Harnessing Competition to Advance Air-Conditioner Technology

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Brought to You by the US Department of Energy

- Office of Energy Efficiency and Renewable Energy
  - Building Technology Program
  - Federal Energy Management Program
- In Partnership with the Defense Logistics Agency

Rooftop Air-Conditioners

The Market for Unitary Air-Conditioners

- Packaged cooling systems serve about 15 Billion ft^2
- 2 million out of 4.6 million air-conditioned buildings in the U.S.
- Sales in the 65-135 kBtu/hr capacity range totaled approx. 200,000 units annually

Rooftop Air-Conditioner Opportunity

- Annual energy use: approx. 700 trillion Btu (70 Terawatt-hours)*
- Manufacturers indicated that EER 13 to 14 is possible if significant numbers of buyers are serious about minimum life-cycle cost

* DOE Energy Policy Act Screening Analysis: 65-240 kBtu/h

The High Cost of Low Efficiency

- When we started, about 14% of available equipment models were considered high efficiency (EER >11.0)
- Most buyers opt for lower efficiency models with lower first cost
- Owners or occupants pay the higher operating costs which exceed the incremental cost of more efficient equipment over time

Technology Options

- Increased effective heat transfer surface area
- Increased effective heat transfer coefficient
- Improved compressor efficiency
- Improved fan efficiency
- Improved capacity control
- Electronic expansion device
- Liquid overfeed technology

Technology Procurement Approach

- Organize large volume buyers and market influencers
- Develop technical specifications in cooperation with buyers and manufacturers
- Issue competitive solicitation requesting bids for products meeting/exceeding specifications
- Select one or more winning products and enter into Basic Ordering Agreements (BOA's)
- Marketing and sales promotion

"You Mean You Just Ask?"

Nobel laureate Richard P. Feynman

Buyers

Interest in purchasing or promoting higher-efficiency equipment expressed by:

- National accounts (Wal*Mart, 7-Eleven, McDonalds)
- Armed services (Defense Logistics Agency)
- ESCO's (Siemens, Enron)
- Energy efficiency/market transformation programs (NY State Energy R&D Authority, Consortium for Energy Efficiency)

Request for Proposals

- Drafted RFP in consultation with Defense Logistics Agency and other buyers
  - Detailed minimum specifications
  - Life-cycle cost formula and simulator
- RFP Issued, January 2002

Evaluation Criteria

- Equipment must meet Consortium for Energy Efficiency (CEE) Tier II levels:
  - Min. EER 11.0
  - Min. IPLV 11.4
- Winners selected based on minimum life cycle cost
- LCC will be scaled by the total capacity yielding a normalized LCC in $/kBtu/hr

Life-Cycle Cost Computation

LCC = P+7.61×E

- P = Price
- E = Annual Electricity Cost
- 10% Discount Rate
- 15 Year Economic Life

HIGH EFFICIENCY UNITARY AIR CONDITIONER TECHNOLOGY PROCUREMENT
ENERGY USE INPUT FORM

INSTRUCTIONS

Step 1: Input your company name, the equipment model number, and ARI rated net capacity in cells "D14," "D15," and "D16."
Step 2: Input first stage capacity (or total capacity for single compressor unit) in Column "P."
Step 3: If your unit has two stages, input total capacity for both stages combined in Column "Q."
Step 4: Input the kW of the supply fan only in Cells "R22" to "S25." The input kW required during economizer operation is for the supply fan operating under the prescribed minimum external pressure in ARI Standard 210/240-94.
Step 5: Input the kW at each temperature bin only for the 1st stage operating in the remainder of Column "R."
Step 6: Input the kW at each temperature bin for all stages operating in the remainder of Column "S."

Manufacturer: ABC Manufacturing
Model Number: ABC120-A1
ARI Net Rated Capacity: 100 kBtuh

Weather Conditions				Cooling Load			Economizer		1st Stage Cooling			All Stages Cooling			INPUTS: Cooling Capacity		INPUTS: Power		
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Outdoor Temperature 5°F Increments	Coincident Wet Bulb Temperature, °F	Outdoor Temperature Difference	Seasonal Cooling Hours, TMY	Sensible Heat Gain, kBtu/h	Ventilation Heat Gain, kBtu/h	Total Heat Gain, kBtu/h	Economizer Cooling Capacity kBtu/h	Remaining Load After Economizer	Duty Factor	Cycling Efficiency	% Run-time	Duty Factor	Cycling Efficiency	% Run-time	1st Stage Capacity (kBtu/h)	All Stages Capacity (kBtu/h)	System Power Input 1st Stage (kW)	System Power Input All Stages (kW)	kWh
50	43.8	0	314	4.1	-15.3	-11.1	-152.6	0.0	0.000	0.000	0.000	0.000	0.000	0.000			2.20	2.20	691
55	47.1	5	347	12.4	-12.7	-0.3	-127.4	0.0	0.000	0.000	0.000	0.000	0.000	0.000			2.20	2.20	763
60	52.4	10	408	20.7	-8.3	12.4	-83.3	0.0	0.000	0.000	0.000	0.000	0.000	0.000			2.20	2.20	898
65	56.9	15	383	29.0	-4.2	24.8	-42.0	0.0	0.000	0.000	0.000	0.000	0.000	0.000			2.20	2.20	843
70	61.6	20	376	37.3	0.5	37.8	0.0	37.8	0.554	0.889	0.624	0.000	0.000	0.000	68.20	136.40	3.33	6.66	1092
75	66.1	25	609	45.6	5.5	51.1	0.0	51.1	0.763	0.941	0.811	0.000	0.000	0.000	67.00	134.00	3.66	7.31	2058
80	69.3	30	606	53.8	9.4	63.3	0.0	63.3	0.956	0.989	0.967	0.000	0.000	0.000	66.15	132.30	3.85	7.70	2300
85	71.7	35	419	62.1	12.5	74.7	0.0	74.7	1.000	1.000	1.000	0.143	0.786	0.182	65.30	130.60	4.05	8.09	2004
90	74.5	40	133	70.4	16.4	86.8	0.0	86.8	1.000	1.000	1.000	0.360	0.840	0.429	63.80	127.60	4.34	8.68	825
95	76.9	45	10	78.7	19.9	98.6	0.0	98.6	1.000	1.000	1.000	0.567	0.892	0.636	62.90	125.80	4.64	9.27	76
																	Total Annual Energy Use		11549

Assumptions
Capacity and electricity consumption shall be measured in accordance with ARI Standard 210/240-94.
The indoor-side air quantity shall be a constant 30.0 scfm per 1000 Btu/h [60.4 SL/s per 1000 W] of rated capacity delivered when operating against the minimum external resistance specified in 5.1.3.6 of ARI 210/240-94.

Winners: Lennox Industries

Model	Btu/hr	EER	IPLV	Price
LCA090H	90,000	11.3	12.0	$2,990
LCA102H	101,000	11.2	12.0	$3,390
LCA120H	120,000	11.0	11.8	$3,990

Winners: Global Energy Group

Model	Btu/hr	EER	IPLV	Price
PH007C	88,000	13.5	13.9	$4,325
PH010C2	115,000	13.4	14.0	$5,525

Activity Over Past Year

- Ordering agreements with winners for commercial sales
- Defense Logistics Agency made winners available to Federal purchasers through their Maintenance Repair and Operations program (http://www.dscp.dla.mil/gi/mro/)
- Promoted purchases in coordination with DOE, utility, state and regional programs
- Publicized the procurement through trade journals and newsletters

WWW.PNL.GOV/UAC

Cost Estimator: Background

- Stemmed from the spreadsheet tool used to evaluate the UAC Technology Procurement
- Takes local climate and part-load efficiency into account
- Fulfills a need for economic analysis with better energy use modeling
- Relatively simple, non-technical inputs
- Access to national 30-year weather data

Cost Estimator: Basics

- Web-based at http://www.pnl.gov/uac/cost-estimator.stm
- For 1-stage or 2-stage equipment
- Based on specific climate conditions for 237 US cities
- Estimates LCC, simple payback, rate of return, savings-to-investment ratio

Alternative Approaches

FLEOH (Full Load Equivalent Hours)

- Pros
  - Requires only FLEOH's and EER's
  - Simple and easy to use
- Cons
  - Oversimplified and imprecise
  - One stage only
  - Doesn't account for part-load operation
  - FLEOH's must be specified to reflect climate

Alternative Approaches (Continued)

Hourly Simulations
(DOE-2, BLAST, EnergyPlus, etc.)

- Pros
  - Accurate
  - Able to model a wide range of systems and conditions
- Cons
  - Complicated, time consuming
  - User must have detailed knowledge of building, equipment, and hourly atmospheric data

Alternative Approaches (Ours)

Temperature Bin

- Pros
  - Compromise between simple and complex
  - Reasonable estimate without complexity of hourly simulation
- Cons
  - Not enough detail for sophisticated modelers
  - Requires aggregated atmospheric data and part-load efficiency curves

Comparative Benefits of the Cost Estimator

- Offers more refined results than simplified tools
- Web-based
- Easy to use (don't have to be an engineer)
- Provides for comparison between two pieces of equipment
- Provides several different financial indicators

Uses for Utilities and Customers

- Supports programs promoting high-efficiency rooftop AC products
- Helps customers "see" energy and financial benefits
- Helps overcome "first cost" and "simple payback" mentality

Cost Estimator: Assumptions

- Unit performance modeled using ASHRAE 90.1-1989 Cost Budget Method Equipment Performance Curves
- "Binned" temperature and humidity conditions based on typical meteorological year (TMY) weather data averaged over 30 years for each city

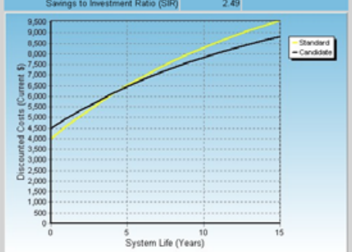
Cost Estimator: Assumptions (Continued)

- Building assumed to be 100% loaded at the TMY 97.5 percentile temperature
- Building loading assumed to be linear function of outdoor temperature
- Indoor and outdoor humidity ratios assumed equal

Data Input Form

UAC COST ESTIMATOR	Home	Submit	Restore
Welcome to the Unitary Air Conditioner (UAC) energy and cost savings estimator.	State	MO	MO
This estimator simulates the energy usage of both a high efficiency and a standard efficiency air conditioner. It then compares their energy and economic performance.	City	KANSAS CITY	Kansas City
To run the estimator, characterize the two systems and their environment using the controls on this page. Then click the 'submit' button. Use your browser 'back' button to return from the results page to this control page. Use the 'restore' button to change all values back to the defaults shown in the far right column.	Schedule	M-Fri, 7 a.m. to 7 p.m.	M-F 7a.m.-7p.m.
Help on each control can be found by moving the mouse cursor over the question mark near the controls name. Note: this help feature works best in the Microsoft Internet Explorer browser.	Indoor Temperature	75 °F	75 °F
	Enable Economizer	☑	Economizer enabled
	Total Capacity	84 kBtuh in 2 stages	84 kBtuh in 2 Stages
	Oversizing Factor	0 %	0%
	Candidate Unit	12 EER @ 4.5 k$	12 EER @ $4,500/unit
	Standard Unit	9 EER @ 4 k$	9 EER @ $4,000/unit
	Electric Utility Rate	0.08 $/kWhrs	0.08 $/kWhrs
	Nominal Discount Rate	10 %	10.0 %
	Escalation Rate	0 %	0.0 %
	Equipment Life	15 years	15 years
	Number of Units	1 units	1 unit
	Show bin calculations	☐	Hide bin calcs
	Chart present value	☑	Chart present value

RESULTS	Candidate	Standard	Savings
Annual Energy Consumption (kWhrs)	5,977	7,698	1,721
Annual Operating Cost ($)	478	616	138
15 Year Life Cycle Cost ($)	8,825	9,571	746
Annualized Cost ($)	976	1,058	82
Net Present Value ($)	746		
Simple Payback (yrs)	3.6		
Rate of Return (%)	27.5		
Savings to Investment Ratio (SIR)	2.49		



BIN CALCULATIONS

ODB	OWB	OH	OHR	IHR	IWB	IRH	IH	Hours	NV-Gain	V-Gain	T-Gain	E-Cap	Load	CapCF	LF1	C-Eff1	RT1	LF2	C-Eff2	RT2	PowCF	E_COff	E_COn
60.0	51.2	21.2	0.0063	0.0063	57.2	32.9	24.9	197	12.7	-4.6	8.1	-41.3	0.0	1.025	0.000	0.000	0.000	0.000	0.000	0.000	0.676	175	0
65.0	56.4	24.4	0.0081	0.0081	60.1	42.2	26.8	223	23.1	-3.1	20.1	-27.6	0.0	1.043	0.000	0.000	0.000	0.000	0.000	0.000	0.745	198	0
70.0	61.4	27.8	0.0101	0.0101	63.1	52.5	29.0	248	33.6	-1.5	32.1	-13.9	18.2	1.065	0.407	0.852	0.478	0.000	0.000	0.000	0.812	168	337
75.0	64.2	29.9	0.0108	0.0108	64.2	56.4	29.9	241	44.1	0.0	44.1	0.0	44.1	1.057	0.994	0.998	0.996	0.000	0.000	0.000	0.854	108	717
80.0	67.8	32.7	0.0123	0.0123	66.3	64.0	31.5	323	54.6	1.5	56.1	0.0	56.1	1.064	1.000	1.000	1.000	0.256	0.814	0.314	0.906	99	1,346
85.0	72.8	37.1	0.0152	0.0152	70.0	78.5	34.6	240	65.1	3.1	68.2	0.0	68.2	1.102	1.000	1.000	1.000	0.473	0.868	0.544	0.974	49	1,263
90.0	75.8	40.0	0.0167	0.0167	71.8	86.0	36.3	170	75.6	4.7	80.2	0.0	80.2	1.108	1.000	1.000	1.000	0.724	0.931	0.778	1.019	17	1,078
95.0	77.3	41.5	0.0169	0.0169	72.1	87.2	36.5	52	86.0	6.2	92.3	0.0	92.3	1.086	1.000	1.000	1.000	1.023	1.000	1.023	1.049	0	386
100.0	76.8	40.9	0.0153	0.0153	70.1	78.9	34.7	4	96.5	7.8	104.3	0.0	104.3	1.026	1.000	1.000	1.000	1.421	1.000	1.421	1.069	0	36

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DEFINITIONS

ELV : Elevation at specified location
P : Standard pressure corrected for elevation
S&I : Solar and Internal gains
ODB : Outside dry bulb (F)
OWB : Outside mean coincident web bulb (F)
OH : Outside enthalpy (Btu/lb dry air)
OHR : Outside humidity ratio
IHR : Inside humidity ratio
IWB : Inside wetbulb (F)
IRH : Inside relative humidity (%)
IH : Inside enthalpy (Btu/lb dry air)
HOURS : Number of hours that this outside condition occurs during the s
NV-GAIN : All loads excluding ventilation (kBtuh)
V-GAIN : Ventilation load
T-GAIN : Total load
E-CAP : Economizer capacity. This is based on the fan capacity (reduce
LOAD : The remaining net load after economizer is considered.
CAP_CF : DOE-2 capacity correction factor to account for operating cond
LF1 : Load fraction for stage 1 (Load / Available capacity)
C-EFF1 : Partload efficiency degredation factor for stage 1
RT1 : Runtime for stage 1 = LF1 / C-EFF1
LF2 : Load fraction for stage 2 (Load / Available capacity)
C-EFF2 : Partload efficiency degredation factor for stage 2
RT2 : Runtime for stage 2 = LF2 / C-EFF2
PowCF : DOE-2 system power correction factor to account for operating c
E_COff : System energy consumption when compressor is off, i.e. inside
E_COn : System energy consumption when compressor is on (kWhrs)

Recent Enhancements

- Advanced settings
  - Outside air ventilation rate
  - Inside relative humidity
  - Ratio of sensible to total load
  - Enthalpy control
- Specific equipment data from DOE UAC Technology Procurement “winners”

Design Features


Unitary Air Conditioner
Technology Procurement

Design Features

This section compares standard or accepted practice with advanced practice in the manufacture, installation, and maintenance of unitary rooftop air conditioners. Our technical specifications call for best performance with lowest possible life-cycle cost. Many different features can contribute to decreased life-cycle cost, including measures to improve energy efficiency, make regular maintenance easier, and protect the unit for long-term operation. Click on the features listed below to view accepted practices, contrasted with advanced measures.

Feature	Accepted Practice	Advanced Practice
Access Panels	Separate access panels attached with sheet metal screws Panels removed during servicing are susceptible to being blown from rooftops, endangering people and property. Here, a removable panel leans against the rooftop unit while the technician checks the unit.	Hinged access panels and tie-back retaining devices permanently attached to the rooftop unit Hinged panels allow access while remaining attached to the unit, thus eliminating the risk of blowing away. The latch holds the panel open for convenience and safety.

Access Panels


Conventional: Panels removed during servicing

Improved: Hinged panels allow access while remaining attached

Filter Replacement Access


Conventional: Access panels requiring tools to open them

Improved: This access panel can be opened without tools

Dirty Filter Indication

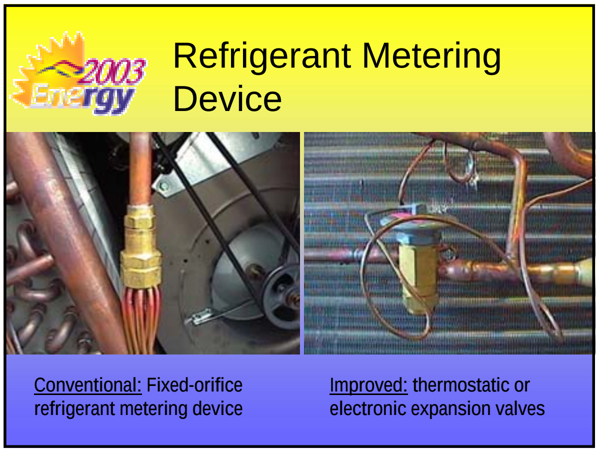

Conventional: These filters have been neglected for years

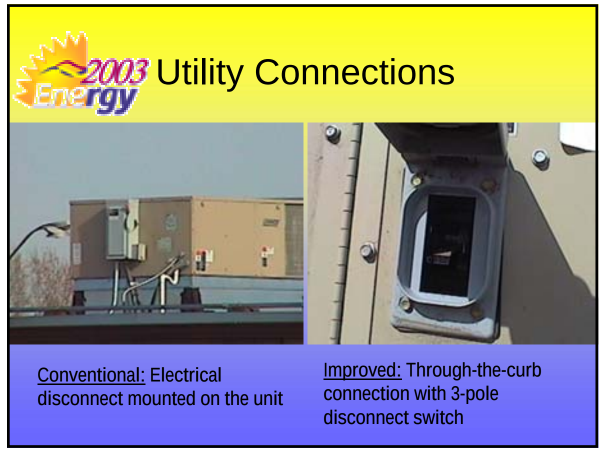
Improved: A dedicated differential pressure switch is available to sense a clogged filter

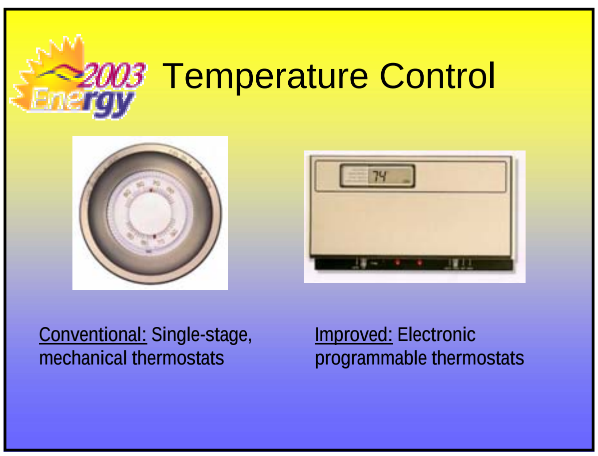
Condensate Drain Pan


Conventional: Many existing units still have steel condensate drain pans

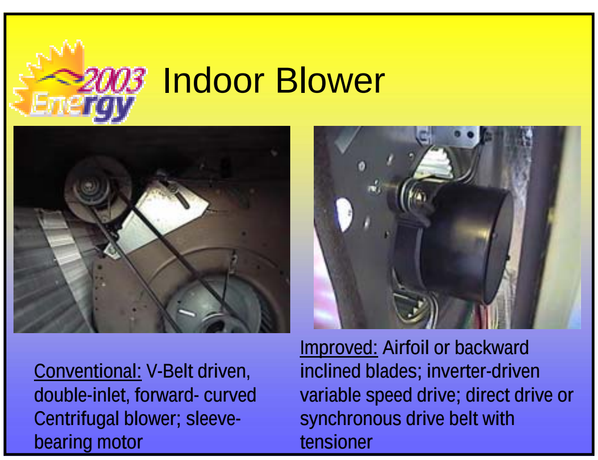
Improved: Condensate drain pans made of corrosion-resistant materials and sloped to assure proper drainage

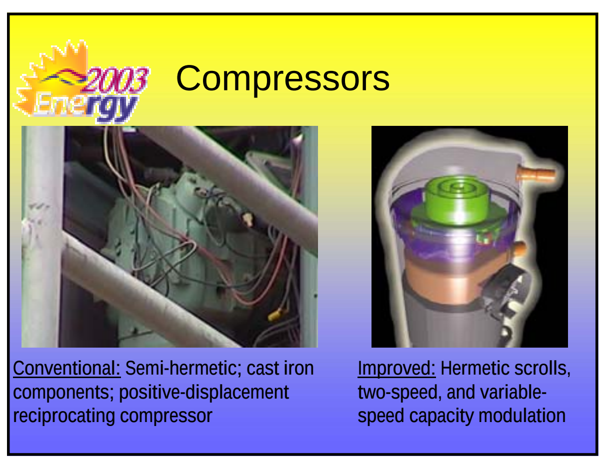

2003 Energy
Refrigerant Metering Device
Conventional: Fixed-orifice refrigerant metering device
Improved: thermostatic or electronic expansion valves


2003 Energy
Utility Connections
Conventional: Electrical disconnect mounted on the unit
Improved: Through-the-curb connection with 3-pole disconnect switch


2003 Energy
Temperature Control
Conventional: Single-stage, mechanical thermostats
Improved: Electronic programmable thermostats


2003 Energy
Ventilation Air
Conventional: Manually adjustable outside air damper
Improved: Fully integrated economizer


2003 Energy
Indoor Blower
Conventional: V-Belt driven, double-inlet, forward- curved Centrifugal blower; sleeve-bearing motor
Improved: Airfoil or backward inclined blades; inverter-driven variable speed drive; direct drive or synchronous drive belt with tensioner


2003 Energy
Compressors
Conventional: Semi-hermetic; cast iron components; positive-displacement reciprocating compressor
Improved: Hermetic scrolls, two-speed, and variable-speed capacity modulation

Heat-Exchanger Technology

Conventional: Copper or aluminum tubing with aluminum plate fins attached at 10 to 16 fins-per-inch

Improved: Advanced materials and configurations

Cabinet Exterior Finish

Conventional: Darker colors absorb heat from sunlight

Improved: Lighter finishes for higher albedo

Refrigerant Circuits/ Load Tracking

Conventional:

Single refrigerant circuit;
single capacity system

Improved:

Dual electrically and mechanically independent refrigerant circuits;
multiple capacity system

Motor Efficiency

Conventional:
Standard-efficiency motors

Improved:
High-efficiency motors

Refrigerant Pressure Control

Conventional:
No valve to prevent equalization when the compressor goes off

Improved:
Solenoid or check valves to prevent equalization

High Humidity Control

Conventional:
Higher efficiency is sometimes achieved by raising evaporator temperatures, making the air conditioner less effective in removing humidity.

Improved:
Rotating desiccant wheels can absorb additional moisture from the air in high humidity applications.

Contact Information

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