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# UNITARY AND ROOM AIR-CONDITIONERS

by

J. E. Christian

ICES
INTEGRATED COMMUNITY ENERGY SYSTEMS

TECHNOLOGY EVALUATIONS

Prepared by:

Oak Ridge National Laboratory
Operated by Union Carbide Corporation
for the U. S. Energy Research and Development Administration

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J. E. Christian
Oak Ridge National Laboratory

Project Manager
Thomas J. Marciniak
Energy and Environmental Systems Division
Argonne National Laboratory

September 1977



Prepared for

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

by

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
Operated by
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## FOREWORD

The Community Systems Program of the Division of Buildings and Community Systems, Office of Energy Conservation, of the United States Department of Energy (DOE), is concerned with conserving energy and scarce fuels through new methods of satisfying the energy needs of American Communities. These programs are designed to develop innovative ways of combining current, emerging, and advanced technologies into Integrated Community Energy Systems (ICES) that could furnish any, or all, of the energy-using services of a community. The key goals of the Community System Program then, are to identify, evaluate, develop, demonstrate, and deploy energy systems and community designs that will optimally meet the needs of various communities.

The overall Community Systems effort is divided into three main areas: (a) Integrated Systems, (b) Community Planning & Design, and (c) Implementation Mechanisms. The *Integrated Systems* work is intended to develop the technology component and subsystem data base, system analysis methodology, and evaluations of various system conceptual designs which will help those interested in applying integrated systems to communities. Also included in this program is an active participation in demonstrations of ICES. The *Community Planning & Design* effort is designed to develop concepts, tools, and methodologies that relate urban form and energy utilization. This may then be used to optimize the design and operation of community energy systems. *Implementation Mechanisms* activities will provide data and develop strategies to accelerate the acceptance and implementation of community energy systems and energy-conserving community designs.

This report, prepared by Oak Ridge National Laboratory, is part of a series of Technology Evaluations of the performance and costs of components and subsystems which may be included in community energy systems and is part of the Integrated Systems effort. The reports are intended to provide sufficient data on current, emerging and advanced technologies so that they may be used by consulting engineers, architect/engineers, planners, developers, and others in the development of conceptual designs for community energy systems. Furthermore, sufficient detail is provided so that calculational models of each component may be devised for use in computer codes for the design of Integrated Systems. Another task of the Technology Evaluation activity is to devise calculational models which will provide part-load performance and costs of components suitable for use as subroutines in the computer codes being developed to analyze community energy systems. These will be published as supplements to the main Technology Evaluation reports.

It should be noted that an extensive data base already exists in technology evaluation studies completed by Oak Ridge National Laboratory (ORNL) for the Modular Integrated Utility System (MIUS) Program sponsored by the Department of Housing and Urban Development (HUD). These studies, however, were limited in that they were: (a) designed to characterize mainly off-the-shelf technologies up to 1973, (b) size limited to meet community limitations, (c) not designed to augment the development of computer subroutines, (d) intended for use as general information for city officials and keyed to residential communities, and (e) designed specifically for HUD-MIUS needs. The present documents are founded on the ORNL data base but are more technically oriented and are designed to be upgraded periodically to reflect changes in current, emerging, and advanced technologies. Furthermore, they will address the complete range of component sizes and their application to residential, commercial, light industrial, and institutional communities. The overall intent of these documents, however, is not to be a complete documentation of a given technology but will provide sufficient data for conceptual design application by a technically knowledgeable individual.

Data presentation is essentially in two forms. The main report includes a detailed description of the part-load performance, capital, operating and maintenance costs, availability, sizes, environmental effects, material and energy balances, and reliability of each component along with appropriate reference material for further study. Also included are concise data sheets which may be removed for filing in a notebook which will be supplied to interested individuals and organizations. The data sheets are colored and are perforated for ease of removal. Thus, the data sheets can be upgraded periodically while the report itself will be updated much less frequently.

Each document was reviewed by several inividuals from industry, research and development, utility, and consulting engineering organizations and the resulting reports will, hopefully, be of use to those individuals involved in community energy systems.

ABSTRACT

The scope of this technology evaluation on room and unitary air conditioners covers the initial investment and performance characteristics needed for estimating the operating cost of air conditioners installed in an ICES community. Cooling capacities of commercially available room air conditioners range from 4,000 Btu/h to 36,000 Btu/h; unitary air conditioners cover a range from 6,000 Btu/h to 135,000 Btu/h. The information presented is in a form useful to both the computer programmer in the construction of a computer simulation of the packaged air-conditioner's performance and to the design engineer, interested in selecting a suitably sized and designed packaged air conditioner.

# TECHNOLOGY EVALUATION SUMMARY SHEET OF

UNITARY AND ROOM AIR CONDITIONERS

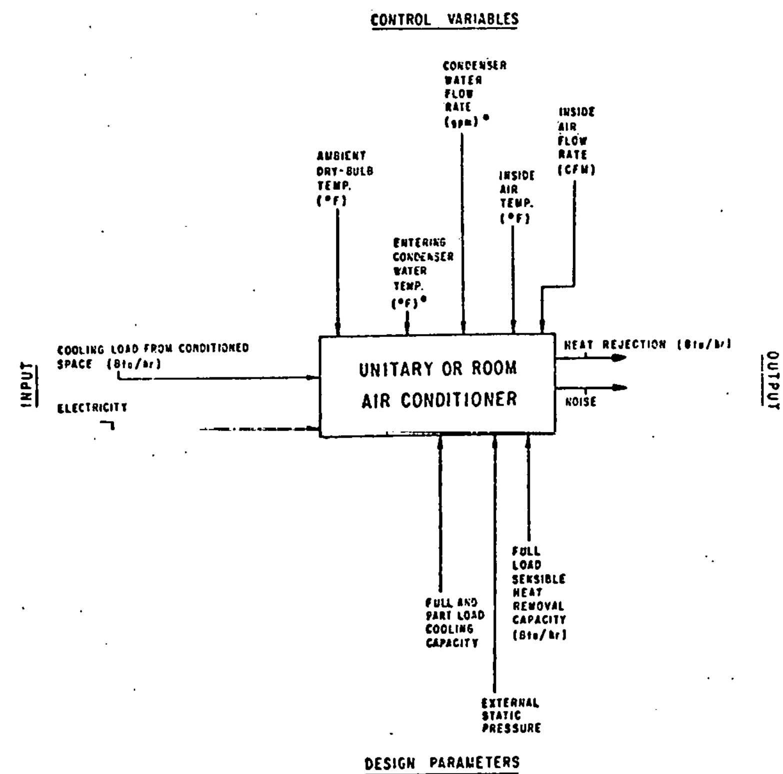
By: J. E. Christian, ORNL September, 1977

## 1 INTRODUCTION

A room air conditioner is defined as a single packaged unit which discharges cooled air directly into the conditioned space; by comparison, the unitary air conditioner generally is designed with fan capability for duct work.

Commercially available room air-conditioner units range in cooling capacity from 4,000 to 36,000 Btu/h. Unitary air conditioners covered here range in cooling capacity from 6,000 to 135,000 Btu/h.

Figure DS-1 shows a schematic of the variables needed to describe the full- and part-load performance of packaged air conditioners.




*APPLIES TO WATER COOLED UNITS ONLY

Fig. DS-1 Schematic of Packaged Air-Conditioning Equipment

ICES TECHNOLOGY EVALUATION

Size selection is based on the following:

1. outdoor design temperature,
2. indoor design temperature,
3. total estimated cooling load,
4. condensing medium and temperature,
5. air delivery requirements, and
6. external static pressure.

Other selection criteria which should be considered are:

1. humidity control, and
2. efficiency (Energy Efficiency Ratio, EER, is the total Btu/h of cooling capacity per input power expressed in watts).

## 2 MATERIAL AND ENERGY BALANCE

The average Energy Efficiency Ratio (EER) for both room and unitary air conditioners, presently available, is about 7.0 Btu/Wh. EER values vary with the manufacturer, and there is no apparent correlation of EER vs capacity. Units are available with EERs ranging from 4.8 to 11.6.

The nameplate EER for air-cooled, packaged air conditioners is estimated by testing the units at room air temperatures of 80°F db and 67°F wb, and outside air of 95°F db and 75°F wb. The EER varies as a function of the environmental control variables.

### 2.1 EFFECT OF VARYING THE DRY-BULB TEMPERATURE

The EER at various ambient dry-bulb temperatures for a typical air conditioner can be estimated by Eq. DS-1 and DS-2. The unit is assumed to have a nameplate EER of 7.0 Btu/Wh. Equation DS-1 approximates the EER of an air conditioner with a continuously operating fan; Eq. DS-2 approximates the EER of a unit with an automatic cycling fan.

$$\% \text{ of nominal EER} = -31{,}317.4 + 1408.9\,(T) - 23.754\,(T)^2 + 0.17836\,(T)^3 - 0.000503\,(T)^4 \qquad \text{(Eq. DS-1)}$$

$$\% \text{ of nominal EER} = 1352.] - 39.45\,(T) + 0.4243\,(T)^2 - 0.001555\,(T)^3 \qquad \text{(Eq. DS-2)}$$

Where:

T = ambient temperature, °F db

## 2.2 EFFECT OF VARYING THE INDOOR WET-BULB TEMPERATURE

If the indoor wet-bulb temperature is higher or lower than 67°F, the correction factors shown in Table DS-1 can be used to adjust the EER accordingly.

Table DS-1 Correction Factors for Various Wet-Bulb Temperatures

| Entering Indoor Air Wet-Bulb Temp. (°F) | Correction Factors | | |
|---|---|---|---|
| | Total Cooling Capacity | Sensible Total Cooling Capacity | EER |
| 63 | 0.93 | 1.26 | 0.96 |
| 67 | 1.0 | 1.0 | 1.0 |
| 71 | 1.06 | 0.75 | 1.02 |

## 2.3 EFFECT OF VARYING THE NOMINAL EXTERNAL STATIC PRESSURE

The higher the external static pressure on the indoor fan of unitary air conditioners, the more electrical power will be required to provide the same amount of cooling. The external static pressure varies according to the amount of resistance resulting from the duct arrangement. Equation DS-3 approximates the increasing amount of electric power required by a unitary air conditioner indoor fan. The nominal external static pressure varies from 0.1 to 0.3 in. of water, depending on the capacity of the individual unit. The electric fan consumes about 10% of the total air-conditioner power requirement.

$$P_F = P_{F^\circ} \, (0.856 + 0.00144 \, EP) \qquad \text{(Eq. DS-3)}$$

where:

$P_F$ = fan power, Watt
$P_{F^\circ}$ = nominal fan power, Watt
$EP$ = % of nominal external static pressure.

## 2.4 EFFECT OF VARYING FAN OPERATION

The seasonal EERs of models with continuously operating fans were, on the average, 8.5% *below* the nameplate EER; whereas, the seasonal EER of models with automatic fans were, on the average, 10.2% *above* the nameplate value.

## 3 OPERATING CONSIDERATIONS

### 3.1 CAPACITY CONTROL

Room and unitary air conditioners generally are operated by an on-off switch controlled by a built-in, adjustable thermostat.

### 3.2 ENVIRONMENTAL IMPACT

The major environmental concern in the installation and operation of an air-conditioning unit is noise that could be unacceptable in sensitive areas.

## 4 COST CONSIDERATIONS

The economic life of a room or unitary air conditioner is estimated to be 10 years. The equipment cost can be estimated by Eq. DS-4 for foom air conditioners with cooling capacities from 4,000 to 36,000 Btu/h and for unitary models from 6,000 to 135,000 Btu/h.

$$\begin{array}{c}\text{FOB}\\ \text{equipment}\\ (\$)\end{array} = 710 \left[\frac{\begin{array}{c}\text{desired}\\ \text{capacity}\\ \text{Btu/h}\end{array}}{24{,}000}\right]^{.8} \qquad \text{(Eq. DS-4)}$$

The installed cost of *room* air conditioners is estimated to be $31/ton plus the FOB cost obtained from Eq. DS-4. The total installed cost of *unitary* air conditioners can be estimated by Eq. DS-5 (all costs are in 1976 dollars).

$$\begin{array}{c}\text{Total}\\ \text{installed}\\ (\$)\end{array} = 1{,}290 \left[\frac{\begin{array}{c}\text{desired}\\ \text{capacity}\\ \text{Btu/h}\end{array}}{24{,}000}\right]^{.83} \qquad \text{(Eq. DS-5)}$$

Maintenance costs for both room and unitary air conditioners can be estimated by Eq. DS-6.

$$\begin{array}{c}\text{Maintenance}\\ \$/\text{year}\end{array} = 109 \left[\frac{\begin{array}{c}\text{capacity}\\ \text{Btu/h}\end{array}}{24{,}000}\right]^{.38} \qquad \text{(Eq. DS-6)}$$

## 5 POTENTIAL FOR IMPROVEMENT

It has been suggested that, as a current state of-the-art limit, the industry may be able to produce room air conditioners with an EER of about 13.5 Btu/Wh.

# TECHNOLOGY EVALUATION OF

UNITARY AND ROOM AIR CONDITIONERS

**Prepared by** J.E. Christian, ORNL

**Date** September, 1977

## 1 INTRODUCTION

### 1.1 DESCRIPTION

This technology evaluation considers commercially available room and unitary air conditioners. Room air conditioners -- defined as single packaged units, mounted in windows or through outside walls -- discharge cooled air directly into the conditioned space.

Unitary air conditioners are designed with fan capability for use with ducts, although some units may be applied to provide direct discharge into the conditioned space.

References 1 and 2 provide descriptive discussions of the many types of available unitary air-conditioner designs. A list of design variations found in unitary air conditioners is given below:

1. *heat rejection* — air-cooled, evaporative condenser, water cooled;
2. *unit exterior design* — decorative, functional for equipment room and ducts, weatherproofed for outside protection from the elements;
3. *style* — floor standing, wall-mounted, ceiling suspended, roof mounted, window;
4. *indoor air* — vertical upflow, downflow, horizontal, 90° and 180° turns, with fan or for use with forced-air furnace;
5. *locations* — (1) indoor unit (in duct work, concealed in closets, attics, basements, garages, utility rooms, or equipment rooms); (2) outdoor unit (rooftop, wall-mounted, or on concrete slab adjacent to the building).

Figure 1.1 shows a schematic of the variables necessary to describe the performance of packaged air-conditioning equipment. The relationships among the control, design, input, and output variables are presented in Sect. 2, *Material and Energy Balance*.

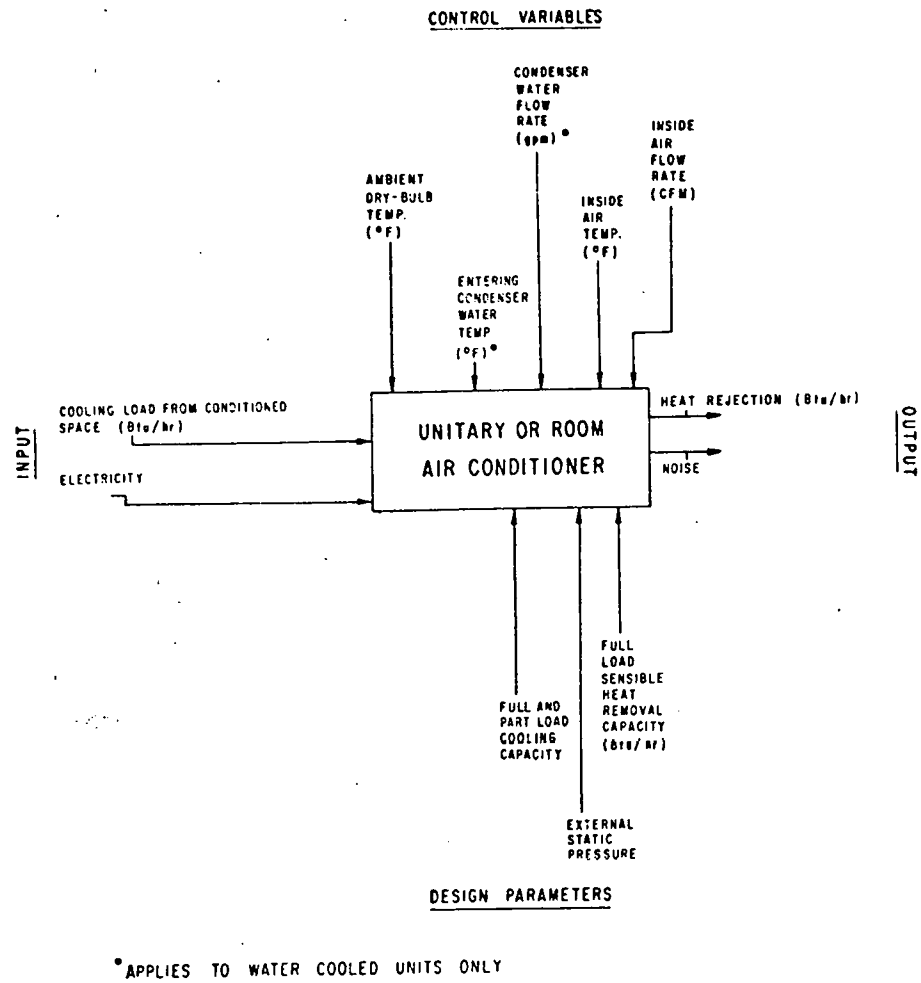



Fig. 1.1 Schematic of Packaged Air Conditioning Equipment

## 1.2 AVAILABLE SIZE RANGE

The cooling capacity of commercially available room air-conditioning units ranges from 4,000 to 36,000 Btu/h. The cooling capacity of unitary air conditioning units covered here ranges from 6,000 to 135,000 Btu/h.

## 1.3 SELECTION CRITERIA

### 1.3.1 Size

The required cooling capacity of an air-conditioning unit is determined by the following design conditions:

1. *Outdoor design temperature:*
   (a) Wet-bulb for water-cooled and evaporative condenser units.
   (b) Dry-bulb for air-cooled condensers.
   (A map of the wet-bulb design temperatures for heat rejection from air conditioning units is provided in the ICES Technology Evaluation of heat rejection equipment.)[3]
2. *Indoor design temperatures:* ASHRAE Standard 90-75 recommends 78°F for the indoor design condition where comfort air-conditioning is required.
3. *Total cooling load at design conditions.*
4. *Condensing medium and temperature.*
5. *Air delivery requirements.*
6. *External static pressure.*

To select an air-conditioning unit, an estimate must be made of the design cooling load for the space to be be conditioned. The cooling load is based on the design ambient temperature and the desired indoor conditions. After a cooling capacity is determined for design indoor and outdoor temperatures, the correlations of capacity vs operating variables can be used to convert the design cooling capacity to nominal rated capacity for a suitably sized unit that will meet the design conditions.

### 1.3.2 Humidity Control

From a humidity standpoint, a slightly undersized unit is preferable to an oversized unit. The undersized unit will keep the evaporator cold longer; this is necessary for good latent heat removal. An oversized unit cycles even during the hottest weather and will reevaporate moisture into the air while the compressor is off.

### 1.3.3 Efficiency

*Room air conditioners.* The Association of Home Appliance Manufacturers (AHAM) sponsors a certification program for room air conditioners, and almost all manufacturers and marketers of such units participate. The energy efficiency ratio (EER), which is defined as the unit's cooling capacity (Btu/h) divided by its power requirements (watts), for each room air conditioner listed is provided in the *Directory of Certified Room Air Conditioners.*[4] The test conditions used to measure EER are:

| | |
|---|---|
| room air temperature | 80°F db, 67°F wb; and |
| outside air temperature | 90°F db, 75°F wb. |

These test conditions are in compliance with American National Standard Z234.1 (AHAM Standard RAC-1).

The spread of EERs (efficiencies) found in the *April 1976 Association of Home Appliance Manufacturers' Directory of Room Air Conditioners*, ranges from 4.8 to 11.6 Btu/Wh. The high-efficiency unit would consume only 41% as much power as the low-efficiency unit to accomplish the same amount of cooling. Although there are numerous exceptions, most units have efficiencies between 6 and 8 Btu/Wh.

It has been shown[5] that there is no strong trend toward either higher or lower efficiency with increasing capacity and, except for two groupings of units, there is no marked difference in efficiencies for 115-volt vs 230-volt units. The two exceptions are units designed with 115 volts, 7.5 amps and 115 volts, 12 amps. The groupings result from manufacturers' efforts to produce units having large cooling capacity ratings that can be used with existing or easily added electrical circuits and still comply with the requirements of the National Electric Code (NEC).[6]

The smallest branch circuit rating permitted by NEC is 15 amps. The NEC requires that the amp rating of an air conditioner shall not exceed 50% of the circuit rating if lighting units or other appliances are also supplied by the circuit, and that the amp rating of an air conditioner shall not exceed 80% of the circuit rating if the circuit supplies nothing else.[5]

*Unitary air conditioners.* The efficiencies of most unitary air conditioners are listed in the *Air Conditioning and Refrigeration Institute (ARI) Directory of Certified Unitary Air Conditioners.*[7] All test conditions are in compliance with ARI Standard 210-75; room air temperature of 80°F db, 67°F wb, and outside air temperature of 95°F db and 75°F wb. The standard rating conditions for unitary air conditioners are the same as the AHAM tests for air conditioners.

The spread of EER ratings found in the June 30, 1977 *ARI's Directory for Air-Cooled Units* ranges from 4.9 to 10.3, and for the water-cooled units from 8.0 - 11.0. Figure 1.2 shows the spread of efficiencies of unitary air conditioners taken from the *ARI Directory.*[8] Visual inspection of Fig. 1.2 indicates the average EER of unitary air conditioning equipment is around 7 Btu/Wh. For some purposes, a more appropriate average might be one that is weighted by sales of each unit, but sales data were not available at the time of this report.

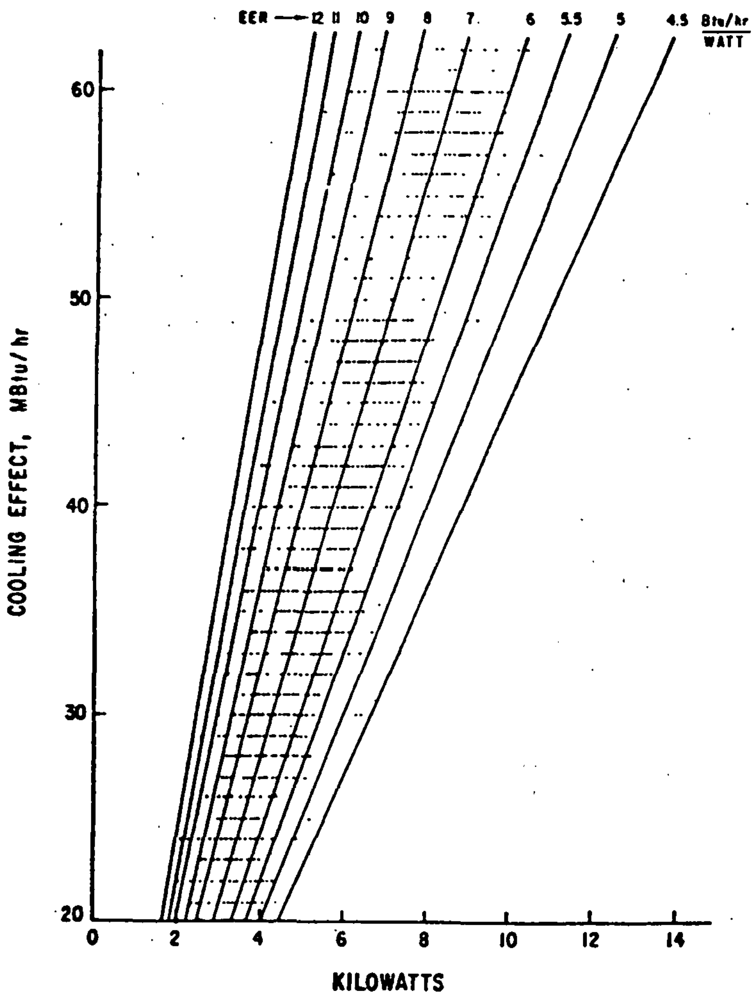



Fig. 1.2 Relative Efficiencies of Unitary Air Conditioners[8]

1.3.4 Location

In general, the unitary air conditioner is positioned where space is available and where adverse aesthetic and noise impacts will be minimized. If possible, the air conditioner should be located in a shaded area so as to improve the actual EER.

1.4 DIMENSIONS AND WEIGHT

Tables 1.1 and 1.2 show the dimensions and shipping weights, respectively, for various room and unitary air conditioners. The *room* air-conditioning units shown are all single-package and air-cooled; whereas, the *unitary* air conditioners shown are for both single-package and split systems. The split systems usually consist of: (1) the compressor and condenser contained in the outside component, placed on the roof or concrete slab adjacent to the building; and (2) the evaporator and indoor fan, contained in the inside component.

Table 1.1 Room Air-Conditioner Dimensions and Shipping Weights

| Nominal capacity (Btu/h) | Depth x width x height (ft) | Shipping weight (lb) |
|---|---|---|
| 4,000 | 1.6 x 1.6 x 1.1 | 75 |
| 6,000 | 1.7 x 1.7 x 1.1 | 87 |
| 12,000 | 2.0 x 2.0 x 1.3 | 147 |
| 18,000 | 2.3 x 2.2 x 1.6 | 220 |
| 24,000 | 2.3 x 2.2 x 1.6 | 220 |
| 30,000 | 3.0 x 2.3 x 1.7 | 287 |
| 36,000 | 3.1 x 2.3 x 1.7 | 330 |

1.5 ELECTRICAL REQUIREMENTS

1.5.1 Room Air Conditioners

Room air conditioners usually come equipped with line cords that may be plugged into standard or special electric circuits. Most units are designed to operate at 115, 208, 230, or 230/208 volts, single-phase, 60-cycle power. The maximum rating of a 115-volt unit generally is limited to either 7.5 or 12 ampere. Therefore, room air conditioners larger than 12,000 -- 14,000 Btu/h are designed as 208, 230, or 230/208-volt units with proper line cord and plug cap to plug into a 230-or 208-volt circuit.

Table 1.2 Unitary Air-Conditioner Dimensions and Shipping Weights

| Nominal capacity (Btu/h) | Length x Width x Height (ft) | Air Flow[a] | Shipping Weight (lb) |
|---|---|---|---|
| Single Package - air cooled | | | |
| 24,000 | 3.3 x 3.3 x 2.0 | H | 375 |
| 36,000 | 3.8 x 3.2 x 1.8 | H | 430 |
| 48,000 | 3.9 x 3.8 x 2.7 | H | 515 |
| 60,000 | 3.9 x 3.8 x 2.7 | H | 540 |
| 84,000 | 4.5 x 3.8 x 2.7 | H | 850 |
| | 2.5 x 4.4 x 5.9 | V | 850 |
| 120,000 | 2.7 x 4.4 x 5.9 | V | 1,000 |
| Single Package - water cooled | | | |
| 41,000 | 1.8 x 3.1 x 6.9 | V | 510 |
| 60,000 | 4.0 x 3.8 x 2.7 | H | 670 |
| 96,000 | 4.0 x 4.9 x 7.4 | V | 800 |
| 132,000 | 2.0 x 4.9 x 7.5 | V | 1,010 |
| Split System - air cooled | | | |
| 36,000 | | | |
| Indoor unit | 4.0 x 3.5 x 5.0 | V | 100 |
| Outdoor unit | 2.5 x 2.2 x 2.3 | | 210 |
| 60,000 | | | |
| Indoor unit | 4.0 x 4.0 x 5.0 | V | 200 |
| Outdoor unit | 2.5 x 2.2 x 2.9 | | 260 |

[a] H = horizontal; V = vertical

### 1.5.2 Unitary Air Conditioners

Unitary air conditioners usually are designed for 208, 230, or 230/208 volts; single- or three-phase; 60-cycle power. Generally, units under 50,000 Btu/h of cooling capacity are wired for single phase. Unitary air conditioners with capacities exceeding about 65,000 Btu/h usually are wired for three-phase current.

# 2 MATERIAL AND ENERGY BALANCE

With any given installations, the type of data required to determine seasonal performance varies significantly with the method of analysis. The simplest approach to estimate total power consumption would be to use an estimated seasonal EER for a "typical" application in the climate of interest along with seasonal cooling requirements. The seasonal EER is defined as the average efficiency of an installed unit operating over one complete cooling season. The electrical input includes power delivered to fans, controls, and the compressor.

Computer simulations could be used to obtain hourly performance based on heat gain within the conditioned space (the cooling load) and air conditioner capacity and EER based on actual indoor and outdoor temperatures. A more detailed computer simulation might distinguish between sensible and latent heat removal. With some installations, fan and compressor power may need to be determined separately. This section provides the detailed and seasonal performance data needed to meet the requirements of various methods of analyses.

## 2.1 FULL-LOAD PERFORMANCE AT NOMINAL CONDITIONS

There appears to be no strong trend toward either higher or lower efficiency with increasing capacity or when comparing room air conditioners with unitary air conditioners. An average EER presently available for both room and unitary air conditioners is about 7.0 Btu/Wh.[5] The FEA (now part of DOE) by law, was required to prescribe energy efficiency improvement targets for various appliance categories. The average energy efficiency targets to be achieved by 1980 for unitary and room air-conditioners are:[10]

| | FEA Avg. EER Target for 1980 |
|---|---|
| 1. Unitary central air conditioner | |
| a) Single package | 7.44 |
| b) Split systems | 8.64 |
| 2. Room air conditioners | 8.46 |

It is likely that there will be an improvement in the efficiency of the packaged air conditioner by 1980 resulting in an average EER of between 8.0 and 10.5. The more efficient units usually may have a higher initial capital cost; this incremental cost is discussed in Sect. 5, Cost Considerations.

The nominal test conditions used to assign EERs to all air-conditioning units consist of:

- 80°F db; 67°F wb indoor air;
- 95°F db; 75°F wb outside air for air-cooled units, and 75°F entering, 95°F exiting water for water-cooled units;
- Air flow across both evaporator and condenser not to exceed 37.5 cfm/1000 Btu/h;
- minimum external resistances.

Table 2.1 shows minimum external resistances at various standard cooling ratings.

Table 2.1 Minimum External Resistances at Various Standard Cooling Ratings

| Standard Cooling Rating (Btu/h) | Minimum External Resistance (in. of water) |
|---|---|
| Up through 28,000 | 0.10 |
| 29,000 through 42,000 | 0.15 |
| 43,000 through 70,000 | 0.20 |
| 71,000 through 105,000 | 0.25 |
| 106,000 through 134,000 | 0.30 |

At nominal test conditions, the fan motor requires about 10% of the total power requirement for an average unitary and room air-conditioner unit.

Sensible heat removal capacity at nominal conditions for most air conditioning appears to be about 70 -- 75% of the total rated cooling capacity; this ratio holds relatively fixed for varying outdoor air dry-bulb temperatures.

The performance of the water-cooled unitary air conditioners will vary with the temperature of the condenser water. The relationship between off-nominal conditions and the unit EER can be found in the ICES technology evaluation of *Compressive Chillers*.[11]

## 2.2 PERFORMANCE AT VARIOUS AMBIENT DRY-BULB TEMPERATURES

Figure 2.1 shows the EER variation with outdoor temperatures for air-conditioning units with continuous and automatic fan operation.[12]

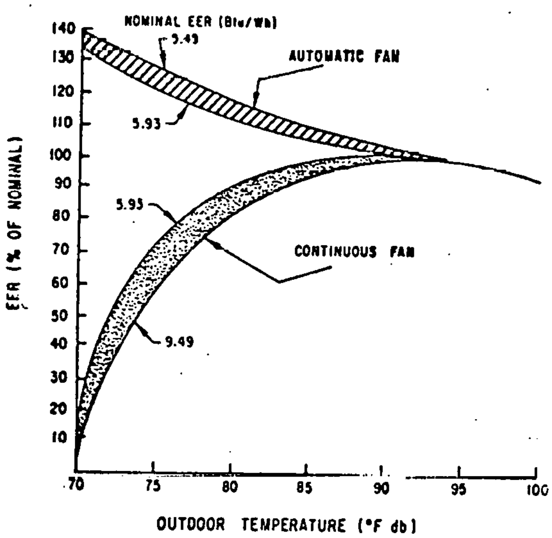



Fig. 2.1 Percent of the Nameplate EER (Btu/Wh) Vs Outdoor Temperature for Continuous and Automatic Fan Operation*

---

*Indoor Temperature = 78°F DB; 67°F WB

The lower set of curves represents typical air conditioners with a continuously operating fan. As the temperature drops, the cooling load inside the conditioned space decreases, and the compressor operates less frequently; yet the fan continues to operate and draws the same amount of power as when the compressor is running the full hour.

The top range of curves in Fig. 2.1 shows the EER of air-conditioning units with automatic fans that shut off when the thermostat trips off the compressor. The overall efficiency of units with automatic fans increases as the outside temperature decreases. The spread shown in this figure indicates that units with higher EERs are more adversely affected by the fan power requirements during the compressor off cycle than are the lower efficiency models.[12] Nameplate EER values corresponding to each edge of the curve bands are noted in Fig. 2.1.

Table 2.2 shows a set of coefficients of the generalized Eq. 2.1 which may be used to estimate the percent of nominal EER (Y) at various ambient dry-bulb temperatures (X, °F) for six representative air conditioners.

$$Y = A + BX + CX^2 + DX^3 + EX^4 \qquad \text{(Eq. 2.1)}$$

Table 2.2 Generalized Equation Coefficients - Percent of Nominal EER (Y) Vs Outdoor DB Air Temperature (X, °F)*

| Nameplate EER | Fan Operation | Coefficients A | B | C | D | E |
|---|---|---|---|---|---|---|
| 5.93 | Automatic | 2,036.1 | -63.90 | 0.71143 | -0.0026666 | 0.0 |
| | Continuous | -38,513.8 | 1,740.53 | -29.43770 | 0.2213540 | -0.00062424 |
| 7.0 | Automatic | 1,352.1 | -39.45 | 0.42430 | -0.0015555 | 0.0 |
| | Continuous | -31,317.4 | 1,408.9 | -23.754 | 0.17836 | -0.000503 |
| 9.49 | Automatic | 804.3 | -19.764 | 0.19333 | -0.0006666 | 0.0 |
| | Continuous | -25,936.5 | 1,156.3 | -19.350 | 0.1445 | -0.000406 |

*$70 \leq X \leq 100$

The units listed have nameplate EERs of 5.93, 7.0, and 9.49 and have two control schemes for operating the indoor blower: continuous operation and automatic shutoff.

Figure 2.2 shows that at lower outdoor dry-bulb temperatures, the capacity of the air conditioner increases. This increased capacity, along

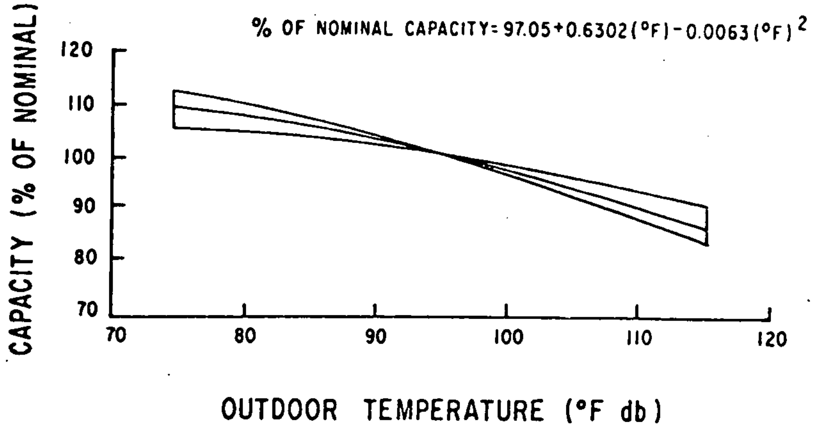



Fig. 2.2 Effect of Outdoor Temperature (°F DB) on Cooling Capacity of Various Room and Unitary Air Conditioners*

*Based on Fedders CTF 524-973 and Westinghouse UB-B2 performance data.

with a reduction in the cooling load with a lower outdoor DB temperature, means that the machine will cycle on and off more frequently. As the cooling load is decreased from 100%, the air conditioner will cycle more frequently, until the 50% load point; then the cycling on and off will decrease as the load falls below 50%. The effect of cycling (heat pump) compressors on and off has been investigated by Parken, Beausoliel, and Kelly at the National Bureau of Standards.[13] Their data suggest that with a cooling load of 15%, the EER is approximately 70% of the steady-state value at the same indoor and outdoor conditions. These results were obtained by experimenting with a heat pump operating in the cooling mode. However, it is believed that the results are applicable to reciprocating-type air conditioners as well. The performance curves shown in this section are based on several manufacturers' data.

## 2.3 PERFORMANCE AT VARIOUS INDOOR CONDITIONS

### 2.3.1 Wet-Bulb Variations

The performance curves shown in Figs. 2.1 and 2.2 are based on 67°F indoor wet-bulb temperature.[14] Table 2.3 provides correction factors for estimating the air conditioner total cooling capacity, sensible heat capacity, and EER at three different indoor wet-bulb temperatures.

Table 2.3 Correction Factors for Various Wet-Bulb Temperatures

| Entering Indoor Air Wet-Bulb Temp. (°F) | Correction Factors | | |
|---|---|---|---|
| | Total Cooling Capacity | Sensible Total Cooling Capacity | EER |
| 63 | 0.93 | 1.18 | 0.96 |
| 67 | 1.0 | 1.0 | 1.0 |
| 71 | 1.06 | 0.75 | 1.02 |

### 2.3.2 Dry-Bulb Variations

Figure 2.3 shows that the air conditioner sensible cooling capacity increases as the indoor dry-bulb temperature setting increases. The shaded area represents the variation found over six representative air-conditioning units.[14,15]

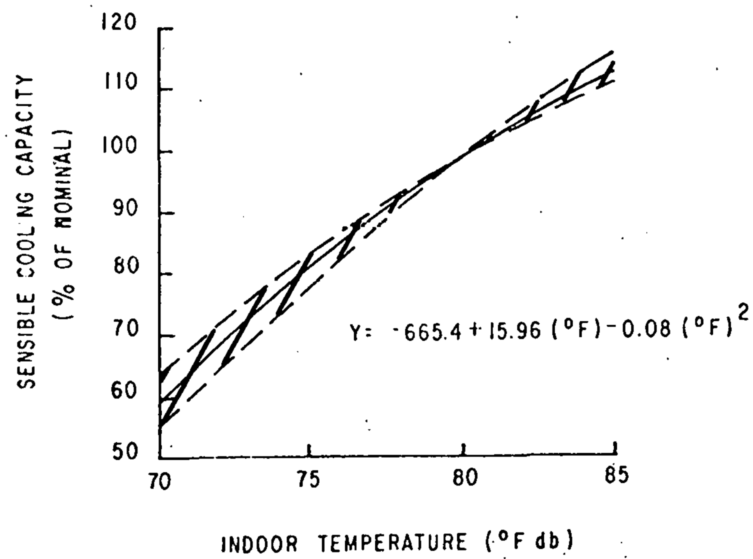



Fig. 2.3 Effect of Indoor Dry-Bulb Temperature on Sensible Cooling Capacity of Air-Conditioning Unit

## 2.4 FAN POWER

### 2.4.1 External Static Pressure

The nominal external static pressure, resulting from impelling air through an air duct and used to rate performance of the unitary air-conditioning unit, varies according to the unit cooling capacity as shown in Sect. 2.1. However, some installations may require a larger or smaller external static pressure on the evaporator fan.

Figure 2.4 shows a typical relationship between fan power and external static pressures.[15]

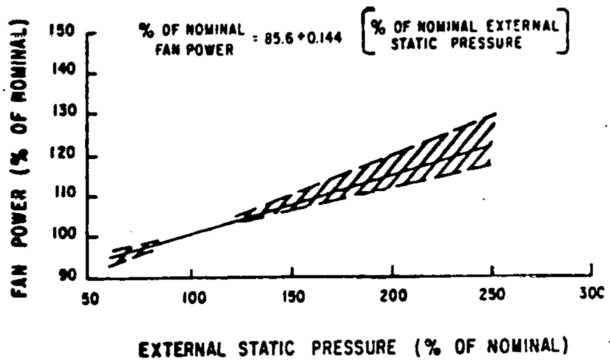



Fig. 2.4 Effect of External Static Pressure on Various Representative Evaporative Fans Installed in Unitary Air Conditioners

Assuming that the cooling capacity remains relatively constant, the EER can be adjusted for various external static pressures on the evaporator fan by assuming the fan power to be 10% of the total air-conditioner power requirement. The shaded area shown in Fig. 2.4 indicates the range found by examining a variety of representative air conditioner manufacturers' performance data.

2.4.2 Variable Speed Fan Motors

Figure 2.5 shows a representative relationship between fan speed and both fan power requirements and air flow.[15] The curve is based on one manufacturer's fan performance data.

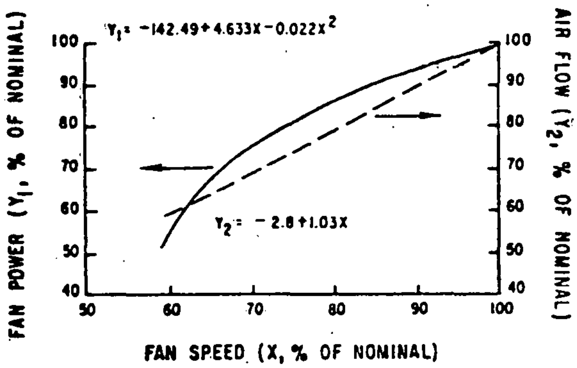



Fig. 2.5 Representative Effect of Fan Speed on Fan Power and Air Flow in a Unitary Air Conditioner

Figure 2.6 shows the effect on the air conditioner's EER of lower air flows past the evaporative coil.[15] At lower air flows, the EER drops. Thus, even though some fan motor electrical power is saved by operating the indoor fan at lower speeds, the total unitary air conditioner EER is reduced because the overall cooling capacity is reduced. However, lower fan speeds provide better humidity control and reduce noise.

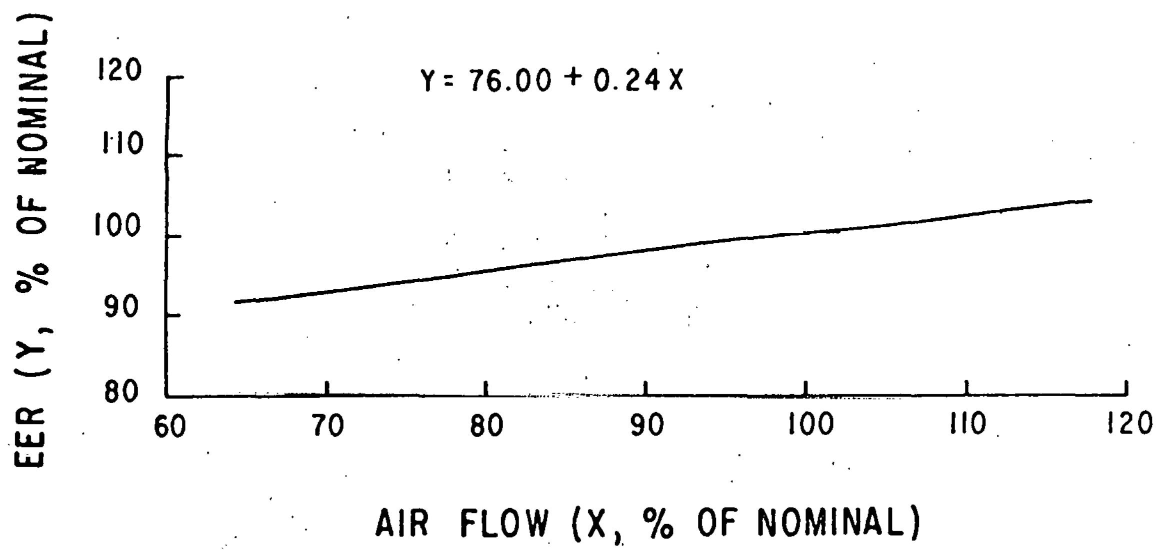



Fig. 2.6 Representative Effect on EER of Unitary Air Conditioner Indoor Air Flowrate

## 2.5 SEASONAL EERs

The performance has been simulated for four room air conditioners with various rated EERs installed in a typical single-family home in ten cities.[12] Table 2.4 shows the resulting seasonal EERs from the computer simulation for installations where the conditioned space is naturally ventilated at outdoor temperatures between 75° and 78°F and air conditioned at 78°F (and above).

Table 2.4 Seasonal EER for Several Cities[12]

| City | Unit A (5.45)[a] | | Unit B (9.22) | | Unit C (5.93) | | Unit D (9.49) | |
|---|---|---|---|---|---|---|---|---|
| | Continuous Fan | Automatic Fan | Continuous Fan | Automatic Fan | Continuous Fan | Automatic Fan | Continuous Fan | Automatic Fan |
| Atlanta | 5.2 | 6.0 | 8.3 | 10.5 | 5.8 | 6.6 | 8.8 | 10.9 |
| Chicago | 5.0 | 5.9 | 7.8 | 10.2 | 5.5 | 6.4 | 8.3 | 10.5 |
| Dallas | 5.1 | 5.8 | 8.1 | 10.0 | 5.6 | 6.3 | 8.6 | 10.3 |
| Miami | 5.3 | 6.0 | 8.5 | 10.5 | 5.9 | 6.6 | 9.0 | 10.8 |
| Minneapolis | 4.9 | 5.8 | 7.5 | 10.1 | 5.4 | 6.4 | 8.0 | 10.4 |
| New Orleans | 5.3 | 6.0 | 8.5 | 10.5 | 5.9 | 6.6 | 9.0 | 10.9 |
| New York | 5.2 | 6.0 | 8.3 | 10.4 | 5.8 | 6.5 | 8.8 | 10.7 |
| Phoenix | 4.9 | 5.7 | 7.6 | 9.7 | 5.4 | 6.2 | 8.1 | 10.0 |
| San Diego | 5.1 | 6.1 | 8.0 | 10.6 | 5.7 | 6.7 | 8.6 | 11.0 |
| Topeka | 5.0 | 5.9 | 7.8 | 10.2 | 5.5 | 6.5 | 8.3 | 10.5 |

[a] Nameplate EER is given in parentheses.

The seasonal EERs of models with continuously operating fans were found to average 8.5% below the nameplate EER (listed in the *AHAM Directory*[4]), and the seasonal EER of models with automatic fans were on the average 10.2% above the nameplate value.

# 3 OPERATING DATA

## 3.1 CAPACITY CONTROL

Room and unitary air conditioners generally are operated by an on-off switch controlled by a built-in adjustable thermostat. Although the air circulation blower usually runs without interruption, many unitary air conditioners allow operation of the blower only when the compressor is operating. Some units provide for optional cycling of the blower in a two-step sequence[2] when the compressor is off.

Single-compressor systems, larger than five tons, may offer capacity reduction through the use of cylinder-unloading compressors. At full-load operation, efficiency is unimpaired. However, reduced-capacity operation generally results in a reduction in efficiency.[2] A part-load efficiency curve for a reciprocating-type air conditioner is shown in the ICES technology evaluation of *Compressive Chillers*.[11]

## 3.2 INSTALLATION IN AN ICES COMMUNITY

In an ICES community, fixed storm windows are energy consumers during the cooling season. They prohibit the use of natural ventilation cooling. Outdoor noise and polluted air are two environmental conditions to be avoided because these adverse conditions would tend to limit the use of natural ventilation.

Natural ventilation at outdoor temperatures between 75° and 78°F reduces air-conditioning requirements substantially.[12] For the ten cities investigated, air conditioning combined with natural ventilation reduced air-conditioning requirements by 12% in Phoenix to 73% in San Diego.[12]

Some units have open-air cycling, which is a device that compares the outside wet-bulb temperature to the inside wet-bulb temperature and then activates a vent to permit the use of outside air rather than return air when the ratio is less than 1. This feature is said to be most useful for energy conservation in geographical areas that have high humidity and cool nighttime temperatures.[16]

When the outside air enthalpy is lower than the return air, it becomes advantageous to vent the return air and use outside air for the cooler intake. A control device is required to compare outside with return air wb temperatures. When the outside wb falls below the return air wb, a vent is actuated to permit the use of outside air rather than the return air.

## 3.3 MULTIPLE UNIT INSTALLATIONS

Multiple unitary air-conditioner installations can be operated with a central control panel. This panel can include controls for: (1) starting and stopping unit fans, (2) fresh air damper adjustment, (3) manual summer-winter switches, (4) fan-speed control switches, (5) remote adjustment of thermostat set points, and (6) remote space temperature readings.

## 3.4 SAFETY

Following is a list of relevant national safety codes and standards which apply both to room and to unitary air-conditioning equipment:

<u>American National Standards Institute</u>

ANSI B 9.1 — *Safety Code for Mechanical Refrigeration.*

ANSI B315 — *Code for Pressure Piping (Refrigeration Piping).*

ANSI C1 — *National Electrical Code (NEPA 75).*

ANSI C 84.1 — *Voltage Ratings for Electric Power Systems and Equipment (60 Hz).*

<u>National Fire Protection Association</u>

NEPA #90A — *Installation of Air Conditioning and Ventilating Systems (1975).*

<u>Underwriters Laboratories, Inc.</u>

UL 207 — *Refrigerant-Containing Components.*

UL 303 — *Refrigeration and Air Conditioning Condensing and Compressor Units.*

UL 484 — (ANSC 33.14) *Standards for Room Air Conditioners.*

UL 873 — ANSI B131.1-1972, *Temperature Indicating and Regulating Equipment.*

UL 984 — ANSI B143.1-1972, *Sealed (Hermetic Type) Motor-Compressors.*

## 3.5 ENVIRONMENTAL CONSIDERATIONS

Noise is the major environmental concern in the installation and operation of an air-conditioning unit. Much attention is given to the design of the unitary air conditioners for noise control, and published results of noise tests on most models are available from manufacturers.[7]

The applicable noise standards developed for rating individual air conditioners operating noise levels are listed below:

ASHRAE Standard 36-72, *Methods of Testing for Sound Rating Heating, Refrigerating & Air Conditioning Equipment.*

ARI 270-67, *Standard for Sound Rating of Outdoor Unitary Equipment.*

ARI 275-69, *Standard for Application of Sound-Ratio Outdoor Unitary Equipment.*

AHAM RAC-2SR, *Standards for Sound Rating of Room Air Conditioners.*

# 4 MAINTENANCE AND RELIABILITY

## 4.1 MAINTENANCE REQUIREMENTS

The efficiency of an air conditioner deteriorates somewhat with age and use. This deterioration is due largely to the accumulation of foreign material (dust, lint, leaves, spider webs, etc.) in the finned evaporator and condenser coils. Such accumulation partially blocks the flow of air through the coils and also tends to insulate the surfaces against ready transfer of heat.

Frequent changes or cleaning of the filter retards the accumulation of dirt in the evaporator and allows free air flow through the filter itself. However, because the filters used in room air conditioners generally are not too effective, periodic cleaning of the evaporator, as well as the condenser, is beneficial. Preferably, the air-conditioner chassis should be removed from its cabinet for cleaning. Cleaning may be accomplished by the application of a mild detergent solution with a soft, long-bristle brush, followed by a thorough flushing with clean water. Electrical parts and controls should be protected by covering them with plastic, and the unit should be allowed to dry before use. Fins that have been bent should be straightened to allow free passage of air.[5]

## 4.2 ECONOMIC LIFE

The 1973 ASHRAE *Systems Handbook* give Internal Revenue Service determined values for minimum depreciation periods for air conditioning systems as:[17]

| | Years |
|---|---|
| Under 5 tons | 10 |
| 5-15 tons | 5-15 |

These minimum depreciation periods are assumed equal to the economic life of the equipment.

## 5.1 ESTIMATED F.O.B. CAPITAL COST

The equipment cost for room and unitary air conditioning equipment is shown in Fig. 5.1. The lower solid line represents the cost from a variety of manufacturers' and cost estimating manuals,[18,19,20] and the dashed lines reflect the range of values found for the equipment. A few manufacturers offer a variety of chassis stylings in room air-conditioner models with the same cooling capacity, but the EER and retail prices vary significantly; thus the cost estimating curve shown in Fig. 5.1 should be used only with caution. Increasing the EER of a room air conditioner from 6 to 10 Btu/Wh results in increasing the equipment cost from 13 to 29%.[5]

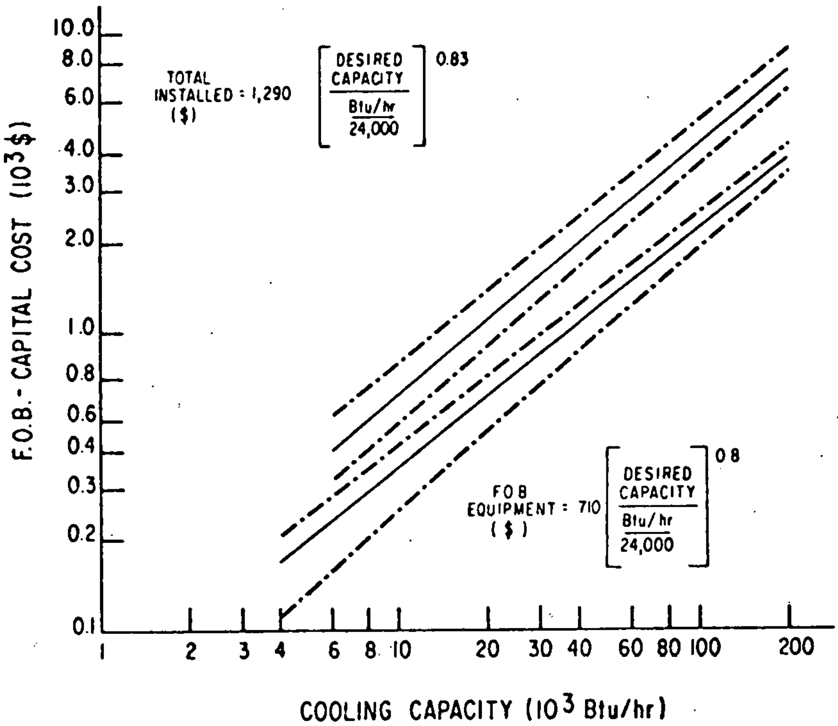



Fig. 5.1 Equipment and Total Installation Costs of Air Conditioners, in 1976 Dollars

## 5.2 ESTIMATED TOTAL INSTALLATION COST

The total installed cost of unitary air conditioners also is shown in Fig. 5.1 The top line represents the total installed cost found by using the procedures and cost estimating values from Ref. 18 and 19.

The labor rate is assumed to be \$13.55/h. The installation cost of room air conditioners, estimated at about \$31/ton,[19] is not reflected in the installation costs shown in Fig. 5.1. The installed cost applies to those units installed by the dealer, not the portable, customer-installed air conditioners.

## 5.3 MAINTENANCE COST

Figure 5.2 shows the estimated maintenance cost for an installation having more than one air conditioner. The costs reflect total maintenance which includes six inspections per year.[18]

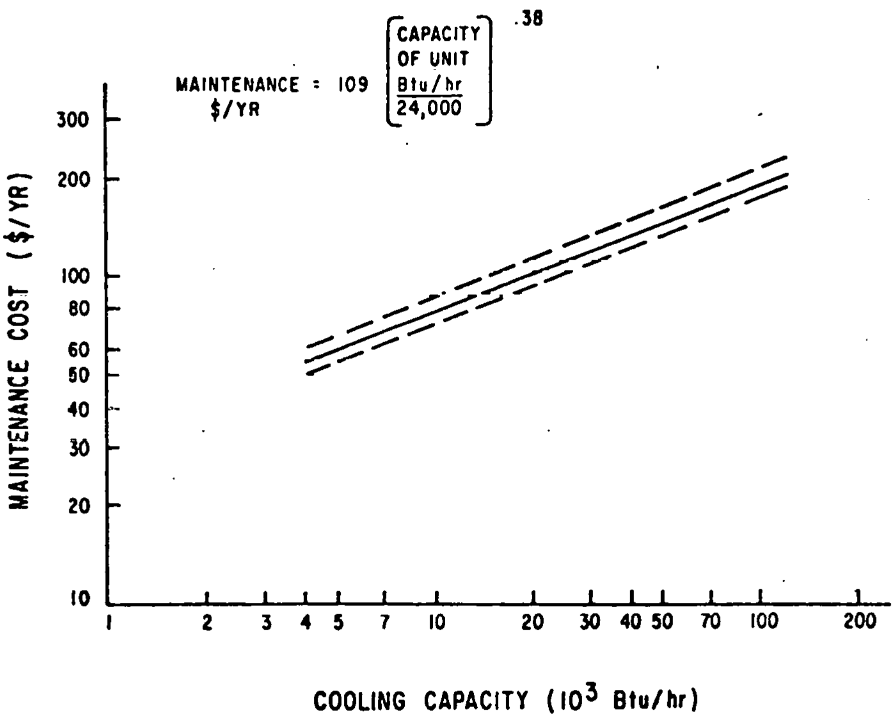



Fig. 5.2 Annual Maintenance Cost in 1976 Dollars for Unitary Conditioners Ranging from 4000 to 120,000 Btu/h

# 6 STATUS OF DEVELOPMENT AND POTENTIAL FOR IMPROVEMENT

## 6.1 IMPROVED PART-LOAD EFFICIENCY

Most air conditioner units available today meet part-load requirements by cycling on and off as needed. Efforts to improve the EER of most classes of equipment have consisted of adjusting the heat transfer surface and configuration of the condenser and evaporator in amounts that may reduce condensing temperature by 10° to 20°F and raise evaporator temperature by some 55°F at design conditions. An alternative approach is to adjust the capacity of the compression equipment itself to more nearly match the load, such as by use of variable-speed or dual compressors.

In 1976, a computer simulation was run to compare the seasonal performance of a typical 3-ton air conditioner with that of two 1-1/2-ton air-conditioner units, satisfying a typical residence cooling requirements.[21] The typical residence was located in Harrisburg, Pennsylvania.

It was found that the use of dual compressors — arranged so that one compressor alone carried the load when both were not needed — resulted in a 7% improvement in the seasonal EER.

## 6.2 ELECTRIC MOTOR IMPROVEMENT

> *"It has been standard practice to use the least expensive fan motor that will fulfill the requirements. Emphasis on efficiency eliminates the shaded pole type of fan motor from consideration. Permanent split capacitor (PSC) motors normally operate at approximately 50-55% efficiency. Through optimization of windings, rotor characteristics, and capacitor microfarads, PSC fan motor efficiency can be increased to over 60%."*[9]

## 6.3 COMPRESSOR EFFICIENCY IMPROVEMENT

Compressor efficiency can be improved by improving valve designs, reducing bearing friction, and improving volumetric efficiency.[22]

## 6.4 HEAT EXCHANGER EFFICIENCY IMPROVEMENT

From a practical design standpoint, minimum temperature difference between evaporator and condenser is also the minimum pressure difference or compression ratio across the compressor. The reduced compression ratio is the main factor that contributes to a reduction in power. Thus, to obtain the smallest compression ratio in any given air conditioner, it is necessary to use that largest, yet practical, evaporator and condenser available.

Compressor efficiency reportedly improves 0.10 Btu/Wh for each 1°F increase in evaporator temperature and 0.13 Btu/Wh for each 1°F decrease in condenser temperature.[9]

Figure 6.1 indicates the approximate response of air conditioner heat exchanger size and cost when the inside refrigerant-evaporating heat exchanger is changed, when the outside refrigerent-condensing heat exchanger is changed, and when both heat exchangers are changed simultaneously. It is obvious from this graph that the condensing section represents the better design trade-off of size and costs for improved efficiency.[23]

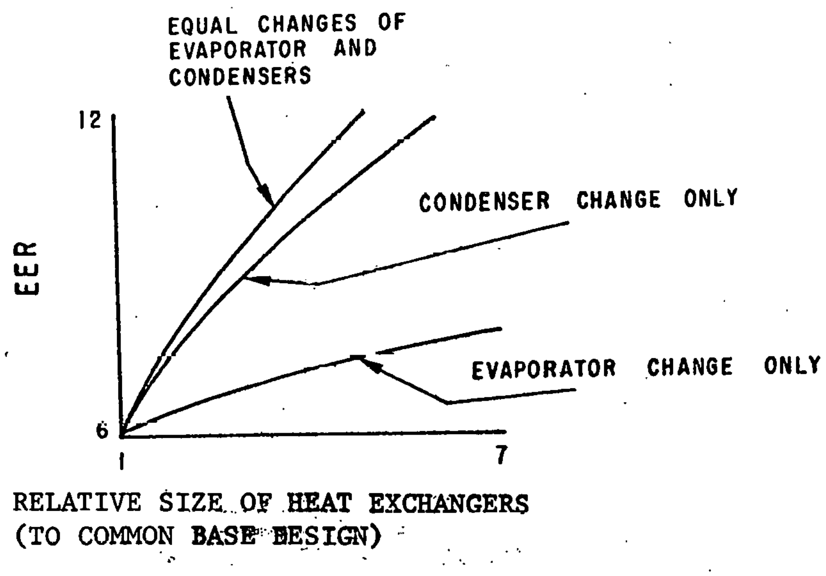



Fig. 6.1 Effect of Heat-Exchanger Size on Air-Conditioner EER*

*The size increase in relative to a common base design.

## 6.5 TOTAL POTENTIAL EER IMPROVEMENT

It has been suggested that as a current state-of-the-art limit, the room air-conditioner industry may be able to produce room air conditioners with an EER of about 13.5.[24] A room air-conditioning unit with a theoretical EER of 13.5 is based on a marginal ability to satisfy human comfort needs, because no water would be extracted. Moreover, the heat exchanger technology, cost, weight, and fan development assumed is beyond present capability. The best practical machine, developed to date by the industry, has yielded an EER of approximately 12.

## REFERENCES


1. Strock, C., and R. L. Koral, *Handbook of Air Conditioning, Heating, and Ventilating,* pp. 3-1, 3-13, The Industrial Press (1965).

2. *ASHRAE Guide and Data Book,* Equipment Volume, Chapt. 21, American Society of Heating, Refrigeration, and Air Conditioning Engineers, New York (1975).

3. Christian, J. E., ICES Technology Evaluation Data, *Heat Rejection Equipment,* ORNL (1976) DRAFT.

4. *Directory of Certified Room Air Conditioners,* Issued quarterly, Association of Home Appliance Manufacturers, Chicago (1976).

5. Moyers, J. C., *The Room Air Conditioner as an Energy Consumer,* ORNL-NSF-EP-59 (October, 1973).

6. National Electrical Code, 1971, NEPA No. 70-1971, ANSI C1-1971, National Fire Protection Association, Boston (1971).

7. *Air Conditioning and Refrigeration Institute Directory of Certified Unitary Air Conditioner,* Air Conditioning and Refrigeration Institute (June 30, 1977).

8. Dole, S. H., *Energy Use and Conservation in the Residential Sector: A Regional Analysis,* R-1641-NSF p. 36 (June, 1975).

9. Wrench, J. C., *Factors Affecting RAC Efficiency,* ASHRAE 17(2): 42-43 (February, 1975).

10. U.S. National Archives, Library of Congress, *Federal Register,* Volume 42, No. 136, Washington, D.C., pp. 36618-670, (July 15, 1977).

11. Christian, J. E., ICES Technology Evaluation Data, *Compressive Chillers,* ORNL (1977) DRAFT.

12. Pilati, D. A., *Room Air Conditioner Lifetime Cost Considerations: Annual Operating Hours and Efficiencies,* ORNL-NSF-EP-85, Oak Ridge National Laboratory, Oak Ridge, Tenn. (October, 1975).

13. Parken, W. H., Jr., Beausoliel, R. W., Kelly, G. E., *Factors Affecting the Performance of a Residential Air-to-Air Heat Pump,* ASHRAE Transactions Volume 583 (1977).

14. Fedders Adaptomatic Package Air Conditioners, Bulletin CTS 519, Fedders Corp., 1975.

15. *Packaged Central Cooling Model UR030, 036, 048, & 060,* Bulletin UR-A1, Westinghouse Electric Company (June 1975).

16. Harvey, D. G., J. A. Kudrick, and G. Leighton, *Minimization of Residential Energy Consumption,* Proceedings of the Seventh Intersociety Energy Conversion Engineering Conference, pp. 1241-55, San Diego, California (September 25-29, 1972).

17. *ASHRAE Guide and Data Book,* Systems Volume, Chapter 44. American Society of Heating, Refrigeration, and Air Conditioning Engineers, New York (1973).

18. Ottaviano, V. B. *National Mechanical Estimator*, pp. 1-3, Ottaviano Technical Services (April 1976).

19. Means, R. S., *Building Construction Cost Data*, 34th ed., (1976).

20. Sears Fall-Winter 1976 Catalogue, Sears Roebuck and Co., Atlanta, Georgia.

21. LaFrance, L. J. and A. B. Newton, *Seasonal Energy Reduction Through Use of Dual Compressor Systems*, presented at the 1976 Conference Improving the Performance of HVAC Equipment (April 12-14, 1976).

22. Riffle, O. R., *High Efficiency Reciprocating Compressors*, ASHRAE Journal, 17(9): 76-79 (September, 1975).

23. *Air Conditioner Efficiency Considerations*, Electrical World, 179(11): 56-58 (June 1, 1973).

24. Schulze, J. L., *Room Air Conditioner Efficiency - Potential and Limitations*, Proceedings of the Conference on Improving Efficiency in HVAC Equipment and Components for Residential and Small Commercial Buildings, pp. 91-102, Purdue University (October 7-8, 1974).

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Frauel, H. Dean, National Assoc., of Govt. Engineers, DC
Freeman, S. David, Bethesda, MD
Frumerman, Mr. Robert, Frumerman Associates, Pittsburgh
Furlong, D.A., Vice Pres., Combustion Power Company, Inc., Menlo Park, CA
Gallina, R.J., Senior Engineer, Baltimore Gas & Electric Co.
Gamze, Maurice G., V.P., Korobkin & Caloger, Inc., Chicago
Garcia, Carlos A., Energy Programs Department, IBM, White Plains, NY
Gardner, Dr. Dwayne, Dir., Counsel of Educational Facility Planners, Columbus, OH
Geiringer, Stefan L., Paul L. Geiringer & Associates, New York,
Gibson, Mr. Urban, Texas Power & Light Co., Dallas
Given, Willard W., Willard Given & Associates, St. Louis
Glaser, Dr. Peter, Vice Pres., Arthur D. Little Co. Cambridge, MA
Glass, C.D., V.P., Gulf States Utilities Co., Beaumont, TX
Glenn, Ms. Regina L., Technology Transfer Center, Tacoma, WA
Goble, Robert L., Clark University, Worcester, MA
Goldin, Vice Pres., Atlanta Gas & Light Co.
Goldschmidt, Victor, Ray W. Herrick Laboratories, West Lafayette, IN
Gordon, Mr. R.H., Gibbs & Hill, New York
Gorham, William, Pres., Urban Institute, DC
Green, Dr. Richard, Mgr., Jet Propulsion Lab, Pasadena
Grifalconi, John W., Environs Associates, Kingston, R.I.
Gutstein, Martin, Nat'l. Aeronautics & Space Projects, Cleveland
Hagler, Harold, Principal, Resource Planning Associates, DC
Haliff, B., Albert H. Haliff Associates, Inc., Dallas
Hamrick, John, V.P., Marketing, San Diego Gas & Electric Co., San Diego
Hankinson, William B., Syska & Hennessy, Inc. Engineers, New York
Harrington, W.G., Nat'l. Assn. of County Engineers, Cedar Rapids, IA

Harris, B.L., Technical Dir., Edgewood Arsenal, Aberdeen Proving Ground, MD
Hart, F. Donald, Pres., American Gas Association, Arlington, VA
Heimsath, Clovis, Pres., Clovis Heimsath Associates, Houston
Henry, John P. Jr., Dir., Stanford Research Institute, Menlo Park, CA
Hillenbrand, Bernard F., National Assoc. of Counties, DC
Hincks, Mr. Joel P., Gulf Oil Real Estate Development Co., Reston, VA
Hines, Gerald B., Houston, TX
Hittle, Douglas C., Dept. of the Army, Champaign, IL
Hoffer, Mr. Stu, Hamilton Standard, Windsor Locks, CT
Hoffman, J.R., HDQT DAEN-FEP, DC
Holter, Marvin, Exec. Mgr., Environmental Research Institute, Ann Arbor, MI
Howell, John, Dir., University of Houston
Howell, Ronald H., University of Missouri-Rolla
Hufford, Paul E., Exec. V.P., Energy Ltd., Unlimited, New Britain, CT
Hullinger, Mr. E. Paul, Utah State University, Logan
Hunn, Bruce D., Los Almos Science Lab, NM
Iles, Mr. Tom, AiResearch Mfg. Co., Torrance, CA
Inselberg, Dr. A., Scientific Staff Member, IBM, Data Processing Div., Los Angeles
Ingram, James M. Jr., Leo A. Daly Co., Omaha
Irvine Co., Newport Beach, CA
Jacobs, John F., Senior Vice Pres., Mitre Corp., Bedford, MA
Jacoby, Earl F., Ziel-Blossom & Associates, Inc., Cincinnati
Jarshow, Bruce, City of Chicago, Dept. of Development & Planning
Jaumotte, Joe, Dynatech R/D6, Northfield, IL
Johnson, Mr. Dale R., Pres., Nelson & Johnson Engineering, Inc. Boulder, CO
Johnson, Mr. Ralph J., NAUB Research Foundation Inc., Rockville, MD
Johnson, William L., Hennington, Durham and Richardson, Des Plaines, IL
Jones, Mr. Harvey C., Reedy Creek Utilities Co., Inc., Lake Buena Vista, FL
Jones, Mr. Ron, Pres., Research & Planning Consultants, Austin, TX
Jordan, Richard C., University of Minnesota, Minneapolis
Joyner, Fred, Tennessee Public Service Commission, Nashville
Kalkstein, Howard, International Council of Shopping Centers, New York
Kelly, Michael, F., Pres., Dayton Hudson Properties, Minneapolis
Killian, R.D., Mgr., Research & Develop., State of Illinois, Springfield
Kirkwood, Roderick R., John Graham & Co., Seattle
Kirmse, Dale, Reynolds, Smith, & Hills, Jacksonville, FL
Kirmse, Dale W., University of Florida, Ganesville
Klein, E.L., Williams Research Corp. Walled Lake, MI
Kleinau, J.H. Vice Pres., Copeland Systems, Inc., Oak Brook, IL
Knipe, Edward C., V.P., Gordon Associates, Corvallis, OR
Koski, Dr. J.A., Bechtel Corporation, San Francisco
Krause, Ed, Electrical Administrator, Garland, TX
Kremer, Peter C., Exec. V.P., Newhall Land & Farming Co., Valencia, CA
Kroner, Walter M., Rensselaer Polytechnic Institute, Troy, NY
Kugelman, Irwin Jay, MERL-EPA, Cincinnati
Kurht, W.A., V.P., Tech., United Technologies Corp., Hartford, CT
Kwok, C.F., U.S. Veterans Administration, DC
Lambert, Robert E., Environment Research Institute of Michigan, Ann Arbor
Landsberg, H., Dir., Resources for the Future, DC
LaRock, Ralph I., Director, NASA Headquarters, Solar Energy Div., DC
Lau, T.K., Office of Fossil Energy, DOE, DC
Leigh, Richard, Brookhaven National Laboratory, Upton, NY
Leighton, G.S., Office of Conservation, DOE, DC
Levinson, Joel, Levinson, Lebowitz & Zapravskis, Philadelphia

Lewis, Milt, U.S. Dept. of Health, Ed. & Welfare, DC
Liles, James, Federal Power Commission, DC
Linsteadt, G.F., Naval Weapons Center, China Lake, CA
Lockwood, Rodney, Pres., Rodney Lockwood & Co., Birmingham, MI
Loftness, Dr. Robert L., Electric Power Research Institute, DC
Love, Nash M., Consulting Engineer, Nash M. Love & Assoc., DC
Lovely, Joseph D., St. Clair Shore, MI
Lovin, Glenn H., Edison Electric Institute, DC
Low, Dr. D.W., Los Angeles Data Processing Div., Scientific Center
Loyd, Harold L., Turner, Colie, & Braden, Houston
MacDonald, Robert, Tech. Agent, Conference of Municipalities, New Haven, CT
Mackay, Mr. Robin, Garrett Corp., Los Angeles
Maffin, Robert W., Nat'l. Assoc., of Housing & Redevelopment Officials, DC
Maggard, James E., Watkins and Associates, Inc., Lexington, KY
Magnus, D.E., KLD Associates, Inc., Huntington, NY
Maloney, Laurence J., Love, Friberg & Assoc., Inc., Fort Worth
Manning, David, Stewart & Stevenson, Houston
Marcus, Genevieve, Exec. Dir., Experimental Cities, Pacific Palisades, CA
Marder, Sidney M., Marder and Associates, Springfield, IL
Martin, John H., Sheaffer & Rolan, Chicago
Martin, Joseph, Associate Dir., The University of Michigan, Ann Arbor
Maschke, H.H., Department of Defense, HQDA (DAEN-MCE-U) DC
Mason, J.L., V.P. Engineering, Garrett Corp., Los Angeles
Mavro, Robert L., Dir. of Energy Research, American Public Power Assn., DC
Mazarakis, Gus, Peoples Gas Light & Coke Co., Chicago
McBride, M.F., Owens Corning Fiberglas, Bldg. Research Lab., Granville, OH
McClernon, Dr. Mark F., Black & Veatch, Kansas City, MO
McClure, Charles J.R., Pres., McClure & Assoc., Inc., St. Louis
McGinty, Mr. John M., The McGinty Partnership, Houston
McPherson, Harry, Construction Battalion Center, Port Hueme, CA
Mendenhall, Mr. Jerry, Foster & Mendenhall, Houston
Meriwether, Ross F., Pres., Ross F. Meriwether & Assoc., Inc., San Antonio
Mermelstein, Mrs. Betty, The Futures Group, Glastonbury, CT
Mesko, Mr. John, Pope, Evans & Robbins, Inc., New York
Michaelson, William G., Mgr., Public Service Electric & Gas Co., Newark, N.J.
Miller, A.J., Knoxville, TN
Mixon, W.R., Oak Ridge National Laboratory, Oak Ridge, TN, (75)
Moeller, Griswold L., Michael Baker Jr. of NY
Montanerilli, Nicholas, National Science Foundation, DC
Morris, George L., Senior Vice Pres., Brown & Root, Inc., Houston
Morrison, Dr. David L., Battelle Columbus Laboratories, Columbus, OH
Morrison, J.E., DeLaureal Engrs., Inc., New Orleans, LA
Mulf, Richard, U.S. Dept. of HUD, D.C.
Murphy, Timothy J., Engineering Mgr., Grumman Aerospace Corp., Bethpage, NY
Myers, Edward A., Chairman EEI, Southern California Edison Co., Rosemead
Nakata, Clifford S., Clifford S. Nakata & Associates, Colorado Springs
Nash, Herbert D., V.P., Pennsylvania Power & Light Co., Allentown
Nayamark, Ronald, NPL, Inc., Campbell, CA
Neal, John, U.S. DOE, DC
Neff, N. Thomas, Vice Pres., Consulting Engineer, Cincinnati
Nelsen, Dr. S.H., Energy Systems Research Group, Inc., Rochester, NY
Newell, Mr. J.C., West Chester, PA
Nicholls, G.L., Energy Resources, Bellevue, WA
Nimmo, Morris, National Bureau of Standards, DC

Novinsky, M.H., Office of Planning and Development, Dept. of HEW-OFEPM, DC
O'Connor, W.G., Williams Research Corp., Walled Lake, MI
Olivieri, Joseph B., OEM Associates Inc., St. Clair Shores, MI
Olson, G. Perry, City of St. Cloud, City Hall, MN
Opperman, A. Peter, University of Michigan, Ann Arbor
Orlando, J., Mathematica, Inc., Princeton, NJ
O'Sullivan, Michael, Los Angeles
Overman, Mr. Jack, Hittman Assoc., Inc., Columbia, MD
Parante, Mr. Emil J., Ralph M. Parsons Co., Pasadena, CA
Partridge, Robert D., Exec. V.P., Nat'l. Rural Electric Cooperative Assn., DC
Paster, J.H., Inter-Technology Corp., Warrenton, VA
Patterson, Mr. Neil, Mgr., The Trane Co., LaCrosse, WI
Perks, Ruth, Library, DOE, DC
Philadelphia Electric Co., Vice President for Planning
Phillips, C.W., National Bureau of Standards, DC
Piccirelli, Mr. Robert A., Michigan Energy and Research Assn., Detroit
Piper, James R., Piper Hydro, Anaheim, CA
Plunkett, Mr. J.D., Montana Energy and MHD Research and Develop. Inst., Inc.
Pollard, Thomas E., Mgr., Field Facilities Engr. & Operations, IBM, Chicago
Powell, William R., John Hopkins U., Laurel, MD
Pozzo, R.J., Energy Analyst, State Energy Office, Tallahassee
Pripusich, J.F., Inter-Development, Inc., Arlington, VA
Pritchard, Allen E. Jr., Exec. Vice Pres., National League of Cities, DC
Pronk, Dick, U.S. General Service Admin., DC
Public Technology Inc., Washington, DC
Radin, Alex, Gen. Manager, American Public Power Association, DC
Rahm, Allen M., Consultant, Colts Neck, NJ
Rajan, Mr. S.D., Mitre Corp, McLean, VA
Rastelli, Dr. Leonard, Dir., Southwest Research Institute, San Antonio
Reese, Mr. William R., Interstate Development Corp., St. Charles, MD
Reeves, George, Manager, Long Range Planning, Electric Energy Institute, NY
Reich, Larry, Dir. of Planning, City of Baltimore
Reid, Robert O., Energy & Environmental Analysis, Inc., Arlington, VA
Reikenis, Richard, Vice Pres., Century Engineer, Inc., Towson, MD
Research and Tech. Support Div., DOE, Oak Ridge, TN
Restall, Wesley F., Keyes Associates, Waltham, MA
Riddle, William G., Riddle Engineering, Inc., Kansas City
Rienerth, Thomas, Dir., Delmarva Advisory Council, Salisbury, MD
Rittleman, Bernard, Burt, Hill & Assoc., Butler, PA
Roberts, James S., First National Bank of Chicago
Rodgers, Paul, Nat'l. Assn. of Regulatory Utility Commissioners, DC
Rodousakis, John C., Program Manager, Community Systems Branch, DOE, DC
Romine, Thomas B. Jr., Romine & Romine, Consulting Engineers, Fort Worth
Rosenberry, Robert, Veterans Administration, DC
Rosoff, David, U.S. Dept. of HUD, DC
Ross, Donald K., Ross & Barruzzini, Inc., St. Louis
Rothenberg, J.H., HUD-MIUS, Program Manager, Dept. of HUD, DC
Roubal, James P., Dana, Larson, Roubal and Associates, Omaha, NB
Rudy, Prof. William, University of Pittsburgh
Russell, May, Pres., Community Assoc. Institute, DC
Ryan, J.D., National Bureau of Standards, DC
Samos, John, Langley Research Center, Hampton, VA
Sasso, John A., Nat'l Model Cities Community Develop. Directors Assn., DC
Saunders, Walt, Office of Fossil Energy, DOE, DC

Saunders, Walton, Program Manager, Coal Conversion and Utilization, DOE, DC
Sayan, Michael, Rochester Public Utility, MN
Scause, James W., Scause & Associates, Phoenix
Schmalz, Mr. Arvid, IBM, Energy Research Project, Los Angeles
Schneider, Burkhard, H., Manager Planning & Research, Detroit Edison Co.
Schnizer, Arthur W., Tech. Dir., Day & Zimmerman, Inc., Philadelphia
Schoen, Richard, University of California, Los Angeles
Schuster, Ray, Comm. Div., Electrical Power Research Inst., Palo Alto, CA
Sebastion, E.J., Chief Mechanical Eng., DeLeuw, Cather & Company, Chicago
Sedlacek, Frank E., Pres., Fast Hills, Inc., Omaha
Shaffer, Richard, Combustion Power Co. Inc., Menlo Park, CA
Shannon, Wayne E., Lockheed Missiles & Space Co., Sunneyvale, CA
Sharp, E.G., Mitre Corp., McLean, VA
Sheffield, David G., The Architects Callaborative, Inc., Cambridge, MA
Sherfy, James D., Bristol Tennessee Electrical System, Bristol
Sherman, J., Department of HUD, DC
Siegel, A.R., Director, Dept. of HUD, DC
Sizemore, Michael M., Sizemore & Associates, Atlanta
Smith, Robert Lee, Pres., Experimental Cities, Pacific Palisades, CA
Smollen, William, Regional Planning Commission, New Orleans
Spiegel, Walter F., W.F. Spiegel, Inc., Jenkintown, PA
Stamper, D.E., Chairman, New Jersey Institute of Technology, Newark
Stautz, Mr. C. David, Director of Planning, Homart Development Co., Chicago
Steger, Wilbur A., Consad Research Corp., Pittsburgh
Steigelmann, Mr. William, Franklin Institute Research Labs, Philadelphia
Stenhouse, Douglas S., Los Angeles
Stolz, Otto G., U.S. Dept. of HUD, DC
Sutz, Chief Conservation Section, Arizona State Fuel & Energy Office, Phoenix
Sykora, Mr. Don, Gen. Mgr., Houston Lighting and Power Co., Houston
Tanner, Howard, Director, Department of Natural Resources, Lansing, MI
Tao, William K.Y., William Tao & Associates, St. Louis
Taravella, J.P., Westinghouse Electric, Coral Spring, FL
Taussig, Robert T., Mathematical Sciences NorthWest, Inc., Bellevue, WA
Taylor, L.D., Prof. of Economics, University of Arizona, Tucson
Telkas, Dr. Maria, University of Delaware, Newark
Terry, Gary A., Exec. Vice Pres., American Land Development Assoc., DC
Thomas, John P., National Assn. of County Admin., DC
Thompson, Mr. Russell G., Research for Growth and Transfer, Inc., Houston
Todd, J.W., Presiding & Chief Operating Officer, Gulf Reston, Reston, VA
Trevino, Mr. Alberto, Urban Interface Group, Laguna Beach, CA
Tulley, Gordon F., Massdesign Architects & Planners, Inc., Cambridge, MA
Tumilty, Jack, Chairman, Consulting Engineer, Tulsa, OK
Turner, John B., Pres., Friendswood Development Co., Houston
Uhl, Mr. Robert H., Watkins & Associates Inc., Lexington, KY
University of Tennessee, Engineering Library, Knoxville
U.S. Army Engineer R & D Laboratories Library, Fort Belvoir, VA
U.S. Naval Civil Engineering Laboratories, Port Hueneme, CA
Vandegriff, A.E., Midwest Research Institute, Minneapolis
Weinberg, A.M., Director, Institute for Energy Analysis, Oak Ridge, TN
Wheeler, Arthur E., Consulting Engineer, Henry Adams, Inc., Towson, MD
White, Robert E., Loup River Public Power District, Columbus, NB
Widowsky, Arthur, NASA Headquarters, DC
Winders, Marvin S., Engineering Supervisor Co., Newport Beach, CA
Wolfe, Jack, Southwest Research Institute, San Antonio

Woodburn, James D., Public Service Department, Burbank, CA
Yallaly, James G., Delta Engineering Consultants, Cape Girardeau, MO
Yarosh, M.M., Dir., Florida Solar Energy Center, Cape Canaveral
Young, Thomas C., Exec. Dir., Engine Manufacturers Assoc., Chicago
Zaloudek, Bob, Larry Smith & Co., Ltd., Northfield, IL
Zoues, Tom, Walt Disney World, Lake Buena Vista, FL
Zovich, John, WED Enterprises, Glendale, CA

U.S. Department of Energy
ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue, Argonne, Illinois 60439 Telephone 312/972-

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Technology Evaluations
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Argonne National Laboratory
9700 S. Cass Ave.
Argonne, Illinois 60439

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