

Overview of DOE/ORNL Heat Pump Design Model and Use of Web Versions

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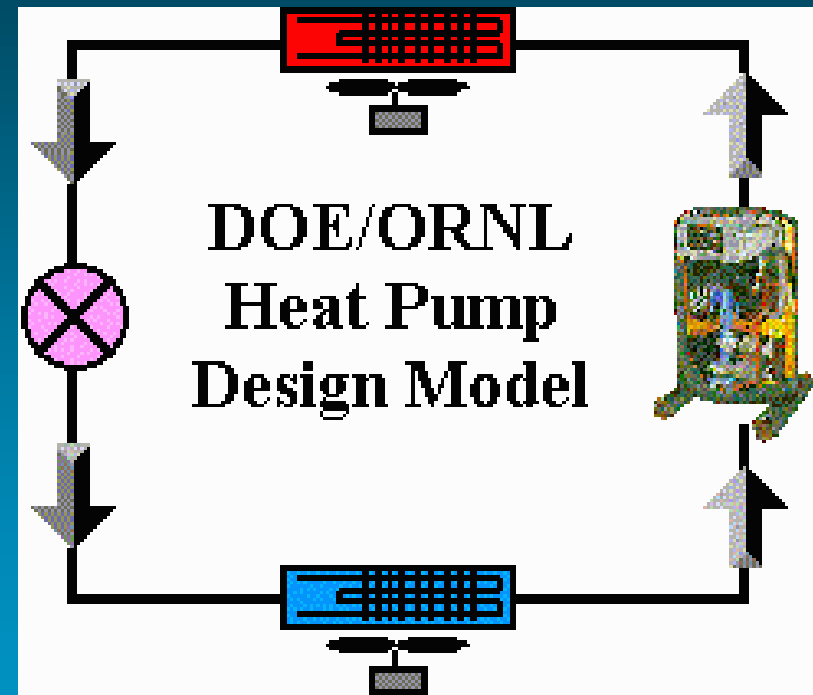
Oak Ridge National Lab

USNC/IIR Short Course on Simulation Tools

July 13, 2004

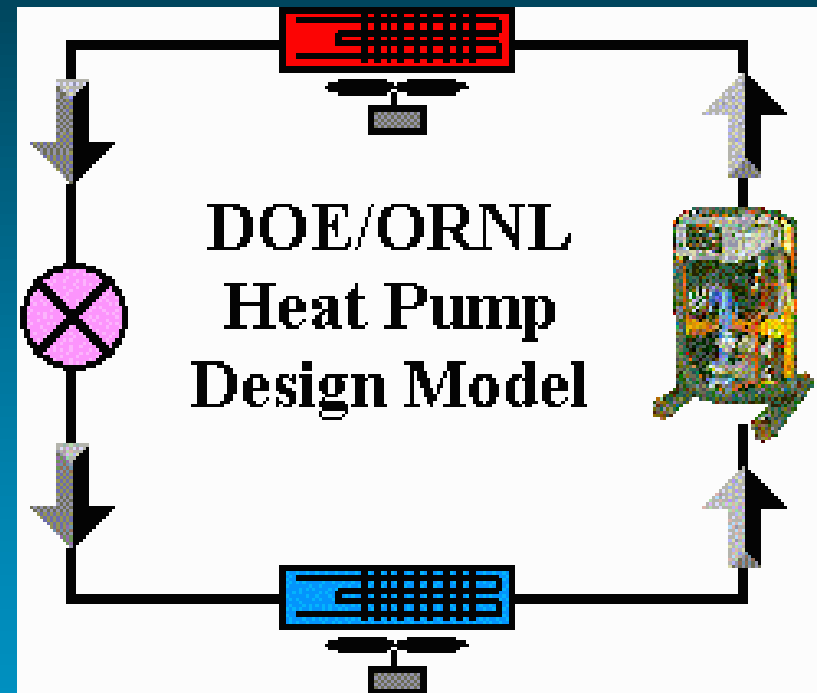
Outline - First Part

- **HPDM History**
- **General Capabilities**
- **HX Assumptions**
- **Solution Approach**
- **Application Modeling**
 - Design Analysis
 - Off-Design Simulation
- **Flow Control Types**



Outline - Second Part

- **Web-Based Models**
 - Sample Demo Run
 - Parametrics
- **Mark VI Changes**
- **Results – HP Test Case**
- **Mark 7 Development**



HPDM History

- MIT Origin (Hiller 76)
- Initial ORNL Version (78)
- Mark III (85), PC
- Mark IV (91), PC, Var-Speed, Params.
- **Mark V (94-96), PC/Web**
- **Mark VI (98-04), Web**
- **Mark 7 (Under Development)**

General Capabilities

- **Air-to-Air Heat Pumps**
 - **Steady-State Cooling and Heating**
 - **Hardware-Based Representations**
 - **Fin-and-Tube HXs**
 - **Compressor Performance Maps**
 - **Single- or Variable-Speed Compr/Fans**
 - **Explicit or Implicit Flow Controls**
 - **Fixed Cycle Arrangement**

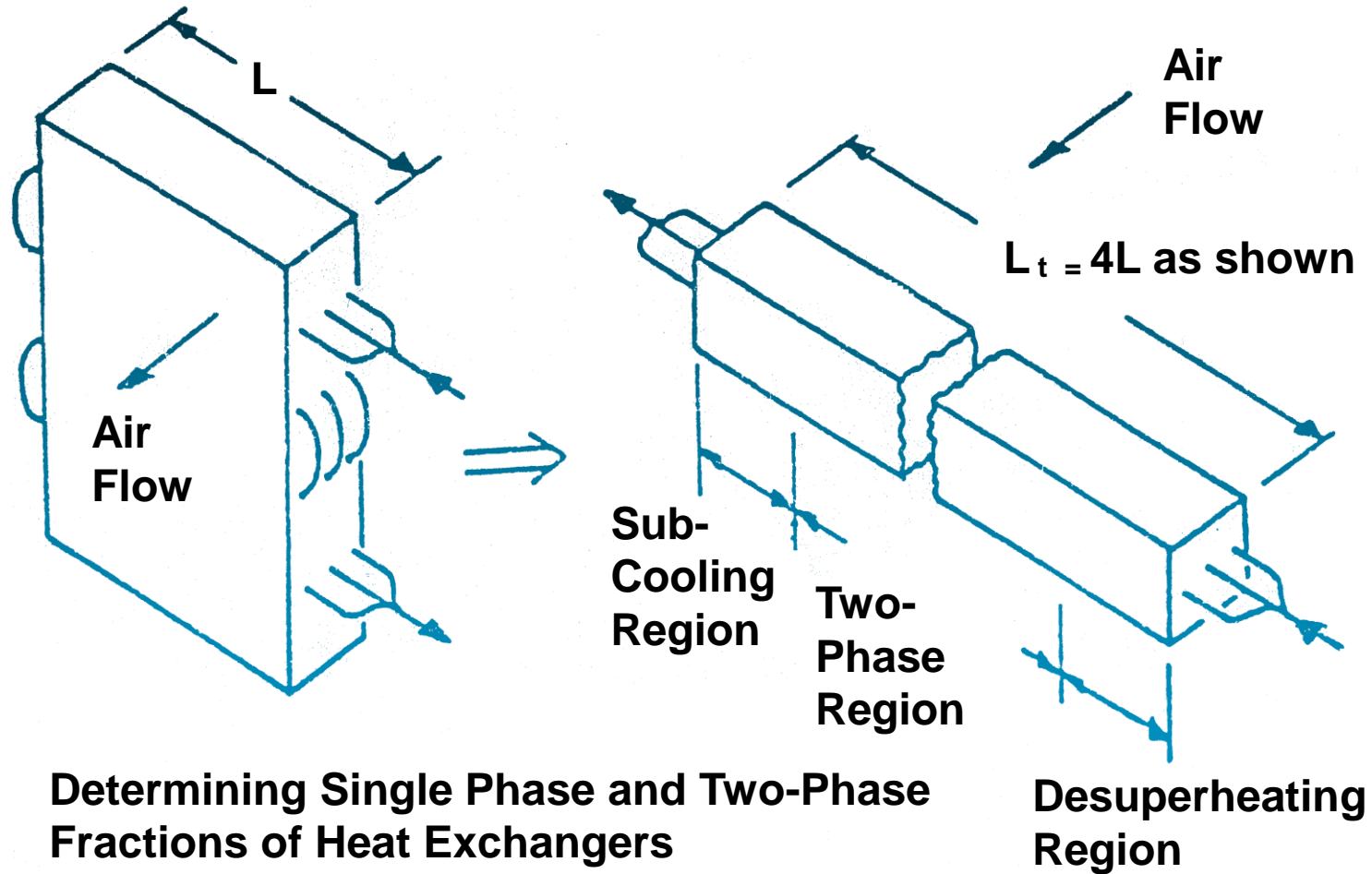
Design/Simulation Capabilities

- **Design or Off-Design Analysis**
 - **Charge Inventory Calculation or Balancing**
- **Sizing Options**
 - **For compressors and flow controls**
- **1- or 2-Variable Parametrics**
 - **Ambient control options**
 - **ex., SH or SC as a $F(\text{ambient})$**

HX Assumptions

- **Region-by-Region Refr.-Side Analysis**
 - **For Heat Transfer and Pressure Drop**
 - **3-Region Condenser, 2-Region Evap**
 - **Crossflow Treatment of Airflow**
 - **Airflow Across Single-Phase Regions Determined by Refr. Fraction**

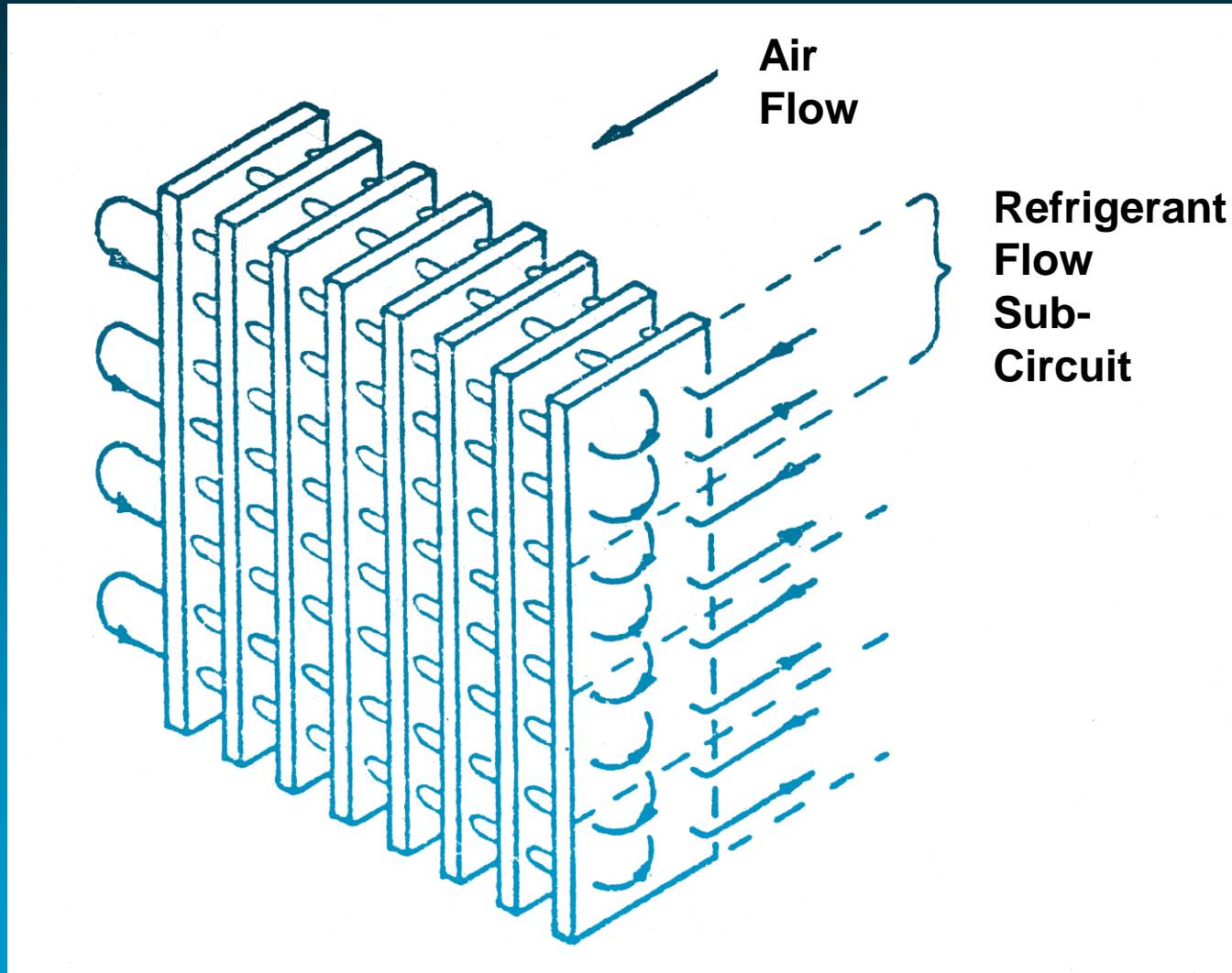
Determining Refrigerant Region Fractions



HX Assumptions

- **Parallel Equivalent Circuits**
 - **Equal Flow Split**
 - **Single Circuit Analysis**
 - **Much Faster than Tube-by-Tube**
 - **But More Idealized**
 - **No Circuit Branching**
 - **Assumes a Well-Balanced HX Design**
 - **With 2-Phase Refr. Regions Dominant**
 - **Diff. Regions See Same Inlet Air**
 - **or 1-phase is ahead of two-phase**

Finned Tube Heat Exchanger With Parallel Circuits And Single-Phase Regions on Leading Edge



HX Assumptions

- **Air-to Refrigerant H.T. Within Regions**
 - **Effectiveness/NTU Relations**
 - **Single-Phase Regions**
 - **Many-Row Unmixed on Both Sides (Mark V)**
 - **1-to-N-Row Crossflow (Mark VI)**
 - **Two-Phase Regions**
 - **Use Two-Phase Temp. At Average Pressure**
 - **Flow Configuration Independent**

Solution Approach

- **Successive Substitution (Sequential)**
 - **Specify**
 - **Inlet Air Temps**
 - **HX Exit Conditions/Control**
 - **Or Design Charge in Place of One Condition**
 - **Guess Saturation Temps**
- **Generally Fast, Stable Convergence**
 - **Always Solving a Real System**
 - **Easier to Trace Problems That May Occur**

Solution Approach

- **Charge Independent Solution**
 - **Specify Inlet Temps, Evap. Exit Superheat**
 - **Adjust Sat. Temps until**
 - **High-Side Convergence on**
 - **Exit Subcooling -- if sizing flow controls**
 - **Mass flow -- if flow control specified**
 - **Low-Side Convergence on**
 - **Specified Inlet Temp**
 - **At Specified Exit Superheat**
 - **Determine Required Charge (optional)**

Solution Approach

- **Charge Dependent Solution**
 - **Specify Refrigerant Charge**
 - **In Place of One HX Exit Location**
 - **Guess Cond SC or Evap SH for This Location**
 - **Adjust Sat. Temps for Hi-/Lo-Side Bal**
 - **Find Charge for Gussed SC or SH**
 - **Iterate SC or SH until Required Charge is Matched**

Application Modeling

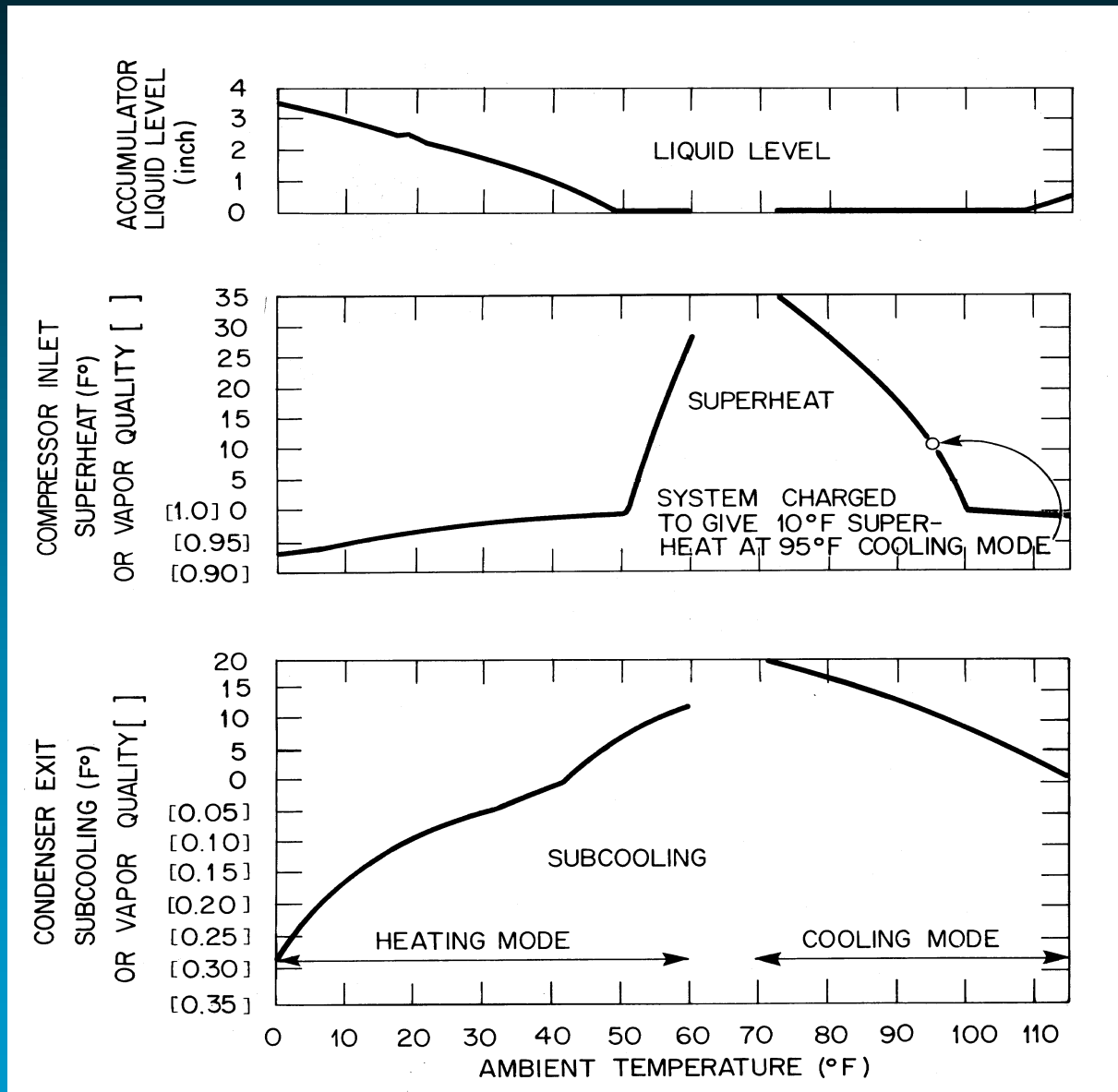
- **Design Analysis**
 - **Specify for Application**
 - Design Ambient Conditions
 - Design Values of SC and SH
 - **And (optionally) Design Capacity**
 - **Calculate**
 - Required Charge and Flow Control Sizes
 - **And (optionally) Required Compressor Size**
 - Design Condition Performance with Given HXs

Application Modeling

- **Off-Design Simulation**
 - **Specify for Application**
 - **Off-Design Ambient Conditions**
 - **Design Charge and Flow Control Type/Size**
 - **Compressor Size**
 - **Calculate**
 - **Cond SC and Evap SH**
 - **Off-Design Performance with Given Equipment**

Cap Tube Flow Control -- Fixed Charge w Accum

Similar But Smaller SH/SC Trends with Short-Tube Orifice



Flow Control Types

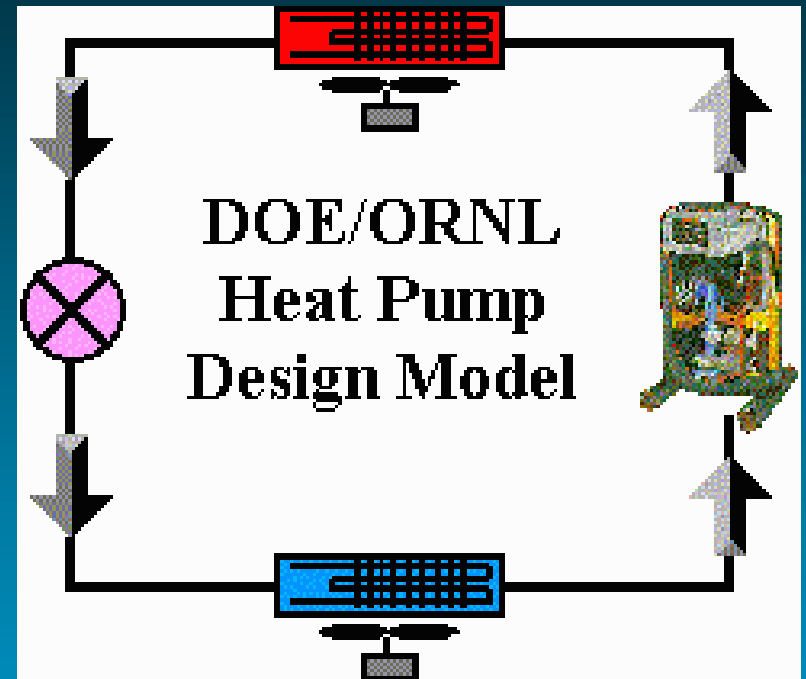
- **Explicit**
 - **Capillary Tube(s)**
 - with fixed SH or charge
 - **Short-Tube Orifice(s)**
 - with fixed SH or charge
 - **Thermal Expansion Valve (TXV)**
 - **Fixed Opening**
 - if used with fixed SH
 - **Variable Opening (often unstable conv.)**
 - if fixed charge

Flow Control Types

- **Implicit**
 - **SH/SC Control**
 - **fixed SH and SC**
 - **(simplest way to approx. TXV, TEV)**
 - **SH/Charge Control**
 - **fixed SH and SH**
 - **(can be used as TXV model)**
 - **SH/SC Programmed Control**
 - **SC and/or SH controlled as $F(\text{ambient or speed})$**
 - **SC Control (can give conv. instabilities)**
 - **fixed charge and SC (SH may vary widely)**

Web-Based HPDM

- **Mark V & VI**
- **Fully Accessible Online from Any Web Browser**
- **Exportable Data Sets**
 - Input & Output
- **Design and Operating Parametrics**
- **Online Plots/Tables**



Web Address

www.ornl.gov/~wlj/hpdm/MarkVI.html

DOE Web Site for Software Tools

OFFICE OF **BUILDING** TECHNOLOGY, STATE AND COMMUNITY PROGRAMS

CATEGORIES

- Building Energy Software Tools

FEATURED TOOLS

blast

Whole Building Analysis

- Energy Simulation
- Load Calculation
- Renewable Energy
- Retrofit Analysis
- Sustainability/ Green Buildings

Envelope Systems

HVAC Equipment and Systems

Lighting Systems

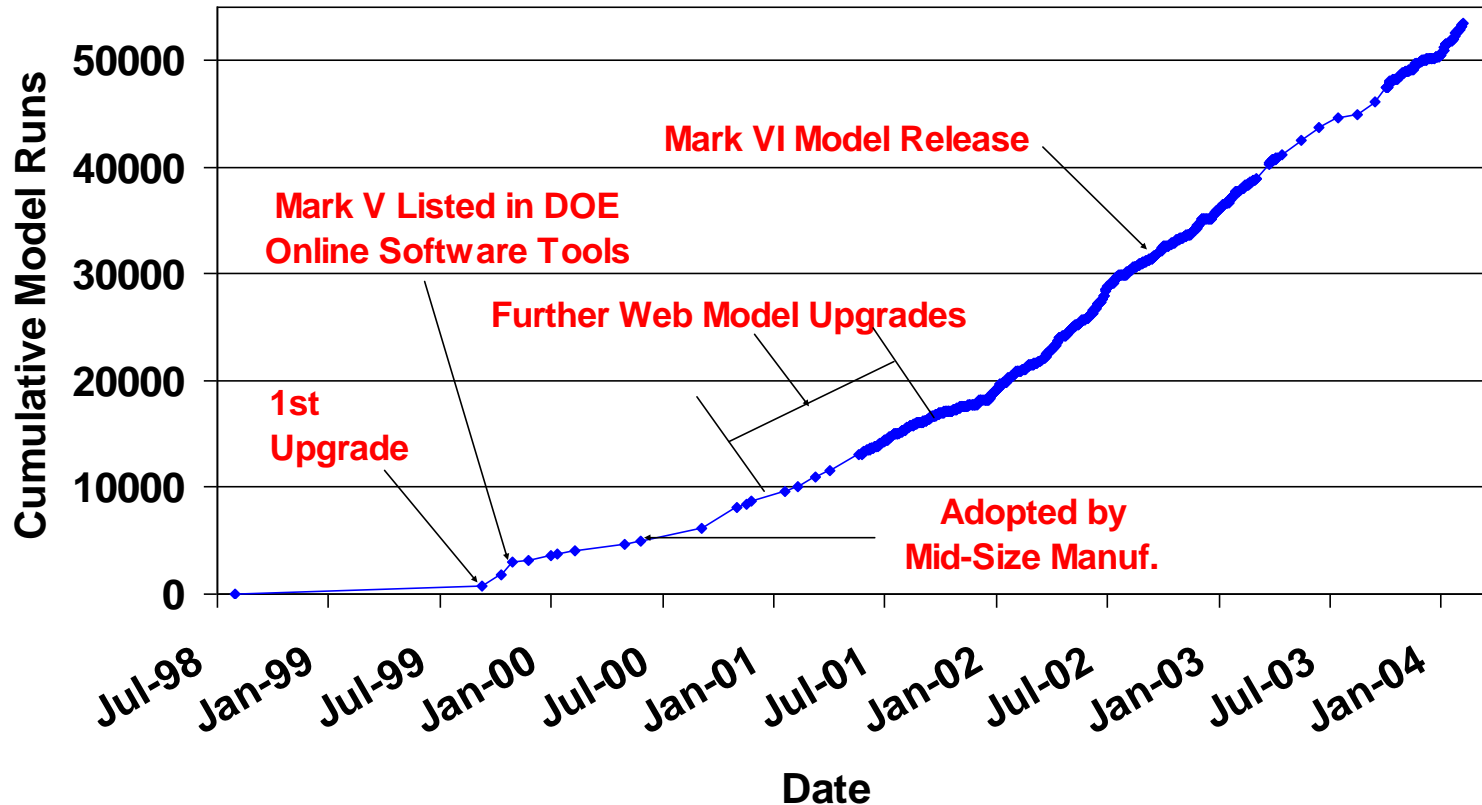
Materials, Components, Equipment & Systems

Web Address

http://erendev.nrel.gov/buildings/tools_directory/

Web Version of HPDM Has Seen Steady Use in Recent Years

15,000 Uses of Web Model in 2003, 55,000 Since Launch

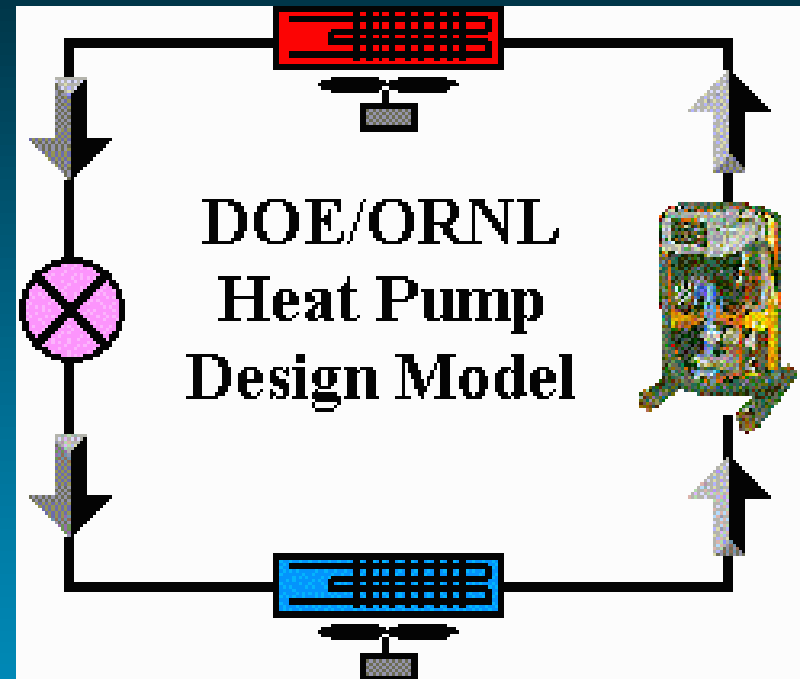


Online Demo of Web Version

- **Model Walk Through**
 - **Overview of Input Sheets for Sample HP**
 - **Design Condition Case**
 - **View Cycle Output**
 - **Setup Charge/Flow Control Values for Off-Design Run**
 - **Run Off-Design Ambient Parametrics**
 - **View Output Options**

Web-Based HPDM

- **Fully Accessible Online from Browser**
- **Exportable Data Sets**
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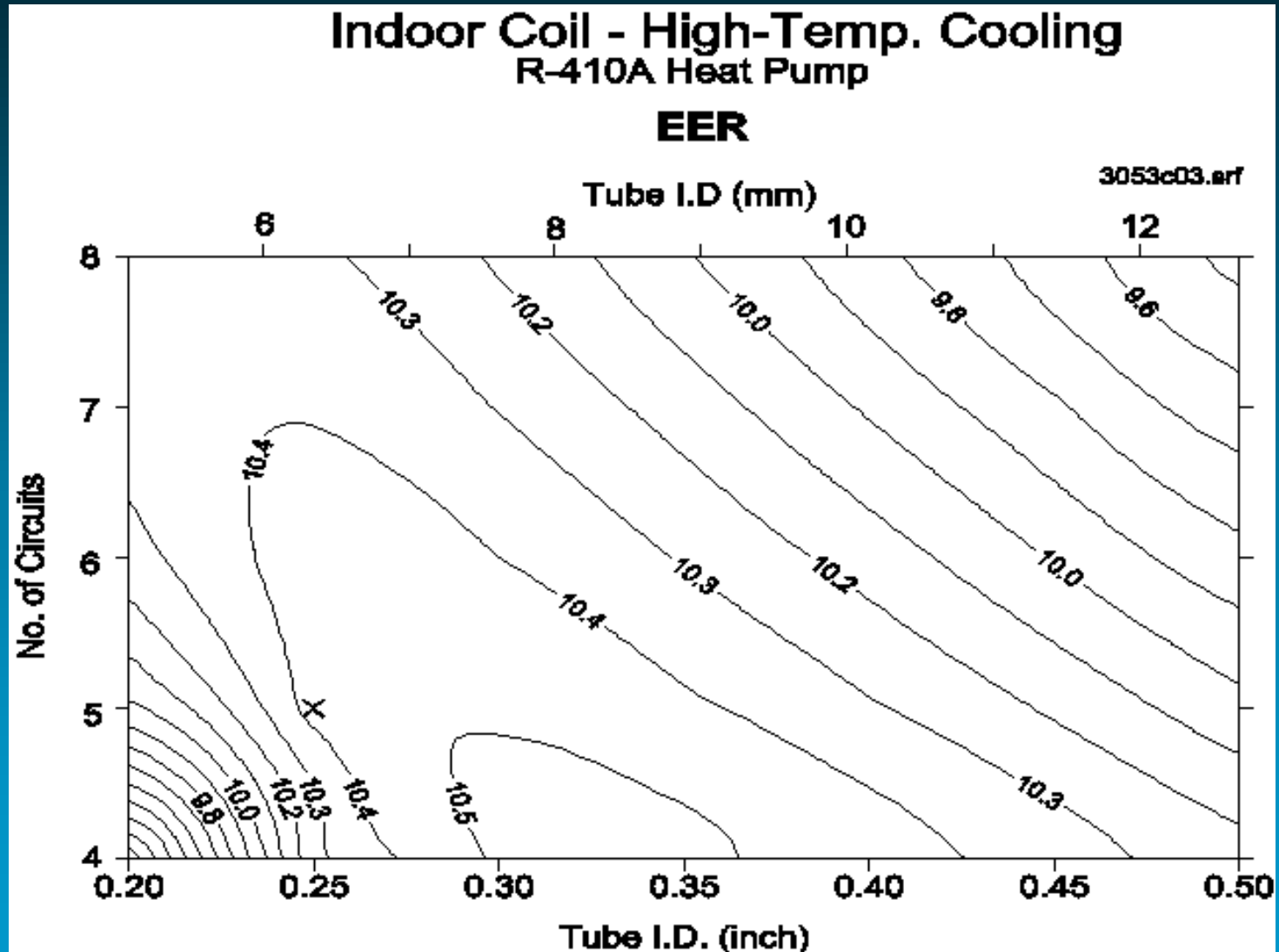
Available Web Versions

[Original Mark V](#)

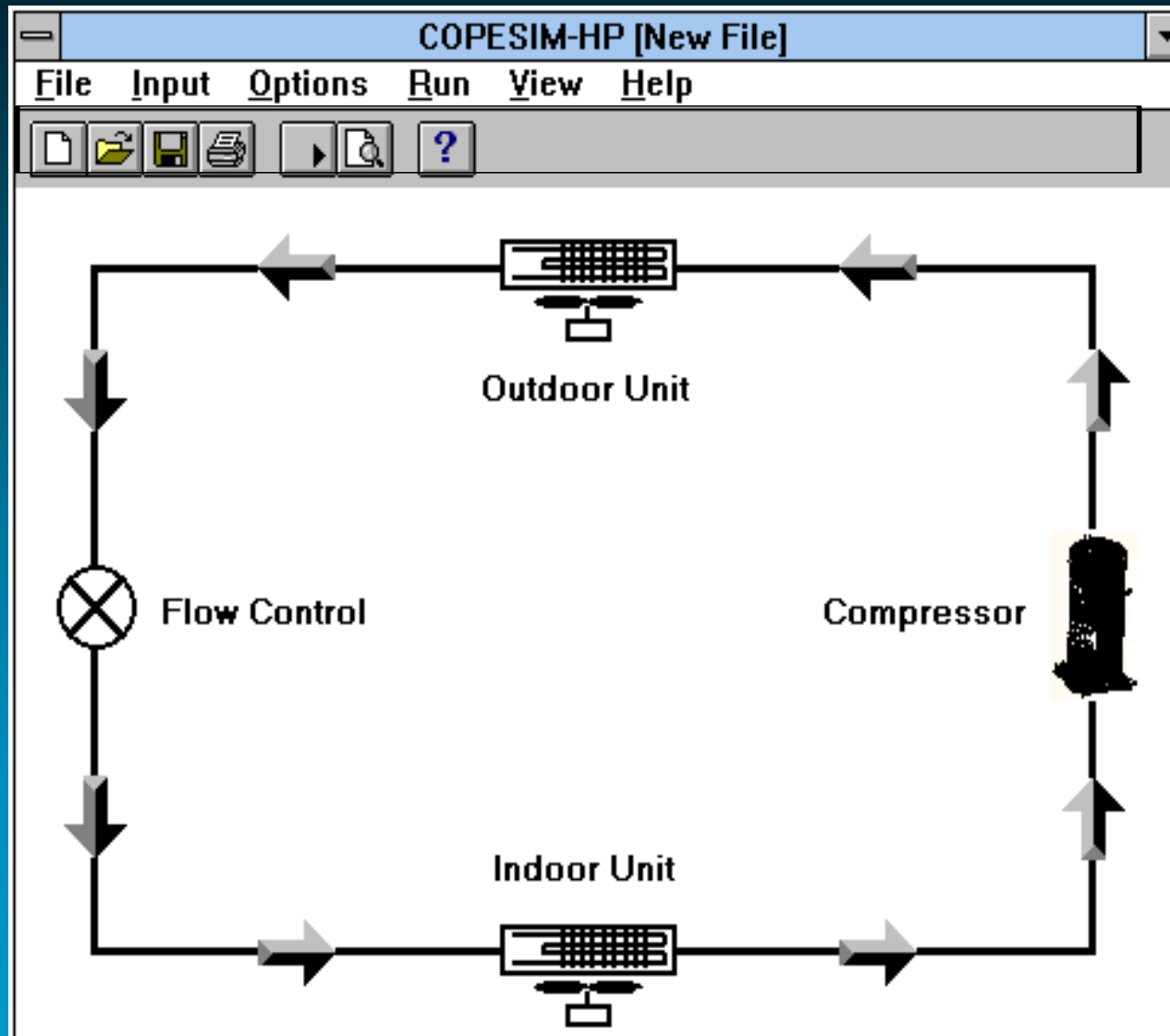
[New Mark VI](#)

Two-Variable Design Parametrics

EER for a Range of Tube Ids and Circuits



Not a fan of this? Not a fan of this?



Search for Compressor

Compressor Database

Compressor Search Criteria

Type
 Recip
 Scroll

Nom. Capacity
3-Ton

Hertz
 50
 60

Phase
 Single
 Three

Voltage
230

Refrigerant
 R-22
 R-410A

Search Database

Compressor Selection

Models Found
3

ZP35K3E-PFV
ZP36K3E-PFV
ZP38K3E-PFV

Select Compressor

Model
ZP36K3E-PFV

Revision Date
6/27/96

Performance At 20°F Superheat And 15°F Subcooling

	45°F/130°F	45°F/100°F	30°F/110°F
Capacity (btu/hr)	36200.0	44770.8	31011.8
EER (btu/Wh)	9.80	18.40	10.84

OK
Cancel
Help

