EXH. CAK-4 (Apdx. B)
DOCKETS UE-19___/UG-19___
2019 PSE GENERAL RATE CASE
WITNESS: CATHERINE A. KOCH

BEFORE THE
WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION, **Complainant,** **v.** **PUGET SOUND ENERGY,** **Respondent.**	**Docket UE-19____** **Docket UG-19____**

APPENDIX B (NONCONFIDENTIAL) TO THE THIRD EXHIBIT TO THE PREFILED DIRECT TESTIMONY OF

CATHERINE A. KOCH

ON BEHALF OF PUGET SOUND ENERGY

JUNE 20, 2019

PSE Gas AMR Gas Module Weibull Analysis

1 Introduction:

PSE has enlisted the services of Maintenance and Test Engineering LLC to perform a Weibull statistical analysis on AMR meter and module failure data. This analysis is to assist PSE in better predicting the future reliability of its AMR system currently operated by Landis + Gyr. While the initial intent was to analyze gas module and battery populations, time did not permit any detailed analysis of the batteries. This analysis is limited to Landis + Gyr gas AMR modules.

Due to data availability problems and the inability to segregate failure data by exact cause of failure, this analysis should not be considered as exact but it is of enough detail and accuracy to provide decision makers with insights into the current and future performance of the Landis + Gyr gas AMR system. The findings of this analysis should not be used to characterize the electric AMR system.

2 EXECUTIVE SUMMARY

PSE has been using the L+G AMR system for almost 15 years and the system is nearing the end of it contractual life but its true operational life is unknown. In order to better determine the true operating life of the gas AMR system, a statistical approach known as Weibull Analysis was employed to obtain a better understanding of the actual reliability characteristics of the gas AMR system.

For PSE AMR gas installations, there are three distinct elements that fail:

- The gas meter
- The battery
- The Landis + Gyr gas module

PSE has nearly a century of experience with the gas meters and while an analysis of meter failure characteristics would be interesting and helpful, probably little new information would be gained from the analysis. Similarly, battery life has been well documented by both the manufacturers and users of batteries and little or no new insights would be gained by an in-depth analysis. Gas modules are different, user experience is limited and detailed reliability documentation is unavailable. Analysis of gas module failure data is of high value to PSE and thus a prime candidate for Weibull Analysis.

In a Weibull Analysis, homogeneous data sets are identified, analyzed and life characteristics determined. In the case of PSE, gas meter homogeneous modules data sets (subpopulations) were defined by:

- Module part number

  Modules with the same part number are of the same base design and generally are manufactured in similar ways.

- Cause of failure
  Generally the mechanism for a specific cause of failure is repeatable and the consequence of common device characteristics. For example, tire wear is generally a function of road miles but tire blow-outs are a function of road conditions and thus a separate cause of tire failure.

The results of a Weibull analysis are the parameters for an equation (Weibull function) that identifies:

- The age of the device population when 63% of the population is expected to fail.
- How the failure rate changes with time (does it stay constant, increase with age, decrease with age)
- The guarantee period, the period of time when no failure are expected. *Note: the guarantee parameter was not applicable to the subpopulations studied since failures started to take place very early in the module's life.*

The Weibull analysis was performed on nine (9) separate module subpopulations covering over 95% of the modules installed by PSE and three modes of failure. This actual analysis included data from over 1 million gas modules or 83% of the total historical population of modules installed by PSE. The remaining 17% of the gas modules were excluded for mainly two reasons:

- Failure and population data was not available or unusable
- The subpopulation of the homogenous group was small, less than 1% of the total.

Results from the analysis are summarized as follows:

- Gas module failure rates for all homogenous subpopulations are higher than one would expect from a modern AMI gas module. For some populations, annual failure rates are more than 10 times higher than expected. Because these modules are an important element of the revenue stream, high reliability are generally expected.
- On an annual basis, the annual failure rate of all gas modules nears 2%, nearly four times higher than the 0.5% expected by many utilities.
- For most homogeneous subpopulations the failure rates are increasing with time, for a few subpopulation they are stable but still at a higher than desirable level.
- Newer subpopulations are generally less reliable than older subpopulations.
- Active retirement of some subpopulations should be considered.

3 About Weibull

The Weibull distribution is widely used for life analysis. The Weibull probability distribution was first developed in 1951 and since that time has been used widely by equipment manufactures to predict failure rates, warrantee replacements and to identify unique modes and causes of failures. Landis + Gyr has previously used Weibull techniques to determine the reliability of AMR modules. Some of these findings have been shared with PSE.

3.1 The Weibull Equation

The Weibull cumulative probability function has an explicit equation:

$$F(t) = 1 - e^{-(t/\eta)^{\beta}}$$

Where: F(t) = fraction of the population failing

t = failure time

η =characteristic life

β = slope or shape parameter

A software tool named WeibullSmith™ was used to both to create Weibull plots and compute the above parameters. Three critical concepts to understand to when looking at the results generated by the Weibull Smith software are:

- η or the characteristic life is the time at which 63% of the population of modules under analysis are expected to have failed.
- β or the shape parameter describes the rate of failure:
  - β < 1 indicates failures are decreasing with time
  - β = 1 indicates the failure rate is constant and failures are random
  - β > 1 indicates the failure rate is increasing with time
- When the data on a Weibull forms a straight line, one cause of failure is generally dominant, if the plot has a “dog leg” more than one cause of failure is occurring.

3.2 Weibull Software

WeibullSmith™ software developed by Fulton Findings was used in this analysis. The software allowed for the easy loading of data. Two general types of data were entered for each subpopulation:

- Failures-For a specific mode of failure, the age of each failed module was imported into the analytic tool.
- Suspension-The age of every module that had not failed was imported into the tool. The age was based on the original installation date and either:
  - The date last removed from service
  - July 1, 2014-the date of the data extract from PSE’s MDMS

3.3 Data Source

The primary main source of the data was the PSE Meter Data Management System. The system has tracked gas module installation since 2003 as well as removal and failure information. The secondary data source was Landis + Gyr. L+G who provided module installation dates for those modules installed prior to 2003 and also module part numbers that identified unique module population sets.

3.4 Typical Weibull Plot-CDF

A typical Weibull plot showing the Cumulative Density Function (CDF) is shown Figure 3-1 below along with some of the key attributes.

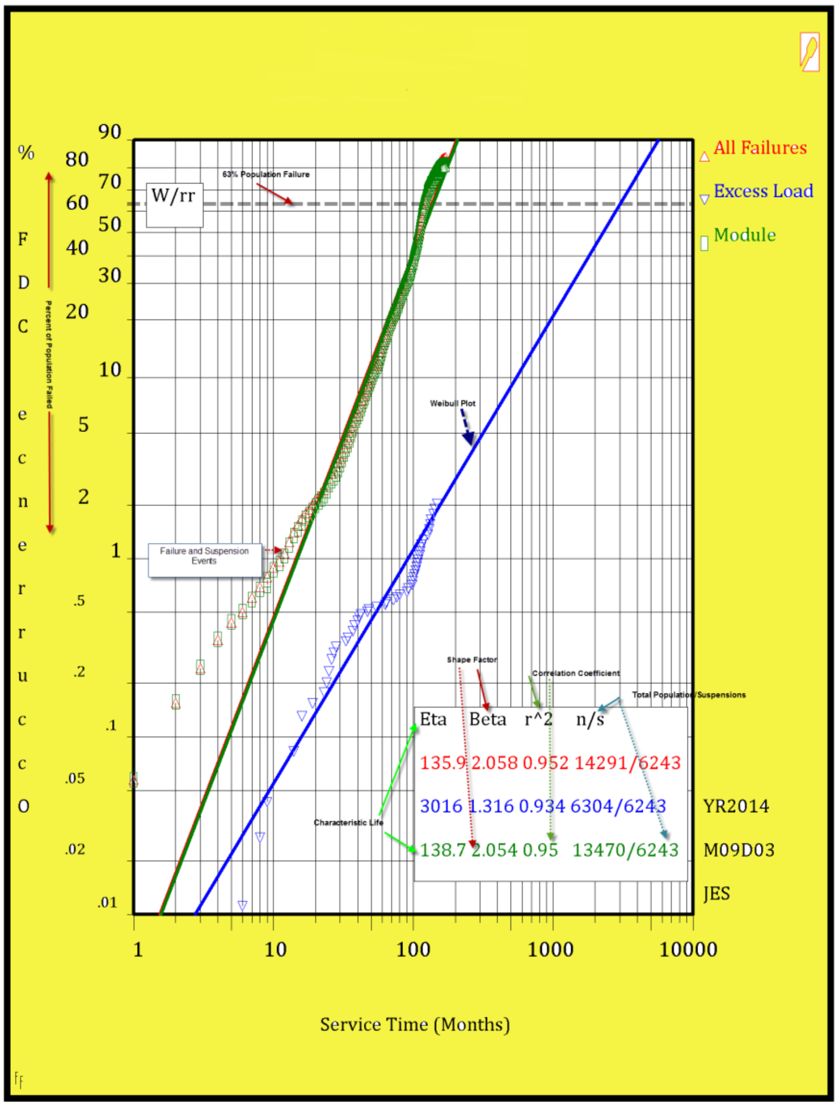

Figure 3-1: Typical Weibull Graph-Cumulative Density Function

3.5 The Probability Density Function (PDF)

For the two largest populations of gas modules, a plot of the Probability Density Function (PDF) is also provided. The Probability Density Function has the following properties:

- The plot shows the probability of failure as the module ages.
- The area bounded by the curve of the density function and the x-axis is equal to 1, when computed over the life of the module.
- Using the average age of the module population, this curve is a prediction of the failure rate for the complete population. Multiplying the probability values by 12 results in the annual failure rate.

4 Population Examined and Analyzed

Since the introduction of gas AMR at PSE, existing mechanical gas meters have been retrofitted with at least 66 AMR modules from Landis + Gyr each having different part numbers. The subpopulation for each part number ranges from a low of one module installed to a high exceeding one-half million. Over 95% of the installed modules are contained within a group of nine (9) different part numbers. These nine (9) part numbers are the focus of this analysis and represented in the graphs below.

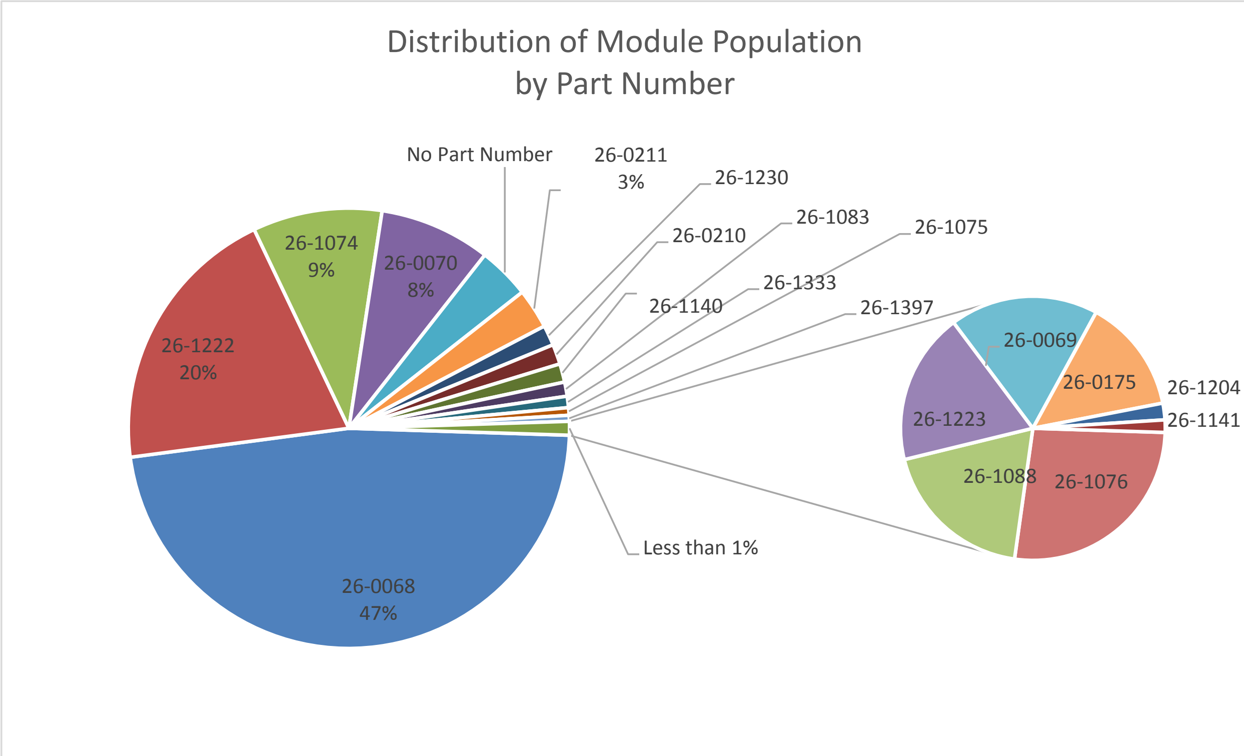

Figure 4-1: Distribution of L+G Gas Module Part Numbers at PSE

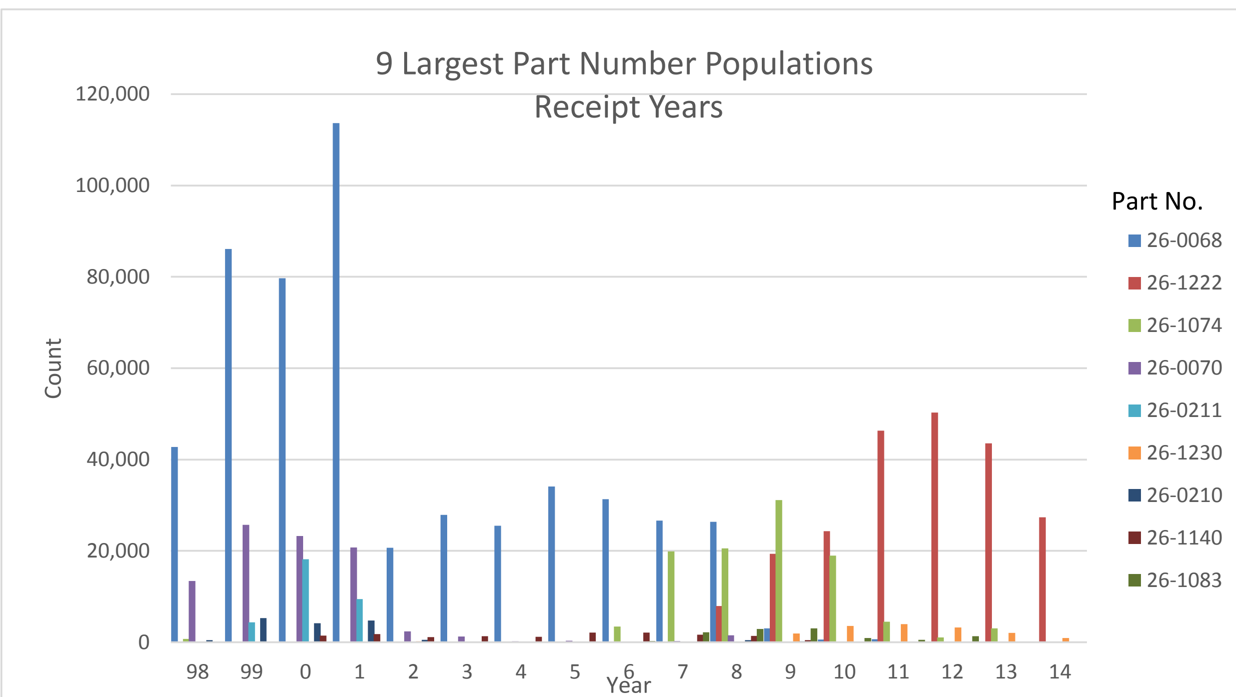

Figure 4-2: Gas Module Installation Years Segmented by Part Number for the Nine Largest Gas Module Subpopulations

5 Modes of Failure

While the L+G gas module has self-test capabilities and problem flags are transmitted through the network to their Op Center, detailed cause information is not provided by the AMR system or L+G. In the event of a module failure, repair personnel could sometimes determine the general cause of module failure and report their findings. Because the cause of failure was generally fairly vague, Weibull analysis could only be performed at the "Mode" level and not the more detailed "Cause" level. While this lack of failure detail does result in analytic compromises, they are not considered as severe. Fortunately, since most modes of failure have only one or two dominant cause, the compromises only tend to impact module manufacturing and design decisions but not operational decisions being considered by PSE.

For all 9 modules families analyzed, three categories of failure were investigated and reported:

- All Failures-includes any failure that were attributed directly to the module and the module drive mechanism. Excluded Battery failures and failures of an unknown origin
- Excessive Load-Excessive leakage/drain current caused by the module resulting in a shortened battery life (4 years or less)
- Module-Electronic and firmware components that are found on or programmed into the module circuit board.

6 Analytical Challenges

While both PSE and Landis + Gyr have collected a tremendous amount of gas module failure and operational data, the data sets were adequate but by no means perfect. Dealing with continuously changing data from more than a million modules for over a decade has challenges. Some of the challenges included:

6.1 No Part Number

The L+G part number was the dominant means of identifying unique module populations, over 41 thousand (3%) modules are not associated with a specific part number. These modules were excluded from the analysis.

6.2 Default Install Date

The installation date of a module was a critical parameter for the Weibull analysis. The PSE MDMS went into service in approximately 2003 while the installation of gas modules began in 1998. Modules installed during much of AMR deployment were assigned a default installation date of January 3, 2003. L+G was able to provide installation dates for many of these pre-2003 modules but still 137,000 modules had to be excluded from the analysis because their installation date was unknown.

6.3 No Failure Cause Reported

Most of the module replacement work performed by the L+G contractor that was recorded in the MDMS used only a single task completion code thus giving little or no insight into the cause of the module failure. For these modules, the L+G MARP code was used identify the mode of failure.

6.4 Field Actions of Insufficient Detail

On a large population of meters, the mechanical interface between the module and the gas meter failed. The cause of the failure included:

- Installation errors
- Excessive module drag
- Weak meter components

It was impossible to accurately segregate these causes.

7 Results

Gas module failure and suspension data from the PSE MDMS was segmented by L+G module part number into nine (9) unique datasets and analyzed using WeibullSmith™ software. The results are tabulated and graphed below (sections 7.3 through 7.3.10). A short commentary follows each set of figures.

7.1 Residential Gas Module Summary Results

As shown in Figure 4-2, residential gas meters make up the majority of the PSE gas module population and thus their projected reliability are of great importance to PSE decision makers. Two part numbers (26-0068 and 12-1222) installed on residential gas meters are of special importance because of their relative large population size (67% of the total) and the fact that part number 12-1222 is being used to replace part number 26-00068. The Weibull results are summarized in sections 7.3.1 and 7.3.2 and their projected performance is summarized in Table 7-1 below. This table indicates that peak module replacement for these two modules will occur in 2021 where approximately 4,000 more modules will need to be replaced than PSE is currently replacing.

While replacement module part number 12-1222 is a much better performer than module part number 26-0068, it still has a disappointing average annual failure rate, probably 5 times higher and one would expect of modern electronics.

26-0068	(11.4 Years-Average Age)								
Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Beginning Population	372,996								
Annual Failure Rate	3.56%	3.72%	3.84%	3.92%	3.97%	3.98%	3.95%	3.90%	3.82%
Modules Replaced	13,266	13,860	14,312	14,622	14,795	14,834	14,747	14,543	14,232
26-1222	(2.5 Years-Average Age)								
Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Beginning Population	206,908								
Failure Rate	1.99%	2.01%	2.01%	2.00%	1.98%	1.96%	1.93%	1.90%	1.87%
Modules Replaced	4,274	4,835	5,246	5,630	6,000	6,358	6,700	7,027	7,334
Total New Installs	17,540	18,695	19,557	20,252	20,795	21,192	21,447	21,569	21,567

Table 7-1: Projected Reliability of Two Primary Residential Gas Modules.

7.2 Commercial Gas Module Summary

As shown in Figure 4-2, commercial gas meters make up the minority but never-the-less important portion of the PSE gas module population and thus their projected reliability are of great importance to PSE decision makers. Two part numbers (26-1140 and 12-1230) installed on commercial gas meters are of special importance because they are the dominant C&I Module and the fact that part number 12-1230 is being used to replace part number 26-1140. The Weibull results are summarized in sections 7.3.7 and 7.3.9 and their projected performance is summarized in Table 7-2 below. This table indicates that peak module replacement for these two modules will occur in 2015 where approximately 220 more modules will need to be replaced than PSE is currently replacing.

Weibull statistics indicate that the replacement module part number 26-1230 performs worse than module 26-1140.

26-1140	(7.6 Years in Service)								
Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Beginning Population	6,430								
Annual Failure Rate	7.55%	7.71%	7.61%	7.30%	6.81%	6.19%	5.50%	4.77%	4.04%
Modules Replaced	486	496	489	469	438	398	353	307	260
26-1230	(2.5 Years in Service)								
Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Beginning Population	10,955								
Failure Rate	12.21%	10.28%	8.65%	7.28%	6.13%	5.16%	4.34%	3.66%	3.08%
Modules Replaced	1,489	1,699	1,632	1,575	1,488	1,383	1,265	1,142	1,020
Total New Installs	1,974	2,195	2,122	2,044	1,926	1,781	1,618	1,449	1,280

Table 7-2: Projected Reliability of Two Primary Commercial Gas Modules.

7.3 Detailed Results

Detailed Weibull analysis of the 9 unique module populations follow.

7.3.1 Part Number 26-0068

L+G Gas Module Part Number 26-0068 is the dominant module deployed at PSE with installations dating back to the start of the project. Currently, 46% of all installed modules are of this part number. Nearly 30% of the population has failed over a 16 year period.

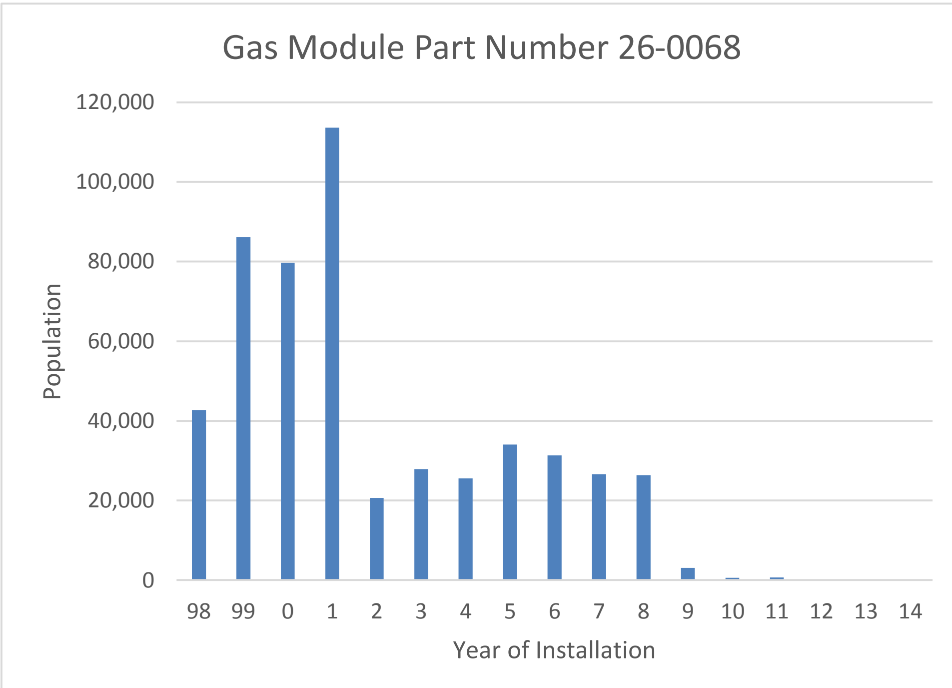

Figure 7-1: Distribution of Module Install Dates for Gas Module Part Number 26-0068

Metric	Value
Total PSE Population	604,473
In-Service	372,996
Average years in Service	11.4
Percent of Current Active Module Population	46%
Suspended	362,064
Excluded because of data problems	89,353
Failed	153,056
Percent Analyzed that have Failed	30%
Average Annual Failure Rate Experienced by PSE	2.6%

Table 7-3: Summary Statistics for Module Part Number 26-0068

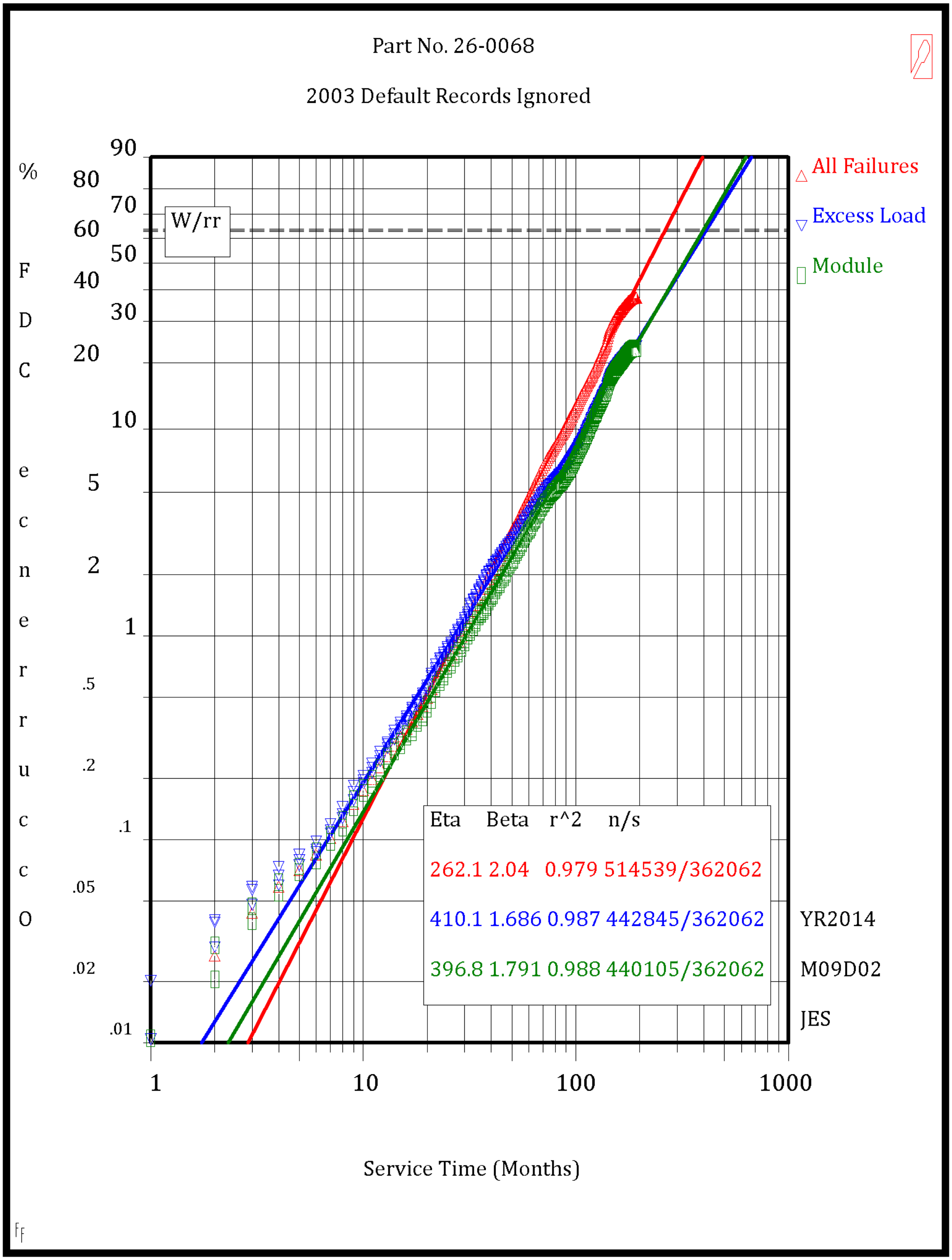

Figure 7-2 - Weibull Plot for Module Part Number 26-0068

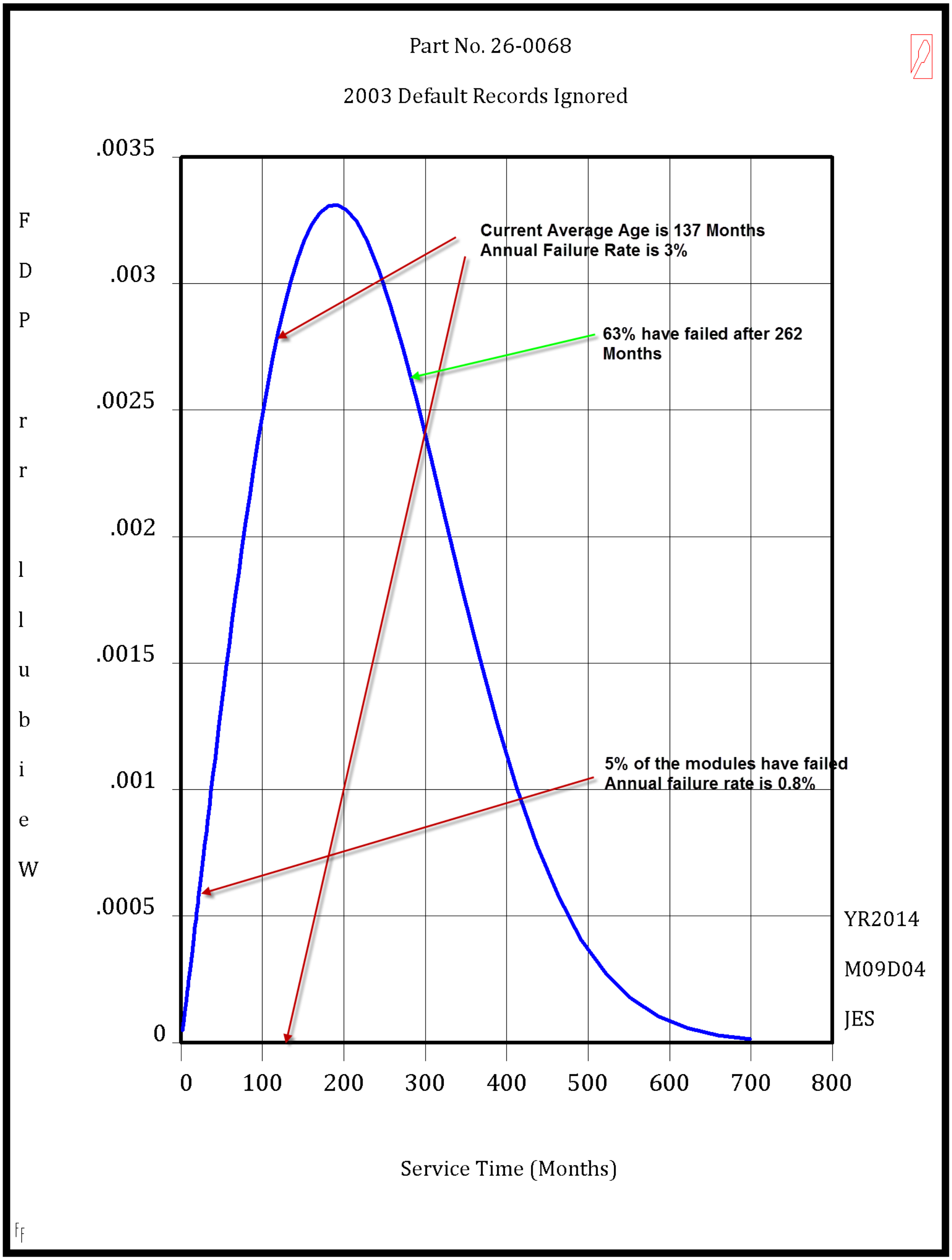

Figure 7-3: The Probability Density Function (PDF)-Failure Rate as a Function of Age (Months) for Part Number 26-0068

7.3.1.1 General Commentary:

This population of gas modules has had a long life and poor reliability. While the annual failure rate at the time when 5% of the population has failed is approximately 0.8% is better than most L+G gas modules, it is not what one should experience from a modern AMI system where annual failure rates of 0.2% to 0.5% are achievable. Unfortunately, this module fails at a higher rate as it ages and thus has an average annual failure rate of 2.6% over its 11.4 year history.

Higher energy usage or excessive leakage current resulting in lower battery life is also an issue with this module part number. Shorter than normal battery life is typical for this population.

7.3.1.2 Future Reliability

The Weibull analysis yields a “beta” value close to two (1.79 to 2.04) which is typical of a module that degrades at an accelerated rate with age. Weibull projections indicate increasing failure rates in the near future, which may be problematic due to the part number’s widespread usage. The Probability Density Function (PDF) for this module part number is shown in Figure 7-3 which illustrates how the failure rate is predicted to vary with time, increasing failures in the near term and then decreasing total failures as the in-service population shrinks.

7.3.2 Part Number 26-1222

This is the second largest subpopulation of modules and is a later generation than the previous subpopulation (part number 26-0068). Over a quarter of the modules in-service today are of this part number.

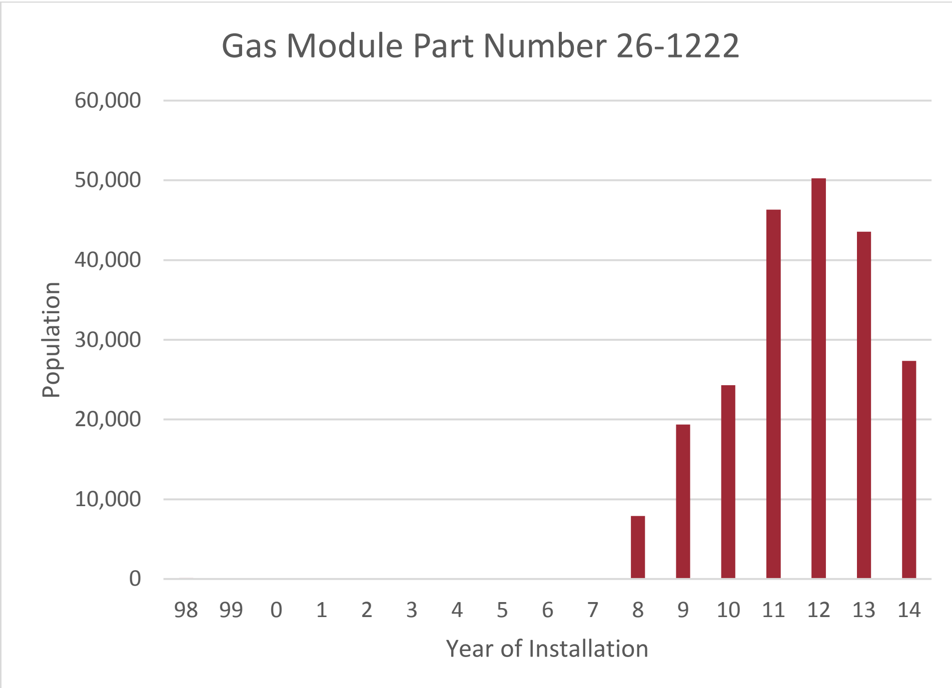

Figure 7-4: Distribution of Module Install Dates for Part Number 26-1222

Metric	Value
Total PSE Population	219,514
In-Service	206,908
Average Years in Service	2.5
Percent of Current Active Module Population	26%
Suspended	207,361
Excluded because of data problems	1,711
Failed	10,442
Percent Analyzed that have Failed	5%
Average Annual Failure Rate Experienced by PSE	1.9%

Table 7-4: Summary Statistics for Module Part Number 26-1222

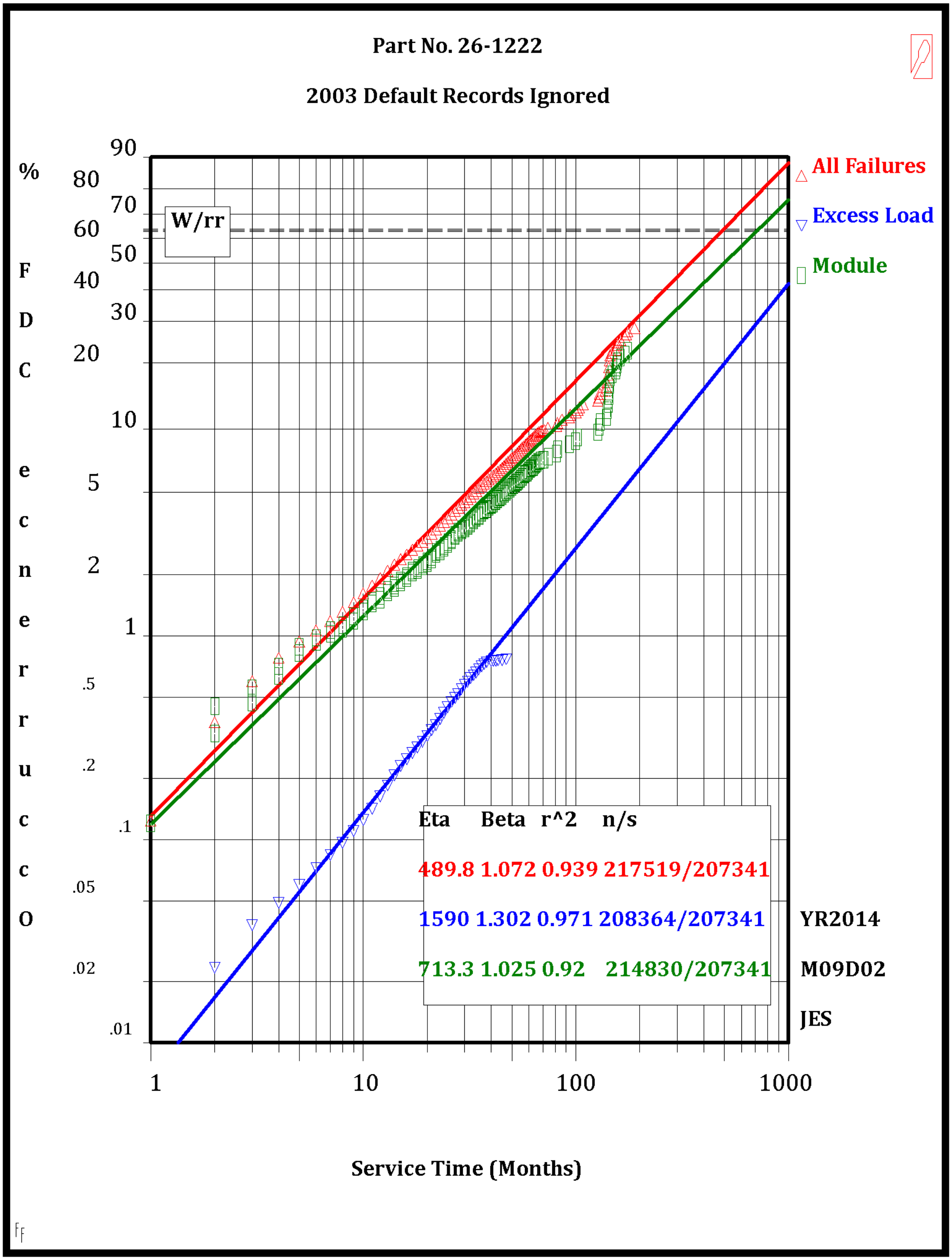

Figure 7-5: Weibull Plot for Module Part Number 26-1222

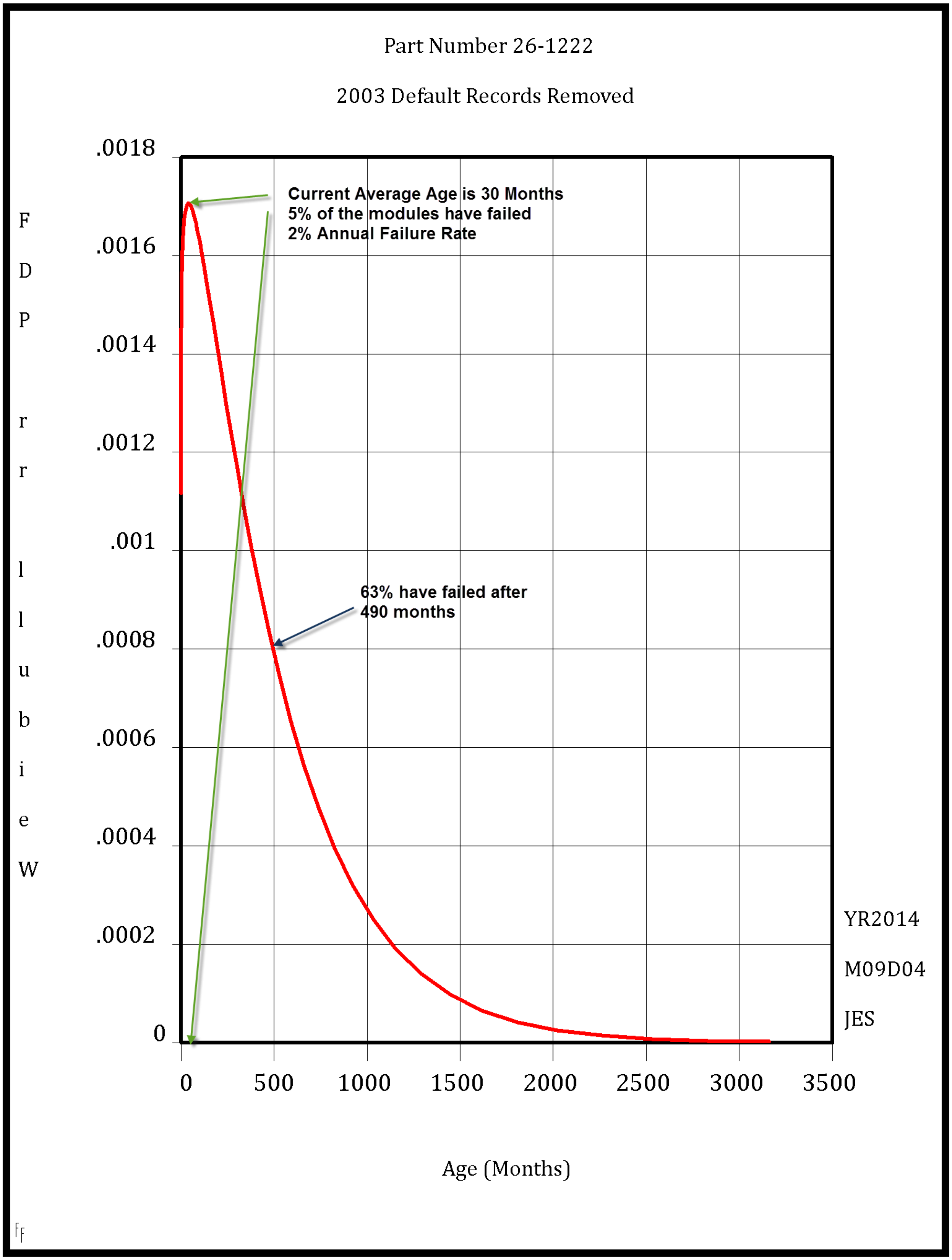

Figure 7-6- The Probability Density Function (PDF)-Failure Rate as a Function of Age (Months) for Part Number 26-1222

7.3.2.1 General Commentary:

This population of gas modules is relatively new but of poor reliability. The annual failure rate of approximately 1.9% is high but average for L+G gas modules. The Weibull characteristic life for this part number is higher than most meters, one would expect this for a module of later design

Excessive leakage current or power consumption resulting in lower battery life is not an issue with module part number. Normal and predictable battery life is typical for this population.

7.3.2.2 Future Reliability

The Weibull analysis yields a “beta” value close to one (1.07) which is typical of a stable module with no dominant cause of failure. Weibull projections indicate no reliability improvements as the subpopulation passes through the infant mortality stage. The shorter characteristic life indicates this part number has an operation life that matches its contractual life.

The Probability Density Function (PDF) for gas module part number 26-1222 is plotted in Figure 7-6. The plot indicates that the failure rate has peaked and should decline as the population ages and decreases. While this sounds like good news, this module is the replacement module for part number 26-0068; operationally, the population will grow as replacements take place in the near term keeping the average age low and the overall population failure rate high.

7.3.3 Part Number 26-1074

This part number has been used mainly for new modules and module replacements. While probably of a later design and manufacture than the original modules, its reliability is suspect.

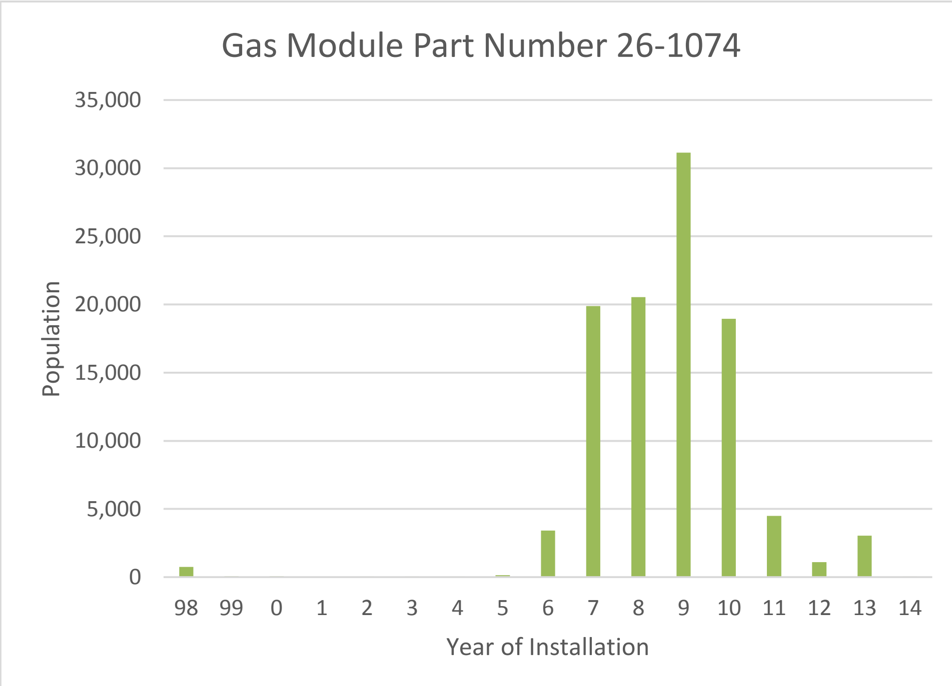

Figure 7-7: Distribution of Module Install Date for Part Number 26-1074

Metric	Value
Total PSE Population	103,801
In-Service	71,175
Average Years in Service	4.8
Percent of Current Active Module Population	9%
Suspended	71,562
Excluded because of data problems	920
Failed	31,319
Percent Analyzed that have Failed	30%
Average Annual Failure Rate Experienced by PSE	6.3%

Table 7-5: Summary Statistics for Module Part Number 26-1074

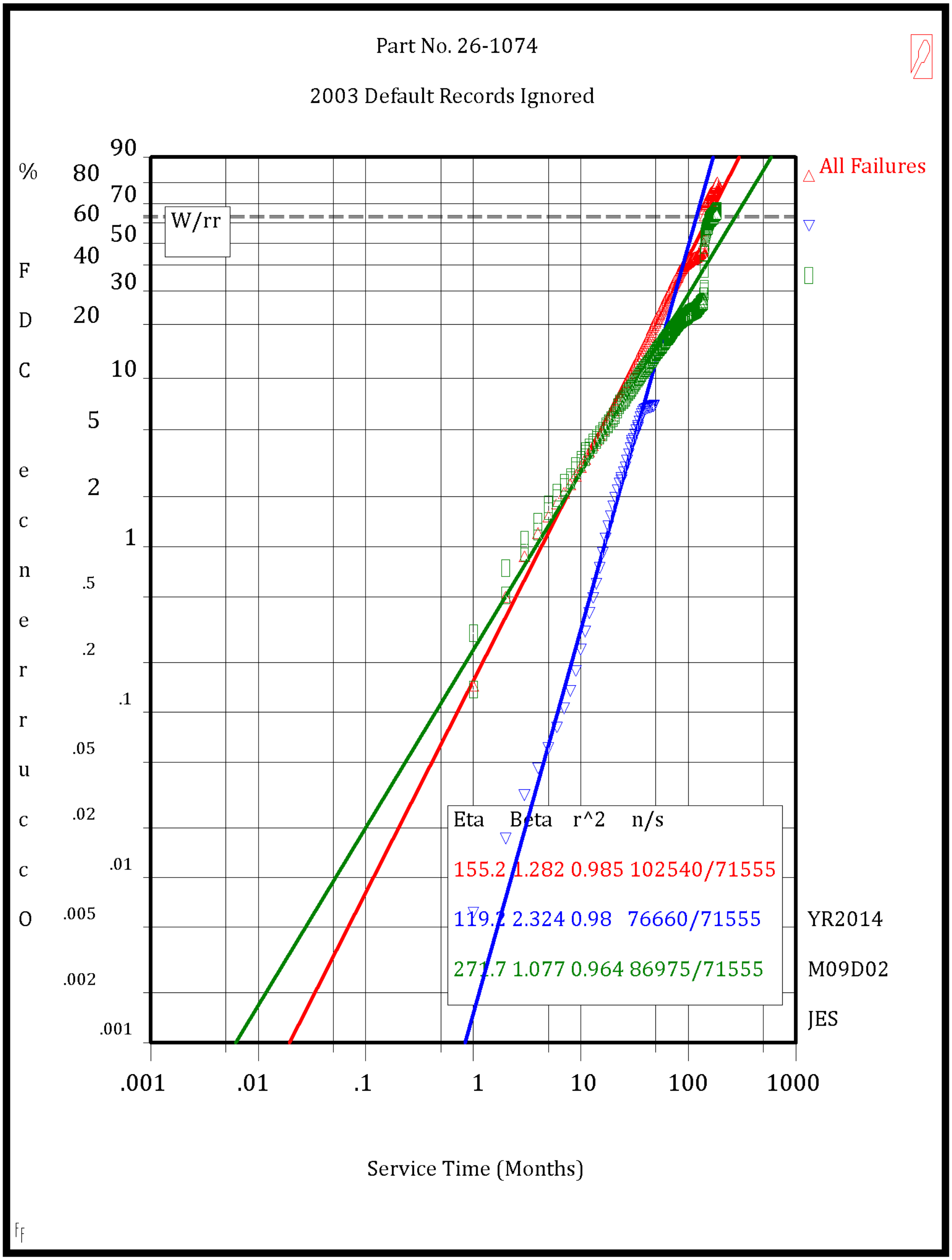

Figure 7-8: Weibull Plot for Module Part Number 26-1074

7.3.3.1 General Commentary:

Module part number 26-1074 has not experienced a long service life and has been one of the most unreliable modules. Having an average service age of approximately 5 years with nearly 30% failed indicates significant issues with the design, manufacturing, installation or all three. The module part number also appears to significantly degrade battery life.

7.3.3.2 Future Reliability

This is another problematic population with an abnormally short characteristic life and a "Beta" slightly greater than one indicating a slowly increasing failure rate as it ages. This population will be problematic until it is retired.

7.3.4 Part Number 26-0070

This part number is associated with early module installations and has been of relatively good reliability.

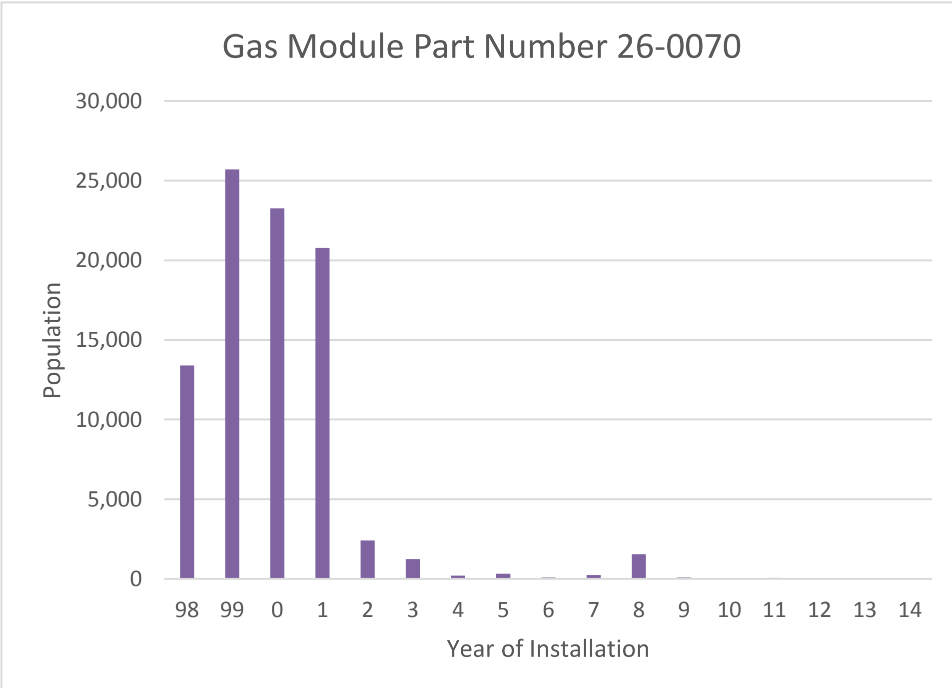

Figure 7-9: Distribution of Module Install Date for Part Number 26-0070

Metric	Value
Total PSE Population	113,750
In-Service	71,531
Average Years in Service	13.2
Percent of Current Active Module Population	9%
Suspended	67,525
Excluded because of data problems	26,070
Failed	20,155
Percent Analyzed that have Failed	23%
Average Annual Failure Rate Experienced by PSE	1.7%

Table 7-6: Summary Statistics for Module Part Number 26-0070

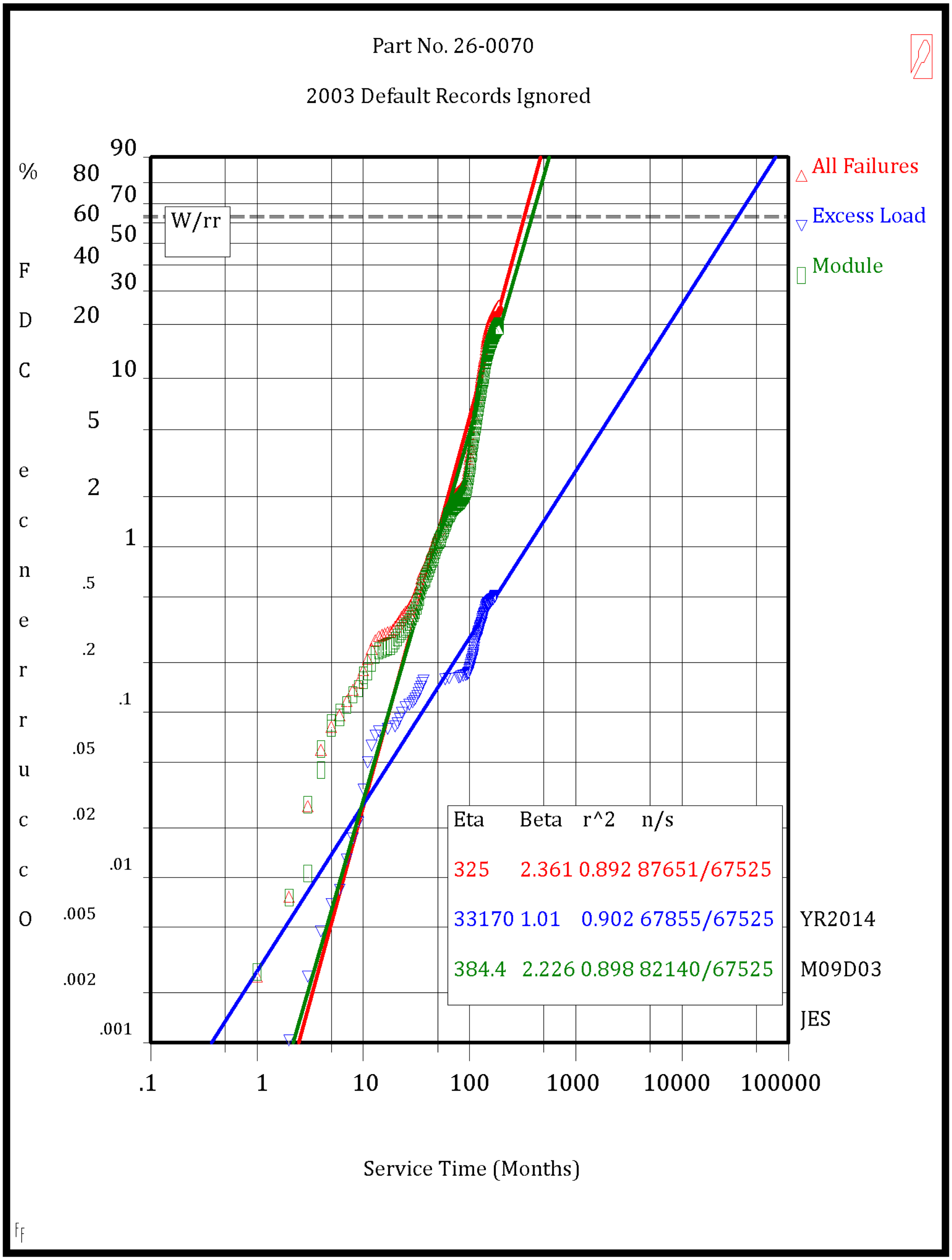

Figure 7-10: Weibull Plot for Module Part Number 26-0070

7.3.4.1 General Commentary:

Until recently, module part number 26-0070 is one of the better performing modules. While its initial average annual failure rate of 0.6% is higher than one would expect today, it has been respectable. Unfortunately, the higher than normal "beta" coupled with a shorter characteristic life means that failure rates will be increasing as the population ages. This can be seen with the aged population PSE has, the failure rate of this module since its installation has averaged 1.7% with modules having an average age of 4.8 years.

Shortened battery life due to excessive leakage current is not problematic for this part number.

7.3.4.2 Future Reliability

This module has a shorter characteristic life and a "Beta" greater than two (2) indicating an increasing failure rate as it ages. This population will become more problematic in the future.

7.3.5 No Part

The following table is meant demonstrate the relatively small population modules not having part numbers that had to be excluded from the analysis. Most of these modules have failed and thus would have resulted in a lowering of reliability metrics for their associated subpopulations but since they comprise less than 4% of the total module population the impact of excluding them is not of great significance.

Metric	Value
Total PSE Population	41,782
In-Service	2,456
Percent of Current Active Module Population	0.3%
Suspended	3,262
Excluded because of data problems	41,801
Failed	38,366

Table 7-7: Summary Statistics for Modules with no part number

7.3.6 Part Number 26-0211

This part number was used during AMR rollout and has performed relatively well.

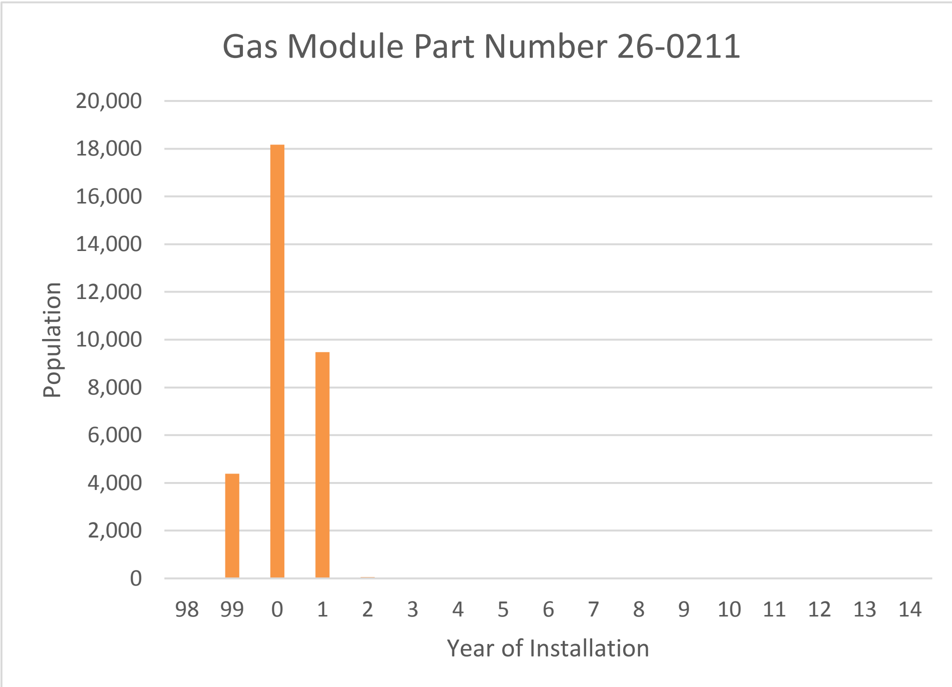

Figure 7-11: Distribution of Module Install Date for Part Number 26-0211

Metric	Value
Total PSE Population	32,343
In-Service	29,094
Average Years in Service	13.8
Percent of Current Active Module Population	4%
Suspended	28,929
Excluded because of data problems	382
Failed	3,032
Percent Analyzed that have Failed	9%
Average Annual Failure Rate Experienced by PSE	0.7%

Table 7-8: Summary Statistics for Module Part Number 26-0211

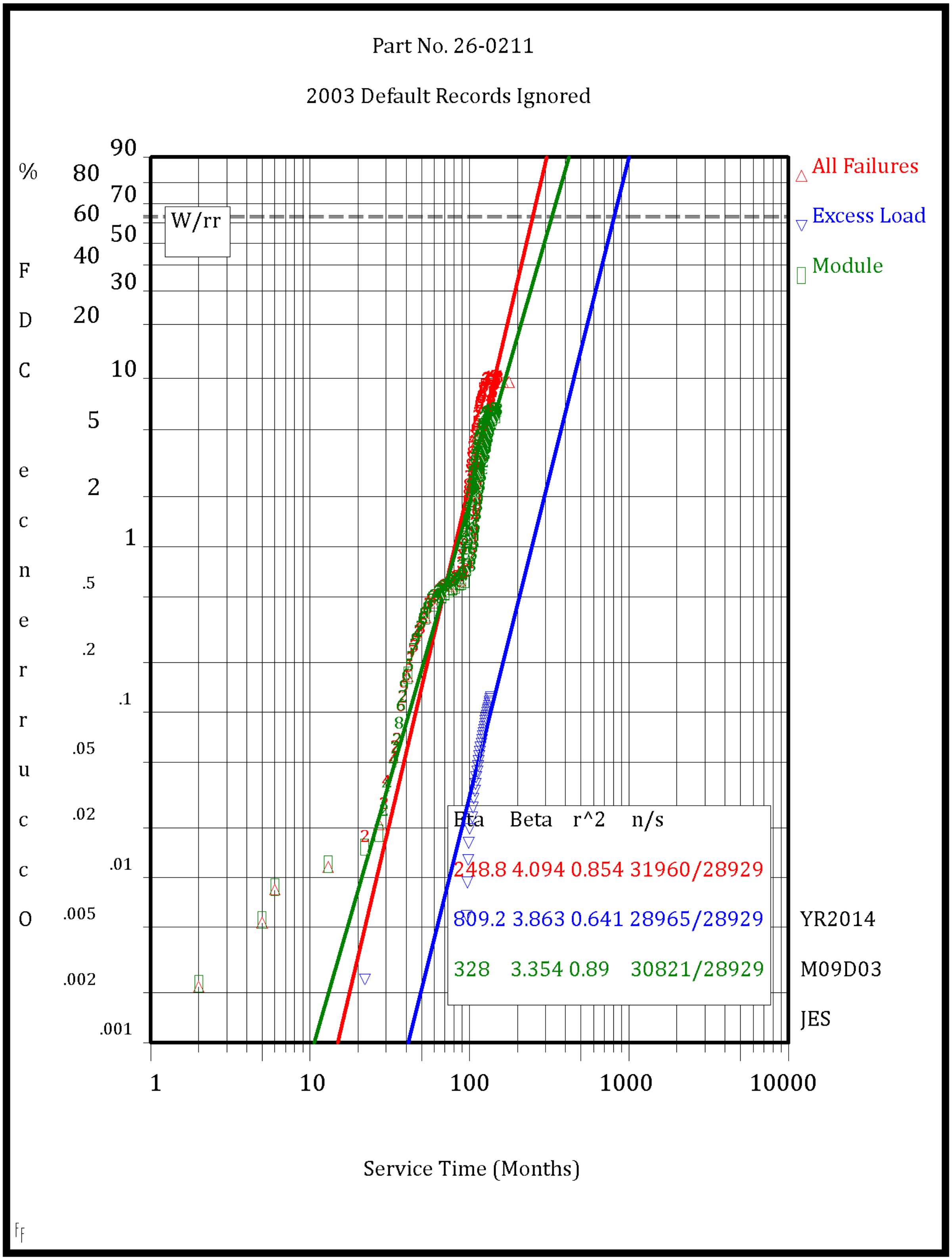

Figure 7-12: Weibull Plot for Module Part Number 26—0211

7.3.6.1 General Commentary:

This has historically been one of the better performing populations with an experienced average annual failure rate of 0.7%. Since this was one of the earlier installed part numbers it is older than most and with a "beta" exceeding 3, failure rates have risen dramatically in the later years. The Weibull plot has a "dog leg" on it indicating multiple causes of failure.

Shorten battery life due to excessive leakage current or load is not problematic for this part number.

7.3.6.2 Future Reliability

With an average age of nearly 14 years, a short characteristic life and a large "beta", the future is not bright for this module. Retirement of these modules when opportunities arise should be considered.

7.3.7 Part Number 26-1230

While this is only a small part of the active gas module population, it is a very poor performing module.

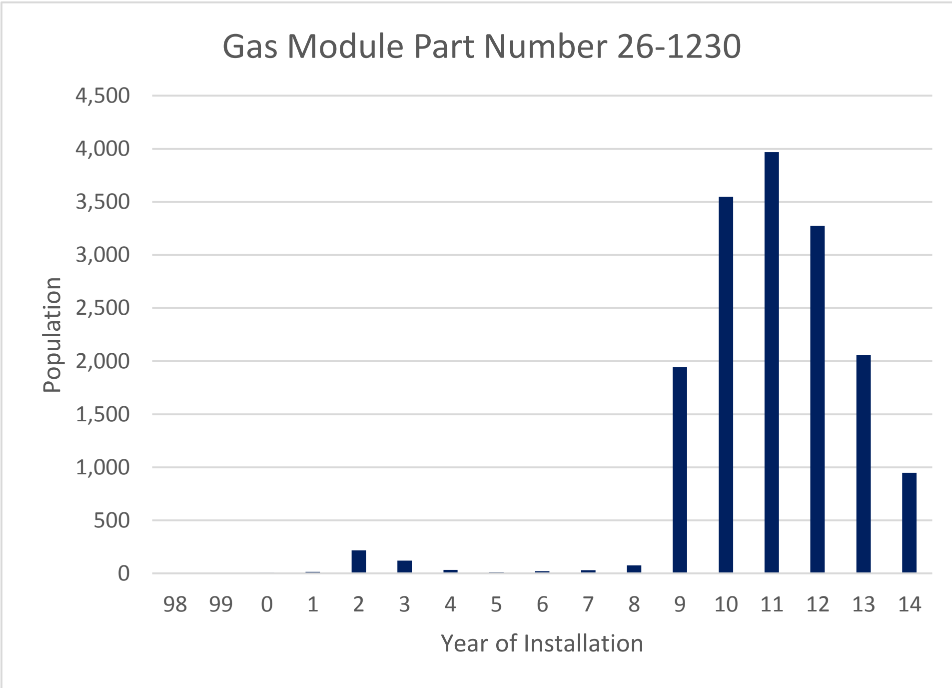

Figure 7-13: Distribution of Module Install Date for Part Number 26-1230

Metric	Value
Total PSE Population	16,282
In-Service	10,955
Average Years in Service	2.5
Percent of Current Active Module Population	1%
Suspended	11,048
Excluded because of data problems	567
Failed	4,667
Percent Analyzed that have Failed	30%
Average Annual Failure Rate Experienced by PSE	11.7%

Table 7-9: Summary Statistics for Module Part Number 26-1230

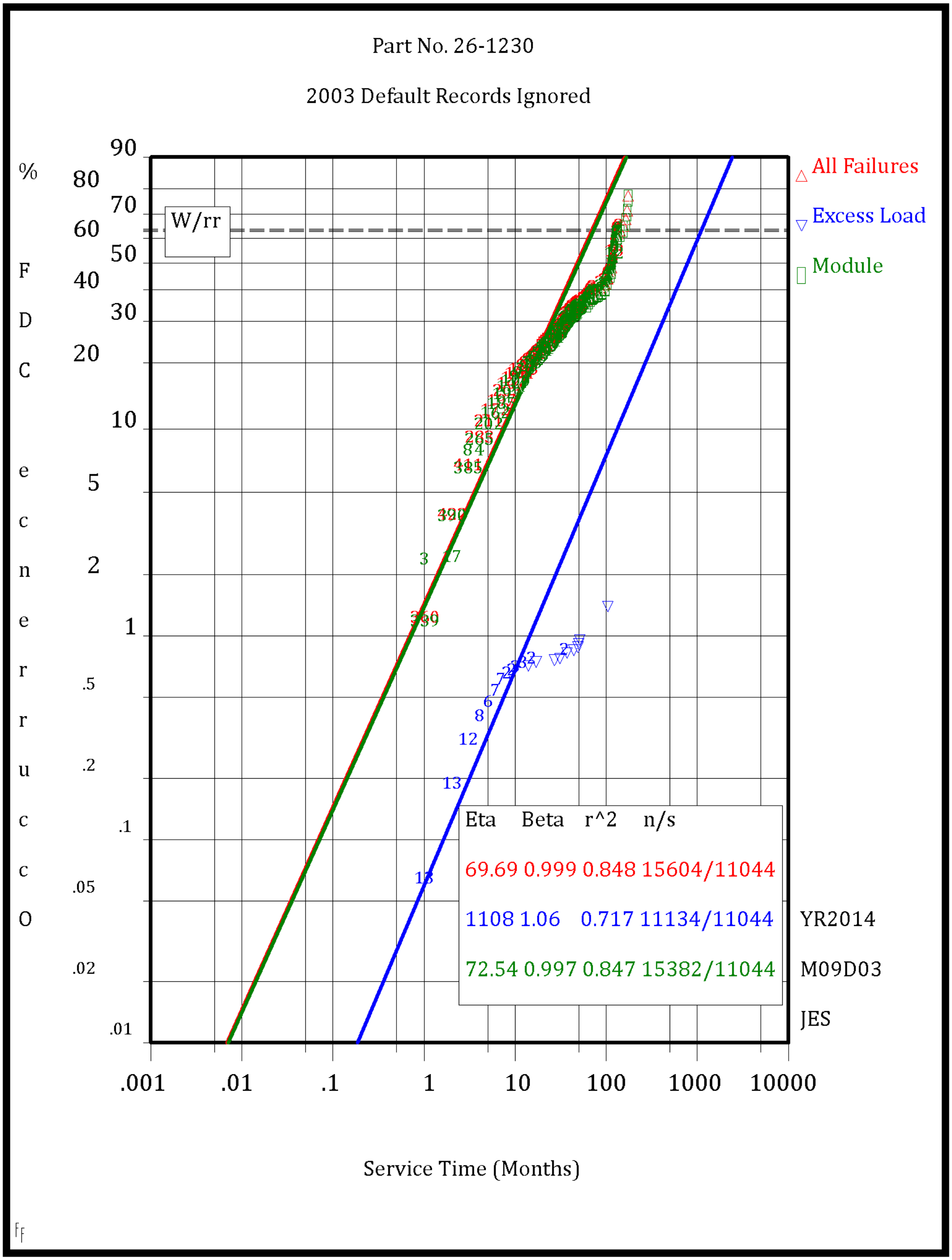

Figure 7-14: Weibull Plot for Module Part Number 26-1230

7.3.7.1 General Commentary:

This is by far the worst performing population of part numbers analyzed. Having an average age of 2.5 years and yet 30% failures tells the story.

Shortened battery life due to excessive leakage current is not problematic for this part number, it is doubtful that most modules of this part number will be in-service long enough to use the total available energy of the battery.

7.3.7.2 Future Reliability

The future is very bleak for this part number. The high annual failure rate is expected to continue.

7.3.8 Part Number 26-0210

Part of the original installation of gas modules, this population has had acceptable performance but is nearing end-of-life.

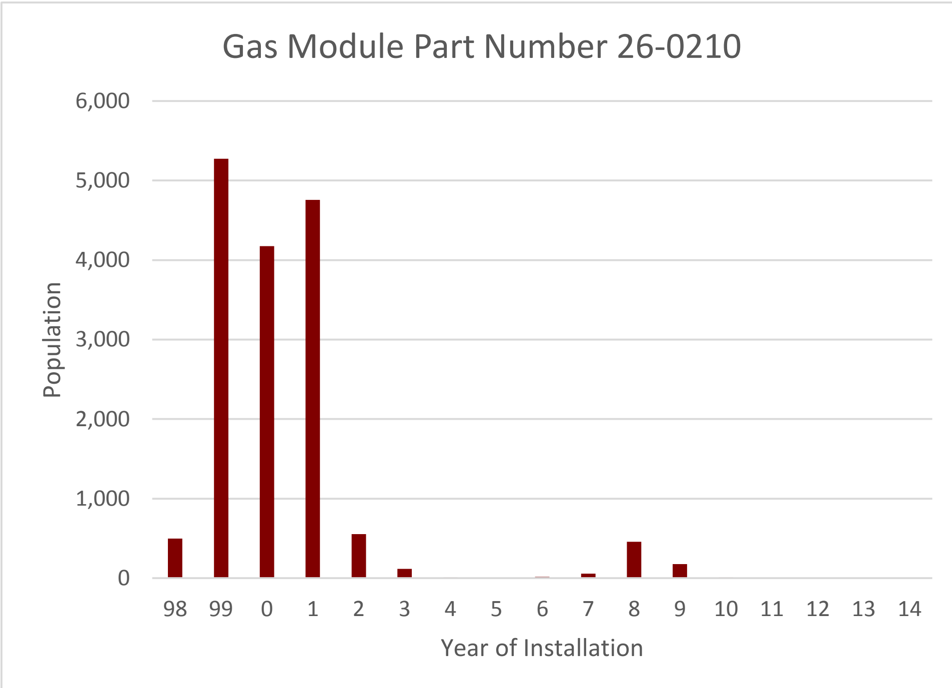

Figure 7-15: Distribution of Module Install Date for Part Number 26-0210

Metric	Value
Total PSE Population	22,340
In-Service	10,519
Average Years in Service	12.3
Percent of Current Active Module Population	1%
Suspended	9,682
Excluded because of data problems	6,350
Failed	6,308
Percent Analyzed that have Failed	39%
Average Annual Failure Rate Experienced by PSE	3.2%

Table 7-10: Summary Statistics for Module Part Number 26-0210

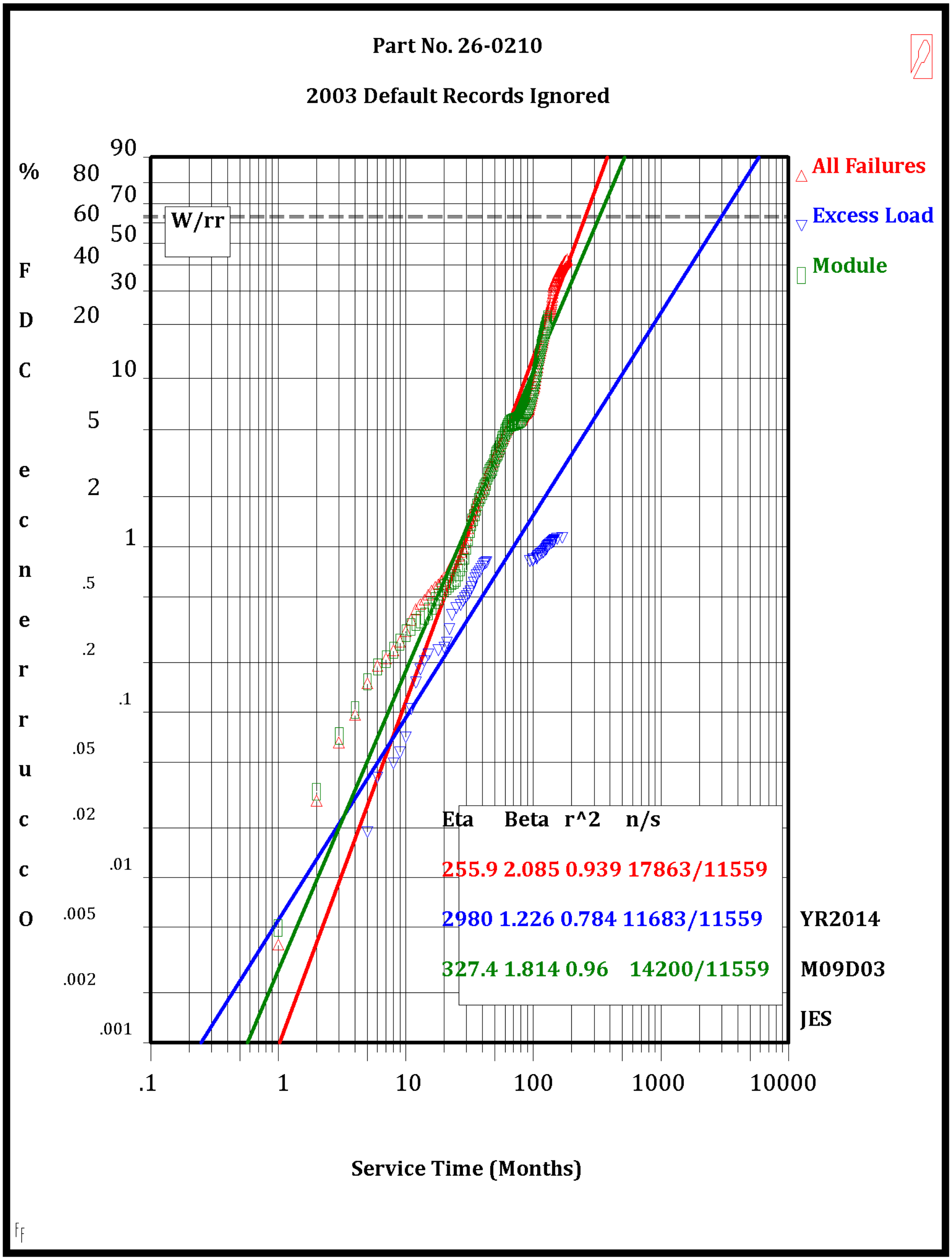

Figure 7-16: Weibull Plot for Module Part Number 26-0210

7.3.8.1 General Commentary:

This has been a relatively reliable part number that is coming close to the end of its life.

Shortened battery life due to excessive leakage current or module load is not problematic for this part number.

7.3.8.2 Future Reliability

With 39% of this part number failed, an average age exceeding 12 years, and a "Beta" of approximately two (2) the part number is at the end-of its useful life and should be considered for retirement.

7.3.9 Part Number 26-1140

This was "mid project" module that has not performed well; over 50% of the modules have failed.

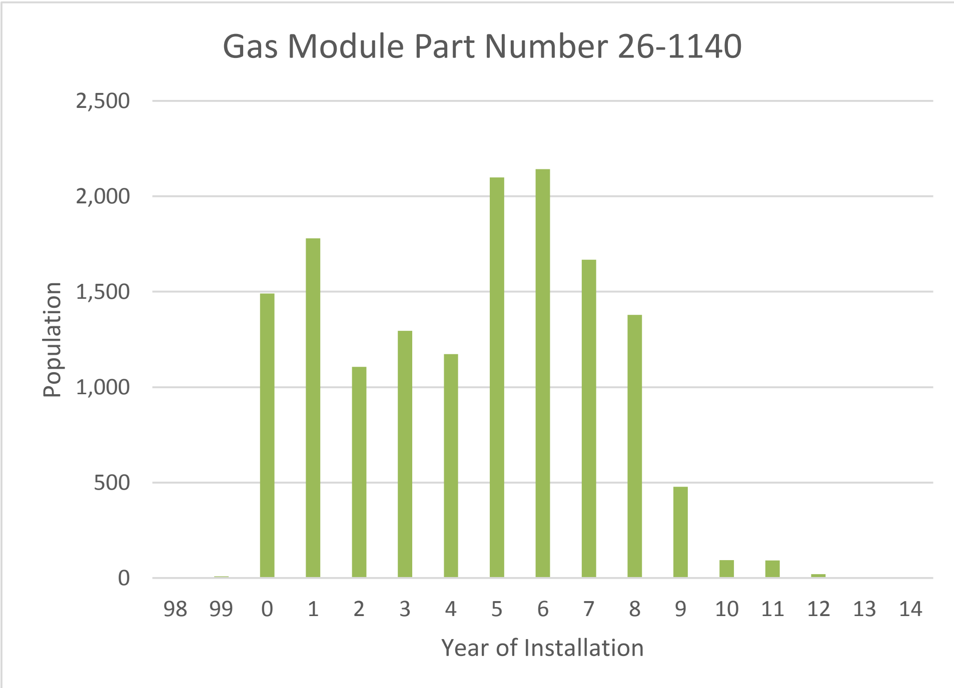

Figure 7-17: Distribution of Module Install Date for Part Number 26-1140

Metric	Value
Total PSE Population	20,005
In-Service	6,430
Average Years in Service	7.6
Percent of Current Active Module Population	1%
Suspended	6,243
Excluded because of data problems	5,670
Failed	8,092
Percent Analyzed that have Failed	56%
Average Annual Failure Rate Experienced by PSE	7.4%

Table 7-11: Summary Statistics for Module Part Number 26-1140

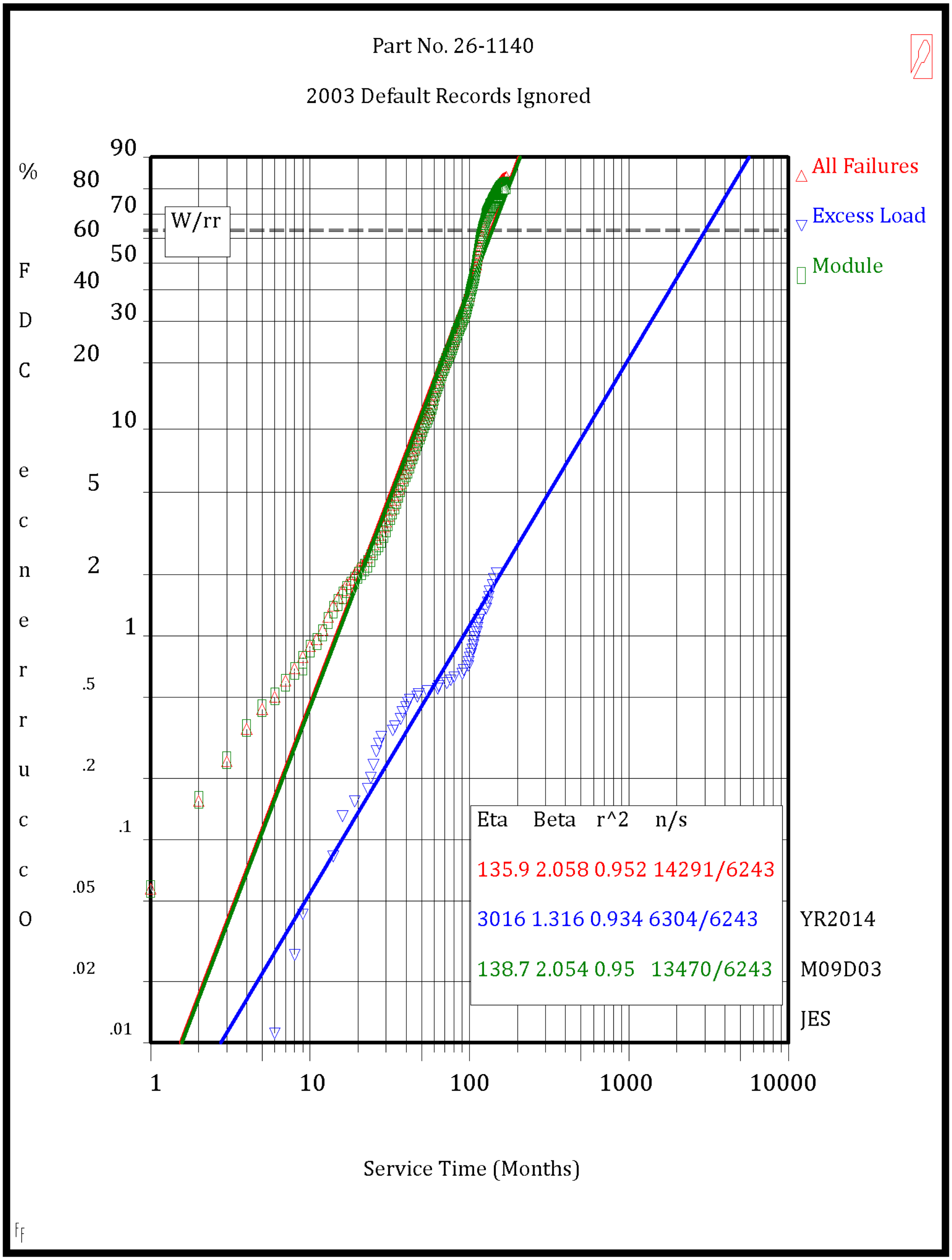

Figure 7-18: Weibull Plot for Module Part Number 26-1140

7.3.9.1 General Commentary:

This has not been a reliable part number that is coming close to the end of its life. Over 50% of the population has failed in less than 8 years. Weibull analysis predicts 63% of the modules will have failed in the first 11.3 years.

Shortened battery life due to excessive leakage current or load is not problematic for this part number.

7.3.9.2 Future Reliability

With 56% of this part number failed, an average age exceeding 7.6 years, and a “Beta” of exceeding two (2); the part number is at the end-of its useful life and should be retired.

7.3.10 Part Number 26-1083

This part number makes up a small percentage of the module population but its reliability has been poor.

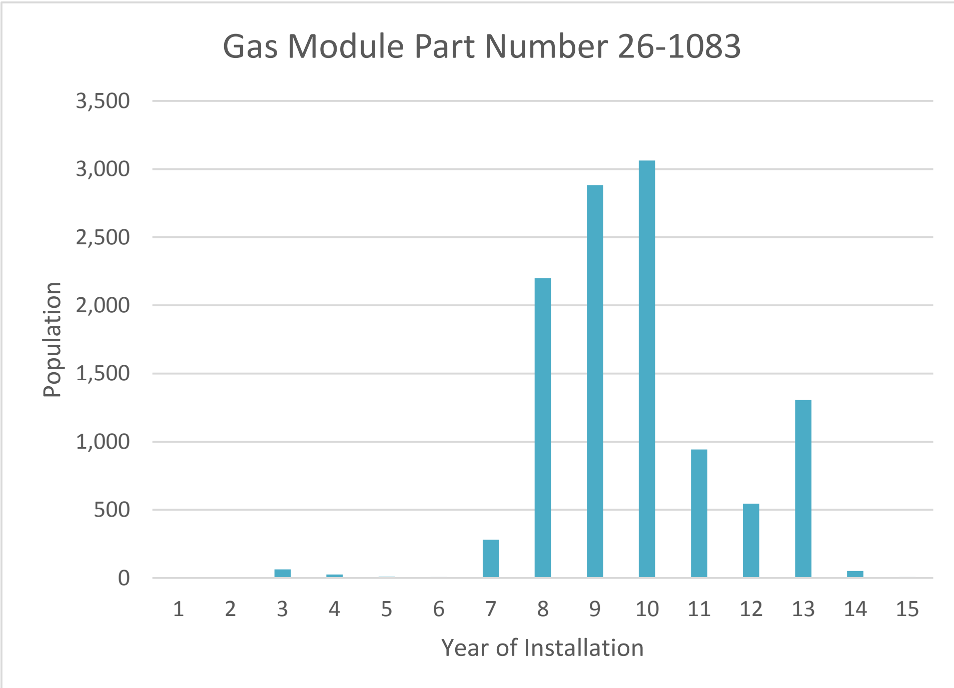

Figure 7-19: Distribution of Module Install Date for Part Number 26-1083

Metric	Value
Total PSE Population	11,392
In-Service	6,840
Average Years in Service	4.3
Percent of Current Active Module Population	1%
Suspended	6,928
Excluded because of data problems	468
Failed	3,996
Percent Analyzed that have Failed	37%
Average Annual Failure Rate Experienced by PSE	8.5%

Table 7-12: Summary Statistics for Module Part Number 26-1083

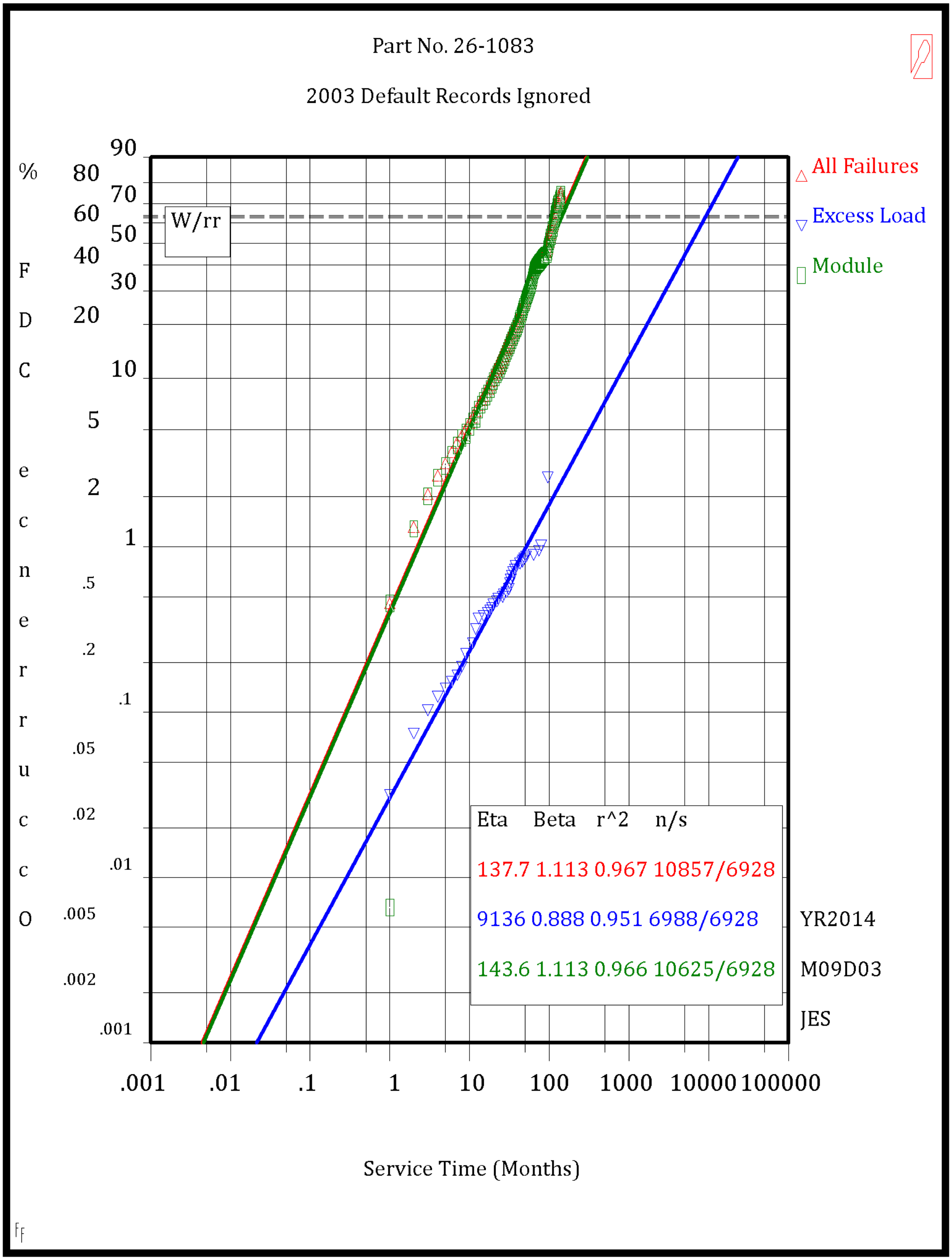

Figure 7-20: Weibull Plot for Module Part Number 26—1083

7.3.10.1 General Commentary:

This has not been a reliable part number that is in midlife. Over 35% of the population has failed in less than 6 years. 63% of the modules are expected to fail in the first 11.5 years.

Shortened battery life due to excessive leakage current or load is not problematic for this part number.

7.3.10.2 Future Reliability

With 37% of this part number failed, a short characteristic life, an average age exceeding 4.3 years, and a “Beta” of approximately one (1); the part number will have a relatively short life but failure rates will remain constant. Planned retirement of this modules is suggested.

8 NOTE OF THANKS

Thanks to Jane Docherty who created Oracle table space, populated the tables used for this analysis and ran a significant number of ad-hoc queries. Because a significant amount of the original data was incomplete, in error and just plain “dirty” special queries had to be written and run by Jane to correct these deficiencies. Without the help, this analysis would not have been possible.