

APPENDIX 8C. LIFETIME DISTRIBUTIONS

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APPENDIX 8C. LIFETIME DISTRIBUTIONS

8C.1 INTRODUCTION

For each product class, DOE characterized the product lifetime using a Weibull probability distribution that ranged from the minimum to maximum lifetime estimates described in chapter 8, section 8.2.3. The Weibull distribution is recommended for applying lifetime data because it can be shaped to match low, most likely or average, and high values, yet still allow some probability of exceeding the high value. The Weibull distribution has a long tail, which the analyst can use to specify a distribution with some chance of exceeding the high value.^{1,2}

8C.2 DERIVATION OF WEIBULL DISTRIBUTION PARAMETERS

DOE utilized an approach for calculating the Weibull distribution using product lifetime data to determine low, average, high value, and percentile of high value. A similar approach is described by Crystal Ball Technical Note, which uses most likely value instead of average.³ Available data is used to assign low, average, and high values to a random variable with unknown distribution parameters.

The Weibull distribution can be defined as:

$$f(x) = \frac{\beta}{\alpha} \left(\frac{x-L}{\alpha} \right)^{\beta-1} \exp \left(- \left(\frac{x-L}{\alpha} \right)^\beta \right) \quad \text{Eq. 1}$$

where

L	=	location
Alpha	=	scale
Beta	=	shape

Therefore, the cumulative distribution is

$$F(x) = 1 - \exp \left(- \left(\frac{x-L}{\alpha} \right)^\beta \right) \quad \text{Eq. 2}$$

Based on available data, Weibull distribution parameters are specified in the following manner:

1. The output deviates must be greater than the expert opinion for low value,
2. The average X_{avg} , must be equal to the average value from the available data,
3. The high value, x_b , must correspond to some particular percentile point (e. g., 95%, or 90%)

The values for the parameters in Eq.1 and Eq. 2 are determined using the approach outlined in Crystal Ball’s Technote.³

This solution can be checked using Crystal Ball by specifying a Weibull distribution with the calculated parameters (location, scale, and shape) in an assumption cell and generate a forecast that equals the assumption. Forecast histogram and statistics verify that the Weibull distribution matches the desired shape.

8C.3 COOKING PRODUCTS – COOKTOP AND OVEN LIFETIME DISTRIBUTIONS

Table 8C.3.1 shows the average, minimum, maximum lifetime, and maximum percentile values used to determine the Weibull distribution parameters alpha and beta. DOE estimated that the maximum lifetime percentile for both electric and gas cooking products was 99 percent.

Table 8C.3.1 Cooktops and Ovens

Product Class	Expert Opinion Values				Weibull Parameters	
	Minimum <i>years</i>	Average <i>years</i>	Maximum <i>years</i>	Maximum percentile <i>%</i>	Alpha (scale)	Beta (shape)
Electric Cooktops and Ovens	10	19	28	99	10.126	2.655
Gas Cooktops and Ovens	12	19	26	99	7.876	2.655

Figures 8C.3.1 to 8C.3.2 show the Weibull distribution as well as the cumulative Weibull distribution for electric cooktops and ovens. Figures 8C.3.3 to 8C.3.4 show the Weibull distribution as well as the cumulative Weibull distribution for gas cooktops and ovens.

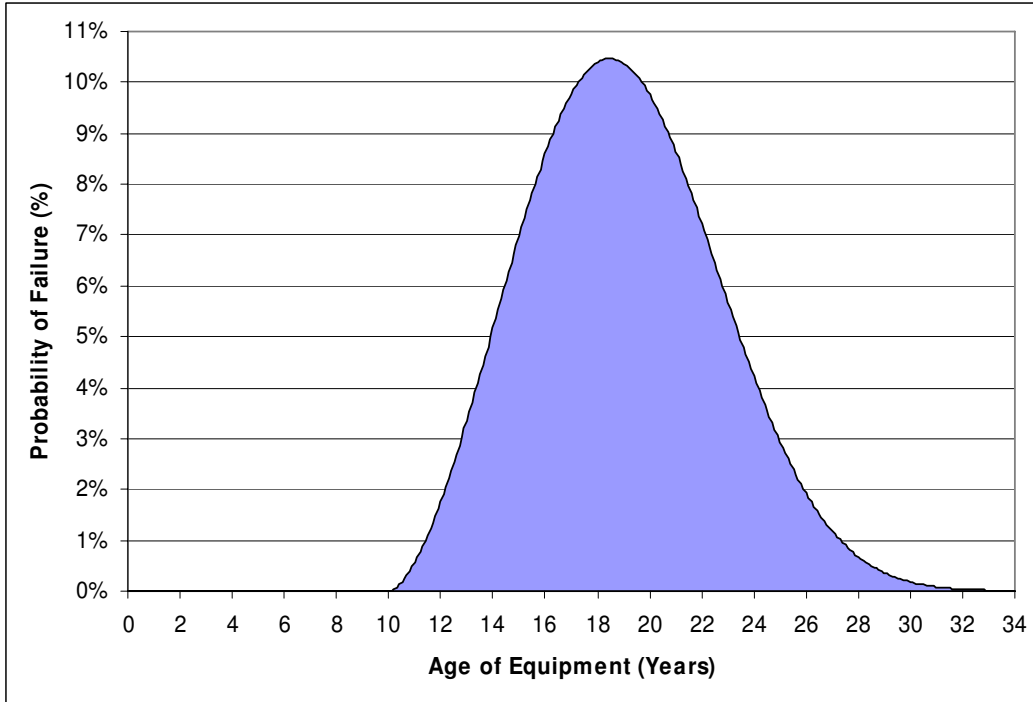


Figure 8C.3.1 Fraction of the Electric Cooktops and Ovens Failing

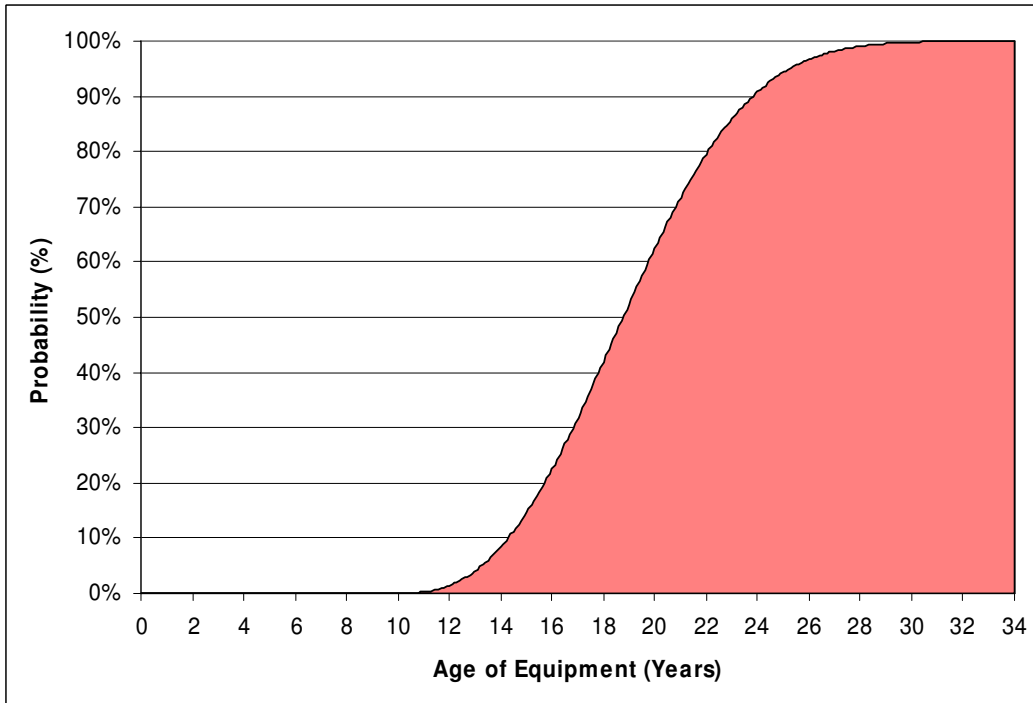


Figure 8C.3.2 Cumulative Lifetime Length of Electric Cooktops and Ovens

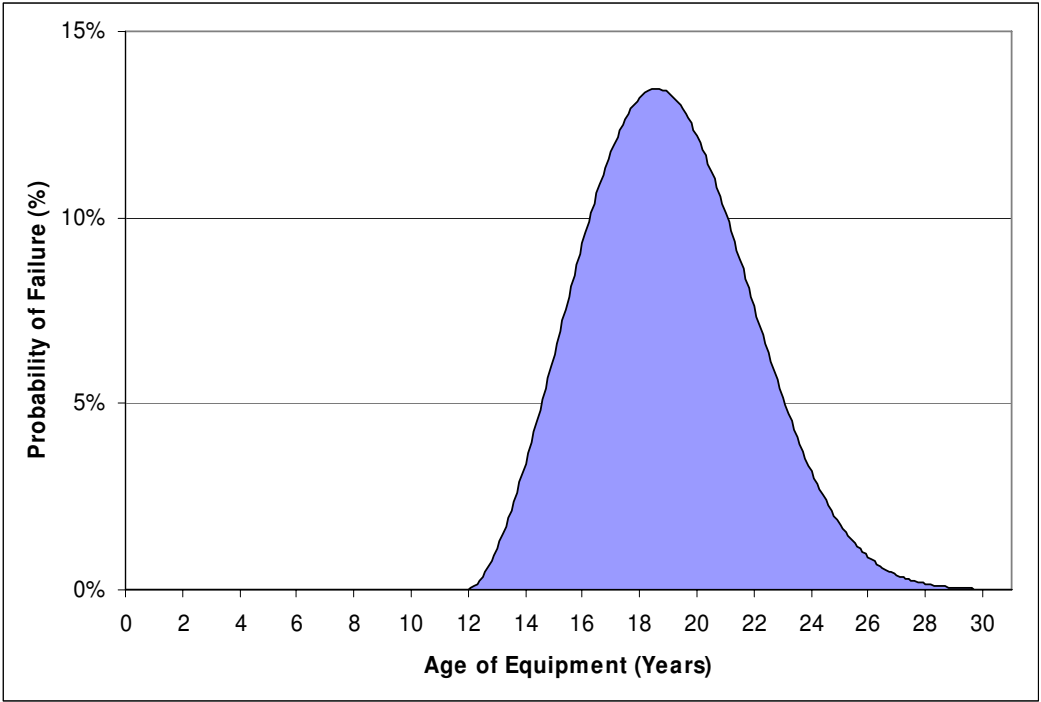


Figure 8C.3.3 Fraction of the Gas Cooktops and Ovens Failing

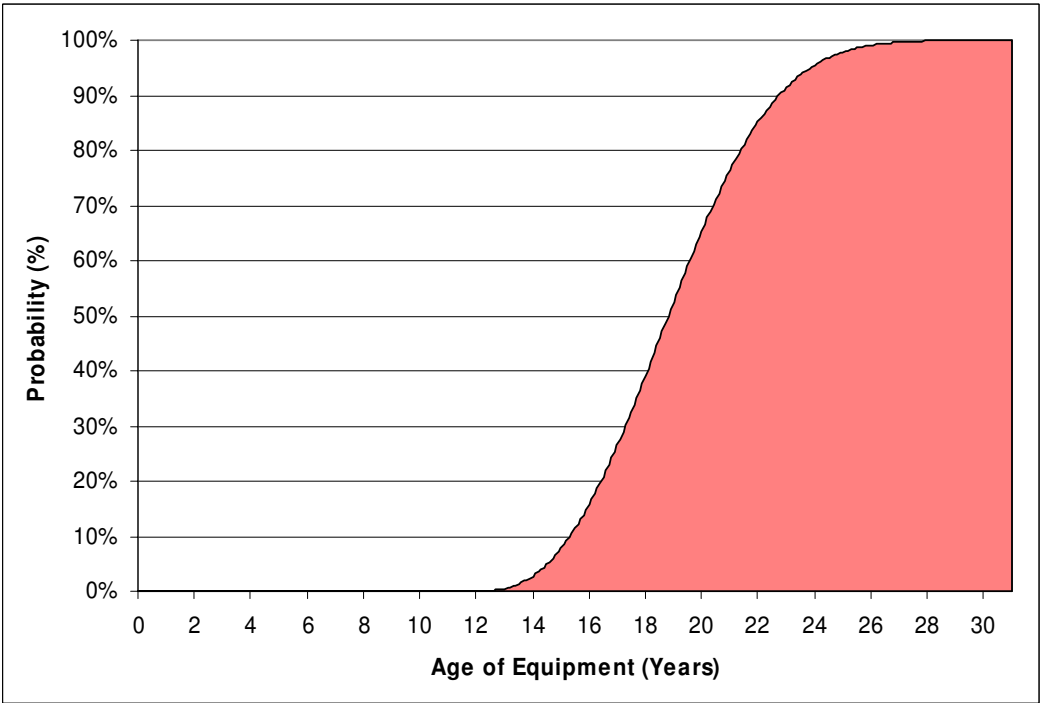


Figure 8C.3.4 Cumulative Lifetime Length of Gas Cooktops and Ovens

8C.4 MICROWAVE OVEN LIFETIME DISTRIBUTIONS

Table 8C.4.1 shows the average, minimum, maximum lifetime, and maximum percentile values used to determine the Weibull distribution parameters alpha and beta. DOE estimated that the maximum lifetime percentile for microwave ovens was 99 percent.

Table 8C.4.1 Microwave Ovens

Product Class	Expert Opinion Values				Weibull Parameters	
	Minimum <i>years</i>	Average <i>years</i>	Maximum <i>years</i>	Maximum percentile <i>%</i>	Alpha (scale)	Beta (shape)
Gas-Fired Pool Heaters	7	9	10	99	2.183	4.806

Figures 8C.4.1 to 8C.4.2 show the Weibull distribution as well as the cumulative Weibull distribution for microwave ovens.

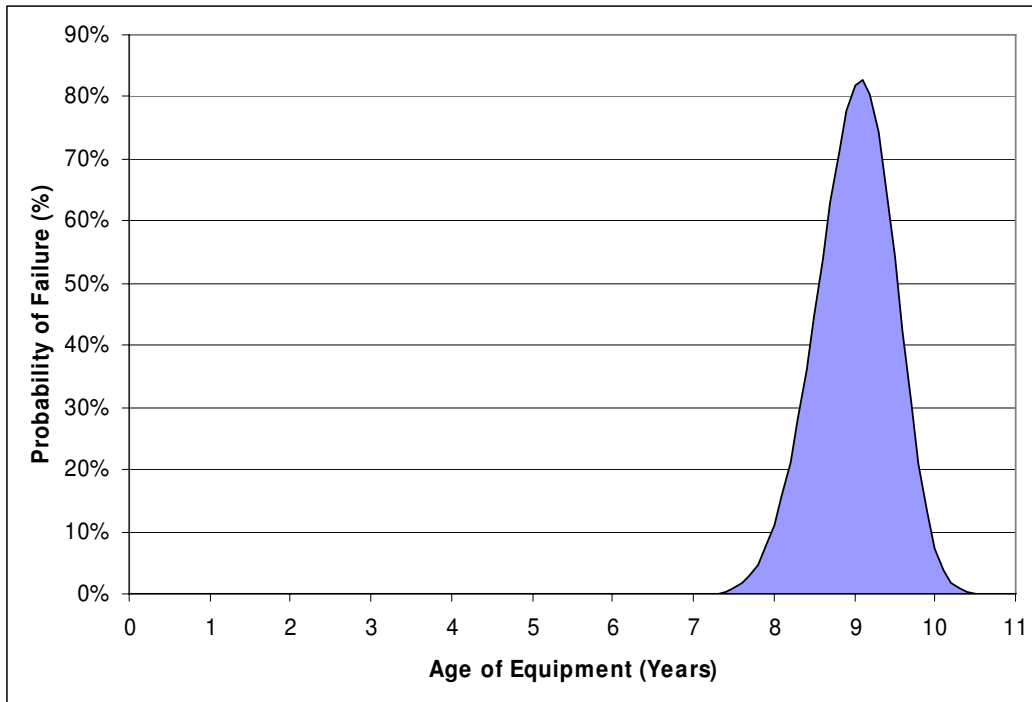


Figure 8C.4.1 Fraction of the Microwave Ovens Failing



Figure 8C.4.2 Cumulative Lifetime Length of Microwave Ovens

8C.5 COMMERCIAL CLOTHES WASHER LIFETIME DISTRIBUTIONS

Table 8C.5.1 shows the average, minimum, maximum lifetime, and maximum percentile values used to determine the Weibull distribution parameters alpha and beta. For commercial clothes washers, DOE developed two lifetime estimates based on product application—one for multi-family applications and another for Laundromats. DOE estimated that product lifetimes did not vary based on whether the washer was top-loading or front-loading. DOE estimated that the maximum lifetime percentile for both product applications was 99 percent.

Table 8C.5.1 Commercial Clothes Washers

Product Application	Expert Opinion Values				Weibull Parameters	
	Minimum <i>years</i>	Average <i>years</i>	Maximum <i>years</i>	Maximum percentile <i>%</i>	Alpha (scale)	Beta (shape)
Multi-Family	7	11.3	15.5	99	4.782	2.655
Laundromat	5	7.1	9.3	99	2.391	2.655

Figures 8C.5.1 to 8C.5.4 show the Weibull distribution as well as the cumulative Weibull distribution for each commercial clothes washer product application.

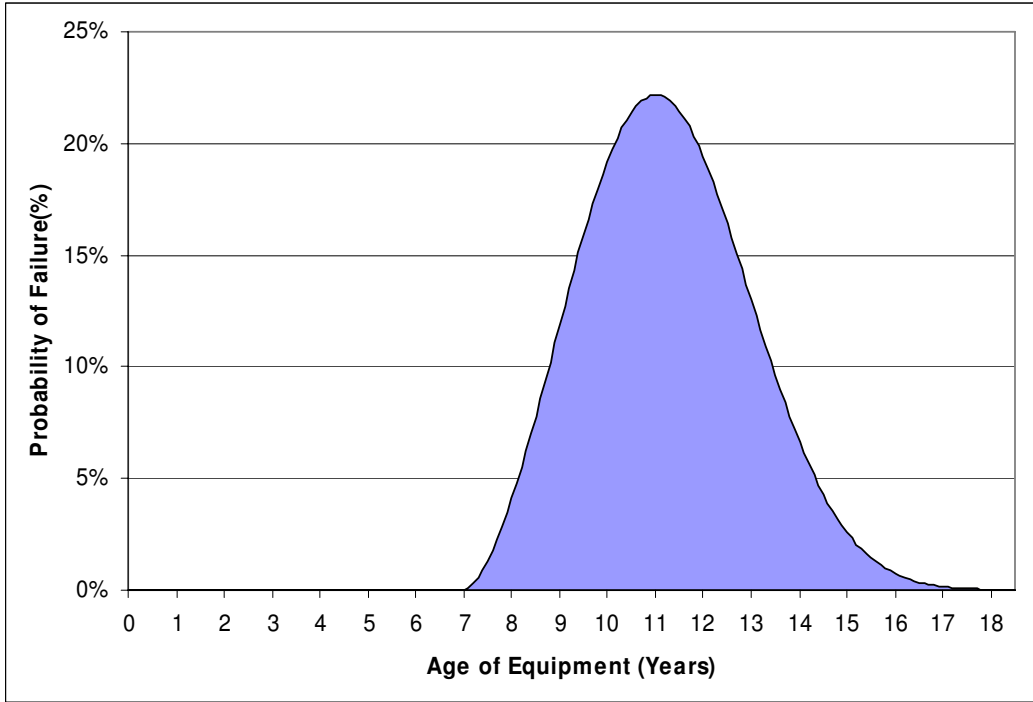


Figure 8C.5.1 Fraction of the Commercial Clothes Washers Failing, Multi-Family

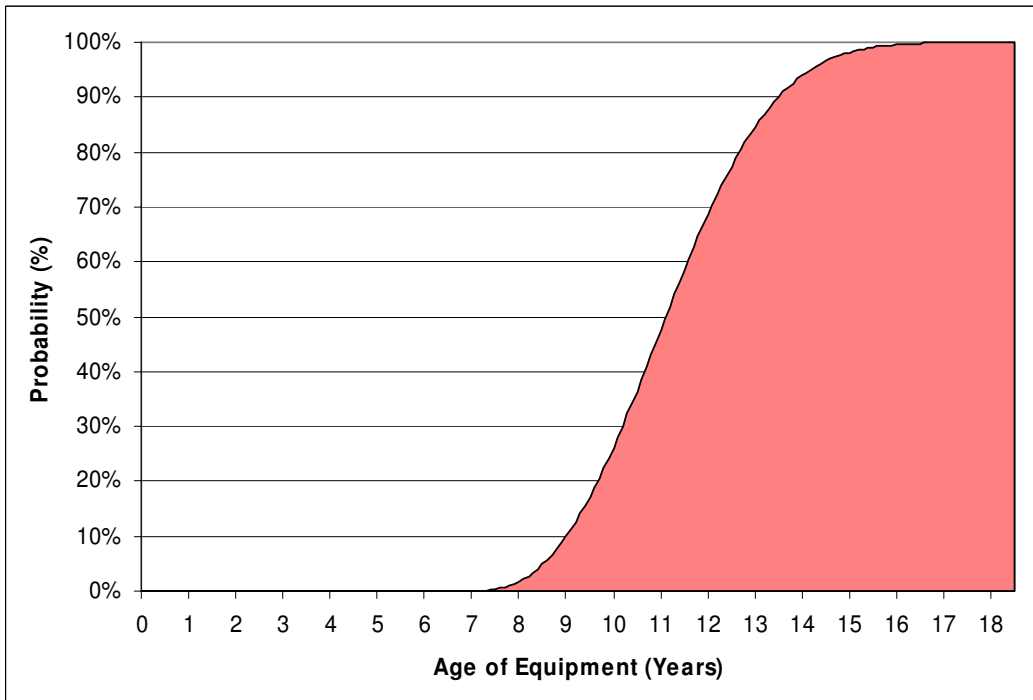


Figure 8C.5.2 Cumulative Lifetime Length of Commercial Clothes Washers, Multi-Family

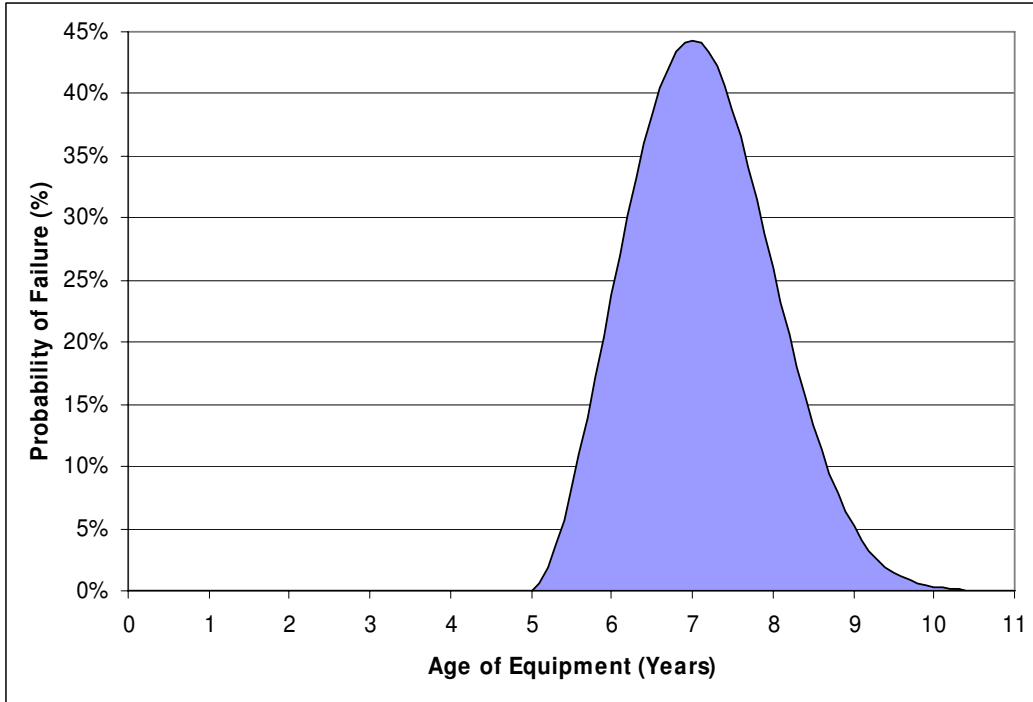


Figure 8C.5.3 Fraction of the Commercial Clothes Washers Failing, Laundromat

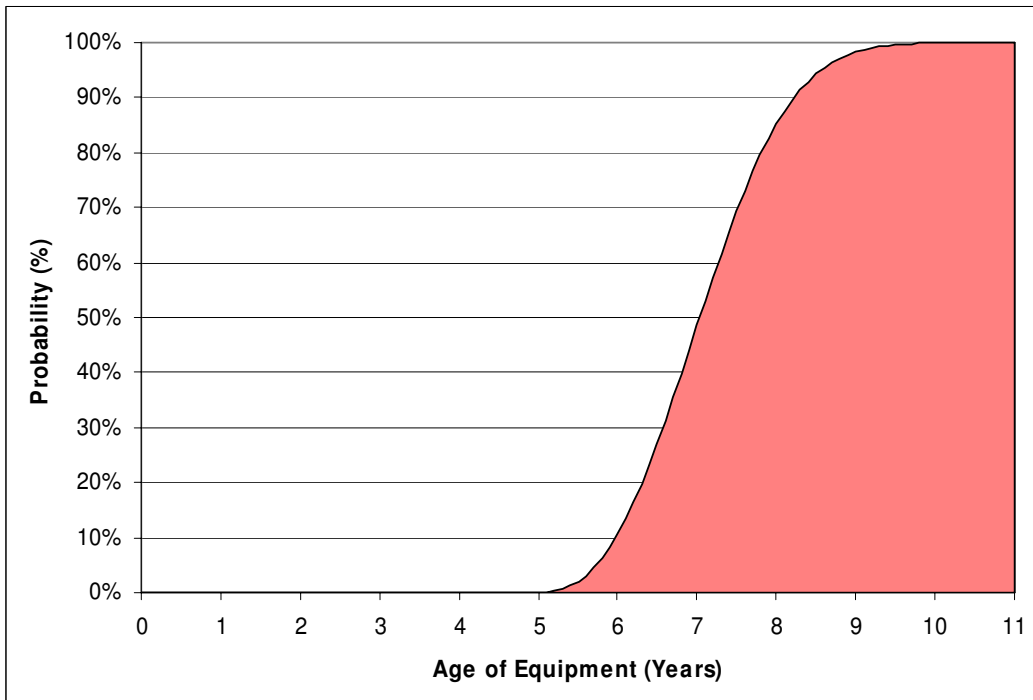


Figure 8C.5.4 Cumulative Lifetime Length of Commercial Clothes Washers, Laundromat

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- ² Karr, T., *Making the Most of Life Test Data*, in *Appliance Magazine*. 2003.
- ³ Crystal Ball. *Technote: Derivation of Weibull Distribution Parameters When the Minimum, Most Likely Value, and a Percentile are Known*. 2007 [cited; Available from: http://www.crystalball.com/support/simulation/cbl_gen_021A.html].