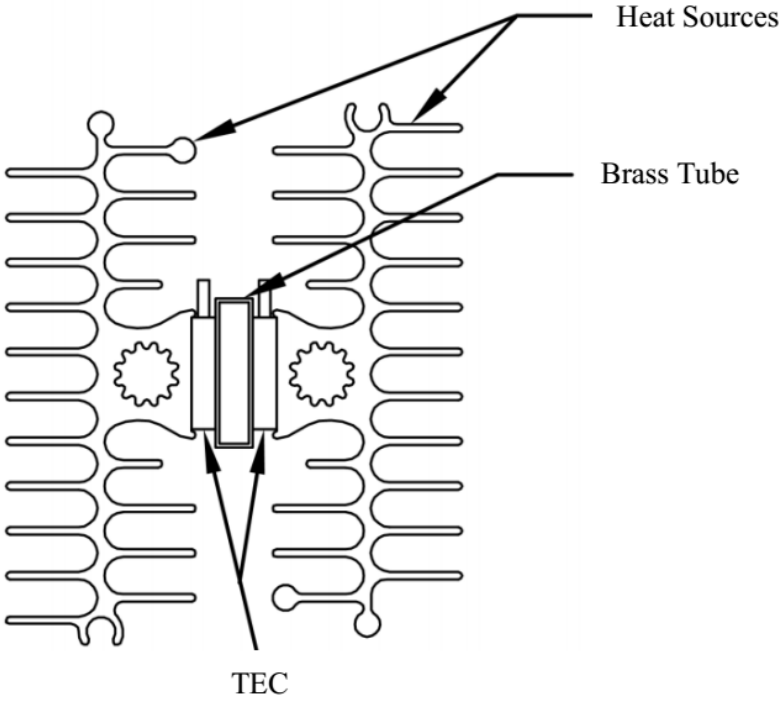


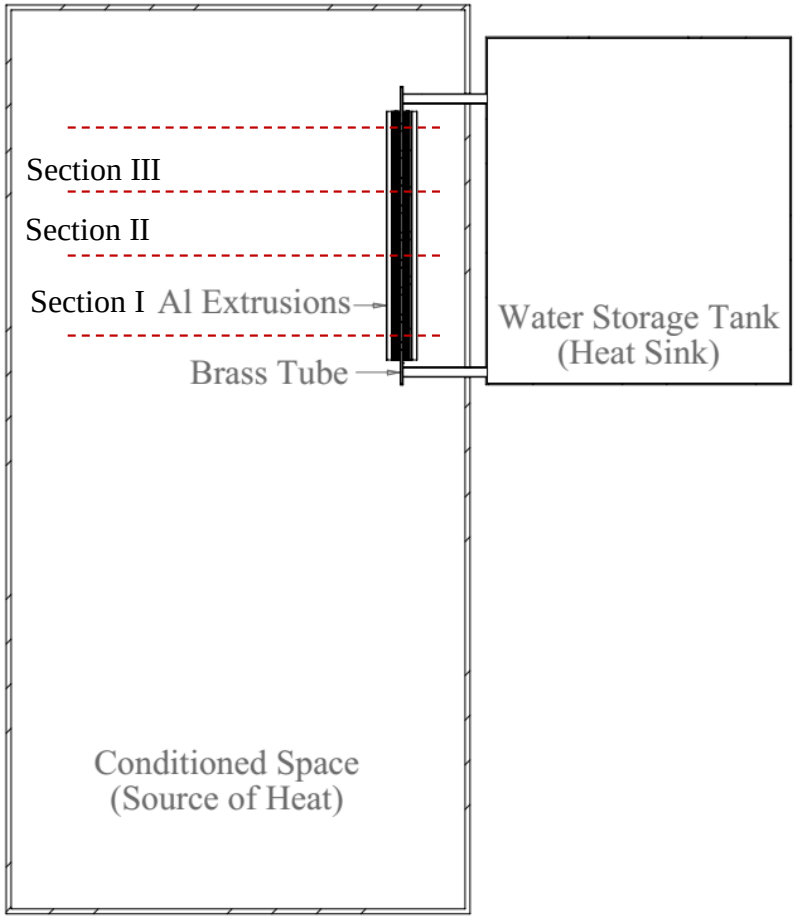


- ***Superimposed Two Plots***
  - » Q_c vs dt_{hc}
  - » V_{dc} vs dt_{hc}

ARRANGEMENT OF TEST SETUP

Arrangement of Components and Experimental Test Setup

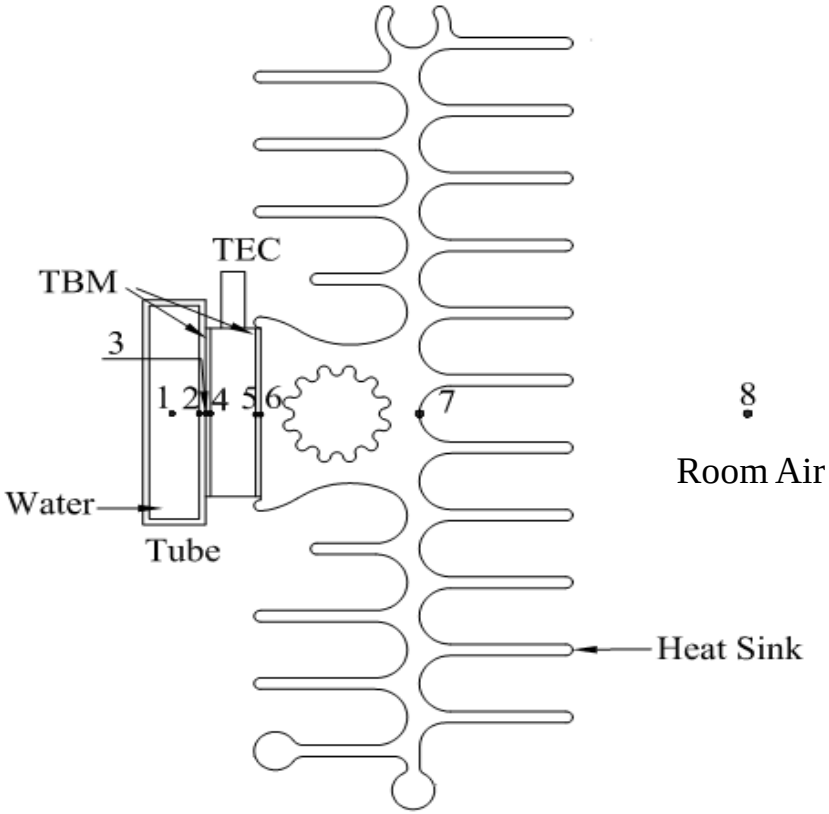




- **Specially Designed Aluminium Extrusion**
  - » Air side surface area
    - – 0.568 m^2/m length of extrusion
    - – Total area provided 0.568 m^2 for 90 W_c
- **TES1-03139 Chips 18 for 90 W_c**

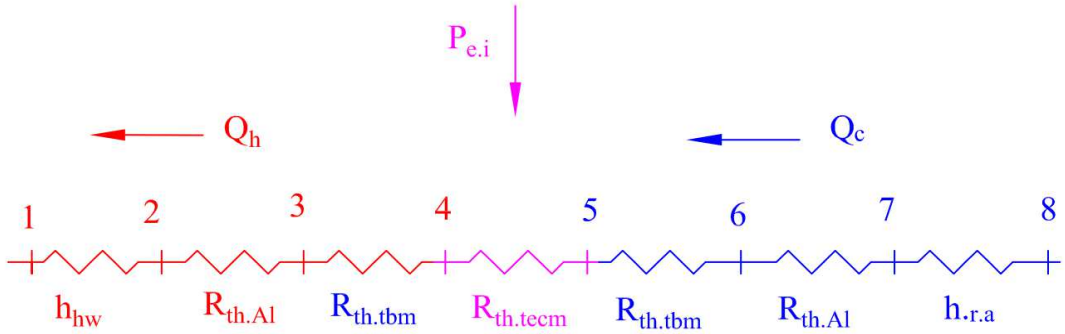
TE MULTI-UTILITY WATER HEATER

Thermal Resistances in Heat Flow from Room Air to Water



1. ***Bulk temperature of water***
2. ***Inside surface temperature of tube***
3. ***Outside surface temperature of tube***
4. ***Temperature at tube and TBM contact***
5. ***Temperature at TBM and TEC contact***
6. ***Temperature at TBM and heat sink contact***
7. ***Outside temperature at heat sink base surface***
8. ***Room air***

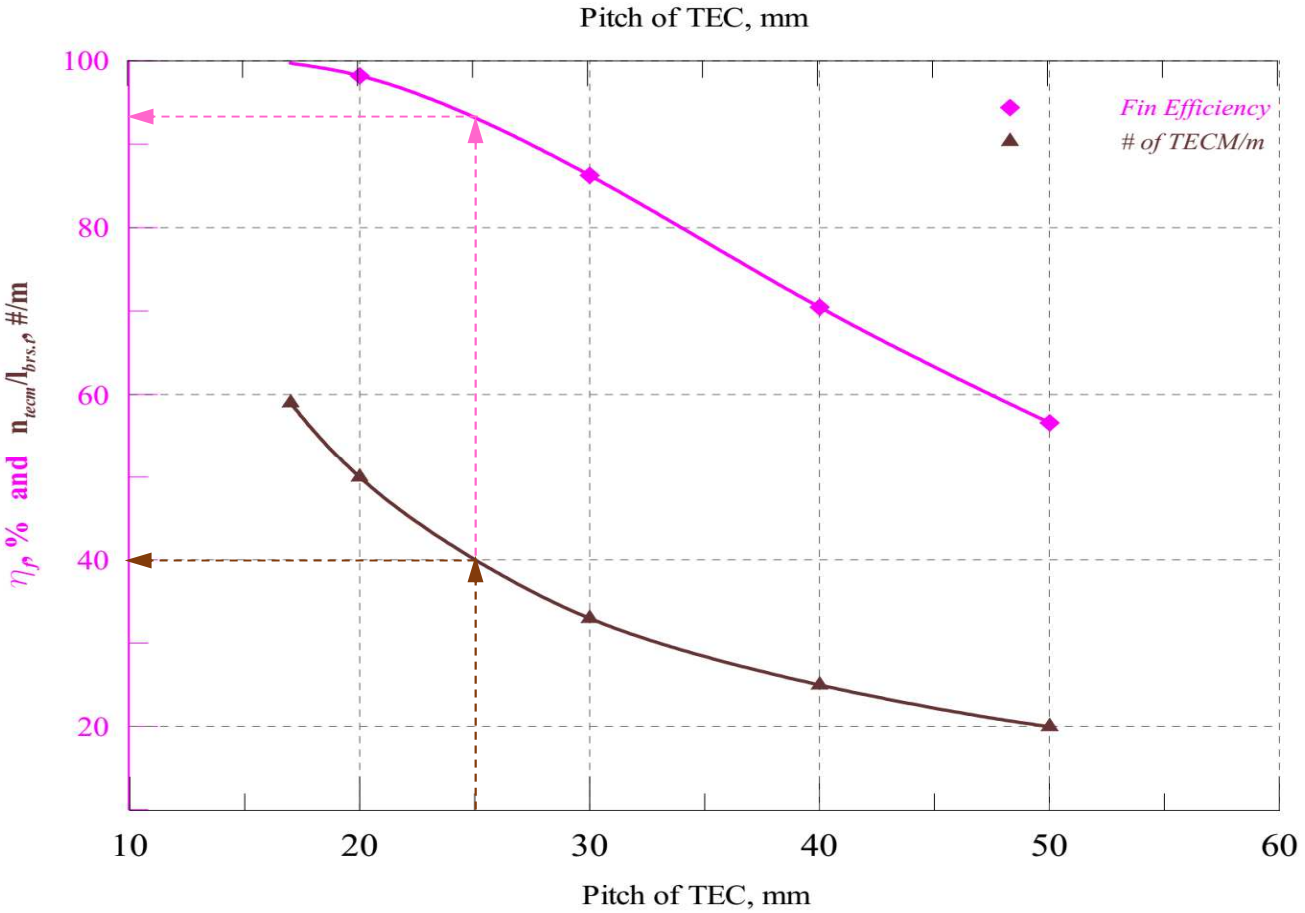
TEC	Thermoelectric Chip
TBM	Thermal Bonding Material



EFFECT OF PITCH ON FIN EFFICIENCY

Based on Simulation using SolidWorks

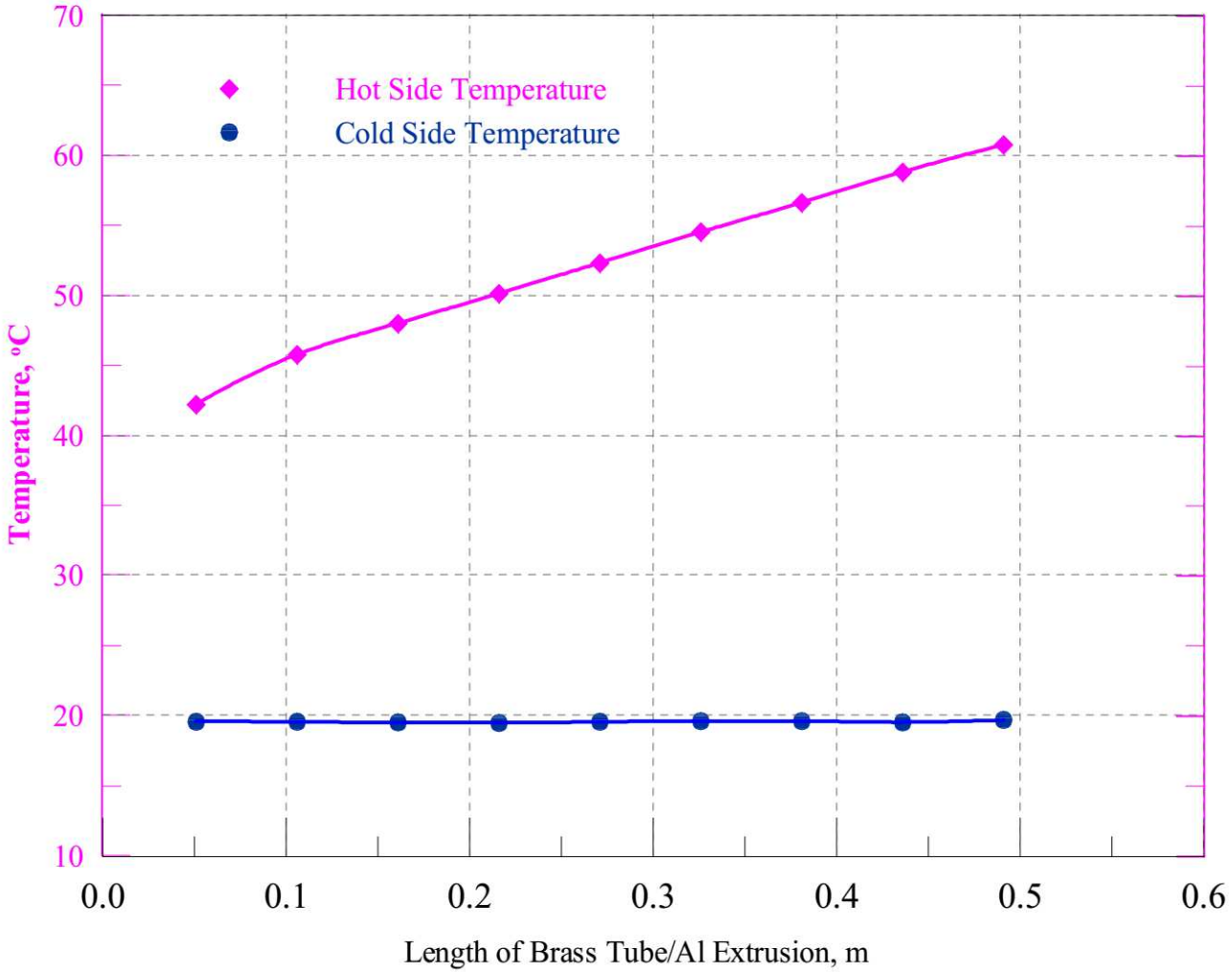
Fin Efficiency of Tube at Pitch along Tube Length



- ***Pitch of 25 mm can be Selected Based on the Efficiency 92.5%***

PERFORMANCE OF TE_MUWHcAC

Variation on Cold and Hot Side Temperature of TE Chips



- ***Temperature Difference***
  - » 11 to 42°C
- ***Room Temperature***
  - » Dropped from 27°C to 19.4°C
  - » In 1110 s
- ***Tap Water***
  - » Heated from 25°C to 50°C
  - » In once through mode

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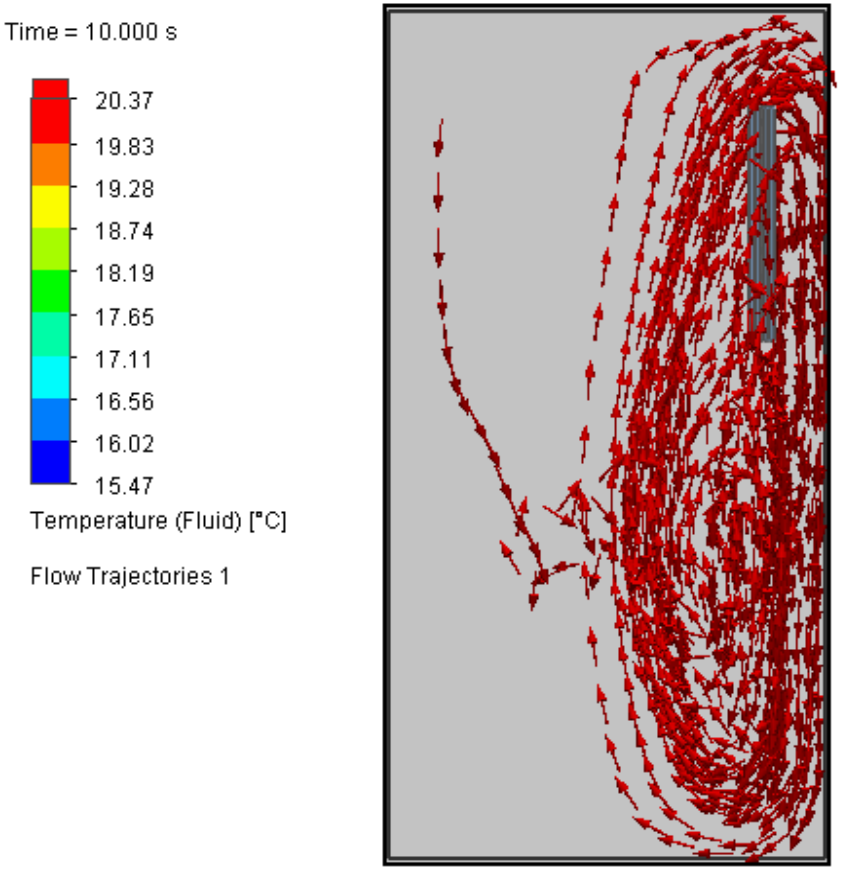
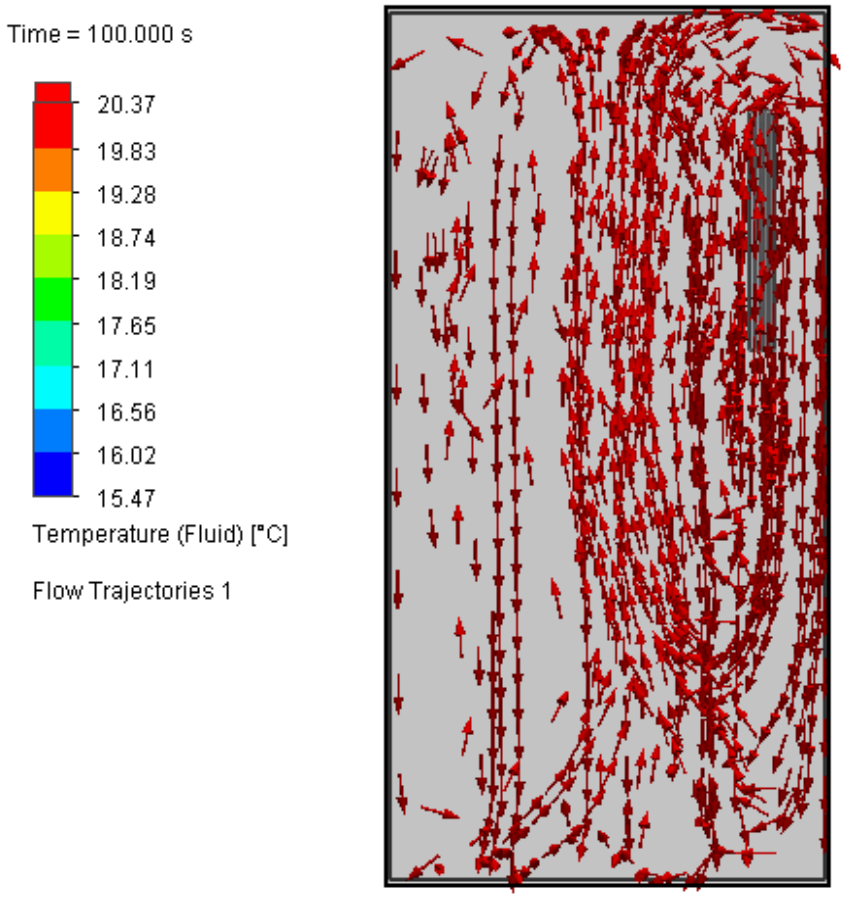
TEMPERTURE DISTRIBUTION

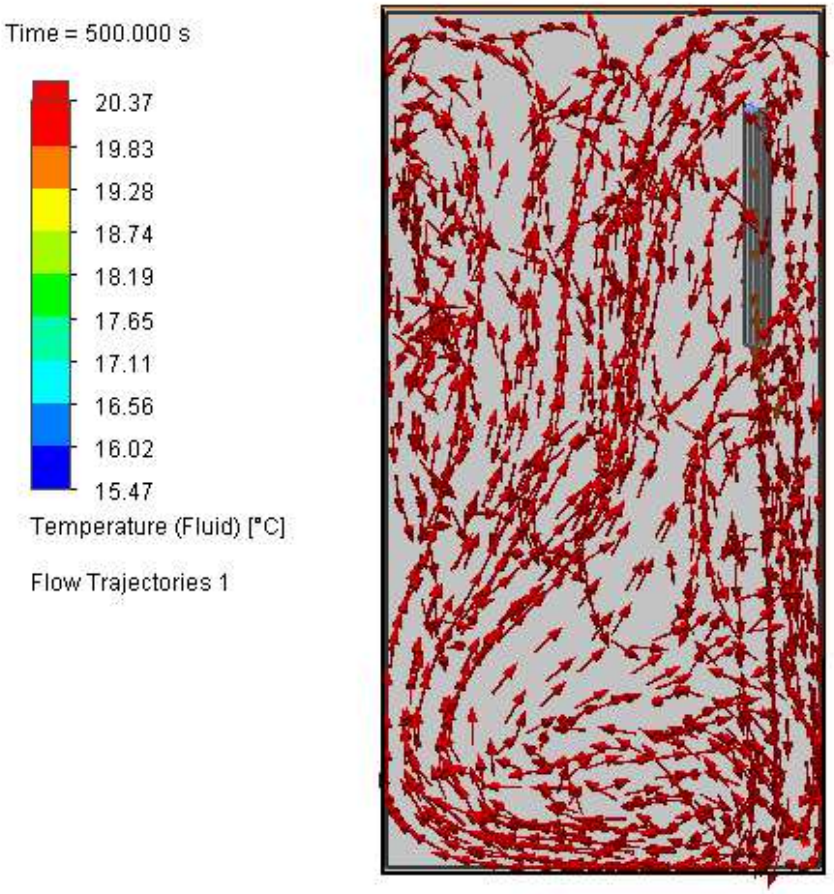
In the Conditioned Space at t = 10 s and t = 100 s





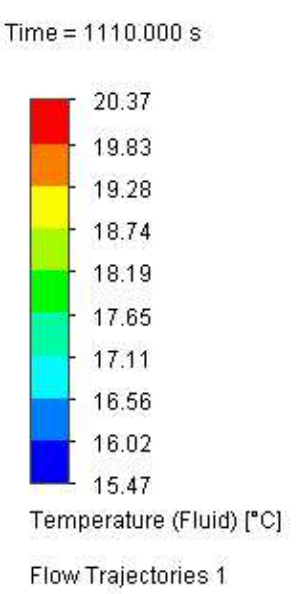
TEMPERTURE DISTRIBUTION

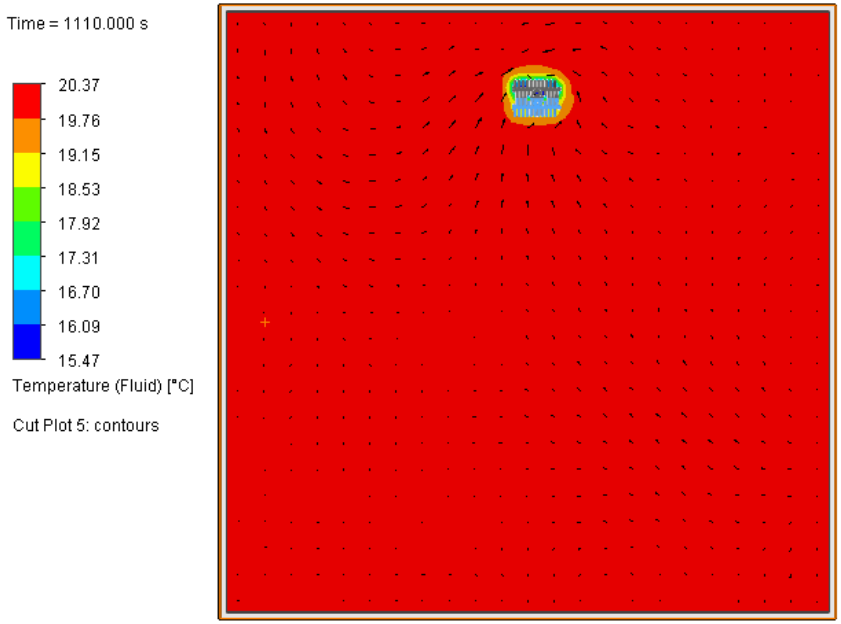
In the Conditioned Space at t = 500 s and t = 1000 s



TEMPERTURE DISTRIBUTION

In the Conditioned Space at t = 1110 s





CONCLUSIONS

Thermoelectric Multi-Utility Water Heater cum Air-Conditioner

- ***Thermoelectric Multi-Utility Water Heater cum Air-Conditioner***
  - » Judicious design based on ***Panel Heat Exchanger*** and conventional TE chips
  - » Simple, reliable system without moving parts and refrigerants
  - » Simultaneous water heating and air conditioning is enabled
- ***Effect of Pitch of TE Chips on Fin Efficiency***
  - » Selected 25 mm, h_f 92.5%, n_{tec} 40 #/m
- ***Temperature Variation in Cold and Hot Side of Chip***
  - » Varies from 22.6 to 41.1^oC
- ***Once Through Heating of Tap Water from 25^oC to 50^oC and Concurrent AC***
  - » dt_{hc} ***11 to 42^oC***
  - » ***COP_h of 2*** and COP_c of 1
  - » Operation for 16 to 17 h/d ***saves 97% electric demand***
    - – Compared to electric residential water heaters
  - » ***Reduce CO_2 emissions by ~54%***

THANKS