Summary of Research Activities

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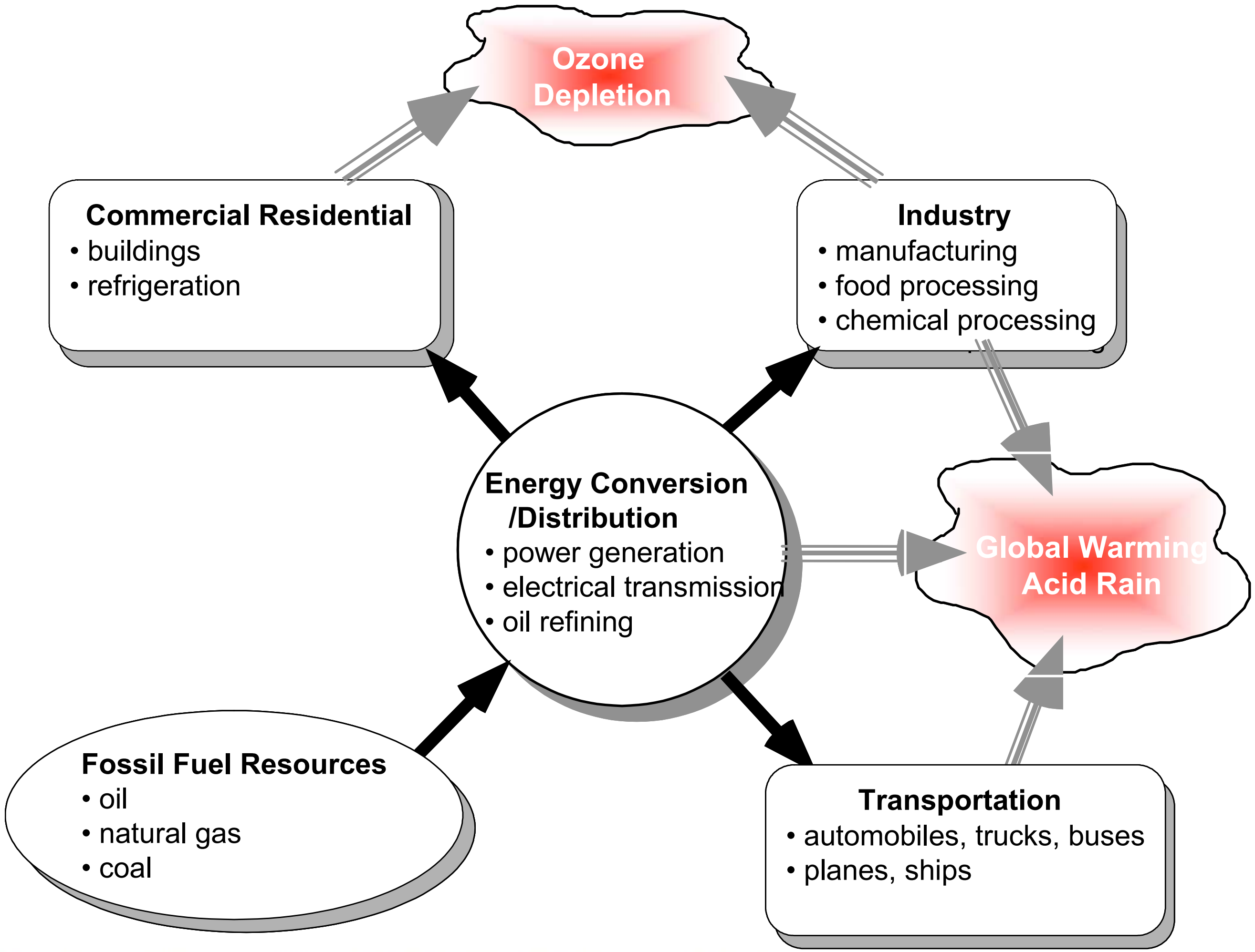
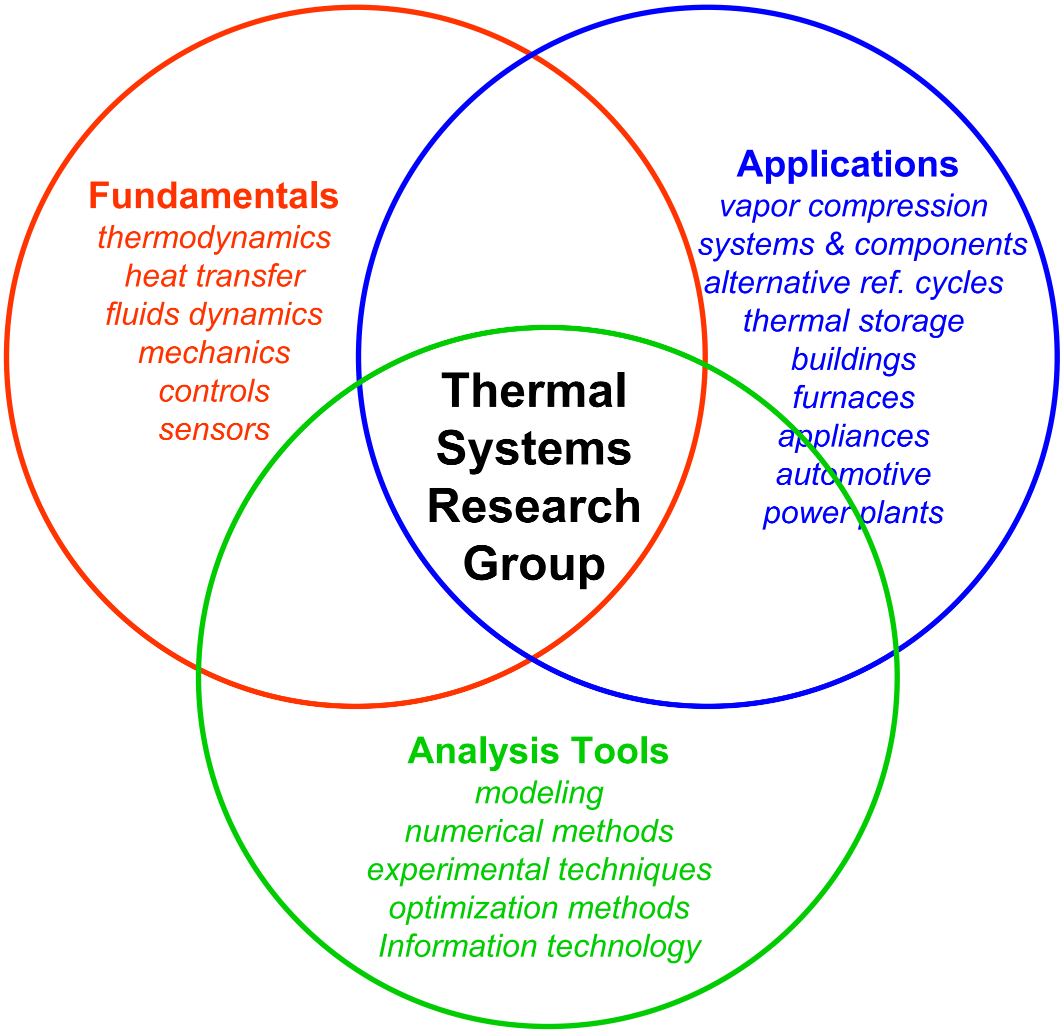
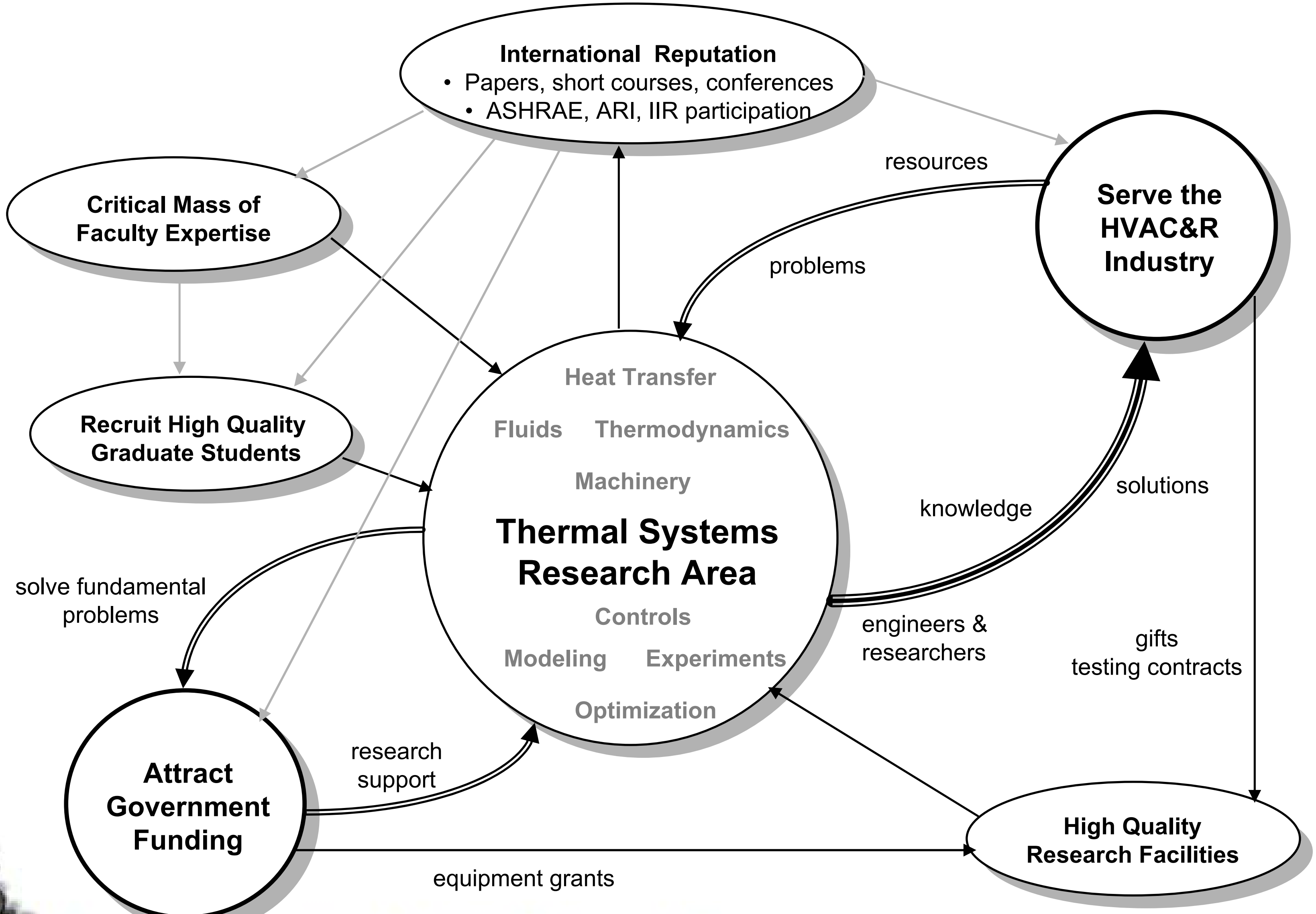
Main Driving Factors for Research are Energy and Environment



Thermal System Research Area



Thermal Systems Strategic Plan



Main Research Thrusts

- Alternative Technologies for heat pumping, air conditioning, refrigeration, drying, etc.:
  - Analysis of transcritical CO_2-cycle technology (some details later on)
  - Evaluation of thermoelectric refrigeration and air conditioning
  - Stirling cycle coolers
  - Ericsson cycle coolers
  - Air-cycle technology (reversed Brayton cycle) for transport air conditioning and drying applications.
  - Combined absorption/compression cycle (vapor compression cycle with solution circuit) utilizing working pairs such as ammonia/water, CO_2/Acetone, and HFC-23/DEGDME.

Main Research Thrusts, cont'd

- Improved Components, such as compressors, heat exchangers, expansion devices, distributors, etc.:
  - Modeling, analysis, and testing of positive displacement compressors (some details later on)
  - Evaluation of scroll or screw compressors for the combined compression of refrigerant vapor and solution in absorption/compression cycles
  - Modeling, analysis, and testing of two-phase work output expansion machines
  - Development of an improved method for refrigerant flow distribution
  - Analysis and design of heat exchangers
  - Heat transfer and pressure drop characteristics during in-tube gas-cooling, condensation, and evaporation of new/substitute refrigerants
  - Performance evaluation and investigation of the fouling behavior of air-to-refrigerant heat exchangers

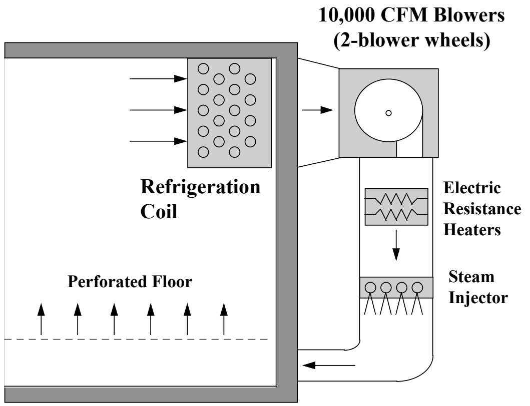
Main Research Thrusts, cont'd

- Improved Systems, (Air Conditioners and Heat Pumps, Chillers, Refrigerators, Furnaces, etc.) through modeling optimization, reliability studies:
  - Improved steady-state design models for air conditioners and heat pumps (some details later on)
  - Transient models unitary systems and chillers
  - HFCs and HFC mixtures as a replacement for R-22 in unitary air conditioning and heat pumping equipment
  - Hydrocarbons and their mixtures as a replacement for HCFC-22 in unitary equipment and as a replacement for R-134a in domestic refrigerator/freezers
  - Secondary loop refrigeration systems using ammonia or hydrocarbons for commercial and unitary applications
  - A cost-based methodology for determining optimal refrigerants
  - Impact of heat exchanger fouling on system performance

Main Research Thrusts, cont'd

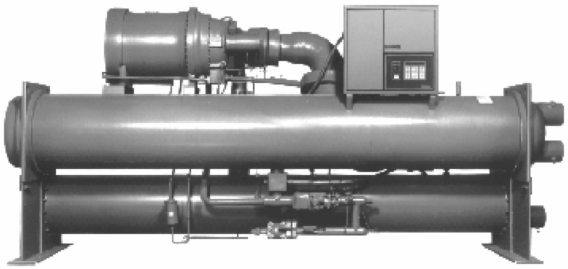
- Miniature-Scale Refrigeration Systems (MSRS) for electronics cooling:
  - Performance evaluation of miniature-scale refrigeration systems for electronics cooling (some details later on)
  - Modeling, analysis, design and testing of miniature-scale compressors for electronics cooling
  - Evaluation of miniature-scale diaphragm compressors for electronics cooling

Test Facilities



<u>Two Large Environmental Chambers</u>

- Testing of AC, HP and Refrig. Systems
- -20 C to + 50 C, < 5-ton equipment
- Steady-state and cyclic testing of existing, modified, or new equipment designs



<u>90-ton Centrifugal Chiller</u>

- Automated control of boundary conditions

<u>Heat Exchanger Test Facility</u>

- Testing of coiling coils, heating coils, evaporators, condensers
- Capable of controlled heat exchanger fouling

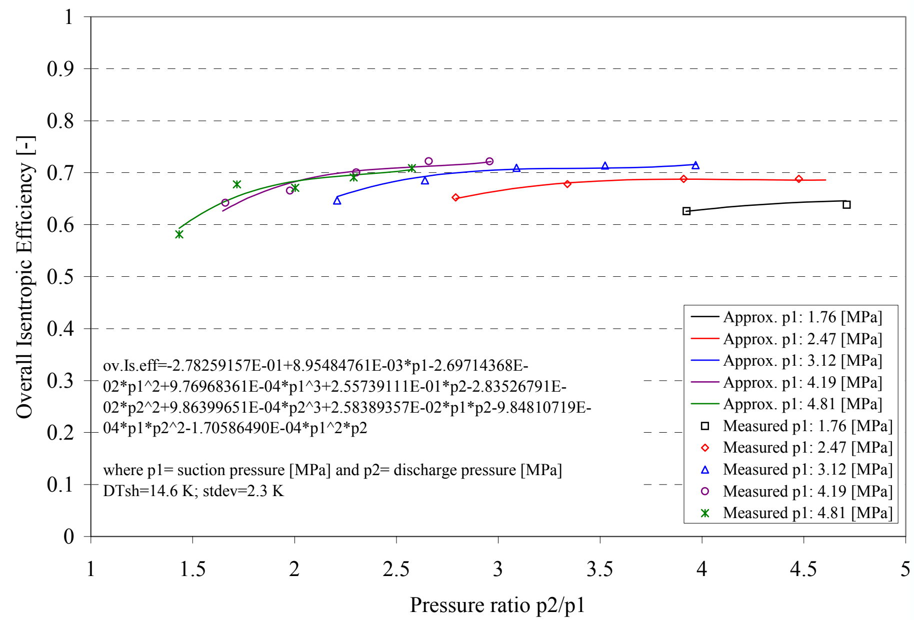
<u>Compressor Load Stands</u>

- CO_2, R-22, R-410a

Alternative Refrigeration Technologies: Transcritical CO_2 Cycle

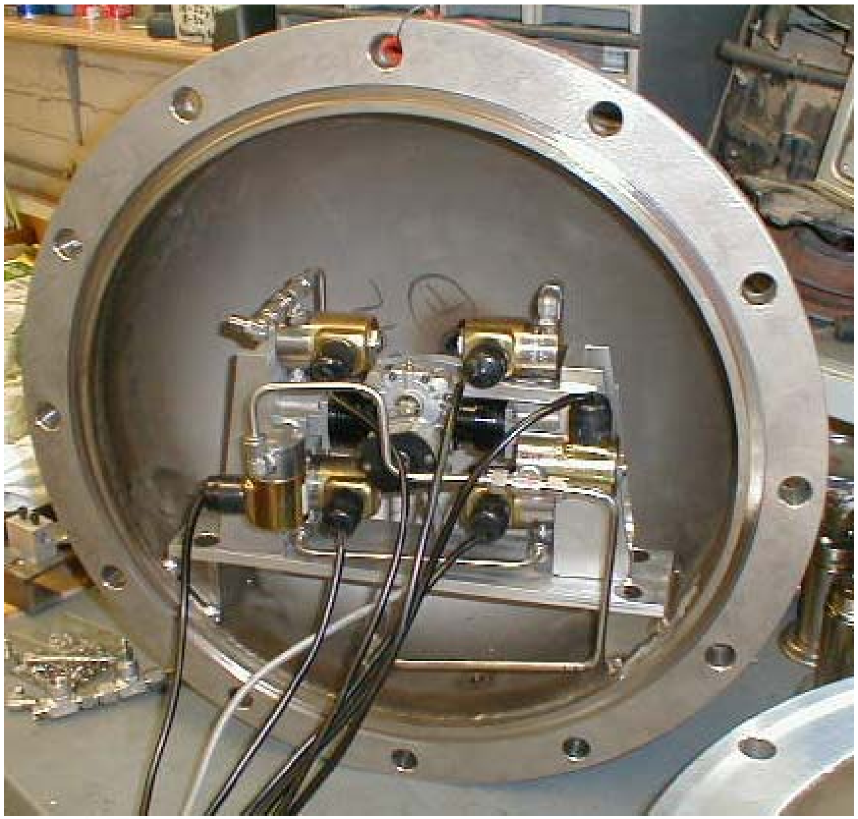
CO_2 Compressor Load Stand:

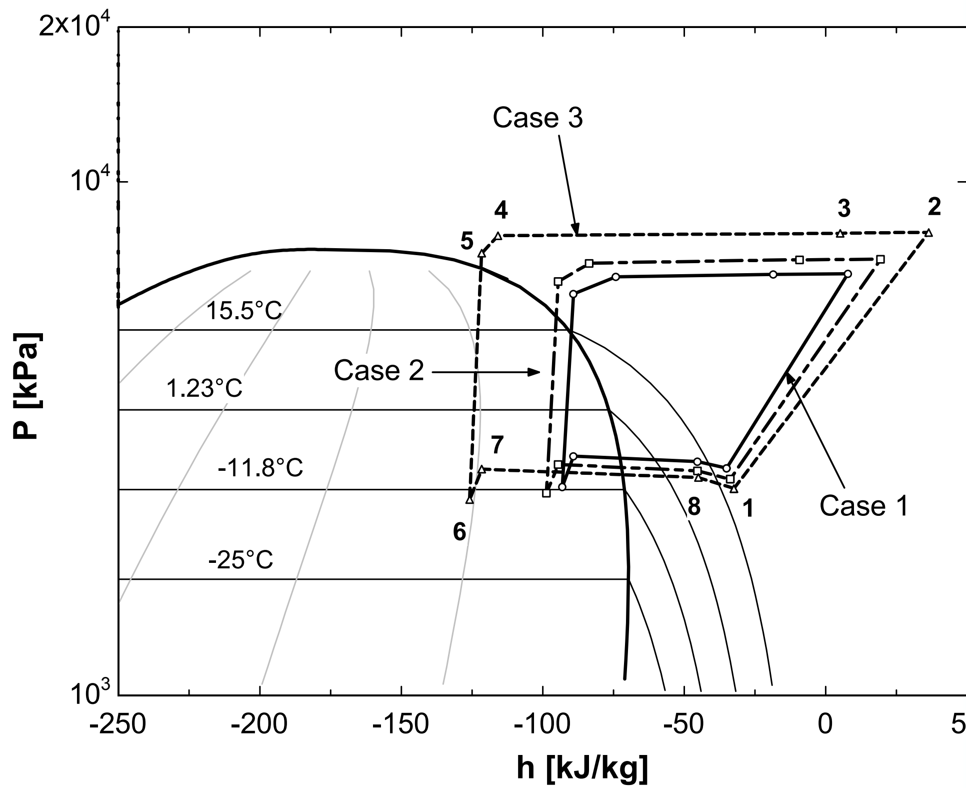
Performance of CO_2 Prototype Compressor:



Alternative Refrigeration Technologies: Transcritical CO_2 Cycle

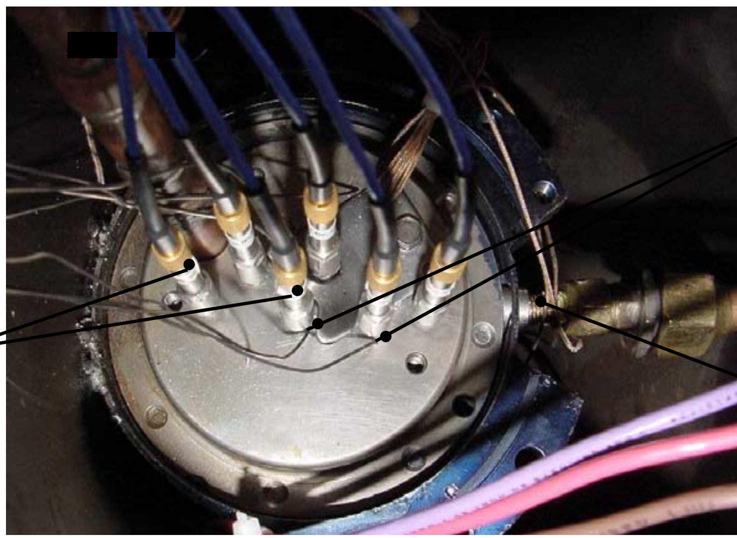
Expansion Work Output Machine:



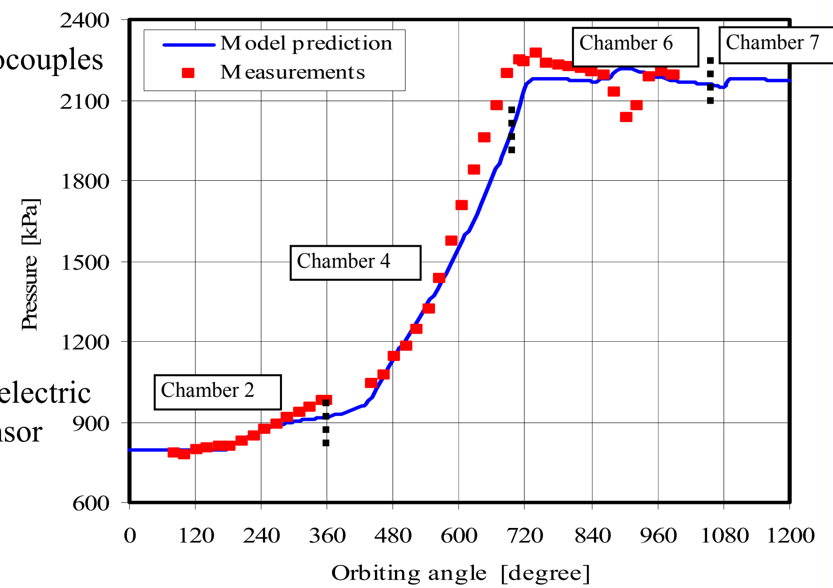


Improved Components: Scroll Compressor Analysis

Experimental Setup:



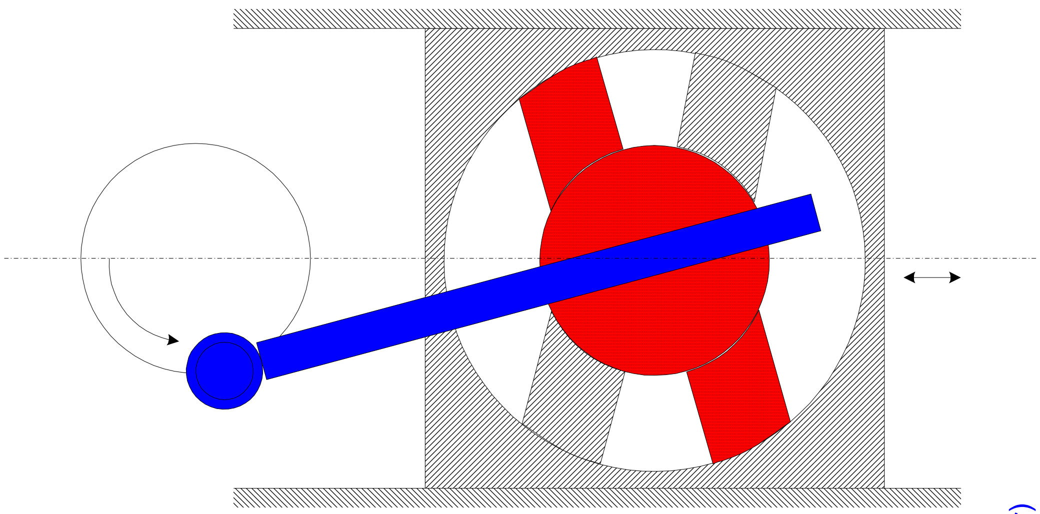
Model Validation:



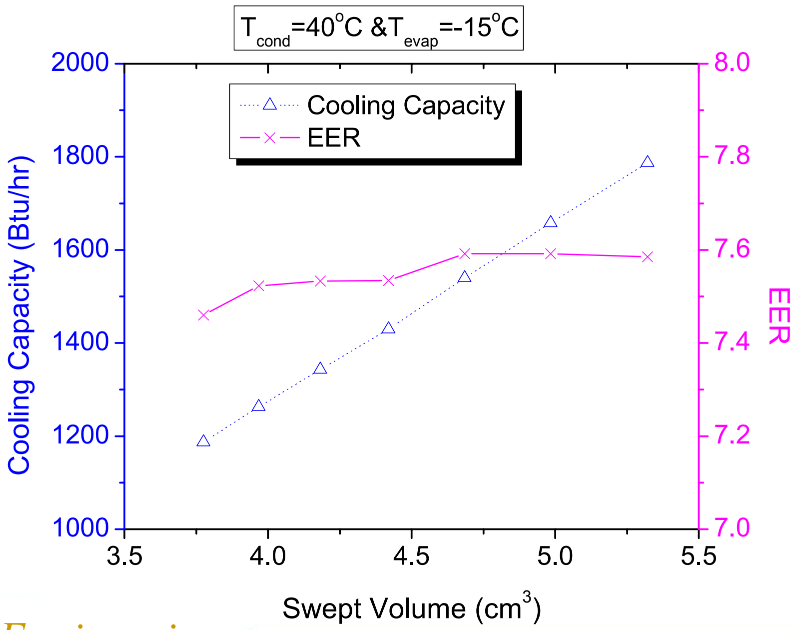
Improved Components:

Beard-Pennock Variable-Stroke Compressor (1988)

Concept:

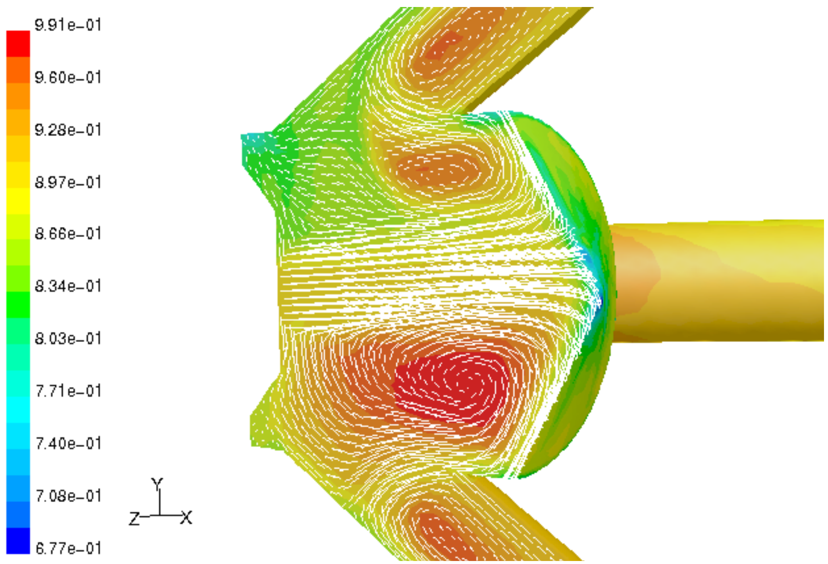


Predicted Performance:

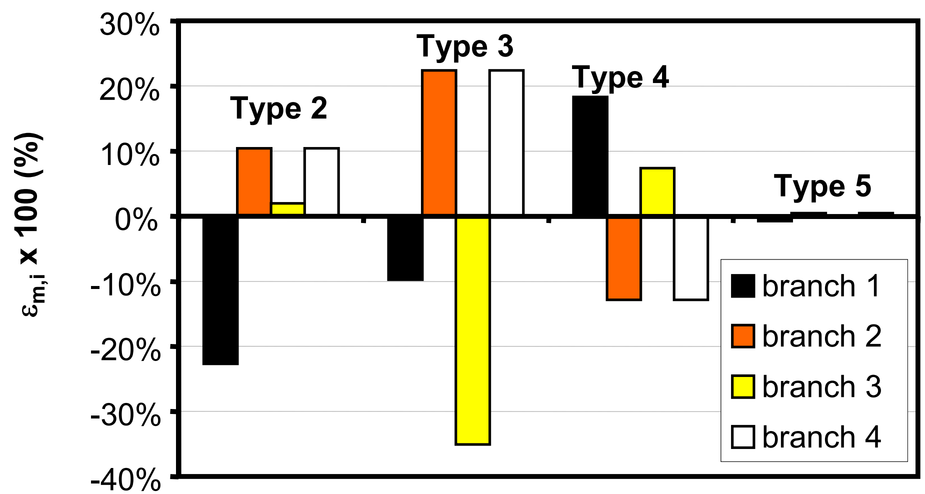


Improved Components:
Refrigerant Flow Distributor Analysis

CFD Modeling of Refrigerant Flow Distribution

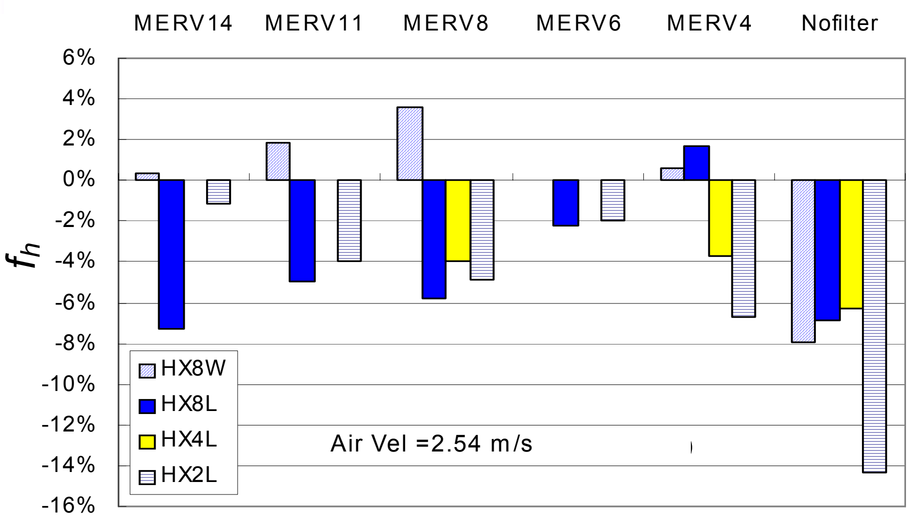


Refrigerant Mal-distribution:



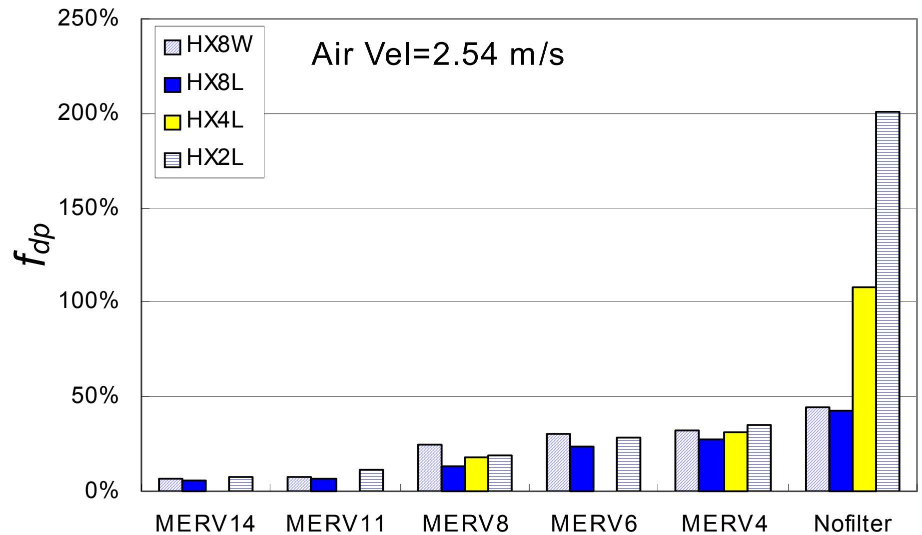
Improved Components:
Air-Side Heat Exchanger Fouling Analysis

Air-side Effective Heat Transfer Coefficient Fouling Factor (Measured):



$$f_h = \frac{100(h_f - h_c)}{h_c}\%$$

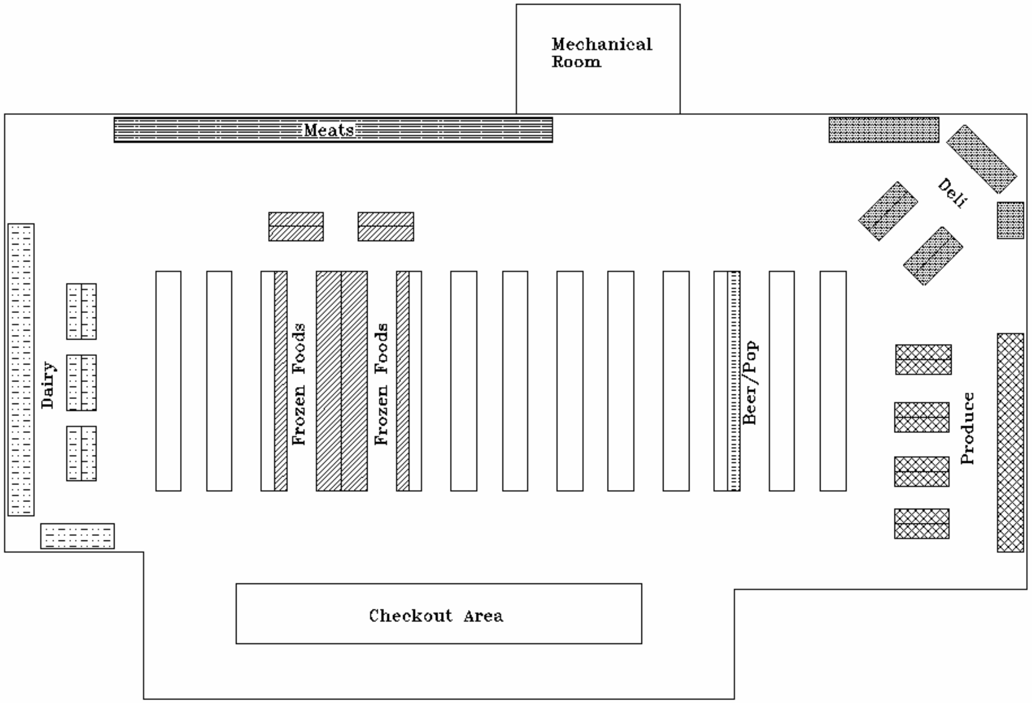
Air-side Pressure Drop Fouling Factors (Measured)



$$f_{dp} = \frac{100(\Delta P_{c,f} - \Delta P_{c,c})}{\Delta P_{c,c}}\%$$

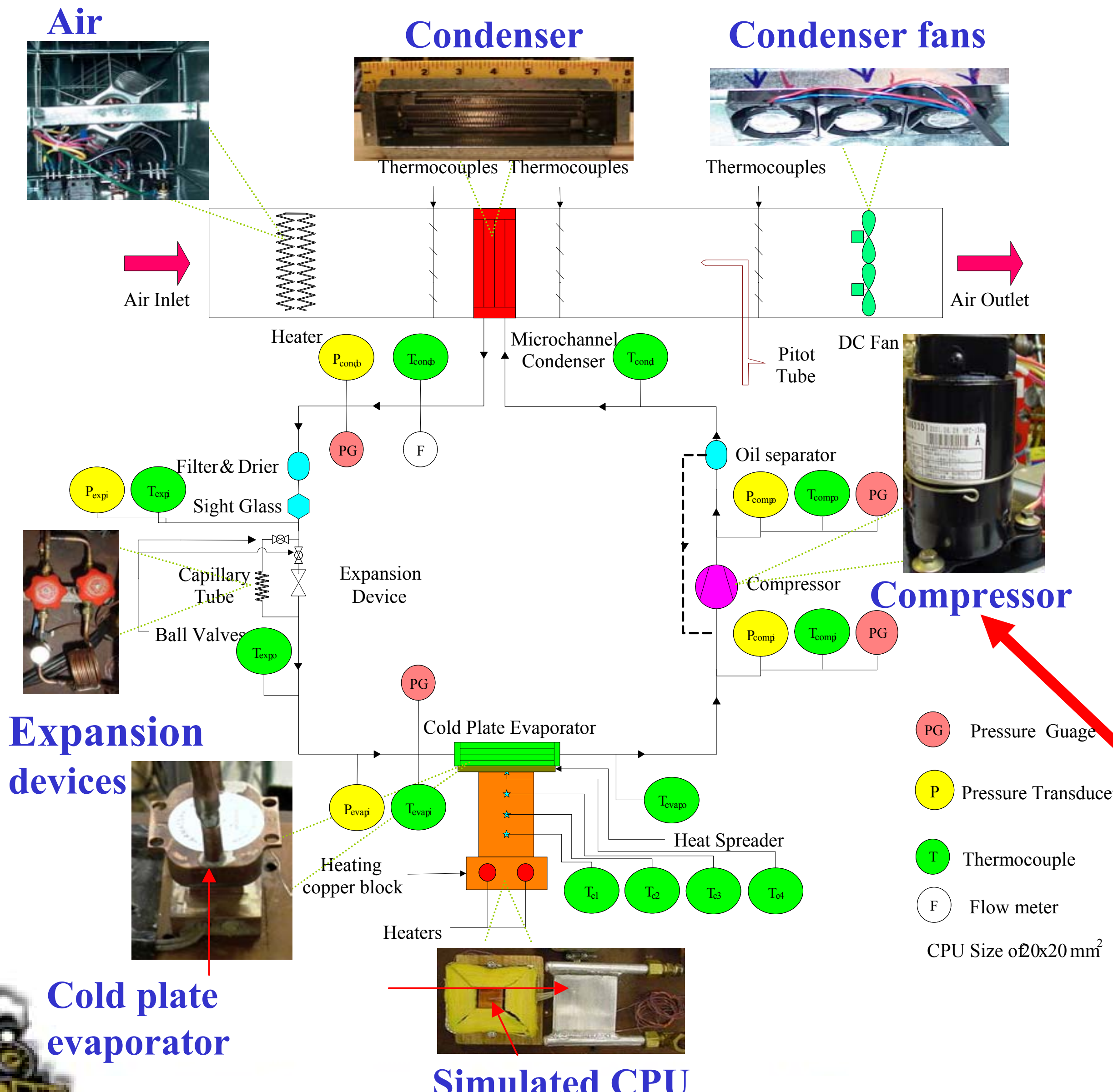
Improved Systems:
Secondary-Loop Refrigeration Systems

Supermarket Case Study:



Medium Temperature DX (R-22)	COP 2.01
Low Temperature DX (R-404A)	COP 1.19
Medium Temperature SL (R-717/HFE)	COP 2.31
Low Temperature SL (R-717/HFE)	COP 1.56

Miniature-Scale Refrigeration System (MSRS)



Target Operating Conditions

- Cooling capacity: ≥ 200W
- Evaporating temperature: 10 to 25 °C
- Condensing temperature: 40 to 55 °C
- Superheat: 3 to 8 °C
- Subcooling: 3 to 10 °C
- Ambient temperature: 25 to 45 °C

DC rotary compressor; ϕ 85 mm & 166 mm height & 2.8 kg weight

Future Research Opportunities

Driving Factors	Research Directions
Global warming Utility deregulation Limited generating capacity Information technologies Consolidation of service providers Worker Productivity Low-cost sensors & computers Population Growth Food Quality Demands Electronic cooling needs Medical needs	Energy efficiency improvements Alternative technologies Performance monitoring & diagnostics Intelligent controls Integrated facility management Human perception and productivity Distributed power generation Improved food production, preservation, transportation, and storage Small-scale refrigeration systems Low temperature system / cryogenics