RETENTION STUDY OF PACIFIC GAS AND ELECTRIC COMPANY'S 1996 AND 1997 APPLIANCE ENERGY EFFICIENCY PROGRAMS

1996 -1997 Residential Refrigeration Fourth Year Retention
Study ID 373 1R1

March 1, 2001

Measurement and Evaluation
Customer Energy Efficiency Policy & Evaluation Section
Pacific Gas and Electric Company
San Francisco, California

All inquiries should be directed to:

Janice Frazier-Hampton
Revenue Requirements
Pacific Gas and Electric Company
P. O. Box 770000, Mail Code B9A
San Francisco, CA 94177

FOURTH YEAR RETENTION STUDY FOR PG&E'S 1996 AND 1997 RESIDENTIAL AEI PROGRAM REFRIGERATION TECHNOLOGIES

Purpose of Study

This study was conducted in compliance with the requirements specified in "Protocols and Procedures for the Verification of Costs, Benefits, and Shareholders Earnings from Demand-Side Management Programs", as adopted by California Public Utilities Commission Decision 93-05-063, revised March 1998, Pursuant to Decisions 94-05-063, 94-10-059, 94-12-021, 95-12-054, 96-12-079, 98-03-063, and 99-06-052.

This study measures the effective useful life (EUL) for all energy efficient refrigeration technologies for which rebates were paid in 1996 and 1997 by Pacific Gas & Electric Company's (PG&E's) Residential Appliance Efficiency Incentive (RAEI) Program.

Methodology

The Protocols assert the purpose of a retention study is to collect data on the fraction of installed measures in place and operable in order to produce a revised estimate of its EUL. The ultimate goal is to estimate the EUL (or the median number of years that the measure is still in place and operable), which can be realized by identifying the measure's survival function. For this study, the survival function describes the percentage of measures installed that are still operable and in place at a given time. Survival analysis is the process of analyzing empirical failure/removal data in order to model a measure's survival function. As much as possible, we have attempted to employ classical survival analysis techniques to our study approach.

For this study, all units were in place less than five years. Because the ex ante EUL is 20 years, it is very unlikely that our data will be capable of accurately estimating the survival function for the studied measures.

Our overall approach consists of five analysis steps that were used to estimate each of the studied measures' EULs:

1. ***Compile summary statistics*** on the raw retention data. This step immediately illustrated the difficulties posed for analysis since there were so few "failures" over the first five years.

2. ***Visually inspect*** the retention data. By calculating the cumulative percentage of equipment that had failed in a given month, and plotting this percentage over time, an empirical survival function emerged.

3. ***Develop a trend line*** from the survival plots. Using the plots developed in (2) above, we estimated a trend line using standard linear regression techniques. We attempted to model the trend as a linear and an exponential function. In each case, we plotted the resulting trend line and visually compared it to the survival plot developed in (2). Furthermore, we used the resulting trend line to estimate the EUL.

4. ***Develop a survival function*** using classical survival techniques. Using the SAS System and the SAS companion guide, "Survival Analysis Using the SAS System," we modeled the survival function assuming five of the most common survival distributions: exponential, logistic, lognormal, Weibull and gamma. In each case, we plotted the resulting distribution and visually compared it to the survival plot developed in (2). Furthermore, we used the resulting survival function to estimate the EUL.

5. ***Develop a competing risks model*** that incorporates different distributions for failures and removals. A second competing risks model was developed using the failure data for the old refrigerators and the removal data obtained during data collection. This additional analysis step provides valuable results that have not been previously utilized in retention studies.

Final Results

The final study results are based on the rebated refrigerator failure and removal data modeled using the Log-logistic distribution for failures and the Weibull distribution for removals. This method is chosen for several reasons. The competing risks model allows for different events to be modeled with different distributions (LIFEREG does not have this capability), while at the same time allowing for interval censored data. The choice of Log-logistic failure and Weibull removal distributions was made because both distributions fit the rebated refrigerator and old refrigerator data very well and these distributions forecast curve shapes that are intuitively expected over time.

Because this estimate does not reject the ex ante estimate at the 80% confidence interval, the ex post EUL will remain 20 years. Therefore, the program realization rate, which is the ratio of the ex ante and ex post estimates, is one. These results are summarized in the following exhibit.

PG&E's 1996 and 1997 Residential Appliance Efficiency Incentives Program
Summary of Ex Post Effective Useful Life Estimates
Refrigeration End Use

End Use	Technology	Ex Ante	Study Results Upper	Median	Lower	Ex Post	Realization Rate
Refrigeration	20 Percent More Efficient	20	5,505	947	0	20	100%
	25 Percent More Efficient	20	5,505	947	0	20	100%
	30 Percent More Efficient	20	5,505	947	0	20	100%

Regulatory Waivers

No regulatory waivers were filed for this study.

FOURTH YEAR RETENTION STUDY FOR PG&E'S 1996 & 1997 RESIDENTIAL AEI PROGRAM REFRIGERATION TECHNOLOGY

PG&E Study ID#: 373 1R1

FINAL REPORT

March 1, 2001

Submitted to

Mary Kay Gobris
Market Planning and Research
Pacific Gas & Electric Co.
245 Market Street Room 656B
San Francisco, CA 94105-1702

Prepared by

QUANTUM CONSULTING INC.
2030 Addison Street
Berkeley, CA 94704

and

MEGDAL & ASSOCIATES
198 High Street
Acton, MA 01720

TABLE OF CONTENTS

ATTACHMENTS

LIST OF EXHIBITS

1. EXECUTIVE SUMMARY

This section presents a summary of the retention study results of Pacific Gas & Electric Company's (PG&E's) Residential Appliance Efficiency Incentive (RAEI) Program for refrigeration technologies. The retention study described in this report covers all refrigeration technologies installed at residential accounts that were paid during 1996 and 1997.

1.1 PROTOCOL REQUIREMENTS

This study was conducted under the rules specified in the "Protocols and Procedures for the Verification of Cost, Benefits, and Shareholder Earnings from Demand Side Management Programs" (the Protocols).[1] This evaluation has endeavored to meet all Protocol requirements.

The retention study results in ex post effective useful lives for the high efficiency refrigeration measure, and a comparison of realization rates from the ex ante to ex post estimates. The definition of the effective useful life, provided in Appendix A, Measurement Terms and Definitions, of the Protocols is: "an estimate of the median number of years that the measures installed under the program are still in place and operable".

The Protocols require high efficiency refrigeration measures to be studied for the RAEI program. This study focuses only on residential refrigeration measures for which rebates were *paid* during calendar year 1996 and 1997. The Protocols also require that two Program Years, 1996 and 1997, be combined and that the studies be conducted on the schedule for Program Year 1996. The Protocols state that combining the two studies "should increase the accuracy of the survival function and decrease the cost of completing the retention studies." Furthermore, "the retention studies shall include data from participant groups from two or more sequential years to increase the robustness of the sample and to allow for the estimation of a survival function for a number of different measures." Because the 1996 refrigerator program is virtually identical to the 1997 refrigerator program, the Protocol's suggestion to combine the two studies will greatly enhance the accuracy of the retention study, without incurring additional cost.

1.2 STUDY APPROACH OVERVIEW

As stated above, the Protocols assert the purpose of a retention study is to collect data on the fraction of installed measures in place and operable in order to produce a revised estimate of its EUL. The ultimate goal is to estimate the EUL (or the median number of years that the measure is still in place and operable), which can be realized by identifying the measure's survival function. For this study, the survival function describes the percentage of measures installed that are still operable and in place at a given time. Survival analysis is the process of

[1] California Public Utilities Commission Decision 93-05-063, Revised March 1998, Pursuant to Decisions 94-05-063, 94-10-059, 94-12-021, 95-12-054, 96-12-079, 98-03-063, and 99-06-052.

analyzing empirical failure/removal data in order to model a measure's survival function. As much as possible, we have attempted to employ classical survival analysis techniques to our study approach.

For this study, all refrigerators were in place less than five years. Because the ex ante EUL is 20 years for this measure, it is very unlikely that our data will be capable of accurately estimating the survival function for high efficiency refrigerators.

Our overall approach consists of five analysis steps that were used to estimate each of the studied measures' EULs:

1. ***Compile summary statistics*** on the raw retention data. This step immediately illustrated the difficulties posed for analysis since there were so few "failures" over the first five years.

2. ***Visually inspect*** the retention data. By calculating the cumulative percentage of equipment that had failed in a given month, and plotting this percentage over time, an empirical survival function emerged.

3. ***Develop a trend line*** from the survival plots. Using the plots developed in (2) above, we estimated a trend line using standard linear regression techniques. We attempted to model the trend as a linear and an exponential function. In each case, we plotted the resulting trend line and visually compared it to the survival plot developed in (2). Furthermore, we used the resulting trend line to estimate the EUL.

4. ***Develop a survival function*** using classical survival techniques. Using the SAS System and the SAS companion guide, "Survival Analysis Using the SAS System," we modeled the survival function assuming five of the most common survival distributions: exponential, logistic, lognormal, Weibull and gamma. In each case, we plotted the resulting distribution and visually compared it to the survival plot developed in (2). Furthermore, we used the resulting survival function to estimate the EUL.

5. ***Develop a competing risks model*** that incorporates different distributions for failures and removals. A second competing risks model was developed using the failure data for the old refrigerators and the removal data obtained during data collection. This additional analysis step provides valuable results that have not been previously utilized in retention studies.

1.3 STUDY RESULTS FOR REBATED REFRIGERATORS

Based on our extensive analysis of the retention data, we believe that there is insufficient data to provide reliable model results. Out of the 589 surveys completed, only one failure and nine removals were observed. Furthermore, data were collected only 3 to 4 years into the measures life, which is expected to be 20 years. Although there may be sufficient sample sizes to produce statistically significant results for some models, there clearly is not enough data over time to reliably estimate the median EUL. This can be illustrated by the sensitivity in the model results, as shown in Exhibit 1-1.

Exhibit 1-1
Summary of Study Results for Rebated Refrigerators

		Analysis Methods		
Approach	**Model**	**Median EUL**	**Upper Bound**	**Lower Bound**
Summary Statistics	Exponential	143	-	-
Trendlines	Linear	59	62	56
	Exponential	46	49	44
LIFEREG	Exponential	73	114	32
	Logistic	2,121	10,097	0
	Log-Normal	16,040	91,228	0
	Weibull	1,168	5,633	0
	Gamma	562	11,434	0
Competing Risks	Best Fit	947	5,505	0
	Min EUL	73	114	32
	Max EUL	-	-	-

At this time, the competing risks model provides the best fit for the data. Although the EUL is unreasonably high, we believe that it is due to the elapsed time from the rebated refrigerator purchase to the study. The maximum EUL model did not reach the median point after 10,000 months and the model was stopped. The competing risks model was validated by testing it with failure data from old refrigerators that had a much larger study period (15 years). Over this time period, the model provided an adequate number of events to reasonably estimate the EUL of the old refrigerators. The modeling of the old refrigerators will be discussed in the next section.

1.4 ANALYSIS OF OLD REFRIGERATORS

To confirm the conclusion of keeping the ex-ante EUL of 20 years for the rebated refrigerators, we analyzed the median EUL for the old refrigerators. Data was collected on the refrigerators that were replaced by the rebated refrigerator. Information collected was limited to age, operating condition, and known operating problems. Note that only information on failures was collected. There was no attempt to collect removal data due to the difficulty of tracking the removal of old refrigerators.

The failure data for the old refrigerators was analyzed using the same methodology as the rebated refrigerators. Exhibit 1-2 presents the results from the failure data modeled using the LIFEREG procedure and the results from combining the failure data with rebated refrigerator removal data in the competing risks model.

Exhibit 1-2
Summary of Study Results for Old Refrigerators

		Analysis Methods		
Approach	**Model**	**Median EUL**	**Upper Bound**	**Lower Bound**
LIFEREG	Exponential	110	123	98
	Logistic	36	38	34
	Log-Normal	38	40	36
	Weibull	36	37	34
	Gamma	51	54	47
Competing Risks	Best Fit	20	30	10
	Min EUL	19	22	16
	Max EUL	23	37	10

As shown in the exhibit, the values are much lower than those of the rebated refrigerator. This is mainly due to the empirical data existing over a much larger time period so that the model has an adequate number of events over time to develop the distribution.

We have concerns with using the old refrigerator data because we feel it may not be representative of the true failure curve associated with the rebated refrigerators. There are issues regarding vintage, efficiency, demographics, manufacturing methods, lifestyle changes, and how the survey data were applied. The old refrigerators will likely have a different survival distribution than the rebated units. In addition, as discussed above, if a customer indicated during the survey that there were any operating problems with the refrigerator, then the unit was considered a failure. This is very conservative, because many of the problems mentioned were minor, and in fact, many customers were still using the unit as a backup.

1.5 FINAL RESULTS

The final study results are based on the rebated refrigerator failure and removal data modeled using the Log-logistic distribution for failures and the Weibull distribution for removals. This method is chosen for several reasons. The competing risks model allows for different events to be modeled with different distributions (LIFEREG does not have this capability), while at the same time allowing for interval censored data. The choice of Log-logistic failure and Weibull removal distributions was made because both distributions fit the rebated refrigerator and old refrigerator data very well and these distributions forecast curve shapes that are intuitively expected over time.

Because this estimate does not reject the ex ante estimate at the 80% confidence interval, the ex post EUL will remain 20 years. Therefore, the program realization rate, which is the ratio of the ex ante and ex post estimates, is one. These results are summarized in Exhibit 1-3.

Exhibit 1-3
Final Ex Post EUL Estimate

End Use	Technology	Ex Ante	Study Results Upper	Median	Lower	Ex Post	Realization Rate
Refrigeration	20 Percent More Efficient	20	5,505	947	0	20	100%
	25 Percent More Efficient	20	5,505	947	0	20	100%
	30 Percent More Efficient	20	5,505	947	0	20	100%

It is interesting to note that the best fit model is based on the same distribution (log-logistic) using the old refrigerator or the rebated refrigerator failure data. It is also interesting to note that the EUL for the old refrigerator failure-rebated refrigerator removal model is the same as the ex ante. The bottom line is that any model selected would have resulted in accepting the ex ante estimate.

2. INTRODUCTION

This report summarizes the retention study of Pacific Gas & Electric Company's (PG&E's) Residential Appliance Efficiency Incentive (RAEI) Program for refrigeration technologies. The evaluation effort includes all refrigeration technologies installed at residential accounts that had rebates paid during 1996 and 1997.

2.1 THE RESIDENTIAL APPLIANCE EFFICIENCY INCENTIVE PROGRAM

The RAEI Program offered fixed rebates to customers who installed refrigerators meeting specific electric energy-efficiency requirements. Rebates of $40, $60, and $80 were paid for refrigerators that were, respectively, at least 20, 25, or 30 percent more efficient than baseline efficiency standards. The programs assumed that customers were in the process of replacing their existing refrigerators, and offered the incentive to influence them to purchase more efficient models.

2.2 STUDY REQUIREMENTS

The retention study described in this report covers all refrigeration measures installed at residential accounts, as determined by the Marketing Decision Support System (MDSS) sector code, that were included under the RAE and RR programs and for which rebates were *paid* during calendar year 1996 and 1997.

This study was conducted under the rules specified in the "Protocols and Procedures for the Verification of Cost, Benefits, and Shareholder Earnings from Demand Side Management Programs" (the Protocols).[1] This evaluation has endeavored to meet all Protocol requirements.

The retention study results in an ex post effective useful life for refrigeration equipment, and a comparison of the realization rate from the ex ante to ex post estimate. The definition of the effective useful life, provided in Appendix A, Measurement Terms and Definitions, of the Protocols is:

Effective Useful Life (EUL) – An estimate of the median number of years that the measures installed under the program are still in place and operable.

2.2.1 Studied Measures

The Protocols require high efficiency refrigeration measures to be studied for the RAEI program. This study focuses only on residential refrigeration measures for which rebates were *paid* during calendar year 1996 and 1997.

[1] California Public Utilities Commission Decision 93-05-063, Revised March 1998, Pursuant to Decisions 94-05-063, 94-10-059, 94-12-021, 95-12-054, 96-12-079, 98-03-063, and 99-06-052.

2.2.2 Combining Program Years

The Protocols also require that two Program Years, 1996 and 1997, be combined and that the studies be conducted on the schedule for Program Year 1996. The Protocols state that combining the two studies "should increase the accuracy of the survival function and decrease the cost of completing the retention studies." Furthermore, "the retention studies shall include data from participant groups from two or more sequential years to increase the robustness of the sample and to allow for the estimation of a survival function for a number of different measures."

Because the 1996 refrigerator program is virtually identical to the 1997 refrigerator program, the Protocol's suggestion to combine the two studies will greatly enhance the accuracy of the retention study, without incurring additional cost.

2.2.3 Accepting Ex Post EULs

The Protocols state that "the estimated ex post measure EULs that result from the retention study will be compared to the ex ante EUL estimates. Hypothesis testing procedures will be used to determine if the estimated ex post measure EUL is statistically significantly different from the ex ante measure EUL. If the estimated ex post measure EUL is significantly different than the ex ante measure EUL, the estimated ex post measure EUL will be used. Otherwise, the ex ante estimate will continue to be used. Hypothesis testing will be conducted at the 20% significance level."

2.2.4 Objectives

The research objectives are therefore as follows

- Collect data to determine if rebated refrigerators are in place and operable.
- Calculate the ex post EUL, and the realization rates from ex ante to ex post.
- Complete tables 6 and 7 of the Protocols.

2.3 STUDY APPROACH OVERVIEW

As stated above, the Protocols assert the purpose of a retention study is to collect data on the fraction of installed measures in place and operable in order to produce a revised estimate of its EUL. The ultimate goal is to estimate the EUL (or the median number of years that the measure is still in place and operable), which can be realized by identifying the measure's survival function. For this study, the survival function describes the percentage of measures installed that are still operable and in place at a given time. At any given time, the hazard rate is the rate at which measures fail or are removed. Survival analysis is the process of analyzing empirical failure/removal data in order to model a measure's survival function. As much as possible, we have attempted to employ classical survival analysis techniques to our study approach.

Our overall approach was to apply survival analysis to our collected retention data in order to develop a survival function. Some of the common survival functions take on the logistic cumulative distribution function. Although there is no documentation to support the ex ante survival function assumptions, discussions with the authors of the Protocols indicated that the ex ante EULs are based on a logistic survival function.

However, the form of the logistic survival function assumed by the Protocol authors is *not* the commonly used form of the logistic model. Generally, in survival analysis, the log-logistic model is used, which is a special form of the logistic distribution. Other commonly used survival functions are based on the exponential, Weibull, lognormal, and gamma distributions. For this retention study, we have examined each of these distributions. We have used the SAS System and the SAS companion guide, "Survival Analysis Using the SAS System[2]," in order to estimate the survival functions based on the retention data.

An important issue to keep in mind for this analysis is the definition of survival. Recall that the EUL is defined as the median number of years that the measures installed under the program are still in place and operable. Therefore, to "survive", a measure must not have been removed or have failed. Unfortunately, it is likely that the underlying distribution of measures having failed is very different than the distribution of removals.

The results suggest, for example, that refrigerator failures follow a log-logistic distribution. The log-logistic survival function has an increasing hazard rate over the reasonable life of the refrigerator. In other words, the rate at which refrigerators fail increases over time. This theory is founded on the fact that refrigerators are more likely to fail as they become older.

However, the removal of a refrigerator is more dependent on human interaction. For example, consider the act of relocating to another state. The participant may either move the refrigerator with them or leave it behind for the new occupant. When the refrigerator is fairly new and in good working condition, the participant is more likely to take the refrigerator with them. On the other hand, as the refrigerator becomes old and approaches the end of its useful life, the participant is more likely to leave the refrigerator behind. This implies that the hazard rate decreases over time. Therefore, it is likely that the survival function of equipment removal differs from the survival function of the equipment failure.

For this study, all of the refrigerators were in place less than five years (none were rebated prior to 1996, and follow-up data collection was conducted no later than October 2000). Because the ex ante EUL is 20 years, it was unlikely from the start that our data would be capable of accurately estimating this joint probability density function of failures and removals. In an effort to increase the value of this study, data was collected on the old refrigerator that was replaced. This provided information on historical failure rates of refrigerators that was used in the analysis.

Our overall approach consists of five analysis steps that were used to estimate the EUL for rebated refrigerators:

---

[2] Allison, Paul D., "Survival Analysis Using the SAS System, A Practical Guide", SAS Institute, NC, 1995.

1. ***Compile summary statistics*** on the raw retention data. This step immediately illustrated the difficulties posed for analysis since there were so few "failures" over the first five years.

2. ***Visually inspect*** the retention data. By calculating the cumulative percentage of equipment that had failed in a given month, and plotting this percentage over time, an empirical survival function emerged.

3. ***Develop a trend line*** from the survival plots. Using the plots developed in (2) above, we estimated a trend line using standard linear regression techniques. We attempted to model the trend as a linear and an exponential function. In each case, we plotted the resulting trend line and visually compared it to the survival plot developed in (2). Furthermore, we used the resulting trend line to estimate the EUL.

4. ***Develop a survival function*** using classical survival techniques. Using the SAS System and the SAS companion guide, "Survival Analysis Using the SAS System," we modeled the survival function assuming five of the most common survival distributions: exponential, logistic, lognormal, Weibull and gamma. In each case, we plotted the resulting distribution and visually compared it to the survival plot developed in (2). Furthermore, we used the resulting survival function to estimate the EUL.

5. ***Develop a competing risks model*** that incorporates different distributions for failures and removals. A second competing risks model was developed using the failure data for the old refrigerators and the removal data obtained during data collection. This additional analysis step provides valuable results that have not been previously utilized in retention studies.

The details surrounding each of these steps are provided in Section 3.

2.4 REPORT LAYOUT

This report is divided into four sections, plus attachments. *Sections 1 and 2* are the *Executive Summary* and the *Introduction. Section 3* presents the *Methodology* of the evaluation. *Section 4* presents the detailed results and a discussion of important findings. *Attachment 1* provides the Protocol Tables 6B and 7B. *Attachment 2* provides final versions of the three survey instruments implemented for the data collection portion of this study.

3. METHODOLOGY

This section provides the specifics surrounding the methods used to conduct the Retention Study for the 1996 and 1997 Pacific Gas & Electric Company (PG&E) Residential Appliance Efficiency Incentive (RAEI) Program for refrigeration technologies. It begins with a brief overview of the study objectives and methodology. This is followed by a detailed discussion on the sampling plan for the Retention Study. From there, details regarding the study methodology are presented, along with intermediate results from each of the five approaches implemented.

3.1 STUDY OVERVIEW

The objective of the Retention Study was to estimate ex post effective useful lives for each refrigeration measure, and to compare the realization rates from the ex ante to ex post estimates. The definition of the effective useful life, provided in Appendix A, Measurement Terms and Definitions, of the Protocols is:

Effective Useful Life (EUL) – An estimate of the median number of years that the measures installed under the program are still in place and operable.

Because of the incidence of participants moving and taking their refrigerator with them, there existed an additional level of complexity in estimating the EUL. Operating units that have moved from the original premise to a new premise within PG&E's service territory are considered in place and operable. When estimating the EUL for refrigerators, the following events were considered:

Was the unit still at its original premise?

Has the unit been moved to a premise within PG&E's service Territory?

Was the unit still in place and operating?

3.1.1 Failure Types

There are two cases where a unit is considered to have "failed": (1) if the equipment actually failed and was not replaced under warranty[1], and (2) if the unit was moved outside of PG&E's service territory. Each of these cases has a different underlying distribution of occurrence. For example, it is likely that actual failures occur very late in life, and have a distribution with an increasing rate of failure, perhaps similar to the Weibull distribution. Units that are moved outside of PG&E's service territory will have a significantly different distribution than failures. Units moved are likely to have a decreasing rate of "failure" over time, not increasing. As the unit becomes older, it is less likely that the owner would take the

[1] It should also be noted that the CADMAC allows failed units replaced under warranty to be considered in place and operable.

unit during a move. Therefore, modeling this event with a Weibull distribution would be wrong, as a Weibull distribution assumes an increasing failure rate.

This is very important to note, because the majority of "failures" that occur early in life (first 5 years or so) are more likely to occur as a result of the unit being moved. This concept was observed during the course of this study and will be elaborated on later in this section.

3.1.2 Data Collection

Three different surveys were fielded for this study to capture survival data on rebated refrigerators: Original Participant, New Occupant, and Participant Mover. Each survey captured critical information regarding the fate of the rebated refrigerator, but did so in a unique way that was tailored to the respondents that were being surveyed.

Before fielding the three surveys, the population of participants was divided into two groups: non-movers and movers. The non-movers were fielded in the Original Participant survey. From the mover sample, the occupants at the address the rebated refrigerator was purchased for were surveyed using the New Occupant survey. Results from this survey were used to identify participants that moved their refrigerator with them. People Search (a professional locator service) was contracted to locate as many of the participants as possible. Results from our own search were appended to the search results obtained by People Search. This sample of participants was surveyed using the Participant Mover survey.

The samples for the Original Participant and New Occupant surveys were drawn proportional to the population, with the New Occupants being slightly over-sampled to ensure a sufficient Participant Mover sample size. Unless otherwise noted, all analysis results were weighted to represent the population.

3.1.3 Analysis Strategy

Our overall approach consists of five analysis steps that were used to estimate the EUL for rebated refrigerators:

1. ***Compile summary statistics*** on the raw retention data. This step immediately illustrated the difficulties posed for analysis since there were so few "failures" over the first five years.

2. ***Visually inspect*** the retention data. By calculating the cumulative percentage of equipment that had failed in a given month, and plotting this percentage over time, an empirical survival function emerged.

3. ***Develop a trend line*** from the survival plots. Using the plots developed in (2) above, we estimated a trend line using standard linear regression techniques. We attempted to model the trend as a linear and an exponential function. In each case, we plotted the resulting trend line and visually compared it to the survival plot developed in (2). Furthermore, we used the resulting trend line to estimate the EUL.

4. ***Develop a survival function*** using classical survival techniques. Using the SAS System and the SAS companion guide, "Survival Analysis Using the SAS System," we

modeled the survival function assuming five of the most common survival distributions: exponential, logistic, lognormal, Weibull and gamma. In each case, we plotted the resulting distribution and visually compared it to the survival plot developed in (2). Furthermore, we used the resulting survival function to estimate the EUL.

5. ***Develop a competing risks model*** that incorporates different distributions for failures and removals. As discussed earlier in this section, failures and removals have different distributions over time. Therefore, assuming one model with one event type will result in erroneous estimates of the EUL. Competing risks models allow for multiple event types to be modeled at once. The fundamental characteristic of a competing risks model is that if one event type occurs, the individual is removed from risk of all the other event types. Relating this characteristic to this study, if a participant has a refrigerator that fails, then they are no longer part of the equation for the distribution of removals. Two competing risks models were developed for this study. The first model accounts for failures and removals of rebated refrigerators. A second competing risks model was developed using the failure data for the old refrigerators and the removal data obtained during data collection. This additional analysis step provides valuable results that have not been previously utilized in retention studies.

Each of these steps will be developed further in the remainder of this section.

3.2 SAMPLE DESIGN

3.2.1 Existing Data Sources

The Retention Study incorporated a variety of data currently available; in particular PG&E's program participation data (Marketing Decision Support System [MDSS]), retention study databases, and other program-related documentation.

- *Program Participant Tracking System*. The participant tracking system data, maintained in PG&E's MDSS, contains vital project and technical information about the measures rebated. In addition, participant contact information is stored in the MDSS.
- *Residential Population CIS*. PG&E residential customer information system (CIS) data was used to obtain contact information as well as to identify movers and non-movers using the date on premise.
- *Program Marketing Data*. PG&E program marketing data contains a detailed description of the installation and rebate program procedures.

3.2.2 Sample Frame

Preparing the survey sample dataset began with identifying participants who moved since participating in the refrigeration rebate program. Three variables were used to identify movers and non-movers. The participant's last name and telephone number were compared with the corresponding CIS record. If either the name or telephone number was the same in the participant datasets and the CIS then the participant was flagged as a non-mover. A comparison of participation dates (check issue date) and the date on premise from the CIS dataset was used to identify movers. If the date on premise was prior to the date of participation, then the participant was flagged as a non-mover. If the date on premise was more recent than the participation date the participant was flagged as a mover.

The distribution of the participant population by residency status and year of participation is provided in Exhibit 3-1. As illustrated, non-movers make up approximately 75% of the population, while movers make up the remaining 25% of the population. The final sample was drawn proportional to the population.

Exhibit 3-1
Distribution of Participant Population by Residency Status and Year

Residency Status	Year of Participation	Count	Percent of Population
Mover	1996	8,354	14.1%
Mover	1997	6,621	11.2%
Non-Mover	1996	20,966	35.5%
Non-Mover	1997	23,170	39.2%
Total		59,111	100.0%

The three different levels of energy efficiency for the refrigeration program were 20%, 25%, and 30% more energy efficient than standards. These levels are represented in the participant population as shown in Exhibit 3-2. Our sample frame was also drawn proportionally to the population distribution.

Exhibit 3-2
Distribution of Efficiency Level for Participant Population

Efficiency Level	Count	Percent of Population
20%	22,379	37.9%
25%	23,670	40.0%
30%	13,062	22.1%
Total	59,111	100.0%

3.2.3 Data Collection Strategy

Three telephone surveys were implemented by QC to obtain survival information on energy efficient refrigerators that were rebated under 1996 and 1997 program years. The first survey to be fielded was aimed at "New Occupants", or residential customers that were believed to have moved into a home that a rebated refrigerator was purchased for. The second survey to be fielded was aimed at "Original Participants", or participants that did not move since purchasing the rebated refrigerator. Finally, the "Participant Mover" survey was fielded. This sample was developed from responses to the New Occupant survey and search results obtained from a locator service. Copies of all three survey instruments are provided in *Attachment 2*.

These surveys were all implemented by our Computer Aided Telephone Interview (CATI) center. Surveys were provided in electronic form, along with samples for interviewers to survey. A disposition of the results from the interviews is provided in Exhibit 3-3. As shown in this exhibit, both the New Occupant and the Original Participant had an adequate number of sample points from which to obtain the proposed number of completes. Due to the limited sample frame for Participant Movers, a great deal of time was spent attempting to complete each data point.

Exhibit 3-3
Raw Survey Data Disposition

Disposition	Survey		
	New Occupant	Original Participant	Participant Mover
Complete	251	461	45
Sample Not Dialed	1012	6934	0
Sample Dialed but not Completed	744	82	0
Refusal	74	57	8
Thank and terminate	95	116	4
Unobtainable	1021	1139	111
Total	3197	8789	168

Equipment survival data were collected by the QC interviewer, who prompted each survey participant to locate the rebated refrigerator by make and model using information available from the participation records. At that time, information was recorded regarding the success or failure in locating the rebated equipment.

For each refrigerator, it was determined whether (1) the equipment was still installed within PG&E's service territory, and (2) if it was operable. If the equipment was not in place or was not operable, it was determined when it was removed or stopped operating according to the owner's best recollection. Reasons for removal or failure to operate were also collected. If equipment was replaced, it was determined if replaced equipment was done so under warranty. If the refrigerator was removed, interviewers attempted to determine the present location of the refrigerator. During the New Occupant survey, if the respondent claimed that the rebated refrigerator was not there upon move-in, then the corresponding participant record was sent to People Search to locate the original participant for the Participant Mover survey.

Additionally, respondents were asked the age of their old refrigerator that was replaced by the rebated refrigerator, the working condition of the old refrigerator, and the type of problems that the old refrigerator had. These responses were used to develop failure distributions used to support the survival analysis, as discussed in more detail at the end of this section.

3.2.4 *Final Distribution*

A summary of the final disposition of the three surveys is presented in Exhibit 3-4.

Exhibit 3-4
Final Sample Disposition[2]

Type and Number of Surveys Conducted		In Place & Operating	Failed	Removed	Total
New Occupant	251	83	0	0	83
Original Participant	461	456	3	2	461
Participant Mover	45	37	1	7	45
Total	757	576	4	9	589

The New Occupant survey yielded 251 complete responses, and respondents were placed into the following categories based upon their responses:

- 83 New Occupants identified the rebated refrigerator and claimed that it was in place and operable at their residence.
- 168 New Occupants were unable to verify that the rebated refrigerator was left at their residence.

None of the New Occupants who identified the rebated refrigerator and claimed that the refrigerator was left behind by the participant indicated that it had failed or been removed.

The Original Participant survey yielded 461 complete responses with the following characteristics:

- 3 of the rebated refrigerators have failed. All three of these replacements were replaced under warranty.
- 2 of the rebated refrigerators were removed from PG&E's service territory. One refrigerator is still owned by the original participant, and is still operable, but was placed at a second home outside of PG&E's service territory. The other refrigerator was, according to the respondent, sold or given away somewhere in California, but outside of central or northern California. The respondent was unable to specify a city where the refrigerator was located. The unit was operable up to the date of removal.

---

[2] Only 83 of the 251 respondents from the New Occupant survey were able to confirm that the rebated refrigerator was left by the original participant. The remaining 168 respondents either did not have a refrigerator at the residence upon move-in or were unable to confirm that the refrigerator was the rebated refrigerator based upon make and model number of the rebated refrigerator.

Although the respondent could not specify the city, and it may still be within PG&E's service territory, we are counting the unit as a removal in order to keep our estimates conservative.

From the 168 New Occupants that claimed that the refrigerator was not in place upon move-in, original participant contact information from the corresponding 168 Participant Movers was sent to People Search to obtain current contact information for the participant. We also performed an independent search for many of the Participant Movers to both validate the results obtained from People Search and to increase the sample size. Combining all search results with the original participation records, we attempted to locate as many of the 168 Participant Movers as possible. Of these, 45 were contacted during the Participant Mover survey with the following characteristics:

- 37 of the Participant Movers indicated that the refrigerator was still operable in PG&E's service territory.
- 7 of the Participant Movers removed their refrigerator from PG&E's service territory.
- 1 Participant Mover claimed that the rebated refrigerator had failed.
- 1 Participant Mover was unable to provide information to use in the analysis.

Prior to analysis, all three datasets were combined into one dataset. Each of the three surveys was weighted so that it would provide an accurate representation of the population. Unless otherwise noted, the remainder of this report will present weighted results.

3.3 ANALYSIS OVERVIEW

As discussed in Section 2.3, the purpose of this Retention Study is to collect data on the fraction of refrigerators in place and operable in order to produce a revised estimate of the EUL. The desired result of our approach was to apply survival analysis to our collected retention data in order to develop a survival function for the rebated refrigerators. However, because our retention data only includes information over the first few years of the refrigerators' lives (which are expected to have a median life of 20 years), we were concerned that our data would not support an accurate estimation of a survival function.

Exhibit 3-5
Unweighted Summary Statistics on Retention Sample Data

Survey Type	Number of Surveys Conducted	Number of Units that Failed, were Removed, or Replaced	Number of Units Replaced Under Warranty	Number of Units in Place and Operable	Percent Failed, Removed, Replaced
New Occupant	83	0	0	83	0.00%
Original Participant	461	5	3	459	0.43%
Participant Mover	45	8	0	37	17.78%
Total	589	13	3	579	1.70%

Our concern is supported by Exhibit 3-5 above, which presents the number of sampled sites that had at least one unit that failed or was removed. Of the 589 sites sampled, only 13 of them (2.6% unweighted) had either a failure or a removal. In addition, three of the failures were replaced under warranty. Therefore, it would be difficult to develop a survival function that provided a statistically significant EUL.

The analysis that QC implemented used SAS to statistically model the survival function of the rebated refrigerators over time. These models use binary indicators to provide information on events (failures or removals), where a "1" indicates that an event has taken place and a "0" indicates that no event has taken place. Dates for each event are also provided, along with covariates that may be helpful in explaining some causal relationships.

There were five main steps in our approach to the survival analysis. Our five-step approach included the following activities:

1. The first step in the analysis was to compile summary statistics on the raw retention data. Although the analysis was performed on one combined dataset, results from each of the three surveys were examined individually to provide insight.

2. Next, we visually inspected the retention data. By calculating the cumulative percentage of equipment that had failed in a given month, and plotting this percentage over time, an empirical survival function emerged.

3. The third step in the analysis was to develop a trend line. Using the survival plots developed in (2) above, we estimated trend lines using standard linear regression techniques. The trend was modeled as a linear and an exponential function. In each case, we plotted the resulting trend line and visually compared it to the survival plot developed in (2). Furthermore, we used the resulting trend line to develop a preliminary estimate of the EUL.

4. The survival functions were modeled using classical survival techniques. Using the SAS System and the SAS companion guide, "Survival Analysis Using the SAS System," five different survival distributions were modeled: exponential, log-logistic,

log-normal, Weibull, and gamma. Due to censoring restrictions, a partial hazards model was unable to be used in this analysis.

5. Competing risk models were developed to estimate survival functions capable of integrating any two survival distributions for failures and removals. One model was developed using failure and removal data for rebated refrigerators and one model was developed using failure data for old refrigerators and removal data for rebated refrigerators. In each case, we plotted the resulting distribution and visually compared it to the survival plot developed in (2). Furthermore, we used the resulting survival function to estimate the EUL.

We believe that it was necessary to review summary statistics and visually inspect the data prior to modeling, as these steps reveal analysis issues that need to be addressed during the survival analysis. In addition, these earlier steps provided further validation for the results of the survival function. The details surrounding each of these methods are provided below.

3.4 SUMMARY STATISTICS

As discussed above, the first step of our analysis was to compile unweighted summary statistics on the sample retention data. These statistics include:

- the number of sites surveyed;
- the number of units still in place and operable;
- the number of units that had failed, been removed and been replaced;
- the number of failed units that had been replaced under warranty;
- the percentage of units that had failed, been removed or been replaced; and
- the ex ante EUL.

Exhibit 3-5 (in Section 3.3 above) summarizes this data by survey type. As shown in this exhibit, it will be impossible to develop a survival function or an ex post EUL estimate for the New Occupant group because this group exhibited no failures or removals in the sample. Furthermore, the Original Participant group exhibited only five failures or removals in the sample, with three failures replaced under warranty. Even though the Participant Mover group did exhibit a 17.78 percent failure/removal rate, this is based on seven removals and only one failure. Due to the obvious bias that exists among the individual surveyed groups, all subsequent analyses were conducted on the entire sample frame and weighted accordingly, such that our combined analysis dataset would be representative of the population of rebated refrigerators.

For the total sample frame, we had enough data on failures and removals to proceed to the next analysis step. However, examination of the data presented in Exhibit 3-5 indicated that we will likely obtain an ex post estimate of the EUL that greatly exceed the ex ante.

If we make the assumption that the failure/removal rates provided in Exhibit 3-5 are constant over time, then our survival function would take on the exponential distribution, which is one of the most commonly used distributions in survival analysis. Assuming the failures/removals occurred over a 3.5-year period (measures have been in place for 3 to 4 years), we estimated the median EUL. Exhibit 3-6 provides the unweighted estimated EULs based on these assumptions for the combined dataset, for failures only, and for removals only. Exhibit 3-6 also examines the effect of the warranty on these initial estimates.

Exhibit 3-6
Illustrative Ex Post Unweighted EUL Estimates
Based on Exponential Distribution and Conservative Assumptions

Survey Type	Percent Failed, Removed, Replaced	Annualized Failure, Removal, Replacement Rate^	Mean Life*	Median Life*	Ex Ante EUL
Combined (No Warranty)	2.21%	0.63%	159	110	20
Combined (Warranty)	1.70%	0.49%	206	143	20
Failures (No Warranty)	0.68%	0.19%	515	357	20
Failures (Warranty)	0.17%	0.05%	2,062	1,429	20
Removals	1.53%	0.44%	229	159	20

^ Assuming a percentage of failed, removed, replaced occurs over 3.5 years.
* Assuming a constant failure rate over time.

Even based on the conservative assumption that warrantied equipment counts as a failure, the estimate of median life greatly exceeds the ex ante estimate of EUL.

3.5 VISUAL INSPECTION

For this step, we developed an empirical survival function that was observed from the raw retention data over the first three to four years of the measures' lives. This task was conducted separately for failures, removals, and the combined distribution.

To develop the empirical function, we calculated for each month the percentage of equipment that was in place and operable. Although this appears to be a straightforward calculation, there were two issues that arose:

- The dates associated with failures and removals were not always well populated.
- Not all customers were surveyed over the same length of time.

Missing Failure Dates

Three common terms used in classical survival analysis are "left-hand censoring", "right-hand censoring", and "interval censoring". Left-hand censoring means that it is known that a failure/removal has occurred, but it is unknown when the failure/removal occurred. It is only known that the failure/removal occurred before a certain date.

Right-hand censoring is more common in our data. Right-hand censoring means that at the last time the customer was surveyed, a failure/removal had not occurred, so the time when the equipment will fail or be removed is unknown.

Interval censoring, as the name implies, means that it is known that a failure/removal has occurred during a known interval. If no event has occurred, the interval is assumed to be right-hand censored.

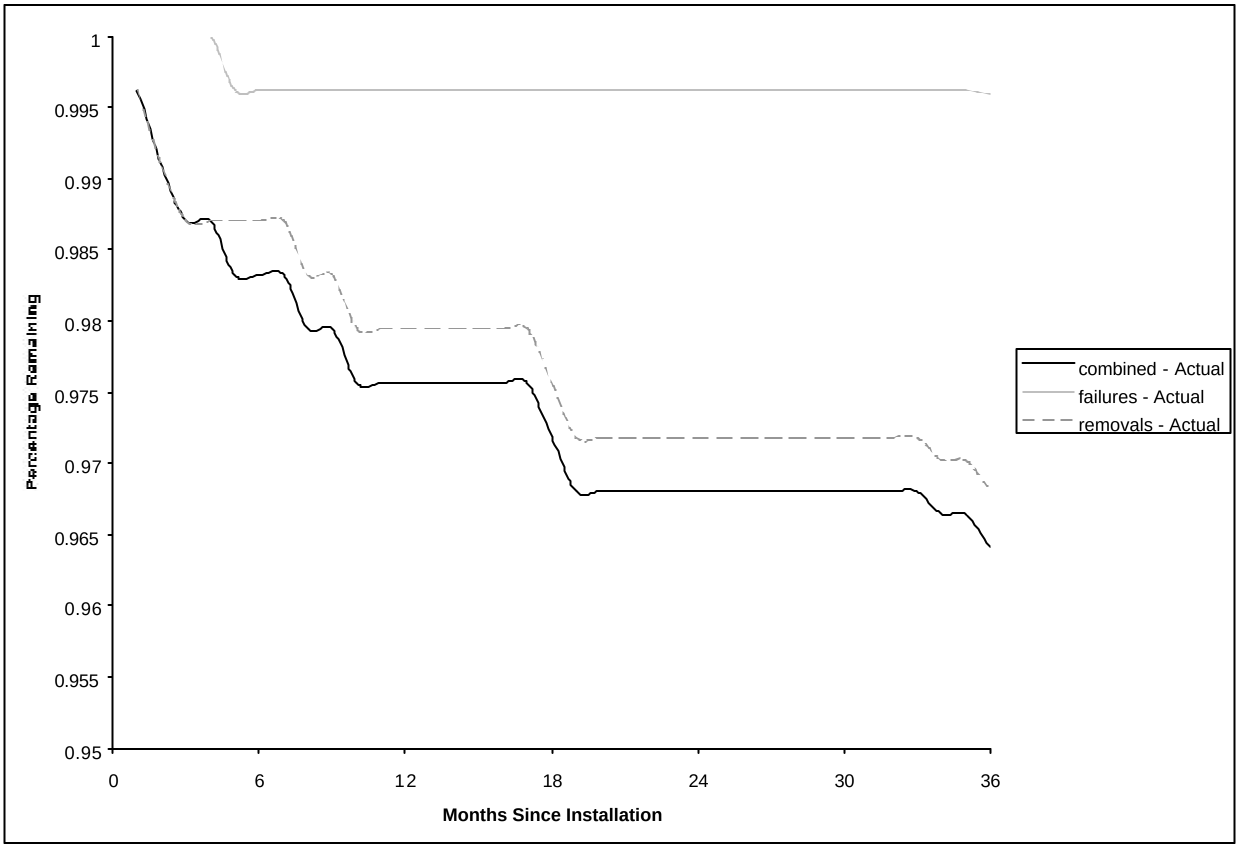
The SAS procedures that are discussed below in Section 3.7 are capable of handling right-hand censored data and in some cases left-hand and interval censored data. But for this more simplistic task, some assumptions were required.

Exhibit 3-7 presents the final empirical survival function developed for the combined dataset, failures only, and removals only. This survival function is based on the following assumptions:

1. For missing failure/removal dates, generate a random date (based on a uniform distribution) between the date the rebate check was issued and date the follow-up survey was conducted.

2. To estimate the percentage of equipment operable and in place in month M, do not include the equipment if the survey length is less than month M, regardless if a failure/removal occurred prior to month M.

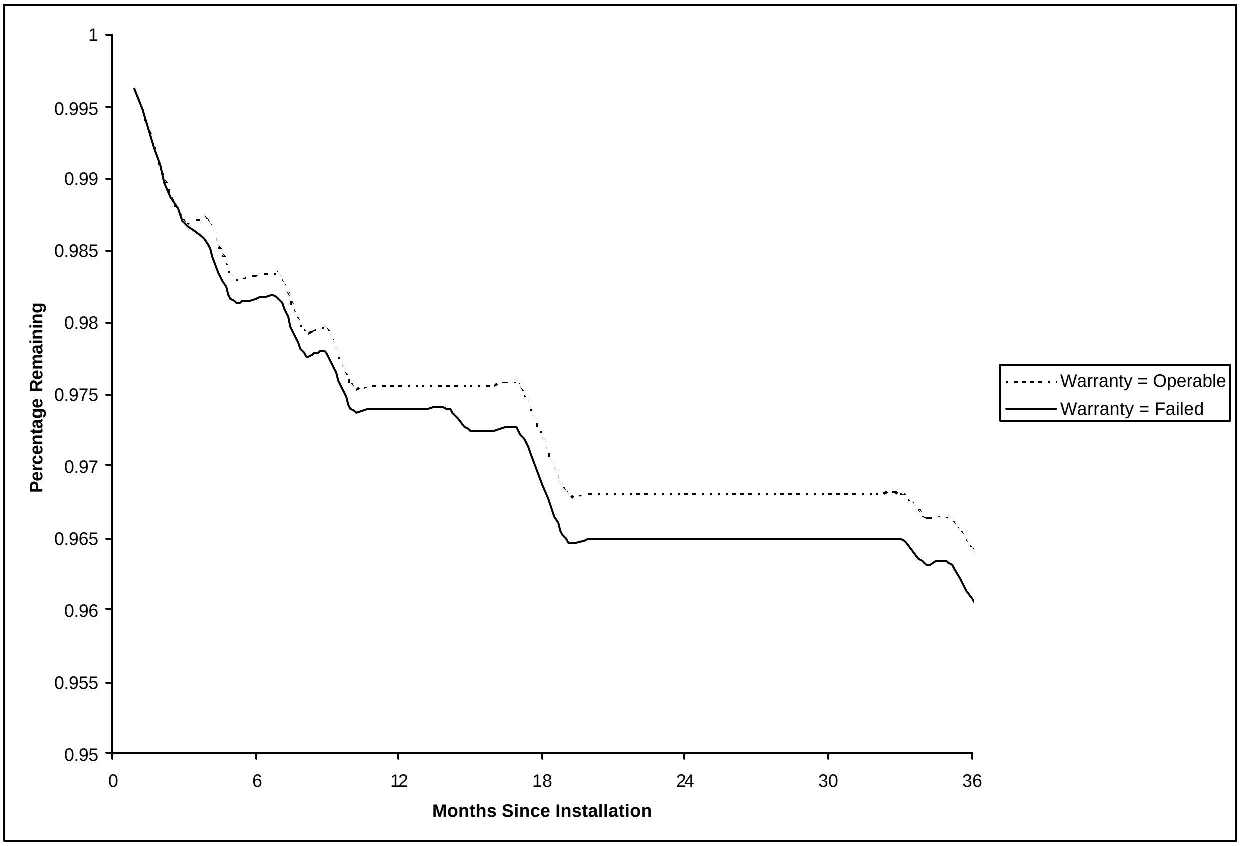
Exhibit 3-7
Final Empirical Survival Function



Because of assumption 2 above, the empirical data was limited to 36 months. Beyond 36 months, the survival function has several periods of increasing values over time due to the sharp decrease in the number of points available for analysis. The most significant feature of Exhibit 3-7 is the overwhelming effect on the combined empirical survival function of the removals as opposed to the failures. In fact, there is only one failure over the study period (after accounting for warrantied equipment).

One other interesting issue is that of warrantied equipment. As stated above, failed equipment that is replaced under warranty counts as if it is still operable and in place. Survey results show that 75 percent of the failed equipment was replaced under warranty. Exhibit 3-8 compares how the empirical survival function would change if warrantied equipment did not count as operable and in place.

Exhibit 3-8
Sensitivity to Warranty



3.6 TREND LINES

Based on the empirical survival functions presented above, trend lines were developed to estimate the survival functions over the life of the measure, and estimate the measure's EUL. As discussed above, only the first 36 months of the empirical survival functions were used. This was done for the combined, failure, and removal datasets.

Two trend lines were estimated using linear regression:

- The first trend line was assumed to have a linear relationship over time. Therefore, the trend line was developed using a linear regression with the percentage of equipment operable and in place as the dependent variable, and the month as the independent variable.

- The second trend line was assumed to follow the exponential distribution, which is one of the most common distributions used in survival analysis. The trend line was also used with linear regression by making a transformation on the percentage of equipment operable and in place. The natural log of the percentage of equipment operable and in place was used as the dependent variable, and the month as the independent variable.

The results of these analyses are provided below.

Linear Trends

Exhibits 3-9 and 3-10 provide the linear survival functions for the "failures only" and "removals only" datasets and compares them to the empirical survival functions developed above.

Exhibit 3-9
Comparison of Empirical Survival Function and Linear Trendline
Failure Dataset

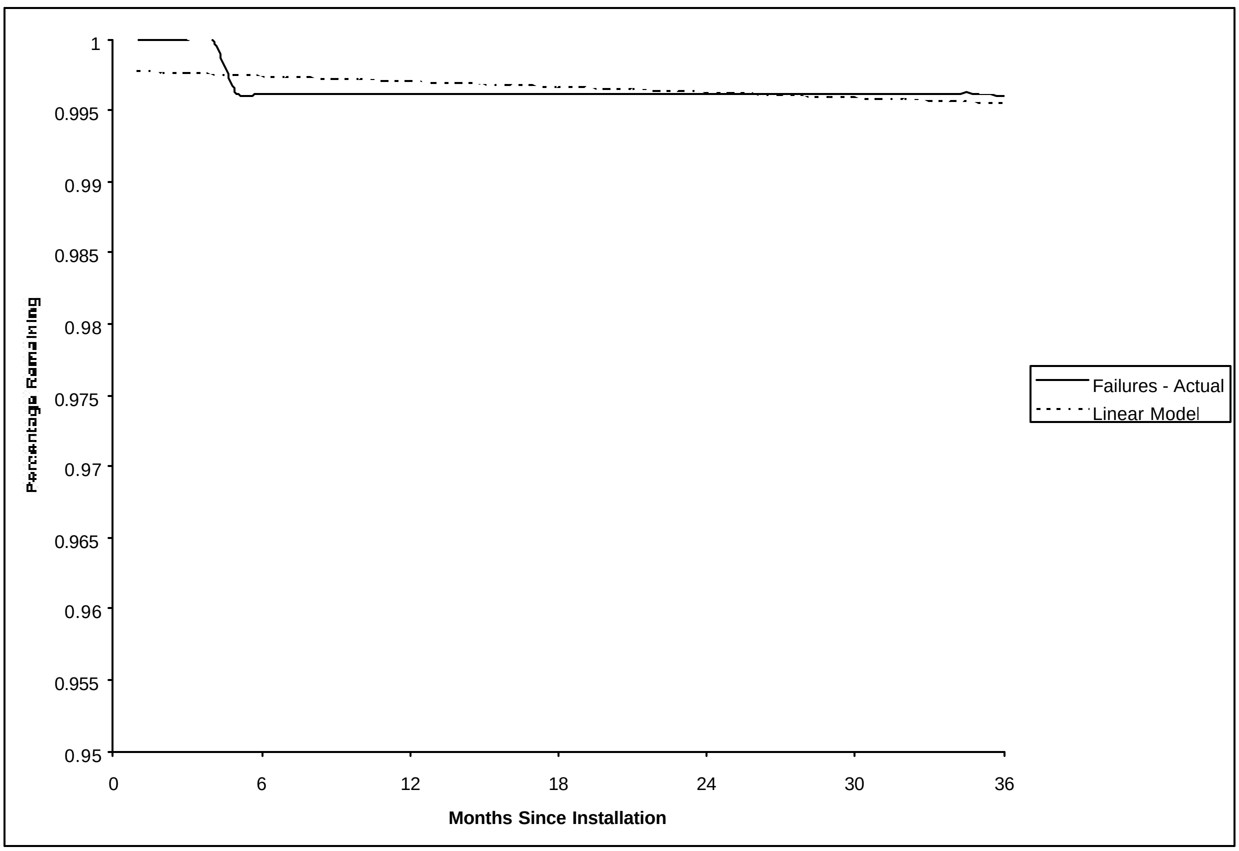


Exhibit 3-10
Comparison of Empirical Survival Function and Linear Trendline
Removals Dataset

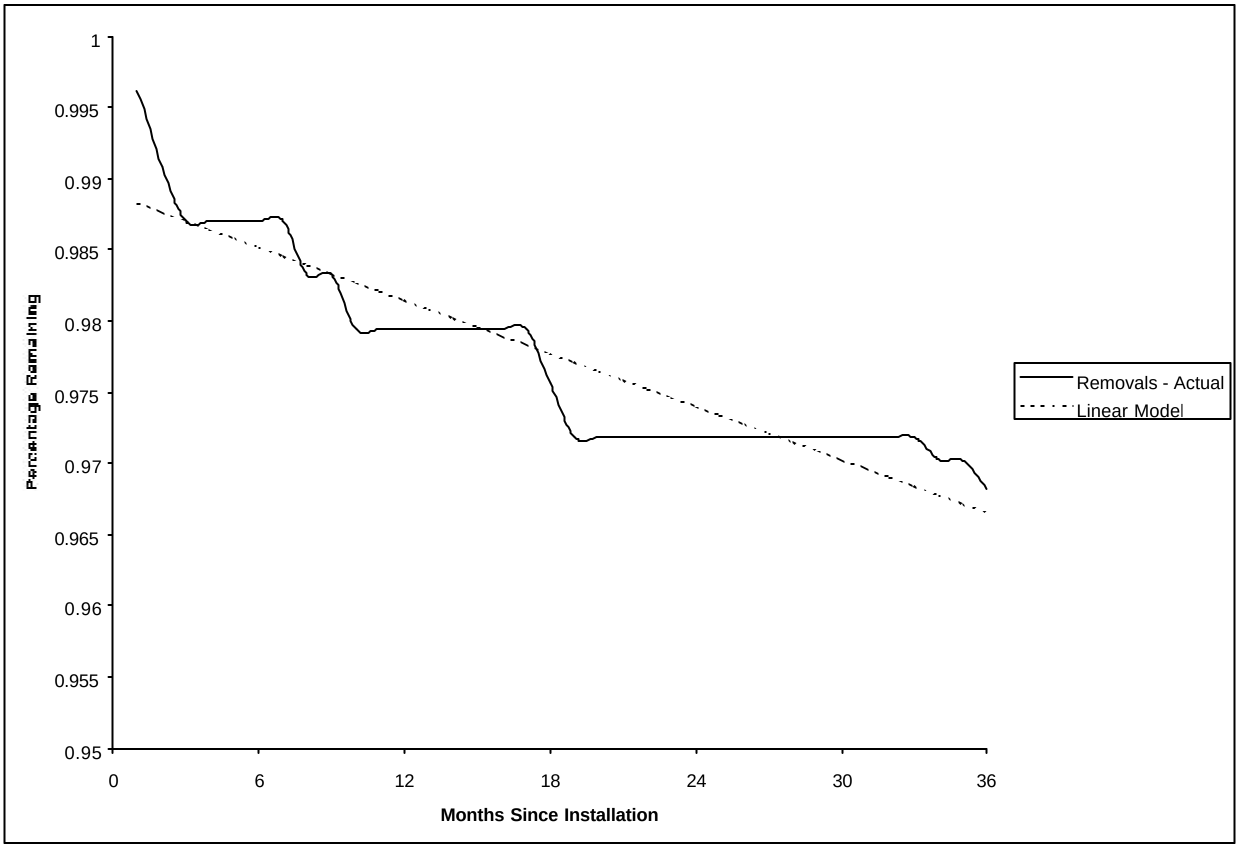
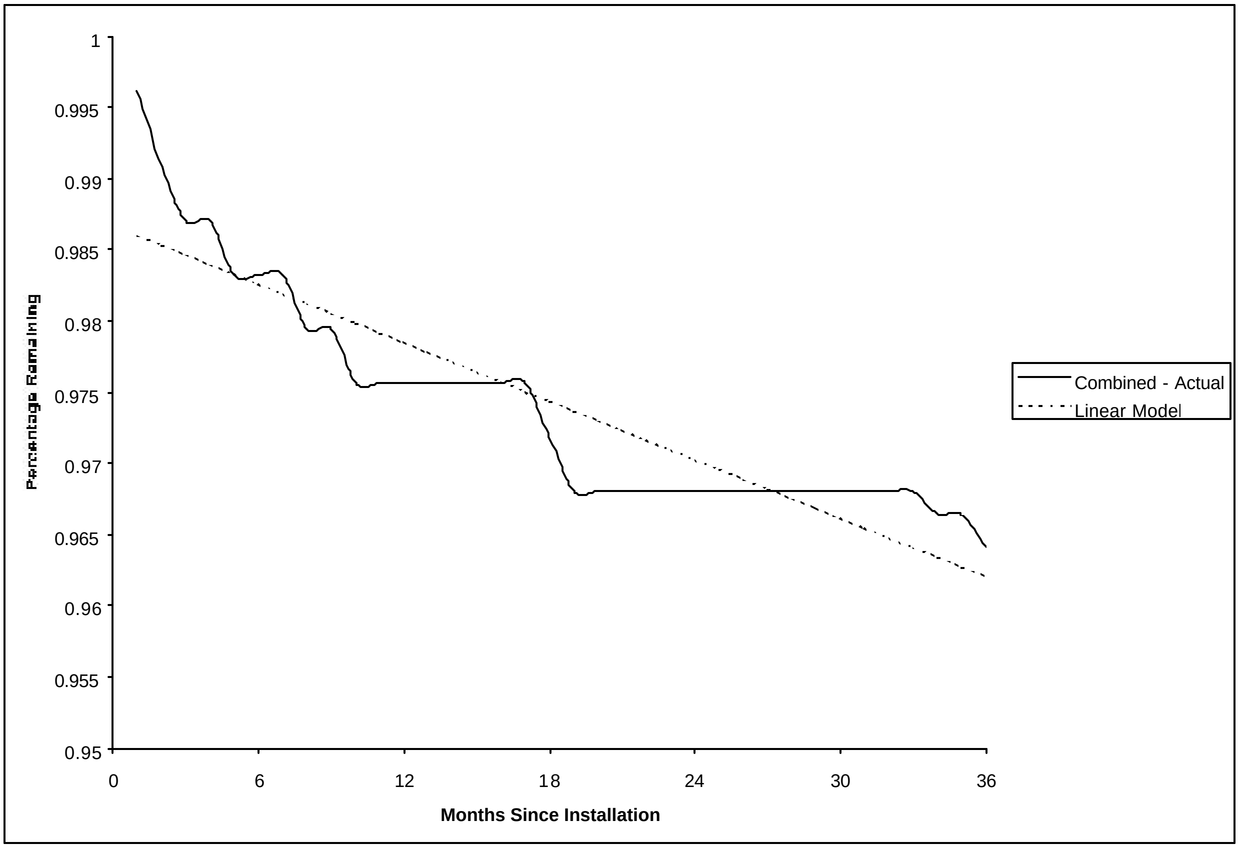


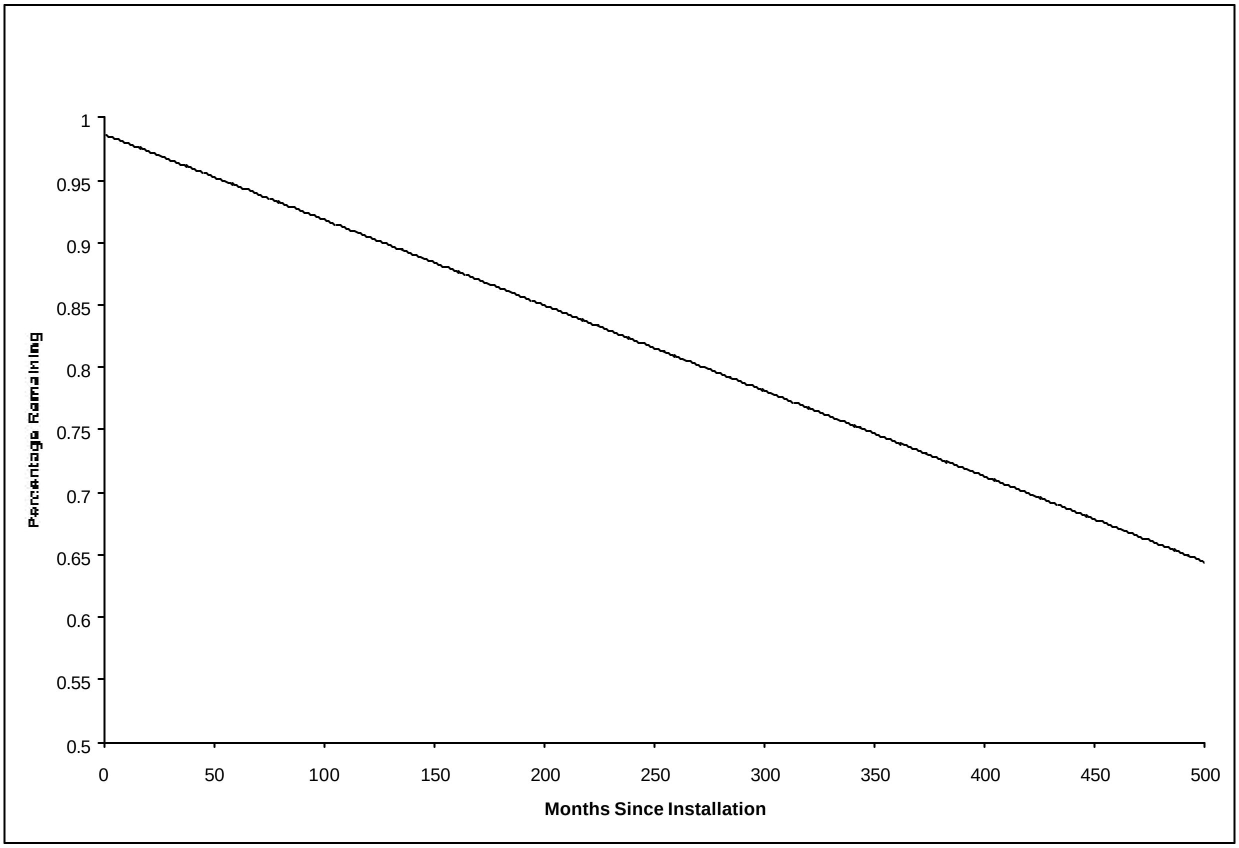
Exhibit 3-11 provides the resulting survival function assuming a linear trend for the combined dataset and compares it with the empirical function developed above, for the first 36 months of the measure's life.

Exhibit 3-11
Comparison of Empirical Survival Function and Linear Trendline
Combined Dataset



This exhibit illustrates how well the linear trend compares to the empirical function during the earlier parts of the measure's life. Exhibit 3-12 examines the linear model as it forecasts the survival function over the first 500 months of the refrigerator's life.

Exhibit 3-12
Survival Function Based on a Linear Trendline
Combined Dataset



Even after 500 months (over 40 years), the model predicts that 64% of the refrigerators are still in place and operable. This scenario is highly unlikely, suggesting that the distribution does not follow a linear path but instead has a changing rate of failure or removal. A linear distribution indicates that a constant number of failures or removals occur during each period, regardless of the number of units remaining, or the life of the remaining units. This property is highly unlikely, and would suggest that the rate of failure rapidly increases over time, which is very conservative.[3] Results from more statistically valid methodologies, discussed later in this section, will further illustrate why the linear function is not appropriate. However, because of the conservative nature of this distribution, these results do help to illustrate that the timeframe over which this study was conducted was insufficient to provide reliable estimates of the EUL, as the estimated EUL is still significantly larger than the ex ante, as shown in Exhibit 3-13.

[3] Consider a linear distribution where we start with 100 units and 10 of the units fail in each year. In year one, the failure rate would be 10% (10 of the 100). In year two, the failure rate would be 11% (10 of the remaining 90). This would increase up to 100% in year 10, when the remaining 10 units would all fail.

It is also interesting to note the obvious difference in slope that the failure and removal datasets produce. The results of the linear regressions are provided in Exhibit 3-13 for each of the three methods. Also provided in Exhibit 3-13 is the estimated EUL for each measure. For a linear survival function, the EUL (median life) is calculated as:

EUL = (0.5 – intercept) / slope

Exhibit 3-13
Regression Results of Linear Trendline
and Resulting Ex Post EUL Estimates

Model Description	Intercept	t-Statistic	Slope	t-Statistic	EUL
Failures Only	1.00	2,861	-0.0001	-3.88	651
Removals Only	0.99	1,065	-0.0006	-14.20	66
Combined Model	0.99	871	-0.0007	-12.82	59

Clearly, the results of the linear trendline estimate indicate that the ex post EUL estimate is significantly larger than the ex ante estimates (which are all 20 years). Each of these results would easily reject the ex ante estimate at the 80 percent confidence level.

Exponential Trends

Exhibit 3-14 and 3-15 provide the resulting survival functions assuming an exponential trend for the failure and removal datasets and compares them to the empirical functions developed above, for the first 36 months of the measure's life.

Exhibit 3-14
Comparison of Empirical Survival Function and Exponential Trendline
Failure Dataset

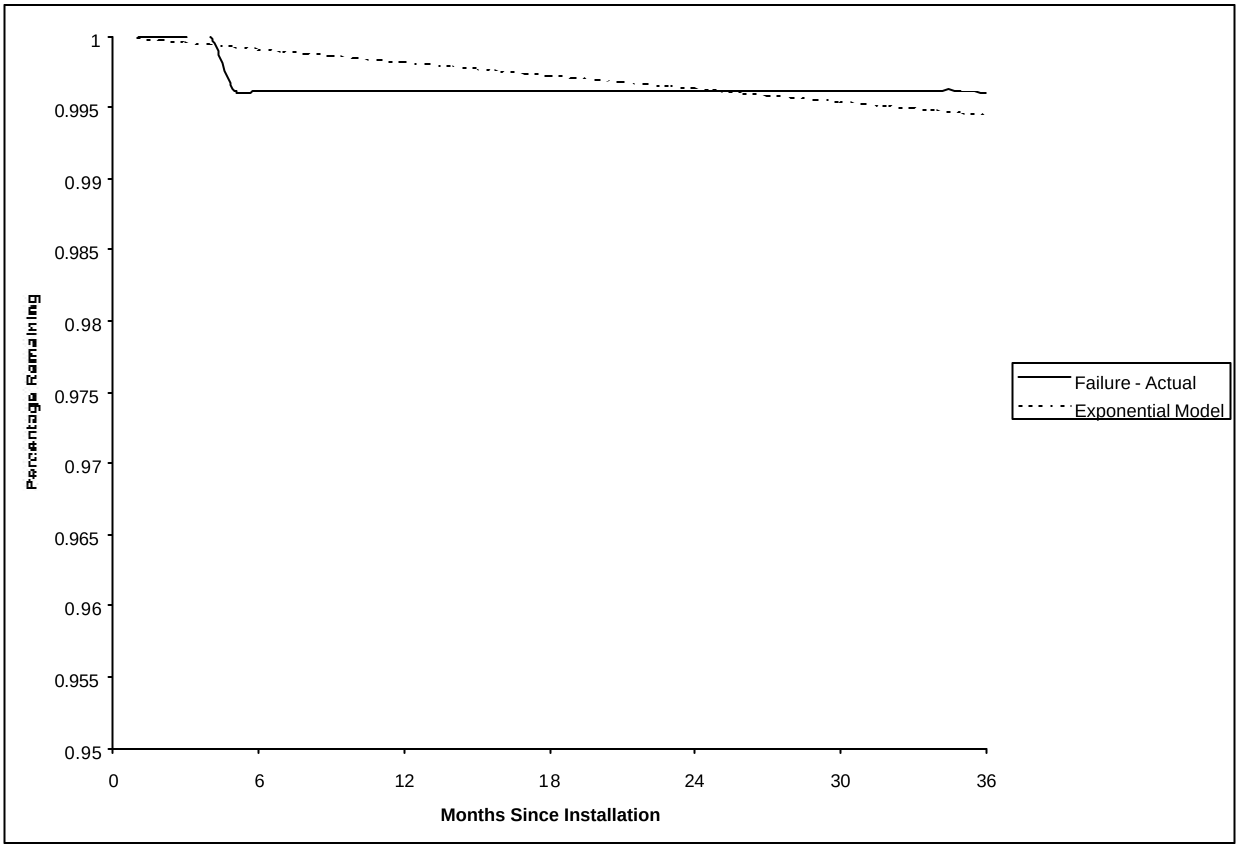
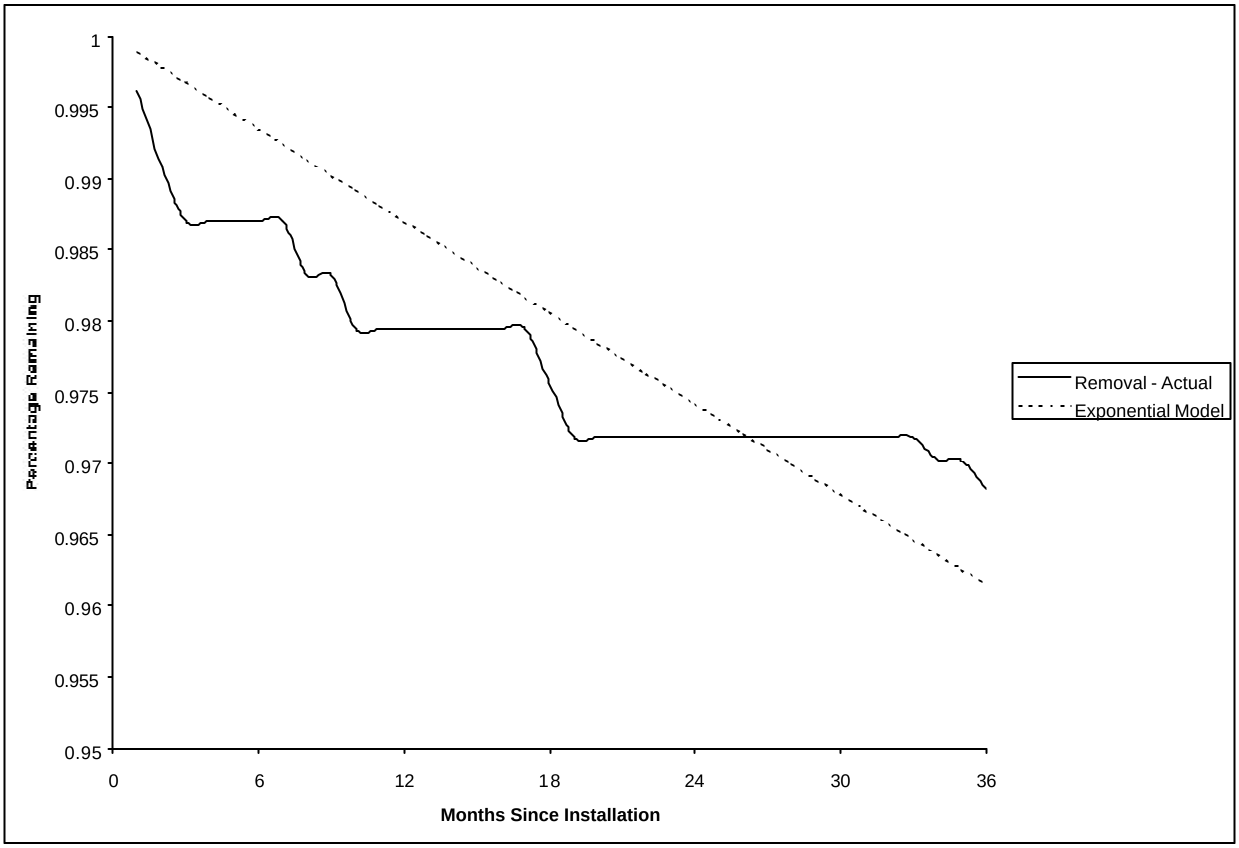


Exhibit 3-15
Comparison of Empirical Survival Function and Exponential Trendline
Removal Dataset



Similarly, Exhibit 3-16 provides the exponential survival function, and compares it to the empirical survival function for the combined dataset. This exhibit illustrates how well the exponential trend compares to the empirical function during the earlier parts of the measure's life.

Exhibit 3-16
Comparison of Empirical Survival Function and Exponential Trendline
Combined Dataset

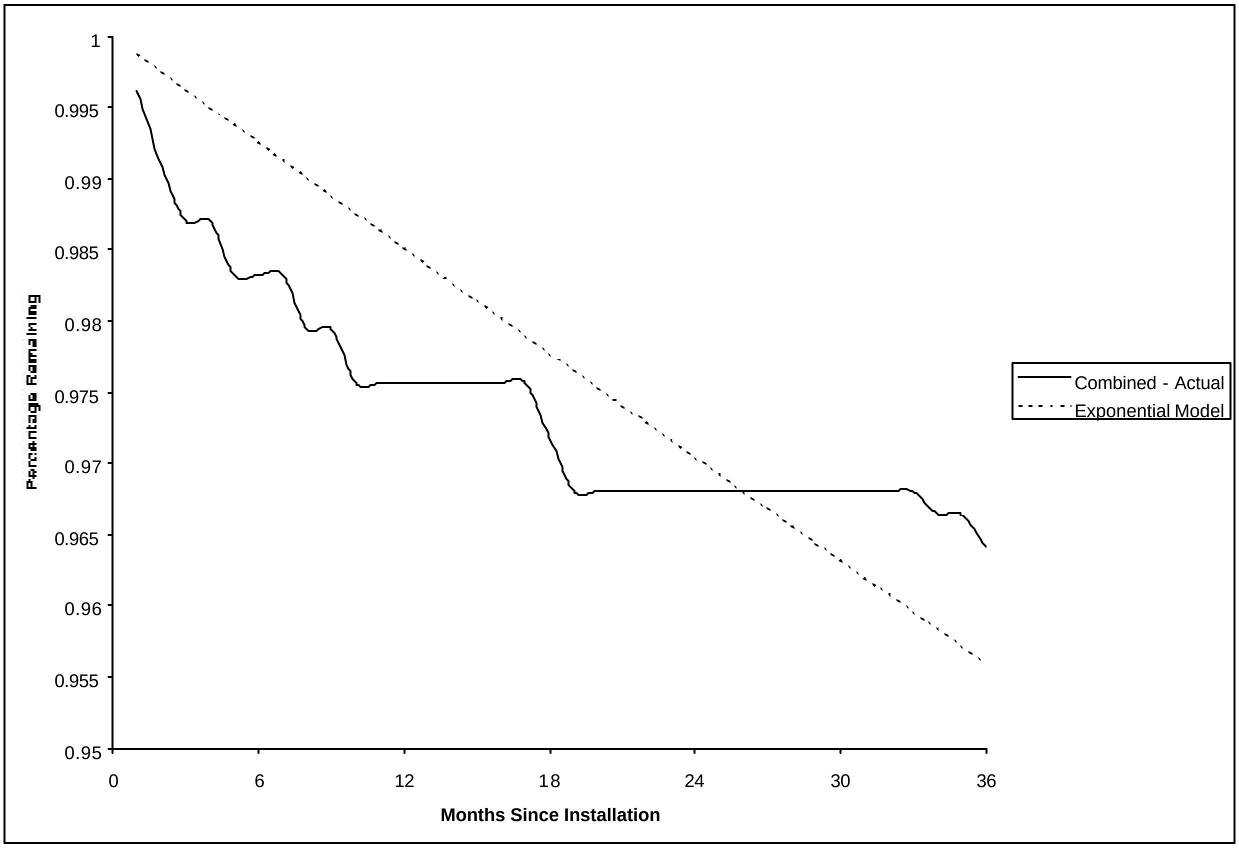
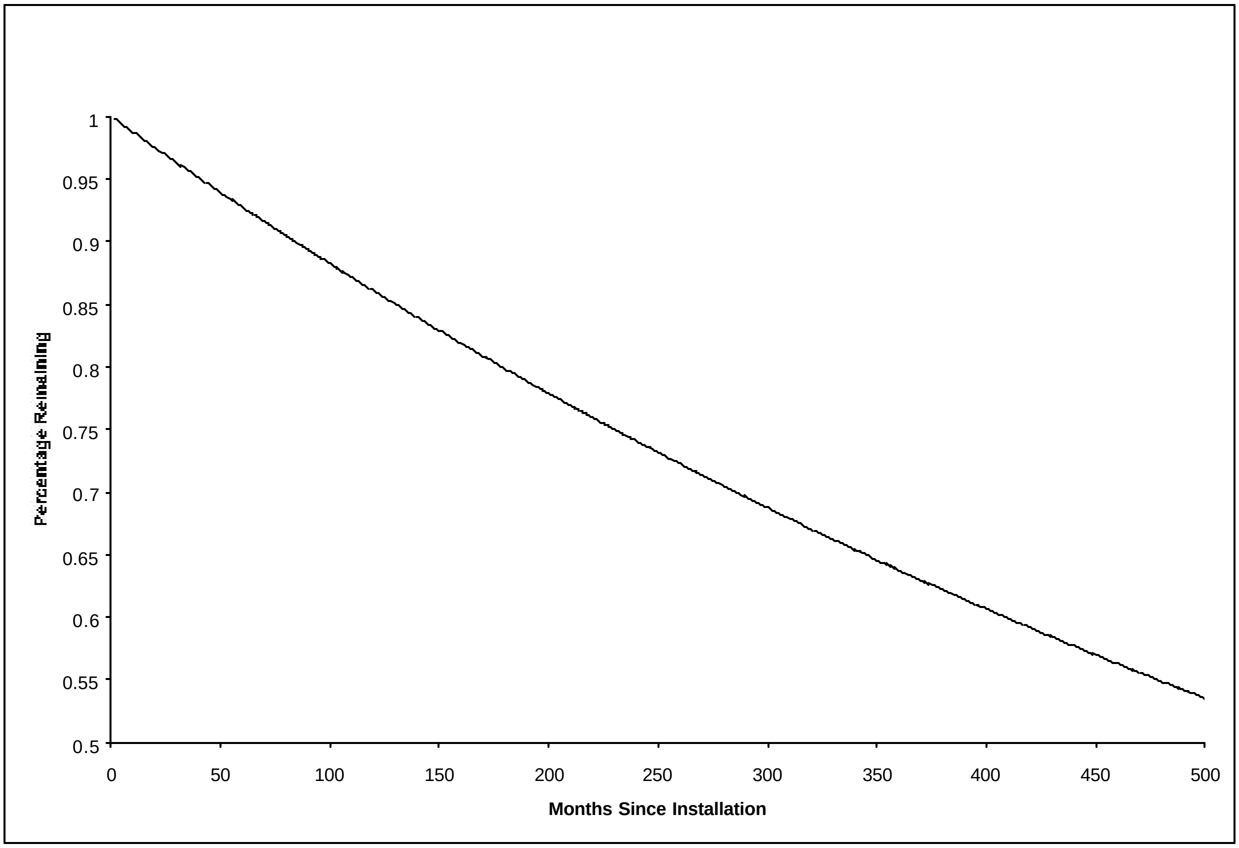


Exhibit 3-17 provides the resulting survival function assuming an exponential trend for the combined dataset over 500 months. Referring back to the linear model for the removal datasets (Exhibit 3-12), the differences between the two approaches are more apparent. Due to the constant hazard rate of the exponential model, the curve will flatten out over time, asymptotically approaching zero. The linear model, however, will continue with the same slope until no refrigerators remain.

Exhibit 3-17
Survival Function Based on an Exponential Trendline
Combined Dataset



The results of the exponential regressions are provided in Exhibit 3-18 for each of the three models. Also provided in Exhibit 3-18 is the estimated EUL for each model. For an exponential survival function, the EUL (median life) is calculated as:

$$EUL = \ln(2) / slope$$

Exhibit 3-18
Regression Results of Exponential Trendline
and Resulting Ex Post EUL Estimates

Model Description	Slope	t-Statistic	EUL
Failures Only	0.0002	13.19	374
Removals Only	0.0011	22.52	53
Combined Model	0.0013	21.42	46

The results of the exponential trendline estimates are slightly less than for the linear trendline estimates. Again, these results clearly indicate that the ex post EUL estimate is significantly larger than the ex ante estimates (which are all 20 years). Each of these results would easily reject the ex ante estimate at the 80 percent confidence level.

The exponential distribution has some important assumptions that should be addressed. Most importantly, the exponential distribution assumes a constant hazard rate. Although this distribution works well to explain certain data, this assumption is not believed to be valid for refrigerators. If this were the case, then study results indicate that energy efficient refrigerators purchased without the program and the removal restrictions of utility service territory would have an EUL of 374 years.

As we will discuss in more detail in Section 4, this approach is not recommended for the final study results. In addition to the concern of the exponential distribution having properties that are not in line with our expectations, developing a trend line on empirical data in this manner is not optimal. The empirical data is interval and right hand censored, meaning that for some failures/removals, the time of the event is unknown; and it is also unknown when currently operating equipment may fail. This trendline approach does not statistically correct for censored data in the way that classical survival analysis approaches do, as discussed in the following section.

3.7 CLASSICAL SURVIVAL ANALYSIS

This step in our approach is founded on applying classical survival analysis techniques to the retention data in order to develop a survival function. Using the SAS System and the SAS companion guide, "Survival Analysis Using the SAS System," we have modeled the survival function assuming five of the most common survival distributions: exponential, logistic, lognormal, Weibull and gamma. In each case, we have plotted the resulting distribution and visually compared it to the empirical functions developed above. Furthermore, we have used the resulting survival function to estimate the EUL.

Some of the same issues we faced when developing the empirical survival function need to be addressed here as well. The problem of right-hand censoring is not an issue for SAS. The LIFEREG procedure, which we used for all of our modeling in this step, is capable of handling right-hand censored data.

SAS is also capable of handling left-hand censored data. In fact, our retention data is actually not left-hand censored, but interval censored. The true definition of left-hand censoring is that we know that an event occurred earlier than some time t, but we don't know exactly when. Interval censoring occurs when the time of failure occurrence is known to be somewhere between two times, but we don't know exactly when. Left censoring can be seen as a special case of interval censoring.

Although the LIFEREG procedure is capable of handling both left and interval censoring, interval censored data is more predictive than left hand censoring. Another commonly used survival analysis procedure in SAS is PHREG. Unfortunately, this procedure cannot handle either left or interval censored data. Therefore, we only conducted our analysis using the LIFEREG procedure.

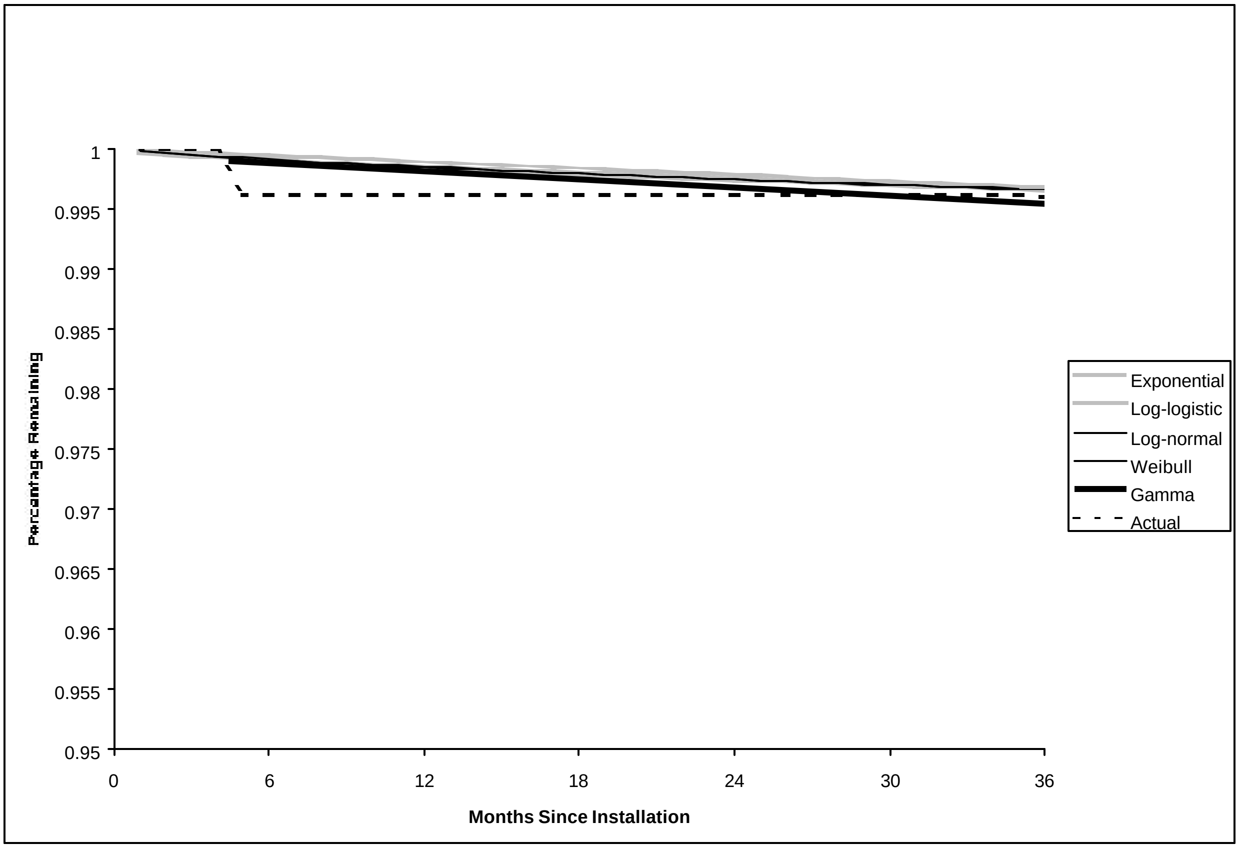
Another important feature of the LIFEREG procedure is the use of covariates. This feature enabled us to use other predictive variables to help estimate the survival functions. Several covariates were tested for correlation, including owning vs. renting a home, dwelling type, and whether a kitchen remodel had occurred. None of the covariates tested proved to be statistically significant. Therefore, we did not use covariates in the final models.

As discussed above, the LIFEREG procedure was used to model the survival function for the rebated refrigerators. Exhibits 3-19 through 3-22 present comparisons of various modeling techniques for the failures only dataset, the removals only dataset, and the combined dataset. This level of detail is shown to develop an understanding of the differences among event types.

Failure Dataset

Exhibit 3-19 provides the survival functions based on the exponential, logistic, lognormal, Weibull and gamma distributions, estimated for the failure dataset using the LIFEREG procedure and compares these five survival functions with the empirical survival function, over the first 36 months of the measure's life.

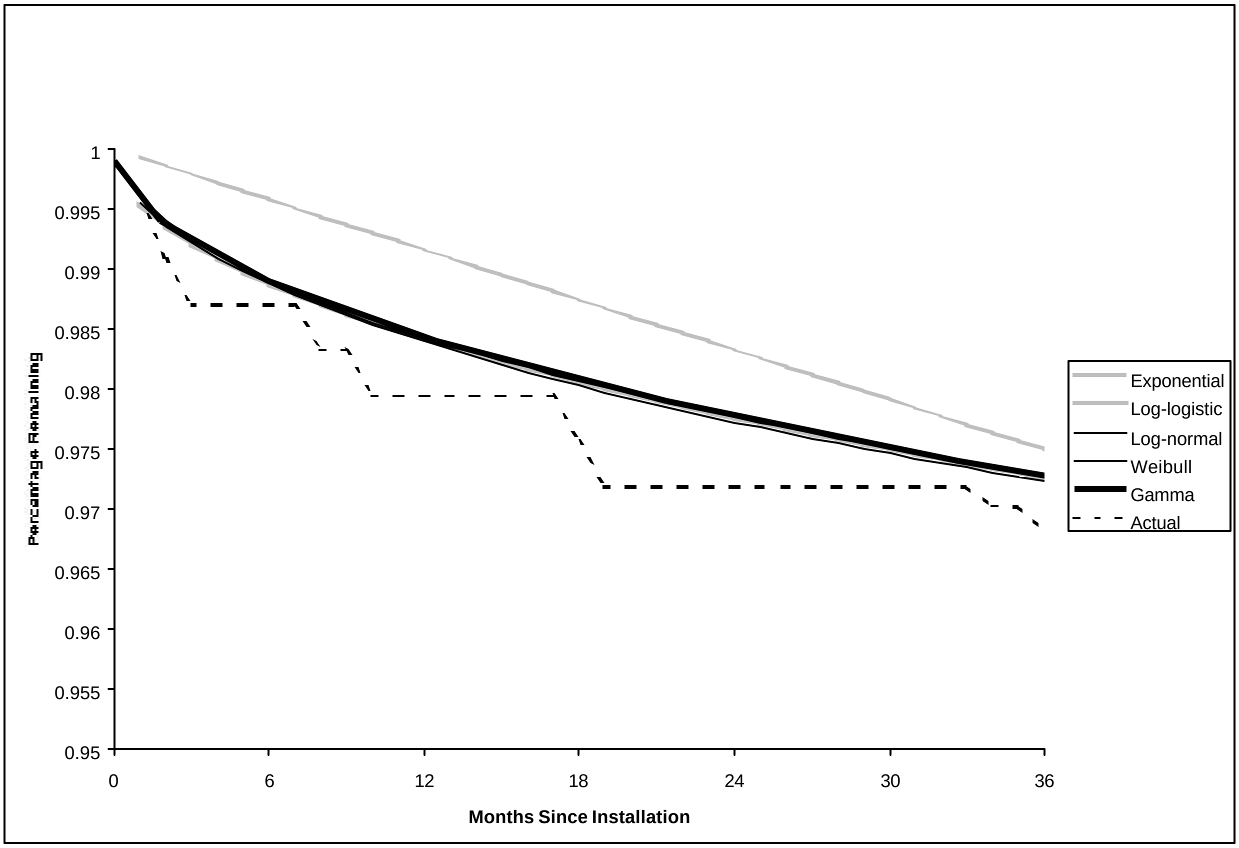
Exhibit 3-19
Comparison of Survival Functions
Exponential, Logistic, Lognormal, Weibull and Gamma versus Empirical Function
Failure Dataset



Removal Dataset

Exhibit 3-20 provides the survival functions based on the exponential, logistic, lognormal, Weibull and gamma distributions, estimated for the removal dataset using the LIFEREG procedure and compares these five survival functions with the empirical survival function, over the first 36 months of the measure's life.

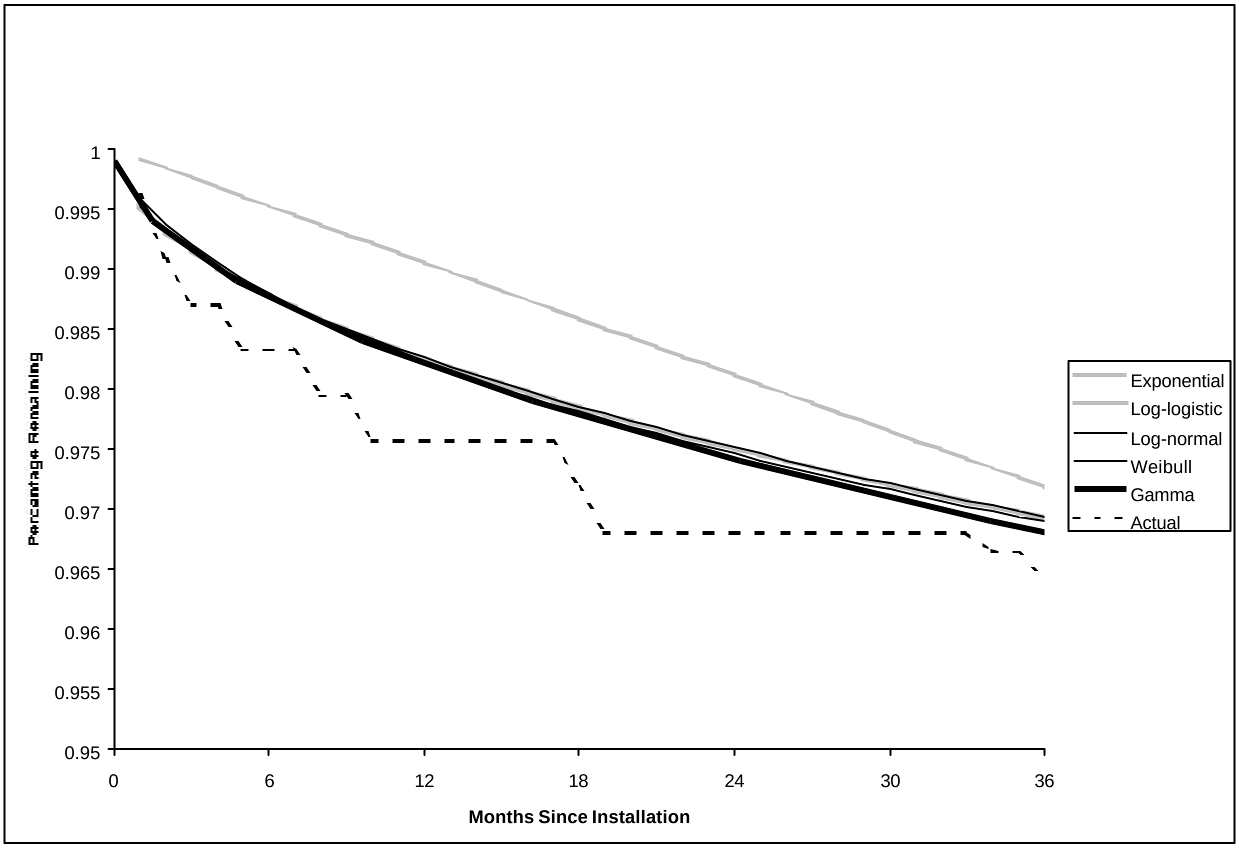
Exhibit 3-20
Comparison of Survival Functions
Exponential, Logistic, Lognormal, Weibull and Gamma versus Empirical Function
Removal Dataset



Combined Dataset

Exhibit 3-21 provides the survival functions based on the exponential, logistic, lognormal, Weibull and gamma distributions, estimated for the combined dataset using the LIFEREG procedure and compares these five survival functions with the empirical survival function, over the first 36 months of the measure's life.

Exhibit 3-21
Comparison of Survival Functions
Exponential, Logistic, Lognormal, Weibull and Gamma versus Empirical Function
Combined Dataset



As evidenced by the previous three exhibits, the models all tend to over-estimate the percentage of remaining equipment over the first 36 months. Exhibit 3-22 extends the models produced in LIFEREG to 500 months to examine how the distributions differ over time.

Exhibit 3-22
Exponential, Logistic, Lognormal, Weibull and Gamma Survival Functions
Based on LIFEREG Procedure
Combined Dataset

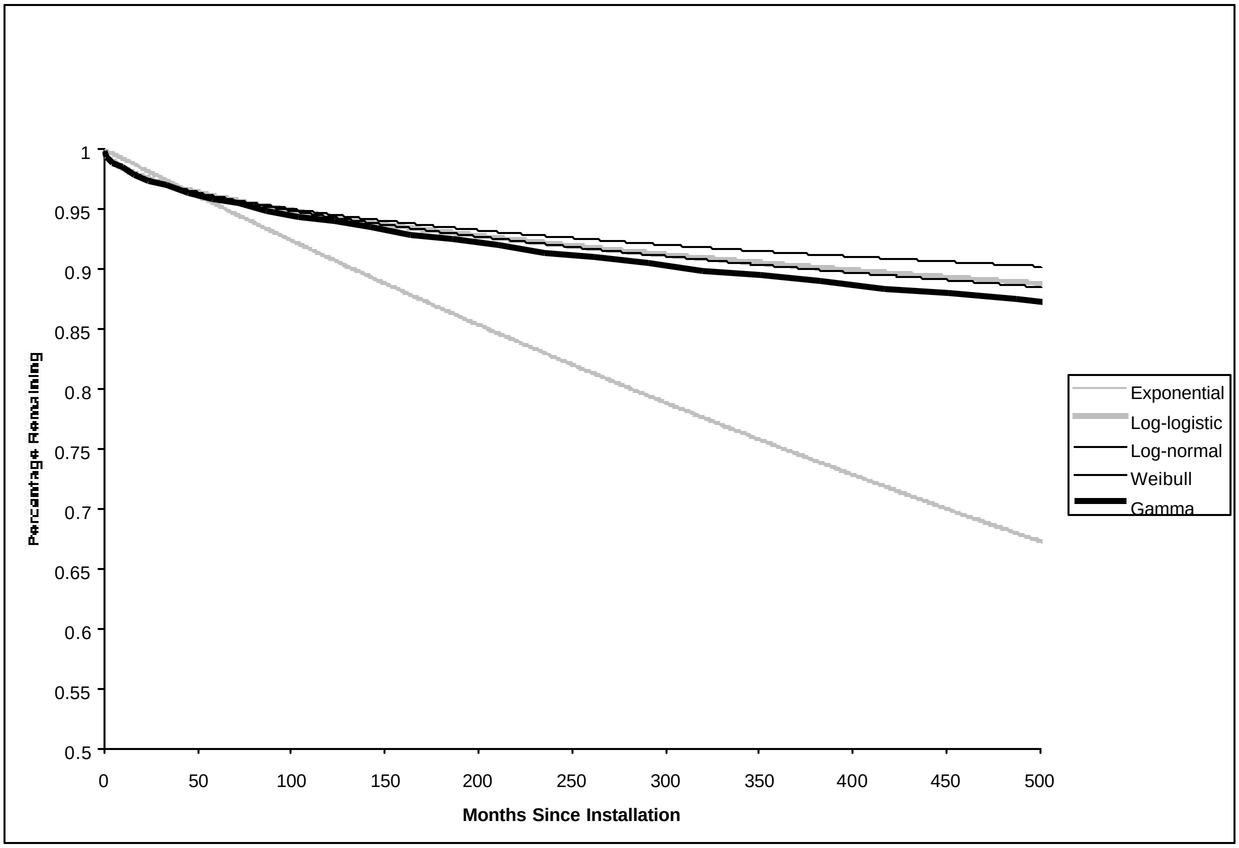


Exhibit 3-22 illustrates how the LIFEREG procedure models the survival function, forecasting out over time. It is likely that the model interprets the empirical data as beginning to "level off", by having a decreasing hazard rate. This interpretation leads the model to forecast somewhat of an asymptotic curve over time for the distributions that are capable of modeling a decreasing hazard rate. This is true for all of the modeled distributions, except for the exponential distribution, which has the property of having a constant hazard rate. That is why we see the exponential distribution deviate from the others: it has a constant hazard rate, while the others are modeled as having decreasing hazard rates over time, as seen in the empirical data.

It is also worth noting that of the five distributions modeled, the gamma distribution is the most adaptive. The LIFEREG procedure models the generalized gamma distribution, which has three parameters. Because this model has at least one more parameter than any of the other distributions, it can take on a wide variety of shapes. In addition, the exponential, Weibull and log-normal distributions are all special cases of the generalized gamma model. But the generalized gamma model can also take on shapes that are unlike any of these special cases. Most importantly, it can have hazard functions with U or bathtub shapes, in which the failure rate (or hazard function) declines, reaches a minimum, and then increases.

Exhibit 3-23 below summarizes the results of the LIFEREG models for the rebated refrigerators. Shown for each model are the parameter estimates and standard errors for every variable included in the model specification. Furthermore, the resulting EUL and its associated standard error are provided.

Exhibit 3-23
Comparison of Survival Model Results
Exponential, Logistic, Lognormal, Weibull and Gamma Models

			Variable		Resulting
Measure	**Model**		**Intercept**	**Scale**	**EUL**
Combined	Exponential	Parameter Estimate	7.14	1.00	**73**
		Standard Error	0.44	0.00	32
	Logistic	Parameter Estimate	10.14	1.90	**2,121**
		Standard Error	2.93	0.83	6,222
	Log-Normal	Parameter Estimate	12.17	4.60	**16,040**
		Standard Error	3.66	1.86	58,649
	Weibull	Parameter Estimate	10.25	1.92	**1,168**
		Standard Error	2.98	0.85	3,483
	Gamma	Estimate	9.91	0.82	**562**
		Standard Error	15.08	43.77	8,480
Failures	Exponential	Parameter Estimate	9.32	1.00	**73**
		Standard Error	1.32	0.00	96
	Logistic	Parameter Estimate	11.44	1.38	**7,772**
		Standard Error	10.37	1.84	80,598
	Log-Normal	Parameter Estimate	14.85	4.17	**235,177**
		Standard Error	14.41	5.30	3,389,004
	Weibull	Parameter Estimate	11.46	1.39	**4,745**
		Standard Error	10.39	1.84	49,320
	Gamma	Estimate	11.05	0.70	**1,592**
		Standard Error	10.40	27.93	16,565
Removals	Exponential	Parameter Estimate	7.26	1.00	**82**
		Standard Error	0.47	0.00	39
	Logistic	Parameter Estimate	10.61	1.97	**3,390**
		Standard Error	3.33	0.91	11,290
	Log-Normal	Parameter Estimate	12.86	4.84	**32,158**
		Standard Error	4.18	2.08	134,561
	Weibull	Parameter Estimate	10.71	1.99	**1,809**
		Standard Error	3.38	0.93	6,112
	Gamma	Estimate	10.42	1.62	**1,415**
		Standard Error	3.23	0.75	4,570

Although we feel that the results using the LIFEREG procedure are superior to those based on the trendlines, we do not recommend using this approach for our final results, as will be discussed in more detail in Section 4. The primary reason for this is that the combined LIFEREG model is incapable of differentiating between failures and removals. As we have discussed, we believe that the distributions for failures and removals are inherently different. Therefore, we have developed competing risks models, discussed in the following section, which are designed to allow for multiple "failure" events and integrate multiple survival distributions into a single function.

3.8 COMPETING RISKS MODEL

The final analysis step, as described in Section 3.3 above, was to develop competing risks models to account for multiple events influencing the survival distribution. The first task in developing competing risk models was to calculate hazard functions for all events. The hazard rate at each time step is simply the derivative of the survival function, or the number of events occurring over that time step divided by the remaining population at that time.

The next task is to create the competing risk model. This is accomplished by combining hazard rates from both failures and removals into one joint probability function.

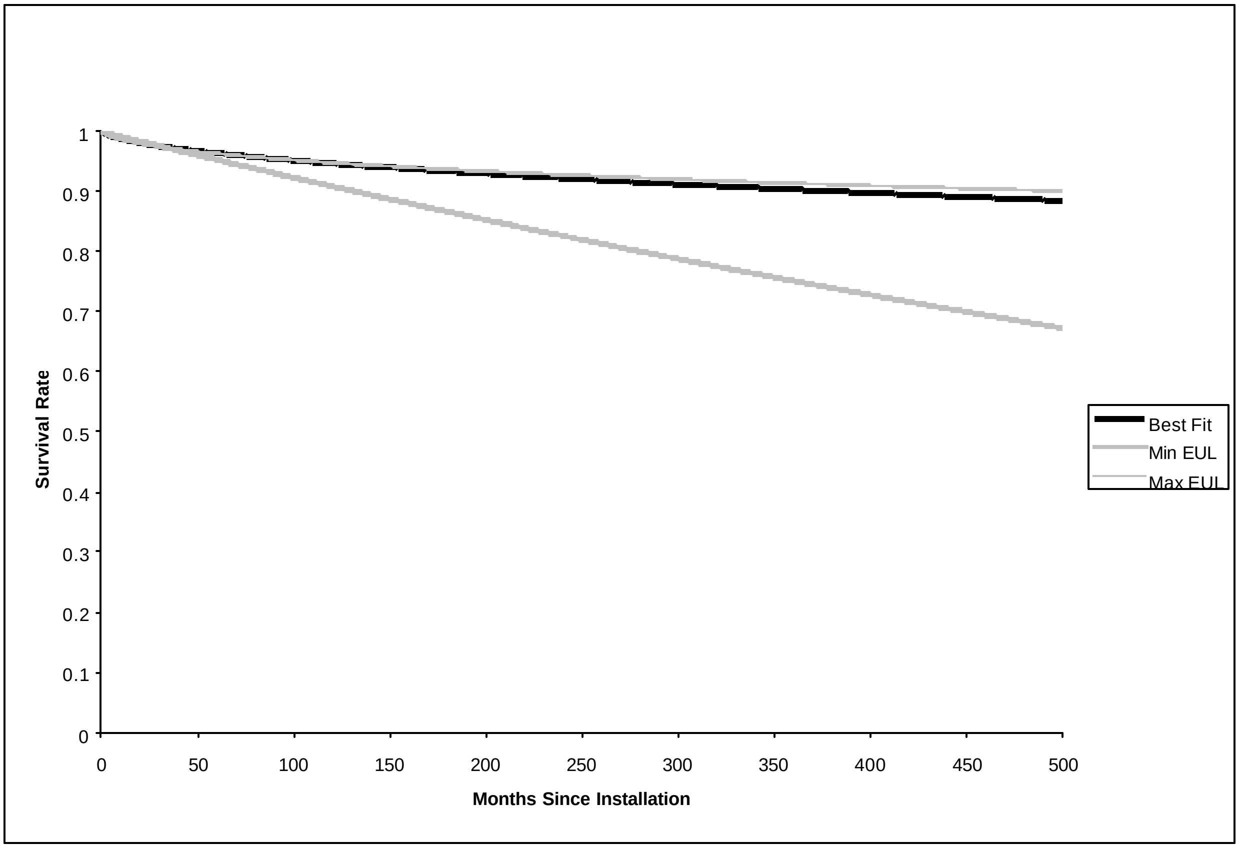
Three different sets of output were generated from this model. The first output contains the best-fitting distribution for each event based on the log-likelihood estimate, which is a parameter output by SAS used to judge how well the model fits the actual data. The second output provides the minimum EUL estimate, and the third output provides the maximum EUL estimate. A summary of the different distributions that were chosen for each of the models is presented in Exhibit 3-24.

Exhibit 3-24
Comparison of Distributions used in the Competing Risks Model

Model Description	Failure Distribution	Removal Distribution
Best Fit	Log-logistic	Weibull
Minimum EUL	Exponential	Exponential
Maximum EUL	Log-normal	Log-normal

The resulting survival functions are provided in Exhibit 3-25. For the best fitting model, the log-logistic distribution was used for failures, and the Weibull distribution was used for removals. The minimum EUL was based on the exponential distribution for both failures and removals. The maximum EUL was created using the log-normal distribution for both failures and removals.

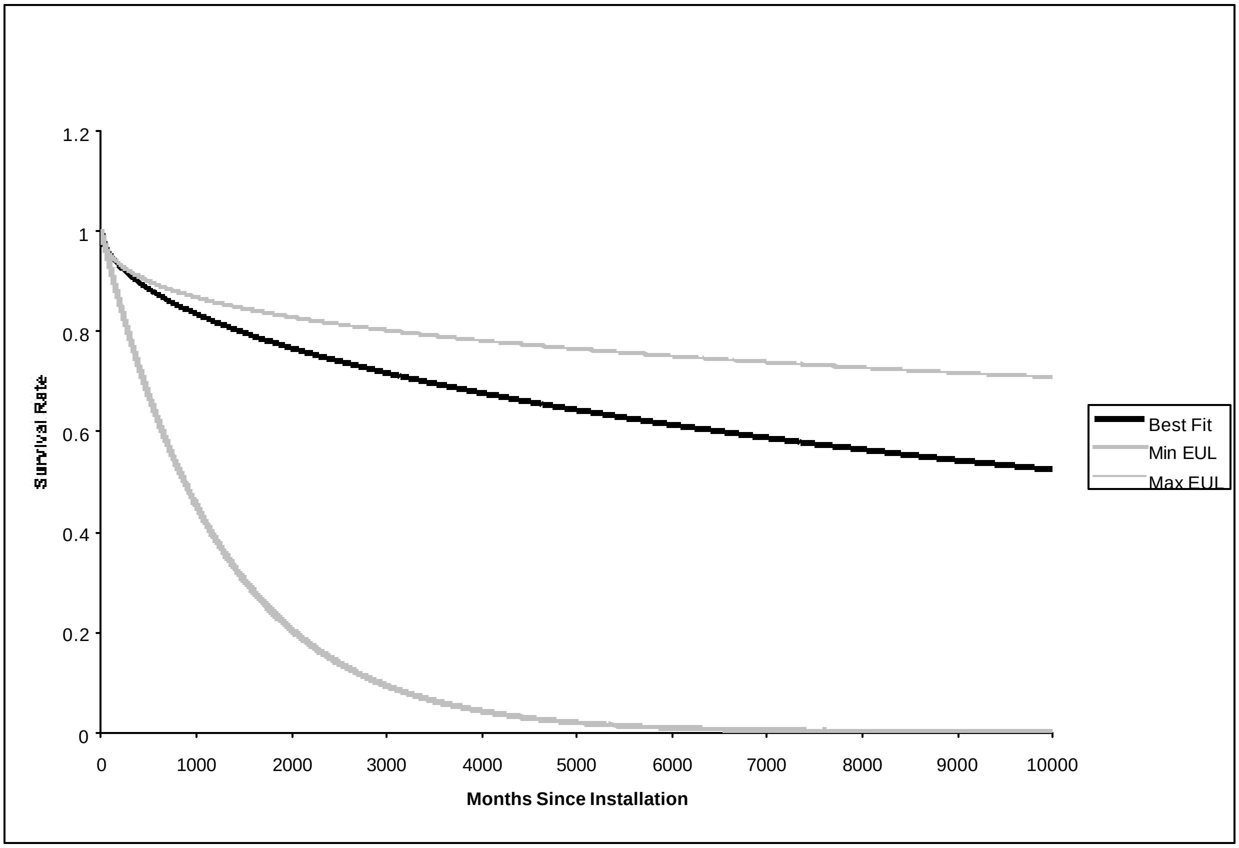
Exhibit 3-25
Comparison of Survival Functions from Competing Risk Model
Using Rebated Refrigerator for Failures and Removals



Although it is not apparent from the exhibit, even the minimum EUL is 73 years. The model was allowed to run for 1,000 years in order to see the EUL predicted by the best fitting model. The maximum EUL case was not reached in 1,000 years, and the model was stopped. As shown in the exhibit, the best fit model and the minimum EUL model predict almost identical distributions over the 500 month time period shown. It is only when the timeline is extended to about 1200 months that the differences in the distributions become apparent.

Exhibit 3-26 illustrates the differences between the distributions over 10,000 months. Obviously, the models are unable to provide accurate results at such an early stage. Only the minimum EUL case reaches its median within this time period.

Exhibit 3-26
Survival Functions from the Competing Risks Model
Over 10,000 Month Time Period



Results from the competing risks model are presented in Exhibit 3-27. For each case, the competing risks model EUL prediction is given along with its associated standard error. The properties for the failure and removal distributions (from the LIFEREG procedure in SAS) used to construct each competing risks model are also provided.

Exhibit 3-27
Competing Risks Model Results

Method	Model	Distribution		Variable Intercept	Variable Scale	Resulting EUL
Best Fit	Combined		Parameter Estimate	-	-	**947**
			Standard Error	-	-	4,558
	Failures	Logistic	Parameter Estimate	11.44	1.38	**7,772**
			Standard Error	10.37	1.84	80,598
	Removals	Weibull	Parameter Estimate	10.71	1.99	**1,809**
			Standard Error	3.38	0.93	6,112
Min EUL	Combined		Parameter Estimate	-	-	**73**
			Standard Error	-	-	41
	Failures	Exponential	Parameter Estimate	9.32	1.00	**73**
			Standard Error	1.32	0.00	96
	Removals	Exponential	Parameter Estimate	7.26	1.00	**82**
			Standard Error	0.47	0.00	39
Max EUL	Combined		Parameter Estimate	-	-	**-**
			Standard Error	-	-	-
	Failures	Log-Normal	Parameter Estimate	14.85	4.17	**235,177**
			Standard Error	14.41	5.30	3,389,004
	Removals	Log-Normal	Parameter Estimate	12.86	4.84	**32,158**
			Standard Error	4.18	2.08	134,561

As discussed above, the competing risks model did not coverage for the Max EUL case within a 1,000 year period. It is likely that the expected EUL under this scenario would be in excess of 10,000 years given the EUL for the individual failure and removal components.

3.9 ANALYSIS OF OLD REFRIGERATOR DATA

One of the greatest obstacles for this study is the short time period that has elapsed since the installation of the refrigerators. With such a short time period, very few failures and removals have occurred, making it difficult (if not impossible) to accurately predict the appropriate distribution and corresponding EUL. In an effort to reduce this uncertainty, we attempted to model the distribution of failures for old refrigerators replaced due to the program.

As a part of the survey instruments, participants were asked a battery of questions pertaining to the replaced refrigerator. The questions attempted to obtain the age of the old refrigerator, whether it was in working condition, and what was wrong with it. The responses from the survey were subjected to the same analysis as that of the rebated refrigerators. Note that these results are for failures only, and do not take into account removals. Furthermore, if a customer stated that there were any operating problems with the refrigerator, then the unit was considered a failure. This is very conservative, because many of the problems mentioned were minor, and in fact, many customers were still using the unit as a backup.

Failure data collected for the old refrigerators were subjected to the same analysis as the rebated refrigerators. Exhibit 3-28 provides the survival functions based on the exponential, logistic, lognormal, Weibull and gamma distributions, estimated for the removal of old refrigerators using the LIFEREG procedure and compares these five survival functions with the empirical survival function, over 180 months of the refrigerator's life.

Exhibit 3-28
Comparison of Survival Functions
Exponential, Logistic, Lognormal, Weibull and Gamma versus Empirical Function
Old Refrigerators

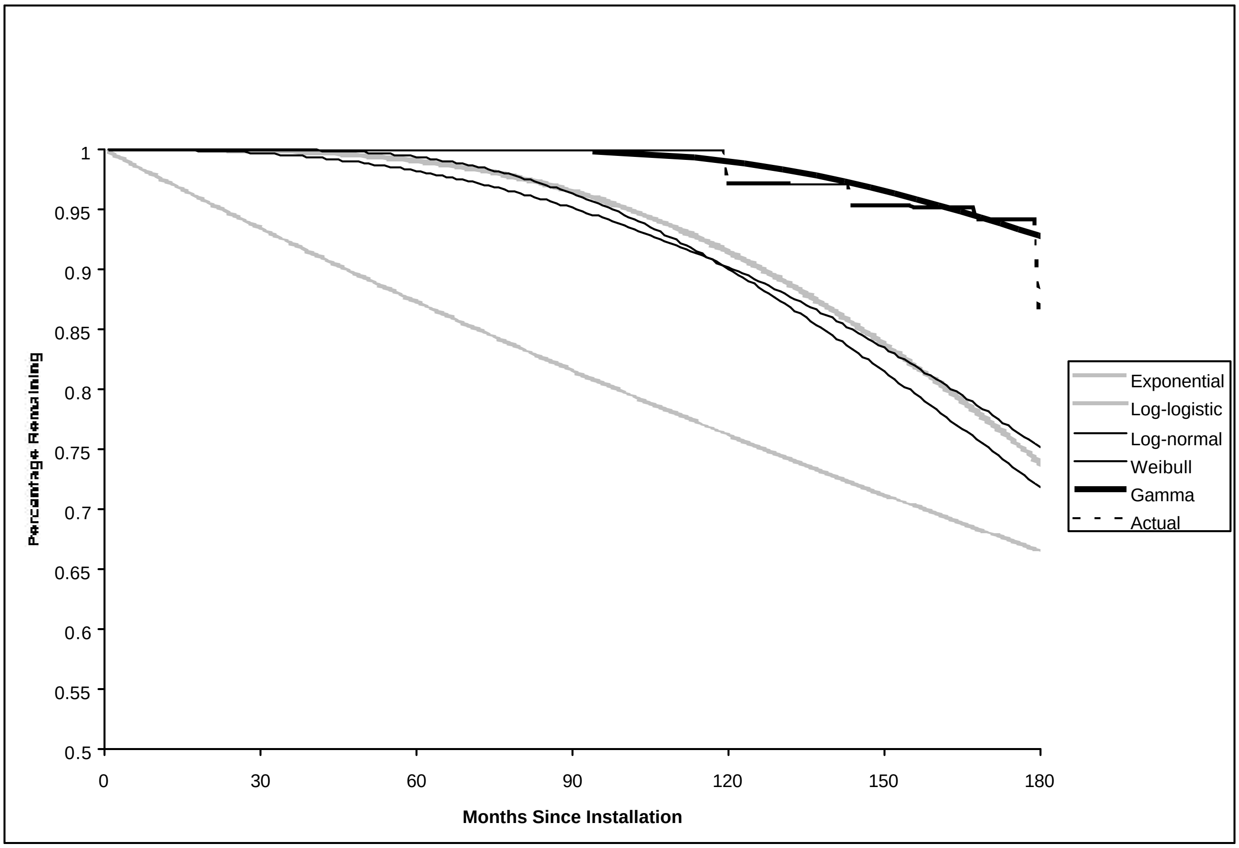


Exhibit 3-29 below summarizes the results of the LIFEREG models using failure data based on the old refrigerators. Shown for each model are the parameter estimates and standard errors for every variable included in the model specification. Furthermore, the resulting EUL and its associated standard error are provided.

Exhibit 3-29
Comparison of Survival Model Results
Exponential, Logistic, Lognormal, Weibull and Gamma Models
Old Refrigerator Failures

			Variable		Resulting
Measure	**Model**		**Intercept**	**Scale**	**EUL**
Old	Exponential	Parameter Estimate	6.09	1.00	**26**
		Standard Error	0.09	0.00	2
	Logistic	Parameter Estimate	5.51	0.30	**21**
		Standard Error	0.04	0.02	1
	Log-Normal	Parameter Estimate	5.52	0.57	**21**
		Standard Error	0.04	0.04	1
	Weibull	Parameter Estimate	5.69	0.40	**21**
		Standard Error	0.04	0.03	1
	Gamma	Estimate	5.63	0.45	**21**
		Standard Error	0.05	0.05	1

The old refrigerator failure data was then combined with removal data from the rebated refrigerators in order to develop a competing risks model similar to that developed for the rebated units. Survival functions from this model are presented in Exhibit 3-30 and a tabular presentation of the results from the competing risks model is presented in Exhibit 3-31.

Exhibit 3-30
Comparison of Survival Functions From Competing Risk Model Using Old Refrigerator Failures and Rebated Refrigerator Removals

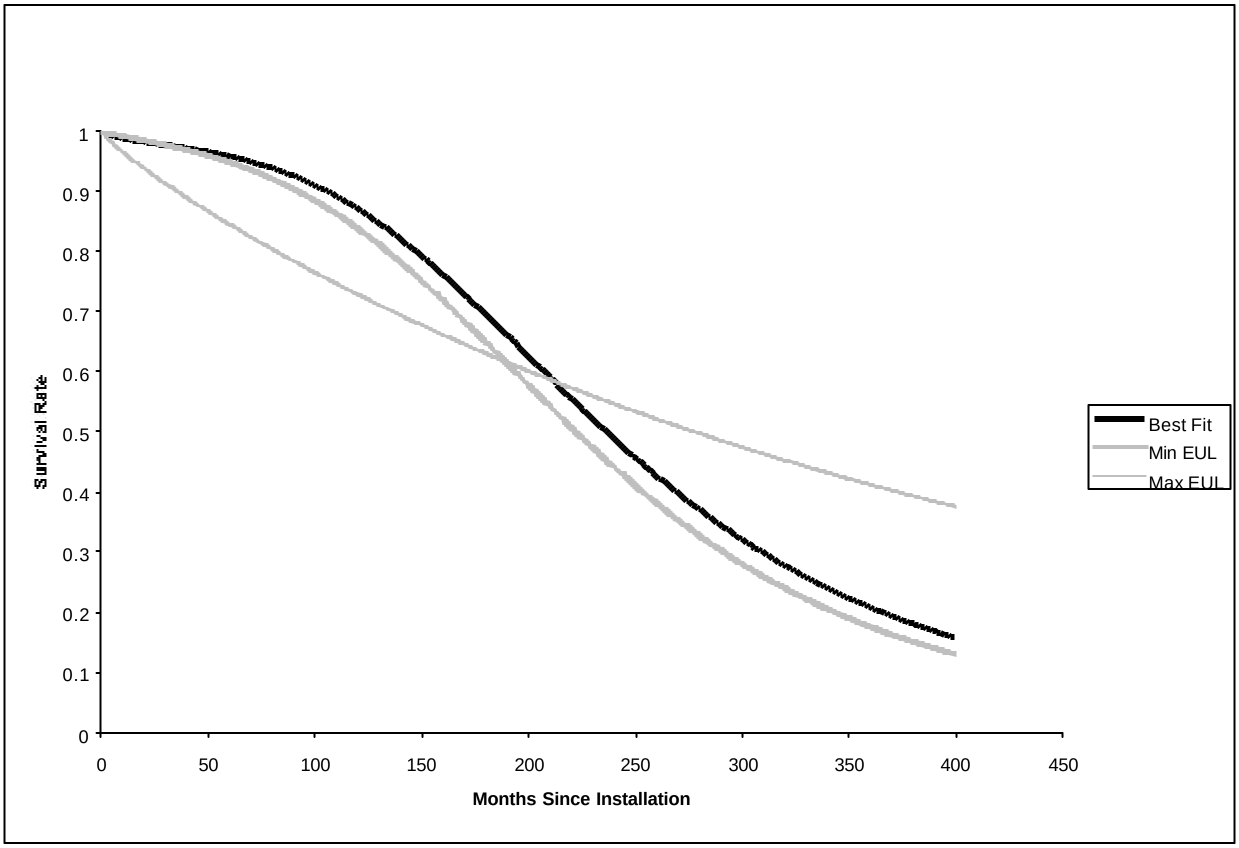


Exhibit 3-31
Results from Competing Risks Model
Old Refrigerator Failures

				Variable		Resulting
Method	**Model**	**Distribution**		**Intercept**	**Scale**	**EUL**
Best Fit	Combined		Parameter Estimate	-	-	**20**
			Standard Error	-	-	10
	Failures	Logistic	Parameter Estimate	5.51	0.30	**36**
			Standard Error	0.04	0.02	1
	Removals	Weibull	Parameter Estimate	10.71	1.99	**1,809**
			Standard Error	3.38	0.93	6,112
Min EUL	Combined		Parameter Estimate	-	-	**19**
			Standard Error	-	-	3
	Failures	Logistic	Parameter Estimate	5.51	0.30	**36**
			Standard Error	0.04	0.02	1
	Removals	Exponential	Parameter Estimate	7.26	1.00	**82**
			Standard Error	0.47	0.00	39
Max EUL	Combined		Parameter Estimate	-	-	**23**
			Standard Error	-	-	14
	Failures	Exponential	Parameter Estimate	6.09	1.00	**110**
			Standard Error	0.09	0.00	10
	Removals	Log-Normal	Parameter Estimate	12.86	4.84	**32,158**
			Standard Error	4.18	2.08	134,561

As shown in the above exhibit, the EUL predicted by the combination of old refrigerator failure data and rebated refrigerator removal data is significantly lower than those predicted using the rebated refrigerator data for both failures and removals. However attractive these results appear, there are several assumptions and data collection issues that may be influencing these numbers. The data collection methods were not nearly as comprehensive for the old refrigerator data as they were for the rebated refrigerator. As stated above, any refrigerator with minor problems was counted as a failed unit, even though the participant may still be using it as a second refrigerator. In addition, factors such as changes in manufacturing methods, features included in the refrigerators (i.e. ice makers and water dispensers), mechanical innovations, family sizes, lifestyle changes (percent of meals prepared vs. dining out), etc. may be biasing these results. Without a comprehensive data collection effort, the results from the old refrigerators should not be used to determine the EUL for the rebated refrigerators. Instead, the data for the old refrigerators should be used only to validate results obtained for the rebated refrigerators.

Section 4 provides the recommended results and summarizes all of the results developed in this section.

4. RESULTS

This section presents the final results of the 1996 and 1997 RAEI Retention Study. As discussed in detail in Section 3, the overall approach consists of five analysis steps that were used to estimate the EUL for rebated refrigerators:

1. ***Compile summary statistics*** on the raw retention data.

2. ***Visually inspect*** the retention data.

3. ***Develop a trend line*** from the survival plots.

4. ***Develop a survival function*** using classical survival techniques.

5. ***Develop competing risk models*** to obtain final results

4.1 COMPILE SUMMARY STATISTICS

Although the analysis was conducted on one combined dataset, initial summary statistics were produced for each survey type. This provided insight on the number and type of events by survey type. For example, the survey results confirm the initial assumption that the Participant Mover group would exhibit a higher proportion of removals. In addition, it became clear that such a small percentage of failures and removals had occurred, that it would be nearly impossible to model the equipment's survival function.

Exhibit 4-1 presents the percentage of refrigerators that were found to have failed or been removed over the study period.

Exhibit 4-1
Unweighted Summary Statistics on Raw Retention Data

Survey Type	Number of Surveys Conducted	Number of Units that Failed, were Removed, or Replaced	Number of Units Replaced Under Warranty	Number of Units in Place and Operable	Percent Failed, Removed, Replaced
New Occupant	83	0	0	83	0.00%
Original Participant	461	5	3	459	0.43%
Participant Mover	45	8	0	37	17.78%
Total	589	13	3	579	1.70%

The raw retention data was then combined to form one analysis dataset. Failures and removals were modeled both as one event and separately so that the differences in the distributions between failures and removals could be examined. In addition, refrigerators that were replaced under warranty were modeled twice; once counting as failures and once counting as in place and operable. Exhibit 4-2 shows results from this effort. An unweighted percentage of units that have failed or been removed was calculated. From this percentage, an EUL was estimated, assuming a constant failure rate over the life of the measure.

Exhibit 4-2
Illustrative Ex Post Unweighted EUL Estimates
Based on Exponential Distribution and Conservative Assumptions

Survey Type	Percent Failed, Removed, Replaced	Annualized Failure, Removal, Replacement Rate^	Mean Life*	Median Life*	Ex Ante EUL
Combined (No Warranty)	2.21%	0.63%	159	110	20
Combined (Warranty)	1.70%	0.49%	206	143	20
Failures (No Warranty)	0.68%	0.19%	515	357	20
Failures (Warranty)	0.17%	0.05%	2,062	1,429	20
Removals	1.53%	0.44%	229	159	20

^ Assuming a percentage of failed, removed, replaced occurs over 3.5 years.
* Assuming a constant failure rate over time.

Exhibit 4-2 demonstrates the difficulty that was encountered attempting to develop a survival function or an ex post EUL estimate, since very few failures or removals occurred during the study period. With such limited data on failures, a reliable survival function cannot be developed nor can an ex post EUL estimate.

4.2 VISUAL INSPECTION

Using the raw retention data, we developed empirical distributions of the survival function. This step clearly illustrated that there was not enough data over time to support an accurate estimate of the survival function. For this study, the vast majority of refrigerators were in place less than four years. Because the ex ante EUL is 20 years, our data were not capable of accurately estimating the survival function of failures and removals.

4.3 DEVELOP A TREND LINE

Using the empirical functions developed above, a trend line was estimated using standard linear regression techniques. We modeled the trend as a linear and an exponential function (by taking the log of the percentage operable). In each case, we plotted the resulting trend line and visually compared it to the empirical survival function developed above.

The results of the trendline regressions are provided in Exhibit 4-3 for each of the three analysis methods. Also provided in Exhibit 4-3 is the estimated EUL for each method. Clearly, the results of the linear and exponential trendline estimate indicate that the ex post EUL estimates are significantly larger than the ex ante estimates (which are all 20 years).

Each of these results would easily reject the ex ante estimate at the 80 percent confidence level.

Exhibit 4-3
Regression Results of Linear and Exponential Trendlines and Resulting Ex Post EUL Estimates

Measure Description	Intercept	t-Statistic	Slope	t-Statistic	EUL
Linear Distribution					
Combined Model	0.99	870.65	-0.0007	-12.82	59
Failures Only	1.00	2,861	-0.0001	-3.88	651
Removals Only	0.99	1,065	-0.0006	-14.20	66
Exponential Distribution					
Combined Model	-	-	0.0013	21.42	46
Failures Only	-	-	0.0002	13.19	374
Removals Only	-	-	0.0011	22.52	53

4.4 DEVELOP A SURVIVAL FUNCTION

Using classical survival techniques, we modeled the survival function assuming five of the most common survival distributions: exponential, logistic, lognormal, Weibull and gamma. In each case, we plotted the resulting distribution and visually compared it to the survival plot developed above. Furthermore, we used the resulting survival function to estimate the EUL.

Exhibit 4-4 provides the results of the classical survival analysis. Shown are the model results for each analysis dataset, and for each type of distribution modeled. Furthermore, the resulting EUL estimates are provided.

Exhibit 4-4
Comparison of Survival Model Results for Rebated Refrigerators
Exponential, Logistic, Lognormal, Weibull and Gamma Models

			Variable		Resulting
Measure	**Model**		**Intercept**	**Scale**	**EUL**
Combined	Exponential	Parameter Estimate	7.14	1.00	**73**
		Standard Error	0.44	0.00	32
	Logistic	Parameter Estimate	10.14	1.90	**2,121**
		Standard Error	2.93	0.83	6,222
	Log-Normal	Parameter Estimate	12.17	4.60	**16,040**
		Standard Error	3.66	1.86	58,649
	Weibull	Parameter Estimate	10.25	1.92	**1,168**
		Standard Error	2.98	0.85	3,483
	Gamma	Estimate	9.91	0.82	**562**
		Standard Error	15.08	43.77	8,480
Failures	Exponential	Parameter Estimate	9.32	1.00	**73**
		Standard Error	1.32	0.00	96
	Logistic	Parameter Estimate	11.44	1.38	**7,772**
		Standard Error	10.37	1.84	80,598
	Log-Normal	Parameter Estimate	14.85	4.17	**235,177**
		Standard Error	14.41	5.30	3,389,004
	Weibull	Parameter Estimate	11.46	1.39	**4,745**
		Standard Error	10.39	1.84	49,320
	Gamma	Estimate	11.05	0.70	**1,592**
		Standard Error	10.40	27.93	16,565
Removals	Exponential	Parameter Estimate	7.26	1.00	**82**
		Standard Error	0.47	0.00	39
	Logistic	Parameter Estimate	10.61	1.97	**3,390**
		Standard Error	3.33	0.91	11,290
	Log-Normal	Parameter Estimate	12.86	4.84	**32,158**
		Standard Error	4.18	2.08	134,561
	Weibull	Parameter Estimate	10.71	1.99	**1,809**
		Standard Error	3.38	0.93	6,112
	Gamma	Estimate	10.42	1.62	**1,415**
		Standard Error	3.23	0.75	4,570

4.5 DEVELOP COMPETING RISKS MODELS

As discussed in Section 3, competing risks models were developed to incorporate multiple event types having differing distributions into one combined distribution. The model contains three different distribution combinations. The first combination is what we believe to be the best estimate of the actual distribution, based on log-likelihood estimates produced by SAS. The second combination presents the minimum EUL. Conversely, the third combination presents the maximum EUL. Each combination of failures and removals was modeled to develop survival functions as presented in Section 3. The resulting EUL predictions from the competing risks models are presented in Exhibit 4-5.

Exhibit 4-5
Competing Risks Model Results

				Variable		Resulting
Method	**Model**	**Distribution**		**Intercept**	**Scale**	**EUL**
Best Fit	Combined		Parameter Estimate	-	-	**947**
			Standard Error	-	-	4,558
	Failures	Logistic	Parameter Estimate	11.44	1.38	**7,772**
			Standard Error	10.37	1.84	80,598
	Removals	Weibull	Parameter Estimate	10.71	1.99	**1,809**
			Standard Error	3.38	0.93	6,112
Min EUL	Combined		Parameter Estimate	-	-	**73**
			Standard Error	-	-	41
	Failures	Exponential	Parameter Estimate	9.32	1.00	**73**
			Standard Error	1.32	0.00	96
	Removals	Exponential	Parameter Estimate	7.26	1.00	**82**
			Standard Error	0.47	0.00	39
Max EUL	Combined		Parameter Estimate	-	-	**-**
			Standard Error	-	-	-
	Failures	Log-Normal	Parameter Estimate	14.85	4.17	**235,177**
			Standard Error	14.41	5.30	3,389,004
	Removals	Log-Normal	Parameter Estimate	12.86	4.84	**32,158**
			Standard Error	4.18	2.08	134,561

As discussed in Section 3, the competing risks model did not coverage for the Max EUL case within a 1,000 year period. It is likely that the expected EUL under this scenario would be in excess of 10,000 years given the EUL for the individual failure and removal components.

4.6 ANALYSIS OF OLD REFRIGERATOR DATA

Because of the limited number of failures, we also modeled failure data collected on the old refrigerator that was replaced under the program. This data represents failures only, and is based on unknown vintages and efficiency levels. This data was collected primarily to validate the distribution of failures over a much greater time frame than this study was intended. If a customer stated that there were any operating problems with the refrigerator, then the unit was considered a failure. This is very conservative, because many of the problems mentioned were minor, and in fact, many customers were still using the unit as a backup.

The failure data collected for old refrigerators was modeled using the same methodology as the rebated refrigerator. Exhibit 4-6 provides the results of the classical survival analysis. Shown are the model results for each type of distribution modeled. Furthermore, the resulting EUL estimates are provided.

Exhibit 4-6
Comparison of Survival Model Results for Old Refrigerators
Exponential, Logistic, Lognormal, Weibull and Gamma Models

			Variable		Resulting
Measure	**Model**		**Intercept**	**Scale**	**EUL**
Old	Exponential	Parameter Estimate	6.09	1.00	**110**
		Standard Error	0.09	0.00	10
	Logistic	Parameter Estimate	5.51	0.30	**36**
		Standard Error	0.04	0.02	1
	Log-Normal	Parameter Estimate	5.52	0.57	**38**
		Standard Error	0.04	0.04	2
	Weibull	Parameter Estimate	5.69	0.40	**36**
		Standard Error	0.04	0.03	1
	Gamma	Estimate	5.63	0.45	**51**
		Standard Error	0.05	0.05	3

A competing risks model was then developed that combined the failure data from the old refrigerators with removal data from the rebated refrigerators. Results from this competing risks model are presented in Exhibit 4-7.

Exhibit 4-7
Results from Competing Risks Model
Old Refrigerator Failures and Rebated Refrigerator Removals

				Variable		Resulting
Method	**Model**	**Distribution**		**Intercept**	**Scale**	**EUL**
Best Fit	Combined		Parameter Estimate	-	-	**20**
			Standard Error	-	-	10
	Failures	Logistic	Parameter Estimate	5.51	0.30	**36**
			Standard Error	0.04	0.02	1
	Removals	Weibull	Parameter Estimate	10.71	1.99	**1,809**
			Standard Error	3.38	0.93	6,112
Min EUL	Combined		Parameter Estimate	-	-	**19**
			Standard Error	-	-	3
	Failures	Logistic	Parameter Estimate	5.51	0.30	**36**
			Standard Error	0.04	0.02	1
	Removals	Exponential	Parameter Estimate	7.26	1.00	**82**
			Standard Error	0.47	0.00	39
Max EUL	Combined		Parameter Estimate	-	-	**23**
			Standard Error	-	-	14
	Failures	Exponential	Parameter Estimate	6.09	1.00	**110**
			Standard Error	0.09	0.00	10
	Removals	Log-Normal	Parameter Estimate	12.86	4.84	**32,158**
			Standard Error	4.18	2.08	134,561

4.7 FINAL RESULTS

Exhibit 4-8 summarizes the estimated EULs from the survival analysis for each analysis dataset and corresponding model. The median EULs are provided, along with the upper and lower confidence bounds, based on the 80 percent confidence interval.

Exhibit 4-8
Comparison of Survival Model Results
Linear, Exponential, Logistic, Lognormal, Weibull and Gamma Models

			Analysis Methods			
Approach	**Model**		**Combined Data**	**Failures Only**	**Removals Only**	**Old Refrigerator Failures Only**
Summary Statistics	Exponential	Median EUL	143	1,429	159	-
		Upper Bound	-	-	-	-
		Lower Bound	-	-	-	-
Trendlines	Linear	Median EUL	59	651	66	-
		Upper Bound	62	750	75	-
		Lower Bound	56	551	56	-
	Exponential	Median EUL	46	374	53	-
		Upper Bound	49	432	61	-
		Lower Bound	44	316	45	-
LIFEREG	Exponential	Median EUL	73	73	82	26
		Upper Bound	114	196	132	28
		Lower Bound	32	-50	33	23
	Logistic	Median EUL	2,121	7,772	3,390	21
		Upper Bound	10,097	111,099	17,864	22
		Lower Bound	-5,856	-95,556	-11,084	20
	Log-Normal	Median EUL	16,040	235,177	32,158	21
		Upper Bound	91,228	4,579,880	204,665	22
		Lower Bound	-59,148	-4,109,526	-140,349	20
	Weibull	Median EUL	1,168	4,745	1,809	21
		Upper Bound	5,633	67,974	9,644	22
		Lower Bound	-3,297	-58,483	-6,027	20
	Gamma	Median EUL	562	1,592	1,415	21
		Upper Bound	11,434	22,828	7,274	22
		Lower Bound	-10,310	-19,644	-4,444	20

Exhibit 4-9 summarizes the estimated EULs from the competing risks model for each analysis dataset and corresponding model. The median EULs are provided, along with the upper and lower confidence bounds, based on the 80 percent confidence interval. For the maximum EUL model outputs using the rebated refrigerator failure and removal data, the competing risks model did not converge to a median value at 1,000 years. Therefore, the EUL based on the maximum EUL model exceeds 1,000 years.

Exhibit 4-9
Comparison of Competing Risks Model Results

Model Output	Failure Distribution	Removal Distribution	EUL	Upper Bound	Lower Bound
Rebated Refrigerator Failure and Removal Data					
Best Case	Log-logistic	Weibull	947	5,505	0
Minimum EUL	Exponential	Exponential	73	114	32
Maximum EUL	Log-normal	Log-normal	-	-	-
Old Refrigerator Failure Data and Rebated Refrigerator Removal Data					
Best Case	Log-logistic	Weibull	20	30	10
Minimum EUL	Log-logistic	Exponential	19	22	16
Maximum EUL	Exponential	Log-normal	23	37	10

Although we are not suggesting that the failure data from the old refrigerators be used as an estimator of the EUL for the rebated refrigerators, it is interesting to look at the distribution that is created when this data is modeled. The failure curve takes on the expected shape, validating our methodology for using the competing risks model. In fact, the resulting distribution using failure data from the old refrigerators and removal data from the rebated refrigerators yields the U or bathtub shaped hazard function for two out of the three model outputs.

4.8 RECOMMENDATIONS

Based on our extensive analysis of the retention data, we believe that there is insufficient data to provide reliable model results. There may be sufficient sample sizes to produce statistically significant results for some models, but there clearly is not enough data over time to reliably estimate the median EUL. This can be illustrated by the sensitivity in the model results.

Take, for example, the differences between the two competing risks models. The best fitting model, based on both the failures and removals from the rebated refrigerator data, has an EUL of over 947 years. When compared to the 20 year EUL obtained by substituting the failure data from the old refrigerator into the model, it is obvious that an accurate estimate of the EUL is not possible at this time. If we had a sufficient amount of data over time, such that the retention data actually covered the true median, we would expect the median result for the two models to be much closer. Recall that only 3 to 4 years of valid data was collected for this measure, and that the ex ante EUL is 20 years.

We also have concerns with using the old refrigerator data because we feel it may not be representative of the true failure curve associated with the rebated refrigerators. The data collection methods were not nearly as comprehensive for the old refrigerator data as they were for the rebated refrigerator. As discussed earlier, if a customer indicated during the survey that there were any operating problems with the refrigerator, then the unit was considered a failure. This is very conservative, because many of the problems mentioned were minor, and in fact, many customers were still using the unit as a backup. In addition, factors such as changes in manufacturing methods, features included in the refrigerators (i.e. ice makers and water dispensers), mechanical innovations, family sizes, lifestyle changes (percent of meals prepared vs. dining out), etc. may be biasing these results. Without a comprehensive data collection effort, the results from the old refrigerators should not be used to determine the EUL for the rebated refrigerators. Instead, the data for the old refrigerators should be used only to validate results obtained for the rebated refrigerators.

Our recommendation would be to discard all of the model results on the basis that there is insufficient data over the life of the measures. We want to stress that we believe the sample sizes are sufficient. It is only that we have not observed the sample over a long enough period of time. However, because we are required by the Protocols to report a study result, we will select one of the approaches as our recommended result.

The results based on the summary statistics are not recommended, as they based solely on the overall failure/removal rate observed during the study period. In addition, the results based on the trendlines are not recommended, as they are based on a number of assumptions, as discussed earlier. One of the primary reasons both of these methods are not recommended is that they are not capable of explicitly handling interval and right hand censored data, as the LIFEREG procedure is.

Therefore, the recommended results are based on the classical survival analysis using the LIFEREG procedure. As we have discussed earlier, we believe that failures and removals have different underlying distributions, which can only be handled using competing risk models. This is yet another reason why the approaches based on the summary statistics and the trendlines are not recommended. This is also the primary reason why the combined data models using the LIFEREG procedure are not recommended.

For these reasons, we recommend using the Competing Risk Model approach. We also recommend using results based only on the rebated refrigerator data. As discussed above, we believe the results based on the old refrigerator failure data may be biased. The distributions that provided the best model fit as measured by the log-likelihood estimate resulted in a Log-logistic failure distribution and a Weibull removal distribution. It is important to note that best fit distribution for failures based on the old refrigerator data was also the Log-logistic distribution. Unfortunately, the EUL based on these distributions did not result in a statistically significant result at the 80% confidence. This is somewhat expected due to the early timing of this study and the small number of failures and removals observed. In fact, the only distribution that resulted in a statistically significant result was using the exponential distribution for both failures and removals.

Therefore, the final study results are based on the rebated refrigerator failure and removal data modeled using the Log-logistic distribution for failures and the Weibull distribution for removals. Because this estimate does not reject the ex ante estimate at the 80% confidence interval, the ex post EUL will remain 20 years. The program realization rate, which is the ratio of the ex ante and ex post estimates, is one. These results are summarized in Exhibit 4-10.

Exhibit 4-10
Final Ex Post EUL Estimate

End Use	Technology	Ex Ante	Study Results Upper	Study Results Median	Study Results Lower	Ex Post	Realization Rate
Refrigeration	20 Percent More Efficient	20	5,505	947	0	20	100%
	25 Percent More Efficient	20	5,505	947	0	20	100%
	30 Percent More Efficient	20	5,505	947	0	20	100%

Attachments

Attachment 1

Protocol Tables 6 and 7

PROTOCOL TABLES 6B AND 7B

FOURTH YEAR RETENTION STUDY FOR
PG&E'S 1996 & 1997 RESIDENTIAL AEI PROGRAM REFRIGERATION TECHNOLOGY

PG&E STUDY ID # 373 1R1

This Attachment presents Tables 6B and 7B for the above referenced study as required under the "Protocols and Procedures for the Verification of Cost, Benefits, and Shareholder Earnings from Demand Side Management Programs" (the Protocols), as adopted by the California Public Utility Commission (CPUC) Decision 93-05-063, Revised March 1998 Pursuant to Decisions 94-05-063, 94-10-059, 94-12-021, 95-12-054, 96-12-079, 98-03-063, and 99-06-052.

The Table 7B synopsis of analytical methods applied follows Protocol Table 6B.

Protocol Table 6.B
Results of Retention Study
PG&E 1996 & 1997 Residential AEI Program Refrigeration Technology
Study ID # 373 1R1

		Item 2		Item 3	Item 4	Item 5	Item 6		Item 7	Item 8	Item 9
Studied Measure Description	**End Use**	**Ex Ante EUL**	**Source of Ex Ante EUL**	**Ex post EUL from Study**	**Ex Post EUL to be used in Claim**	**Ex Post EUL Standard Error**	**80% Conf. Interval Lower Bound**	**80% Conf. Interval Upper Bound**	**p-Value for Ex Post EUL**	**EUL Realizat'n Rate (ex post/ex ante)**	**"Like" Measures Associated with Studied Measure (by measure code)**
Refrigerator Rebate, Exceeds Standards by 20%	Refrigeration	20	Advice Filing	947	20	3555	0	5505	0.999	100%	n/a
Refrigerator Rebate, Exceeds Standards by 25%	Refrigeration	20	Advice Filing	947	20	3555	0	5505	0.999	100%	n/a
Refrigerator Rebate, Exceeds Standards by 30%	Refrigeration	20	Advice Filing	947	20	3555	0	5505	0.999	100%	n/a

PROTOCOL TABLE 7B

FOURTH YEAR RETENTION STUDY FOR PG&E'S 1996 & 1997 RESIDENTIAL AEI PROGRAM REFRIGERATION TECHNOLOGY PG&E STUDY ID # 373 1R1

The purpose of this section is to provide the documentation for data quality and processing as required in Table 7B of the California Public Utility Commission (CPUC) Evaluation and Measurement Protocols (the Protocols). The major topics covered in this section are organized and presented in the same order as they are listed in Table 7B for ease of reference and review. For items discussed in detail elsewhere in the report, only a brief summary will be given in this section to avoid redundancy.

1. OVERVIEW INFORMATION

A. Study Title and Study ID Number

Study Title: Fourth Year Retention Study of PG&E's 1996 & 1997 Residential AEI Program Refrigeration Technology.

Study ID Number: 373 1R1

B. Program, Program Year and Program Description

Program: PG&E Residential AEI Program, Refrigeration Technology.

Program Year: 1996 and 1997

Program Description:

The Residential AEI Program offered fixed rebates to customers who installed refrigerators meeting specific electric energy-efficiency requirements. Rebates of $40, $60, and $80 were paid for refrigerators that were, respectively, at least 20, 25, or 30 percent more efficient than baseline efficiency standards. The programs assumed that customers were in the process of replacing their existing refrigerators, and offered the incentive to influence them to purchase more efficient models.

C. End Uses and/or Measures Covered

Refrigerators.

D. Methods and Models Used

Our overall approach consists of five analysis steps that were used to estimate the EUL for rebated refrigerators:

1. ***Compile summary statistics*** on the raw retention data. This step immediately illustrated the difficulties posed for analysis since there were so few “failures” over the first five years.

2. ***Visually inspect*** the retention data. By calculating the cumulative percentage of equipment that had failed in a given month, and plotting this percentage over time, an empirical survival function emerged.

3. ***Develop a trend line*** from the survival plots. Using the plots developed in (2) above, we estimated a trend line using standard linear regression techniques. We attempted to model the trend as a linear and an exponential function. In each case, we plotted the resulting trend line and visually compared it to the survival plot developed in (2). Furthermore, we used the resulting trend line to estimate the EUL.

4. ***Develop a survival function*** using classical survival techniques. Using the SAS System and the SAS companion guide, “Survival Analysis Using the SAS System,” we modeled the survival function assuming five of the most common survival distributions: exponential, logistic, lognormal, Weibull and gamma. In each case, we plotted the resulting distribution and visually compared it to the survival plot developed in (2). Furthermore, we used the resulting survival function to estimate the EUL.

5. ***Develop a competing risks model*** that incorporates different distributions for failures and removals. A second competing risks model was developed using the failure data for the old refrigerators and the removal data obtained during data collection. This additional analysis step provides valuable results that have not been previously utilized in retention studies.

The details surrounding each of these steps are provided in Section 3 of the report.

E. Analysis Sample Size

The exhibit below provides the final sample disposition used in the study analysis. *Section 3.2* discusses the sample plan in detail.

Final Sample Disposition[1]

Type and Number of Surveys Conducted		In Place & Operating	Failed	Removed	Total
New Occupant	251	83	0	0	83
Original Participant	461	456	3	2	461
Participant Mover	45	37	1	7	45
Total	757	576	4	9	589

2. DATABASE MANAGEMENT

A. Key Data Elements and Sources

The Retention Study incorporated a variety of data currently available; in particular PG&E's program participation data (Marketing Decision Support System [MDSS]), retention study databases, and other program-related documentation.

- *Program Participant Tracking System*. The participant tracking system data, maintained in PG&E's MDSS, contains vital project and technical information about the measures rebated. In addition, participant contact information is stored in the MDSS.

- *Residential Population CIS*. PG&E residential customer information system (CIS) data was used to obtain contact information as well as to identify movers and non-movers using the date on premise.

- *Program Marketing Data*. PG&E program marketing data contains a detailed description of the installation and rebate program procedures.

In addition, telephone surveys were conducted to support the analysis, as discussed in *Section 3* of the report.

B. Data Attrition Process

All data points that had survey data on a rebated refrigerator were utilized in the analysis. As discussed in *Section 3*, the SAS analysis procedures we implemented were able to handle interval censored data, in the cases when failure/removal dates were not obtainable.

[1] Only 83 of the 251 respondents from the New Occupant survey were able to confirm that the rebated refrigerator was left by the original participant. The remaining 168 respondents either did not have a refrigerator at the residence upon move-in or were unable to confirm that the refrigerator was the rebated refrigerator based upon make and model number of the rebated refrigerator.

C. *Internal Data Quality Procedures*

The Evaluation contractor of this project, Quantum Consulting Inc. (QC), has performed extensive data quality control on all retention and follow-up survey data. QC's data quality procedures are consistent with PG&E's internal database guidelines and the guidelines established in the Protocols.

Throughout every step of this project, numerous data quality assurance procedures were in place to ensure that all data used in analysis and all survey data collected was of the highest quality. All data entry was performed using blind double-key data entry. On questionable responses follow-up phone calls or site visits were made.

D. *Unused Data Elements*

Without exception, all data collected specifically for the Evaluation were utilized in the analysis.

3. *SAMPLING*

A. *Sampling Procedures and Protocols*

Section 3.2 describes the sample procedures and protocols.

B. *Survey Information*

The data collection instrument is presented in the *Attachment 2.* The exhibit below provides the final sample disposition, which contains the number of customers that were surveyed.

Final Sample Disposition[2]

Type and Number of Surveys Conducted		In Place & Operating	Failed	Removed	Total
New Occupant	251	83	0	0	83
Original Participant	461	456	3	2	461
Participant Mover	45	37	1	7	45
Total	757	576	4	9	589

[2] Only 83 of the 251 respondents from the New Occupant survey were able to confirm that the rebated refrigerator was left by the original participant. The remaining 168 respondents either did not have a refrigerator at the residence upon move-in or were unable to confirm that the refrigerator was the rebated refrigerator based upon make and model number of the rebated refrigerator.

C. Statistical Descriptions

Statistics variables that were used in the survival models are presented in *Section 3*. The exhibit below provides the raw summary statistics of the data utilized for the analysis.

Unweighted Summary Statistics on Retention Sample Data

Survey Type	Number of Surveys Conducted	Number of Units that Failed, were Removed, or Replaced	Number of Units Replaced Under Warranty	Number of Units in Place and Operable	Percent Failed, Removed, Replaced
New Occupant	83	0	0	83	0.00%
Original Participant	461	5	3	459	0.43%
Participant Mover	45	8	0	37	17.78%
Total	589	13	3	579	1.70%

4. DATA SCREENING AND ANALYSIS

A. Procedures for Treating Outliers and Missing Data

All data points that had survey data on a rebated refrigerator were utilized in the analysis. As discussed in *Section 3*, the SAS analysis procedures we implemented were able to handle interval censored data, in the cases when failure/removal dates were not obtainable.

B. Background Variables

Due to the nature of this analysis (survival analysis), background variables, such as interest rates, unemployment rates and other economic factors, were not considered to be a necessary component of the analysis.

C. Data Screen Process

Again, all data points that had survey data on a rebated refrigerator were utilized in the analysis.

D. Regression Statistics

The regression statistics for the models implemented are provided in *Section 3*.

E. Model Specification

The model specifications are presented in *Section 3*.

F. Measurement Errors

For the survival analysis, the main source of measurement errors is the survey data. Our approach has been to proactively stop the problem before it happens so that statistical corrections are kept to a minimum.

Measurement errors are a combination of random and non-random error components that plague all survey data. The non-random error frequently takes the form of systematic bias, which includes, but is not limited to, ill-formed or misleading questions and mis-coded study variables. In this project, we implemented several controls to reduce systematic bias in the data. These steps include a thorough interviewer training and survey instrument pretest.

The random measurement error, such as data entry error, has no impact on estimating mean values because the errors are typically unbiased. For the measures that were modeled in the survival analysis, the impact of random unbiased measurement errors was accounted for as part of the overall standard variance in the parameter estimate.

G. Influential Data Points

No diagnostics were used to identify outliers.

H. Missing Data

As discussed in *Section 3*, the SAS analysis procedures we implemented were able to handle interval censored data, in the cases when failure/removal dates were missing. There were no other missing data points, other than failure/removal dates.

I. Precision

The SAS output provided the standard errors for the 50^{th} percentile (or median).

Attachment 2

Final Survey Data Collection Instruments

PG&E Residential Refrigeration Retention Survey
Original Participant Survey

Vars Needed for CATI:
Name
Rebate Year
Address

Hello, this is ________________________, calling from Quantum Consulting on behalf of PG&E. May I speak with (NAME)? (IF THIS PERSON IS AVAILABLE, PROCEED. IF NOT, READ May I speak to the head of the household? IF THIS PERSON IS NOT AVAILABLE, GET HIS/HER NAME AND MAKE ARRANGEMENTS TO CALL LATER.

IF THERE IS SOMEONE TO TALK TO, READ: PG&E is conducting research on certain refrigerators purchased through their rebate program, to see if they are still working properly. We are not trying to sell you anything and the survey will take 5 to 10 minutes.

IF RESPONDENT SAYS THEY HAVE NO REFRIGERATOR REBATED BY PG&E: According to PG&E's records, there was a refrigerator purchased by this household in (REBATE YEAR).

IF NECESSARY: PG&E is required by law to conduct these surveys to determine the operating status of refrigerators for which they provided rebates to customers.

SC. SCREENER SECTION

SC1. First, I want to make sure that I reached you at (ADDRESS). Is this your correct address?

1	Yes	SC2
2	No	T&T
88	Refused	T&T
99	Don't Know	T&T

SC2. Is (ADDRESS) a home, a place of business, or both?

1	Home (including those that telecommute)	SC3
2	Place of business	T&T
3	Both	SC3
88	Refused	T&T
99	Don't Know	T&T

SC3. Do you recall your household purchasing a refrigerator in (REBATE YEAR)?

1	Yes	R1
2	No	T&T
88	Refused	T&T
989	Don't Know	T&T

R.REFRIGERATOR REBATE PARTICIPANTS SECTION

I would now like to ask you some questions about the refrigerator purchased in (REBATE YEAR)

R1. Is the refrigerator still at (ADDRESS)?

1	Yes	R30
2	No	R21
88	Refused	T&T
99	Don't Know	T&T

R21. What happened to the refrigerator? (DO NOT READ LIST)

1	Broke	R21b
2	Damaged in fire, earthquake, flood or other disaster	R21b
3	Sold it or gave it away	R21a
4	Put it at another address I'm responsible for	R21b
5	Brought it with me when I moved	R21b
77	Other (Specify)	R21b
88	Refused	T&T
99	Don't Know	T&T

R21a. Why did you sell or give away your refrigerator away?

1	Remodeled Kitchen	R21b
2	Needed Larger Unit	R21b
3	Didn't like Unit	R21b
4	Had Repair Problems	R21b
5	Was Given better Unit	R21b
77	Other (Specify)	R21b
88	Refused	R22b
99	Don't Know	R22b

R21b. In what year and month did this happen?

R21b Year

1	1995	R21c
2	1996	R21c
3	1997	R21c
4	1998	R21c
5	1999	R21c
6	2000	R21c
88	Refused	R22a
99	Don't Know	R22a

R21c Month

1	January	R22a
2	February	R22a
3	March	R22a

4	April	R22a
R25	May	R22a
6	June	R22a
7	July	R22a
8	August	R22a
9	September	R22a
10	October	R22a
11	November	R22a
12	December	R22a
88	Refused	R22a
99	Don’t Know	R22a

IF R21 = 1 then ask R22a
IF R21 = 2 then ask R22b
Else Skip to R23

R22a. Was the unit replaced under warranty?

1	Yes	R22d
2	No	R22c
88	Refused	R22c
99	Don’t Know	R22c

R22b. Was the unit replaced through insurance?

1	Yes	R22d	R2
2	No	R22c	R2
88	Refused	R22c	R2
99	Don’t Know	R22c	R2

R22c. Was the unit replaced at all?

1	Yes	R22d
2	No	R26
88	Refused	R26
99	Don’t Know	R26

R22d. Was it replaced with a refrigerator of the same efficiency?

1	Yes	R26
2	No	R26
88	Refused	R26
99	Don’t Know	R26

IF R21 = 3,4,5,77 then ask R23, Else Skip to R26

R23. To the best of your knowledge, is the new owner or new location of the refrigerator somewhere in central or northern California?

1	Yes	R25
2	No	R24
88	Refused	R26
99	Don't Know	R26

R24. What state is the refrigerator now in?

1	Specify	R25
88	Refused	R25
99	Don't Know	R25

R25. What city/area is the refrigerator now in?

1	Specify	R26
88	Refused	R26
99	Don't Know	R26

IF R21 = 3, 77, Then Ask R26
Else,
IF R21=1 or 2 THEN SKIP TO R31
IF R21=4 or 5 or R1 = 1, THEN SKIP TO R30

R26. Was the refrigerator still in good working condition when you last had it?

1	Yes	R31
2	No	R27
88	Refused	R31
99	Don't Know	R31

R27. What problems did you have with the refrigerator? (DO NOT READ)

1	Broken/Needed Major Repair/Too Expensive to Fix	R31
2	Needed Minor Repair	R31
3	Made Noises	R31
4	Leaked	R31
5	Too expensive to operate	R31
77	Specify	R31
88	Refused	R31
99	Don't Know	R31

Only ask if R1 = 1, or R21=4 or 5,

R30. How is the refrigerator currently being used?

1	As a main refrigerator	R30a	R3
2	As a spare or secondary refrigerator	R30a	R3
3	Stored unused/unplugged	R30a	R3
88	Refused	R30a	R3
99	Don't know	R30a	R3

R30a. Is the refrigerator still in good working condition?

1	Yes	R31
2	No	R30b
88	Refused	R31
99	Don't Know	R31

R30b. What problems did you have with the refrigerator? (DO NOT READ)

1	Broken/Needed Major Repair/Too Expensive to Fix	R31
2	Needed Minor Repair	R31
3	Made Noises	R31
4	Leaked	R31
5	Too expensive to operate	R31
77	Specify	R31
88	Refused	R31
99	Don't Know	R31

ASK ALL

Now we'd like to ask you a few questions about your old refrigerator which you replaced in [REBATE YEAR].

R31. What was the age of the old refrigerator when it was replaced?
(NOTE TO INTERVIEWERS: if unit not replaced, get current age, or age at the time last seen)

1	Enter Years	R32
2	Did not own one	R35
88	Refused	R32
99	Don't Know	R32

R32. Was the old refrigerator still in good working condition at the time it was replaced?
(NOTE TO INTERVIEWERS: if unit not replaced, get current condition, or condition at the time last seen)

1	Yes	R35
2	No	R33
88	Refused	R35
99	Don't Know	R35

R33. What problems did you have with the old refrigerator? (DO NOT READ)

1	Broken/Needed Major Repair	R35
2	Needed Minor Repair	R35
3	Made Noises	R35
4	Leaked	R35
5	Too expensive to operate	R35
77	Specify	R35
88	Refused	R35
99	Don't Know	R35

NOTE To Author & Mary Kay: We'll only use this data for estimating a survival curve based on failures. It will be too difficult to track down the disposition of the unit if customer moved, or unit was sold or given away.

Read to All:
Now, we'd like to ask you about any spare refrigerator you might own.

If R30 = 2 or 3 skip to R36, Else ask R35.
R35. Do you own a second refrigerator?

1	Yes	R36
2	No	R40
88	Refused	R40
99	Don't Know	R40

R36. How often is your spare refrigerator plugged in and being used?

1	Always	R37
2	Most of the time	R37
3	About half the time	R37
4	Some of the time	R37
5	Rarely or Never	R40
88	Refused	R37
99	Don't Know	R37

R37. During the summer, how often is the refrigerator being used?

1	Always	R40
2	Most of the time	R40

3	About half the time	R40
4	Some of the time	R40
5	Rarely or Never	R40
88	Refused	R40
99	Don’t Know	R40

Read to All:
Now, we’d like to ask you a few questions about your home.

R40. To the best of your knowledge has there been any major kitchen remodeling or renovation performed at (ADDRESS) since (REBATE YEAR)?

1	Yes	R41
2	No	R42
88	Refused	R42
99	Don’t Know	R42

R41 During what year did that remodeling occur?

R41 Year

1	1995	R42
2	1996	R42
3	1997	R42
4	1998	R42
5	1999	R42
6	2000	R42
88	Refused	R42
99	Don’t Know	R42

R42. What type of residence do you live in?

1	Single Family Detached Home	R43
2	Townhouse (also duet home, duplex)	R43
3	Condo	R43
4	Apartment (also multifamily, multi-unit)	R43
5	Mobile Home	R43
77	Other (specify)	R43
88	Refused	R43
99	Don’t Know	R43

R43. Do you own or rent this residence?

1	Own/buying	R44
2	Rent/lease	R44
77	Other (specify)	R44
88	Refused	R44
99	Don’t Know	R44

R44. How many people are in your household, including yourself?

1	Number of people	R300
88	Refused	R300
99	Don't Know	R300

R300 Goodbye!

Those are all of my questions. Thank you very much for taking the time to participate in this study.

PG&E Residential Refrigeration Retention Survey
Participant Mover Survey

Vars Needed for CATI:
Name
Rebate Year
Old STREET
Old CITY

Hello, this is ________________________, calling from Quantum Consulting on behalf of Pacific Gas & Electric. May I speak with (NAME)? (IF THIS PERSON IS AVAILABLE, PROCEED. IF NOT, May I speak to the head of the household? IF THIS PERSON IS NOT AVAILABLE, GET HIS/HER NAME AND MAKE ARRANGEMENTS TO CALL LATER.

IF THERE IS SOMEONE TO TALK TO, READ: PG&E is conducting research on certain refrigerators purchased through their rebate program, to see if they are still working properly. We are not trying to sell you anything and the survey will take 5 to 10 minutes.

IF RESPONDENT SAYS THEY HAVE NO REFRIGERATOR REBATED BY PG&E: According to PG&E's records, there may have been a refrigerator purchased by this household in (REBATE YEAR), which may have been installed at a previous address.

IF NECESSARY: PG&E is required by law to conduct these surveys to determine the operating status of refrigerators for which they provided rebates to customers.

SC. SCREENER SECTION

SC1A. According to PG&E's records, you purchased a refrigerator in (REBATE YEAR), which may have been installed at (OLD STREET, OLD CITY)? Is this correct?

1	Yes	SC1
2	No	T&T
88	Refused	T&T
99	Don't Know	T&T

IF ADDRESS = '999999' SKIP to SC3, else ask SC1.

SC1. I would also like to verify that I have reached you at (ADDRESS). Is this your correct address?

1	Yes	SC3
2	No	SC3
88	Refused	SC3
99	Don't Know	SC3

SC3. Do you currently receive your electricity service from Pacific Gas and Electric?

1	Yes	SC4
2	No	SC4
88	Refused	SC4

99	Don’t Know	SC4

SC4. Did you previously live at (OLD STREET)and move since purchasing the refrigerator?

1	Yes	SC5
2	No	R1
88	Refused	R1
989	Don’t Know	R1

SC5. What month and year did you move out of your previous address at (OLD STREET)?
SC5a Year

1	1995	SC5b
2	1996	SC5b
3	1997	SC5b
4	1998	SC5b
5	1999	SC5b
6	2000	SC5b
88	Refused	R1
99	Don’t Know	R1

SC5b Month

1	January	R1
2	February	R1
3	March	R1
4	April	R1
5	May	R1
6	June	R1
7	July	R1
8	August	R1
9	September	R1
10	October	R1
11	November	R1
12	December	R1
88	Refused	R1
99	Don’t Know	R1

R.REFRIGERATOR REBATE PARTICIPANTS SECTION

I would now like to ask you some questions about the refrigerator purchased in (REBATE YEAR)

R1. Did you move your refrigerator from (OLD STREET) to your current residence?

1	Yes	R2
2	No	R21
88	Refused	T&T
99	Don’t Know	T&T

R2. Do you still have the refrigerator at your current residence?

1	Yes	R30
2	No	R21
88	Refused	T&T
99	Don't Know	T&T

R21. What happened to the refrigerator? (DO NOT READ LIST)

1	Broke	R21b
2	Damaged in fire, earthquake, flood or other disaster	R21b
3	Sold it or gave it away	R21a
4	Put it at another address I'm responsible for	R21b
5	Still have it	R30
6	Left it at old address	R26
77	Other (Specify)	R21b
88	Refused	T&T
99	Don't Know	T&T

NOTE TO AUTHOR and Mary Kay: If a customer is no longer in the PG&E service territory (per SC3), I think we should just go ahead and finish the survey anyway. There should not be very many of these customers to begin with. Plus, I'd rather have this data just in case we wanted to double check against the CIS that this individual really is a PG&E customer. Since there are likely to be so few, I'd rather be safe than sorry.

R21a. Why did you sell or give away your refrigerator away?

1	Remodeled Kitchen	R21b
2	Needed Larger Unit	R21b
3	Didn't like Unit	R21b
4	Had Repair Problems	R21b
5	Was Given better Unit	R21b
77	Other (Specify)	R21b
88	Refused	R22b
99	Don't Know	R22b

R21b. In what year and month did this happen?

R21b Year

1	1995	R21c
2	1996	R21c
3	1997	R21c
4	1998	R21c
5	1999	R21c
6	2000	R21c
88	Refused	R22a

99	Don’t Know	R22a

R21c Month

1	January	R22a
2	February	R22a
3	March	R22a
4	April	R22a
R25	May	R22a
6	June	R22a
7	July	R22a
8	August	R22a
9	September	R22a
10	October	R22a
11	November	R22a
12	December	R22a
88	Refused	R22a
99	Don’t Know	R22a

IF R21 = 1 then ask R22a
IF R21 = 2 then ask R22b
Else Skip to R23

R22a. Was the unit replaced under warranty?

1	Yes	R22d
2	No	R22c
88	Refused	R22c
99	Don’t Know	R22c

R22b. Was the unit replaced through insurance?

1	Yes	R22d	R
2	No	R22c	R
88	Refused	R22c	R
99	Don’t Know	R22c	R

R22c. Was the unit replaced at all?

1	Yes	R22d
2	No	R26
88	Refused	R26
99	Don’t Know	R26

R22d. Was it replaced with a refrigerator of the same efficiency?

1	Yes	R26
2	No	R26

88	Refused	R26
99	Don't Know	R26

IF R21 = 3,4,77 then ask R23, Else Skip to R26

R23. To the best of your knowledge, is the new owner or new location of the refrigerator somewhere in central or northern California?

1	Yes	R25
2	No	R24
88	Refused	R26
99	Don't Know	R26

R24. What state is the refrigerator now in?

1	Specify	R25
88	Refused	R25
99	Don't Know	R25

R25. What city/area is the refrigerator now in?

1	Specify	R26
88	Refused	R26
99	Don't Know	R26

IF R21 = 3, 6, 77 Then Ask R26
Else,
IF R21=1 or 2 THEN SKIP TO R31
IF R21=4 or 5, or R2 = 1 THEN SKIP TO R30

R26. Was the refrigerator still in good working condition when you last had it?

1	Yes	R31
2	No	R27
88	Refused	R31
99	Don't Know	R31

R27. What problems did you have with the refrigerator? (DO NOT READ)

1	Broken/Needed Major Repair/Too Expensive to Fix	R31
2	Needed Minor Repair	R31
3	Made Noises	R31
4	Leaked	R31
5	Too expensive to operate	R31
77	Specify	R31
88	Refused	R31
99	Don't Know	R31

Only ask if R2 = 1, or R21=4 or 5,

R30. How is the refrigerator currently being used?

1	As a main refrigerator	R30a	R3
2	As a spare or secondary refrigerator	R30a	R3
3	Stored unused/unplugged	R30a	R3
88	Refused	R30a	R3
99	Don’t know	R30a	R3

R30a. Is the refrigerator still in good working condition?

1	Yes	R31
2	No	R30b
88	Refused	R31
99	Don’t Know	R31

R30b. What problems did you have with the refrigerator? (DO NOT READ)

1	Broken/Needed Major Repair/Too Expensive to Fix	R31
2	Needed Minor Repair	R31
3	Made Noises	R31
4	Leaked	R31
5	Too expensive to operate	R31
77	Specify	R31
88	Refused	R31
99	Don’t Know	R31

Read to ALL

Now we’d like to ask you a few questions about your old refrigerator which you replaced in [REBATE YEAR].

R31. What was the age of the old refrigerator when it was replaced?
(NOTE TO INTERVIEWERS: if unit not replaced, get current age, or age at the time last seen)

1	Enter Years	R32
2	Did not own one	R35
88	Refused	R32
99	Don’t Know	R32

R32. Was the old refrigerator still in good working condition at the time it was replaced?
(NOTE TO INTERVIEWERS: if unit not replaced, get current condition, or condition at the time last seen)

1	Yes	R35
2	No	R33
88	Refused	R35
99	Don't Know	R35

R33. What problems did you have with the old refrigerator? (DO NOT READ)

1	Broken/Needed Major Repair	R35
2	Needed Minor Repair	R35
3	Made Noises	R35
4	Leaked	R35
5	Too expensive to operate	R35
77	Specify	R35
88	Refused	R35
99	Don't Know	R35

NOTE To Author & Mary Kay: We'll only use this data for estimating a survival curve based on failures. It will be too difficult to track down the disposition of the unit if customer moved, or unit was sold or given away.

Read to All:
Now, we'd like to ask you about any spare refrigerator you might own.

If R30 = 2 or 3 skip to R36, Else ask R35.
R35. Do you own a second refrigerator?

1	Yes	R36
2	No	R40
88	Refused	R40
99	Don't Know	R40

R36. How often is your spare refrigerator plugged in and being used?

1	Always	R37
2	Most of the time	R37
3	About half the time	R37
4	Some of the time	R37
5	Rarely or Never	R40
88	Refused	R37
99	Don't Know	R37

R37. During the summer, how often is the refrigerator being used?

1	Always	R40

2	Most of the time	R40
3	About half the time	R40
4	Some of the time	R40
5	Rarely or Never	R40
88	Refused	R40
99	Don't Know	R40

Read to All:
Now, we'd like to ask you a few questions about your home.

R40. To the best of your knowledge have you done any major kitchen remodeling or renovation to either this or your previous address since (REBATE YEAR)?
(NOTE TO INTERVIEWER: remodel/renovation should have occurred while they lived at current or previous address)

1	Yes	R41
2	No	R42
88	Refused	R42
99	Don't Know	R42

R41 During what year did that remodeling occur?

R41 Year

1	1995	R42
2	1996	R42
3	1997	R42
4	1998	R42
5	1999	R42
6	2000	R42
88	Refused	R42
99	Don't Know	R42

R42. What type of residence do you live in?

1	Single Family Detached Home	R44
2	Townhouse (also duet home, duplex)	R44
3	Condo	R44
4	Apartment (also multifamily, multi-unit)	R44
5	Mobile Home	R44
77	Other (specify)	R44
88	Refused	R44
99	Don't Know	R44

R44. How many people are in your household, including yourself?

1	Number of people	R45
88	Refused	R45
99	Don't Know	R45

R45. Finally, we would like to ask you one last question about your old address at [OLD STREET]. Did you own or rent that residence?

1	Own/buying	R200
2	Rent/lease	R200
77	Other (specify)	R200
88	Refused	R200
99	Don't Know	R200

IF SC1 = 1 then Skip to R300, else Ask R200

R200. For our records, would you mind providing us with your current zip code?

1	Specify Zip	R300
88	Refused	R300
99	Don't Know	R300

R300 Goodbye!

Those are all of my questions. Thank you very much for taking the time to participate in this study.

PG&E Residential Refrigeration Retention Survey
New Occupant Survey

Vars Needed for CATI:
Name
Rebate Year
Rebate Month
Address
Brand
Type
Old Name
Maybe Moved

Hello, this is ________________________, calling from Quantum Consulting on behalf of PG&E. May I speak with (NAME)? (IF THIS PERSON IS AVAILABLE, PROCEED. IF NOT, READ:) May I speak to the head of the household? IF THIS PERSON IS NOT AVAILABLE, GET HIS/HER NAME AND MAKE ARRANGEMENTS TO CALL LATER.

IF THERE IS SOMEONE TO TALK TO, READ: PG&E is conducting research on certain refrigerators purchased through their rebate program, to see if they are still working properly. We are not trying to sell you anything and the survey will take 5 to 10 minutes.

IF RESPONDENT SAYS THEY HAVE NO REFRIGERATOR REBATED BY PG&E: According to PG&E's records there was a refrigerator purchased for this household in (REBATE YEAR), which may have been installed by a previous occupant.

IF NECESSARY: PG&E is required by law to conduct these surveys to determine the operating status of refrigerators for which they provided rebates to customers.

SC. SCREENER SECTION

SC1. First, I want to make sure that I reached you at (ADDRESS). Is this your correct address?

1	Yes	SC2
2	No	T&T
88	Refused	T&T
99	Don't Know	T&T

SC2. Did you move to this address since (REBATE MONTH, REBATE YEAR)?

1	Yes	SC3a
2	No	T&T
88	Refused	T&T
99	Don't Know	T&T

SC3. What month and year did you move into this residence?
SC3a Year

1	1995	SC3b
2	1996	SC3b
3	1997	SC3b

4	1998	SC3b
5	1999	SC3b
6	2000	SC3b
88	Refused	R9
99	Don't Know	R9

SC3b Month

1	January	R9
2	February	R9
3	March	R9
4	April	R9
5	May	R9
6	June	R9
7	July	R9
8	August	R9
9	September	R9
10	October	R9
11	November	R9
12	December	R9
88	Refused	R9
99	Don't Know	R9

IF (SC3a = 2 and [REBATE YEAR] = 1996) or (SC3a = 3 and [REBATE YEAR] = 1997) or ([MAYBE MOVED] = 1) then ask R9, Else Skip to R10.

R9. Did you purchase a refrigerator for this address during 1996 or 1997, for which you received a rebate from PG&E?

1	Yes	T&T
2	No	R10
88	Refused	R10
99	Don't Know	R10

R.HOUSEHOLDS WHERE THERE USED TO BE REFRIGERATOR REBATE PARTICIPANT

READ: I would now like to ask you some questions about your refrigerator.

R10. Was there a refrigerator at (ADDRESS) when you moved in?

1	Yes	R20
2	No	R100
88	Refused	R11
99	Don't Know	R11

R11. When you moved into your home, what best describes how you obtained your refrigerator?

1	We moved our refrigerator from our previous address.	R100
2	We purchased a new refrigerator.	R100

3	Someone gave us a refrigerator.	R100
4	We kept the existing refrigerator from the previous occupant.	R20
5	Our landlord provided us with a refrigerator.	R20
88	Refused	T&T
99	Don’t Know	T&T

R20. Was the refrigerator a (BRAND), which was a (TYPE) unit?

1	Yes	R20a
2	No	R100
88	Refused	R20a
99	Don’t Know	R20a

R20a. Do you still have this refrigerator?

1	Yes	R30
2	No	R21
88	Refused	R21
99	Don’t Know	R21

R21. What happened to the refrigerator? (DO NOT READ LIST)

1	Broke	R21b
2	Damaged in fire, earthquake, flood or other disaster	R21b
3	Sold it or gave it away	R21a
4	Put it at another address I’m responsible for	R21b
5	Still have it	R30
77	Other (Specify)	R21b
88	Refused	T&T
99	Don’t Know	T&T

R21a. Why did you sell or give away your refrigerator away?

1	Remodeled Kitchen	R21b
2	Needed Larger Unit	R21b
3	Didn’t like Unit	R21b
4	Had Repair Problems	R21b
5	Was Given better Unit	R21b
77	Other (Specify)	R21b
88	Refused	R22b
99	Don’t Know	R22b

R21b. In what year and month did this happen?

R21b Year

1	1995	R21c
2	1996	R21c
3	1997	R21c
4	1998	R21c
5	1999	R21c
6	2000	R21c
88	Refused	R22a
99	Don’t Know	R22a

R21c Month

1	January	R22a
2	February	R22a
3	March	R22a
4	April	R22a
R25	May	R22a
6	June	R22a
7	July	R22a
8	August	R22a
9	September	R22a
10	October	R22a
11	November	R22a
12	December	R22a
88	Refused	R22a
99	Don’t Know	R22a

IF R21 = 1 then ask R22a
IF R21 = 2 then ask R22b
Else Skip to R23

R22a. Was the unit replaced under warranty?

1	Yes	R22d
2	No	R22c
88	Refused	R22c
99	Don’t Know	R22c

R22b. Was the unit replaced through insurance?

1	Yes	R22d	R2
2	No	R22c	R2
88	Refused	R22c	R2
99	Don’t Know	R22c	R2

R22c. Was the unit replaced at all?

1	Yes	R22d
2	No	R26
88	Refused	R26
99	Don’t Know	R26

R22d. Was it replaced with a refrigerator of the same efficiency?

1	Yes	R26
2	No	R26
88	Refused	R26
99	Don’t Know	R26

IF R21 = 3,4,77 then ask R23, Else Skip to R26

R23. To the best of your knowledge, is the new owner or new location of the refrigerator somewhere in central or northern California?

1	Yes	R25
2	No	R24
88	Refused	R26
99	Don’t Know	R26

R24. What state is the refrigerator now in?

1	Specify	R25
88	Refused	R25
99	Don’t Know	R25

R25. What city/area is the refrigerator now in?

1	Specify	R26
88	Refused	R26
99	Don’t Know	R26

IF R21 = 3,77, Then Ask R26
Else,
IF R21=1 or 2 THEN SKIP TO R35
IF R21=4 or 5, or R20a=1 THEN SKIP TO R30

R26. Was the refrigerator still in good working condition when you last had it?

1	Yes	R35
2	No	R27
88	Refused	R35
99	Don’t Know	R35

R27. What problems did you have with the refrigerator? (DO NOT READ)

1	Broken/Needed Major Repair/Too Expensive to Fix	R35
2	Needed Minor Repair	R35
3	Made Noises	R35
4	Leaked	R35
5	Too expensive to operate	R35
77	Specify	R35
88	Refused	R35
99	Don’t Know	R35

Only ask if R21=4 or 5, or R20a=1

R30. How is the refrigerator currently being used?

1	As a main refrigerator	R30a
2	As a spare or secondary refrigerator	R30a
3	Stored unused/unplugged	R30a
88	Refused	R30a
99	Don’t know	R30a

R30a. Is the refrigerator still in good working condition?

1	Yes	R35
2	No	R30b
88	Refused	R35
99	Don’t Know	R35

R30b. What problems did you have with the refrigerator? (DO NOT READ)

1	Broken/Needed Major Repair/Too Expensive to Fix	R35
2	Needed Minor Repair	R35
3	Made Noises	R35
4	Leaked	R35
5	Too expensive to operate	R35
77	Specify	R35
88	Refused	R35
99	Don’t Know	R35

Read to All:
Now, we’d like to ask you about any spare refrigerator you might own.

If R30 = 2 or 3 skip to R36, Else ask R35.
R35. Do you own a second refrigerator?

1	Yes	R36
2	No	R40
88	Refused	R40
99	Don't Know	R40

R36. How often is your spare refrigerator plugged in and being used?

1	Always	R37
2	Most of the time	R37
3	About half the time	R37
4	Some of the time	R37
5	Rarely or Never	R40
88	Refused	R37
99	Don't Know	R37

R37. During the summer, how often is the refrigerator being used?

1	Always	R40
2	Most of the time	R40
3	About half the time	R40
4	Some of the time	R40
5	Rarely or Never	R40
88	Refused	R40
99	Don't Know	R40

Read to All:
Now, we'd like to ask you a few questions about your home.

R40. To the best of your knowledge has there been any major kitchen remodeling or renovation performed at (ADDRESS) since (REBATE YEAR)?

1	Yes	R41
2	No	R42
88	Refused	R42
99	Don't Know	R42

R41 During what year did that remodeling occur?

R41 Year

1	1995	R42
2	1996	R42
3	1997	R42
4	1998	R42
5	1999	R42
6	2000	R42
88	Refused	R42
99	Don't Know	R42

R42. What type of residence do you live in?

1	Single Family Detached Home	R43
2	Townhouse (also duet home, duplex)	R43
3	Condo	R43
4	Apartment (also multifamily, multi-unit)	R43
5	Mobile Home	R43
77	Other (specify)	R43
88	Refused	R43
99	Don't Know	R43

R43. Do you own or rent this residence?

1	Own/buying	R44
2	Rent/lease	R44
77	Other (specify)	R44
88	Refused	R44
99	Don't Know	R44

R44. How many people are in your household, including yourself?

1	Number of people	R99
88	Refused	R99
99	Don't Know	R99

ASK R99 if (R20 = 88 or 99) AND (R20a = 1 or R21 = 5)
Else skip to R300
R99. Can you go to the refrigerator for me, and verify if it is a (BRAND), (TYPE) unit?

1	Yes	R300
2	No	R300
88	Refused	R300
99	Don't Know	R300

NOTE TO AUTHOR: provide instructions to interviewers for location of brand name for commonly installed units through the program.

ASK R100 IF R10 = 2, or R11 = 1, 2, 3, or R20 = 2
Else skip to R300
R100. What is the age of your current refrigerator? (IF MORE THAN ONE, ONLY ASK ABOUT PRIMARY REFRIGERATOR).

1	Enter Years	R101
88	Refused	R101
99	Don't Know	R101

R101. It is important to PG&E to speak with the previous occupant of your home to obtain information about their refrigerator. Our records show that the name of the previous occupant was [OLD NAME]. Do you know the city and state [OLD NAME] has moved to?

R101a. City

1	Specify City	R101b	R
88	Refused	R101b	R
99	Don’t Know	R101b	R

R101a. State

1	California	R300	R
77	Specify State	R300	R
88	Refused	R300	R
99	Don’t Know	R300	R

R300 Goodbye!

Those are all of my questions. Thank you very much for taking the time to participate in this study.