Ammonia-Water Absorption Heat Pump

Rocky Research

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Overall Objectives of the Project

- Develop a Commercially Viable Technology Platform for Thermally Activated HVAC & Heat Pump Products
- Provide End-Use Hardware with Positive Impact on Electric Grid Relief, Fuel Versatility and Energy Efficiency for Unitary Markets
- Facilitate the Use of Exhaust Heat from On-Site Power Generation Equipment for Cooling, Refrigeration and Heat Pumping in the Unitary Size Range

Major Milestones for Entire Project

- Simultaneous Achievement of Chiller Performance (COP = 0.7 plus part load improvements) and Product Cost to the Distributor of $500/RT

- Achievement of Heat Pump Energy Efficiency (140% and Widened Ambient Operating Temperature Range) at a Product Cost of $700/RT to the Distributor

Specific Objectives for 2003

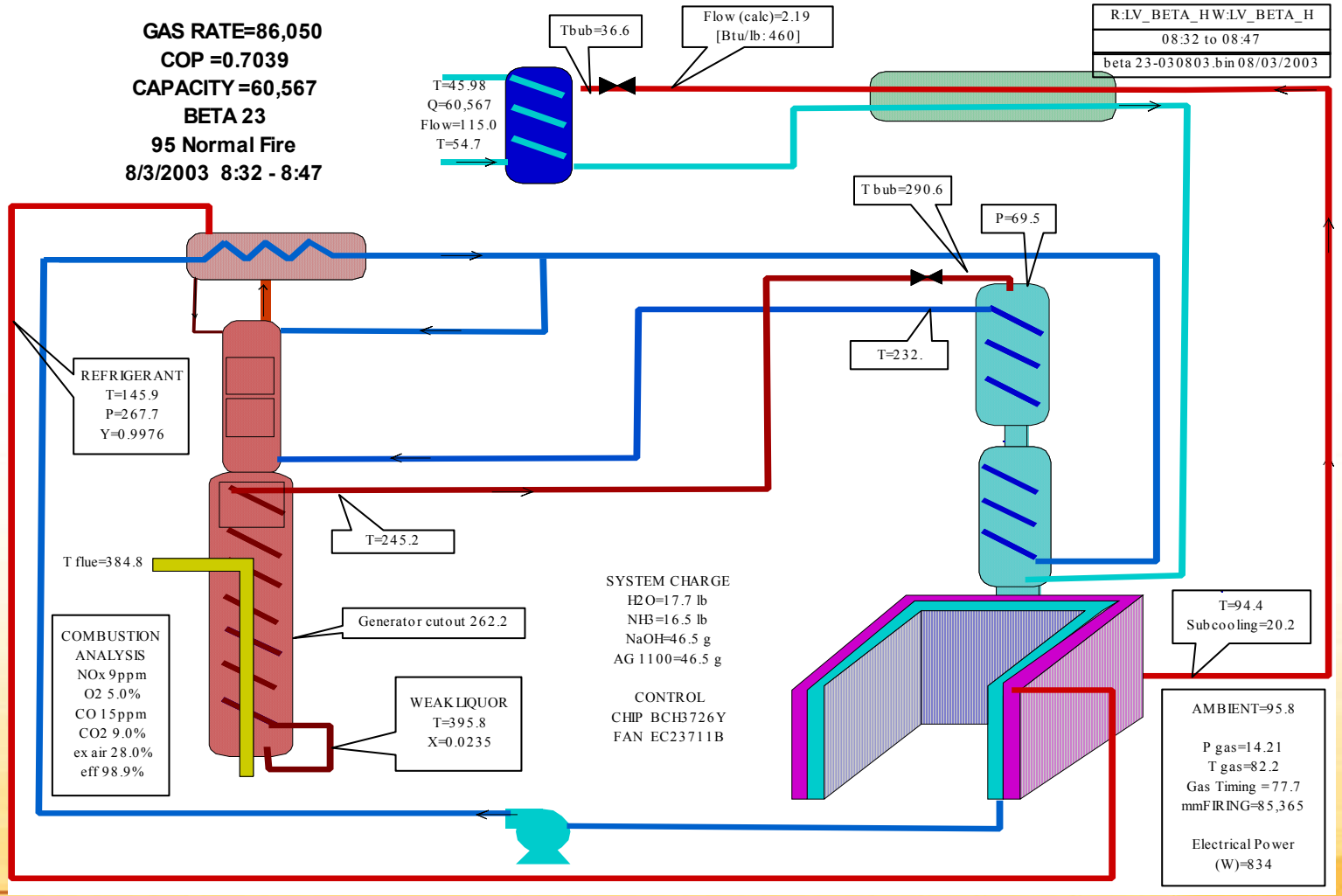
- **Chiller Objectives**
  1. Demonstrate Packaged Chiller Operation with COP = 0.7 at 95 F
  2. Demonstrate Part-Load Operation with Improved Efficiency
  3. Develop Manufacturing Process at 30% Below Current Cost

- **Heat Pump Objectives**
  4. Develop First Packaged Prototype Heat Pump Operating at a Heating Efficiency of COP = 1.4
  5. Demonstrate Heating Capacity of at Least 25% Above Vapor Compression Products at 47 F Ambient
  6. Demonstrate Heat Pump Operation Below 17 F Ambient

2003 Objectives – Accomplishments (1)

Chiller Operation with COP = 0.7

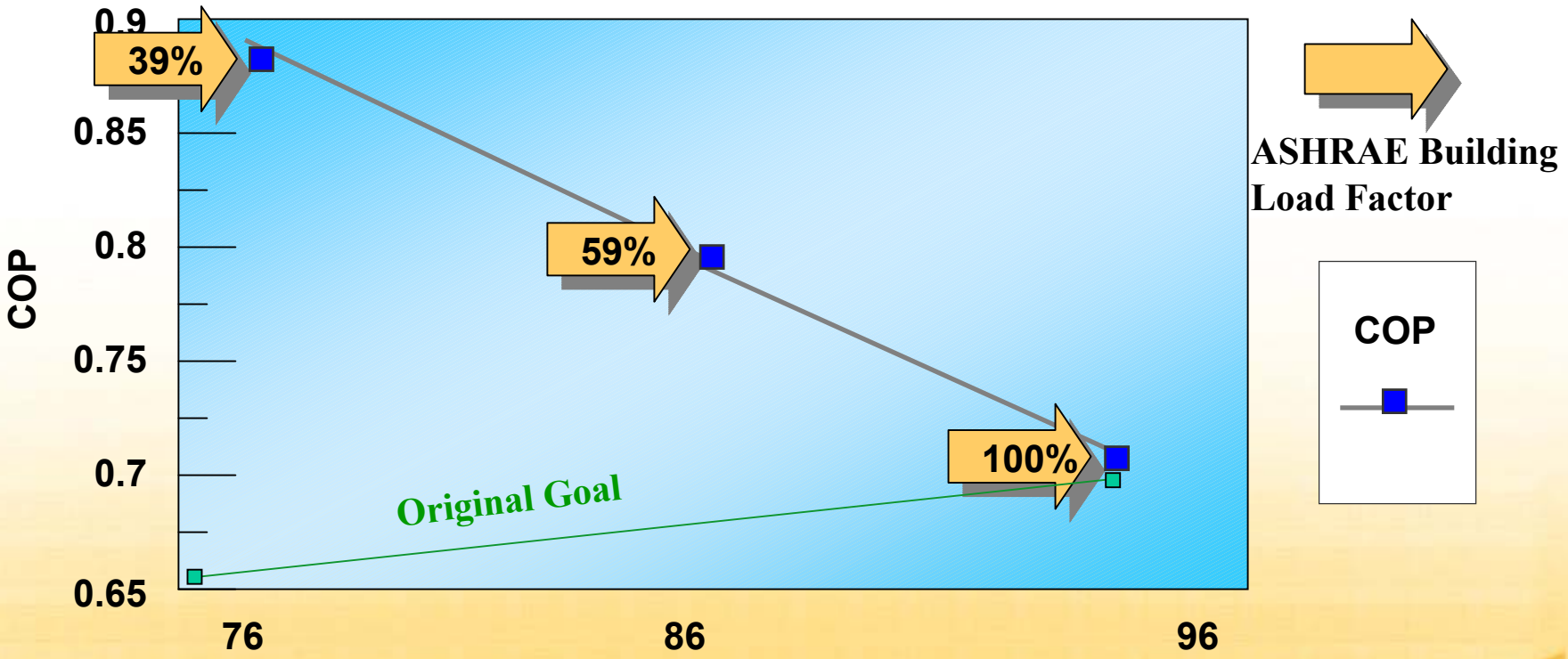
Test Chamber Chiller Efficiency Confirmation at 95 F (Third party audited and verified within 1.5%)



2003 Objectives – Accomplishments (2)
Part-Load Operation with Improved Efficiency

- **Part Load Multi-Speed Chiller Operation**

  (Confirmed by field operation and at third party test lab within 2%)



2003 Objectives – Accomplishments (2a)

Part-Load Operation with Improved Efficiency

2003 Objectives – Accomplishments (3)
Manufacturing Process at 30% Below Current Cost

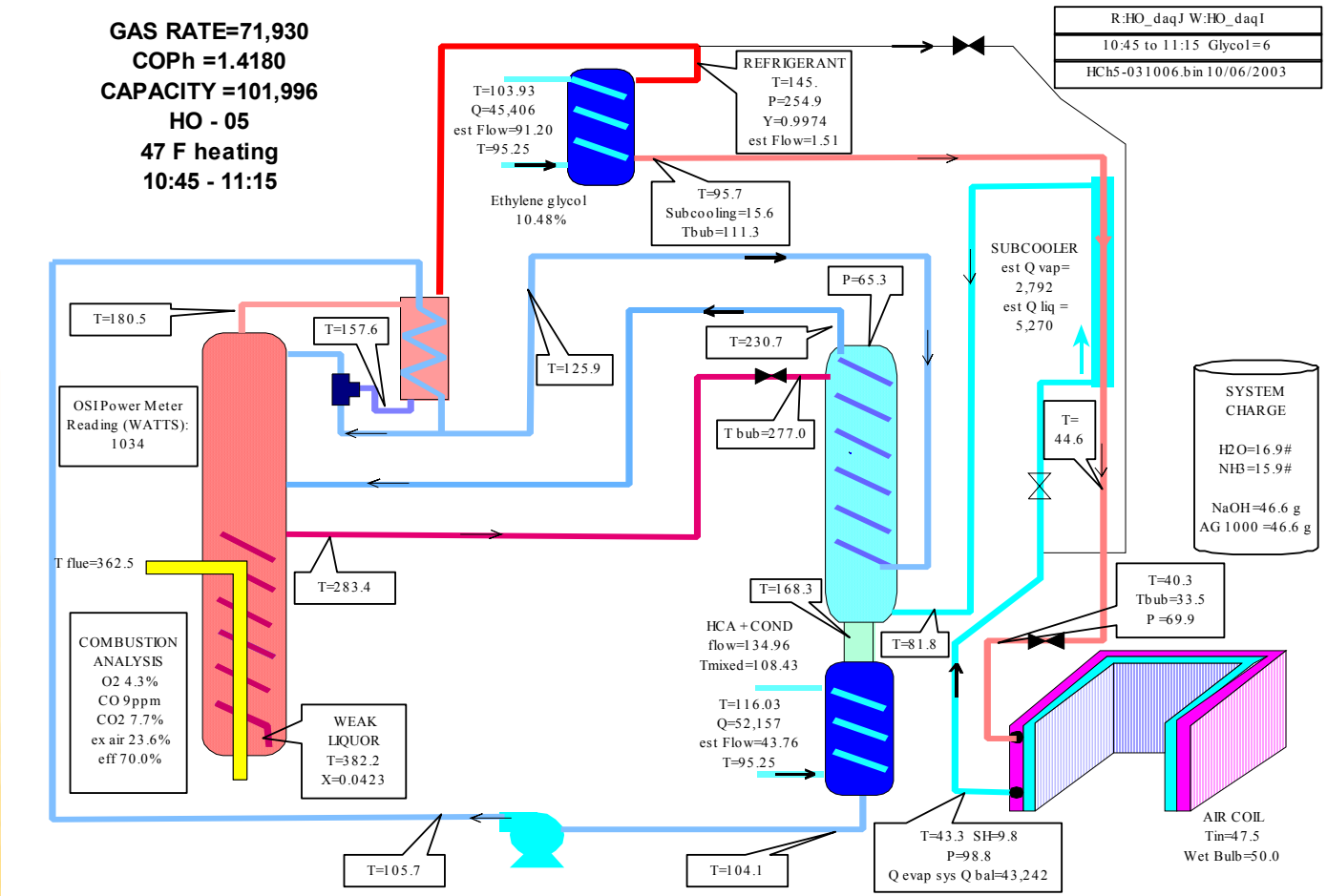
- **Manufacturing Process Details for Chiller**

  (Direct Cost Details verified & assessed by third party ITT& DECT)

- **At Manufacturing Volumes of 8,000 to 10,000 per year:**
  - **Projected Labor Hours: < 12 hours/unit**
  - **Parts and Materials: < $1,200/unit**
  - **Floor Labor Efficiency: 85% (timed & measured)**
- **Reached Manufacturing Cost Goal of $2,500 per 5RT unit in 1998 Dollars (audited and verified)**
- **Implemented Design with Minimal Premium at 5,000 Units per Year and Component Commonality**

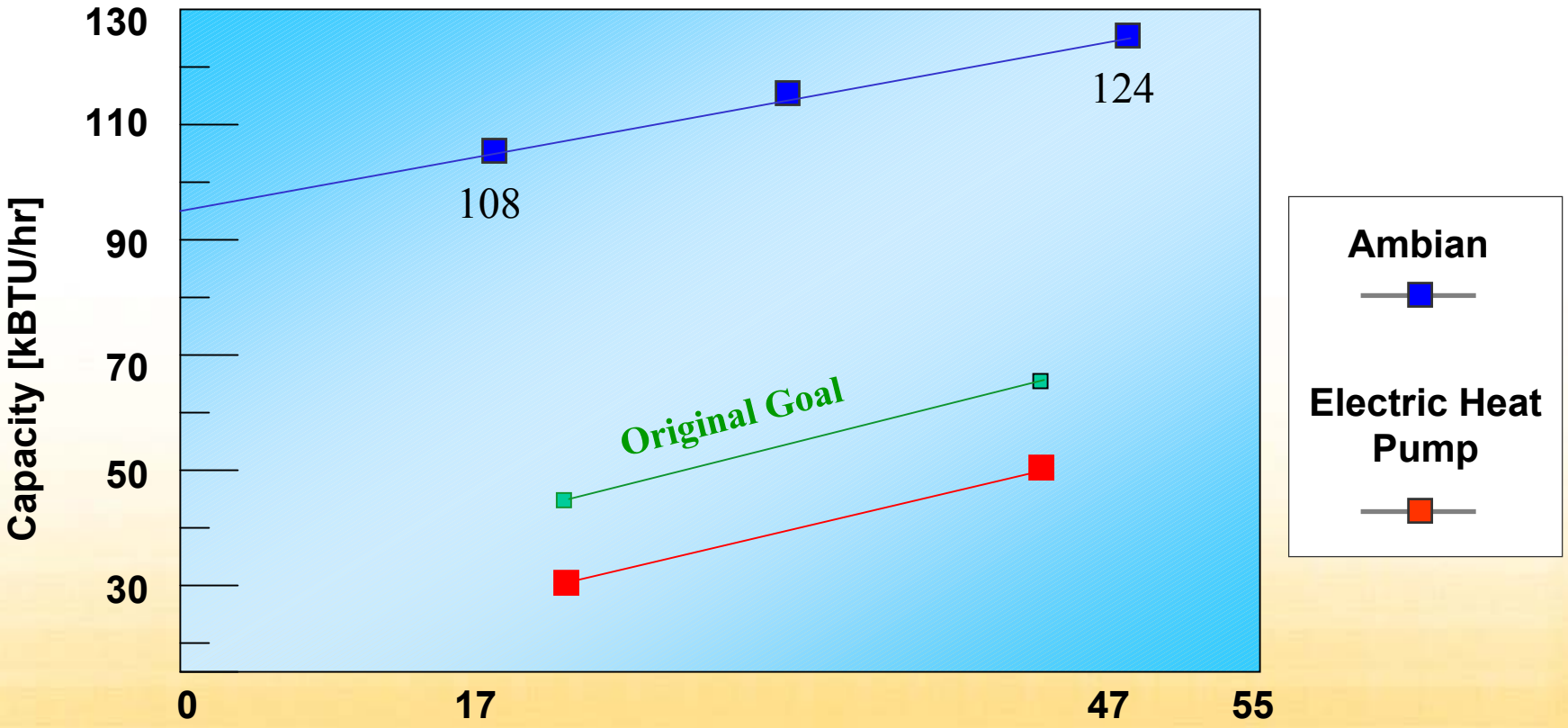
2003 Objectives – Accomplishments (4)
Heat Pump Heating Efficiency of COP = 1.4

- Heat Pump Efficiency Confirmation at 47 F



2003 Objectives – Accomplishments (5 & 6)
Heating Capacity 25+% Above Vapor Compression Heat Pump Operation Below 17 F Ambient

- Heat Pump Capacity at 47 F and Operating Range



2003 Objectives – Additional Accomplishments

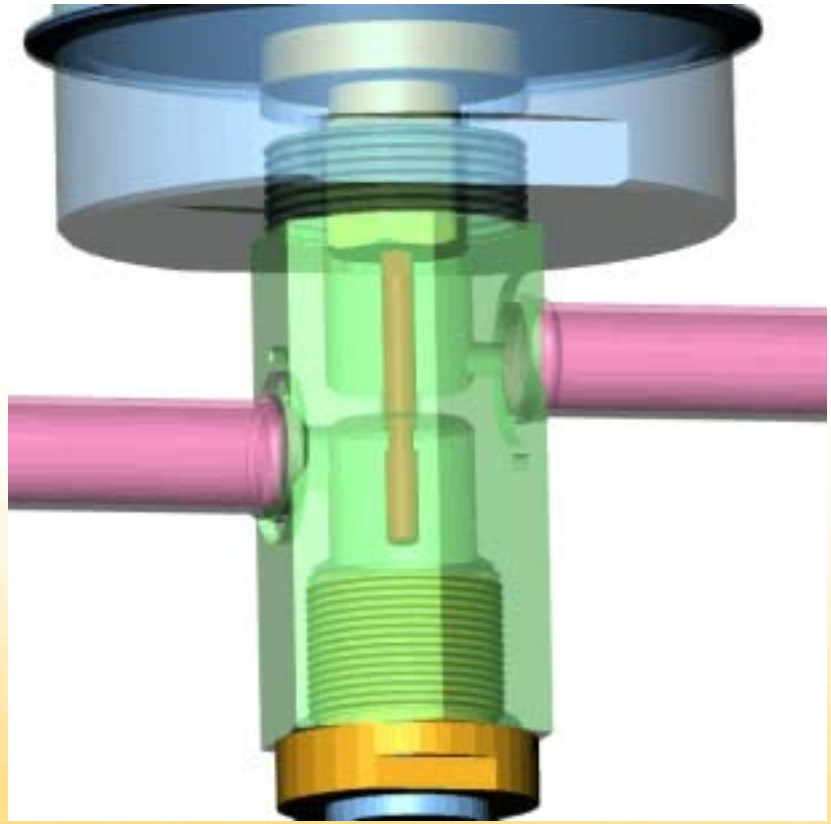
- **Accomplishments that Facilitated the Major Milestone Achievements:**
  - Product Height, Size and Weight Reduction
  - Implementation of Variable Speed Burner
  - Verification of Partial Flow Full Surface Wetting
  - Precise Pulsing Refrigerant Flow Control
  - Low Cost Pump Operable at Negative Suction Pressure
  - Use of Outdoor Coil as Evaporator in Heat Pump Mode
  - Use of Microprocessor Control ECM Motor Technology
  - Use of Component Commonality for Chillers and Heat Pumps

2003 Product Height Reduction

2003 Solution Pump Improvement

2003 Refrigerant Flow Control Improvement

- Precise Superheat Control
- Tolerates Refrigerant Purity Limitations (98% to 99.8%)
- Covers Full Variable Capacity Range



2003 Component Commonality Verification

- Built and Operated Prototype Heat Pump Using Identical:
  - Solution Cooled and GAX Absorber Sections
  - Generator
  - Rectifier
  - Sub-cooler
  - Solution Pump
  - Valves and Piping
- Built and Operated Prototype Heat Pump Using:
  - Chiller Air Cooled Coil as Evaporator
  - Solution Cooled Absorber in Lieu of Air-Cooled Absorber
- Built Packaged Heating Heat Pump Confirming “On-Track” Manufacturing Cost Forecast for $700/RT 5 RT Heat Pump

Project Partners and Roles

Major Project Partners Support to Rocky Research and USDOE Can be Divided into Several Categories:

- Financial Co-Sponsors provide cash cost-share to the USDOE Funded Technology Development Work at Rocky Research
- Project Partners also Contribute to substantial additional work in support of product commercialization (beyond scope of DOE funded technology development project)
  - Project Partners Contribute to DFM, Process Development and Manufacturing
  - Project Partners include Contributors to the Development of Product Positioning, Training, Distribution, Sales and Service

Project Partners – Co-Sponsors

Ambian Climate Technologies, LLC:

- Atmos Energies
- Southwest Gas
- Texas Gas Transmission
- Southern California Gas
- Southern Natural Gas
- GRI International

Project Partners – Main Manufacturing Process Contributors

- ITT Heat Transfer
  - Automated Specialty Pressure Vessel Handling
  - Welding
  - Coiled Heat Transfer System Assembly
  - Heat Exchanger Surface Treatment
  - Tech Transfer to Component Suppliers
- IPAC 2000
  - Design and Manufacture of Structural Support
  - Sheet Metal and Powder Coating
  - Wiring, Insulation and Product Packaging
- Infinity Lab
  - Micro-Processor Based Controls

Project Partners – Deployment Support

- Ambian and its Owner Companies
  - Field Test Installations and Data Gathering
  - Installation & Service Training Support
  - Market Analyses and Sales Potential Research
- Dectron International
  - Support Training for Installation and Service
  - Customer and Rep Feedback Analyses
  - Support of Specific Introduction Market Analysis
- GodwinGroup
  - Product Positioning for Commercial Introduction
  - Market Segment Analyses
- Richard English
  - Training Support for Installation and Service

2004 Plans and Expectations

- **Product Manufacturing and Reliability**
  - Development and Establishment of Metrics
  - Development of Tooling Specifications
  - Verification of Component/Product Repeatability in Manufacture
  - Operation of Chillers over a Complete Season
  - Continue Component Reliability Testing
- **Reversing Heat Pump Development**
  - Absorption Cycle Prototype with Reversing Valves
  - Liquid Solution Inventory Management in Heat Pump Mode
  - Operation of First Fully Reversible Packaged Prototypes

2004 DOE Milestones

- **Chiller Operation**
  - Continue Operation of Multiple Chillers and Report Test Results
  - Achieve at Least 2,000 Operating Hours Each with Two Chillers
- **Reversing Heat Pump Development**
  - Develop and Test a Reversible Absorption Heat Pump Prototype in an Environmental Chamber
  - Build and Operate at Least 3 Fully Reversible Packaged Prototypes for Field Installations

Additional Work To Be Initiated in 2004

- **Manufacturing**
  - Consolidate Manufacturing to a Single Key Entity for Factory Floor Lay-Out, Tooling and Quality Control Implementation – One Step Manufacture
  - Acquire Critical Equipment Items to Design Tooling and to Train Factory Labor Force – Time to Market in Six Sigma Process
- **Commercialization**
  - Develop Introductory Niche Market Plan and Partner with Appropriate Entity Present in Such Market
  - Adapt Installation Sales and Service Training for Partnership with Existing Infrastructure

Out-Year Plans and Milestones

- Expansion of Product Line
  - Develop 3RT Capacity Chillers, Chiller-Heaters and Heat Pumps
  - Develop Multi-Unit Links and Controls to Address 10 RT to 40 RT Load Applications
- DER Applications
  - Develop an Air-Cooled Chiller and Heat Pump Capable of Utilizing the Exhaust from On-Site Generation Equipment as Thermal Heat Source
    - Design to Allow for Heat Integration At or Below 300F
    - Provide for Dual Fuel Back-Up Capability
    - Develop Economics that Reduce the Payback Period for the Entire System