1994 Residential New Construction Ninth-Year Retention Evaluation
(Energy Advantage Home Program)
Study Number 716A

Submitted to:

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Introduction

1.1 Overview

This is the ninth-year retention study for the Southern Gas Company's (SoCalGas) 1994 Energy Advantage Home Program (EAHP). The objective of this measure retention study is to assess and verify effective useful lifetimes[1] of the various measures installed through the EAHP. The CPUC Protocols state that for persistence studies the "utilities will perform individual retention studies for any of the top ten measures or the number of measures that constitute the first 50% of the estimated resource value, whichever number of measures is less, not covered by the statewide studies."[2] For the EAHP, the measures in this category are high efficiency furnaces and duct testing. Estimated EULs are compared to *ex ante* estimates of measure lifetimes for these measures. If the *ex ante* estimates differ from the study estimates, then the program savings estimates should be adjusted accordingly.

The 1994 EAHP was designed to induce builders to increase energy efficiency in new homes beyond the levels required by Title 20 and Title 24. The program offered informational and training workshops for builders and provided incentives for a variety of DSM measures. Table 1-1 summarizes the DSM measures covered in the 1994 EAHP, including the number of installations and the *ex ante* per unit and annual savings in therms for each measure.

[1] EUL is defined as "An estimate of the median number of years that the measures installed under the program are still in place and operable." See California Public Utilities Commission (CPUC) Decision 93-05-063, Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings from Demand-Side Management Programs, Appendix A, revised March 1998 (hereinafter referred to as the CPUC Protocols).

[2] CPUC Protocols, Table 9B.

Table 1-1: Summary of DSM Measures in 1994 EAH Program

Program Measure	Number Installed	Per Unit Savings (therms)	Total Annual Savings (therms)
DSM Measures			
Duct Testing	7,159	22	157,498
Furnace (88% AFUE)	1,512	29	43,848
Water Heater (.60-.69 EF)	1,608	14	22,512
Water Heater (.70 EF)	7	30	210
Combination System (.58 EF)	1,095	23	25,185
Duct Insulation	10	5	50
Heat Traps	146	10	1,460
Recirculating Controls	1	405	405
MH Water Heaters (.60 EF)	0	21	0
MH Furnace (80%-87% AFUE)	34	14	476
MH Furnace (88+% AFUE)	0	37	0
All DSM Measures	**-**	**-**	**251,644**
Fuel Substitution Measures			
Furnaces	68	-147	9,996
Gas Ovens	1,529	-19	29,051
All Fuel Substitution Measures			**39,047**

1.2 Overview of Approach

An on-site survey was conducted to collect data on measure retention, usage, and repair. Data were collected from 122 sites. The survey was used to collect detailed information on whether installed measures are still installed and operational. In cases where the measure has been removed or is no longer operational, data were collected on why and when the measure was removed or ceased to work. Additionally, duct blaster tests were conducted at 30 sites. Data from these tests were used to develop a degradation factor for duct integrity. Appendix A includes a copy of the on-site survey instrument and the duct blaster test instrument.

To estimate the EULs, Itron used three specific statistical analyses:

- ***Construct Summary Statistics.*** Itron constructed summary statistics of measure lifetimes.

- *Retention fraction,* which is computed as the ratio of the number of measures that exist at the time of inspection over the total number of measures installed.
- *Average Measure Lifetime*, which is computed as the average lifetime of the measures. Here, a measure lifetime is defined as the lesser of the time interval between (a) inspection and installation of the measure, or (b) date of failure and installation of the measure.

These estimates of measure life can be subject to biases from measurement and censoring of the data. Because of these biases, the following two modeling approaches were used when feasible.

- ***Life Table Method.*** This approach estimates survivor functions using estimates of hazard functions. In this analysis, Itron used an estimator of the survivor function that is constructed from an estimate of the hazard function. The hazard is the probability that a program measure in place at month *t* will fail in the following month. The estimator of the hazard function accounts for censoring and individual differences in observation period (the interval between inspection and installation of the measure).
- ***Parametric Models.*** For measures with long *ex ante* EULs, it is possible that more than half of the installed measures will exist and be operable at the time of the verification audits. In this case, estimates of EULs derived using the life table method will not be plausible since the median lifetime will not be observed. In this case, parametric specifications of the survivor function are required in order to extend beyond the censored lifetimes. Under this approach, Itron *fit* the observed data to three alternative parametric specifications of the survivor function: log-normal, log-logistic and Weibull. These estimated functions were then used to construct an 80% confidence interval around the estimated EUL.

Per the Protocols, the *ex ante* EUL was compared to the estimated EUL to determine if the two values were statistically different—that is, to determine whether the *ex ante* EUL falls within the estimated 80% confidence interval. Because the above approach for developing estimates of EUL is subject to measurement error, estimates of EULS from other studies were also used to confirm the results of this study.

1.3 Preview of Results

Table 1-2 presents a summary of the retention fractions and EULs for each measure. Although the ex-post EUL estimates for duct testing are significantly different from the ex-ante EUL, revision of the ex-ante EUL is not recommended since, due to the low number of failures in the data, the ex-post EUL estimates are not considered reliable. Therefore, the results of this study do not suggest changing any of the assumed EULs used by SoCalGas in their earnings claims.

Table 1-2: Summary of Estimated Retention Fraction and a Comparison of Estimated EULs with Existing *Ex Ante* EULs (Years)

Measures	Retention Fraction	Ex-Ante EUL	Estimated EUL from Ninth-Year Retention Study	Recom-mended EUL from Ninth-Year Retention Study
High Efficiency Furnace	1.000	18	18	18
Duct Testing	0.982	25	44 to 4,333	25

1.4 Organization of the Report

The remainder of the report is organized as follows:

- Section 2 discusses the data collection effort,
- Section 3 presents the methodology and results from the analysis,
- Appendix A contains a copy of the on-site data collection instrument and the duct blaster test instrument, and
- Appendix B contains CPUC Protocol Tables 6 and 7.

2

Data

2.1 Overview

To meet the project objectives, the following data collection activities were completed:

- Design and implement the on-site surveys,
  - Develop and finalize the on-site survey instrument
  - Develop the on-site sample targets,
  - Develop the on-site data collection protocol,
  - Collect on-site data,
  - Perform data entry and data review, and
- Conduct Duct Blaster tests.

Each activity is discussed below.

2.2 Design and Implementation of the On-Site Surveys

The design and implementation of the on-site surveys required the completion of six major tasks:

- Develop the on-site survey instrument,
- Develop the on-site sample targets,
- Finalize the survey instrument,
- Develop the on-site data collection protocol,
- Collect on-site data, and
- Data entry and data review.

Each element is discussed in further detail in the pages that follow. Additionally, the climate zone distribution of the ninth-year retention survey population and the climate zone distribution of the completed on-site surveys and duct blaster tests are presented.

2.2.1 Develop and Finalize the On-site Survey Instrument

The on-site survey instrument was primarily designed to obtain the following information:

- To verify that the measure is in place,
- To verify that the measure is operational,
- To verify the condition of the measure if it is operational,
- To collect information relating to the reasons for removal of measures if the measures are not found, and
- To collect information relating to the reasons for the measure no longer being operational.

The draft survey instrument was based on the final survey instrument used in the fourth-year retention study conducted by Itron. The Study Manager approved this draft survey instrument and the instrument was finalized. A copy of the final on-site survey is included in Appendix A.

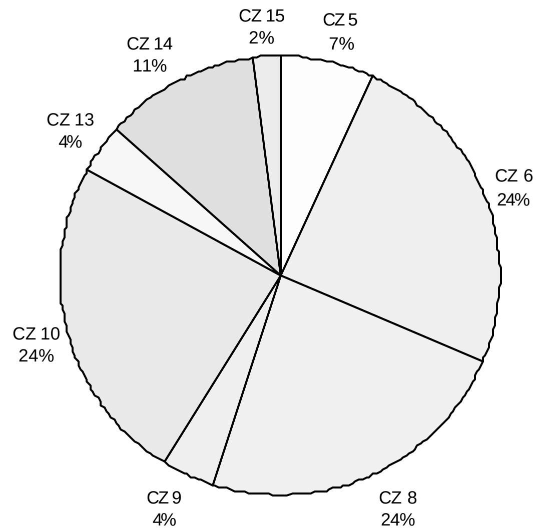
2.2.2 Sample Design

Itron retrieved the database created to support the first-year impact analysis, and compiled a list of customers originally surveyed as part of the first-year impact study from this database. The list was screened to ensure that only homes with duct sealing, energy efficient furnaces, or both measures installed under the Energy Advantage Home Program were included in the survey population for the ninth-year retention study. This list was then screened to ensure that only customers for whom contact information was available from SoCalGas were included in the survey population for the ninth-year retention study.

Thus, 14 of the original 303 customers surveyed in the first-year analysis were removed from the population due to lack of sufficient contact information. Additionally, 33 customers who had installed neither duct sealing nor an energy efficient furnace were removed from the population since the ninth-year impact analysis focused on these measures only. Of the remaining 256 customers, 184 had installed duct sealing, one installed an energy efficient furnace, and 71 installed both duct sealing and an energy efficient furnace under the EAHP. The primary samples and replacement contacts for the on-site surveys and duct blaster tests for Itron's subcontractors were drawn from this final list of 255 customers.

Figure 2-1 illustrates the climate zone distribution of customers with duct sealing, energy efficient furnaces, or both measures installed. As shown, the climate zones most heavily represented in the ninth-year retention study population are 6, 8, 10, and 14.

Figure 2-1: Climate Zone Distribution of EAHP Customers with Duct Sealing, Energy Efficient Furnaces, or Both Measures Installed



Itron's subcontractors were originally slated to conduct on-site surveys and duct blaster tests as follows:

- ASW Engineering, Inc. (ASW) was to conduct 100 on-site surveys of selected customers who installed duct sealing, energy efficient furnaces, or both measures under the EAHP, and
- Energy Calc Services, Inc. (Energy Calc) was to conduct 50 on-site surveys and duct blaster tests for selected customers with duct sealing only under the program.

The services of a third subcontractor, Action Now, were later required to complete sample targets for on-site surveys and duct blaster tests. Since Action Now's involvement in the project was not foreseen, the original sample targets were allocated only between Energy Calc and ASW.

As mentioned previously, Energy Calc was responsible for conducting on-site surveys and duct blaster tests for 50 customers who had installed duct sealing only under the EAHP. Itron was to provide Energy Calc with a list of 50 customers that represented the primary sample targets, and a list of 50 customers that represented the secondary sample (i.e., replacement contacts in the event primary contacts could not be reached).

To develop Energy Calc's sample, customers who installed duct sealing only under the EAHP were stratified into climate zones[1] according to zip code. To ensure a representative geographic distribution of customers in the samples, the samples were drawn from the four most heavily represented climate zones in the population of customers with duct sealing only under the EAHP by applying a constant fraction to the total number of sites in each of the climate zones. This fraction was calculated as the proportion of total customers in Energy Calc's primary and secondary samples to the total population of customers with duct sealing only under the EAHP.

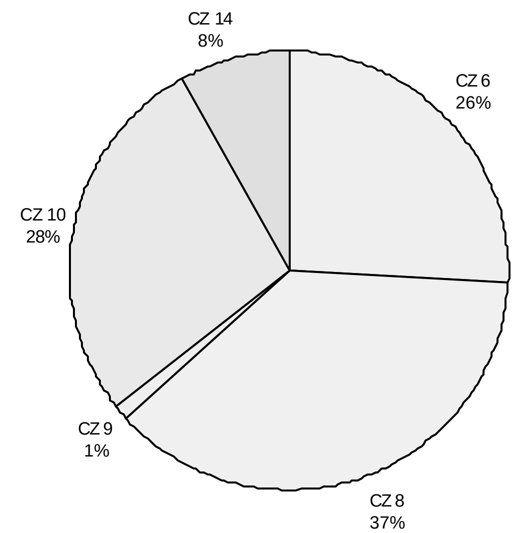
The 18 customers who had undergone duct blaster tests as primary sample targets in the fourth-year retention study were identified as primary sample targets for Energy Calc. The remaining 82 targets in Energy Calc's primary and secondary samples were selected using stratified random sampling without replacement from the remaining customers who had installed duct sealing only under the EAHP.

Figure 2-2 illustrates the final climate zone distribution for Energy Calc's primary sample:

- Thirteen customers were selected from Climate Zone 6,
- Eighteen customers were selected from Climate Zone 8,
- One customer was selected from Climate Zone 9,
- Fourteen customers were selected from Climate Zone 10, and
- Four customers were selected from Climate Zone 14.

[1] The California building state climate zones were used in the sample design. The original weather zone information used in the fourth-year persistence study was not available at the time of the sample design.

Figure 2-2: Climate Zone Distribution of Customers Participating in Both On-Site Surveys and Duct Blaster Tests – Energy Calc Primary Sample



The final climate zone distribution for Energy Calc's replacement contacts was nearly identical to the climate zone distribution of its primary sample. For Energy Calc's secondary sample, 19 customers were selected from Climate Zone 8, and no customers were selected to represent Climate Zone 9. Climate Zone 9 was not one of the four most heavily represented climate zones in the stratum population of customers with duct sealing installed only under the EAHP, but was included since the single customer in Climate Zone 9 in the primary sample had originally undergone a duct blaster test in the fourth-year retention study.

As mentioned previously, ASW was responsible for conducting 100 on-site surveys. ASW's primary sample targets included all customers with energy efficient furnaces (1) and all customers with both energy efficient furnaces and duct sealing under the EAHP (71) who had participated in the first-year retention study. The remaining 28 primary sample targets for ASW were drawn from the pool of 84 customers with duct sealing only who had not been selected for either of Energy Calc's samples using simple random sampling techniques. The remaining 56 customers with duct sealing only were identified as replacement contacts for ASW.

Additionally, due to the difficulties experienced in recruiting customers for the study, the services of an additional subcontractor, Action Now, were required midway through the data collection process. Action Now as its primary sample adopted all customers in Climate Zones 6 and 8 from Energy Calc's primary sample who had not already undergone an on-site survey and duct blaster test. Similarly, Action Now's list of replacement contacts consisted of all Climate Zone 6 and 8 customers in Energy Calc's secondary sample whom Energy Calc had not already recruited.

2.2.3 On-Site Data Collection Protocol

Once the samples had been selected, Itron created site survey protocols, disposition logs, and data entry databases to complete the following key steps of the data collection strategy in a professional and non-intrusive manner:

- Recruit customers in the sample,
- Schedule on-site visits,
- Conduct on-site visits,
- Monitor the survey effort, and
- Input and review the survey data.

Each key element of the on-site data collection procedure is discussed in further detail below.

Recruit Customers in Sample and Schedule On-Site Visits

ASW and Energy Calc staff were responsible for recruiting customers and scheduling on-site surveys and/or duct blaster tests. Customers agreeing to participate in an on-site survey were offered a $25 incentive, and customers agreeing to duct blaster tests were offered an additional incentive of $50.

The customer recruiting process used a five-callback protocol. In particular, each qualified number was called up to five times to attempt to establish contact with the customer and identify the appropriate person to discuss participation in the study. If a customer could not be reached after five attempts, or if a customer declined to participate in the study, the number was removed from the sample and a replacement contact was selected. Where possible, replacement contacts were selected from the same climate zone as the original contact in order to maintain a representative sample.

When a recruiter was successful in establishing contact with a customer, the recruiter explained the purpose of the study, indicated the amount of time required to complete the on-site visit from the contact person or other member of the household, and offered the incentive for participation. If the customer was willing to participate, the recruiter arranged a mutually acceptable time for data collection and reconfirmed the customer's street address. Contact calls were placed at differing times of the day in an attempt to reach the maximum amount of customers. Recruiters logged each call attempt and the disposition of each attempted customer contact in disposition logs created by Itron. Recruiters also logged appointment times and surveyor names after appointments were confirmed with customers.

Introductory letters sent on SoCalGas' letterhead and signed by the Study Manager were furnished in case customers required additional information or confirmation regarding the survey's legitimacy. Surveyors provided introductory letters to customers upon request and mailed the letters to customers prior to site visits. The introductory letters explained the purpose of the project, introduced the surveyors to the customers, and explained $25 incentives offered for participating in the on-site survey and the $50 incentives offered for undergoing a duct blaster test. Surveyor-specific letters were developed for each subcontractor.

However, despite introductory letters and exhaustive attempts to contact customers via telephone, recruiters encountered considerable difficulties in scheduling appointments for duct blaster tests. When it became apparent that Energy Calc and Action Now's survey targets might not be met within the required timeframe, Itron augmented Energy Calc and Action Now's samples with customers originally assigned to ASW's samples. Contact information for customers who were administered the on-site survey only by ASW was provided to Energy Calc or Action Now, depending on the location of the customer's home. Such customers were more receptive to recruiting efforts for duct blaster tests than the general population since most had already received their $25 incentive checks for participation in the on-site survey. These customers were offered the additional incentive of $50 for undergoing a duct blaster test. For such customers successfully recruited, Energy Calc and Action Now verified on-site survey data gathered by ASW and provided Itron with any additional information gathered from on-site visits to conduct duct blaster tests.

Conduct On-Site Survey Effort and Develop Retention Analysis Database

In general, after recruiters arranged an on-site visit, a field staff member visited the customer's home to conduct the visual on-site survey and/or duct blaster test. Itron summarized disposition logs furnished by ASW and Energy Calc, and provided the Study Manager with biweekly status reports on the progress of the on-site survey activities. ASW was responsible for data entry of the on-site surveys it conducted, along with performing verification and data quality review of the database. Itron was responsible for data entry and quality control for on-site surveys and duct blaster tests administered by Energy Calc and Action Now.

2.3 Completed Surveys

The original sample target for on-site surveys was 150 distinct sites. In total, 122 distinct sites were administered the on-site survey. This represents a response rate of 81%. Of the 122 distinct sites surveyed, two reported having installed an energy efficient furnace only, 69 reported having installed duct sealing only, and 51 reported having installed both measures under the EAHP. Figure 2-3 displays the climate zone distribution of the completed on-site surveys.

As Figure 2-3 shows, the final distribution of completed on-site surveys by climate zone is very similar to the distribution of customers shown in Figure 2-1 who installed high efficiency furnaces, duct sealing, or both. Table 2-1 also illustrates the response rates and climate zone distribution of on-site surveys.

Figure 2-3: Climate Zone Distribution of Completed On-Site Surveys

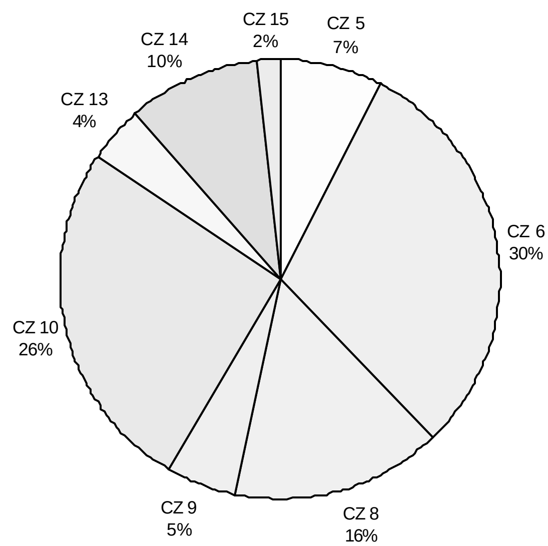


Table 2-1: Completed On-site Surveys by Climate Zone[2]

Climate Zone	Population	Target	Complete	Response (%)
CZ 5	18	9	9	100%
CZ 6	62	41	37	90%
CZ 8	60	26	19	73%
CZ 9	10	5	6	120%
CZ 10	62	38	32	84%
CZ 13	9	7	5	71%
CZ 14	29	20	12	60%
CZ 15	5	4	2	50%
Total	**255**	**150**	**122**	**81%**

2.3.1 Data Attrition and Sample Weights

Of the 122 completed on-site surveys, all but one had duct or furnace measures installed through the 1994 EAHP. Of the remaining surveys, one was omitted from the database because the homeowner reported the house had burned down and been rebuilt. For the duct analysis, five additional sites were omitted because the auditor was unable to confirm the ducts were in place and working.

Data from the fourth-year study were also used in the ninth-year evaluation. From the fourth-year study data, 112 completed surveys had either ducts or furnaces installed in the 1994 EAHP.

Using the number of completed surveys, weights were constructed for the analysis. Because data from the fourth-year study were also used in the analysis, weights were constructed using the weather zone stratification used in that study. Table 2-2 shows the distribution of sites and the number of population and completion sites used to construct the weights. For each sample strata (weather zone and residence type), the weight is the ratio of the population over the number of completed surveys. The population shown in Table 2-2 is the population of 1994 EAHP participants.

[2] Response rates by climate zone may exceed 100% since surveyors were asked to replace primary sample targets with replacement contacts in the same climate zone *where possible*. When a replacement contact within a specific climate zone could not be identified in the surveyor's secondary sample, the surveyor was allowed to deviate from the original climate zone distribution requested for completed surveys in the sample design phase.

Table 2-2: EAHP Participants and Completed Surveys

Residence Type	Weather Zone	Population	Completed Fourth- and Ninth-Year Surveys with Furnaces or Ducts
Single Family	Mountain	5	0
	Low Desert	197	4
	Coastal	592	31
	High Desert	879	36
	Inland Valley	1,161	76
	L.A. Basin	1,185	76
Multi-Family	Mountain	0	0
	Low Desert	0	0
	Coastal	257	9
	High Desert	97	2
	Inland Valley	6	0
	L.A. Basin	672	33
All Single Family		4,019	223
All Multifamily		1,032	11
Total		**5,051**	**234**

2.4 Duct Blaster Tests

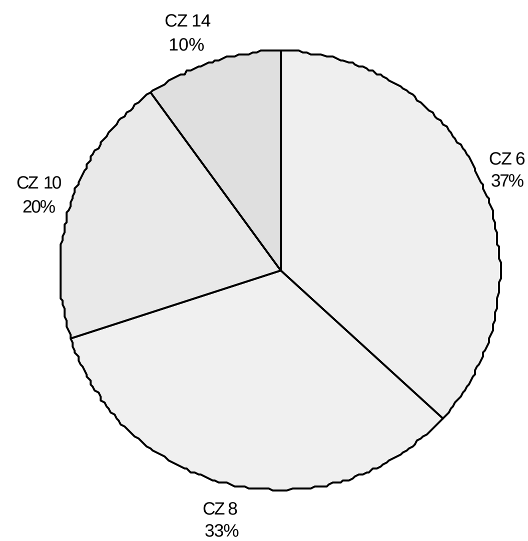
Duct blaster tests were completed for 18 participant homes during the first-year impact study. As mentioned previously, Energy Calc and Action Now attempted to conduct follow-up duct blaster tests for these 18 homes, in addition to 32 other homes selected from climate zones heavily represented in the ninth-year retention study survey population. An additional incentive of $50 was offered to homeowners who underwent the duct blaster test.

Multi-point duct blaster tests were conducted at 25 and 50 pascals.[3] Energy Calc and Action Now were responsible for completing these tests. Appendix A provides a copy of the duct blaster test survey form.

[3] All comparisons were made using the reading from the 50 Pascals test. This is necessary for comparison with the original program requirements of a minimum of 140 CFM of leakage at 50 Pascals.

Ultimately, 30 homes were subjected to a duct blaster test. Of these, 19 reported results at 50 pascals. Figure 2-4 illustrates the climate zone distribution of customers who underwent duct blaster tests. As with the on-site surveys, the climate zone distribution of customers who underwent duct blaster tests was similar to the climate zone distribution of customers with duct sealing only identified as primary sample targets in the sample design phase.

Figure 2-4: Climate Zone Distribution of Completed Duct Blaster Tests



3

Methodology and Results

3.1 Introduction

This section discusses the methodology used in the retention analysis and presents the results from the study. Subsection 3.2 provides a detailed discussion of the development of a retention fraction, average useful life, and effective useful lifetime. Subsection 3.3 presents the results of the analysis for high efficiency furnaces and duct sealing and testing. Subsection 3.4 summarizes the findings.

3.2 Methodology

This section discusses the general analysis approach.[1] The discussion covers the methods used to estimate the Effective Useful Life (EUL) for high efficiency furnaces and duct sealing and testing. As stated in the DSM Protocols, a measure's EUL is "an estimate of the median number of years that the measures installed under the program are still in place and operable." Specifically, the analysis attempts to compute the following:[2]

- An estimate of the survivor curve, and
- An estimate of the EUL and corresponding standard error.

These statistics were then used to construct an 80% confidence interval around the estimated EUL. Per the CPUC Protocols, the *ex ante* EUL is compared to the estimated EUL to determine if the two values are statistically different—that is, to determine whether the *ex ante* EUL falls within the estimated 80% confidence interval. Because the proposed approach for developing EUL estimates is subject to measurement error, estimates of EULs from other studies are included for comparison and to confirm the results of this study.[3]

1 The discussion of methodology is taken from the fourth-year retention study report.

2 Due to the absence of reported failures for furnaces, survivor functions were estimated for duct sealing and testing only.

3 When Itron (formerly Regional Economic Research, Inc.) conducted the fourth-year retention study for the EAHP, a secondary literature search was performed to summarize estimates from other studies. The results of that effort are used for comparison in this ninth-year study.

A natural first step in estimating a measure's EUL is to construct summary statistics of the program lifetimes. Two such statistics are described below:

- ***Retention Fraction,*** which is computed as the ratio of the number of measures that exist at the time of inspection over the total number of measures installed.
- ***Average Measure Lifetime,*** which is computed as the average lifetime of the measures. Here, a measure lifetime is defined as the lesser of the time interval between (1) inspection and installation of the measure, or (2) date of failure and installation of the measure.

Program evaluations based on these statistics are subject to two important biases. The first bias is due to differing observation periods for the installed measures. In particular, differences in the estimated retention fractions across program years could be due to differing average observation periods.[4] The second bias is censoring bias; not all measure lifetimes are completed by the time of the on-site inspections. Estimates of average measure lifetimes based on completed lifetime data, as defined above, are underestimates of the true mean duration. What is required is an estimation method that accounts for differing observation periods and for censoring.

Where possible, an estimate of each measure's survivor function was used to compute the EUL and corresponding confidence interval.[5] The survivor function, call it $S(t)$, gives the probability that the survival of a measure exceeds length t; so $1-S(t)$ is the cumulative distribution function of the random variable t. Given estimates of $S(t)$, the measure's EUL and the confidence intervals around this estimate can be readily computed. The statistical methods used to estimate these functions are described below.

- ***Life Tables.*** Kalbfleish and Prentice, *The Statistical Analysis of Failure Time Data*, Wiley and Sons (1980) suggest an estimator of $S(t)$, which is constructed from an estimate of the hazard function, call it $h(t)$. The hazard is the probability of a program measure that is in place at month t will fail in the following month. The estimator of the hazard function accounts for censoring and individual differences in observation period (the interval between inspection and installation of the measure). Estimates of $S(t)$ are computed as follows:

$$\hat{S}_{t+1} = \hat{S}_t \left(1 - \hat{h}_t\right) \tag{1}$$

where estimates of the hazard function are given below:

$$\hat{h}_t = \frac{Number\ of\ Measures\ with\ Lifetimes\ of\ Length\ t}{Number\ of\ Measures\ With\ Lifetimes\ of\ Length\ t\ or\ Longer} \tag{2}$$

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4 Insofar as this is the study of only one program year, this might not be a significant factor.

5 For this ninth-year study, this was only possible for duct sealing and testing.

The adjustment made for a measure with a censored lifetime of length *t* is to contribute one-half to the denominator, rather than one. For example, the estimate of the hazard function for lifetimes of 18 months would be computed as follows. The numerator in equation (2) would contain the total number of measures with completed lifetimes of 18 months. The denominator would contain the sum of the total number of measures with completed lifetimes of 18 months or longer, plus half of the measures that have censored lifetimes of 18 months.

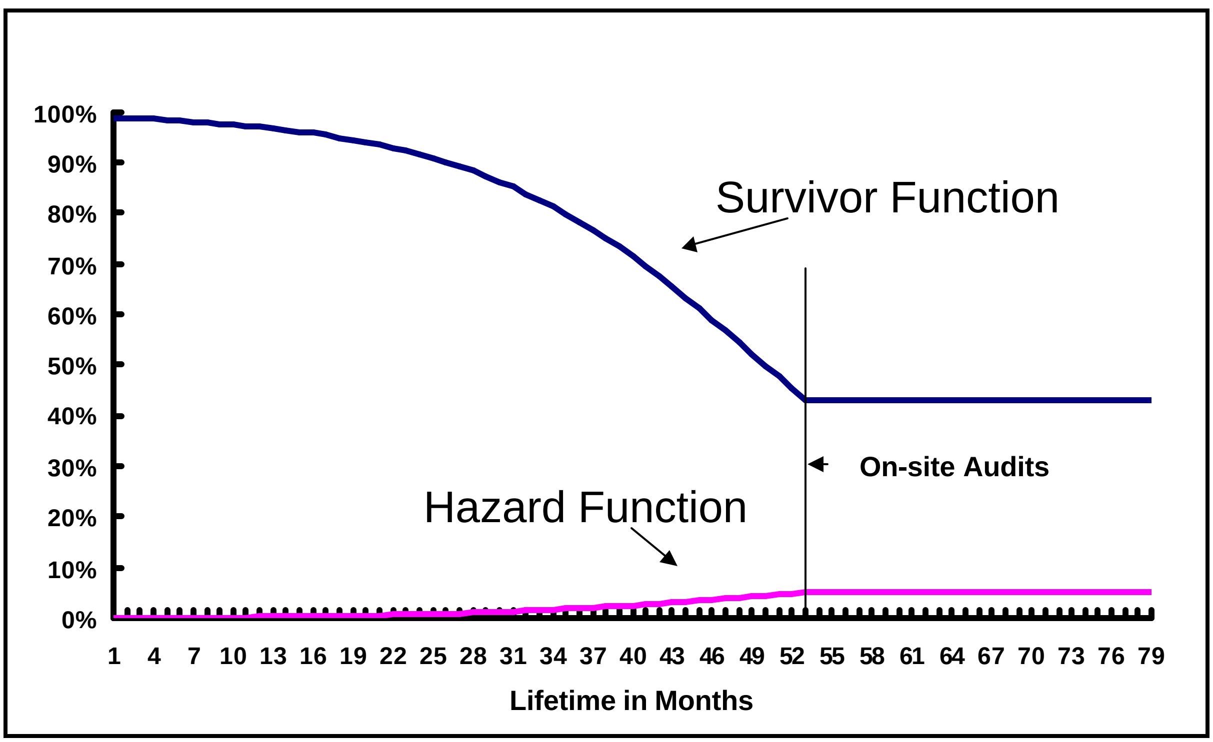
By construction, unless the longest observed measure lifetime is completed, the survivor curve will not go to zero. This is the case for the estimated survivor function depicted in Figure 3-1. In the case depicted, measure lifetimes are observed up to the time of the on-site audits. Measures that persist beyond the on-site visits are treated as censored.

Given an estimate of the survivor function, the estimated EUL is computed as follows:

$$EffectiveUseful\ Life = \frac{t_{j-1} - t_{median} + \left[\dfrac{\hat{S}_{j-1} - \hat{S}_{median}}{2}\right]}{\hat{S}_{j-1} - \hat{S}_j} \qquad (3)$$

where the interval t_{j-1}, t_j is selected such that $\hat{S}_{j-1} \geq \hat{S}_{median}/2 \geq \hat{S}_j$.

Figure 3-1: Estimated Survivor and Hazard Function



The corresponding standard error is estimated by:

$$\hat{s}_{EUL} = \frac{\hat{S}_{median}}{\left(2\,\hat{S}_j \hat{h}_j \sqrt{n_{median}}\right)} \tag{4}$$

where $\hat{h}_j$ is the estimate of the hazard function at month j.

The confidence interval around the estimated median measure life is given by:

$$Effective\,Useful\,Life \pm z_{a/2}\hat{s}_{EUL} \tag{5}$$

where, $z_{a/2}$ is the critical value for the normal distribution.

- ***Parametric Models.*** For measures with long *ex ante* EUL, it is possible that more than half of the installed measures will exist and be operable at the time of the verification audits. In this case, estimates of EULs derived using the life table method will not be plausible since the median lifetimes were not observed. In this case, parametric specifications of the survivor function are required in order to extend beyond the censored lifetimes. Under this approach, the observed data were fit to three alternative parametric specifications of the survivor function: log-normal, log-logistic, and Weibull.

  Specifically:

  Log-Logistic Survivor Function,

$$S_t = \frac{1}{\left(1 + e^{\left(t-m/s\right)}\right)} \tag{6}$$

  Log-Normal Survivor Function,

$$S_t = 1 - F\left((t-m)/s\right) \tag{7}$$

  where F is the cumulative distribution function for the normal distribution.

  Weibull Survivor Function,

$$S_t = e^{\left(-e^{\left(t-m/s\right)}\right)} \tag{8}$$

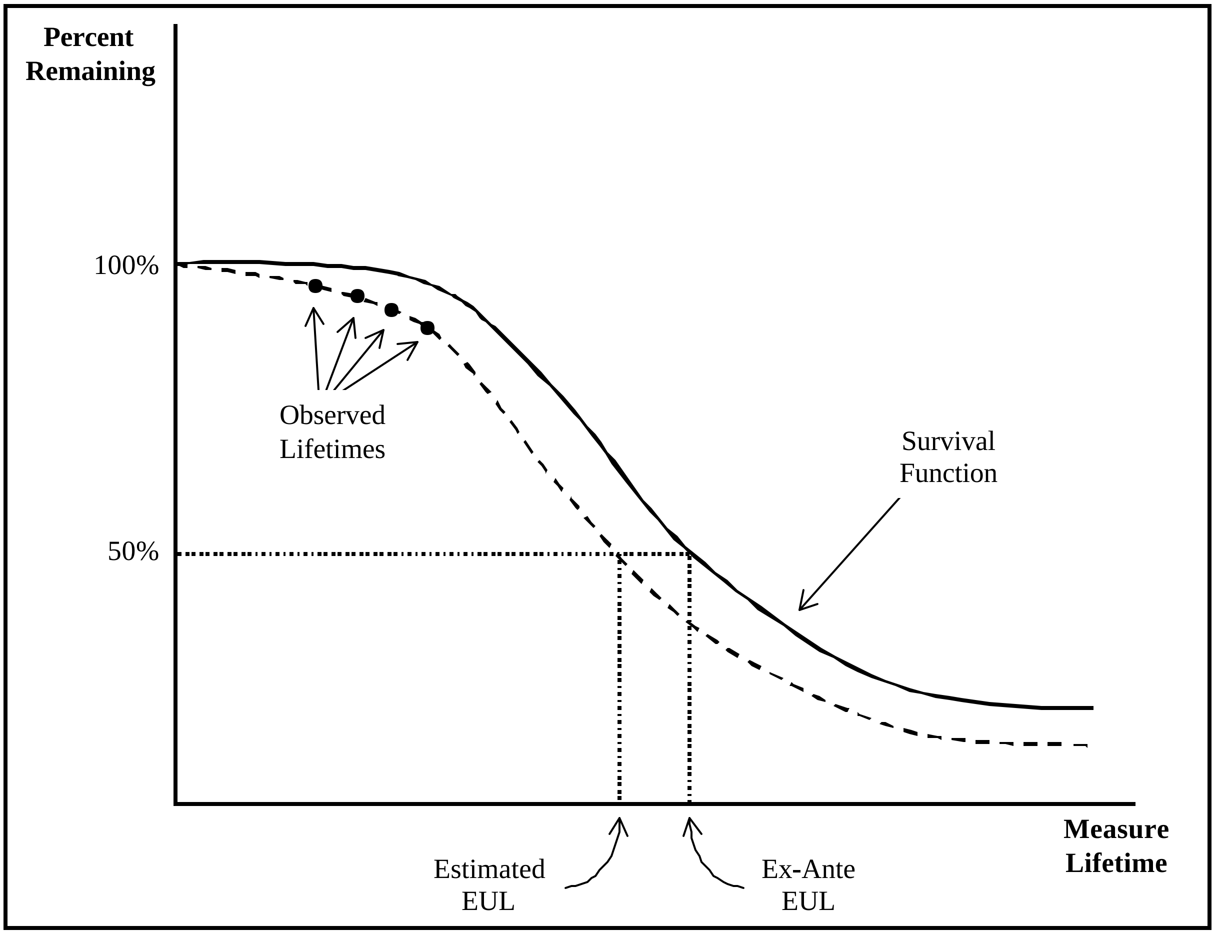
  Each of these functions has been widely used in the medical and unemployment duration literature and is documented in detail in Kalbfleish and Prentice (1980).

  Because each function differs in the amount of weight placed in the upper tail of the estimated function, the implied estimated EUL differs. For estimates falling within the 80% confidence interval from the midpoint estimate, the midpoint estimate for the EUL was chosen. Estimated EULs that differ significantly were compared to estimates drawn from other studies in order to select the candidate EUL.

A survivor function was estimated for measures with an adequate amount of failures using data collected as part of the on-site verification audits.

Figure 3-2 presents an overview of the parametric approach. The *ex ante* EUL is derived from the assumed survival function. Using the observed lifetimes gathered in the on-site visit, a new survival function is estimated. The resulting EUL is then compared to the *ex ante* EUL using the criterion specified in the CPUC Protocols (Table 10).

Figure 3-2: Overview of Parametric Approach to Estimating Survival Function and EUL



3.3 Results

The major objective of the project is to provide estimates of effective useful lifetimes for measures in the 1994 EAHP that account for 50% of the claimed savings, i.e., high efficiency furnaces and duct testing. Table 3-1 presents these two measures and the assumed *ex ante* EULs.

Table 3-1: *Ex Ante* EULs for Measures Evaluated (Years)

Measures	EUL
High Efficiency Furnaces	18
Duct Testing	25

The following sections discuss the estimation of the EULs and include the following:

- A summary of the secondary lifetime comparisons.[6]
- An estimate of the retention fraction, which is computed as the ratio of the number of measures that exist at the time of inspection over the total number of measures, installed.
- An estimate of the average measure lifetime, which is computed as the average lifetime of the measures. Here, a measure lifetime is defined as the lesser of the time interval between (1) inspection and installation of the measure, or (2) date of failure and installation of the measure.
- The estimated effective useful life which is defined to be "an estimate of the median number of years that the measures installed under the program are still in place and operable."

3.3.1 High Efficiency Furnaces

This section discusses the estimation of the EUL for the installation of energy-efficient gas furnaces. The 1994 EAH program *ex ante* EUL for energy-efficient gas furnaces is 18 years or 216 months. Table 3-2 presents a summary of gas furnace failures by rebated (high-efficiency) and non-rebated (might or might not be high efficiency) measures. As shown, no failures were found in the surveyed sites.

6 These were researched in the fourth-year study and are included herein for comparison.

Table 3-2: Summary of Gas Furnace Failures

Measure	Measures in Survey		Failed Measures	
	Rebated	Non-Rebated	Rebated	Non-Rebated
Gas Furnaces	52	46	0	0

Summary of Estimates of Measure Lifetimes from Secondary Data

Estimates of EULs from other studies are presented in Table 3-3. The range on expected lifetimes is from 13 to 35 years. The EUL from two independent sources, DOE and PG&E, provides estimates that match the 18 years used by SoCalGas as the *ex ante* EUL.

Table 3-3: Estimated EULs for Energy Efficient Gas Furnaces (Years)

Sources	Minimum	EUL	Maximum
Ex Ante EUL		18	
Appendix F – PG&E		18	
REEPS 1987 Default Database	13		23
Appliance Magazine – September 1998[7]	15	25	35
DOE – FEMP – October 1998[8]		18	

Retention Fraction

The retention fraction is computed as the ratio of the number of measures that exist at the time of inspection over the total number of measures installed. A total of 52 sites in which energy-efficient gas furnaces had been installed in the 1994 EAH program year were surveyed. Of these, all were in place and working at the time of the on-site survey. The estimated retention fraction for the installed gas furnaces is 100%.

Average Measure Lifetime

Average Measure Lifetime is computed as the average lifetime of the measures. Here, a measure lifetime is defined as the lesser of the time interval between (a) inspection and installation of the measure, or (b) date of failure and installation of the measure. Due to censoring bias, estimates of average measure lifetimes based on data on completed lifetimes,

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7 Appliance Magazine – Listed as Gas Furnace - Low, high, and average years are based on first-owner use of the product and do not necessarily mean the appliance is worn out. Estimates are based on expert judgment of Appliance Magazine staff based on input from many sources.

8 Federal Energy Management Program. "*How to Buy an Energy-Efficient Gas Furnace.*" October 1998.

as defined above, are underestimates of the true mean duration. As a result, the best that can be concluded is the EUL for gas furnaces is at least 113 months.

Effective Useful Lifetime

Insofar as no failures have been observed, no EUL can be estimated using either the life table or parametric methods.

Summary of Findings for High-Efficiency Gas Furnaces

Data from the on-site survey are inconclusive with regard to estimating the EUL of high-efficiency gas furnaces. However, the literature search and review of secondary data supports the current assumed EUL of 18 years.

3.3.2 Duct Testing

This section discusses the estimation of the EUL for the performance of duct testing. The duct testing measure required that ducts be tested using a standardized protocol and that the duct system must achieve duct leakage rates of less that 140 CFM at 50 pascals.

Duct testing in the 1994 EAHP was the largest component of claimed savings. Itron recognizes that the definition of retention in the context of duct testing is not clear. For the purpose of this study, Itron has treated duct testing as duct sealing.

In order to define measure lifetime, Itron assumes that the duct sealing vis-a-vis duct testing *is still in place and operating effectively* if the following is true:

1) There are no catastrophic failures, or
2) Based on a three-point visual inspection system developed and used during the on-site survey, there are no signs of severe failure of the duct system. Particular attention was paid to aspects of the system that are more failure prone, such as connections at the plenum and duct joints.

Additionally, as with the fourth-year study, Itron investigated whether a degradation factor is appropriate for this measure. This analysis was designed as a preliminary indicator of degradation and involved the completion of a sample of duct blaster tests.

The 1994 EAHP *ex ante* EUL for duct sealing/testing is 25 years or 00300 months. Table 3-4 presents a summary of duct sealing/testing failures as defined above.

Table 3-4: Summary of Duct Sealing/Testing Failures

Study Year	Measures in Survey		Failed Measures	
	Rebated	Non-Rebated	Rebated	Non-Rebated
Fourth-year	217	35	5	0
Ninth-year	121	1	1	0

Due to the result of the ninth-year survey revealing only one duct failure, the analysis for ducts was completed using datasets from both studies. This allowed an evaluation of six failures. However, because failure dates were not reported in the fourth-year study, the analysis was run using different assumptions for failure dates for the five sites reporting failures in the fourth-year study. The three assumptions used are the following:

- First, it was assumed that ducts failed at or close to the fourth-year survey date,
- Second, it was assumed that ducts failed at the midpoint between installation time and the fourth-year survey date, and
- Third, a random failure date was generated between installation time and the fourth-year survey date.

Summary of Estimates of Measure Lifetimes from Secondary Data

A review of the secondary literature was completed during the fourth-year study. That review indicated that duct lifetime is associated to the lifetime of the house, which is typically assumed to be roughly 30 years. Further, it was found that duct leakage is discussed in the context of the effectiveness of different types of duct sealants. In particular, it is recognized that even though the duct system itself can last 15 to 30 years, the effectiveness of leakage protection is directly related to the type of fasteners and sealants used during installation.

Retention Fraction

The retention fraction is computed as the ratio of the number of measures that exist at the time of inspection over the total number of measures installed. For the ninth-year study, 121 homes that had ducts tested during the 1994 EAH program year were surveyed. Of these, six were omitted from the analysis.[9] Of the remaining 115 sites, 114 showed no signs of catastrophic failure or severe degradation during the on-site inspection, nor were they repaired for catastrophic failure. For the fourth-year study, five out of 217 EAHP installed duct systems failed. Considering the data from both studies, the estimated retention fraction for duct testing is 98.2%.

[9] As described in Section 2, one site was omitted because the house had burned and been rebuilt; five sites were omitted because the auditor was unable to verify the ducts were in place and working.

Average Measure Lifetime

The average measure lifetime is computed as the average lifetime of the measures. Here, a measure lifetime is defined as the lesser of the time interval between (a) inspection and installation of the measure, or (b) date of failure and installation of the measure. Considering the data from both studies, the average measure lifetime for this measure is presented in Table 3-5. Note that the lifetime was estimated using three different assumptions for failure dates associated with the five sites that reported failures during the 1998 survey; for the one site reporting failure during the 2003 survey, the actual failure date was provided by the homeowner.

Table 3-5: Average Duct Lifetime (Months)

Assumption Used in Analysis	Estimated Lifetime
Five sites reporting failure in 1998 were assumed to have failed at or near the date of the 1998 survey	78.8
Five sites reporting failure in 1998 were assumed to have failed at a point midway between the date of installation and the date of the 1998 survey	78.1
Five sites reporting failure in 1998 were assumed to have failed at a point randomly chosen and existing between the date of installation and the date of the 1998 survey	77.8

Measure lifetime evaluations based on the above two summary statistics are subject to two important biases. The first is due to differing observation periods for the installed measures. In particular, differences in the estimated retention fractions across program years could be due to differing average observation periods. The second bias is censoring bias; not all measure lifetimes are completed by the time of the on-site inspections. Estimates of average measure lifetimes based on data on completed lifetimes, as defined above, are underestimates of the true mean duration. As a result, the best that can be concluded is the EUL for duct sealing is roughly 78 months.

Effective Useful Lifetime

Life Tables

To account for differing observation periods and for censoring, Itron used the estimated survivor function to compute the EUL and corresponding confidence interval. The survivor function, call it $S(t)$, gives the probability that the survival of a measure exceeds length t; so $1\text{-}S(t)$ is the cumulative distribution function of the random variable t. Given estimates of $S(t)$, the EUL of a measure and confidence intervals around this estimate can be readily computed.

An estimator of $S(t)$ which is constructed from an estimate of the hazard function, call it $h(t)$ was attempted. The hazard is the probability that a program measure that is in place at month t will fail in the following month. The estimator of the hazard function accounts for censoring and individual differences in observation period (the interval between inspection and installation of the measure). Estimates of $S(t)$ are computed as follows:

$$\hat{S}_{t+1} = \hat{S}_t\left(1 - \hat{h}_t\right) \qquad (9)$$

where estimates of the hazard function are given below:

$$\hat{h}_t = \frac{Number\ of\ Measures\ with\ Lifetimes\ of\ Length\ t}{Number\ of\ Measures\ With\ Lifetimes\ of\ Length\ t\ or\ Longer} \qquad (10)$$

The adjustment made for a measured with a censored lifetime of length t is to contribute one-half to the denominator, rather than one. By construction, unless the longest observed measure lifetime is completed, the survivor curve will not go to zero. This is the case with duct sealing and testing. In this case, duct lifetimes are observed up to the time of the on-site audits. Ducts that persist beyond the on-site visits are treated as censored.

Given an estimate of the survivor function, the estimated EUL is computed as follows.

$$Effective\ Useful\ Life = \frac{t_{j-1} - t_{median} + \left[\dfrac{\hat{S}_{j-1} - \hat{S}_{median}}{2}\right]}{\hat{S}_{j-1} - \hat{S}_j} \qquad (11)$$

where the interval t_{j-1}, t_j is selected such that $\hat{S}_{j-1} \geq \hat{S}_{median}/2 \geq \hat{S}_j$. Specifically, the EUL is that point at which half of the measures have failed. As is the case with this study, if less than half of the measures have failed, then this estimate will be biased downward. Considering data from both studies, the resulting EUL estimates are presented in Table 3-6. These are underestimates of the true EUL for this measure.

Table 3-6: Duct Lifetimes Using Life Table Method (Months)

Assumption Used in Analysis	Estimated Lifetime
Five sites reporting failure in 1998 were assumed to have failed at or near the date of the 1998 survey	95.18
Five sites reporting failure in 1998 were assumed to have failed at a point midway between the date of installation and the date of the 1998 survey	95.04
Five sites reporting failure in 1998 were assumed to have failed at a point randomly chosen and existing between the date of installation and the date of the 1998 survey	94.97

Parametric Models

In the case where less than half the measure lifetimes are observed, all of the above methods provide estimates of EUL that are biased downward. In order to develop estimates that extend beyond the censored lifetimes parametric specifications of the survivor function are required. Under this approach, the observed data are used to estimate three alternative parametric specifications of the survivor function: log-normal, log-logistic and Weibull.

The estimated EUL and upper and lower confidence bounds are presented in Table 3-7. As can be seen, the estimated EULs range from 25525 months to 52,001 months. The *ex ante* EUL of 300 months is well below the EUL estimates and their lower bounds for all three models. Although the ex-post EUL estimates are significantly different from the ex-ante EUL, revision of the ex-ante EUL is not recommended since, due to the low number of failures in the data, the ex-post EUL estimates are not considered reliable.

Table 3-7: Estimated Duct EUL and 80% Confidence Bounds (Months)

Distribution	EUL	Upper Bound	Lower Bound
Assumed five sites reporting failure in 1998 failed at or near the date of the 1998 survey:			
Log-Normal	979	983	974
Weibull	525	523	528
Log-Logistic	617	614	620
Assumed five sites reporting failure in 1998 failed at a point midway between the date of installation and the date of the 1998 survey:			
Log-Normal	10,719	10,475	10,970
Weibull	2,809	2,747	2,873
Log-Logistic	3,880	3,793	3,970
Assumed five sites reporting failure in 1998 failed at a point randomly chosen and existing between the date of installation and the date of the 1998 survey::			
Log-Normal	52,001	50,517	53,529
Weibull	6,707	6,497	6,923
Log-Logistic	10,065	9,749	10,391

The range in estimated EUL suggested by the three distribution assumptions reflect the fact that each distribution differs in the amount of weight that is placed in the upper tail of the estimated function. The differences in the estimated functions can be seen in the following tables and graphs.

Table 3-8 and Figure 3-3 present a comparison of results using a log-normal, log-logistic and Weibull distribution. For this set of results, the failure times for the five sites reporting failure during the 1998 survey were assumed to have occurred at or near the date of the 1998 survey. As shown, 1% of ducts are estimated to fail by 54 months for all three models. Similarly, 10% of ducts are estimated to fail by 191 to 201 months. The models are behaving similarly because they are forced to fit the six failures (representing 3% of the sites in the analysis) of ducts that failed. As higher percentages of ducts are predicted to fail, the estimates differ among the three models, as there are no additional failures in the data.

Table 3-8: Comparison of Estimated Survivor Functions for Ducts (Months)
(assumed five sites reporting failure in 1998 failed at or near the date of the 1998 survey)

Percent of Installations Failed	Estimated Lifetime at Failure (in Months)		
	Log-Normal	Log-Logistic	Weibull
1%	55	54	54
10%	201	193	191
20%	346	296	286
30%	512	394	368
40%	716	498	446
50%	979	617	525
60%	1,339	765	610
70%	1,871	966	706
80%	2,769	1,285	825
90%	4,769	1,974	999
99%	17,344	7,025	1,449

Figure 3-3: Comparison of Estimated Survivor Functions for Ducts (Months)
(assumed five sites reporting failure in 1998 failed at or near the date of the 1998 survey)

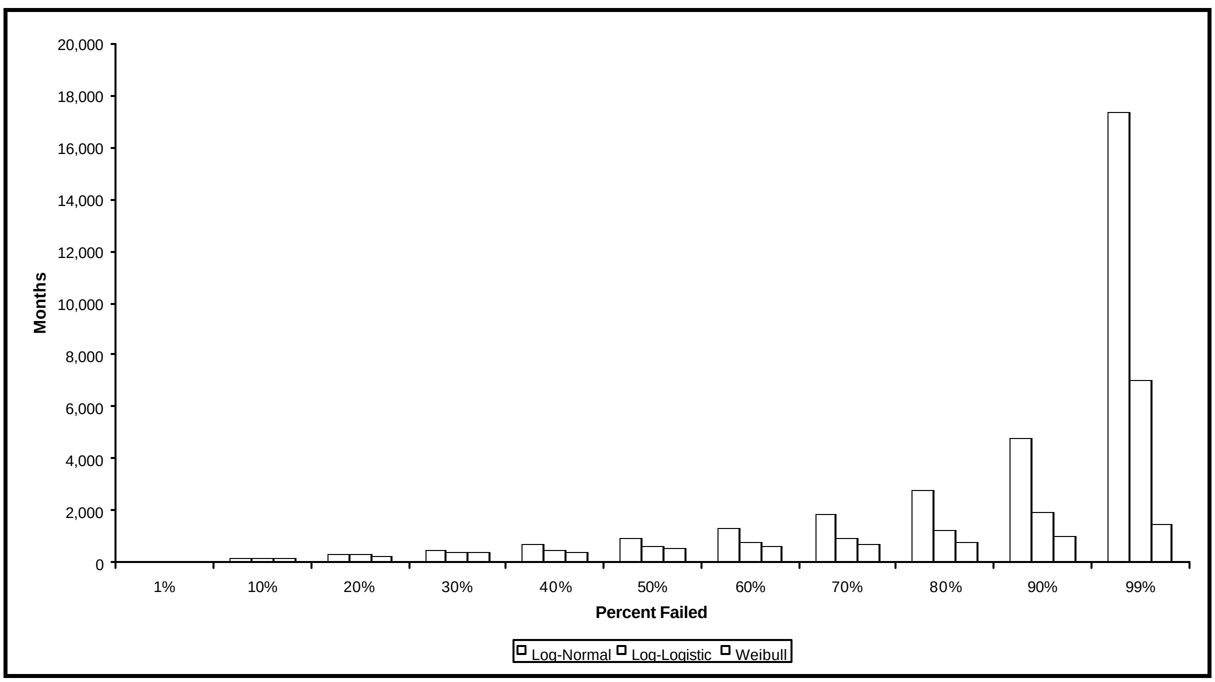


Table 3-9 and

Figure 3-4 present a similar result under the assumption that the failure times for the five sites reporting failure during the 1998 survey occurred at a midpoint between the date of installation and the date of the 1998 survey. As shown, the three models predict the same lifetime for one percent of the installations. The predictions of the three models begin to diverge when considering 10% of the installations, and continue to show differing results thereafter. Again, the results are due to having only a handful of failures in the data.

Table 3-9: Comparison of Estimated Survivor Functions for Ducts (Months)
(assumed five sites reporting failure in 1998 failed at a point midway between the date of installation and the date of the 1998 survey)

Percent of Installations Failed	Estimated Lifetime at Failure (in Months)		
	Log-Normal	Log-Logistic	Weibull
1%	35	35	35
10%	461	406	406
20%	1,357	934	886
30%	2,957	1,625	1,441
40%	5,754	2,559	2,093
50%	10,719	3,880	2,873
60%	19,969	5,885	3,838
70%	38,853	9,264	5,096
80%	84,671	16,115	6,888
90%	249,406	37,062	9,989
99%	3,244,507	435,025	20,512

Figure 3-4: Comparison of Estimated Survivor Functions for Ducts (Months)
(assumed five sites reporting failure in 1998 failed at a point midway between the date of installation and the date of the 1998 survey)

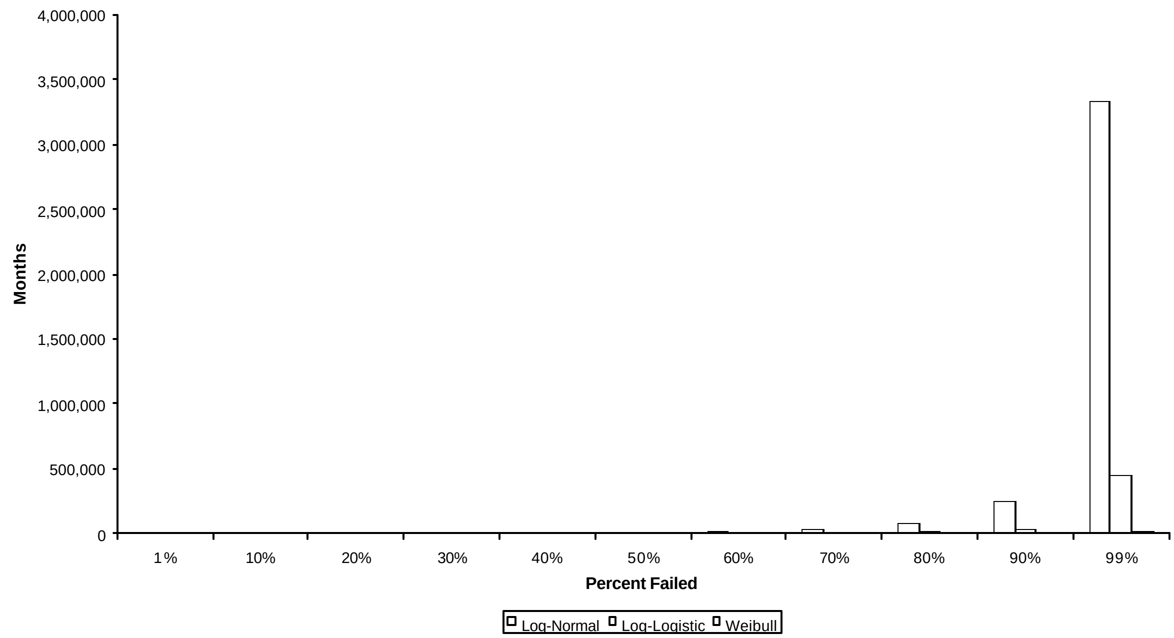
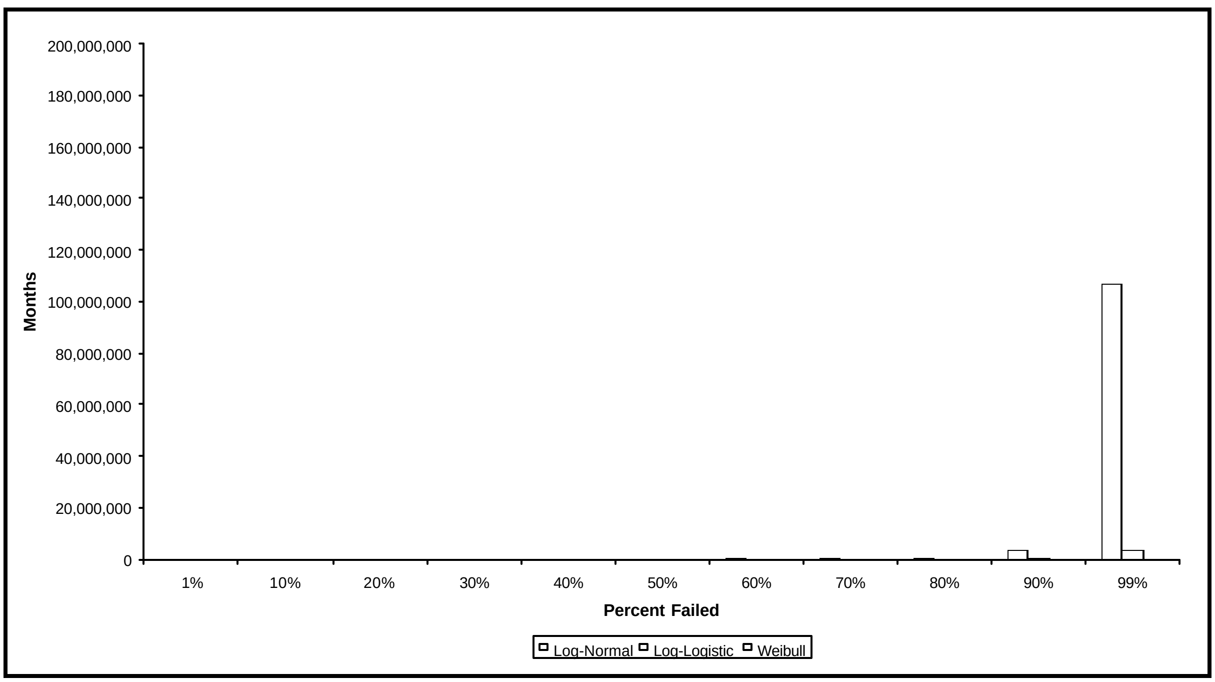


Table 3-10 and Figure 3-5 present the results under the assumption that the failure times for the five sites reporting failure during the 1998 survey occurred at a random point between the date of installation and the date of the 1998 survey. The results are similar to those shown for the previous two assumptions above.

Table 3-10: Comparison of Estimated Survivor Functions for Ducts (Months)
(assumed five sites reporting failure in 1998 failed at a point randomly chosen and existing between the date of installation and the date of the 1998 survey)

Percent of Installations Failed	Estimated Lifetime at Failure (in Months)		
	Log-Normal	Log-Logistic	Weibull
1%	26	28	28
10%	796	603	585
20%	3,342	1,704	1,547
30%	9,403	3,399	2,838
40%	22,760	5,987	4,518
50%	52,001	10,065	6,707
60%	118,808	16,921	9,625
70%	287,579	29,804	13,706
80%	809,204	59,452	19,956
90%	3,397,508	168,027	31,725
99%	102,559,247	3,627,327	77,813

Figure 3-5: Comparison of Estimated Survivor Functions for Ducts (Months)
(assumed five sites reporting failure in 1998 failed at a point randomly chosen and existing between the date of installation and the date of the 1998 survey)



Summary of Findings for Duct Testing

The ninth-year onsite surveys revealed only one failure of ducts. In order to perform the analysis, the data was combined with data from the fourth-year study which included five failures; however, the failure dates for these were not reported. The analysis was performed with both sets of data, using three assumptions for failure dates for the fourth-year data. The resulting dataset included six failures, with all but one occurring within four years of installation. Because there were few failures in the data, and the majority of failures occurred early, the parametric survival analysis resulted in estimates of extremely long lives for each of the models tested. Although these ex-post EUL estimates are significantly different from the ex-ante EUL, revision of the ex-ante EUL is not recommended since, due to the low number of failures in the data, the ex-post EUL estimates are not considered reliable.

It was found in the fourth-year study that there is considerable discussion in the literature indicating that duct testing lifetimes should be linked to the degradation in duct leakage rates. This issue is explored in more detail below.

Analysis of Duct Leakage Degradation

The criterion for passing the duct inspection measure in the 1994 EAH residential new construction program was for the tests to exhibit leakage rates of less than 140 CFM at 50 pascals. Further, there were strict protocols for administering the duct blaster tests. The analysis of duct leakage degradation involved the completion of 30 duct blaster tests, and 29 of these were conducted on participant homes also tested in the first-year impact study. From these 29 tests, 19 reported results of duct leakage tested at 50 pascals.

Table 3-11 presents a summary of the duct blaster test results for these 19 homes. In addition, results are provided from the first and fourth year studies for comparison. The leakage values are presented in fan flow in cubic feet per minute (CFM) and CFM per square feet of floor area (CFM/SF).

Table 3-11: Summary of Duct Blaster Test Results (CFM/SF)

Survey	Average Leakage (CFM)	Average Leakage (CFM/SF)
1994 First-Year Impact Study (1996)	364 *(SE 204)*	0.20 *(SE .19)*
1994 Fourth-Year Retention Study (1999)	381 *(SE 192)*	0.21 *(SE 16)*
1994 Ninth-Year Retention Study (2004)	336 *(SE 50)*	0.20 *(SE 0.03)*

These results appear to show an initial degradation between the time of measure installation and the First-Year Impact Study, with no subsequent degradation. However, testing the differences between means reveals that there is no statistical difference between these results.[10] It should be noted that the sample size for the duct blaster tests is relatively small and the results should therefore be considered carefully. In fact, there is no clear evidence on how and when duct failure occurs. Therefore, these results provide no statistical evidence to suggest changing the existing assumption for duct testing lifetime.

3.4 Summary of Findings

Table 3-12 presents a summary of the retention fractions and EULs for each measure. As stated above, although the ex-post EUL estimates for duct testing are significantly different from the ex-ante EUL, revision of the ex-ante EUL is not recommended since, due to the low number of failures in the data, the ex-post EUL estimates are not considered reliable. Therefore, the results of this study do not suggest changing any of the assumed EULs used by SoCalGas in their earnings claims.

Table 3-12: Summary of Estimated Retention Fraction and a Comparison of Estimated EULs with Existing *Ex Ante* EULs (Years)

Measures	Retention Fraction	Ex-Ante EUL	Estimated EUL from Ninth-Year Retention Study	Recommended EUL from Ninth-Year Retention Study
High Efficiency Furnace	1.000	18	18	18
Duct Sealing & Testing	0.982	25	44 to 4,333	25

10 Using a difference of means test at a 95% confidence level.

Appendix A

Survey Instruments

SoCalGas Energy Advantage Home Program
Ninth-Year Retention Study
On-Site Data Collection Form

Name:____

Street Address:____

City, State:____

Zip Code:____

Home Phone:____

Work Phone:____

Premise ID:____

Climate Zone:____

<u>Energy Conservation Measures installed through the Energy Advantage Program:</u>
(Check all that apply)

Measure	Installed		Comments
Furnace	Yes	N.A.	If Yes, details to be filled on page ___
Duct Testing Sealing	Yes	N.A.	If Yes, details to be filled on page ___

N.A. = Not Applicable

<u>Survey Tracking Information:</u>

Surveyor:____

Survey Date:____

Data Entry Date:____

Survey Shipped Date:____

General Information

1. What type of residence is this?
   - ❑ Single Family
   - ❑ Condominium
   - ❑ Townhouse
   - ❑ Apartment (building has fewer than five units)
   - ❑ Apartment (building has greater than four units)
   - ❑ Other

2. When did you move into this residence? ______ / ______ (Month / Year) ☐ Don't know

3. Are you the original owner of this house?
   - ❑ Yes **? Skip to Question 5**
   - ❑ No

4. When was the residence built? _______ / ______ (Month / Year) ☐ Don't know

5. Have you added any square feet to your home since you moved in?
   - ❑ Yes ***(Measure the added square feet)*** **?** _______square feet ☐ Don't know
   - ❑ No

Now I would like to inspect the measure(s) and come back and ask you a few questions.

Furnaces

6a. Furnace Equipment Verification

Technology Details	Existing Information	New Information	Change
Furnace Model Number:			☐ Same ☐ Different ☐ N.A. ☐ Not There
AFUE:			☐ Same ☐ Different ☐ N.A. ☐ Not There
Manufacturer:			☐ Same ☐ Different ☐ N.A. ☐ Not There
Thermostat (automatic or manual)			☐ Same ☐ Different ☐ N.A. ☐ Not There
Thermostat Setting:	N.A.		☐ Same ☐ Different ☐ N.A. ☐ Not There
Year of Manufacture:			☐ Same ☐ Different ☐ N.A. ☐ Not There
Location:			☐ Same ☐ Different ☐ N.A. ☐ Not There

N.A. = Not Applicable

6b. Furnace Equipment Performance Verification

Is the equipment in good working condition?

7b1. Furnace	❑ Yes ❑ No ? Describe the problem: ______________________________ ______________________________ ______________________________ ______________________________
Check the condition of the filters. Are they blocked?	

Additional Surveyor Notes:

____

____

____

Duct Sealing / Insulation

7a. Duct Equipment Verification

Technology Details	Existing Information	New Information	Change
Duct Seal Type: (Ma) Mastic (B) Butyl Tape (Me) Metal Tape (D) Duct Tape	☐ Ma ☐ B ☐ Me ☐ D		☐ Same ☐ Different ☐ N.A. ☐ Not There
Duct Insulation R - Value			☐ Same ☐ Different ☐ N.A. ☐ Not There
Location of Ducts: (C) crawl space (A) attic (O) other	☐ C ☐ A ☐ O		☐ Same ☐ Different ☐ N.A. ☐ Not There

N.A. = Not Applicable

7b. Duct Equipment Performance Verification

Is the equipment in good working condition?

1). The surveyor needs to check visually where the duct work connects to the plenum.
2). A visual check of the suspension of the ducting, noting crushed or damaged areas.
3). Any observable degradation of the duct sealing at joints or seams shall be noted. If a fair or poor condition is noted, surveyor shall photograph condition.

7b1. Duct Sealing	☐ Yes ☐ No ? Describe the problem: Plenum Connection: ____________________________ Condition: ☐ Good ☐ Fair ☐ Poor Suspension Observations: ______________________ Condition: ☐ Good ☐ Fair ☐ Poor Duct Sealing: ________________________________ Condition: ☐ Good ☐ Fair ☐ Poor
7b2. Duct Insulation Check visually for material degradation.	☐ Yes ☐ No ? Describe the problem: ________________________________ ________________________________ ________________________________ ________________________________

Additional Surveyor Notes: ____

____

Differences in Customer Usage

8. I notice the following changes in equipment from what we saw the last time. What month and year were they changed?

   (If the resident is unsure of the date, please probe to find out if there is a warranty or an invoice that can be used to check the date)

<u>Check all that apply:</u>

Measure	Status	Month	Year	Primary reason for removing / replacing measure:
Furnace	❑ Replaced ? ❑ Removed ? ❑ N.A.			❑ Equipment Failed ❑ Other ? Describe: ____________________ ____________________
Ducts	❑ Replaced ? ❑ Removed ? ❑ N.A.			❑ Equipment Failed ❑ Other ? Describe: ____________________ ____________________

N.A. = Not Applicable

Other Factors

9. What thermostat settings do you use?

Season	Day (Degrees F)	Night (Degrees F)
Summer		
Winter		

Maintenance Programs

10. Are you participating in any maintenance program for furnaces?

Type of Maintenance	Frequency of Maintenance
❑ Self – Maintain equip. myself ❑ Service agreement w/mfr./dist./retail ❑ Call service store when needed ❑ Other ? ________________________ ❑ None ❑ N.A.	❑ Once/Year ❑ Twice/Year ❑ Monthly ❑ Never ❑ Do not know

N.A. = Not Applicable

Equipment Repair

11. Has the_________________equipment ever been repaired?
(Ask this question about all the relevant measures)

Measure		When (Month/Year)
11a. Furnace	❑ Yes ? ❑ No ❑ N.A.	__________ / ____
11b. Duct Sealing	❑ Yes ? ❑ No ❑ N.A.	__________ / ____

N.A. = Not Applicable

Additional Surveyor Notes:

____

____

Demographics

12. How many people of the following ages live at this residence <u>at least nine months of the year</u>, including yourself?

Under 2 years	_______________
2-5 years	_______________
6-21 years	_______________
22-39 years	_______________
40-64 years	_______________
65 years and over	_______________
Refused	☐

13. Have there been any changes in the number of people living at this residence since 1999?
   - ☐ Yes ? **Go to Question 14**
   - ☐ No ? **Go to Question 15**
   - ☐ Didn't live here in 1999 ? **Go to Question 15**

14. Please describe the changes:

Persons	Age	Added/Left	Year	Month
		☐ Added ☐ Left		
		☐ Added ☐ Left		
		☐ Added ☐ Left		
		☐ Added ☐ Left		
		☐ Added ☐ Left		

15. What is your household's current annual income before taxes?

   - ☐ Under $20,000
   - ☐ $20,000 – $39,999
   - ☐ $40,000 - $59,999
   - ☐ $60,000 - $79,999
   - ☐ $80,000 - $120,000
   - ☐ Over $120,000
   - ☐ Refused
   - ☐ Don't know

Thanks for your time.

DUCT LEAKAGE TEST PROCEDURE

DUCT LEAKAGE TEST

The objective of the duct leakage test is to determine the integrity of air tightness of the forced air unit (FAU) air distribution system excluding platform returns and return air chase spaces. In order to perform the duct leakage test, the entire system is sealed at all supply registers and return grilles and then pressurized using an approved duct testers (duct blasters). Excluding the platform return and/or return air chases from the distribution system being tested requires using different sealing and testing configurations depending upon the type of FAU installed and the return air system.

The following guidelines are intended to provide guidance for the contractor performing duct leakage tests, regardless of the type of system installed. If the configuration of the HVAC system being tested precludes the use of these guidelines, please contact the Itron Project Manager for additional guidance.

GENERAL CONDITIONS

The duct leakage test is designed to measure the duct leakage in cubic feet per minute (cfm) at specific pressure differentials between the house and the duct system. The following conditions are necessary to perform reliable tests:

- Ensure that the FAU blower will not turn on unexpectedly during the test by turning the thermostat to the off position, disconnecting the power supply or other means as necessary.
- Open all interior doors in the house.
- If the FAU is located within the house, close all exterior doors and windows except for one open door or window. It is best, but not essential, to close the attic access door and crawl space access.
- If the FAU is located in the attic and the testing equipment is used in the house, close all exterior doors and windows except for one open door or window. It is best, but not essential, to close the attic access door and crawl space access.
- If the FAU is located in the garage, close the large garage door but leave one small door or window in the garage open. The door between the house and garage may be left open.

The intention of these guidelines is to measure accurately the air leakage from the duct system while reducing the impact of wind upon the test gauges.

HVAC SYSTEMS

The set-up of the duct testing equipment depends upon both the type of HVAC system and the return air system. Guidelines have been provided for the following types of systems:

- FAUs with Platform Return or Return Air Chase
- FAUs without Platform Return
- Attic FAUs with Return Air Chase
- FAUs with Sealed Blower Compartments

FAUs WITH PLATFORM RETURNS OR RETURN AIR CHASE

These guidelines apply to furnaces typically installed in closets or garages. The return air flows directly from the house into the furnace platform, or the return air is ducted from the house to a return air platform or the return air is drawn through a chase space from the house to a return air platform. The platform, return air ducts and chases may be included or they may be excluded from the duct pressurization testing. If the platform or return air system is included, the testing is the same as described below for **FAUs without Platform Return**. If the platform and return air system is excluded from the testing, the following guidelines apply. **NOTE:** If the furnace has a sealed blower compartment, see the section below for **Furnaces with Sealed Blower Compartment**.

- Seal all outlet registers by taping blanking panels over the registers of cover the entire face of each register with tape.
- Remove the blower door compartment cover and furnace filter, if a filter is in place.
- Seal the bottom of the blower compartment using rigid plastic or cardboard and tape. The integrity of this seal is important since any leakage around the seal will count against the overall duct system leakage. By sealing the bottom of the FAU, the return air portion of the system should be eliminated from testing.
- Cut a piece of rigid plastic or cardboard into place instead of the blower compartment cover. Tape this plastic or cardboard into place instead of the blower compartment cover. Cut a round hole in the plastic or cardboard the approximate size of the hole in the duct tester transition assembly (approximately 10 inches in diameter). NOTE: Cut the hole in the plastic or cardboard as low as practical so that the air flow stream is directed into the compartment, not directly at the blower housing.
- Tape the transition assembly onto the plastic or cardboard, aligning the hole in the transition assembly with the hole in the plastic or cardboard.
- Tape the plastic or cardboard, with the attached transition assembly, onto the blower compartment cover opening.
- Proceed as described in **Performing the Duct Leakage Test**.

FAUs WITHOUT PLATFORM RETURN

These guidelines apply to horizontal attic units, package heating and cooling units or any FAU without a platform return system. The testing guidelines for these systems are based on one premise: both the supply and return are connected to the FAU by sheet metal or duct board plenums.

- Seal all outlet registers by taping blanking panels over all registers or cover the entire face of each register with tape.
- Connect the duct tester transition assembly to the return air grille closest to the furnace. The return air grille must be at least as large (one square foot) as the transition assembly. If there are additional return air grilles, seal them with blanking panels or tape over the entire grille.
- Proceed as described in **Performing the Duct Leakage Test**.

ATTIC FAUs WITH RETURN AIR CHASE

These guidelines apply to attic furnaces where the return air is drawn through a chase space from the house to the attic FAU. If the attic FAU has the return air system ducted directly the return plenum, see the guidelines for **FAUs without Platform Return**. The return air chase may be included or it may be excluded from the duct pressurization testing. If the return air system is included, the testing is the same as described for **FAUs without Platform Return**. If the return air system is excluded from the testing, the following guidelines apply. **NOTE:** If the furnace has a sealed blower compartment, see the section below for **FAUs with Sealed Blower Compartment**.

- These guidelines allow the duct pressurization test to be conducted within the house, but sealing of the furnace must be performed in the attic. At the preference of the tester, the duct test could be performed in the attic following the guidelines for **FAUs with Platform Return or Return Air Chase**.
- Connect the duct blaster transition piece to a supply register that is at least as large as the transition piece (one square foot). Connect the duct blaster to the transition piece.
- Seal all the other outlet registers by taping blanking panels over all registers or cover the entire face of each register with tape.
- Remove the blower door compartment cover and furnace filter, if a filter is in place.
- Seal the bottom (return air side) of the blower compartment using rigid plastic or cardboard and tape. The integrity of this seal is important since any leakage around the seal will count against the overall duct system leakage. By sealing the bottom (side) of the FAU, the return air portion of the system should be eliminated from testing.
- Replace the blower compartment cover.
- Proceed as described in **Performing the Duct Leakage Test**.

FAUs WITH SEALED BLOWER COMPARTMENTS

If the system being tested has a sealed blower compartment, the duct pressurization testing will vary depending upon the type of FAU system. If the system does NOT have a platform return, use the guidelines for **FAUs without Platform Return**. If the system has a platform return, use the following guidelines:

- Seal all supply registers exactly the same as with any platform return system.
- The transition assembly cannot be connected to the front of the blower door compartment, so it must be installed through the platform on the bottom of the blower compartment.
- Cut a piece of rigid plastic or cardboard the approximate size of the bottom of the blower compartment. This plastic or cardboard will be taped into place on the bottom of the blower compartment. Cut a round hole in the plastic or cardboard the approximate size of the hole in the duct tester transition assembly (approximately 10 inches in diameter). **NOTE:** Cut the hole in the plastic or cardboard so that the air flow stream is directed into the compartment, not directly at the blower housing.
- Tape the transition assembly onto the plastic or cardboard, aligning the hole in the transition assembly with the hole in the plastic or cardboard.
- Tape the plastic or cardboard, with the attached transition assembly, onto the blower compartment opening.
- Proceed as described in **Performing the Duct Leakage Test**.

PERFORMING THE DUCT LEAKAGE TEST

- Ensure that the power to the FAU blower is disconnected.
- Connect the duct testing equipment blower and gauges in accordance with the manufacturer's specification.
- Perform the duct pressurization test at the prescribed duct pressures and enter the results in the "Test Data" section of the "Duct Blaster Data Collection Form."

The two duct pressures are:

- Test 1 25 Pascals (0.10 in. wg)
- Test 2 50 Pascals (0.20 in. wg)
- Convert the fan pressure readings into cfm using the conversion tables provided by the equipment manufacturer. Enter the results into the "Test Data" section of the "Duct Blaster Data Collection Form."

TEST EQUIPMENT REMOVAL AND FINAL WALK THROUGH

- Disconnect and remove the testing equipment.
- Remove any plastic or cardboard from the FAU.
- Return all HVAC system components to same condition as before testing.
- Replace the furnace filter if appropriate.
- If the thermostat was adjusted, return it to its original setting.
- Remove all tape and/or blanking panels from the supply registers and return air supply.
- Perform final walk through to ensure that all conditions within the house and garage are in the same condition as prior to the Duct Leakage Test.

Duct Blaster Data Collection Form

Customer Name:	**Customer Phone #**	**Customer Job #:**
Customer Address:	**Home:**	**Test performed by:**
City, Zip:	**Work:**	**Date test performed:**

TEST RESULTS	TEST SEQUENCE
	CUSTOMER INTRODUCTION / OVERVIEW • Briefly explain process to customer. • Make them aware of test conditions.
	PREPARE FOR DUCT LEAKAGE TEST • Tape all supply registers and any secondary returns. • Mount Duct Blaster to primary return. • Install one input hose to fan. • Install one input hose to register between 5-10 feet from air handler.
DUCT BLASTER MULTI-POINT TEST ***25 Pascals:*** ________ **Fan Pressure** _1 2 3__ **Flow Ring** ________ **Fan Flow** ***50 Pascals:*** ________ **Fan Pressure** _1 2 3__ **Flow Ring** ________ **Fan Flow**	**CONDUCT MULTI-POINT DUCT BLASTER TEST** • Zero pressure gauge on Duct Blaster (off/on). • Check all registers for tape blow out, correct as needed. • Take readings at 25 and 50 pascals with reference to outside (house not pressurized). **ADDITIONAL COMMENTS / DIAGRAM**
	TAKE DOWN ALL EQUIPMENT / CLEAN UP • Remove all equipment and load in vehicle. • Remove all tape from registers and returns. • Return all appliances to original settings. • Return all dampers to original settings. • Replace HVAC air filter.
	CLOSE WITH CUSTOMER • Inform the customer that you are finished and that the home is restored to

	pre-test conditions. • Complete "On-Site Data Collection Form" with customer if not already complete. • Inform customer that they should be receiving an incentive check within two weeks.

Appendix B

CPUC M&E Protocols Tables 6 and 7

CPUC M&E Protocols

Table 6

Results Used to Support PY94 Third-Earnings Claim
for
Residential New Construction Program
Fourth-Year Retention Evaluation

February 2004

Study ID No. 716A

TABLE 6 for RETENTION STUDIES
PROGRAM: Residential New Construction
YEAR(S): PY94

1. End Use	1. Measure	2. *ex-ante* EUL	2. *ex-ante* EUL Source	3. *ex-post* EUL from Study	4. *ex-post* EUL for 3rd & 4th claim	5. Std. Error	6. Upper & lower bounds @ 80% Conf Int		7. P Value	8. Realization Rate	9. "Like" Measures to be Adjusted
HVAC	Duct Testing	25	1994 EAH Filing	82	25	1.004	82	81	0	1.00	none
HVAC	Furnace (88%+ AFUE)	18	1994 EAH Filing	18	18	n/a	n/a	n/a	n/a	1.00	none

"n/a" indicates failures were not observed

Results shown for duct testing are for one set of assumptions; results using other assumptions were provided in the report. See Table 3-7 for remaining results.

Note that for duct testing the ex-post EUL from the study is significantly different from the ex-ante EUL. Revision of the ex-ante EUL is not recommended, however, since, due to the low number of failures in the data, the ex-post EUL estimate is not considered reliable.

CPUC M&E Protocols

Table 7

Data Quality and Processing Documentation for Residential New Construction Program Fourth-Year Retention Evaluation

February 2004

Study ID No. 716A

1 Overview Information

a) **Study Title and Study ID:** 1994 Residential New Construction Program – Ninth Year Retention Evaluation, February 2004, Study ID No. 716A.

b) **Program, Program Year(s), and Program Description (Design):** Residential New Construction Program for the 1994 program year. The Program was designed to induce builders to increase energy efficiency in new homes beyond Title 20 and Title 24 requirements. The program offerred informational and training workshops for builders and provided incentives for a variety of DSM measures.

c) **End Uses and Measures Covered:** Duct testing, gas furnaces (88% AFUE), gas water heaters (.60 - .69 EF), gas water heaters (.70 EF) combination heating and water heating systems, duct insulation, water heater heat traps, recirculating controls, MH water heaters (.60 EF), MH furnaces (80% - 87% AFUE), MH furnaces (88%+ AFUE), multi-family furnaces, and gas ovens.

d) **Methods and Models Used:** See Section 3.

e) **Analysis sample size:**

Program Year	Measure	# of Customers in Program	# of Installations in Program	# of Measures Installed in Program	# of Measures in Sample Frame	Date of Retention Study
DSM Measures						
1994	Duct Testing	1994 EAH[1]	1994 EAH[1]	7,159	217	1998
					255	2003
1994	Furnace (88% AFUE)	1994 EAH[1]	1994 EAH[1]	1,512	58	1998
					72	2003

1. See SoCalGas' 1994 EAHP program filing.

2 DATABASE MANAGEMENT

a) **Data sources:** the data came from the following sources:

- The on-site survey database from the 303 program participants covered under the first-year program impact study was retreived. The on-site survey collected detailed information on whether installed measures were still in the home and if they were still operational.
- Duct blaster tests were conducted for 30 homes.

b) **Data Attrition:** Of the 303 participant sites from the first-year impact study, 150 were targeted for onsite surveys for this study, and 122 surveys were completed. One of the completed surveys was omitted from the analysis because the homeowner reported the house had burned and been rebuilt. Five additional sites were omitted from the duct analysis because the auditor was unable to verify the ducts were in working condition. See Section 2.3.

c) **Data Quality Checks:** Itron and the on-site contractor ASW developed protocols and methods to ensure a high level of data quality. A survey pre-test was used to to test the survey instrument, customer recruitment, survey and data entry protocols. Prior to the statistical analysis steps, the on-site survey database was subject to a series of statistical and manual data checks to ensure completeness of the data.

d) **Analysis Database.** All of the data collected on the on-site survey instrument has been entered into the analysis database. A copy of the survey instrument is included in Appendix A.

3 SAMPLING

a) **Sampling Procedures and Protocols:** Itron attempted to survey 150 participant sites of the first-year impact study. The on-site data collection protocol is discussed in Section 2.2.

b) **Survey Information:** Appendix A includes a copy of the on-site survey. A total of 122 of the targeted 150 on-site surveys were completed, giving a survey response rate of 81%. The completed on-site survey sample by climate zone is presented in Table 2-1. Given the relatively high response rates, we did not attempt to test for non-response bias.

c) **Statistical Descriptions:** The key variable of interest is the measure lifetime which is summarized in Section 3. No comparison group was used as part of this analysis.

DATA SCREENING AND ANALYSIS

a) **Treatment of Outliers and Missing Data Points.** The main problem in computing estimates of the EULs for the measures studied is that the majority of the measures had not failed at the time of the on-site survey. Thus, the observed lifetimes are censored. To control for censoring a series of statistical models were estimated for one of the measures. The statistical method employed is described in Section 3.2.

b) **Background Variables.** Whether a measure had failed or not at the time of the on-site survey is independent of economic and political activity.

c) **Screened Data.** The measures studied were based on the first year impact study sample. No additional screens were employed.

d) **Model statistics:** See Table 6 for estimates of EULs and upper and lower confidence bounds.

e) **Specification:** Where possible survivor functions were estimated for the measure. In these cases, three alternative model specifications were estimated: Log-logistic, log-normal and Weibull survivor functions. The EUL and 80% upper and lower confidence bounds are presented in Section 3. A detailed description of the model specifications are presented in Section 3.2. Because of the small sample sizes it was not feasible to include factors that would account for heterogeneity of customers.

- **Heterogeneity:** Because of the small sample sizes it was not feasible to include factors that would describe the heterogenity of the customers.
- **Omitted Factors:** All relevant data were used.

f) **Error in Measuring Variables:** The key statistical problem is that the observed measure lifetimes are censored. That is, for those measures that were still in place and operating at the time of the on-site survey, the true lifetime was not observed. When possible, the analyis was extended to control for this censoring. See Section 3.2 for a detailed description of the method used.

g) **Influential Data Points:** Not applicable.

h) **Missing Data:** Not applicable.

i) **Precision:** See Section 3.2 for a description of how the standard errors were calculated.