ORIGINAL

BEFORE THE FLORIDA PUBLIC SERVICE COMMISSION

DOCKET NO: 981591_EG

PREPARED REBUTTAL TESTIMONY AND

EXHIBIT OF DAVID A. SHELL

AUGUST 26, 1999

Gulf Power Company

Before the Florida Public Service Commission
Rebuttal Testimony of
David A. Shell
Docket No. 981591-EG
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Q. Please state your name, business address, and occupation.

A. My name is David A. Shell. My business address is One Energy Place, Pensacola, Florida 32520. I am employed by Gulf Power Company as a Residential Market Specialist.

Q. Please describe your background, job responsibilities and experience.

A. I have a Bachelor's degree in Marketing from the University of West Florida. I have been employed by Gulf Power Company for 12 years during which time I have held positions working with residential customers; heating, ventilation, and air conditioning (HVAC) contractors; home builders; and others dealing with energy conservation, home comfort, and efficiency. During my career I have received a substantial amount of training including the following: heating and cooling system operation and diagnostics; residential load calculation; commercial load calculation; HVAC equipment selection; HVAC duct design; and HVAC performance testing. I have spent considerable time working with HVAC contractors to insure proper HVAC equipment sizing, selection, and operation for our common customers. I have often been called upon by these contractors to provide technical assistance in resolving problems related to HVAC equipment performance, durability, efficiency and homeowner comfort. In my current position as Residential Market Specialist I am responsible for program planning and implementation as well as support of Gulf Power Company's Residential Energy Consultants working with Gulf's residential customers, HVAC contractors and builders. I regularly provide technical assistance to these groups and individuals.

Q. Do you have any exhibits to include with your testimony?

A. Yes. I have one exhibit, Exhibit No.___(DAS-1).This exhibit contains the following:

1. Survey of Residential Air-to-Air Heat Pump Service Life and Maintenance Issues referred to herein as the Easton study.
2. A Study of Heat Pump Service Life referred to herein as the Hiller and Lovvorn study.
3. Presentation of a method for modeling HVAC units

in service and failure probability by age.

Q. Have you reviewed the direct testimony and Exhibit JWM-1 submitted by Mr. Joseph W. McCormick on August 5, 1999 on behalf of Peoples Gas System?

A. Yes, I have.

Q. What is the purpose of your testimony in this docket?

A. The purpose of my testimony is to provide information that will show that the positions taken in Mr. McCormick's testimony with respect to HVAC systems are flawed. Specifically, I find fault with Mr. McCormick's reliance on the HVAC service life information taken from the ASHRAE and ARI sources discussed in his testimony. It appears that he also believes "service life", as presented by the ASHRAE table, to be the same as "useful life" or functional life.

Q. Please describe the terms "HVAC" and "HVAC system" as you will use them in your testimony.

A. For the purposes of my testimony, the use of the term "HVAC" or "HVAC system" will refer to a "split system" central air conditioner and combustion furnace combination or heat pump utilizing an outdoor, air-to-air condenser or heat exchanger. These are, by far, the most common types of systems utilized for heating and cooling residential dwellings in Northwest Florida.

Q. Would you please discuss why you disagree with Mr. McCormick's interpretation and application of ASHRAE information on HVAC service life?

A. Mr. McCormick relies upon the ASHRAE table contained on Exhibit JWM-1, page 9 to support the use of 15 year HVAC service life. The ASHRAE table understates actual service life for HVAC systems in that time period because the table represents a compromise by a committee divided over two studies.

- The first of these, the Easton study (referenced by the table), was seriously flawed and proposed a point estimate for heat pump service life of 12 years. The Easton study utilized simply a survey of HVAC dealers which queried, through telephone interviews, the age of units removed for any reason, including energy costs, remodeling, etc., not just those that had experienced debilitating mechanical failure. This inclusion of all units, including those removed for operating cost reasons during a period of rapidly increasing energy costs, in addition to the failure to consider units still in service, caused the Easton study to greatly understate useful life. It estimated the average age of units removed from service based on dealer opinions without considering the age of units still in service. It was replete with significant bias in that the data, the interview responses, were only as good as the information the interviewees encountered and how well they absorbed and processed it subconsciously.

- The second, the Hiller and Lovvorn study (also referenced by the table) of 1984, provides much more credible data based upon actual heat pump installations, not opinions. This study tracked the history of 1,689 specific units installed in Alabama from 1964 to 1974 and indicates a median service life of approximately 20 years. In support of this determination, Hiller and Lovvorn noted two key elements in their conclusion. The first was that "A large percentage of the original known heat pump sample are still in operation, with more than 50% of the units 20 years old still in active use, 75% of the units 15 years old, and nearly 100% for units 10 years old." And second, they found that nearly 50% of the relatively small number of units that were replaced were still <u>fully operational</u> at the time of replacement. They went on to say "Such replacements appear to have been motivated both by the perception of expected life, and by marketing and promotional efforts of dealer/contractors and the local utility." Pages 17 through 23 of Exhibit DAS-1 contain a copy of the Hiller and Lovvorn study.

The ASHRAE table, in addition to the previous flaw noted, understates service life for systems in Northwest Florida because it provides data (flawed as it is) for intended application to HVAC systems in service nation-wide. Whereas:

- The NW Florida climate is milder than the national average.
- National average wider temperature extremes exact a harsher toll on compressors (including straight a/c compressors), solenoids, condenser coils, joints, fittings, outdoor electronic controls, etc.
- HVAC systems operating in Northwest Florida can reasonably be expected to have a service life that is somewhat greater than the national average.

The ASHRAE table also understates service life for systems being installed from 1985-1990, and in 2000 and beyond. In other words, it is out of date.

- The studies on which the table is based analyzed actual units manufactured between 1964 and 1974 and the opinions of HVAC dealers in 1985.
- HVAC manufacturers have been continuously improving service life in addition to efficiency. ARI statements included in Mr. McCormick's exhibit support this. On page 2 of Mr. McCormick's Exhibit JWM-1, the ARI Q&A #5 states that "Newer units [than those built in the 1970's and 1980's] are expected to last even longer."
- A reasonable estimation of the general trend in these improvements would indicate a 10% longer service life for units manufactured from 1985-1990, compared to the population of units used for the preparation of the table.
- The general trend in these improvements would also indicate an even longer expected service life for units manufactured in 2000 and beyond compared to the population of units used for the preparation of the table.

Q. Would you please discuss why the ARI source should not be relied on for determining HVAC service life?

A. The ARI Q&A #5 that references a 14 year life was not, according to Dave Martz, ARI Vice President of

Administration and Statistics, recent information and was most likely based upon an informal survey of ARI members. It is ARI's own position that this equipment life study is old and based upon non-scientific data.

Q. What errors are introduced in Mr. McCormick's testimony by the use of "service" life from the ASHRAE table or the ARI reference as the "normal useful life?"

A. "Service life", as reported by these dated industry sources, was the age at which 50% of the units had been removed from service for <u>any</u> reason. While, in many instances, that reason would have been major mechanical failure, in many other instances the unit would have been replaced due to a desire on the part of the homeowner for lower energy costs via higher efficiency equipment, a need for more or less capacity due to remodeling or thermal envelope improvements, or even unexpected unit damage (as opposed to "failure") due to such events as lightning. Replacements due to energy cost concerns were particularly prevalent during the period relevant to the studies as this was the time when the energy industry was experiencing as much as double digit percentage increases in energy costs each year. In all of these instances the units were replaced for reasons other than an expected actuarial-type failure and for reasons other than an expectation that the unit would be failing in the very near future. Mr. McCormick's misuse or oversight of this aspect of the definition of service life as presented by the table invalidates his conclusions.

Q. What length of expected service life for an HVAC system should be used in lieu of the 15-year life proposed by Mr. McCormick?

A. For HVAC systems manufactured during 1985-1990 and installed and utilized in Northwest Florida, the 20-year median service life found in the Hiller and Lovvorn study provides the best starting point. That 20 years can be increased by 10% as noted earlier for the improvement in service life over time from the vintage of HVAC systems studied by Hiller and Lovvorn versus those produced in the late 1980's. While the expected service life could be further increased for applications in Northwest Florida versus the climates considered by Hiller and Lovvorn, I disregarded this factor in order to maintain a clear element of conservatism with respect to this issue. The 10% increase for this later vintage, when applied to 20 years, yields an expected service life of 22 years for units manufactured in the late 1980's. For HVAC systems currently being manufactured, installed, and utilized in Northwest Florida, the 20-year median service life found in the Hiller and Lovvorn study should be increased by 15% for the improvement in service life over time and the same nominal 5% for applications in Northwest Florida versus the climates considered by Hiller and Lovvorn. This total of a 20% increase, when applied to 20 years, yields an expected service life of 24 years for units currently being manufactured. However, to be conservative in service life assumptions, the 22 years could be utilized for all considerations in this particular proceeding.

Q. How has Mr. McCormick's dependence on the ASHRAE and ARI service life information misguided the positions presented in his testimony?

A. First, it is apparent that Mr. McCormick's presumption of a 15-year <u>service</u> life is the basis for his position that the 10 to 15 year old units targeted by Gulf's proposed program are effectively at the end of their "normal useful life." When the proper definition of "service life" and the much more accurate service life figure of 22 years are considered, his position that they would otherwise be replaced at the same time absent this program is totally without merit. In the year 2000, the systems manufactured and installed in 1985 would have only a 5.0% probability of failure within the following 12 months, as indicated on page 24 of Exhibit DAS-1. With a probability of short term failure this low, customers with this vintage equipment contemplating participation in Gulf's proposed program would not reasonably consider their HVAC system to be at or near the end of its "normal useful life." Similarly, a customer with a system installed in 1990 would have only a 4.0% probability of system failure within the following 12 months and, again, would not reasonably consider their system to be worn out. That's a perspective of the two ends of the spectrum of the 10-15 year age, with all unit vintages in between falling between these two probabilities. Naturally, the continuing improvement in service life would continue for this program's application in 2001, 2002, etc., with the associated decreases in the probabilities of failure. Next, Mr. McCormick's flawed presumption of a 15 year useful life appears to be the basis for his position that Gulf's program analysis period should be limited to 15 years. This clearly would not be a responsible limitation. Any program evaluation for Northwest Florida that is utilizing new-unit HVAC service life as an analysis parameter in any fashion should, with ample conservatism, use an expected service life of 22 years. Any use of a service life less than 22 years is being unreasonably conservative and any life significantly less than that, such as the 15 years proposed by Mr. McCormick, is seriously and erroneously understating the capabilities of today's HVAC systems operating in Northwest Florida's climate.

Q. Would you please explain the development and application of page 24 of Exhibit DAS-1 as referenced in your testimony?

A. That page contains a chart which depicts the creation of a simple linear model that can be used to calculate the portion of HVAC units of a certain vintage that could be expected to remain functional at various ages or years in service. The model development began by taking a plot of the data from the Hiller and Lovvorn study and expanding it for a median service life of 22 years as previously explained. That yielded the "Expected results" line of the chart. The "Expected results" line was then modeled as closely as possible, by the dashed straight line labeled "Modeled results". The depiction of the Hiller and Lovvorn based data with the straight lines allows simple calculations of expected HVAC populations and failure probabilities by vintage with excellent accuracy, particularly in the range of 10 years to 34 years of life. In that range, it is reasonable to expect that, for any particular vintage, approximately 3.8% of the original units would fail during each year. At any particular age for that vintage, the probability of a unit failing during a 12 month period is simply the 3.8% expected to fail divided by the percentage of the original units still in service at that time.

Q. Is this model usable for unit ages less than 10 years old or greater than 33 years?

A. No, it is not. In these ranges of unit life the straight line approximation, the "modeled results", is not a close enough fit to the observed data, i.e. the "expected results", to be useful. As an example, at age 34 the model would indicate a 100% probability of failure within the next 12 months, however, from a purely statistical approach that expectation is unreasonable. In the qualified range of 10 to 33 years, however, the model provides an excellent match to observed data and the probabilities it yields are the best available.

Q. Could this same modeling method be used to determine the expected probabilities of failure for HVAC units if a 15-year service life is presumed?

A. Again, the presumption of a 15-year service life or utilization of service life for useful life is, in and of itself, not at all responsible. However, if it is presumed, albeit erroneously, this same modeling approach can be used. This is done by, once again, setting the departure point from 100% in service point at 9 years, the 50% in service point at 15 years, and the 0% in service point at 21 years. In this case, the model will be reasonably accurate in the range of 10 to 19 years. Using the same modeling process and calculations as before, the 12-month probability of failure for a 10-year old unit will be 8.3%, and for a 15-year old unit the probability would be 16.7%.

Logically, for a 15-year service life the beginning departure point from 100% in service could be set at less than 9 years, e.g. 8 years, with a correspondingly longer time to reach 0% in service, but this would produce even smaller probabilities for failure within 12-months than the figures given above. Once again, we have chosen the more conservative approach.

Based on my experience of actually working with residential customers in their considerations of the health of their current HVAC system, these probabilities would still not point to a reasonable conclusion that their unit was at or near the end of its "normal useful life."

Q. In your past years of field experience have you had occasion to observe the equipment replacement decisions of customers, who, having once made a significant change in their HVAC equipment, years later experience the failure of that equipment?

A. Yes, I have. The vast majority of these customers, after having experienced the energy economies and enhanced comfort of a high-efficiency heat pump, choose to replace that heat pump with the latest and greatest high-efficiency heat pump at that time rather than revert back to their former type of equipment.

Q. Does that conclude your testimony?

A. Yes, it does.

AFFIDAVIT

STATE OF FLORIDA)
)
COUNTY OF ESCAMBIA)

Docket No. 981591-EG

Before me the undersigned authority, personally appeared David A. Shell, who being first duly sworn, deposes and says that he a Residential Market Specialist of Gulf Power Company, a Maine Corporation, that the foregoing is true and correct to the best of his knowledge, information and belief. He is personally known to me.

David A. Shell

David A. Shell
Residential Market Specialist

Sworn to and subscribed before me this 25th day of August, 1999.

Jessica L. Pfeiffer
Notary Public, State of Florida at Large

Jessica L. Pfeiffer
MY COMMISSION EXPIRES
FEBRUARY 7, 2001
#CC 619321
Bonded thru
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NY 87-09-3

SURVEY OF RESIDENTIAL AIR-TO-AIR HEAT PUMP SERVICE LIFE AND MAINTENANCE ISSUES

J.E. Lewis

ABSTRACT

A telephone survey was conducted among a national sample of 492 large HVAC dealer/contractors to elicit estimates of residential heat pump replacement age and other related issues. Similar data for unitary air conditioners and gas furnaces were collected to provide a relative perspective.

The sample selection and interviewing were designed to produce unbiased results and to provide appropriate data reliability for summaries at the national level and for three geographic regions (north, south, and west). The survey was conducted between December 4 and December 23, 1985. The key findings of the survey:

- The dealers' average estimate of age at replacement for unitary air-conditioning units is 12.1 years; air-conditioner compressors, 8.8 years; heat pump units, 10.9 years; heat pump compressors, 8.0 years; and gas furnaces, 16.3 years.
- Eighty-six percent of the dealers believe that heat pump reliability has been improved over the past few years, but slightly less than 50% expect the service life of heat pumps being installed today to be materially longer than that of the past.
- Only about 26% of the dealers use life-cycle cost analysis, and the average replacement age estimates for heat pumps used in customer discussions is 11.2 years.
- Estimates indicate that the installed cost of replacement compressors is 40-45% of the cost of a total new unit.

INTRODUCTION

The residential HVAC market is large, diverse, and complex. The introduction of new equipment with various levels of energy efficiency and other performance characteristics has added to the competitive intensity and complexity of the market environment. Within such a complex environment, issues of equipment replacement age are inherently complex and increasingly important as customers face a greater variety of choices and decisions.

It is difficult to collect accurate service life data, and few published studies are unbiased with respect to the sample from which the data were collected, the methods of data analysis, or the form in which the results are presented. There have been particular concerns about the average replacement age of heat pumps because of the market development pattern for this product. A number of technological changes are also occurring, designed to improve reliability of the heat pump. There are questions concerning the average replacement age for heat pumps based on actual experience and the effect that technological changes may have on heat pump service life going forward.

A survey of HVAC dealer/contractors was designed to elicit estimates and perceptions concerning issues of replacement age and maintenance for residential heat pumps. By incorporating similar information for unitary air conditioners and gas furnaces, the study would

James E. Lewis is a founding partner of Easton Consultants, Inc., Management Consultants, Stamford, CT.

provide practical market perspectives and indicate dealer estimates of the relative replacement ages of these three products. (It should be noted, however, that the survey and questionnaire were specifically designed and structured to elicit information on heat pumps. The information on air conditioners and gas furnaces was included for perspective, and the survey results may not delineate as well the data on these products.)

The primary focus of the study was a telephone survey of large HVAC dealer/contractors, approximating the regional distribution of installed heat pumps. Sample selection was random within the basic dealer size and geographical location parameters (described below). Only residential equipment was covered.

The objectives of the dealer survey were to (1) obtain estimates of national and regional replacement age averages and ranges for the heat pump; (2) obtain estimates of similar information for unitary air conditioners and gas furnaces that could provide perspective and relative measures; and (3) describe dealer perceptions of service issues, maintenance costs, and other related information.

METHODOLOGY

A primary criterion of the methodology was to provide unbiased results that would accurately reflect the dealers' experiences and perceptions within a complex market environment. Interpretations, based on more than two dozen previous HVAC market studies and "qualitative" field research conducted as part of this study, are intended to provide a context for viewing the quantitative results of the dealer survey.

Sample

The basic sample selection approach was to start with the broadest possible base from which to draw the sample and to employ only limited screening parameters to avoid biasing the sample. The only parameters used were the size of the dealer/contractor firm and the degree of experience with heat pumps. The basic parameters and data sources included:

- A data base that includes more than 27,000 companies with 1711 as their primary industrial classification was used as the sample source (plumbing, heating, and air conditioning).

- A proportional distribution of installed heat pumps by state was based on data provided in the annual statistical issue of Air Conditioning and Refrigeration News (based on the 1980 census of population and housing).

- The primary sample drawn from the data base included firms with annual revenues between $700,000 and $8 million. A subsequent sample was drawn from firms with annual sales between $400,000 and $699,999.

It was estimated that a total U.S. sample of approximately 500 large dealer/contractors should provide adequate reliability. Given the regional distribution of installed heat pumps, about one-half of the sample would be needed for the South and one-quarter each for the northern and western regions. These levels should provide reasonable reliability for regional summaries, and the regional estimates could be more precisely weighted to derive proportionately weighted figures for the total U.S. (based on the estimated regional distribution of total in-place equipment installations).

A draft questionnaire was completed based on exploratory interviews with dealer/contractors and past experience in studies of this nature. The questionnaire was tested and a number of minor revisions were made. Interviews using the final questionnaire took between 15 and 20 minutes to complete. The actual telephone interviewing was conducted between December 4 and December 23, 1985.

A total of 492 interviews were completed with 80% being HVAC dealer/contractors and 20% being service contractors. Regional breakdowns were North, 122; South, 248; and West, 122. Respondents averaged:

- Annual revenue of $1.6 million.

- 249 annual unitary air-conditioning installations, which, extended by the number of respondents, represented approximately 5% of total U.S. sales.

- 147 annual heat pump installations, which, extended by the number of respondents, represented approximately 8% of total U.S. heat pump sales.

- 165 annual gas furnace installations, which, extended by the number of respondents, represented approximately 4% of total U.S. sales.

In addition to tabulations of raw data, regional weightings were applied to most of the questions to reflect distribution of equipment by region. For example, the South represented 50% of the responses but represents about 51% of unitary air-conditioning installations and 65% of heat pump installations. This procedure was designed to appropriately weight regional responses to derive national totals.

FINDINGS

Replacement Age

Four measures of replacement age experience were derived from the survey data. Respondent estimates of the average, minimum, and maximum replacement age for the total unit and for the replacement of compressors were gathered. This indicates a replacement age range, as well as two measures of the average: the stated estimated average and the midpoint of the estimated minimum/maximum range. These estimates are based upon dealer experiences and, therefore, relate to equipment installed in the past.

For unitary air conditioners, the estimated average is 12.1 years and the midpoint of the range is 12.6 years. For unitary air-conditioner compressors, the estimated average is 8.8 years and the midpoint of the range is 9.7 years. For heat pump units, the estimated average is 10.9 years and the midpoint of the range is 11.4 years. For heat pump compressors, the estimated average is 8.0 and the midpoint of the range is 8.4 years. For gas furnaces, the estimated average is 16.3 years and the midpoint of the range is 17.2 years (Figure 1).

The estimates for heat pump replacement age (both units and compressors) are about 90% of the estimated age for unitary air conditioners.

The estimates of replacement age for air conditioner and heat pump compressors bear a consistent relationship to estimates for unit replacement. Compressor replacement estimates are about 70% to 75% of the estimated unit replacement ages.

In addition, the service life expectancy used by dealer/contractors in customer discussions was also analyzed. This should relate to the perceptions of dealers with respect to changes in equipment technologies and the possible effects on service life.

The unit service life estimates used by dealers in customer discussions are similar to the estimated replacement age averages based on experiences and reflect the conservative nature of the HVAC trade.

- For unitary air-conditioning units, the estimated mean is 11.7 years

- For heat pump units, the estimated mean is 11.2 years

- For gas furnaces, the estimated mean is 15.2 years.

Estimates of replacement age for unitary air conditioners are similar in the North and West and lower in the South (Figure 2).

The estimates for the electric heat pump show a somewhat different regional pattern in which the lowest estimated average replacement age is in the North, followed by the South, and then the West. This possibly reflects the differences in heating requirements, combined heating and cooling requirements, and equipment-purchasing patterns among the regions. The dealer estimates in this survey seem to be consistent with regional market characteristics as defined by published market data and our previous studies. Since the heat pump provides both cooling and heating service, the number of hours and load "stress" for each mode of operation, as well as the total combination, will affect the estimated equipment service life (measured in years).

Where cooling requirements are greater than heating requirements, heat pump service life should be heavily influenced by the cooling load and thus similar to that of unitary air conditioners. This is the case in the South and West, where the heat pump service life is 95% and 93%, respectively, of the estimated service life for unitary air conditioners.

Where the heating load is significantly greater than the cooling load, as in the North, the heat pump service life can be expected to be less closely related to the estimated life for unitary air conditioners. This reflects not only the number of annual hours in the heating mode, but also the degree of stress experienced in the heating mode. The climate in the North imposes a greater stress on the heat pump heating mode than is generally the case in the other regions. The higher estimated ages in the West reflect a climate that is generally less extreme with respect to both the cooling and heating loads.

Estimates of replacement age for gas furnaces are highest in the North, followed by the West, and are lowest in the South. Heating requirements are relatively more important in the North, and, based upon previous proprietary surveys, customers generally have a greater tendency to purchase higher quality furnaces (which tend to have a longer service life). Gas furnaces have fewer "wear parts" and are less directly affected by annual hours of operation than air conditioners and heat pumps. The use of central (warm air) heating systems is a more recent (last 20-25 years) trend in the South and West, and over this period of time, the new construction portion of total furnace sales in the South and West has been considerably higher than in the North. Since lower-to-medium quality units (which tend to have shorter service lives) often are used in new construction, the estimated replacement age based upon dealer experience can be expected to be lower in these two regions than in the North.

The estimates of replacement age for compressors show similar patterns and relationships as those for unitary air conditioner and heat pump units (Figure 3). The estimates for compressor replacement age are consistently between 70% and 75% of the estimated total unit replacement ages for all regions.

On average, the estimated replacement age for heat pumps for the total U.S. is about 90% of the estimates for unitary air conditioners. As in the case for total units, the estimated ages are closer to those of unitary air conditioners in the South and West, with greater differences in the North.

The distribution of average replacement age estimates for unitary air conditioners indicates a two-humped distribution for total unit replacement (Figure 4). This reflects the complexities and practicalities of the marketplace. It indicates that there are several populations of equipment (within the total distribution) that vary in quality, number of annual operating hours, quality of service, and service life.

The estimated distribution for compressor replacement is fairly tight around the mean of 8.8 years.

- Almost 60% of compressor replacements are estimated to occur between 6 and 10 years.
- Approximately equal percentages for replacement are estimated to occur between 5 and 6 years and after 10 years.

The combination of distributions indicates some replacement tendencies that have to be considered in evaluating equipment replacement age. If a unit's compressor fails:

- Within the first six years, there appears to be a tendency to replace the compressor, as the other components of the unit may still have considerable service life.
- In the 8-to-12 year period, the compressor versus total unit replacement decision is more complex and could go either way.
- After 12 years, in most cases the total unit would be replaced, as the other components are viewed as having a somewhat limited additional service life.

The estimated replacement age distribution for heat pumps shows a less distinct two-humped pattern and greater concentration of replacement age estimates in the 6-to-12 year period than unitary air conditioners (Figure 5).

- Estimates suggest that about 64% of heat pump units are replaced between 6 and 12 years.

- Approximately 30% are estimated to be replaced in the 12-to-20 year range.

- As with the unitary air conditioners, it is believed that the humped pattern reflects somewhat different equipment populations, average operating hours per year, and quality of service. The upper end of the distribution would also include heat pumps that have had compressors replaced earlier in their service lives.

The estimated distribution for heat pump compressors is also similar to that for unitary air conditioners, with the distribution shifted slightly toward earlier replacement age.

Dealer estimates of the heat pump unit replacement distribution suggests that over 50% of replacements occur by the end of year 10. Likewise, dealers estimate that over 80% of heat pump compressor replacements occur by the end of year 10.

The distribution of average replacement age estimates for gas furnaces shows a distinct two-humped distribution pattern (Figure 6).

- Less than 9% of respondents estimated average replacement age at 10 years or less, versus about 42% for air conditioners and 54% for heat pumps.

- Almost 10% of estimates for gas furnaces were greater than 20 years, versus less than 1% for air conditioners and heat pumps.

- Almost 64% of replacement age estimates for gas furnaces fall in the 15-20 year period, with 31% at 15-16 years, 13% at 17-18 years, and 20% at 19-20 years.

As indicated earlier, the unit service life used in customer discussions should reflect dealers' perceptions of the expected life of equipment being installed today. It is, however, influenced by dealers' conservatism, and these values tend to be somewhat less than dealers' estimates of equipment life based on their experience. The respondents indicated that they considered manufacturers' estimates for expected service life but relied heavily on their own experience with respect to the expected service lives they were willing to discuss with customers.

Replacement Influences

Replacement decisions are influenced by a broad range of factors. Other proprietary studies conducted by the author suggest that from 50% to 60% of such decisions are due to actual failure of the total unit or a major (expensive) component. Other reasons include:

- Anticipation of probable failure within the next year or so, based upon increasing service costs, dealer suggestions, or simple concern about the age of the equipment.

- Dissatisfaction with system performance.

- Major home remodeling or alterations that increase heating or cooling requirements beyond the capacity of the current system.

- Replacement of both components of a dual-service system (furnace/air conditioner) when one of the components (air conditioner) fails, particularly when the other component (furnace) is believed to have five years or less service life remaining.

- Replacement of "live" equipment to achieve improved energy efficiency and energy cost savings.

Typically, lower-to-medium quality appliances ("builder" models) are installed in new construction. These units can generally be expected to have higher service costs and shorter service life expectancies than higher quality equipment. A unit that has had proper routine maintenance throughout its service life can be expected to have a longer service life. This is particularly true for air conditioners and heat pumps, where refrigerant leaks are a major service issue. If refrigerant leaks are not detected, the loss of refrigerant can lead to failures of major components (e.g., compressor).

Figure 7 shows a conceptual depiction of replacement tendencies derived from "qualitative" comments by trade contacts and supported by the analysis of the dealers' quantitative estimates of unit and compressor replacement ages. The figure reflects the pattern for both unitary air conditioners and heat pumps.

- The numerical values shown are a combination of the data derived from the survey results for both types of equipment. The figures are meant to provide perspective only.

- No attempt was made to estimate the vertical dimension, the relative proportions of compressor/unit replacement by time period, or the percentage of units that have a compressor replacement before the unit itself is replaced.

If the compressor fails within the first eight years or so, there is a strong tendency to replace the compressor as the other components of the unit are believed to have significant service life remaining: approximately 33% of compressor replacements but only about 6% of unit replacements occur during this period.

The period between about 8 and 13 years involves a more complex decision. The efficiency and quality of the original unit, satisfaction with the unit's performance, service costs related to components other than the compressor, and dealer marketing and promotional activities are likely to influence the decision. This is a heavy period of replacement of both compressors and units: about 62% of unit replacements and 60% of compressor replacements occur during this period.

After 13 years, there is a strong tendency to replace the total unit if the compressor fails because of the remaining service life of the other components: about 32% of unit replacements and 7% of compressor replacements occur after 13 years.

This pattern has important implications for estimating realistic service lives, as the effects of compressor replacement versus unit replacement must be considered. It raises the question of how a 15-year-old unit that has not had a compressor replacement can and should be viewed and compared to a 15-year-old unit that has had a compressor replacement.

- With respect to life cycle cost analysis, the incidence of compressor replacement must be considered in the analysis.

- The patterns in the marketplace are clearly complex, and the influencing factors must also be considered in setting average replacement age and procedures for conducting life-cycle cost analyses.

<u>Trends</u>

Given the changes that are occurring in the technology and in the market, dealer perceptions concerning trends in equipment reliability, service requirements, and service life are of interest. While the primary focus of technical development over the past few years has been improved efficiency, dealers believe that other improvements have been made.

The dealers expect that the improvements in reliability will have some influence on the service requirements for equipment being installed today. The largest portion, however, believe that the improved reliability will not materially affect service requirements for air conditioners and heat pumps.

- For unitary air conditioners, over 50% believe that service requirements will remain basically the same.

- About 40% believe that heat pump service requirements will remain basically the same. Almost a third believe that the improved reliability will reduce service requirements, while a slightly lower percentage believe they will be greater.

These results indicated that dealers perceive that certain of the technologies being employed to improve equipment reliability and efficiency (for all types) also make the equipment more complex, and that an equal or greater amount of service activity may be required to deal with these technologies.

Dealers do not perceive that improvements in reliability will necessarily lead to longer service life. Improvements may relate to the functional reliability within a defined service life, rather than specifically increase service life.

- With respect to unitary air conditioners, over 60% of the dealers expect replacement age to remain the same or in fact be shorter than in the past.

- Although more than 86% of the dealers perceived improvements in heat pump reliability, slightly more than 52% believed that the replacement age will remain the same or in fact be shorter.

The use of incentives to promote electric heat pumps has increased, and about 60% of the dealers in the survey indicated that electric utilities are offering incentives in their area: 20% cash incentives, 27% rebates (39% in the West), 23% co-op advertising (31% in the North), and 17% other incentives (i.e., low-rate financing or loans repaid through electric bill add-ons). In many areas, the size of the incentive is being tied to specific efficiency levels and/or the replacement of specific types of equipment (including gas equipment).

Maintenance Issues and Costs

Although maintenance costs were a secondary area of the survey, heat pump service costs (excluding air handler) were consistently estimated in the survey to be 20% to 30% higher than those for unitary air conditioners and 55% to 60% higher than those for gas furnaces. In addition, the average per-unit first year service reserve fund for heat pumps is:

- 33% higher ($101 versus $75) than air conditioners,
- 65% higher ($101 versus $61) than gas furnaces.

The survey did not attempt to determine rates of major component failure for heat pumps but did ask dealer/contractors to estimate the relative proportion of service calls for a selected list of service categories (other service activities were not investigated).

Refrigerant leaks	19%
Fans (blower, wheels, relays, motors, etc.)	19%
Compressor motor circuits	17%
Defrosting components	17%
Compressor failure	16%
Refrigerant components	12%
	100%

Dealer/contractor estimates of the average installed cost (equipment and labor) for a typical (3 ton) replacement compressor in their area were $793 for unitary air conditioners and $880 for heat pumps. Average estimates for the cost (installed) of a replacement compressor as a percentage of the cost of a totally new unit ranged from 40% to 45%.

CONCLUSIONS

Determining actual service life or replacement age in the marketplace is difficult due to the complexities of the market environment and the interactions of a wide range of influencing factors, including variations in equipment quality, installation quality, service/maintenance quality and use of annual/routine preventive maintenance, annual load requirements and load extremes (annual operating hours and load stresses), usage patterns, and other replacement influences.

For comparative equipment quality/operating situations, heat pumps must meet the same cooling requirements as air conditioners and, in addition, must meet the heating requirements that can double the number of operating hours. This, combined with market in-use practicalities and the technical aspects of the capability to perform both functions, raises questions of whether a heat pump can be expected to have an actual in-use service life equal to that of an air conditioner of similar quality (even with a specifically designed compressor).

There are strong indications that heat pump replacement age is, on average, lower than that of unitary air conditioners. Dealer/contractor estimates of heat pump replacement age are similar to, but consistently lower (by about 10%) than, their estimates for air conditioners.

Early replacement (of live equipment) is a significant factor in the marketplace and should be considered in evaluating service life benchmarks. A significant amount of heat pump replacement (possibly as much as 40-50%) is estimated to occur in the first 10 years.

The incidence and timing of compressor replacement should be considered in evaluating heat pump service life benchmarks.

- Dealer estimates indicate that a significant amount of compressor replacement occurs in the first 10 years.

- Compressor replacement represents a significant cost, 40-45% of the cost of a total new unit.

Market segmentation and the relative competitiveness of various HVAC products by market segment (e.g., customer type, climate) will be increasingly important in HVAC and energy marketing planning. In most new construction segments, end-users have little or no involvement in the choice of equipment. In the replacement market, the degree of end-user involvement is greater and more complex and would include such factors as constraints imposed by present in-place systems, replacement time frame (immediate failure need versus energy retrofit), and investment horizon (expected length of stay in the present housing). In general, end-users tend to upgrade equipment quality (and energy efficiency) when replacement decisions are made. Thus, the average in-place equipment quality will tend to increase as a market area matures (the ratio of replacement to new construction sales increases).

RECOMMENDATIONS

Estimates from a survey of this nature tend to be conservative and, given the high "efficiency replacement" factor (that can shift over time), a replacement age range may be more meaningful to use for many purposes than a point estimate.

Based upon the data from this dealer survey, the author recommends the following ranges in situations where range estimates would be more meaningful than point estimates:

	Survey Means	Range
Heat Pumps	10.9 yrs	10-13 yrs
Unitary air conditioners	12.1 yrs	12-15 yrs
Gas Furnaces	16.3 yrs	16-19 yrs

For situations where a point estimate of service life is needed, the use of the following benchmarks are recommended. These values retain the relative replacement age relationships indicated in the survey and were derived from cross-correlation analysis of all the data collected in the survey:

- 14 years for unitary air conditioners,

- 12 years for heat pumps,

- 18 years for gas furnaces.

Methods of life-cycle cost analysis used in equipment comparisons should explicitly recognize the incidence and timing of compressor replacement. This can be accomplished by including the cost of compressor replacement in the maintenance cost factor or by adjusting the estimated service life factor.

When service life "year" figures are used as benchmarks, assumptions concerning annual operating hours (and perhaps levels of equipment quality and routine maintenance) should also be clearly stated.

APPENDIX

HVAC DEALER/CONTRACTOR QUESTIONNAIRE

Company Name ____________________ Date ____________________

City/State ____________________ Phone # ____________________

State ____________________ Size ____________________

Region ____________________

Hello, I'm ____________ from ____________, a national marketing research firm. We're doing a study of HVAC equipment service life and service costs and I'd like to ask you a few questions. Some of the questions may deal with data that you don't normally collect, but we would appreciate your opinions and best estimates based on your experience. All individual responses will remain confidential, and will only be reported in summary form to our client. The first couple of questions are for classification purposes only.

Try to speak with 1) Service Manager 2) Owner/Partner

1. Are your company's total annual sales over $400,000
   _______ Yes (continue)
   _______ No (terminate)

2. Do you do more than 10 residential electric heat pump installations in an average year?
   _______ Yes (continue)
   _______ No (terminate)

3a. What percentage of your sales are:
   _______% Residential
   _______% Commercial

3b. What percentage of your residential business is:
   _______% New Construction
   _______% Replacement
   _______% Service

FROM THIS POINT ON, HAVE YOUR RESPONDENTS ANSWER IN TERMS OF THEIR

RESIDENTIAL BUSINESS ONLY.

	Gas Furnaces	Unitary Air Conditioners	Electric Heat Pumps
4a. Approximately how many (READ COLUMN HEADINGS) do you install in a typical year?	_______	_______	_______

FOR EACH EQUIPMENT TYPE ASK:
(Work vertically)

4b. What percentage of _______ were for replacement (rather than new construction)?	_______%	_______%	_______%

4c. Of the replacement, what would you estimate as the percentage where "live" or still functioning equipment

	Gas Furnaces	Unitary Air Conditioners	Electric Heat Pumps
was replaced for energy efficiency (or other) reasons?	______%	______%	______%
4d.1. Based on your experience, what would you estimate has been the average age at replacement (when the total unit is replaced)? If unable to answer, skip to 4d.3	______Avg	______Avg	______Avg
4d.2. What might be a reasonable maximum/minimum replacement age? (Skip to 4e.)	______Min	______Min	______Min
4d.3. Prompt with ranges (for average only):	______Max	______Max	______Max
< 10 years	( )	( )	( )
10-14	( )	( )	( )
15-19	( )	( )	( )
20-24	( )	( )	( )
25+	( )	( )	( )
4e. Based on your experience, has the quality and reliability of ________ been improved in the last couple of years?			
Yes (continue)	( )	( )	( )
No (Go to 5a)	( )	( )	( )
4f. Do you expect this to lead to a ________ service life?			
Increased	( )	( )	( )
Decreased	( )	( )	( )
No change in	( )	( )	( )

FOR EACH EQUIPMENT TYPE ASK:
(Work vertically)

	Gas Furnaces	Unitary Air Conditioners	Electric Heat Pumps
5a. Do you believe that the service life of equipment being installed today will be ________ than has been the case in the past?			
Longer	( )	( )	( )
Shorter	( )	( )	( )
The same as	( )	( )	( )
5b. Do you believe that the ________ being installed today will require ________ service than earlier models?			
Greater	( )	( )	( )
Less	( )	( )	( )
About the same	( )	( )	( )
5c. What average service life (years) does your company use for __________ in discussions with prospective customers or in cost comparisons? (Skip to 5d)	______	______	______

	Gas Furnaces	Unitary Air Conditioners	Electric Heat Pumps
If unable to answer, prompt with ranges:			
< 10 years	( )	( )	( )
10-14	( )	( )	( )
15-19	( )	( )	( )
20-24	( )	( )	( )
25+	( )	( )	( )
Don't know (skip to q. 6)	( )	( )	( )
5d. What is the source of these factors?			
Manufacturer	( )	( )	( )
Distributor	( )	( )	( )
ASHRAE Guidelines	( )	( )	( )
Own experience or opinion	( )	( )	( )

6. What methods do you use to determine the proper sizing of equipment? (Prompt only if necessary)

   a. Replace with comparable equipment ( )

   b. Rule of thumb or other ( )

   c. Manual calculation (standard ACCA J Form; heat loss survey) ( )

   d. Computer-based program ( )

   e. Use in-house computer ( ) }only ask if they
   f. Use utility/mfr's computer service ( ) }use a computer-based program

7. What information or methods do you use when comparing alternative systems in sales presentations to prospective customers? [Read List]

   - Installed equipment cost only ( )
   - Installed equipment and estimated annual energy costs ( )
   - Installed equipment and estimated total annual operating costs (including energy, maintenance, other) ( )
   - Simple payback analysis ( )
   - Life cycle cost analysis ( )

ASK FOR EACH EQUIPMENT TYPE:

	Gas Furnaces	Unitary Air Conditioners	Electric Heat Pumps
10a. Approximately what percentage of your total service activity for ________ is on annual service contracts?	________%	________%	________%
10b. Is this annual service contract portion:			
Increasing	( )	( )	( )
Decreasing	( )	( )	( )
Remaining about the same	( )	( )	( )
10c. Approximately what percentage is on:			
Manufacturers Service Program	$________	$________	$________
Dealers Service Program	$________	$________	$________
10d. What do you estimate the annual maintenance costs would be for a typical ________ in your area?			
On an annual service contract	$________	$________	$________
On an "as needed" service basis	$________	$________	$________
10e. What would be a typical per unit first year service reserve (escrow) fund?	$________	$________	$________

11. What would you estimate the breakdown by efficiency level of the ________ you expect to sell this year?

AFUE		Gas Furnace	SEER	Electric Heat Pump
< 80%	standard	________%	<7.5	________%
80-84%	hi-efficiency	________%	7.5-9.0	________%
85+%	condensing	________%	9.0+	________%

[Relates to Heat Pumps]

12. What incentives are being offered by: ________ in terms of the electric heat pump?

	Manufacturer	Utility
a. Cash	Y ( ) N ( )	Y ( ) N ( )
1. Average Amount	$________	$________
b. Rebates	Y ( ) N ( )	Y ( ) N ( )
1. Average Amount	$________	$________
d. Co-op Advertising	Y ( ) N ( )	Y ( ) N ( )
e. Other	Y ( ) N ( )	Y ( ) N ( )
f. None	Y ( ) N ( )	Y ( ) N ( )

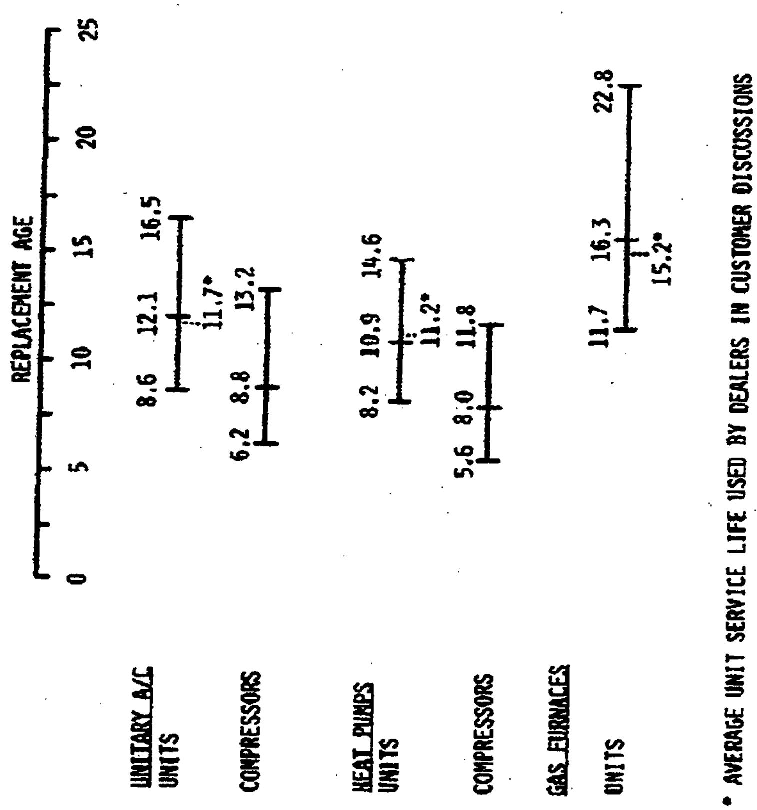

Figure 1. Estimated minimum, average and maximum replacement age

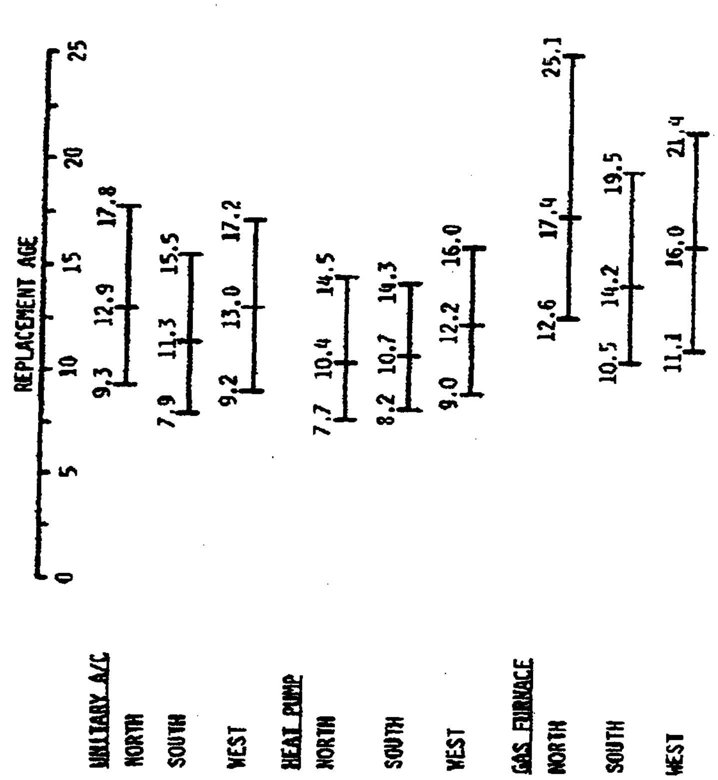

Figure 2. Estimated replacement age by region

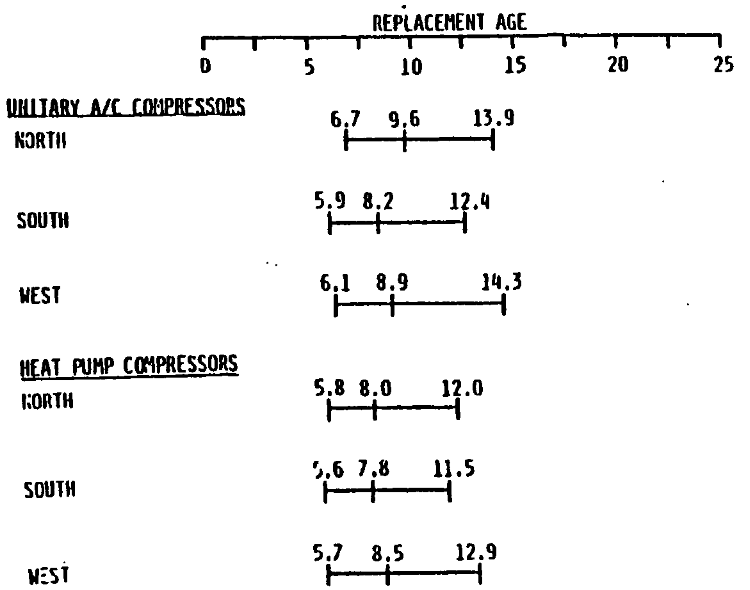

Figure 3. Estimated compressor replacement age by region

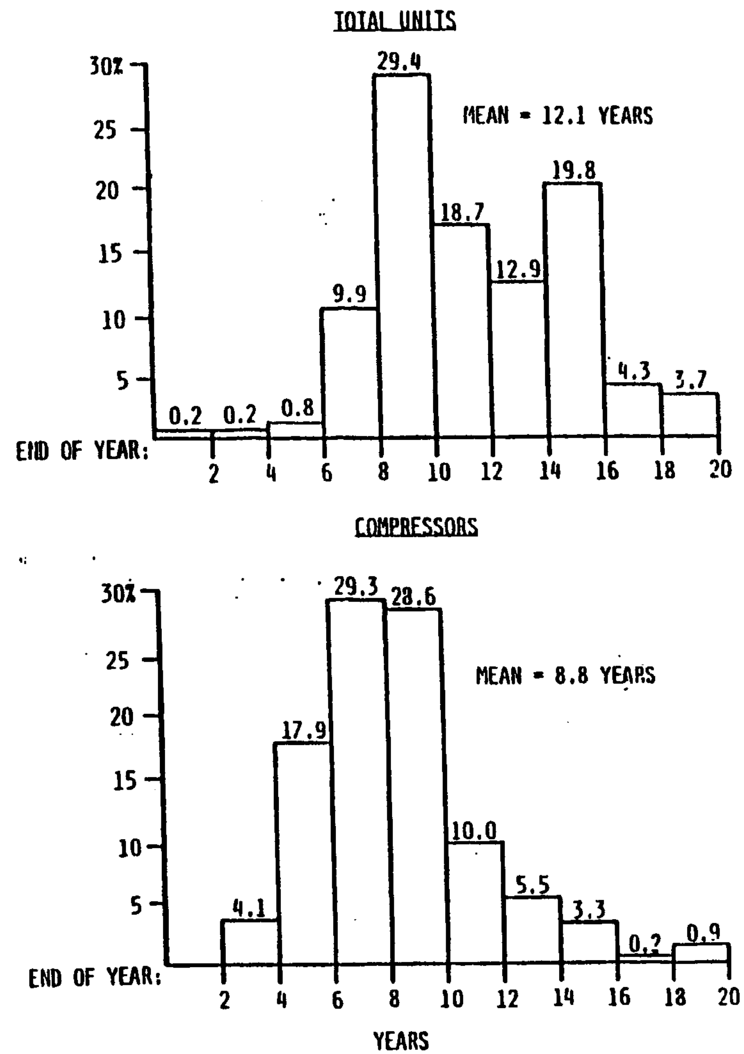

Figure 4. Distribution of unitary AC replacement ages

	Unitary Air Conditioner	Electric Heat Pump
8a. In your experience, what would you estimate as the average service life (age at replacement) of a ___________ compressor?	________ Avg	________ Avg
8b. What might be a reasonable minimum/ maximum replacement age (skip to 8c)	________ Min	________ Min
	________ Max	________ Max
If unable to answer, prompt with ranges (for Avg. only):		
5-7 years	( )	( )
8-10 years	( )	( )
11-14 years	( )	( )
15-19 years	( )	( )
20+ years	( )	( )
8c. What would you estimate as an average installed cost (equipment and labor) for a ___________ replacement compressor (typical or most common size in your area)?	$________	$________
8d. Approximately, what percentage of the installed cost of a totally new ___________ unit would this be?	________ %	________ %
(Skip to 9)		
If unable to answer, prompt with ranges:		
20-30%	( )	( )
30-40%	( )	( )
40-50%	( )	( )
9. In terms of your average annual service calls for _____, what percentage are for:		
Fans (blades, blower wheels, capacitors, relays, motors)	________	________
Compressor Failure	________	________
Compressor Motor Circuits (contractors,capacitors, relays, etc.)	________	________
Defrosting Components	________	________
Refrigerant Components (reversing valve, motoring device, check valves)	________	________
Refrigerant leaks	________	________

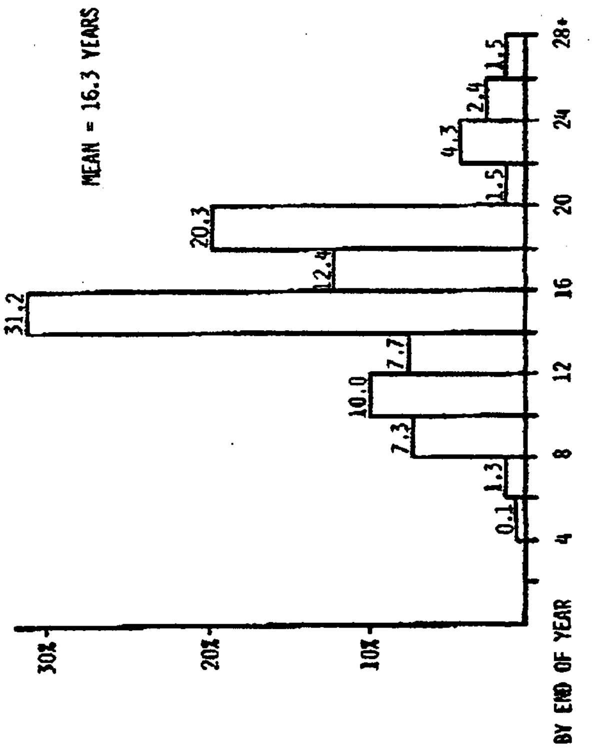

Figure 6. Distribution of gas furnace replacement ages

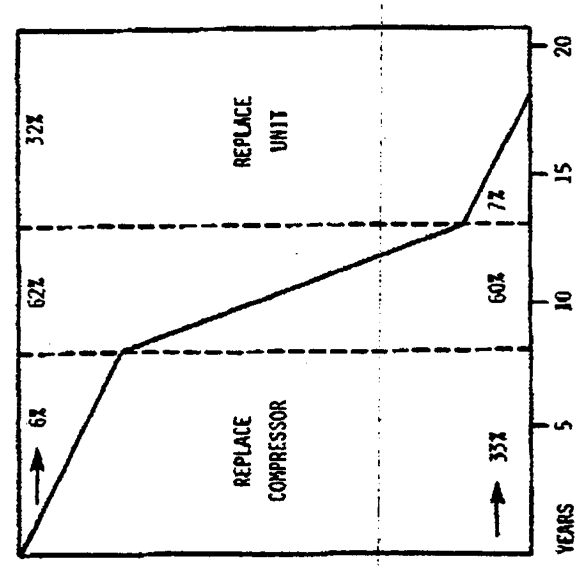

Figure 7. Conceptual depiction of replacement tendencies

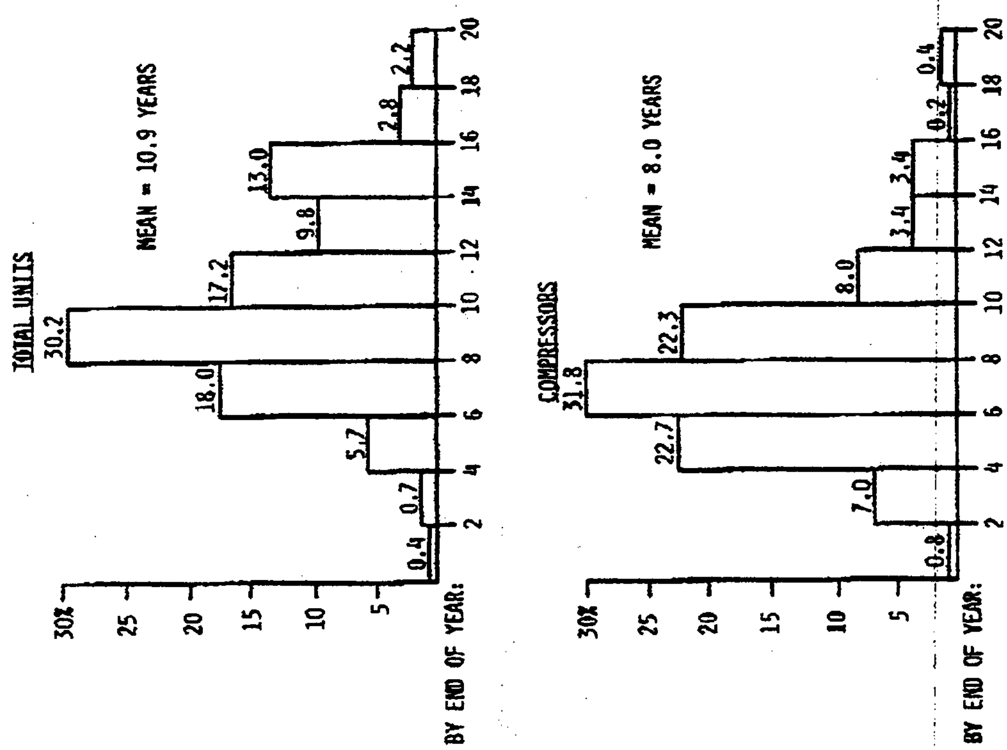

Figure 5. Distribution of heat pump replacement ages

HI-85-10 No. 5

A Study of Heat Pump Service Life

N.C. Lovvorn *ASHRAE Member*

C.C. Hiller, Ph.D. *ASHRAE Member*

ABSTRACT

This paper is based on a study of heat pump service life (age at replacement). The objective of the study was to survey known heat pump owners who had installed heat pumps between 1964 and 1974, gather empirical data that would provide responses to a series of questions concerning the service life of the known heat pump or, if appropriate, the successor, and determine the factors that influence the replacement decision. The major findings include the following:

1. Between 96% and 98% of the respondents surveyed still had heat pumps;
2. A large percentage of the original units are still in operation;
3. The median age of replacement is approximately 20 years in Alabama.

INTROUDUCTION

Much speculation has existed in recent years regarding the actual useful life of heat pumps, but no definitive work has been done to determine quantitatively the actual age at which heat pumps are typically replaced. A study(1) was initiated in 1984 to perform a survey of heat pump replacement life and related issues in Alabama. The Alabama region of the country was selected because of its lengthy experience with heat pumps and the existence of at least one assured service heat pump program(2) which provides a heat pump maintenance contract for up to ten years for a low monthly premium.

Under the particular heat pump service program addressed in this survey, qualifying heat pumps are installed by local dealers who have been certified by the program, and upon passing a check for conformance to the program installation standards, those heat pump installations then qualify for a ten year maintenance contract. The program maintains detailed service records during the ten year period, after which, no records are kept. Maintenance is done only as needed by one of the program's certified dealers. The program stresses the maintenance procedures and practices that must be followed in order for repair or installation work to meet program standards. These standards are primarily a means of ensuring that work is done to the stated requirements of the manufacturers.

The heat pump owners contacted during this survey had heat pumps that had been under the assured service maintenance contract for a full ten years, thus assuring that the results are representative of correctly installed heat pumps. The service program data base was used only for the purpose of generating a list of known heat pump installations and for verifying the

N. C. Lovvorn, Supervisor, Residential Heat Pumps, Alabama Power Company, Birmingham, AL, and Carl C. Hiller, Project Manager, Electric Power Research Institute, Palo Alto, CA.

validity of the survey responses with respect to the age and brand of the original heat pump. A future study is planned to correlate the maintenance history during the first ten years of the specific heat pumps' lives with their replacement age.

Much useful information on reasons for heat pump replacement, factors affecting the replacement selection and more was obtained in addition to information on actual replacement life. The specific objectives of the survey were as follows:

1. Determine actual service life (age at replacement) distribution of heat pumps in Alabama.
2. Determine the proportion of heat pumps in Alabama that are still in operation, as a function of installation date.
3. Determine, categorize, and quantify typical reasons for replacement of the heat pumps (not addressed in this paper).
4. Determine, categorize, and quantify typical factors affecting the choice of the replacement heating system (not addressed in this paper).
5. Determine the various types of heating systems used to replace those heat pumps that have been replaced (not addressed in this paper).
6. Determine seasonal replacement trends (not addressed in this paper).
7. Provide breakdowns of the above information categorized by manufacturer, year of installation, and other appropriate groupings.

METHODOLOGY

A 25-item questionnaire was developed to collect information on heat pumps that had been under a maintenance contract for ten years in Alabama. The participants were divided into three groups according to when they entered the maintenance contract program. The three groups were:

Group 1: Heat pumps installed between March 1964 and May 14, 1967.

Group 2: Heat pumps under maintenance contract installed between May 15, 1967 and Decembr 31, 1971.

Group 3: Heat pumps under maintenance contract installed between January 1, 1972 and April 18, 1974.

The dates of the three groups correspond to dates of changes in the heat pump service program. These groups were proportionally sampled and owners interviewed by telephone to provide the data for the study.

This section contains a discussion of the methods used in conducting the study. The discussion includes sample design, instrumentation, data collection procedures, and methods of data analysis.

Sample

The heat pump service program under discussion has been able to develop detailed tracking records that could be used to validate data generated through a field survey. These records, while not included herein, include histories of the heat pumps, heat pump unit identification information, warranty data, and service information.

The universe for this study was defined as heat pumps covered for a full ten years by the assured service program. The extremely long replacement lives of the heat pumps of this study showed that use of the above universe did not bias the results in any significant way. A total of 5,963 heat pump installations were identified and these were subsequently divided into the three groups previously mentioned. This stratification process allocated 597 names to Group 1; 3,443 names to Group 2; and 1,923 names to Group 3. Each of these three groups was further stratified into six geographic regions within Alabama.

To assure a high level of randomness and avoid the problem of periodicity, the homeowners names in all subgroups were reordered. More specifically, the listing of names was changed from the original format to one that alphabetized them.

The sampling procedure adopted for this study was the stratified sampling technique. This method selected from every stratum a random sample proportionate to the size of the stratum. Different sample sizes were selected for each of the three groups. For Group 1, it was decided that a census (a sampling of 100%) should be attempted because of the small number of units in the universe. For Group 2, it was decided that a sample of 1,000 would provide a safety factor of 20 to 1. In other words, if a survey result shows 20%, the odds are 20 to 1 that this result is accurate within 2.6 points...a census probably would come out between 17.4% and 22.6%. For Group 3, a sample size of 400 was selected.

Survey Questionnaire

In order to carry out the research goals as well as collect other relevant information, a questionnaire was developed. The survey was structured as a general heating and cooling study, and the participants and sponsors were not identified to the homeowner in order to avoid biasing of the responses.(1)

Data Collection Procedure

Data for this study were collected from the sample through telephone interviews. The survey instrument was subjected to a series of pre-survey tests until it was determined that no major flaws existed. The responses to these pre-survey tests provided valuable information on the final wording of several questions.

Survey

On June 13, 1984, the actual telephone interviewing commenced. Because the owners of some heat pumps had changed, attempts to locate the new owners were made using addresses. This resulted in telephone calls to 3,211 owners, of which there were 151 refusals and 1,010 who could not be reached. There were 2,050 completed surveys; and 1,689 which were identified as valid by passing verification and edit routines to check for survey self consistency and agreement with the heat pump service program data base information. The survey was performed by an independent firm normally engaged in market studies.

Data Analysis Procedure

Prior to data analysis, each interview form was edited to assure that the correct procedure had been followed. At this time, coded information was entered on the form, which would later be used to verify the validity and reliability of the information being collected. The next step of the process was to keypunch the information for further processing. Several computer routines were used to identify interviewer errors, internal inconsistencies, and make comparisons with acceptance standards. Once an interview passed all of these validation checks, it became a part of the data bank. All rejected interviews were checked to determine whether the problem could be resolved. Any interviews identified as unresolvable (353) were replaced with a new valid interview.

OVERALL SERVICE LIFE DISTRIBUTION

Figure 1 shows the service life distribution based on an analysis of the data. The actuarial distribution curve(3) is the appropriate curve to use in projecting the expected life of any generic heat pump. The curve in Figure 1 is of great significance, since it indicates that the median service life (age when 50% of the heat pumps are still in operation, and 50% have been replaced) of heat pumps in Alabama is approximately 20 years, as opposed to the more commonly held belief of 14-15 years for air-conditioning systems and even less for heat pump systems. Furthermore, at age 15, approximately 75% of all heat pumps surveyed are still in active use.

Analysis of the heat pump service program maintenance records has shown that on the average, a reasonable fraction of the heat pumps will have required servicing at least once during the first ten years of operation.(4) The curve in Figure 1 is hence even more significant because it conclusively shows that heat pumps in Alabama have very long service lives despite the probability that by age 20, a number of the heat pumps will have had servicing, some major. In other words, compressor failure or other major servicing clearly does not mandate early retirement of the unit. If such major servicing is correctly performed, the unit should continue to operate satisfactorily for an extended period of time.

SERVICE LIFE FOR VARIOUS MANUFACTURERS

Figures 2 through 7 show the service life distributions for manufacturers A, B, C, D, E, and (as a single group) F through V. Once again, the actuarial curves shown are the appropriate curves to examine for predicting the expected probability of survival of any given heat pump for the respective manufacturers.

The figures show that:

-- Manufacturer B's heat pumps have the longest service life with, on the average, approximately 62% of the units expected to be in operation at age 20, and a median service life notably in excess of 20 years.

-- Manufacturer A's and D's heat pumps have comparable service life, with approximately 52-53% of the units expected to be in operation at age 20, and a median service life slightly in excess of 20 years.

-- Manufacturer C's heat pumps have slightly shorter service life, with approximately 45% expected to be in operation at age 20, and a median service life of approximately 19.5 years.

-- Manufacturer E's heat pumps are few and the curve is not reliable, but the observed behavior is consistent with the other heat pumps discussed above.

-- Manufacturers F-V, as a group, have the shortest expected service life, with a median service life of approximately 16 years. Note, however, that there were less than 173 of the various brands F through V in total in the entire survey sample, which is why they were lumped into a single group.

These distributions are estimated from data pooled over different years of installation for each manufacturer. However, the pooling is acceptable because year of installation does not appear to affect service life. This is partly due to the fact that market and other sales promotion activities were found to have a major influence on the decision to replace units.

The actuarial curves for manufacturers B and E are flat at higher ages. This is a result of the small numbers of heat pumps of those manufacturers at higher ages, none of which failed, and of the weighting given to age at replacement in the actuarial method of analysis. For a larger sample of such heat pumps, the curves would decrease at higher ages.

EFFECT OF REPLACING ONLY WHEN A HEAT PUMP FAILS

Since it was found that slightly less than half of the heat pumps replaced were still operational when removed from service, it was thought useful to estimate the service life distribution that would result if all heat pumps had been replaced only at time of failure. Figure 8 shows both the observed actuarial distribution (from Figure 1) of service life, and the speculated actuarial projection of service life assuming units were only replaced at time of failure. As expected, the median heat pump service life, if replacement were done only at time of failure, is considerably longer than the 20 years observed in this study, which serves to point out the impact of homeowner perceptions on the replacement decision, and the influence that marketing and incentive programs can have on such decisions.

CONCLUSIONS

1. A total of 96.4% of the respondents surveyed were identified as still having heat pumps. another 1.6% reportedly have other forms of electric heating (possible reporting error - they could also have been heat pumps).
2. A large percentage of the original known heat pump sample are still in operation, with more than 50% of the units 20 years old still in active use, 75% of the units 15 years old, and nearly 100% for units 10 years old.
3. The median age to replacement (age at which 50% of the units have been removed from service and 50% still remain in service) in Alabama is approximately 20 years.
4. The observed range of median replacement life was from 16 years to notably in excess of 20 years, with the overwhelming majority of the surveys favoring the longer lives.
5. There were no convincing differences in service life between younger and older units, due in large measure to the types of factors that were found to impact the replacement decision.
6. Slightly less than 50% of the relatively small number of units that were replaced were still fully operational at the time of replacement. Such replacements appear to have been motivated both by the perception of expected life, and by marketing and promotional efforts of dealer/contractors and the local utility.

This survey has revealed that heat pump service life in Alabama is considerably better than all values previously published by others. Furthermore, the results of this survey provide conclusive evidence that, if properly performed, major servicing of heat pumps does not appreciably degrade heat pump service life. Moreover, age of the heat pump unit alone need not be a determining factor in making a replacement decision.

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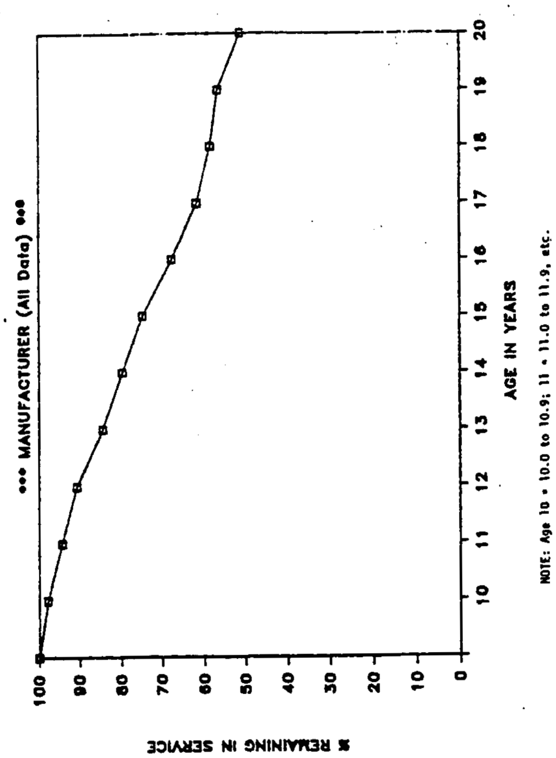


Figure 1. Percent Femaining in service (all)

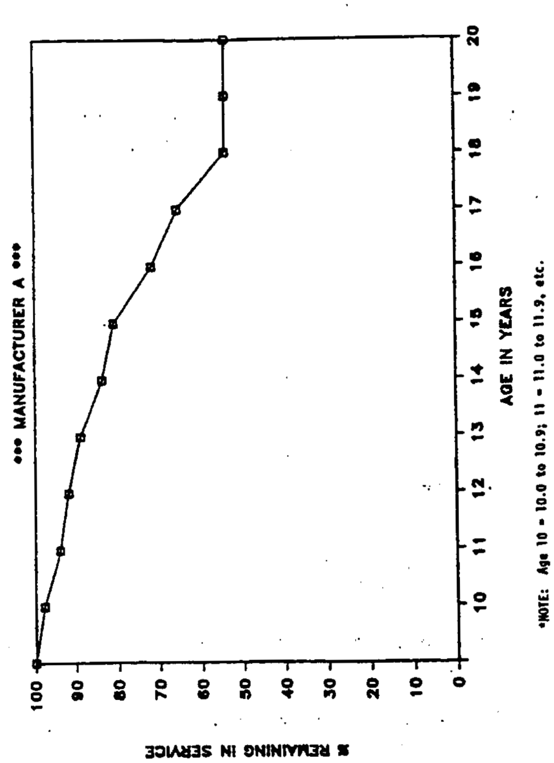


Figure 2. Percent remaining in service (mfg A)

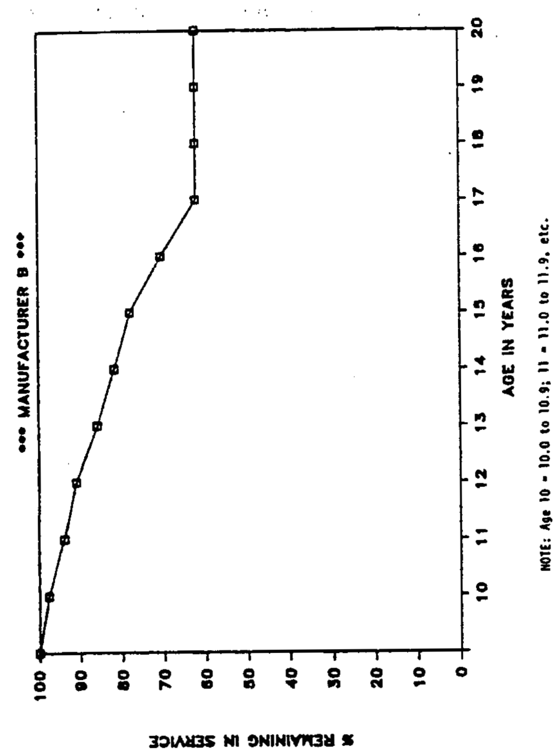


Figure 3. Percent remaining in service (mfg B)

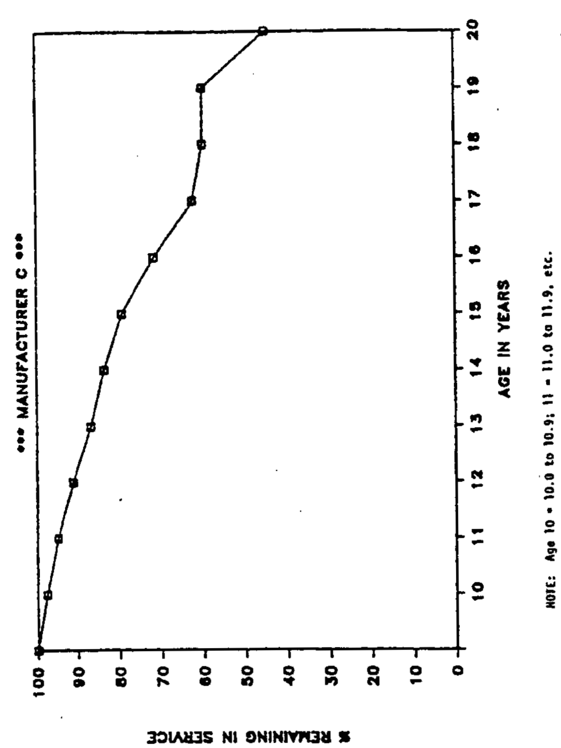
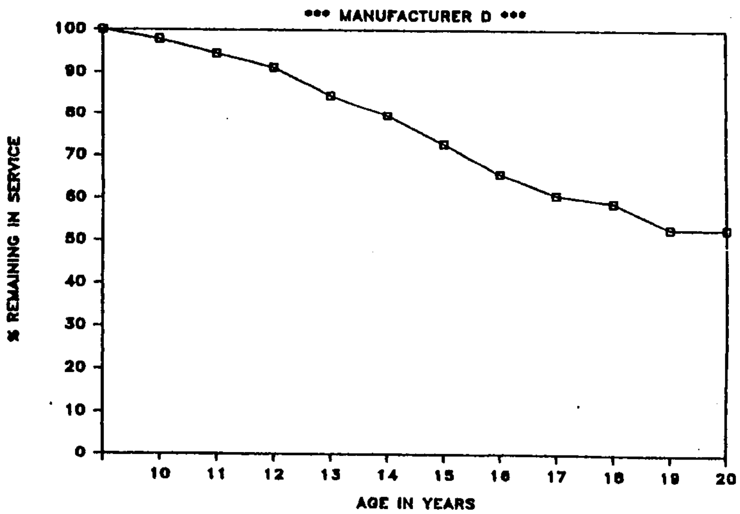
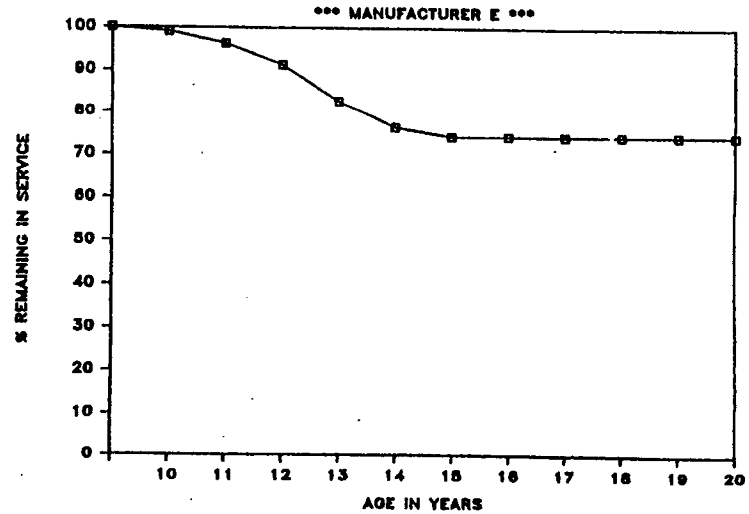


Figure 4. Percent remaining in service (mfg C)



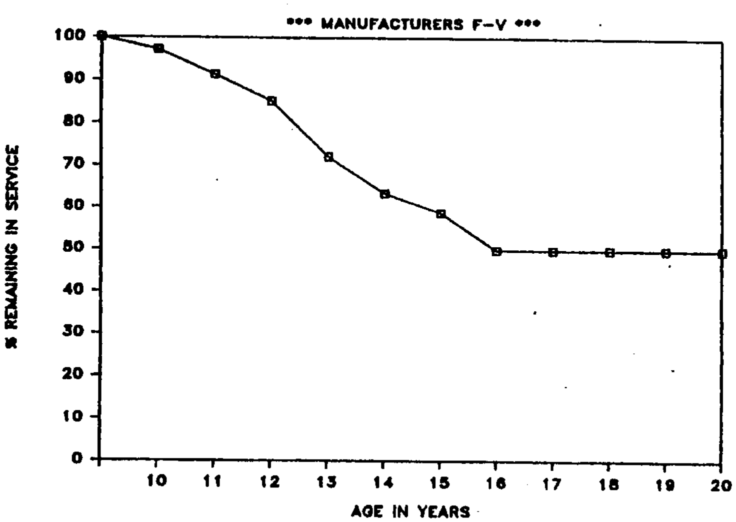
NOTE: Age 10 = 10.0 to 10.9; 11 = 11.0 to 11.9, etc.

Figure 5. Percent remaining in service (mfg D)



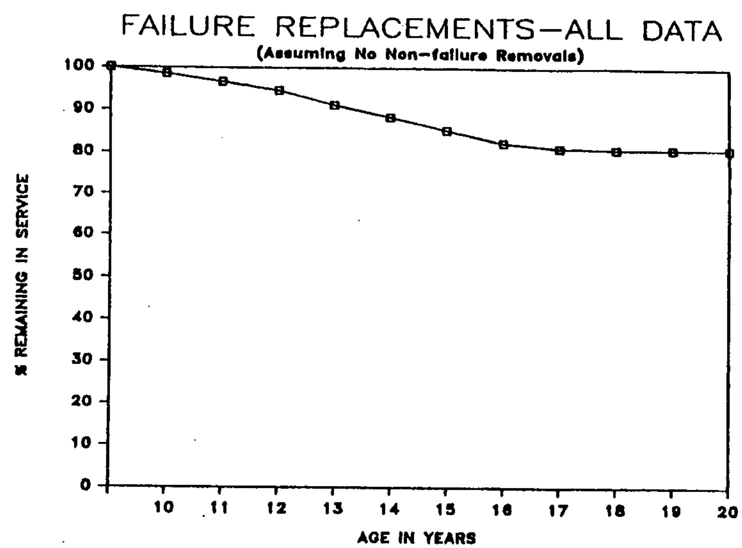
NOTE: Age 10 = 10.0 to 10.9; 11.0 to 11.9, etc.

Figure 6. Percent remaining in service (mfg D)



NOTE: Age 10 = 10.0 to 10.9; 11 = 11.0 to 11.9, etc.

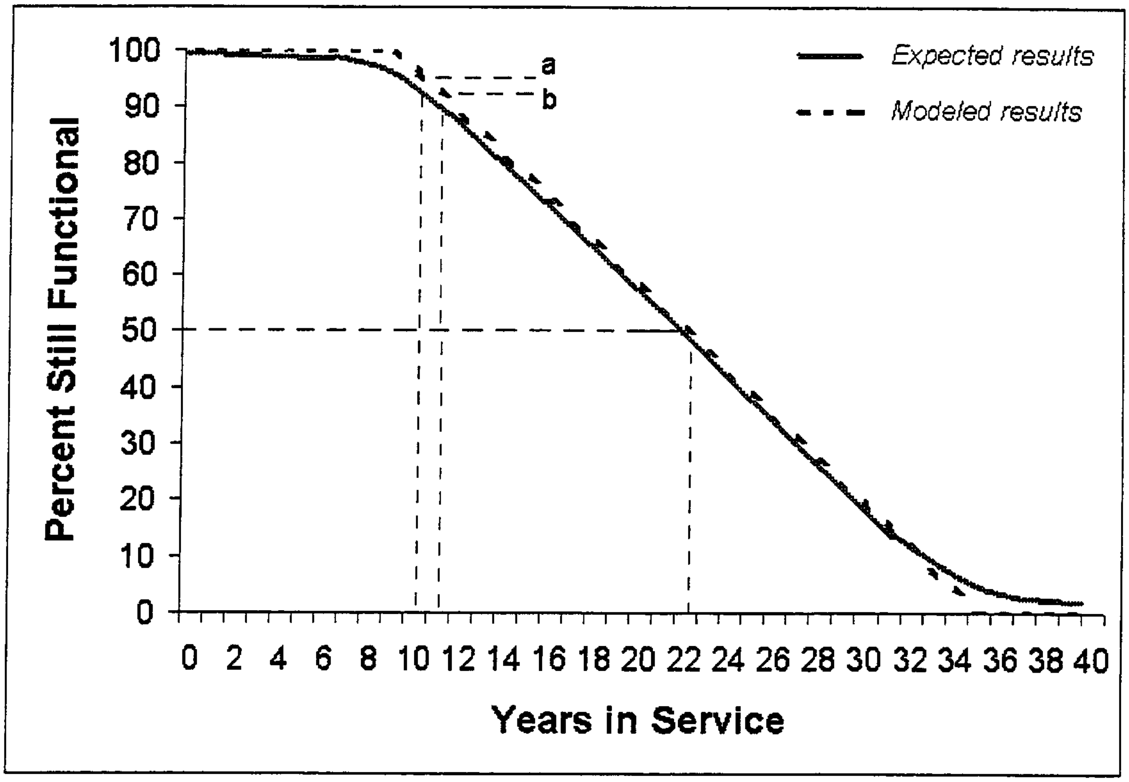
Figure 7. Percent remaining in service (mfg F-V)



NOTE: Age 10 = 10.0 to 10.9; 11 = 11.0 to 11.9, etc.

Figure 8. Percent remaining in service (no non-failure removals)

Derivation of HVAC Units in Service vs. Age and Probability of Failure vs. Age



Model of probability of failure within 12 months:

Example: In year 10, 96.15 percent of units are still in service (a).
In year 11, 92.31 percent of units are still in service (b).
In year 10, the probability of a unit failing within 12 months =

(96.15 – 92.31)/96.15 * 100% = 4.0%

In year 15, the probability of a unit failing within 12 months =

(76.92 – 73.07)/76.92 * 100% = 5.0%

In year 22, the probability of a unit failing within 12 months =

(50.0 – 46.15)/50.0 * 100% = 7.7%