ORNL/TM-13012

**OAK RIDGE
NATIONAL
LABORATORY**

MARTIN MARIETTA

**Prediction of External Corrosion
for UF₆ Cylinders:
Results of an Empirical Method**

B.F. Lyon

**MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY**

This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831; prices available from (615) 576-8401, FTS 626-8401.

Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.

NTIS price codes—Printed Copy: A03 Microfiche A01

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

**Prediction of External Corrosion
for UF₆ Cylinders:
Results of an Empirical Method**

B. F. Lyon

Date Issued--June 1995

Prepared by
Risk Analysis Section
Health Sciences Research Division
Oak Ridge National Laboratory

Prepared for
U.S. Department of Energy
Office of Environmental Restoration and Waste Management
under budget and reporting code EW 20

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6285
managed by
LOCKHEED MARTIN ENERGY SYSTEMS, INC.
under contract no.DE-AC05-84OR21400
with the U.S. DEPARTMENT OF ENERGY

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DLC

CONTENTS

1. INTRODUCTION	1
2. METHODOLOGY	1
3. SUMMARY OF DATA	4
4. DATA ANALYSIS	6
5. RESULTS	7
6. CONCLUSIONS	9
7. RECOMMENDATIONS	11
8. REFERENCES	12
APPENDIX A: DATA USED IN CALCULATIONS	A-1
A.1. Cylinder Wall Thickness Data	A-1
A.2. Cylinder Age Distributions	A-9
APPENDIX B: CALCULATION OF CONFIDENCE LIMITS FOR QUANTILES OF A LOGNORMAL DISTRIBUTION	B-1
APPENDIX C: INTERMEDIATE RESULTS	C-1

FIGURES

Fig. 1.	Fitted lognormal distributions for mean annual corrosion rate	14
Fig. 2.	Predicted number of cylinders with breaches at K-1066-K, assuming initial thickness of 312.5 mils	16
Fig. 3.	Predicted number of cylinders with breaches at K-1066-K, assuming initial thickness of 345.5 mils	17
Fig. 4.	Predicted number of cylinders with minimum thickness of 250 mils or less at K-1066-K, assuming initial thickness of 312.5 mils	18
Fig. 5.	Predicted number of cylinders with minimum thickness of 250 mils or less at K-1066-K, assuming initial thickness of 345.5 mils	19
Fig. 6.	Predicted number of cylinders with breaches at C-745-F, assuming initial thickness of 312.5 mils	20
Fig. 7.	Predicted number of cylinders with breaches at C-745-F, assuming initial thickness of 345.5 mils	21
Fig. 8.	Predicted number of cylinders with minimum thickness of 250 mils or less at C-745-F, assuming initial thickness of 312.5 mils	22
Fig. 9.	Predicted number of cylinders with minimum thickness of 250 mils or less at C-745-F, assuming initial thickness of 345.5 mils	23
Fig. 10.	Predicted number of cylinders with breaches at C-745-G, assuming initial thickness of 312.5 mils	24
Fig. 11.	Predicted number of cylinders with breaches at C-745-G, assuming initial thickness of 345.5 mils	25
Fig. 12.	Predicted number of cylinders with minimum thickness of 250 mils or less at C-745-G, assuming initial thickness of 312.5 mils	26
Fig. 13.	Predicted number of cylinders with minimum thickness of 250 mils or less at C-745-G, assuming initial thickness of 345.5 mils	27
Fig. 14.	Predicted number of cylinders with breaches at X-745-C, assuming initial thickness of 312.5 mils	28
Fig. 15.	Predicted number of cylinders with breaches at X-745-C, assuming initial thickness of 345.5 mils	29
Fig. 16.	Predicted number of cylinders with minimum thickness of 250 mils or less at X-745-C, assuming initial thickness of 312.5 mils	30
Fig. 17.	Predicted number of cylinders with minimum thickness of 250 mils or less at X-745-C, assuming initial thickness of 345.5 mils	31

TABLES

Table 1. Cylinder yards considered in analysis	4
Table 2. Maximum likelihood estimates of lognormal distribution parameters for the average corrosion rate for each yard	7
Table 3. Summary results incorporating estimated probabilities and age distributions, assuming an initial wall thickness of 312.5 mils	8
Table 4. Summary results incorporating estimated probabilities and age distributions, assuming an initial wall thickness of 345.5 mils	8
Table 5. Summary of results: predicted number of breaches at present	10
Table 6. Summary of results: predicted number of breaches in 2020	10
Table 7. Summary of results: predicted number of cylinders with minimum thickness less than 250 mils in 2020	11

THIS PAGE INTENTIONALLY LEFT BLANK

1. INTRODUCTION

Wall thickness data for depleted UF₆ (DU) cylinders in above-ground storage at three Department of Energy (DOE) sites (Oak Ridge, TN; Paducah, KY; Portsmouth, OH) were analyzed in order to address the following questions:

- 1) How many cylinders may have breaches now?
- 2) What will the conditions be like in 2020?

This report summarizes preliminary results of the analyses conducted. These results are to be used as input into models for estimating risks and hazards associated with the cylinders in the various conditions. These models will then be used as a basis for implementing engineering fixes where possible and for management decisions on corrective actions. This is part of the overall assessment of the risks and hazards within the DU management program.

2. METHODOLOGY

Accurate application of mechanistic models of corrosion is difficult due to a combination of the complicated nature of corrosion and the uncertainties regarding important factors that affect corrosion. However, despite weaknesses in the ability to model corrosion, critical decisions depend fundamentally on the consequences of the corrosion processes.

When the details of a process are too complicated to confidently simulate mechanistically, empirical or phenomenological models are frequently used. Broadly speaking, such methods use past behavior as an indicator of the future. The success of such methods depends on the representativeness of the data from which the behavior is derived, as well as the continuation of patterns that have been observed.

In the present analysis, it is the progression of corrosion on a population of DU cylinders that is of interest, rather than its detailed evolution on a single cylinder. An empirical approach is used in which distributions are fit to the observed average corrosion rates, and then predictions are based on the fitted distribution. This approach has the advantage of incorporating the observed variability of the available data, and provides an empirical means of predicting the distribution of cylinder corrosion as a function of time.

The method used is driven by the data available, and so these data are briefly discussed. For four different cylinder yards, minimum wall thickness data are available for a number of cylinders. There are few data for a fixed cylinder at different times, and so it is impossible at present to investigate the change with time of corrosion on a fixed cylinder. Since the age of the cylinder at the date of the measurement can be determined, it is possible to determine the age-averaged corrosion rate. Even for cylinders of a fixed age, there is variability in this corrosion rate.

The main assumption is that if $C(t)$ is the distribution of the amount of corrosion (in mils, where 1 mil = 0.001 inch) by a certain age t (yr), then the ratio $C(t)/t$ can be treated as a sample from a time-independent distribution R . The random variable R is the age-averaged corrosion rate in mils per year. It is stressed that no other assumptions are made regarding the corrosion for a fixed cylinder. In particular, it is not assumed that the corrosion rate is constant for a fixed cylinder.

The distribution R is approximated for each yard based on the data available. This is performed by analyzing the distribution of age-averaged corrosion rates C/t , where t is the age of the cylinder at the time that the measurement was made and C is the depth of corrosion observed on a cylinder.

Once the distribution of R has been determined, one can find the probability that a given amount of corrosion will occur by a given age t by

$$\begin{aligned} \text{Probability of } X \text{ mils of corrosion by time } t &= \text{Probability that } R > X/t \\ &= 1 - F_R(X/t) \end{aligned} \quad (1)$$

where $F_R(y)$ is the cumulative distribution function for R . An estimate of the number of cylinders that have had X mils of corrosion by age t is then determined by multiplying the probability obtained in Eq. 1 by the number of cylinders of age t .

Due to the fact that a finite number of samples is used, there will be uncertainty in this probability. Determination of confidence limits is difficult unless R is of a specific form. If R is normally or lognormally distributed, then confidence limits can be obtained for the quantiles of R based on a given number of samples (Land 1988; Lawless 1982), and these can be used to estimate confidence limits on the number of cylinders that have been subjected to a specified amount of corrosion. Details of how these confidence limits are computed for normal or lognormal distributions are given in Appendix B.

Assuming that R is lognormally distributed, upper confidence limits for the computed estimates of the number of cylinders that have corroded a given amount X by a specified time t can be calculated as described below.

First, an estimate of the percentage of cylinders that have corroded at least X mils, denoted here by $P(X,t)$, is obtained by computing

$$P(X,t) = 1 - F_R(X/t) \quad (2)$$

Next an estimate is obtained for the value p such that the upper 95% confidence limit on the p th percentile of R , denoted by R_p , is equal to the X/t . This means that X/t is the upper 95% confidence limit for the p th percentile of R : one can conclude with a 95% degree of confidence that the $R_p \leq X/t$. But this means that

$$p \leq \text{Prob}\{R < X/t\}$$

which is equivalent to

$$1 - p \geq 1 - \text{Prob}\{R < X/t\} = \text{Prob}\{R > X/t\} = P(X,t)$$

Thus, $1-p$ can serve as an upper 95% confidence limit for the computed probability of having at least X mils of corrosion by time t .

Once the probabilities and associated confidence limits have been estimated, the age distribution of the cylinder population is used to estimate the number of cylinders that have minimum thickness less than a fixed value as a function of time. For example, to determine the number of cylinders that will be breached in 1995, we first estimate how many mils of corrosion must occur. Assuming an initial thickness of Y mils, this is equivalent to estimating the number of cylinders that have had at least Y mils by the year 1995. Then the total number of cylinders that are predicted to have at least Y mils of corrosion by the year 1995, denoted here by $T(1995)$, is given by

$$\begin{aligned} T(1995) &= \{\text{Probability of at least } Y \text{ mils of corrosion in 1 year}\} * \{\text{Number of cylinders of age 1 in 1995}\} \\ &\quad + \{\text{Probability of at least } Y \text{ mils of corrosion in 2 years}\} * \{\text{Number of cylinders of age 2 in 1995}\} \\ &\quad + \{\text{Probability of at least } Y \text{ mils of corrosion in 3 years}\} * \{\text{Number of cylinders of age 3 in 1995}\} \\ &\quad + \dots \\ &= \{\text{Probability } C(1) > Y\} * \{\text{Number of cylinders of age 1 in 1995}\} \\ &\quad + \{\text{Probability } C(2) > Y\} * \{\text{Number of cylinders of age 2 in 1995}\} \\ &\quad + \{\text{Probability } C(3) > Y\} * \{\text{Number of cylinders of age 3 in 1995}\} \\ &\quad + \dots \\ &= \{\text{Probability } R > Y\} * \{\text{Number of cylinders of age 1 in 1995}\} \\ &\quad + \{\text{Probability } R > Y/2\} * \{\text{Number of cylinders of age 2 in 1995}\} \\ &\quad + \{\text{Probability } R > Y/3\} * \{\text{Number of cylinders of age 3 in 1995}\} \\ &\quad + \dots \end{aligned} \tag{3}$$

Confidence limits on the total number of cylinders that have had at least Y mils or corrosion by 1995 are estimated using the calculated confidence limits on the probabilities in Eq. 3.

Although the corrosion rate for an individual cylinder changes as a function of time and storage conditions, this is extremely difficult to quantify, and is not explicitly addressed in this analysis. However, it is stressed that it is not assumed that the corrosion rate is constant: it is only assumed that the distribution of age-averaged corrosion rates is independent of time.

We note that if one makes certain additional assumptions regarding the distribution of rates for a fixed year, then it can be implied that the corrosion rate for a fixed cylinder is constant. For example, if one assumes that the corrosion in a given year has the same mean and variance as R , then one must conclude that the corrosion rate for a fixed cylinder is constant.

3. SUMMARY OF DATA

In this section the data used in the analyses are briefly discussed. Table 1 contains a summary of these data. Appendix A contains the actual data for each yard.

Table 1. Cylinder yards considered in analysis

Yard	Location	Number of Cylinders on Yard	Total No. Measurements Available
K-1066-K	Oak Ridge, TN	2942	138
C-745-F	Paducah, KY	4446	21
C-745-G	Paducah, KY	7233	8
X-745-C	Portsmouth, OH	14693	125

Estimation of Cylinder Age

The cylinder number was available for each cylinder considered in the analysis (Taylor 1994). This unique number can be used to determine the manufacture date of the cylinder, and hence the age of any particular cylinder at the time of any given measurement.

Estimation of Mils Corroded

In principle, estimation of the average corrosion rate is simple: one just divides the mils corroded by time elapsed. However, even with error-free minimum wall thickness data, there is uncertainty in the estimate of the mils corroded due to uncertainty in the initial thickness of cylinder. For most of the cylinders considered (Models 48 OM, 48 T, 48O, 48 H, 48 HX, 48 G), the design thickness was 312.5 mils, with a range of 302.5 to 345.5 mils (Marshall 1994). Separate analyses were performed assuming initial thicknesses of 312.5 and 345.5 mils.

For some cylinders, the measured minimum thickness was larger than the design thickness of 312.5 mils, indicating that the initial thickness was larger than 312.5 mils (this was true for more than 90% of the data for X-745-C). These cylinders were not included in the analysis in which a 312.5 mil initial thickness was assumed.

Minimum Wall Thicknesses of Interest

For the purpose of this analysis, two different minimum wall thicknesses were of interest:

- 1) Minimum wall thickness 0 mils (Cylinder breach)
- 2) Minimum wall thickness of 250 mils (minimum wall thickness per ANSI N14.1, which

is acceptable for hot processing and transporting cylinders)

Using the fitted distributions, a complete analysis was performed for each minimum wall thickness.

K yard at Oak Ridge

K-1066-K yard, located at the K-25 plant in Oak Ridge Tennessee, contains 2942 cylinders, ranging in age from about 30 years to 37 years. These cylinders were initially stored at K-1066-G yard at Oak Ridge starting at about 1966, and relocated in 1983 (Barber et al. 1994). During the six month period 12/93 to 5/94, cylinder wall thickness measurements were made for 136 cylinders (Philpot 1995) using an automated scanner. Both through-wall and pit depth measurements were made. For three cylinders, these measurements were made at two different times. For conservative purposes, the smaller of the two minimum thicknesses were used in the analysis for these cylinders.

The cylinders were chosen for measurement at random, given specific selection criteria and limitations imposed by the automated scanner. The primary selection criteria of the cylinders for measurement were: (1) age; (2) location in the stacking arrangement (e.g., top or bottom); and (3) location within the yard (Philpot 1995). Additional constraints were imposed due to the length of the cord required for the scanner and the clearance between adjacent cylinders and the cylinder and the ground.

For the first group of cylinders measured (21 cylinders), the minimum wall thickness was determined based on the results of the scanner for wall thickness alone. For the rest of the cylinders, additional data were collected using a pit depth probe attached to the scanner that allowed a more accurate determination of the minimum wall thickness. Recent measurements were made by hand for 9 of the cylinders originally measured (Schmidt 1995). These results indicated that, in general, the data collected may be slightly conservative, as the wall thickness was underestimated for 8 of the cylinders. In particular, the difference between the original measurements and the recent measurements for the cylinders in second group ranged from -32 mils to +10 mils, while the similar difference for a cylinder in the first group (cylinder #17909) was -88 mils. Only one of the cylinders from the first group was re-measured because the other such cylinders were either unreachable, or there was no distinct corrosion pattern to allow determination of where the measurements had been made previously.

Also included in the data set were two breached cylinders discovered in 1991 and 1992 (Barber et al. 1994). The age distribution is from Newman (1995), and is given in Appendix A.

G yard at Paducah

C-745-G yard, located at Paducah, Kentucky, contains approximately 7500 cylinders with an age distribution similar to the cylinders in K yard at Oak Ridge. The data set available (Blue 1994) consisted of minimum wall thickness for 8 cylinders measured at the bottom of corrosion pits with a 2 mm diameter ultrasonic probe. These measurements were made in 1994, and the cylinders had been chosen for measurement based on the presence of loose scale corrosion products. Although there is uncertainty regarding the actual minimum depth on the cylinder, a visual inspection was

made of the entire cylinder, rotating the cylinder if necessary. The uncertainty in the measurement itself is estimated at less than 1-2 mils (Blue 1995). The age distribution is from Newman (1995), and is given in Appendix A.

F yard at Paducah

C-745-F yard located at Paducah, Kentucky, contains approximately 4500 cylinders with an age distribution similar to the cylinders in K yard at Oak Ridge. Data were available for 21 cylinders, collected in a manner similar to the data collected for C-745-G (Blue 1994). These data consisted of estimates of the minimum thickness as measured with a flaw detector and 2 mm probe. The age distribution is from Newman (1995), and is given in Appendix A.

C Yard at Portsmouth

X-745-C yard, located at Portsmouth, Ohio, is the largest of the cylinder yards considered, containing 14693 cylinders ranging in age from a few years to 37 years. The wall thickness data set for this yard is the closest to a "random" sampling of the data sets considered in the present analysis. This is because five cylinders (on average) were chosen essentially at random from each order made for each cylinder model type since 1956. Ultrasonic thickness measurements were available for 125 cylinders (Marshall 1995). For each cylinder, 8 measurements were made on each side and 10 on each head. Essentially no surface preparation was performed, in which case the wall thickness measurements may be overestimated (Lykins 1995). Over 90% (111/125) of the measured minimum thicknesses exceeded 312.5 mils. The age distribution is from Newman (1995), and is given in Appendix A.

4. DATA ANALYSIS

Two different analyses were conducted for each yard. In the first, the initial thickness of the cylinder was assumed to be 312.5 mils, while in the second the initial thickness was assumed to be 345.5 mils, which is the upper bound based on the design specifications (Blue 1994).

The computed average corrosion rates were used as samples from the distribution R (see Eq. 1). The maximum likelihood estimates of the mean and standard deviation were then determined for a lognormal distribution. The maximum likelihood estimates are the values that, if the distribution is lognormal, maximize the likelihood of obtaining the data observed. Table 2 shows the parameters of the fitted distributions, and Fig. 1 shows the fitted distributions and the data for each yard (note that figures begin on page 14).

For the data from C-745-F and C-745-G yards, the fits were deemed adequate by a χ^2 goodness-of-fit test ($\alpha = 0.05$) for the two initial thicknesses. For K-1066-K yard and an assumed initial thickness of 312.5 mils, the four highest observed corrosion rates had to be grouped in order to verify an adequate fit. Although the fit was not as good assuming the other initial thickness for the K-1066-K yard data, it was considered adequate for the purpose of this analysis (see Fig. 1b). The fit to the data for X-745-C assuming an initial thickness of 345.5 mils was adequate by the χ^2 goodness-of-fit test, but the fit assuming an initial thickness of 312.5 mils was not (only 14 of the 125 cylinders measured had a minimum thickness of less than 312.5 mils). However, as for

the K-1066-K yard data a lognormal distribution was assumed for the purpose of this analysis.

Although most of the data were consistent with the fitted lognormal distributions using simple chi-squared goodness-of-fit tests, the observed age-averaged corrosion rates are the result of complicated processes, and it is in fact doubtful that the true distributions are lognormal: in the end one can only approximate the actual distribution. In fact, due to the uncertainty in the measurements themselves only an approximation is possible. Use of the lognormal distribution compared to the normal distribution (and many other standard distribution types) is conservative because the likelihood of rare events (e.g., breaches) is driven by the upper tail of the distribution, and the lognormal distribution has a long upper tail. The use of a lognormal distribution also has the advantage that upper confidence limits can be determined on the percentiles, thereby providing an estimate of the sampling uncertainty.

Table 2. Maximum likelihood estimates of lognormal distribution parameters for the average corrosion rate for each yard *

Yard	Initial Thickness 312.5 Mils		Initial Thickness 345.5 Mils	
	μ, σ for Natural Logarithm of Rate	Arithmetic Mean and Standard Deviation	μ, σ for Natural Logarithm of Rate	Arithmetic Mean and Standard Deviation
K-1066-K	0.53, 0.57	2.00, 1.24	1.03, 0.36	2.99, 1.11
C-745-F	1.16, 0.20	3.25, 0.66	1.43, 0.16	4.23, 0.68
C-745-G	1.20, 0.25	3.41, 0.82	1.46, 0.18	4.38, 0.79
X-745- C	-1.37, 1.14	0.49, 0.79	0.25, 0.75	1.70, 1.48

* Due to the differences in how the data were collected for each yard, comparisons should not be made across yards and/or sites without keeping these differences in mind.

Once the distributions were obtained, the probability of exceeding any thickness as a function of time was determined using Eq. 2. These results were then used to estimate the number of cylinders that would have at least a given amount of corrosion by a specified age as shown in Eq. 3, using the age distribution of the cylinders on each yard.

5. RESULTS

Using the methods discussed above, the probability that the minimum thickness is less than a prescribed value was estimated as a function of cylinder age for each cylinder yard. Then the age distributions were used to estimate the number of cylinders using the calculated probabilities. Table 3 shows the results assuming an initial wall thickness of 312.5 mils, and Table 4 shows the results assuming an initial wall thickness of 345.5 mils. Graphs of these data are included for completeness and are shown in Figs. 2-17. Intermediate results used in these calculations are provided in Appendix C.

Table 3. Summary results incorporating estimated probabilities and age distributions, assuming an initial wall thickness of 312.5 mils

	N	Predicted Number of Breached Cylinders													
		1995		1999		2003		2007		2011		2015		2020	
		MLE	Upper 95%	MLE	Upper 95%	MLE	Upper 95%	MLE	Upper 95%	MLE	Upper 95%	MLE	Upper 95%	MLE	Upper 95%
K-1066-K	13														
	8	6	15	10	25	17	37	26	53	37	72	52	94	75	127
C-745-F	21	0	0	0	2	0	5	1	15	2	34	7	69	25	146
C-745-G	8	0	137	2	244	8	394	23	591	57	834	123	1123	271	1542
X-745-C	14	4	125	5	166	8	213	11	263	15	315	19	370	27	441
	N	Predicted Number of Cylinders with Minimum Thickness of 250 mils or less													
		1995		1999		2003		2007		2011		2015		2020	
		MLE	Upper 95%	MLE	Upper 95%	MLE	Upper 95%	MLE	Upper 95%	MLE	Upper 95%	MLE	Upper 95%	MLE	Upper 95%
K-1066-K	13														
	8	1376	1540	1597	1758	1792	1949	1963	2113	2111	2253	2237	2371	2369	2491
C-745-F	21	3524	3732	4057	4214	4337	4408	4423	4442	4442	4446	4445	4446	4446	4446
C-745-G	8	7026	7135	7145	7203	7202	7227	7223	7232	7230	7233	7232	7233	7233	7233
X-745-C	14	205	1084	284	1377	381	1669	491	1955	614	2235	747	2505	923	2832

MLE: predicted results using maximum likelihood estimates of lognormal parameters.

Table 4. Summary results incorporating estimated probabilities and age distributions, assuming an initial wall thickness of 345.5 mils

		Predicted Number of Breached Cylinders													
	N	1995		1999		2003		2007		2011		2015		2020	
		MLE	Upper 95%	MLE	Upper 95%	MLE	Upper 95%	MLE	Upper 95%	MLE	Upper 95%	MLE	Upper 95%	MLE	Upper 95%
K-1066-K	138	1	3	3	8	6	16	12	28	23	48	40	75	71	121
C-745-F	21	0	0	0	1	0	6	1	21	5	56	21	127	79	288
C-745-G	8	0	55	0	132	3	270	14	485	51	791	147	1192	413	1819
X-745-C	125	12	31	19	47	29	69	43	98	62	135	86	181	125	252
		Predicted Number of Cylinders with Minimum Thickness of 250 mils or less													
	N	1995		1999		2003		2007		2011		2015		2020	
		MLE	Upper 95%	MLE	Upper 95%	MLE	Upper 95%	MLE	Upper 95%	MLE	Upper 95%	MLE	Upper 95%	MLE	Upper 95%
K-1066-K	138	1565	1725	1900	2051	2176	2312	2390	2509	2551	2651	2668	2749	2769	2829
C-745-F	21	3148	3301	3625	3827	4156	4291	4385	4429	4437	4445	4445	4446	4446	4446
C-745-G	8	6944	7049	7079	7149	7178	7216	7220	7232	7230	7233	7233	7233	7233	7233
X-745-C	125	653	923	921	1281	1262	1718	1669	2215	2128	2753	2626	3316	3278	4031

MLE: predicted results using maximum likelihood estimates of lognormal parameters.

The dependence of the results on the assumed initial thickness is not obvious, as it depends on the upper tail of the fitted distribution. Although assuming a larger initial thickness results in higher average corrosion rates, it also requires more corrosion to occur. Depending on both the fitted distributions and minimum thickness of interest, either assumption can produce more conservative results than the other. For example, the results assuming an initial thickness of 345.5 mils can be less conservative, as shown by comparing the expected number of breaches for K yard in 1995: 6 are predicted assuming an initial thickness of 312.5 mils, yet only 1 is predicted assuming an initial thickness of 345.5 mils. Conversely, it can also be more conservative, as shown by comparing the expected number of cylinders to have a breach in 2020 in F yard: 25 are predicted assuming an initial thickness of 312.5 mils, and yet 79 are predicted assuming an initial thickness of 345.5 mils.

The small variation in the data for F yard and G yard result in relatively "tight" fitted distributions for both initial thicknesses (Fig. 1). While the average corrosion rates for the F and G yard data are higher than that of the other yards, the small amount of variability results in a smaller probability of extreme events at present. The high number of DU cylinders predicted to have a minimum thickness less than 250 mils for these yards is due to the data available: almost all of the cylinders in the data set had a minimum thickness less than 250 mils.

The results for X-745-C assuming an initial thickness of 312.5 mils should be considered preliminary because it appears that a large fraction of the cylinders on this particular yard were originally much thicker than 312.5 mils.

The magnitude of the difference between the upper 95% confidence limits depends on the number of measurements available: the larger the number of measurements, the smaller the difference is. This is a reflection of the fact that one is obtaining better estimates of the parameters of the (assumed) lognormal distribution. The difference between yards can be dramatic: for K yard, the upper 95% confidence limit is only about three times larger than the MLE value. In contrast, the confidence limits for G yard, where only eight measurements are available, are substantially higher than the MLE value, especially for relatively rare events such as a breach. Depending on the output of interest, increasing the number of samples can substantially reduce the upper 95% confidence limits. The number of samples necessary to achieve a given accuracy can be estimated using the methods described in Appendix B, assuming that the rates are lognormally distributed.

6. CONCLUSIONS

Empirical methods were applied to the available corrosion data for several UF_6 cylinder yards located in Oak Ridge, Portsmouth, and Paducah. The main goal was to address the following questions:

- 1) How many cylinders may have breaches now?
- 2) What will the conditions be like in 2020?

The results for the first question are shown in Table 5, where the probabilities have been used in conjunction with the age distributions to obtain the predicted number of breaches. The

intermediate calculations used to derive these values are provided in Appendix C. We recall that is assumed that for each yard the distribution of the age-averaged corrosion rates is independent of time, and that this distribution can be approximated by a lognormal distribution. Further, it is assumed that the data are representative for the yard from which they are taken. *All results are implications of these assumptions.*

Table 5. Summary of results: predicted number of breaches at present

Location	Number of Cylinders on Yard	Initial Thickness 312.5 mils			Initial Thickness 345.5 mils		
		N	MLE*	Upper 95% Confidence Limit	N	MLE*	Upper 95% Confidence Limit
K-1066-K	2942	138	6	15	138	1	3
C-745-F	4446	21	0	0	21	0	0
C-745-G	7233	8	0	137	8	0	55
X-745-C	14693	14	4	125	125	12	31

* Predicted results using maximum likelihood estimates of distribution parameters.

The results for the second question are shown in Tables 6 and 7.

Table 6. Summary of results: predicted number of breaches in 2020

Location	Number of Cylinders on Yard	Initial Thickness 312.5 mils			Initial Thickness 345.5 mils		
		N	MLE*	Upper 95% Confidence Limit	N	MLE*	Upper 95% Confidence Limit
K-1066-K	2942	138	75	127	138	71	121
C-745-F	4446	21	25	146	21	79	288
C-745-G	7233	8	271	1542	8	413	1819
X-745-C	14693	14	27	441	125	125	252

* Predicted results using maximum likelihood estimates of distribution parameters.

Table 7. Summary of results: predicted number of cylinders with minimum thickness less than 250 mils in 2020

Location	Number of Cylinders on Yard	Initial Thickness 312.5 mils			Initial Thickness 345.5 mils		
		N	MLE*	Upper 95 % Confidence Limit	N	MLE*	Upper 95 % Confidence Limit
K-1066-K	2942	138	2369	2491	138	2769	2829
C-745-F	4446	21	4446	4446	21	4446	4446
C-745-G	7233	8	7233	7233	8	7233	7233
X-745-C	14693	14	923	2832	125	3278	4031

* Predicted results using maximum likelihood estimates of distribution parameters.

The predicted conditions at 2020 are extremely sensitive to small differences in the fitted distributions. This is illustrated by comparing the results for F and G yard at 2020: more than five times as many breaches are predicted using the maximum likelihood estimates, although the differences in the mean and standard deviation of the corrosion rates are at most 0.05 (see Table 2 on page 7).

Using the empirical method described above, sudden changes from current conditions are not predicted near-term (Figs. 2-17). However, for C-745-F and C-745-G at Paducah, the data are probably not representative for the yard from which they are taken. This is because these data were collected from cylinders that were thought to have experienced advanced degrees of corrosion. Because the method used here is essentially fitting an upper tail to the observed distribution of corrosion rates, for these yards we have essentially "fit a tail to a tail of" a distribution.

7. RECOMMENDATIONS

The results derived here are based on the assumptions made. Namely, that for each yard the distribution of the age-averaged corrosion rates is independent of time, and that these distributions can be approximated by lognormal distributions. It is anticipated that for some of the yards, the data may represent extreme corrosion rates, which is an inherent conservative bias. However, because the dependence of the corrosion rate on time is unknown, it is not possible to accurately determine the actual conservatism of the final results. A detailed analysis of the dependence of the distribution of corrosion rates on the age of the cylinders was not addressed here. As more data become available, additional analyses should be conducted that include such an analysis.

Due to the inconsistent dependence of the results on the initial thickness assumed, it is suggested that analyses be conducted using different initial thicknesses. In particular, an additional analysis should be conducted using a lower bound initial thickness.

For relatively rare events such as breaches, the results are driven by the upper tail of the fitted distribution. Although it can be expected that assuming a lognormal distribution will be more

conservative than assuming a normal distribution, this may not be true for other types of distributions. One of the main advantages of using a lognormal distribution is that upper confidence limits can be calculated, thus allowing the inclusion of sampling uncertainty. Future efforts should investigate the sensitivity of the results to the type of distribution fit to the data.

If possible, nonparametric methods should be incorporated to provide additional estimates of the number of breaches. While possibly being more conservative than the results presented here, these methods require few assumptions about the unknown distribution of corrosion, and can be used as an additional tool in support of decisions made within the DU program.

Because the methods used here are simple, they can be applied easily at any time in the future. Future sampling can be conducted in a manner that provides the upper 95% confidence limits that are within a desired range of results using the maximum likelihood estimates, depending on the sampling costs involved. It is suggested that periodic sampling be performed that would also allow a response to any potential change in the distribution of average corrosion rates, as well as to allow more detailed analyses of the change of the corrosion rate with time for a fixed cylinder.

8. REFERENCES

- Barber, E.J., J.H. DeVan, J.M. Googin, and M.S. Taylor (1994). *Investigation of Breached Depleted UF₆ Cylinders at the K-25 Site*. ORNL/TM-12840, Oak Ridge, Tennessee, October 1994.
- S.C. Blue (1994). Facsimile transmittal from S.C. Blue to M. Taylor dated October 27, 1994.
- S.C. Blue (1995). Personal communication with B.F. Lyon on May 24, 1995.
- C.E. Land (1988). Hypothesis Tests and Interval Estimates, in *Lognormal Distributions - Theory and Applications*, E.L. Crow and K. Shimizu, eds., Marcel Dekker, New York.
- J.F. Lawless (1982). *Statistical Models and Methods for Lifetime Data*, John Wiley & Sons, New York.
- M. Lykins (1995). Personal communication with B.F. Lyon on May 25, 1995.
- T. Marshall (1994). Facsimile transmittal from T. Marshall to M. Taylor dated November 11, 1994.
- T. Marshall (1995). Facsimile transmittal from T. Marshall to M. Taylor dated January 4, 1995.
- Newman, V. (1995). Age distribution for UF₆ tails cylinders. Personal communication from V. Newman to B. Lyon January 24, 1995.
- Philpot, H.E. (1995). Report on Ultrasonic Wall Integrity Assessment. Internal memorandum from H.E. Philpot to V.S. Newman and G.A. Person, February 17, 1995.

Schmidt, M.. (1995). Personal communication with B.F. Lyon, , June 1, 1995.

M. Taylor (1994). Large Capacity Cylinders used for UF₆. Personal communication from M. Taylor to B. Lyon on November 22, 1994.

Initial Thickness=312.5 mils

Initial Thickness=345.5 mils

Mean Annual Corrosion Rate (mils/yr)

Mean Annual Corrosion Rate (mils/yr)

Fig. 1a. Fitted lognormal distributions for mean annual corrosion rate.

Initial Thickness=312.5 mils

Initial Thickness=345.5 mils

K-1066-K

K-1066-K

X-745-C

X-745-C

Mean Annual Corrosion Rate (mils/yr)

Mean Annual Corrosion Rate (mils/yr)

Fig. 1b. Fitted lognormal distributions for mean annual corrosion rate.

Fig. 2. Predicted number of cylinders with breaches at K-1066-K, assuming initial thickness of 312.5 mils.

Fig. 3. Predicted number of cylinders with breaches at K-1066-K, assuming initial thickness of 345.5 mils.

Fig. 4. Predicted number of cylinders with minimum thickness of 250.0 mils or less at K-1066-K, assuming initial thickness of 312.5 mils.

Fig. 5. Predicted number of cylinders with minimum thickness of 250.0 mils or less at K-1066-K, assuming initial thickness of 345.5 mils.

Fig. 6. Predicted number of cylinders with breaches at C-745-F, assuming initial thickness of 312.5 mils.

Fig. 7. Predicted number of cylinders with breaches at C-745-F, assuming initial thickness of 345.5 mils.

Fig. 8. Predicted number of cylinders with minimum thickness of 250.0 mils or less at C-745-F, assuming initial thickness of 312.5 mils.

Fig. 9. Predicted number of cylinders with minimum thickness of 250.0 mils or less at C-745-F, assuming initial thickness of 345.5 mils.

Fig. 10. Predicted number of cylinders with breaches at C-745-G, assuming initial thickness of 312.5 mils.

Fig. 11. Predicted number of cylinders with breaches at C-745-G, assuming initial thickness of 345.5 mils.

Fig. 12. Predicted number of cylinders with minimum thickness of 250.0 mils or less at C-745-G, assuming initial thickness of 312.5 mils.

Fig. 13. Predicted number of cylinders with minimum thickness of 250.0 mils or less at C-745-G, assuming initial thickness of 345.5 mils.

Fig. 14. Predicted number of cylinders with breaches at X-745-C, assuming initial thickness of 312.5 mils.

Fig. 15. Predicted number of cylinders with breaches at X-745-C, assuming initial thickness of 345.5 mils.

Fig. 16. Predicted number of cylinders with minimum thickness of 250.0 mils or less at X-745-C, assuming initial thickness of 312.5 mils.

Fig. 17. Predicted number of cylinders with minimum thickness of 250.0 mils or less at X-745-C, assuming initial thickness of 345.5 mils.

APPENDIX A: DATA USED IN CALCULATIONS

A.1. Cylinder Wall Thickness Data

Table A.1. Cylinder wall thickness data for K-1066-K at Oak Ridge, TN (from Barber et al. 1994 and Philpot 1995)

K-1066-K				Initial Thickness 312.5 mils			Initial Thickness 345.5 mils		
Cylinder Number	Date of Measurement	Age at Date of Measurement (yr)	Minimum Thickness (mils)	Average Rate (mil/yr)	Ln of Average Rate	Mils Corroded	Average Rate (mil/yr)	Ln of Average Rate	Mils Corroded
7340	4/1/94	36	140	4.79	1.57	172.5	5.71	1.74	205.5
101708	2/9/94	31	153	5.15	1.64	159.5	6.21	1.83	192.5
101980	2/15/94	31	181	4.24	1.45	131.5	5.31	1.67	164.5
101879	3/22/94	31	190	3.95	1.37	122.5	5.02	1.61	155.5
17071	2/1/94	32	203	3.42	1.23	109.5	4.45	1.49	142.5
101199	2/11/94	31	203	3.53	1.26	109.5	4.60	1.53	142.5
7486	5/13/94	36	205	2.99	1.09	107.5	3.90	1.36	140.5
100736	4/8/94	31	220	2.98	1.09	92.5	4.05	1.40	125.5
101854	4/12/94	31	220	2.98	1.09	92.5	4.05	1.40	125.5
18762	4/21/94	32	220	2.89	1.06	92.5	3.92	1.37	125.5
8723	5/11/94	36	220	2.57	0.94	92.5	3.49	1.25	125.5
17335	2/2/94	32	230	2.58	0.95	82.5	3.61	1.28	115.5
9014	3/30/94	36	230	2.29	0.83	82.5	3.21	1.17	115.5
100861	4/22/94	31	230	2.66	0.98	82.5	3.73	1.32	115.5
5280	5/13/94	38	230	2.17	0.78	82.5	3.04	1.11	115.5
100554	2/1/94	31	235	2.50	0.92	77.5	3.56	1.27	110.5
18124	4/26/94	32	240	2.27	0.82	72.5	3.30	1.19	105.5
5463	5/12/94	38	240	1.91	0.65	72.5	2.78	1.02	105.5
9131	5/12/94	36	240	2.01	0.70	72.5	2.93	1.08	105.5
12500	5/18/94	35	240	2.07	0.73	72.5	3.01	1.10	105.5
101995	3/2/94	31	250	2.02	0.70	62.5	3.08	1.13	95.5
100477	4/14/94	31	250	2.02	0.70	62.5	3.08	1.13	95.5
16145	4/20/94	33	250	1.89	0.64	62.5	2.89	1.06	95.5
8167	5/11/94	36	250	1.74	0.55	62.5	2.65	0.98	95.5
16243	5/18/94	33	250	1.89	0.64	62.5	2.89	1.06	95.5
6294	3/30/94	36	260	1.46	0.38	52.5	2.38	0.87	85.5
101992	4/7/94	31	260	1.69	0.53	52.5	2.76	1.01	85.5
100918	4/12/94	31	260	1.69	0.53	52.5	2.76	1.01	85.5
15547	4/13/94	33	260	1.59	0.46	52.5	2.59	0.95	85.5
101945	4/15/94	31	260	1.69	0.53	52.5	2.76	1.01	85.5
12308	4/21/94	35	260	1.50	0.41	52.5	2.44	0.89	85.5
9123	5/12/94	36	260	1.46	0.38	52.5	2.38	0.87	85.5
100144	1/12/94	31	265	1.53	0.43	47.5	2.60	0.95	80.5
101721	1/12/94	31	265	1.53	0.43	47.5	2.60	0.95	80.5

A-2

K-1066-K				Initial Thickness 312.5 mils			Initial Thickness 345.5 mils		
Cylinder Number	Date of Measurement	Age at Date of Measurement (yr)	Minimum Thickness (mils)	Average Rate (mil/yr)	Ln of Average Rate	Mils Corroded	Average Rate (mil/yr)	Ln of Average Rate	Mils Corroded
100991	5/6/94	31	265	1.53	0.43	47.5	2.60	0.95	80.5
13692	3/18/94	34	270	1.25	0.22	42.5	2.22	0.80	75.5
101653	3/23/94	31	270	1.37	0.32	42.5	2.44	0.89	75.5
8896	4/1/94	36	270	1.18	0.17	42.5	2.10	0.74	75.5
15801	4/13/94	33	270	1.29	0.25	42.5	2.29	0.83	75.5
18585	4/21/94	32	270	1.33	0.28	42.5	2.36	0.86	75.5
101133	5/6/94	31	270	1.37	0.32	42.5	2.44	0.89	75.5
101719	5/7/94	31	270	1.37	0.32	42.5	2.44	0.89	75.5
101801	5/19/94	31	270	1.37	0.32	42.5	2.44	0.89	75.5
101776	5/19/94	31	270	1.37	0.32	42.5	2.44	0.89	75.5
18460	5/19/94	32	270	1.33	0.28	42.5	2.36	0.86	75.5
101814	4/14/94	31	275	1.21	0.19	37.5	2.27	0.82	70.5
7561	1/7/94	36	280	0.90	-0.10	32.5	1.82	0.60	65.5
14375	3/10/94	33	280	0.98	-0.02	32.5	1.98	0.69	65.5
15932	4/6/94	33	280	0.98	-0.02	32.5	1.98	0.69	65.5
100935	4/7/94	31	280	1.05	0.05	32.5	2.11	0.75	65.5
100870	4/8/94	31	280	1.05	0.05	32.5	2.11	0.75	65.5
100619	4/12/94	31	280	1.05	0.05	32.5	2.11	0.75	65.5
6893	5/11/94	36	280	0.90	-0.10	32.5	1.82	0.60	65.5
6102	5/12/94	36	280	0.90	-0.10	32.5	1.82	0.60	65.5
100801	4/13/94	31	290	0.73	-0.32	22.5	1.79	0.58	55.5
101686	5/18/94	31	290	0.73	-0.32	22.5	1.79	0.58	55.5
7300	4/1/94	36	300	0.35	-1.06	12.5	1.26	0.23	45.5
17909	1/26/94	32	150	5.08	1.62	162.5	6.11	1.81	195.5
10394	2/8/94	35	153	4.56	1.52	159.5	5.50	1.70	192.5
17928	1/25/94	32	173	4.36	1.47	139.5	5.39	1.68	172.5
101678	1/14/94	31	185	4.11	1.41	127.5	5.18	1.64	160.5
101463	2/1/94	31	190	3.95	1.37	122.5	5.02	1.61	155.5
101799	4/5/94	31	200	3.63	1.29	112.5	4.69	1.55	145.5
101836	2/15/94	31	203	3.53	1.26	109.5	4.60	1.53	142.5
17299	4/27/94	32	210	3.20	1.16	102.5	4.23	1.44	135.5
100552	3/16/94	31	220	2.98	1.09	92.5	4.05	1.40	125.5
100802	4/20/94	31	220	2.98	1.09	92.5	4.05	1.40	125.5
12027	4/22/94	35	220	2.64	0.97	92.5	3.59	1.28	125.5
18432	4/27/94	32	220	2.89	1.06	92.5	3.92	1.37	125.5
101413	5/17/94	31	220	2.98	1.09	92.5	4.05	1.40	125.5
100681	1/14/94	31	223	2.89	1.06	89.5	3.95	1.37	122.5
11346	3/17/94	35	230	2.36	0.86	82.5	3.30	1.19	115.5
100938	4/14/94	31	230	2.66	0.98	82.5	3.73	1.32	115.5
100430	4/27/94	31	230	2.66	0.98	82.5	3.73	1.32	115.5
8521	3/31/94	36	240	2.01	0.70	72.5	2.93	1.08	105.5
100970	4/6/94	31	240	2.34	0.85	72.5	3.40	1.22	105.5

K-1066-K				Initial Thickness 312.5 mils			Initial Thickness 345.5 mils		
Cylinder Number	Date of Measurement	Age at Date of Measurement (yr)	Minimum Thickness (mils)	Average Rate (mil/yr)	Ln of Average Rate	Mils Corroded	Average Rate (mil/yr)	Ln of Average Rate	Mils Corroded
101803	4/7/94	31	240	2.34	0.85	72.5	3.40	1.22	105.5
100810	4/20/94	31	240	2.34	0.85	72.5	3.40	1.22	105.5
101256	4/22/94	31	240	2.34	0.85	72.5	3.40	1.22	105.5
15908	4/26/94	33	240	2.20	0.79	72.5	3.20	1.16	105.5
7314	5/11/94	36	240	2.01	0.70	72.5	2.93	1.08	105.5
100751	5/19/94	31	240	2.34	0.85	72.5	3.40	1.22	105.5
101340	4/14/94	31	250	2.02	0.70	62.5	3.08	1.13	95.5
101779	4/15/94	31	250	2.02	0.70	62.5	3.08	1.13	95.5
12137	5/5/94	35	250	1.79	0.58	62.5	2.73	1.00	95.5
7783	5/11/94	36	250	1.74	0.55	62.5	2.65	0.98	95.5
6622	5/13/94	36	250	1.74	0.55	62.5	2.65	0.98	95.5
18540	5/19/94	32	250	1.95	0.67	62.5	2.98	1.09	95.5
100480	5/20/94	31	250	2.02	0.70	62.5	3.08	1.13	95.5
101488	3/16/94	31	255	1.85	0.62	57.5	2.92	1.07	90.5
12645	4/13/94	34	255	1.69	0.53	57.5	2.66	0.98	90.5
102180	1/13/94	30	260	1.75	0.56	52.5	2.85	1.05	85.5
16197	4/5/94	33	260	1.59	0.46	52.5	2.59	0.95	85.5
101491	4/13/94	31	260	1.69	0.53	52.5	2.76	1.01	85.5
100852	4/15/94	31	260	1.69	0.53	52.5	2.76	1.01	85.5
10305	4/19/94	35	260	1.50	0.41	52.5	2.44	0.89	85.5
7400	4/21/94	36	260	1.46	0.38	52.5	2.38	0.87	85.5
12142	4/27/94	35	260	1.50	0.41	52.5	2.44	0.89	85.5
100937	5/7/94	31	260	1.69	0.53	52.5	2.76	1.01	85.5
101832	5/18/94	31	260	1.69	0.53	52.5	2.76	1.01	85.5
18113	5/19/94	32	260	1.64	0.50	52.5	2.67	0.98	85.5
101704	5/20/94	31	260	1.69	0.53	52.5	2.76	1.01	85.5
101748	12/13/93	30	265	1.58	0.46	47.5	2.68	0.99	80.5
7448	12/16/93	35	265	1.36	0.31	47.5	2.30	0.83	80.5
6361	12/23/93	35	265	1.36	0.31	47.5	2.30	0.83	80.5
101236	3/15/94	31	265	1.53	0.43	47.5	2.60	0.95	80.5
100855	4/20/94	31	265	1.53	0.43	47.5	2.60	0.95	80.5
5395	12/15/93	37	270	1.15	0.14	42.5	2.04	0.71	75.5
6080	1/11/94	36	270	1.18	0.17	42.5	2.10	0.74	75.5
18784	4/7/94	32	270	1.33	0.28	42.5	2.36	0.86	75.5
101088	4/28/94	31	270	1.37	0.32	42.5	2.44	0.89	75.5
101040	4/29/94	31	270	1.37	0.32	42.5	2.44	0.89	75.5
6948	5/12/94	36	270	1.18	0.17	42.5	2.10	0.74	75.5
100685	5/17/94	31	270	1.37	0.32	42.5	2.44	0.89	75.5
100748	5/18/94	31	270	1.37	0.32	42.5	2.44	0.89	75.5
101802	5/18/94	31	270	1.37	0.32	42.5	2.44	0.89	75.5
18782	5/19/94	32	270	1.33	0.28	42.5	2.36	0.86	75.5
101938	5/19/94	31	270	1.37	0.32	42.5	2.44	0.89	75.5

K-1066-K				Initial Thickness 312.5 mils			Initial Thickness 345.5 mils		
Cylinder Number	Date of Measurement	Age at Date of Measurement (yr)	Minimum Thickness (mils)	Average Rate (mil/yr)	Ln of Average Rate	Mils Corroded	Average Rate (mil/yr)	Ln of Average Rate	Mils Corroded
101516	5/19/94	31	270	1.37	0.32	42.5	2.44	0.89	75.5
18509	5/19/94	32	270	1.33	0.28	42.5	2.36	0.86	75.5
17359	5/6/94	32	275	1.17	0.16	37.5	2.20	0.79	70.5
101744	5/6/94	31	280	1.05	0.05	32.5	2.11	0.75	65.5
17781	5/7/94	32	280	1.02	0.02	32.5	2.05	0.72	65.5
18423	5/17/94	32	280	1.02	0.02	32.5	2.05	0.72	65.5
101561	5/17/94	31	280	1.05	0.05	32.5	2.11	0.75	65.5
101710	5/18/94	31	280	1.05	0.05	32.5	2.11	0.75	65.5
100175	5/17/94	31	285	0.89	-0.12	27.5	1.95	0.67	60.5
10858	5/18/94	35	285	0.79	-0.24	27.5	1.73	0.55	60.5
17901	3/15/94	32	290	0.70	-0.35	22.5	1.73	0.55	55.5
18346	5/5/94	32	290	0.70	-0.35	22.5	1.73	0.55	55.5
18301	5/6/94	32	290	0.70	-0.35	22.5	1.73	0.55	55.5
101764	5/18/94	31	290	0.73	-0.32	22.5	1.79	0.58	55.5
101284	5/18/94	31	290	0.73	-0.32	22.5	1.79	0.58	55.5
8458	1/5/94	36	300	0.35	-1.06	12.5	1.26	0.23	45.5
18261	4/5/94	32	300	0.39	-0.94	12.5	1.42	0.35	45.5
101769	5/17/94	31	300	0.40	-0.91	12.5	1.47	0.38	45.5
101244	12/16/91	29	0	10.78	2.38	312.5	11.91	2.48	345.5
7953	3/17/92	34	0	9.19	2.22	312.5	10.16	2.32	345.5
			Mean	2.00	0.53		3.02	1.03	
			Standard Deviation	1.39	0.57		1.40	0.36	

Table A.2. Cylinder wall thickness data for C-745-F at Paducah, KY (from Blue 1994)

C-745-F				Initial Thickness 312.5 mils			Initial Thickness 345.5 mils		
Cylinder Number	Date of Measurement	Age at Date of Measurement	Minimum thickness (mils)	Average Rate (mil/yr)	Ln of average rate	Mils Corroded	Average Rate (mil/yr)	Ln of average rate	Mils Corroded
10578	1994	35	164	4.24	1.45	148.5	5.19	1.65	181.5
10554	1994	35	168	4.13	1.42	144.5	5.07	1.62	177.5
10392	1994	35	168	4.13	1.42	144.5	5.07	1.62	177.5
10226	1994	35	171	4.04	1.40	141.5	4.99	1.61	174.5
10127	1994	35	192	3.44	1.24	120.5	4.39	1.48	153.5
11540	1994	35	194	3.39	1.22	118.5	4.33	1.47	151.5
10799	1994	35	196	3.33	1.20	116.5	4.27	1.45	149.5
17072	1994	32	200	3.52	1.26	112.5	4.55	1.51	145.5
10563	1994	35	200	3.21	1.17	112.5	4.16	1.42	145.5
14499	1994	33	200	3.41	1.23	112.5	4.41	1.48	145.5
10230	1994	35	204	3.10	1.13	108.5	4.04	1.40	141.5
16060	1994	33	204	3.29	1.19	108.5	4.29	1.46	141.5

C-745-F			Initial Thickness 312.5 mils				Initial Thickness 345.5 mils		
Cylinder Number	Date of Measurement	Age at Date of Measurement	Minimum thickness (mils)	Average Rate (mil/yr)	Ln of average rate	Mils Corroded	Average Rate (mil/yr)	Ln of average rate	Mils Corroded
12560	1994	35	205	3.07	1.12	107.5	4.01	1.39	140.5
10230	1994	35	205	3.07	1.12	107.5	4.01	1.39	140.5
12290	1994	35	205	3.07	1.12	107.5	4.01	1.39	140.5
10950	1994	35	205	3.07	1.12	107.5	4.01	1.39	140.5
10299	1994	35	215	2.79	1.02	97.5	3.73	1.32	130.5
11403	1994	35	220	2.64	0.97	92.5	3.59	1.28	125.5
11825	1994	35	242	2.01	0.70	70.5	2.96	1.08	103.5
12580	1994	35	246	1.90	0.64	66.5	2.84	1.04	99.5
118856	1994	17	257	3.26	1.18	55.5	5.21	1.65	88.5
			Mean	3.24	1.16		4.24	1.43	
			Standard Deviation	0.61	0.20		0.65	0.16	

Table A.3. Cylinder wall thickness data for C-745-G at Paducah, KY (from Blue 1994)

C-745-G			Initial Thickness 312.5 mils				Initial Thickness 345.5 mils		
Cylinder Number	Date of Measurement	Age at Date of Measurement	Minimum Thickness (mils)	Average Rate (mil/yr)	Ln of Average Rate	Mils Corroded	Average Rate (mil/yr)	Ln of Average Rate	Mils Corroded
10524	1994	35	145	4.79	1.57	167.5	5.73	1.75	200.5
11636	1994	35	178	3.84	1.35	134.5	4.79	1.57	167.5
10493	1994	35	179	3.81	1.34	133.5	4.76	1.56	166.5
11650	1994	35	184	3.67	1.30	128.5	4.61	1.53	161.5
16036	1994	33	203	3.32	1.20	109.5	4.32	1.46	142.5
14666	1994	33	209	3.14	1.14	103.5	4.14	1.42	136.5
16121	1994	33	231	2.47	0.90	81.5	3.47	1.24	114.5
15189	1994	33	239	2.23	0.80	73.5	3.23	1.17	106.5
			Mean	3.41	1.20		4.38	1.46	
			Standard Deviation	0.82	0.25		0.79	0.18	

Table A.4. Cylinder wall thickness data for X-745-C at Portsmouth (from Marshall 1995)

X-745-C			Initial Thickness 312.5 mils			Initial Thickness 345.5 mils		
Cylinder Number	Age at Date of Measurement	Minimum thickness (mils)	Average Rate (mil/yr)	Ln of average rate	Mils Corroded	Average Rate (mil/yr)	Ln of average rate	Mils Corroded
10523	35	316	-0.10	NA	-3.5	0.84	-0.17	29.5
10920	35	313	-0.01	NA	-0.5	0.93	-0.07	32.5
11563	35	313	-0.01	NA	-0.5	0.93	-0.07	32.5
11697	35	310	0.07	-2.64	2.5	1.01	0.01	35.5
13183	34	342	-0.87	NA	-29.5	0.10	-2.27	3.5

X-745-C			Initial Thickness 312.5 mils			Initial Thickness 345.5 mils		
Cylinder Number	Age at Date of Measurement	Minimum thickness (mils)	Average Rate (mil/yr)	Ln of average rate	Mils Corroded	Average Rate (mil/yr)	Ln of average rate	Mils Corroded
14402	32	319	-0.20	NA	-6.5	0.83	-0.19	26.5
14487	32	326	-0.42	NA	-13.5	0.61	-0.50	19.5
14525	32	317	-0.14	NA	-4.5	0.89	-0.12	28.5
15583	33	325	-0.38	NA	-12.5	0.62	-0.48	20.5
15614	33	318	-0.17	NA	-5.5	0.83	-0.18	27.5
16738	32	331	-0.58	NA	-18.5	0.45	-0.79	14.5
16833	32	311	0.05	-3.06	1.5	1.08	0.08	34.5
17256	31	303	0.31	-1.18	9.5	1.37	0.32	42.5
17313	31	304	0.27	-1.29	8.5	1.34	0.29	41.5
18352	32	330	-0.55	NA	-17.5	0.48	-0.72	15.5
18399	32	321	-0.27	NA	-8.5	0.77	-0.27	24.5
100321	31	331	-0.60	NA	-18.5	0.47	-0.76	14.5
100398	31	333	-0.66	NA	-20.5	0.40	-0.91	12.5
100988	31	332	-0.63	NA	-19.5	0.44	-0.83	13.5
101111	31	323	-0.34	NA	-10.5	0.73	-0.32	22.5
101515	31	322	-0.31	NA	-9.5	0.76	-0.28	23.5
102012	29	319	-0.22	NA	-6.5	0.91	-0.09	26.5
102149	29	326	-0.47	NA	-13.5	0.67	-0.40	19.5
102159	30	324	-0.38	NA	-11.5	0.72	-0.33	21.5
102193	29	315	-0.09	NA	-2.5	1.05	0.05	30.5
110070	24	322	-0.40	NA	-9.5	0.98	-0.02	23.5
110132	24	319	-0.27	NA	-6.5	1.10	0.10	26.5
110204	24	326	-0.56	NA	-13.5	0.81	-0.21	19.5
110225	24	332	-0.81	NA	-19.5	0.56	-0.58	13.5
110343	24	330	-0.73	NA	-17.5	0.65	-0.44	15.5
110660	21	315	-0.12	NA	-2.5	1.45	0.37	30.5
110666	22	314	-0.07	NA	-1.5	1.43	0.36	31.5
110687	22	322	-0.43	NA	-9.5	1.07	0.07	23.5
110672	21	308	0.21	-1.54	4.5	1.79	0.58	37.5
110673	22	318	-0.25	NA	-5.5	1.25	0.22	27.5
111267	21	328	-0.74	NA	-15.5	0.83	-0.18	17.5
111293	21	322	-0.45	NA	-9.5	1.12	0.11	23.5
111309	21	322	-0.45	NA	-9.5	1.12	0.11	23.5
111314	21	327	-0.69	NA	-14.5	0.88	-0.13	18.5
111334	21	335	-1.07	NA	-22.5	0.50	-0.69	10.5
111338	21	330	-0.83	NA	-17.5	0.74	-0.30	15.5
111353	21	339	-1.26	NA	-26.5	0.31	-1.17	6.5
111967	21	322	-0.45	NA	-9.5	1.12	0.11	23.5
111968	21	322	-0.45	NA	-9.5	1.12	0.11	23.5
112010	21	320	-0.36	NA	-7.5	1.21	0.19	25.5
112018	20	333	-1.03	NA	-20.5	0.63	-0.47	12.5
112025	21	338	-1.21	NA	-25.5	0.36	-1.03	7.5

X-745-C			Initial Thickness 312.5 mils			Initial Thickness 345.5 mils		
Cylinder Number	Age at Date of Measurement	Minimum thickness (mils)	Average Rate (mil/yr)	Ln of average rate	Mils Corroded	Average Rate (mil/yr)	Ln of average rate	Mils Corroded
112026	21	333	-0.98	NA	-20.5	0.60	-0.52	12.5
115414	19	305	0.39	-0.93	7.5	2.13	0.76	40.5
115447	19	314	-0.08	NA	-1.5	1.66	0.51	31.5
115459	19	319	-0.34	NA	-6.5	1.39	0.33	26.5
115460	19	317	-0.24	NA	-4.5	1.50	0.41	28.5
115466	19	311	0.08	-2.54	1.5	1.82	0.60	34.5
117196	18	310	0.14	-1.97	2.5	1.97	0.68	35.5
117205	18	322	-0.53	NA	-9.5	1.31	0.27	23.5
117240	18	327	-0.81	NA	-14.5	1.03	0.03	18.5
117250	18	315	-0.14	NA	-2.5	1.69	0.53	30.5
117251	18	325	-0.69	NA	-12.5	1.14	0.13	20.5
119183	16	322	-0.59	NA	-9.5	1.47	0.38	23.5
121741	15	313	-0.03	NA	-0.5	2.17	0.77	32.5
121820	15	322	-0.63	NA	-9.5	1.57	0.45	23.5
121835	15	320	-0.50	NA	-7.5	1.70	0.53	25.5
121878	15	324	-0.77	NA	-11.5	1.43	0.36	21.5
121891	15	319	-0.43	NA	-6.5	1.77	0.57	26.5
151056	15	336	-1.57	NA	-23.5	0.63	-0.46	9.5
151059	15	330	-1.17	NA	-17.5	1.03	0.03	15.5
151083	15	325	-0.83	NA	-12.5	1.37	0.31	20.5
151085	15	325	-0.83	NA	-12.5	1.37	0.31	20.5
151096	15	325	-0.83	NA	-12.5	1.37	0.31	20.5
152484	12	329	-1.38	NA	-16.5	1.38	0.32	16.5
152486	12	320	-0.63	NA	-7.5	2.13	0.75	25.5
152507	12	330	-1.46	NA	-17.5	1.29	0.26	15.5
152509	12	329	-1.38	NA	-16.5	1.38	0.32	16.5
152764	12	326	-1.13	NA	-13.5	1.63	0.49	19.5
150167	14	311	0.11	-2.23	1.5	2.46	0.90	34.5
150180	14	314	-0.11	NA	-1.5	2.25	0.81	31.5
150571	14	329	-1.18	NA	-16.5	1.18	0.16	16.5
150510	14	338	-1.82	NA	-25.5	0.54	-0.62	7.5
150497	14	345	-2.32	NA	-32.5	0.04	-3.33	0.5
123625	15	314	-0.10	NA	-1.5	2.10	0.74	31.5
123630	15	342	-1.97	NA	-29.5	0.23	-1.46	3.5
123653	14	294	1.32	0.28	18.5	3.68	1.30	51.5
123791	15	323	-0.70	NA	-10.5	1.50	0.41	22.5
123804	14	288	1.75	0.56	24.5	4.11	1.41	57.5
123813	15	323	-0.70	NA	-10.5	1.50	0.41	22.5
123863	14	324	-0.82	NA	-11.5	1.54	0.43	21.5
124126	14	292	1.46	0.38	20.5	3.82	1.34	53.5
125164	13	328	-1.19	NA	-15.5	1.35	0.30	17.5
125165	13	335	-1.73	NA	-22.5	0.81	-0.21	10.5

X-745-C			Initial Thickness 312.5 mils			Initial Thickness 345.5 mils		
Cylinder Number	Age at Date of Measurement	Minimum thickness (mils)	Average Rate (mil/yr)	Ln of average rate	Mils Corroded	Average Rate (mil/yr)	Ln of average rate	Mils Corroded
125166	13	313	-0.04	NA	-0.5	2.50	0.92	32.5
125170	13	333	-1.58	NA	-20.5	0.96	-0.04	12.5
125174	13	322	-0.73	NA	-9.5	1.81	0.59	23.5
125494	12	320	-0.63	NA	-7.5	2.13	0.75	25.5
126634	13	322	-0.73	NA	-9.5	1.81	0.59	23.5
126635	13	325	-0.96	NA	-12.5	1.58	0.46	20.5
126662	13	331	-1.42	NA	-18.5	1.12	0.11	14.5
127483	11	330	-1.59	NA	-17.5	1.41	0.34	15.5
127902	12	368	-4.63	NA	-55.5	-1.88		-22.5
130953	11	332	-1.77	NA	-19.5	1.23	0.20	13.5
130954	11	320	-0.68	NA	-7.5	2.32	0.84	25.5
130956	11	322	-0.86	NA	-9.5	2.14	0.76	23.5
130974	11	324	-1.05	NA	-11.5	1.95	0.67	21.5
131142	11	324	-1.05	NA	-11.5	1.95	0.67	21.5
131148	11	331	-1.68	NA	-18.5	1.32	0.28	14.5
131281	10	322	-0.95	NA	-9.5	2.35	0.85	23.5
131350	11	318	-0.50	NA	-5.5	2.50	0.92	27.5
131367	11	321	-0.77	NA	-8.5	2.23	0.80	24.5
132004	9	310	0.28	-1.28	2.5	3.94	1.37	35.5
132006	9	320	-0.83	NA	-7.5	2.83	1.04	25.5
132010	9	319	-0.72	NA	-6.5	2.94	1.08	26.5
132018	9	319	-0.72	NA	-6.5	2.94	1.08	26.5
132427	9	319	-0.72	NA	-6.5	2.94	1.08	26.5
132441	9	330	-1.94	NA	-17.5	1.72	0.54	15.5
132449	9	321	-0.94	NA	-8.5	2.72	1.00	24.5
132541	8	311	0.19	-1.67	1.5	4.31	1.46	34.5
133044	6	323	-1.75	NA	-10.5	3.75	1.32	22.5
134439	7	318	-0.79	NA	-5.5	3.93	1.37	27.5
134440	7	320	-1.07	NA	-7.5	3.64	1.29	25.5
134444	7	338	-3.64	NA	-25.5	1.07	0.07	7.5
134447	7	332	-2.79	NA	-19.5	1.93	0.66	13.5
135379	5	320	-1.50	NA	-7.5	5.10	1.63	25.5
135405	5	319	-1.30	NA	-6.5	5.30	1.67	26.5
135453	5	324	-2.30	NA	-11.5	4.30	1.46	21.5
135486	5	320	-1.50	NA	-7.5	5.10	1.63	25.5
135854	5	325	-2.50	NA	-12.5	4.10	1.41	20.5
		Average	-0.73	-1.51		1.59	0.25	
		StdDev	0.83	1.03		1.15	0.75	

A.2. Cylinder Age Distributions

Table A.5. Cylinder age distribution for K-1066-K (from Newman 1995)

Manufacture Date	Number of Cylinders
1956	158
1957	1267
1959	98
1960	9
1961	60
1962	333
1963	955
1964	62
Total	2942

Table A.6. Cylinder age distribution for C-745-F (from Newman 1995)

Manufacture Date*	Number of Cylinders
1958 - 1960	1396
1961 - 1976	1671
1977 - 1993	1379
Total	4446

* Lower end of range used in analysis.

Table A.7. Cylinder age distribution for C-745-G (from Newman 1995)

Manufacture Date*	Number of Cylinders
1958 - 1960	3373
1961 - 1976	3575
1977 - 1993	285
Total	7233

* Lower end of range used in analysis.

Table A.8. Cylinder age distribution for X-745-C (from Newman 1995)

Manufacture Date	Number of Cylinders
1956	290
1957	1840
1959	41
1960	7
1961	37
1962	182
1963	74
1964	50
1969	58
1972	253
1973	352
1974	770
1975	842
1976	255
1977	1362
1978	222
1979	848
1980	57
1981	485
1982	773
1985	712
1986	489
1987	177
1988*	4517
Total	14693

REFERENCES

- Barber, E.J., J.H. DeVan, J.M. Googin, and M.S. Taylor (1994). *Investigation of Breached Depleted UF₆ Cylinders at the K-25 Site*. ORNL/TM-12840, Oak Ridge, Tennessee, October 1994.
- S.C. Blue (1994). Facsimile transmittal from S.C. Blue to M. Taylor dated October 27, 1994.
- T. Marshall (1995). Facsimile transmittal from T. Marshall to M. Taylor dated January 4, 1995.
- Newman, V. (1995). Age distribution for UF₆ tails cylinders. Personal communication from V. Newman to B. Lyon January 24, 1995.
- Philpot, H.E. (1995). Report on Ultrasonic Wall Integrity Assessment. Internal memorandum from H.E. Philpot to V.S. Newman and G.A. Person, February 17, 1995.

APPENDIX B: CALCULATION OF CONFIDENCE LIMITS FOR QUANTILES OF A LOGNORMAL DISTRIBUTION

Because specific programs had to be implemented in order to calculate confidence limits for quantiles of the lognormal distribution, the method of calculation is included as an appendix.

If R is lognormally distributed, then by definition $\log R$ is normally distributed. Further, if one obtains confidence limits on a percentile of $\log R$, then the corresponding confidence limit on the percentile of R is obtained by taking the exponential of the confidence limit of $\log R$. For this reason, it is sufficient to discuss confidence limits on the percentiles of a normal distribution.

Confidence Limits for Quantiles of a Normal Distribution

This discussion is based on Lawless (1982). The p th quantile y_p of a normal distribution is given by $y_p = \mu + u_p \sigma$, where μ is the mean, σ is the standard deviation, and u_p is the p th quantile of the standard normal distribution $N(0,1)$ (normal distribution with mean 0 and standard deviation 1). If μ and σ are not known, then one can only obtain confidence limits on the true quantile y_p . Let $\bar{y}$ and s denote the sample mean and standard deviation, respectively. Set

$$Z_p = \frac{(\bar{y} + u_p s) - y_p}{s} = \frac{\hat{y}_p - y_p}{s}$$

where $\hat{y}_p = \bar{y} + u_p s$ is an estimate of y_p . Because for any a

$$\text{Prob}\{Z_p \leq a\} = \text{Prob}\{y_p \geq \bar{y} + (u_p - a)s\}$$

probability statements for Z_p produce confidence limits for y_p . For example, if

$$\text{Prob}\{Z_p \leq a_{0.05}\} = 0.05,$$

then

$$\text{Prob}\{y_p \geq \bar{y} + (u_p - a_{0.05})s\} = 0.05;$$

that is,

$$\text{Prob}\{y_p \leq \bar{y} + (u_p - a_{0.05})s\} = 0.95$$

and so an upper 95th confidence limit for y_p is given by $\bar{y} + (u_p - a_{0.05})s$.

The quantity Z_p can be written in terms of the so-called noncentral t -distribution. We have that

$$\begin{aligned}
\text{Prob}\{Z_p \leq a\} &= \text{Prob}\left\{\frac{\bar{y} + u_p s - y_p}{s} \leq a\right\} \\
&= \text{Prob}\left\{\frac{\bar{y} + u_p s - \mu - u_p \sigma}{s} \leq a\right\} \\
&= \text{Prob}\left\{\frac{\bar{y} - \mu - u_p \sigma}{s} \leq a - u_p\right\} \\
&= \text{Prob}\left\{\frac{\sigma}{s} \left(\frac{\bar{y} - \mu}{\sigma} - u_p\right) \leq a - u_p\right\} \\
&= \text{Prob}\left\{\frac{\sqrt{n} [(\bar{y} - \mu)/\sigma] - u_p \sqrt{n}}{s/\sigma} \leq (a - u_p) \sqrt{n}\right\}
\end{aligned}$$

It is well known that $\sqrt{n} (\bar{y} - \mu)/\sigma \sim N(0,1)$ and $(n-1)s^2/\sigma^2 \sim \chi_{(n-1)}^2$, and that these distributions are independent. The ratio above is then of the form

$$t = \frac{Z + \lambda}{(W/v)^{1/2}}$$

where Z is the standard normal distribution and W is a chi-squared distribution with v degrees of freedom. This distribution is known as the noncentral t distribution, with noncentrality parameter λ (Lawless 1982). It is sometimes denoted $t'_v(\lambda)$. If $\lambda=0$, then the distribution reduces to the standard t distribution. From the above we see that

$$\text{Prob}\{Z_p \leq a\} = \text{Prob}\{t'_{(n-1)}(-u_p \sqrt{n}) \leq (a - u_p) \sqrt{n}\}$$

The steps involved in finding an upper 95th confidence limit for a given quantile y_p are as follows:

- 1) Find the number $T_{0.05}$ such that

$$\text{Prob}\{t'_{(n-1)}(-u_p \sqrt{n}) \leq T_{0.05}\} = 0.05$$

- 2) Compute $a_{0.05}$ by

$$a_{0.05} = u_p + \frac{T_{0.05}}{\sqrt{n}}$$

- 3) The upper 95th confidence limit on the p th quantile, denoted here by $y_{0.95}(p)$, is given

by

$$\begin{aligned} y_{0.95}(p) &= \bar{y} + (u_p - a_{0.05}) s \\ &= \bar{y} - T_{0.05} s / \sqrt{n} \end{aligned}$$

The calculation of the quantiles T_α is described in the next section.

Calculation of the Noncentral t -Distribution

The cumulative distribution function for the noncentral t -distribution is calculated by the method described in Owen (1968). In particular, if T_f denotes the noncentral t -distribution with noncentrality parameter δ and f degrees of freedom, then

$$Prob\{T_f \leq t\} = \frac{\sqrt{2\pi}}{\Gamma(f/2) 2^{(f-2)/2}} \int_0^\infty G\left(\frac{tU}{\sqrt{f}} - \delta\right) U^{f-1} G'(U) dU$$

where $\Gamma()$ is the gamma function and $G(x)$ is the cumulative distribution of the standard normal distribution, given by

$$G(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^x e^{-x^2/2} dx$$

In Owen(1968) it is shown that by integrating by parts repeatedly, one obtains

$$Prob\{T_f \leq t\} = \begin{cases} G(-\delta\sqrt{B}) + 2T(\delta\sqrt{B}, A) + 2 \sum_{i=1}^{(f-1)/2} M_{2i-1} & f \text{ odd} \\ G(-\delta) + \sqrt{2\pi} \sum_{i=0}^{f/2-1} M_{2i} & f \text{ even} \end{cases}$$

and

$$A = \frac{t}{\sqrt{f}} \quad \text{and} \quad B = \frac{f}{f+t^2}$$

and

$$T(h,a) = \frac{1}{2\pi} \int_0^a \frac{\exp\left[-\frac{h^2}{2}(1+x^2)\right]}{1+x^2} dx$$

The coefficients M_k are determined by the following recursion:

$$\begin{aligned} M_{-1} &= 0 \\ M_0 &= A\sqrt{B} G'(\delta\sqrt{B}) G(\delta A\sqrt{B}) \\ M_1 &= B \left[\delta A M_0 + \frac{A}{\sqrt{2\pi}} G'(\delta) \right] \\ M_2 &= \frac{1}{2} B [\delta A M_1 + M_0] \\ M_3 &= \frac{2}{3} B [\delta A M_2 + M_1] \\ &\vdots \\ &\vdots \\ &\vdots \\ M_k &= \frac{k-1}{k} B [a_k \delta A M_{k-1} + M_{k-2}] \end{aligned}$$

where

$$G'(x) = \frac{1}{\sqrt{2\pi}} e^{-x^2/2}$$

and

$$a_k = \frac{1}{(k-2) a_{k-1}} \quad \text{for } k \geq 3 \quad \text{and } a_2 = 1$$

The integrals $T(h,a)$ and $G(x)$ are computed using the algorithms available via anonymous ftp from the STATLIB system at Carnegie Mellon (internet address *lib.stat.cmu.edu*). The algorithm for $T(h,a)$ is AS55 (*Applied Statistics*, 1985), and that for $G(x)$ is AS66 (*Applied Statistics*, 1973).

The method described above has been implemented in Fortran, and the results checked against published tables of the noncentral t -distribution or its equivalent (Owen 1968; Gilbert 1987; Resnikoff and Lieberman 1957). It has also been implemented as a Windows dynamic link library so that it can be called by the Microsoft Excel spreadsheet program in order to be used in this analysis.

REFERENCES

Applied Statistics (1973), Vol. 22, No.3.

Applied Statistics (1985), Vol. 34, No.1.

Gilbert, R.O. (1987). *Statistical Methods for Environmental Pollution Monitoring*. Van Nostrand Reinhold, New York.

Lawless, J.F. (1982). *Statistical Models and Methods for Lifetime Data*. John Wiley and Sons, New York.

Owen, D.B. (1968). A survey of properties and applications of the noncentral t -distribution. *Technometrics*, Vol., 10, No.3.

Resnikoff, G.J. and G.J. Lieberamann. (1957). *Tables of the Non-central t -Distribution*. Stanford University Press, Stanford, CA.

APPENDIX C: INTERMEDIATE RESULTS

In this appendix intermediate results of the calculations are provided.

InitialThicknessChoice 1
 FailureLevel (mils) 0
 Figure Number 2
 YardName K-1066-K

Values used to generate tables below
 Initial Thickness (mils) 312.5
 YardLnMean 0.53
 YardLnStDev 0.57
 TheN 138
 alpha 0.95

	312.5 Mils	345.5 mils
LnMean	0.53	1.03
LnStdev	0.57	0.36
TheN	138	138

Macros to loop through this are in "sumage.mac" BFL, 2-8-95

BreachTableTitle Predicted number of cylinders with breaches at K-1066-K, assuming initial thickness of 312.5 mils.

ThicknessTableTitle Predicted number of cylinders with minimum thickness of 0.0 mils or less at K-1066-K, assuming initial thickness of 312.5 mils.

K-1066-K															
Predicted number of cylinders with breaches at K-1066-K, assuming initial thickness of 312.5 mils.															
		1995		1999		2003		2007		2011		2015		2020	
Manufacture Date	Number	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1956	158	3.25E-03	0.51	5.39E-03	0.85	8.34E-03	1.32	1.22E-02	1.93	1.71E-02	2.70	2.30E-02	3.64	3.20E-02	5.06
1957	1267	2.83E-03	3.59	4.78E-03	6.06	7.52E-03	9.53	1.11E-02	14.13	1.58E-02	19.98	2.14E-02	27.17	3.01E-02	38.10
1959	98	2.11E-03	0.21	3.72E-03	0.36	6.05E-03	0.59	9.22E-03	0.90	1.33E-02	1.31	1.85E-02	1.81	2.64E-02	2.59
1960	9	1.80E-03	0.02	3.25E-03	0.03	5.39E-03	0.05	8.34E-03	0.08	1.22E-02	0.11	1.71E-02	0.15	2.47E-02	0.22
1961	60	1.53E-03	0.09	2.83E-03	0.17	4.78E-03	0.29	7.52E-03	0.45	1.11E-02	0.67	1.58E-02	0.95	2.30E-02	1.38
1962	333	1.29E-03	0.43	2.45E-03	0.82	4.23E-03	1.41	6.75E-03	2.25	1.02E-02	3.38	1.45E-02	4.83	2.14E-02	7.14
1963	955	1.08E-03	1.03	2.11E-03	2.01	3.72E-03	3.55	6.05E-03	5.77	9.22E-03	8.80	1.33E-02	12.73	1.99E-02	19.03
1964	62	8.92E-04	0.06	1.80E-03	0.11	3.25E-03	0.20	5.39E-03	0.33	8.34E-03	0.52	1.22E-02	0.76	1.85E-02	1.15
Total	2942	Total ->	5.93	Total ->	10.42	Total ->	16.93	Total ->	25.84	Total ->	37.46	Total ->	52.04	Total ->	74.66
Upper 95% Confidence Limit on Predicted number of cylinders with breaches at K-1066-K, assuming initial thickness of 312.5 mils.															
		1995		1999		2003		2007		2011		2015		2020	
Manufacture Date	Number	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1956	158	7.89E-03	1.25	1.20E-02	1.89	1.72E-02	2.72	2.36E-02	3.73	3.12E-02	4.93	4.01E-02	6.33	5.27E-02	8.33
1957	1267	7.03E-03	8.91	1.08E-02	13.75	1.58E-02	19.99	2.19E-02	27.73	2.92E-02	37.01	3.77E-02	47.81	5.01E-02	63.42
1959	98	5.51E-03	0.54	8.81E-03	0.86	1.32E-02	1.29	1.87E-02	1.83	2.54E-02	2.49	3.33E-02	3.27	4.49E-02	4.40
1960	9	4.84E-03	0.04	7.89E-03	0.07	1.20E-02	0.11	1.72E-02	0.15	2.36E-02	0.21	3.12E-02	0.28	4.24E-02	0.38
1961	60	4.23E-03	0.25	7.03E-03	0.42	1.08E-02	0.65	1.58E-02	0.95	2.19E-02	1.31	2.92E-02	1.75	4.01E-02	2.40
1962	333	3.67E-03	1.22	6.24E-03	2.08	9.79E-03	3.26	1.44E-02	4.81	2.02E-02	6.74	2.73E-02	9.08	3.77E-02	12.57
1963	955	3.17E-03	3.02	5.51E-03	5.26	8.81E-03	8.41	1.32E-02	12.58	1.87E-02	17.84	2.54E-02	24.25	3.55E-02	33.89
1964	62	2.71E-03	0.17	4.84E-03	0.30	7.89E-03	0.49	1.20E-02	0.74	1.72E-02	1.07	2.36E-02	1.46	3.33E-02	2.07
Total	2942	Total ->	15.41	Total ->	24.63	Total ->	36.92	Total ->	52.53	Total ->	71.61	Total ->	94.23	Total ->	127.47

Initial Thickness (mils)	345.5
YardLnMean	1.03
YardLnStDev	0.36
TheN	138
alpha	0.95

	312.5 Mills	345.5 mills
LnMean	0.53	1.03
LnStdev	0.57	0.36
TheN	138	138

BreachTableTitle	Predicted number of cylinders with breaches at K-1066-K, assuming initial thickness of 345.5 mils.
ThicknessTableTitle	Predicted number of cylinders with minimum thickness of 0.0 mils or less at K-1066-K, assuming initial thickness of 345.5 mils.

K-1066-K		Predicted number of cylinders with breaches at K-1066-K, assuming initial thickness of 345.5 mils.													
		1995		1999		2003		2007		2011		2015		2020	
Manufacture Date	Number	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1956	158	6.91E-04	0.11	1.71E-03	0.27	3.68E-03	0.58	7.08E-03	1.12	1.24E-02	1.96	2.03E-02	3.20	3.42E-02	5.40
1957	1267	5.37E-04	0.68	1.38E-03	1.75	3.07E-03	3.89	6.07E-03	7.69	1.09E-02	13.79	1.80E-02	22.86	3.10E-02	39.28
1959	98	3.12E-04	0.03	8.80E-04	0.09	2.10E-03	0.21	4.38E-03	0.43	8.21E-03	0.80	1.41E-02	1.39	2.52E-02	2.47
1960	9	2.34E-04	0.00	6.91E-04	0.01	1.71E-03	0.02	3.68E-03	0.03	7.08E-03	0.06	1.24E-02	0.11	2.27E-02	0.20
1961	60	1.72E-04	0.01	5.37E-04	0.03	1.38E-03	0.08	3.07E-03	0.18	6.07E-03	0.36	1.09E-02	0.65	2.03E-02	1.22
1962	333	1.25E-04	0.04	4.12E-04	0.14	1.11E-03	0.37	2.55E-03	0.85	5.17E-03	1.72	9.48E-03	3.16	1.80E-02	6.01
1963	955	8.92E-05	0.09	3.12E-04	0.30	8.80E-04	0.84	2.10E-03	2.00	4.38E-03	4.18	8.21E-03	7.84	1.60E-02	15.28
1964	62	6.25E-05	0.00	2.34E-04	0.01	6.91E-04	0.04	1.71E-03	0.11	3.68E-03	0.23	7.08E-03	0.44	1.41E-02	0.88
Total	2942	Total ->	0.96	Total ->	2.60	Total ->	6.03	Total ->	12.41	Total ->	23.11	Total ->	39.65	Total ->	70.74

Upper 95% Confidence Limit on Predicted number of cylinders with breaches at K-1066-K, assuming initial thickness of 345.5 mils.															
		1995		1999		2003		2007		2011		2015		2020	
Manufacture Date	Number	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1956	158	2.20E-03	0.35	4.64E-03	0.73	8.73E-03	1.38	1.50E-02	2.37	2.40E-02	3.79	3.60E-02	5.69	5.57E-02	8.81
1957	1267	1.78E-03	2.26	3.89E-03	4.93	7.52E-03	9.53	1.32E-02	16.74	2.15E-02	27.18	3.27E-02	41.40	5.14E-02	65.06
1959	98	1.14E-03	0.11	2.68E-03	0.26	5.48E-03	0.54	1.01E-02	0.99	1.70E-02	1.66	2.67E-02	2.61	4.32E-02	4.24
1960	9	9.00E-04	0.01	2.20E-03	0.02	4.64E-03	0.04	8.73E-03	0.08	1.50E-02	0.14	2.40E-02	0.22	3.95E-02	0.36
1961	60	7.01E-04	0.04	1.78E-03	0.11	3.89E-03	0.23	7.52E-03	0.45	1.32E-02	0.79	2.15E-02	1.29	3.60E-02	2.16
1962	333	5.38E-04	0.18	1.44E-03	0.48	3.24E-03	1.08	6.44E-03	2.15	1.16E-02	3.85	1.91E-02	6.37	3.27E-02	10.88
1963	955	4.08E-04	0.39	1.14E-03	1.09	2.68E-03	2.56	5.48E-03	5.24	1.01E-02	9.62	1.70E-02	16.22	2.96E-02	28.24
1964	62	3.05E-04	0.02	9.00E-04	0.06	2.20E-03	0.14	4.64E-03	0.29	8.73E-03	0.54	1.50E-02	0.93	2.67E-02	1.65
Total	2942	Total ->	3.36	Total ->	7.68	Total ->	15.50	Total ->	28.30	Total ->	47.57	Total ->	74.72	Total ->	121.40

Values used to generate tables below

InitialThicknessChoice 1
 FailureLevel (mils) 250
 Figure Number 4
 YardName K-1066-K

Initial Thickness (mils) 312.5
 YardLnMean 0.53
 YardLnStDev 0.57
 TheN 138
 alpha 0.95

	312.5 Mils	345.5 mils
LnMean	0.53	1.03
LnStdev	0.57	0.36
TheN	138	138

Macros to loop through this are in "sumage.mac" BFL, 2-8-95

BreachTableTitle Predicted number of cylinders with breaches at K-1066-K, assuming initial thickness of 312.5 mils.

ThicknessTableTitle Predicted number of cylinders with minimum thickness of 250.0 mils or less at K-1066-K, assuming initial thickness of 312.5 mils.

K-1066-K															
Predicted number of cylinders with minimum thickness of 250.0 mils or less at K-1066-K, assuming initial thickness of 312.5 mils.															
Manufacture Date	Number	1995		1999		2003		2007		2011		2015		2020	
		Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1956	158	5.41E-01	85.45	6.08E-01	96.04	6.66E-01	105.28	7.17E-01	113.24	7.60E-01	120.04	7.96E-01	125.83	8.34E-01	131.82
1957	1267	5.23E-01	662.23	5.92E-01	749.95	6.52E-01	826.71	7.05E-01	893.02	7.50E-01	949.80	7.88E-01	998.11	8.27E-01	1048.27
1959	98	4.85E-01	47.52	5.58E-01	54.72	6.23E-01	61.08	6.80E-01	66.61	7.28E-01	71.36	7.69E-01	75.41	8.13E-01	79.63
1960	9	4.65E-01	4.19	5.41E-01	4.87	6.08E-01	5.47	6.66E-01	6.00	7.17E-01	6.45	7.60E-01	6.84	8.05E-01	7.24
1961	60	4.45E-01	26.70	5.23E-01	31.36	5.92E-01	35.51	6.52E-01	39.15	7.05E-01	42.29	7.50E-01	44.98	7.96E-01	47.78
1962	333	4.24E-01	141.33	5.04E-01	167.84	5.75E-01	191.61	6.38E-01	212.50	6.92E-01	230.60	7.39E-01	246.12	7.88E-01	262.33
1963	955	4.03E-01	385.23	4.85E-01	463.03	5.58E-01	533.25	6.23E-01	595.22	6.80E-01	649.07	7.28E-01	695.36	7.79E-01	743.77
1964	62	3.82E-01	23.68	4.65E-01	28.84	5.41E-01	33.53	6.08E-01	37.69	6.66E-01	41.31	7.17E-01	44.44	7.69E-01	47.71
Total	2942	Total ->	1376.32	Total ->	1596.66	Total ->	1792.45	Total ->	1963.42	Total ->	2110.91	Total ->	2237.08	Total ->	2368.56

Upper 95% Confidence Limit on Predicted number of cylinders with minimum thickness of 250.0 mils or less at K-1066-K, assuming initial thickness of 312.5 mils.															
Manufacture Date	Number	1995		1999		2003		2007		2011		2015		2020	
		Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1956	158	5.96E-01	94.15	6.61E-01	104.48	7.17E-01	113.36	7.65E-01	120.91	8.05E-01	127.25	8.39E-01	132.54	8.73E-01	137.91
1957	1267	5.78E-01	732.39	6.46E-01	818.20	7.04E-01	892.30	7.54E-01	955.39	7.96E-01	1008.53	8.31E-01	1052.96	8.67E-01	1098.09
1959	98	5.41E-01	52.99	6.13E-01	60.08	6.76E-01	66.26	7.30E-01	71.56	7.76E-01	76.04	8.14E-01	79.80	8.53E-01	83.64
1960	9	5.21E-01	4.69	5.96E-01	5.36	6.61E-01	5.95	7.17E-01	6.46	7.65E-01	6.89	8.05E-01	7.25	8.46E-01	7.62
1961	60	5.01E-01	30.06	5.78E-01	34.68	6.46E-01	38.75	7.04E-01	42.26	7.54E-01	45.24	7.96E-01	47.76	8.39E-01	50.33
1962	333	4.80E-01	159.99	5.60E-01	186.36	6.30E-01	209.70	6.90E-01	229.93	7.42E-01	247.21	7.86E-01	261.80	8.31E-01	276.75
1963	955	4.59E-01	438.68	5.41E-01	516.35	6.13E-01	585.50	6.76E-01	645.73	7.30E-01	697.34	7.76E-01	741.03	8.23E-01	785.86
1964	62	4.38E-01	27.14	5.21E-01	32.31	5.96E-01	36.94	6.61E-01	41.00	7.17E-01	44.48	7.65E-01	47.44	8.14E-01	50.49
Total	2942	Total ->	1540.09	Total ->	1757.84	Total ->	1948.77	Total ->	2113.22	Total ->	2252.99	Total ->	2370.60	Total ->	2490.66

Values used to generate tables below.

InitialThicknessChoice	1
FailureLevel (mils)	0
Figure Number	6
YardName	C-745-F

Initial Thickness (mils)	312.5
YardLnMean	1.16
YardLnStDev	0.2
TheN	21
alpha	0.95

	312.5 Mils	345.5 mils
LnMean	1.16	1.43
LnStdev	0.2	0.16
TheN	21	21

Macros to loop through this are in "sumage.mac". BFL, 2-8-95

BreachTableTitle Predicted number of cylinders with breaches at C-745-F, assuming initial thickness of 312.5 mils.

ThicknessTableTitle Predicted number of cylinders with minimum thickness of 0.0 mils or less at C-745-F, assuming initial thickness of 312.5 mils.

C-745-F															
Predicted number of cylinders with breaches at C-745-F, assuming initial thickness of 312.5 mils.															
		1995		1999		2003		2007		2011		2015		2020	
Manufacture Date	Number	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1958	1396	5.63E-07	0.00	6.65E-06	0.01	5.02E-05	0.07	2.66E-04	0.37	1.06E-03	1.49	3.39E-03	4.73	1.11E-02	15.48
1961	1671	6.09E-08	0.00	1.10E-06	0.00	1.15E-05	0.02	7.85E-05	0.13	3.86E-04	0.64	1.45E-03	2.42	5.62E-03	9.39
1977	1379	0.00E+00	0.00	4.11E-14	0.00	1.66E-11	0.00	1.64E-09	0.00	6.09E-08	0.00	1.10E-06	0.00	1.92E-05	0.03
Total	4446	Total ->	0.00	Total ->	0.01	Total ->	0.09	Total ->	0.50	Total ->	2.13	Total ->	7.15	Total ->	24.89

Upper 95% Confidence Limit on Predicted number of cylinders with breaches at C-745-F, assuming initial thickness of 312.5 mils.															
		1995		1999		2003		2007		2011		2015		2020	
Manufacture Date	Number	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1958	1396	2.05E-04	0.29	8.19E-04	1.14	2.56E-03	3.57	6.59E-03	9.21	1.46E-02	20.36	2.85E-02	39.76	5.71E-02	79.68
1961	1671	5.91E-05	0.10	2.98E-04	0.50	1.11E-03	1.86	3.29E-03	5.51	8.15E-03	13.61	1.74E-02	29.12	3.83E-02	63.93
1977	1379	9.54E-07	0.00	9.54E-07	0.00	9.54E-07	0.00	7.63E-06	0.01	5.91E-05	0.08	2.98E-04	0.41	1.49E-03	2.05
Total	4446	Total ->	0.39	Total ->	1.64	Total ->	5.43	Total ->	14.72	Total ->	34.06	Total ->	69.29	Total ->	145.66

InitialThicknessChoice	1
FailureLevel (mils)	250
Figure Number	8
YardName	C-745-F

Initial Thickness (mils)	312.5
YardLnMean	1.16
YardLnStDev	0.2
TheN	21
alpha	0.95

	312.5 Mils	345.5 mils
LnMean	1.16	1.43
LnStdev	0.2	0.16
TheN	21	21

ThicknessTableTitle Predicted number of cylinders with minimum thickness of 250.0 mils or less at C-745-F, assuming initial thickness of 312.5 mils.

C-745-F		Predicted number of cylinders with minimum thickness of 250.0 mils or less at C-745-F, assuming initial thickness of 312.5 mils.													
Manufacture Date	Number	1995		1999		2003		2007		2011		2015		2020	
		Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1958	1396	9.99E-01	1394.97	1.00E+00	1395.84	1.00E+00	1395.98	1.00E+00	1396.00	1.00E+00	1396.00	1.00E+00	1396.00	1.00E+00	1396.00
1961	1671	9.97E-01	1666.11	1.00E+00	1670.23	1.00E+00	1670.89	1.00E+00	1670.98	1.00E+00	1671.00	1.00E+00	1671.00	1.00E+00	1671.00
1977	1379	3.36E-01	463.06	7.19E-01	991.27	9.21E-01	1270.63	9.83E-01	1356.14	9.97E-01	1374.97	1.00E+00	1378.36	1.00E+00	1378.94
Total	4446	Total ->	3524.14	Total ->	4057.34	Total ->	4337.49	Total ->	4423.12	Total ->	4441.96	Total ->	4445.36	Total ->	4445.94

C-745-F		Upper 95% Confidence Limit on Predicted number of cylinders with minimum thickness of 250.0 mils or less at C-745-F, assuming initial thickness of 312.5 mils.													
Manufacture Date	Number	1995		1999		2003		2007		2011		2015		2020	
		Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1958	1396	1.00E+00	1395.96	1.00E+00	1396.00	1.00E+00	1396.00	1.00E+00	1396.00	1.00E+00	1396.00	1.00E+00	1396.00	1.00E+00	1396.00
1961	1671	1.00E+00	1670.66	1.00E+00	1670.98	1.00E+00	1671.00	1.00E+00	1671.00	1.00E+00	1671.00	1.00E+00	1671.00	1.00E+00	1671.00
1977	1379	4.83E-01	665.47	8.32E-01	1147.20	9.72E-01	1340.71	9.97E-01	1375.15	1.00E+00	1378.72	1.00E+00	1378.98	1.00E+00	1379.00
Total	4446	Total ->	3732.09	Total ->	4214.17	Total ->	4407.70	Total ->	4442.15	Total ->	4445.72	Total ->	4445.98	Total ->	4446.00

Values used to generate tables below.

Initial Thickness (mils)	345.5
YardLnMean	1.43
YardLnStDev	0.16
TheN	21
alpha	0.95

InitialThicknessChoice	2
FailureLevel (mils)	250
Figure Number	9
YardName	C-745-F

	312.5 Mils	345.5 mils
LnMean	1.16	1.43
LnStdev	0.2	0.16
TheN	21	21

Macros to loop through this are in "sumage.mac". BFL, 2-8-95

BreachTableTitle Predicted number of cylinders with breaches at C-745-F, assuming initial thickness of 345.5 mils.

ThicknessTableTitle Predicted number of cylinders with minimum thickness of 250.0 mils or less at C-745-F, assuming initial thickness of 345.5 mils.

C-745-F													
Predicted number of cylinders with minimum thickness of 250.0 mils or less at C-745-F, assuming initial thickness of 345.5 mils.													
Manufacture Date	Number	1995		1999		2003		2007		2011		2015	
		Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1958	1396	9.99E-01	1394.18	1.00E+00	1395.82	1.00E+00	1395.98	1.00E+00	1396.00	1.00E+00	1396.00	1.00E+00	1396.00
1961	1671	9.93E-01	1660.11	9.99E-01	1669.76	1.00E+00	1670.88	1.00E+00	1670.99	1.00E+00	1671.00	1.00E+00	1671.00
1977	1379	6.78E-02	93.53	4.06E-01	559.78	7.90E-01	1089.27	9.55E-01	1317.60	9.93E-01	1370.01	9.99E-01	1377.98
Total	4446	Total ->	3147.82	Total ->	3625.36	Total ->	4156.13	Total ->	4384.59	Total ->	4437.01	Total ->	4444.98
Upper 95% Confidence Limit on Predicted number of cylinders with minimum thickness of 250.0 mils or less at C-745-F, assuming initial thickness of 345.5 mils													
Manufacture Date	Number	1995		1999		2003		2007		2011		2015	
		Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1958	1396	1.00E+00	1395.92	1.00E+00	1396.00	1.00E+00	1396.00	1.00E+00	1396.00	1.00E+00	1396.00	1.00E+00	1396.00
1961	1671	9.99E-01	1669.85	1.00E+00	1670.96	1.00E+00	1671.00	1.00E+00	1671.00	1.00E+00	1671.00	1.00E+00	1671.00
1977	1379	1.70E-01	234.92	5.51E-01	760.30	8.87E-01	1223.65	9.88E-01	1362.32	9.99E-01	1378.05	1.00E+00	1378.96
Total	4446	Total ->	3300.69	Total ->	3827.25	Total ->	4290.65	Total ->	4429.32	Total ->	4445.05	Total ->	4445.96
Total	4446	Total ->	3300.69	Total ->	3827.25	Total ->	4290.65	Total ->	4429.32	Total ->	4445.05	Total ->	4446.00

C-745-G		Predicted number of cylinders with breaches at C-745-G, assuming initial thickness of 312.5 mils													
Manufacture Date	Number	1995		1999		2003		2007		2011		2015		2020	
1958	3373	9.40E-05	0.32	4.44E-04	1.50	1.58E-03	5.33	4.51E-03	15.22	1.08E-02	36.44	2.24E-02	75.61	4.75E-02	160.12
1961	3575	2.32E-05	0.08	1.43E-04	0.51	6.24E-04	2.23	2.09E-03	7.48	5.70E-03	20.37	1.31E-02	46.92	3.09E-02	110.33
1977	285	1.84E-11	0.00	3.05E-09	0.00	1.33E-07	0.00	2.40E-06	0.00	2.32E-05	0.01	1.43E-04	0.04	8.63E-04	0.25
Total	7233	Total >	0.40	Total >	2.01	Total >	7.56	Total >	22.70	Total >	56.81	Total >	122.58	Total >	270.70
Upper 95% Confidence Limit on Predicted number of cylinders with breaches at C-745-G, assuming initial thickness of 312.5 mils															
Manufacture Date	Number	1995		1999		2003		2007		2011		2015		2020	
1958	3373	2.46E-02	82.96	4.22E-02	142.30	6.62E-02	223.34	9.69E-02	326.90	1.34E-01	452.53	1.78E-01	598.75	2.39E-01	807.06
1961	3575	1.52E-02	54.48	2.84E-02	101.60	4.76E-02	170.08	7.33E-02	261.91	1.06E-01	377.62	1.44E-01	516.41	2.01E-01	719.57
1977	285	1.48E-04	0.04	7.82E-04	0.22	2.71E-03	0.77	7.08E-03	2.02	1.52E-02	4.34	2.84E-02	8.10	5.34E-02	15.21
Total	7233	Total >	137.49	Total >	244.13	Total >	394.20	Total >	590.83	Total >	834.49	Total >	1123.25	Total >	1541.83

Values used to generate tables below

InitialThicknessChoice	2
FailureLevel (mils)	0
Figure Number	11
YardName	C-745-G

Initial Thickness (mils)	345.5
YardLnMean	1.46
YardLnStDev	0.18
TheN	8
alpha	0.95

	312.5 Mils	345.5 mils
LnMean	1.2	1.46
LnStdev	0.25	0.18
TheN	8	8

Macros to loop through this are in "sumage.mac" BFL, 2-8-95

BreachTableTitle Predicted number of cylinders with breaches at C-745-G, assuming initial thickness of 345.5 mils.

ThicknessTableTitle Predicted number of cylinders with minimum thickness of 0.0 mils or less at C-745-G, assuming initial thickness of 345.5 mils.

C-745-G													
Predicted number of cylinders with breaches at C-745-G, assuming initial thickness of 345.5 mils.													
Manufacture Date	Number	1995		1999		2003		2007		2011		2015	
		Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1958	3373	8.53E-06	0.03	9.57E-05	0.32	6.57E-04	2.22	3.07E-03	10.37	1.06E-02	35.80	2.87E-02	96.93
1961	3575	9.21E-07	0.00	1.65E-05	0.06	1.61E-04	0.58	9.98E-04	3.57	4.30E-03	15.37	1.39E-02	49.70
1977	285	0.00E+00	0.00	3.30E-13	0.00	1.93E-10	0.00	2.31E-08	0.00	9.21E-07	0.00	1.65E-05	0.00
Total	7233	Total ->	0.03	Total ->	0.38	Total ->	2.79	Total ->	13.93	Total ->	51.17	Total ->	146.64
Upper 95% Confidence Limit on Predicted number of cylinders with breaches at C-745-G, assuming initial thickness of 345.5 mils.													
Manufacture Date	Number	1995		1999		2003		2007		2011		2015	
		Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1958	3373	1.09E-02	36.60	2.48E-02	83.49	4.85E-02	163.43	8.42E-02	284.06	1.33E-01	449.54	1.96E-01	660.02
1961	3575	5.14E-03	18.39	1.36E-02	48.48	2.97E-02	106.02	5.62E-02	200.89	9.52E-02	340.38	1.48E-01	527.84
1977	285	1.91E-06	0.00	4.01E-05	0.01	3.18E-04	0.09	1.52E-03	0.43	5.14E-03	1.47	1.36E-02	3.86
Total	7233	Total ->	54.99	Total ->	131.98	Total ->	269.53	Total ->	485.38	Total ->	791.39	Total ->	1191.73
												Total ->	1818.84

Values used to generate tables below

InitialThicknessChoice	1
FailureLevel (mils)	250
Figure Number	12
YardName	C-745-G

Initial Thickness (mils)	312.5
YardLnMean	1.2
YardLnStDev	0.25
TheN	8
alpha	0.95

	312.5 Mils	345.5 mils
LnMean	1.2	1.46
LnStdev	0.25	0.18
TheN	8	8

Macros to loop through this are in "sumage.mac" BFL, 2-8-95

BreachTableTitle Predicted number of cylinders with breaches at C-745-G, assuming initial thickness of 312.5 mils.

ThicknessTableTitle Predicted number of cylinders with minimum thickness of 250.0 mils or less at C-745-G, assuming initial thickness of 312.5 mils.

C-745-G															
Predicted number of cylinders with minimum thickness of 250.0 mils or less at C-745-G, assuming initial thickness of 312.5 mils.															
Manufacture Date	Number	1995		1999		2003		2007		2011		2015		2020	
		Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1958	3373	9.97E-01	3361.41	9.99E-01	3369.88	1.00E+00	3372.17	1.00E+00	3372.78	1.00E+00	3372.94	1.00E+00	3372.98	1.00E+00	3373.00
1961	3575	9.91E-01	3542.75	9.98E-01	3566.14	9.99E-01	3572.63	1.00E+00	3574.37	1.00E+00	3574.83	1.00E+00	3574.96	1.00E+00	3574.99
1977	285	4.29E-01	122.24	7.34E-01	209.05	9.02E-01	257.01	9.69E-01	276.12	9.91E-01	282.43	9.98E-01	284.29	1.00E+00	284.86
Total	7233	Total ->	7026.40	Total ->	7145.07	Total ->	7201.81	Total ->	7223.27	Total ->	7230.20	Total ->	7232.23	Total ->	7232.85
Upper 95% Confidence Limit on Predicted number of cylinders with minimum thickness of 250.0 mils or less at C-745-G, assuming initial thickness of 312.5 mils.															
Manufacture Date	Number	1995		1999		2003		2007		2011		2015		2020	
		Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1958	3373	1.00E+00	3372.87	1.00E+00	3372.99	1.00E+00	3373.00	1.00E+00	3373.00	1.00E+00	3373.00	1.00E+00	3373.00	1.00E+00	3373.00
1961	3575	1.00E+00	3574.15	1.00E+00	3574.92	1.00E+00	3575.00	1.00E+00	3575.00	1.00E+00	3575.00	1.00E+00	3575.00	1.00E+00	3575.00
1977	285	6.60E-01	188.23	8.93E-01	254.62	9.81E-01	279.46	9.98E-01	284.31	1.00E+00	284.93	1.00E+00	284.99	1.00E+00	285.00
Total	7233	Total ->	7135.25	Total ->	7202.53	Total ->	7227.45	Total ->	7232.30	Total ->	7232.93	Total ->	7232.99	Total ->	7232.99

InitialThicknessChoice 2
 FailureLevel (mils) 250
 Figure Number 13
 YardName C-745-G

Values used to generate tables below
 Initial Thickness (mils) 345.5
 YardLnMean 1.46
 YardLnStDev 0.18
 TheN 8
 alpha 0.95

	312.5 Mils	345.5 mils
LnMean	1.2	1.46
LnStdev	0.25	0.18
TheN	8	8

Macros to loop through this are in "sumage.mac" BFL, 2-8-95

BreachTableTitle Predicted number of cylinders with breaches at C-745-G, assuming initial thickness of 345.5 mils.

ThicknessTableTitle Predicted number of cylinders with minimum thickness of 250.0 mils or less at C-745-G, assuming initial thickness of 345.5 mils.

C-745-G															
Predicted number of cylinders with minimum thickness of 250.0 mils or less at C-745-G, assuming initial thickness of 345.5 mils.															
		1995		1999		2003		2007		2011		2015		2020	
Manufacture Date	Number	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1958	3373	9.98E-01	3365.47	1.00E+00	3371.92	1.00E+00	3372.86	1.00E+00	3372.98	1.00E+00	3373.00	1.00E+00	3373.00	1.00E+00	3373.00
1961	3575	9.91E-01	3543.51	9.99E-01	3570.04	1.00E+00	3574.30	1.00E+00	3574.91	1.00E+00	3574.99	1.00E+00	3575.00	1.00E+00	3575.00
1977	285	1.23E-01	35.08	4.82E-01	137.40	8.11E-01	231.26	9.53E-01	271.70	9.91E-01	282.49	9.99E-01	284.60	1.00E+00	284.97
Total	7233	Total ->	6944.05	Total ->	7079.35	Total ->	7178.42	Total ->	7219.59	Total ->	7230.48	Total ->	7232.60	Total ->	7232.97

Upper 95% Confidence Limit on Predicted number of cylinders with minimum thickness of 250.0 mils or less at C-745-G, assuming initial thickness of 345.5 mils.															
		1995		1999		2003		2007		2011		2015		2020	
Manufacture Date	Number	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1958	3373	1.00E+00	3372.94	1.00E+00	3373.00	1.00E+00	3373.00	1.00E+00	3373.00	1.00E+00	3373.00	1.00E+00	3373.00	1.00E+00	3373.00
1961	3575	1.00E+00	3574.19	1.00E+00	3574.98	1.00E+00	3575.00	1.00E+00	3575.00	1.00E+00	3575.00	1.00E+00	3575.00	1.00E+00	3575.00
1977	285	3.58E-01	102.10	7.05E-01	200.89	9.40E-01	267.85	9.95E-01	283.55	1.00E+00	284.94	1.00E+00	285.00	1.00E+00	285.00
Total	7233	Total ->	7049.23	Total ->	7148.87	Total ->	7215.84	Total ->	7231.54	Total ->	7232.93	Total ->	7232.99	Total ->	7232.99

Values used to generate table below

InitialThicknessChoice 1
 FailureLevel (mils) 0
 Figure Number 14
 YardName X-745-C

Initial Thickness (mils) 312.5
 YardLnMean -1.36
 YardLnStDev 1.14
 TheN 14
 alpha 0.95

	312.5 Mils	345.5 mils
LnMean	-1.36	0.25
LnStDev	1.14	0.75
TheN	14	125

Macros to run this are in "sumage.mac". BFL, 2-8-95

BreachTableTitle Predicted number of cylinders with breaches at X-745-C, assuming initial thickness of 312.5 mils.

ThicknessTableTitle Predicted number of cylinders with minimum thickness of 0.0 mils or less at X-745-C, assuming initial thickness of 312.5 mils.

X-745-C															
Predicted number of cylinders with breaches at X-745-C, assuming initial thickness of 312.5 mils.															
		1995		1999		2003		2007		2011		2015		2020	
Manufacture Date	Number	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1956	290	1.27E-03	0.37	1.68E-03	0.49	2.15E-03	0.62	2.69E-03	0.78	3.29E-03	0.96	3.96E-03	1.15	4.88E-03	1.42
1957	1840	1.18E-03	2.17	1.57E-03	2.89	2.03E-03	3.73	2.55E-03	4.69	3.14E-03	5.77	3.79E-03	6.97	4.69E-03	8.63
1959	41	1.01E-03	0.04	1.37E-03	0.06	1.79E-03	0.07	2.28E-03	0.09	2.84E-03	0.12	3.46E-03	0.14	4.32E-03	0.18
1960	7	9.25E-04	0.01	1.27E-03	0.01	1.68E-03	0.01	2.15E-03	0.02	2.69E-03	0.02	3.29E-03	0.02	4.14E-03	0.03
1961	37	8.48E-04	0.03	1.18E-03	0.04	1.57E-03	0.06	2.03E-03	0.08	2.55E-03	0.09	3.14E-03	0.12	3.96E-03	0.15
1962	182	7.75E-04	0.14	1.09E-03	0.20	1.47E-03	0.27	1.91E-03	0.35	2.41E-03	0.44	2.99E-03	0.54	3.79E-03	0.69
1963	74	7.07E-04	0.05	1.01E-03	0.07	1.37E-03	0.10	1.79E-03	0.13	2.28E-03	0.17	2.84E-03	0.21	3.62E-03	0.27
1964	50	6.41E-04	0.03	9.25E-04	0.05	1.27E-03	0.06	1.68E-03	0.08	2.15E-03	0.11	2.69E-03	0.13	3.46E-03	0.17
1969	58	3.70E-04	0.02	5.80E-04	0.03	8.48E-04	0.05	1.18E-03	0.07	1.57E-03	0.09	2.03E-03	0.12	2.69E-03	0.16
1972	253	2.49E-04	0.06	4.17E-04	0.11	6.41E-04	0.16	9.25E-04	0.23	1.27E-03	0.32	1.68E-03	0.42	2.28E-03	0.58
1973	352	2.15E-04	0.08	3.70E-04	0.13	5.80E-04	0.20	8.48E-04	0.30	1.18E-03	0.41	1.57E-03	0.55	2.15E-03	0.76
1974	770	1.84E-04	0.14	3.27E-04	0.25	5.22E-04	0.40	7.75E-04	0.60	1.09E-03	0.84	1.47E-03	1.13	2.03E-03	1.56
1975	842	1.57E-04	0.13	2.86E-04	0.24	4.68E-04	0.39	7.07E-04	0.59	1.01E-03	0.85	1.37E-03	1.15	1.91E-03	1.61
1976	255	1.32E-04	0.03	2.49E-04	0.06	4.17E-04	0.11	6.41E-04	0.16	9.25E-04	0.24	1.27E-03	0.32	1.79E-03	0.46
1977	1362	1.09E-04	0.15	2.15E-04	0.29	3.70E-04	0.50	5.80E-04	0.79	8.48E-04	1.16	1.18E-03	1.60	1.68E-03	2.29
1978	222	8.96E-05	0.02	1.84E-04	0.04	3.27E-04	0.07	5.22E-04	0.12	7.75E-04	0.17	1.09E-03	0.24	1.57E-03	0.35
1979	848	7.24E-05	0.06	1.57E-04	0.13	2.86E-04	0.24	4.68E-04	0.40	7.07E-04	0.60	1.01E-03	0.85	1.47E-03	1.24
1980	57	5.75E-05	0.00	1.32E-04	0.01	2.49E-04	0.01	4.17E-04	0.02	6.41E-04	0.04	9.25E-04	0.05	1.37E-03	0.08
1981	485	4.48E-05	0.02	1.09E-04	0.05	2.15E-04	0.10	3.70E-04	0.18	5.80E-04	0.28	8.48E-04	0.41	1.27E-03	0.62
1982	773	3.42E-05	0.03	8.96E-05	0.07	1.84E-04	0.14	3.27E-04	0.25	5.22E-04	0.40	7.75E-04	0.60	1.18E-03	0.91
1985	712	1.26E-05	0.01	4.48E-05	0.03	1.09E-04	0.08	2.15E-04	0.15	3.70E-04	0.26	5.80E-04	0.41	9.25E-04	0.66
1986	489	8.37E-06	0.00	3.42E-05	0.02	8.96E-05	0.04	1.84E-04	0.09	3.27E-04	0.16	5.22E-04	0.26	8.48E-04	0.41
1987	177	5.22E-06	0.00	2.54E-05	0.00	7.24E-05	0.01	1.57E-04	0.03	2.86E-04	0.05	4.68E-04	0.08	7.75E-04	0.14
1988	4517	3.02E-06	0.01	1.83E-05	0.08	5.75E-05	0.26	1.32E-04	0.59	2.49E-04	1.13	4.17E-04	1.89	7.07E-04	3.19
Total	14693	Total ->	3.62	Total ->	5.36	Total ->	7.73	Total ->	10.80	Total ->	14.67	Total ->	19.39	Total ->	26.54
Upper 95% Confidence Limit on Predicted number of cylinders with breaches at X-745-C, assuming initial thickness of 312.5 mils.															
Manufacture Date	Number	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1956	290	2.68E-02	7.76	3.07E-02	8.91	3.47E-02	10.08	3.88E-02	11.26	4.29E-02	12.45	4.71E-02	13.65	5.23E-02	15.16
1957	1840	2.58E-02	47.46	2.97E-02	54.70	3.37E-02	62.07	3.78E-02	69.55	4.19E-02	77.10	4.60E-02	84.70	5.12E-02	94.27
1959	41	2.39E-02	0.98	2.77E-02	1.14	3.17E-02	1.30	3.58E-02	1.47	3.98E-02	1.63	4.40E-02	1.80	4.92E-02	2.02
1960	7	2.29E-02	0.16	2.68E-02	0.19	3.07E-02	0.22	3.47E-02	0.24	3.88E-02	0.27	4.29E-02	0.30	4.81E-02	0.34
1961	37	2.19E-02	0.81	2.58E-02	0.95	2.97E-02	1.10	3.37E-02	1.25	3.78E-02	1.40	4.19E-02	1.55	4.71E-02	1.74
1962	182	2.10E-02	3.82	2.48E-02	4.52	2.87E-02	5.23	3.27E-02	5.96	3.68E-02	6.69	4.09E-02	7.44	4.60E-02	8.38
1963	74	2.01E-02	1.48	2.39E-02	1.77	2.77E-02	2.05	3.17E-02	2.35	3.58E-02	2.65	3.98E-02	2.95	4.50E-02	3.33
1964	50	1.91E-02	0.96	2.29E-02	1.14	2.68E-02	1.34	3.07E-02	1.54	3.47E-02	1.74	3.88E-02	1.94	4.40E-02	2.20
1969	58	1.46E-02	0.85	1.82E-02	1.06	2.19E-02	1.27	2.58E-02	1.50	2.97E-02	1.72	3.37E-02	1.96	3.88E-02	2.25
1972	253	1.21E-02	3.05	1.55E-02	3.93	1.91E-02	4.84	2.29E-02	5.79	2.68E-02	6.77	3.07E-02	7.77	3.58E-02	9.05
1973	352	1.12E-02	3.96	1.46E-02	5.15	1.82E-02	6.41	2.19E-02	7.73	2.58E-02	9.08	2.97E-02	10.46	3.47E-02	12.23
1974	770	1.04E-02	8.03	1.38E-02	10.60	1.73E-02	13.33	2.10E-02	16.17	2.48E-02	19.11	2.87E-02	22.13	3.37E-02	25.97
1975	842	9.64E-03	8.12	1.29E-02	10.87	1.64E-02	13.81	2.01E-02	16.90	2.39E-02	20.09	2.77E-02	23.36	3.27E-02	27.56
1976	255	8.86E-03	2.26	1.21E-02	3.08	1.55E-02	3.96	1.91E-02	4.88	2.29E-02	5.84	2.68E-02	6.83	3.17E-02	8.09
1977	1362	8.10E-03	11.03	1.12E-02	15.32	1.46E-02	19.94	1.82E-02	24.81	2.19E-02	29.89	2.58E-02	35.13	3.07E-02	41.84
1978	222	7.36E-03	1.63	1.04E-02	2.32	1.38E-02	3.06	1.73E-02	3.84	2.10E-02	4.66	2.48E-02	5.51	2.97E-02	6.60
1979	848	6.64E-03	5.63	9.64E-03	8.17	1.29E-02	10.95	1.64E-02	13.91	2.01E-02	17.02	2.39E-02	20.23	2.87E-02	24.37
1980	57	5.95E-03	0.34	8.86E-03	0.51	1.21E-02	0.69	1.55E-02	0.88	1.91E-02	1.09	2.29E-02	1.31	2.77E-02	1.58
1981	485	5.28E-03	2.56	8.10E-03	3.93	1.12E-02	5.45	1.46E-02	7.10	1.82E-02	8.84	2.19E-02	10.64	2.68E-02	12.98
1982	773	4.63E-03	3.58	7.36E-03	5.69	1.04E-02	8.07	1.38E-02	10.64	1.73E-02	13.38	2.10E-02	16.23	2.58E-02	19.94
1985	712	2.88E-03	2.05	5.28E-03	3.76	8.10E-03	5.77	1.12E-02	8.01	1.46E-02	10.42	1.82E-02	12.97	2.29E-02	16.30
1986	489	2.36E-03	1.16	4.63E-03	2.27	7.36E-03	3.60	1.04E-02	5.10	1.38E-02	6.73	1.73E-02	8.46	2.19E-02	10.73
1987	177	1.89E-03	0.33	4.02E-03	0.71	6.64E-03	1.18	9.64E-03	1.71	1.29E-02	2.29	1.64E-02	2.90	2.10E-02	3.72
1988	4517	1.46E-03	6.58	3.43E-03	15.50	5.95E-03	26.86	8.86E-03	40.03	1.21E-02	54.54	1.55E-02	70.09	2.01E-02	90.64
Total	14693	Total ->	124.60	Total ->	166.17	Total ->	212.57	Total ->	262.60	Total ->	315.39	Total ->	370.33	Total ->	441.28

Values used to generate table below

InitialThicknessChoice 2
 FailureLevel (mils) 0
 Figure Number 15
 YardName X-745-C

Initial Thickness (mils) 345.5
 YardLnMean 0.25
 YardLnStDev 0.75
 TheN 125
 alpha 0.95

	312.5 Mils	345.5 mils
LnMean	-1.36	0.25
LnStDev	1.14	0.75
TheN	14	125

Macros to run this are in "simage.mac". BFL, 2-8-95

BreachTableTitle Predicted number of cylinders with breaches at X-745-C, assuming initial thickness of 345.5 mils.

ThicknessTableTitle Predicted number of cylinders with minimum thickness of 0.0 mils or less at X-745-C, assuming initial thickness of 345.5 mils.

X-745-C															
Predicted number of cylinders with breaches at X-745-C, assuming initial thickness of 345.5 mils.															
Manufacture Date	Number	1995		1999		2003		2007		2011		2015		2020	
		Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1956	290	5.01E-03	1.45	7.24E-03	2.10	1.00E-02	2.90	1.33E-02	3.85	1.71E-02	4.97	2.15E-02	6.24	2.78E-02	8.05
1957	1840	4.53E-03	8.33	6.64E-03	12.21	9.26E-03	17.03	1.24E-02	22.85	1.61E-02	29.67	2.04E-02	37.49	2.64E-02	48.66
1959	41	3.66E-03	0.15	5.52E-03	0.23	7.88E-03	0.32	1.08E-02	0.44	1.42E-02	0.58	1.82E-02	0.75	2.39E-02	0.98
1960	7	3.27E-03	0.02	5.01E-03	0.04	7.24E-03	0.05	1.00E-02	0.07	1.33E-02	0.09	1.71E-02	0.12	2.27E-02	0.16
1961	37	2.91E-03	0.11	4.53E-03	0.17	6.64E-03	0.25	9.26E-03	0.34	1.24E-02	0.46	1.61E-02	0.60	2.15E-02	0.80
1962	182	2.57E-03	0.47	4.08E-03	0.74	6.06E-03	1.10	8.55E-03	1.56	1.16E-02	2.11	1.51E-02	2.76	2.04E-02	3.71
1963	74	2.26E-03	0.17	3.66E-03	0.27	5.52E-03	0.41	7.88E-03	0.58	1.08E-02	0.80	1.42E-02	1.05	1.93E-02	1.43
1964	50	1.98E-03	0.10	3.27E-03	0.16	5.01E-03	0.25	7.24E-03	0.36	1.00E-02	0.50	1.33E-02	0.66	1.82E-02	0.91
1969	58	9.17E-04	0.05	1.72E-03	0.10	2.91E-03	0.17	4.53E-03	0.26	6.64E-03	0.38	9.26E-03	0.54	1.33E-02	0.77
1972	253	5.20E-04	0.13	1.09E-03	0.27	1.98E-03	0.50	3.27E-03	0.83	5.01E-03	1.27	7.24E-03	1.83	1.08E-02	2.72
1973	352	4.21E-04	0.15	9.17E-04	0.32	1.72E-03	0.61	2.91E-03	1.02	4.53E-03	1.59	6.64E-03	2.34	1.00E-02	3.52
1974	770	3.36E-04	0.26	7.67E-04	0.59	1.49E-03	1.15	2.57E-03	1.98	4.08E-03	3.14	6.06E-03	4.67	9.26E-03	7.13
1975	842	2.64E-04	0.22	6.35E-04	0.53	1.28E-03	1.07	2.26E-03	1.91	3.66E-03	3.08	5.52E-03	4.65	8.55E-03	7.20
1976	255	2.05E-04	0.05	5.20E-04	0.13	1.09E-03	0.28	1.98E-03	0.50	3.27E-03	0.83	5.01E-03	1.28	7.88E-03	2.01
1977	1362	1.55E-04	0.21	4.21E-04	0.57	9.17E-04	1.25	1.72E-03	2.35	2.91E-03	3.96	4.53E-03	6.17	7.24E-03	9.86
1978	222	1.16E-04	0.03	3.36E-04	0.07	7.67E-04	0.17	1.49E-03	0.33	2.57E-03	0.57	4.08E-03	0.91	6.64E-03	1.47
1979	848	8.39E-05	0.07	2.64E-04	0.22	6.35E-04	0.54	1.28E-03	1.08	2.26E-03	1.92	3.66E-03	3.10	6.06E-03	5.14
1980	57	5.93E-05	0.00	2.05E-04	0.01	5.20E-04	0.03	1.09E-03	0.06	1.98E-03	0.11	3.27E-03	0.19	5.52E-03	0.31
1981	485	4.05E-05	0.02	1.55E-04	0.08	4.21E-04	0.20	9.17E-04	0.44	1.72E-03	0.84	2.91E-03	1.41	5.01E-03	2.43
1982	773	2.67E-05	0.02	1.16E-04	0.09	3.36E-04	0.26	7.67E-04	0.59	1.49E-03	1.15	2.57E-03	1.99	4.53E-03	3.50
1985	712	5.68E-06	0.00	4.05E-05	0.03	1.55E-04	0.11	4.21E-04	0.30	9.17E-04	0.65	1.72E-03	1.23	3.27E-03	2.33
1986	489	2.95E-06	0.00	2.67E-05	0.01	1.16E-04	0.06	3.36E-04	0.16	7.67E-04	0.38	1.49E-03	0.73	2.91E-03	1.42
1987	177	1.39E-06	0.00	1.69E-05	0.00	8.39E-05	0.01	2.64E-04	0.05	6.35E-04	0.11	1.28E-03	0.23	2.57E-03	0.46
1988	4517	5.72E-07	0.00	1.01E-05	0.05	5.93E-05	0.27	2.05E-04	0.92	5.20E-04	2.35	1.09E-03	4.91	2.26E-03	10.22
Total	14693	Total ->	12.03	Total ->	19.01	Total ->	28.99	Total ->	42.85	Total ->	61.51	Total ->	85.81	Total ->	125.19
Upper 95% Confidence Limit on Predicted number of cylinders with breaches at X-745-C, assuming initial thickness of 345.5 mils.															
Manufacture Date	Number	1995		1999		2003		2007		2011		2015		2020	
		Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1956	290	1.17E-02	3.40	1.59E-02	4.60	2.07E-02	6.00	2.61E-02	7.58	3.22E-02	9.35	3.89E-02	11.28	4.80E-02	13.93
1957	1840	1.08E-02	19.87	1.48E-02	27.17	1.94E-02	35.72	2.47E-02	45.48	3.07E-02	56.41	3.72E-02	68.43	4.61E-02	84.90
1959	41	9.07E-03	0.37	1.27E-02	0.52	1.70E-02	0.70	2.20E-02	0.90	2.76E-02	1.13	3.38E-02	1.39	4.25E-02	1.74
1960	7	8.27E-03	0.06	1.17E-02	0.08	1.59E-02	0.11	2.07E-02	0.14	2.61E-02	0.18	3.22E-02	0.23	4.07E-02	0.28
1961	37	7.51E-03	0.28	1.08E-02	0.40	1.48E-02	0.55	1.94E-02	0.72	2.47E-02	0.91	3.07E-02	1.13	3.89E-02	1.44
1962	182	6.79E-03	1.24	9.91E-03	1.80	1.37E-02	2.50	1.82E-02	3.31	2.33E-02	4.25	2.91E-02	5.30	3.72E-02	6.77
1963	74	6.12E-03	0.45	9.07E-03	0.67	1.27E-02	0.94	1.70E-02	1.26	2.20E-02	1.63	2.76E-02	2.04	3.55E-02	2.63
1964	50	5.49E-03	0.27	8.27E-03	0.41	1.17E-02	0.59	1.59E-02	0.79	2.07E-02	1.03	2.61E-02	1.31	3.38E-02	1.69
1969	58	2.93E-03	0.17	4.90E-03	0.28	7.51E-03	0.44	1.08E-02	0.63	1.48E-02	0.86	1.94E-02	1.13	2.61E-02	1.52
1972	253	1.84E-03	0.47	3.36E-03	0.85	5.49E-03	1.39	8.27E-03	2.09	1.17E-02	2.97	1.59E-02	4.01	2.20E-02	5.56
1973	352	1.55E-03	0.55	2.93E-03	1.03	4.90E-03	1.72	7.51E-03	2.64	1.08E-02	3.80	1.48E-02	5.20	2.07E-02	7.28
1974	770	1.29E-03	1.00	2.53E-03	1.95	4.34E-03	3.35	6.79E-03	5.23	9.91E-03	7.63	1.37E-02	10.56	1.94E-02	14.95
1975	842	1.06E-03	0.90	2.17E-03	1.83	3.83E-03	3.23	6.12E-03	5.15	9.07E-03	7.63	1.27E-02	10.69	1.82E-02	15.32
1976	255	8.64E-04	0.22	1.84E-03	0.47	3.36E-03	0.86	5.49E-03	1.40	8.27E-03	2.11	1.17E-02	2.99	1.70E-02	4.34
1977	1362	6.90E-04	0.94	1.55E-03	2.11	2.93E-03	3.99	4.90E-03	6.67	7.51E-03	10.23	1.08E-02	14.71	1.59E-02	21.61
1978	222	5.43E-04	0.12	1.29E-03	0.29	2.53E-03	0.56	4.34E-03	0.96	6.79E-03	1.51	9.91E-03	2.20	1.48E-02	3.28
1979	848	4.19E-04	0.35	1.06E-03	0.90	2.17E-03	1.84	3.83E-03	3.25	6.12E-03	5.19	9.07E-03	7.69	1.37E-02	11.63
1980	57	3.16E-04	0.02	8.64E-04	0.05	1.84E-03	0.11	3.36E-03	0.19	5.49E-03	0.31	8.27E-03	0.47	1.27E-02	0.72
1981	485	2.32E-04	0.11	6.90E-04	0.33	1.55E-03	0.75	2.93E-03	1.42	4.90E-03	2.37	7.51E-03	3.64	1.17E-02	5.69
1982	773	1.65E-04	0.13	5.43E-04	0.42	1.29E-03	1.00	2.53E-03	1.96	4.34E-03	3.36	6.79E-03	5.25	1.08E-02	8.35
1985	712	4.67E-05	0.03	2.32E-04	0.16	6.90E-04	0.49	1.55E-03	1.11	2.93E-03	2.08	4.90E-03	3.49	8.27E-03	5.89
1986	489	2.77E-05	0.01	1.65E-04	0.08	5.43E-04	0.27	1.29E-03	0.63	2.53E-03	1.24	4.34E-03	2.12	7.51E-03	3.67
1987	177	1.43E-05	0.00	1.13E-04	0.02	4.19E-04	0.07	1.06E-03	0.19	2.17E-03	0.38	3.83E-03	0.68	6.79E-03	1.20
1988	4517	6.68E-06	0.03	7.44E-05	0.34	3.16E-04	1.43	8.64E-04	3.90	1.84E-03	8.33	3.36E-03	15.19	6.12E-03	27.64
Total	14693	Total ->	30.98	Total ->	46.78	Total ->	68.58	Total ->	97.61	Total ->	134.90	Total ->	181.12	Total ->	252.01
Upper 95% Confidence Limit on Predicted number of cylinders with breaches at X-745-C, assuming initial thickness of 345.5 mils.															
Manufacture Date	Number	1995		1999		2003		2007		2011		2015		2020	
		Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1956	290	1.17E-02	3.40	1.59E-02	4.60	2.07E-02	6.00	2.61E-02	7.58	3.22E-02	9.35	3.89E-02	11.28	4.80E-02	13.93
1957	1840	1.08E-02	19.87	1.48E-02	27.17	1.94E-02	35.72	2.47E-02	45.48	3.07E-02	56.41	3.72E-02	68.43	4.61E-02	84.90
1959	41	9.07E-03	0.37	1.27E-02	0.52	1.70E-02	0.70	2.20E-02	0.90	2.76E-02	1.13	3.38E-02	1.39	4.25E-02	1.74
1960	7	8.27E-03	0.06	1.17E-02	0.08	1.59E-02	0.11	2.07E-02	0.14	2.61E-02	0.18	3.22E-02	0.23	4.07E-02	0.28
1961	37	7.51E-03	0.28	1.08E-02	0.40	1.48E-02	0.55	1.94E-02	0.72	2.47E-02	0.91	3.07E-02	1.13	3.89E-02	1.44
1962	182	6.79E-03	1.24	9.91E-03	1.80	1.37E-02	2.50	1.82E-02	3.31	2.33E-02	4.25	2.91E-02	5.30	3.72E-02	6.77
1963	74	6.12E-03	0.45	9.07E-03	0.67	1.27E-02	0.94	1.70E-02	1.26	2.20E-02	1.63	2.76E-02	2.04	3.55E-02	2.63
1964	50	5.49E-03	0.27	8.27E-03	0.41	1.17E-02	0.59	1.59E-02	0.79	2.07E-02	1.03	2.61E-02	1.31	3.38E-02	1.69
1969	58	2.93E-03	0.17	4.90E-03	0.28	7.51E-03	0.44	1.08E-02	0.63	1.48E-02	0.86	1.94E-02	1.13	2.61E-02	1.52
1972	253	1.84E-03	0.47	3.36E-03	0.85	5.49E-03	1.39	8.27E-03	2.09	1.17E-02	2.97	1.59E-02	4.01	2.20E-02	5.56
1973	352	1.55E-03	0.55	2.93E-03	1.03	4.90E-03	1.72	7.51E-03	2.64	1.08E-02	3.80	1.48E-02	5.20	2.07E-02	7.28
1974	770	1.29E-03	1.00	2.53E-03	1.95	4.34E-03	3.35	6.79E-03	5.23	9.91E-03	7.63	1.37E-02	10.56	1.94E-02	14.95
1975	842	1.06E-03	0.90	2.17E-03	1.83	3.83E-03	3.23	6.12E-03	5.15	9.07E-03	7.63	1.27E-02	10.69	1.82E-02	15.32
1976	255	8.64E-04	0.22	1.84E-03	0.47	3.36E-03	0.								

InitialThicknessChoice 1
 FailureLevel (mils) 250
 Figure Number 16
 YardName X-745-C

Values used to generate table below
 Initial Thickness (mils) 312.5
 YardLnMean -1.36
 YardLnStDev 1.14
 TheN 14
 alpha 0.95

	312.5 Mils	345.5 mils
LnMean	-1.36	0.25
LnStDev	1.14	0.75
TheN	14	125

Macros to run this are in "sumage.mac". BFL, 2-8-95

BreachTableTitle Predicted number of cylinders with breaches at X-745-C, assuming initial thickness of 312.5 mils.

ThicknessTableTitle Predicted number of cylinders with minimum thickness of 250.0 mils or less at X-745-C, assuming initial thickness of 312.5 mils.

X-745-C															
Predicted number of cylinders with minimum thickness of 250.0 mils or less at X-745-C, assuming initial thickness of 312.5 mils.															
		1995		1999		2003		2007		2011		2015		2020	
Manufacture Date	Number	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1956	290	5.41E-02	15.68	6.41E-02	18.60	7.45E-02	21.61	8.51E-02	24.69	9.59E-02	27.82	1.07E-01	30.98	1.21E-01	34.96
1957	1840	5.16E-02	94.96	6.16E-02	113.30	7.19E-02	132.28	8.25E-02	151.72	9.32E-02	171.52	1.04E-01	191.54	1.18E-01	216.78
1959	41	4.68E-02	1.92	5.65E-02	2.32	6.67E-02	2.73	7.71E-02	3.16	8.78E-02	3.60	9.86E-02	4.04	1.12E-01	4.61
1960	7	4.44E-02	0.31	5.41E-02	0.38	6.41E-02	0.45	7.45E-02	0.52	8.51E-02	0.60	9.59E-02	0.67	1.10E-01	0.77
1961	37	4.21E-02	1.56	5.16E-02	1.91	6.16E-02	2.28	7.19E-02	2.66	8.25E-02	3.05	9.32E-02	3.45	1.07E-01	3.95
1962	182	3.98E-02	7.24	4.92E-02	8.95	5.90E-02	10.75	6.93E-02	12.61	7.98E-02	14.52	9.05E-02	16.47	1.04E-01	18.95
1963	74	3.75E-02	2.78	4.68E-02	3.46	5.65E-02	4.18	6.67E-02	4.94	7.71E-02	5.71	8.78E-02	6.50	1.01E-01	7.50
1964	50	3.53E-02	1.76	4.44E-02	2.22	5.41E-02	2.70	6.41E-02	3.21	7.45E-02	3.73	8.51E-02	4.26	9.86E-02	4.93
1969	58	2.49E-02	1.44	3.31E-02	1.92	4.21E-02	2.44	5.16E-02	2.99	6.16E-02	3.57	7.19E-02	4.17	8.51E-02	4.94
1972	253	1.92E-02	4.87	2.69E-02	6.79	3.53E-02	8.93	4.44E-02	11.24	5.41E-02	13.68	6.41E-02	16.22	7.71E-02	19.52
1973	352	1.75E-02	6.15	2.49E-02	8.75	3.31E-02	11.66	4.21E-02	14.81	5.16E-02	18.17	6.16E-02	21.68	7.45E-02	26.23
1974	770	1.58E-02	12.16	2.29E-02	17.65	3.10E-02	23.86	3.98E-02	30.63	4.92E-02	37.87	5.90E-02	45.47	7.19E-02	55.35
1975	842	1.42E-02	11.93	2.10E-02	17.72	2.89E-02	24.33	3.75E-02	31.59	4.68E-02	39.39	5.65E-02	47.61	6.93E-02	58.34
1976	255	1.26E-02	3.22	1.92E-02	4.90	2.69E-02	6.85	3.53E-02	9.00	4.44E-02	11.33	5.41E-02	13.79	6.67E-02	17.01
1977	1362	1.12E-02	15.20	1.75E-02	23.80	2.49E-02	33.86	3.31E-02	45.11	4.21E-02	57.32	5.16E-02	70.29	6.41E-02	87.34
1978	222	9.77E-03	2.17	1.29E-02	3.51	2.29E-02	5.09	3.10E-02	6.88	3.98E-02	8.83	4.92E-02	10.92	6.16E-02	13.67
1979	848	8.46E-03	7.18	1.42E-02	12.02	2.10E-02	17.85	2.89E-02	24.50	3.75E-02	31.82	4.68E-02	39.67	5.90E-02	50.07
1980	57	7.25E-03	0.41	1.26E-02	0.72	1.92E-02	1.10	2.69E-02	1.53	3.53E-02	2.01	4.44E-02	2.53	5.65E-02	3.22
1981	485	6.12E-03	2.97	1.12E-02	5.41	1.75E-02	8.48	2.49E-02	12.06	3.31E-02	16.06	4.21E-02	20.41	5.41E-02	26.22
1982	773	5.08E-03	3.93	9.77E-03	7.55	1.58E-02	12.21	2.29E-02	17.72	3.10E-02	23.95	3.98E-02	30.75	5.16E-02	39.89
1985	712	2.55E-03	1.82	6.12E-03	4.35	1.12E-02	7.95	1.75E-02	12.44	2.49E-02	17.70	3.31E-02	23.58	4.44E-02	31.62
1986	489	1.91E-03	0.93	5.08E-03	2.48	9.77E-03	4.78	1.58E-02	7.72	2.29E-02	11.21	3.10E-02	15.15	4.21E-02	20.58
1987	177	1.37E-03	0.24	4.14E-03	0.73	8.46E-03	1.50	1.42E-02	2.51	2.10E-02	3.73	2.89E-02	5.11	3.98E-02	7.04
1988	4517	9.25E-04	4.18	3.29E-03	14.88	7.25E-03	32.73	1.26E-02	57.04	1.92E-02	86.87	2.69E-02	121.28	3.75E-02	169.48
Total		14693	Total -> 205.00	Total -> 284.35	Total -> 380.57	Total -> 491.29	Total -> 614.04	Total -> 746.56	Total -> 922.98						
Upper 95% Confidence Limit on Predicted number of cylinders with minimum thickness of 250.0 mils or less at X-745-C, assuming initial thickness of 312.5 mils.															
Manufacture Date	Number	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1956	290	1.81E-01	52.52	1.99E-01	57.60	2.16E-01	62.50	2.32E-01	67.25	2.48E-01	71.84	2.63E-01	76.29	2.82E-01	81.66
1957	1840	1.77E-01	325.02	1.94E-01	357.49	2.11E-01	388.89	2.28E-01	419.26	2.44E-01	448.64	2.59E-01	477.09	2.78E-01	511.41
1959	41	1.68E-01	6.87	1.86E-01	7.61	2.03E-01	8.32	2.20E-01	9.01	2.36E-01	9.67	2.52E-01	10.32	2.71E-01	11.09
1960	7	1.63E-01	1.14	1.81E-01	1.27	1.99E-01	1.39	2.16E-01	1.51	2.32E-01	1.62	2.48E-01	1.73	2.67E-01	1.87
1961	37	1.58E-01	5.86	1.77E-01	6.54	1.94E-01	7.19	2.11E-01	7.82	2.28E-01	8.43	2.44E-01	9.02	2.63E-01	9.73
1962	182	1.54E-01	27.98	1.72E-01	31.33	1.90E-01	34.57	2.07E-01	37.70	2.24E-01	40.73	2.40E-01	43.66	2.59E-01	47.19
1963	74	1.49E-01	11.03	1.68E-01	12.40	1.86E-01	13.73	2.03E-01	15.01	2.20E-01	16.26	2.36E-01	17.46	2.55E-01	18.90
1964	50	1.44E-01	7.22	1.63E-01	8.15	1.81E-01	9.06	1.99E-01	9.93	2.16E-01	10.78	2.32E-01	11.59	2.52E-01	12.58
1969	58	1.20E-01	6.96	1.40E-01	8.09	1.58E-01	9.19	1.77E-01	10.25	1.94E-01	11.27	2.11E-01	12.26	2.32E-01	13.45
1972	253	1.05E-01	26.58	1.25E-01	31.62	1.44E-01	36.51	1.63E-01	41.24	1.81E-01	45.82	1.99E-01	50.25	2.20E-01	55.58
1973	352	1.00E-01	35.19	1.20E-01	42.26	1.40E-01	49.11	1.58E-01	55.75	1.77E-01	62.18	1.94E-01	68.39	2.16E-01	75.87
1974	770	9.49E-02	73.06	1.15E-01	88.62	1.35E-01	103.73	1.54E-01	118.38	1.72E-01	132.55	1.90E-01	146.25	2.11E-01	162.74
1975	842	8.98E-02	75.57	1.10E-01	92.69	1.30E-01	109.35	1.49E-01	125.49	1.68E-01	141.11	1.86E-01	156.23	2.07E-01	174.41
1976	255	8.46E-02	21.57	1.05E-01	26.79	1.25E-01	31.87	1.44E-01	36.80	1.63E-01	41.57	1.81E-01	46.18	2.03E-01	51.74
1977	1362	7.94E-02	108.17	1.00E-01	136.18	1.20E-01	163.51	1.40E-01	190.04	1.58E-01	215.73	1.77E-01	240.59	1.99E-01	270.51
1978	222	7.42E-02	16.48	9.49E-02	21.06	1.15E-01	25.55	1.35E-01	29.91	1.54E-01	34.13	1.72E-01	38.21	1.94E-01	43.13
1979	848	6.90E-02	58.51	8.98E-02	76.11	1.10E-01	93.35	1.30E-01	110.13	1.49E-01	126.39	1.68E-01	142.12	1.90E-01	161.06
1980	57	6.38E-02	3.64	8.46E-02	4.82	1.05E-01	5.99	1.25E-01	7.12	1.44E-01	8.23	1.63E-01	9.29	1.86E-01	10.58
1981	485	5.85E-02	28.39	7.94E-02	38.52	1.00E-01	48.49	1.20E-01	58.22	1.40E-01	67.67	1.58E-01	76.82	1.81E-01	87.84
1982	773	5.33E-02	41.22	7.42E-02	57.37	9.49E-02	73.35	1.15E-01	88.96	1.35E-01	104.14	1.54E-01	118.84	1.77E-01	136.54
1985	712	3.78E-02	26.91	5.85E-02	41.68	7.94E-02	56.55	1.00E-01	71.19	1.20E-01	85.48	1.40E-01	99.34	1.63E-01	116.07
1986	489	3.27E-02	16.00	5.33E-02	26.07	7.42E-02	36.29	9.49E-02	46.40	1.15E-01	56.28	1.35E-01	65.88	1.58E-01	77.45
1987	177	2.77E-02	4.91	4.81E-02	8.52	6.90E-02	12.21	8.98E-02	15.89	1.10E-01	19.49	1.30E-01	22.99	1.54E-01	27.21
1988	4517	2.29E-02	103.43	4.29E-02	193.92	6.38E-02	288.07	8.46E-02	382.14	1.05E-01	474.52	1.25E-01	564.51	1.49E-01	673.21
Total		14693	Total -> 1084.25	Total -> 1376.71	Total -> 1668.76	Total -> 1955.39	Total -> 2234.51	Total -> 2505.32	Total -> 2831.83						

Values used to generate table below

InitialThicknessChoice 2
 FailureLevel (mils) 250
 Figure Number 17
 YardName X-745-C

Initial Thickness (mils) 345.5
 YardLnMean 0.25
 YardLnStdDev 0.75
 TheN 125
 alpha 0.95

	312.5 Mils	345.5 mils
LnMean	-1.36	0.25
LnStdDev	1.14	0.75
TheN	14	125

Macros to run this are in "sumage.mac". BFL, 2-8-95

BreachTableTitle Predicted number of cylinders with breaches at X-745-C, assuming initial thickness of 345.5 mils.

ThicknessTableTitle Predicted number of cylinders with minimum thickness of 250.0 mils or less at X-745-C, assuming initial thickness of 345.5 mils.

X-745-C											
Predicted number of cylinders with minimum thickness of 250.0 mils or less at X-745-C, assuming initial thickness of 345.5 mils.											
Manufacture Date	Number	1995		1999		2003		2007		2011	
		Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1956	290	1.95E-01	56.46	2.33E-01	67.43	2.70E-01	78.38	3.07E-01	89.16	3.44E-01	99.67
1957	1840	1.85E-01	340.93	2.23E-01	410.41	2.61E-01	480.01	2.98E-01	548.76	3.35E-01	615.93
1959	41	1.67E-01	6.83	2.04E-01	8.37	2.42E-01	9.92	2.80E-01	11.47	3.17E-01	12.98
1960	7	1.57E-01	1.10	1.95E-01	1.36	2.33E-01	1.63	2.70E-01	1.89	3.07E-01	2.15
1961	37	1.48E-01	5.49	1.85E-01	6.86	2.23E-01	8.25	2.61E-01	9.65	2.98E-01	11.03
1962	182	1.39E-01	25.35	1.76E-01	32.02	2.14E-01	38.87	2.51E-01	45.76	2.89E-01	52.59
1963	74	1.30E-01	9.65	1.67E-01	12.33	2.04E-01	15.10	2.42E-01	17.91	2.80E-01	20.69
1964	50	1.22E-01	6.08	1.57E-01	7.87	1.95E-01	9.73	2.33E-01	11.63	2.70E-01	13.51
1969	58	8.06E-02	4.67	1.13E-01	6.56	1.48E-01	8.60	1.85E-01	10.75	2.23E-01	12.94
1972	253	5.88E-02	14.88	8.83E-02	22.35	1.22E-01	30.77	1.57E-01	39.83	1.95E-01	49.26
1973	352	5.22E-02	18.37	8.06E-02	28.35	1.13E-01	39.79	1.48E-01	52.21	1.85E-01	65.22
1974	770	4.59E-02	35.33	7.30E-02	56.22	1.05E-01	80.54	1.39E-01	107.26	1.76E-01	135.47
1975	842	4.00E-02	33.64	6.58E-02	55.37	9.64E-02	81.14	1.30E-01	109.79	1.67E-01	140.32
1976	255	3.44E-02	8.77	5.88E-02	15.00	8.83E-02	22.53	1.22E-01	31.02	1.57E-01	40.15
1977	1362	2.93E-02	39.86	5.22E-02	71.06	8.06E-02	109.71	1.13E-01	153.95	1.48E-01	202.01
1978	222	2.45E-02	5.45	4.59E-02	10.19	7.30E-02	16.21	1.05E-01	23.22	1.39E-01	30.92
1979	848	2.02E-02	17.17	4.00E-02	33.88	6.58E-02	55.77	9.64E-02	81.72	1.30E-01	110.58
1980	57	1.64E-02	0.93	3.44E-02	1.96	5.88E-02	3.35	8.83E-02	5.04	1.22E-01	6.93
1981	485	1.30E-02	6.30	2.93E-02	14.19	5.22E-02	25.31	8.06E-02	39.07	1.13E-01	54.82
1982	773	1.00E-02	7.75	2.45E-02	18.97	4.59E-02	35.47	7.30E-02	56.44	1.05E-01	80.86
1985	712	3.73E-03	2.66	1.30E-02	9.24	2.93E-02	20.84	5.22E-02	37.15	8.06E-02	57.35
1986	489	2.43E-03	1.19	1.00E-02	4.90	2.45E-02	12.00	4.59E-02	22.44	7.30E-02	35.71
1987	177	1.48E-03	0.26	7.50E-03	1.33	2.02E-02	3.58	4.00E-02	7.07	6.58E-02	11.64
1988	4517	8.14E-04	3.68	5.41E-03	24.45	1.64E-02	74.03	3.44E-02	155.44	5.88E-02	265.64
Total	14693	Total >	652.80	Total >	920.68	Total >	1261.34	Total >	1668.61	Total >	2128.38
Total		Total >	2625.64	Total >	3278.42	Total >		Total >		Total >	

Upper 95% Confidence Limit on Predicted number of cylinders with minimum thickness of 250.0 mils or less at X-745-C, assuming initial thickness of 345.5 mils.											
Manufacture Date	Number	1995		1999		2003		2007		2011	
		Prob.	#	Prob.	#	Prob.	#	Prob.	#	Prob.	#
1956	290	2.46E-01	71.36	2.87E-01	83.09	3.26E-01	94.59	3.65E-01	105.76	4.02E-01	116.53
1957	1840	2.36E-01	434.03	2.76E-01	508.69	3.16E-01	582.11	3.55E-01	653.56	3.93E-01	722.54
1959	41	2.16E-01	8.84	2.56E-01	10.51	2.97E-01	12.16	3.36E-01	13.77	3.74E-01	15.34
1960	7	2.05E-01	1.44	2.46E-01	1.72	2.87E-01	2.01	3.26E-01	2.28	3.65E-01	2.55
1961	37	1.95E-01	7.22	2.36E-01	8.73	2.76E-01	10.23	3.16E-01	11.71	3.55E-01	13.14
1962	182	1.85E-01	33.68	2.26E-01	41.08	2.66E-01	48.48	3.06E-01	55.78	3.46E-01	62.90
1963	74	1.75E-01	12.95	2.16E-01	15.95	2.56E-01	18.96	2.97E-01	21.94	3.36E-01	24.86
1964	50	1.65E-01	8.25	2.05E-01	10.27	2.46E-01	12.30	2.87E-01	14.33	3.26E-01	16.31
1969	58	1.17E-01	6.77	1.55E-01	9.00	1.95E-01	11.32	2.36E-01	13.68	2.76E-01	16.03
1972	253	8.97E-02	22.68	1.26E-01	31.89	1.65E-01	41.75	2.05E-01	51.95	2.46E-01	62.25
1973	352	8.11E-02	28.56	1.17E-01	41.06	1.55E-01	54.59	1.95E-01	68.70	2.36E-01	83.03
1974	770	7.29E-02	56.13	1.07E-01	82.72	1.45E-01	111.87	1.85E-01	142.50	2.26E-01	173.78
1975	842	6.50E-02	54.71	9.84E-02	82.87	1.36E-01	114.17	1.75E-01	147.35	2.16E-01	181.46
1976	255	5.74E-02	14.64	8.97E-02	22.86	1.26E-01	32.14	1.65E-01	42.08	2.05E-01	52.36
1977	1362	5.02E-02	68.35	8.11E-02	110.50	1.17E-01	158.87	1.55E-01	211.24	1.95E-01	265.83
1978	222	4.34E-02	9.63	7.29E-02	16.18	1.07E-01	23.85	1.45E-01	32.25	1.85E-01	41.08
1979	848	3.70E-02	31.37	6.50E-02	55.10	9.84E-02	83.47	1.36E-01	114.98	1.75E-01	148.40
1980	57	3.11E-02	1.77	5.74E-02	3.27	8.97E-02	5.11	1.26E-01	7.18	1.65E-01	9.41
1981	485	2.56E-02	12.44	5.02E-02	24.34	8.11E-02	39.35	1.17E-01	56.57	1.55E-01	75.22
1982	773	2.07E-02	16.02	4.34E-02	33.53	7.29E-02	56.35	1.07E-01	83.05	1.45E-01	112.30
1985	712	9.21E-03	6.56	2.56E-02	18.26	5.02E-02	35.73	8.11E-02	57.77	1.17E-01	83.05
1986	489	6.49E-03	3.17	2.07E-02	10.13	4.34E-02	21.21	7.29E-02	35.65	1.07E-01	52.53
1987	177	4.31E-03	0.76	1.63E-02	2.89	3.70E-02	6.55	6.50E-02	11.50	9.84E-02	17.42
1988	4517	2.66E-03	12.00	1.25E-02	56.44	3.11E-02	140.36	5.74E-02	259.24	8.97E-02	404.95
Total	14693	Total >	923.31	Total >	1281.07	Total >	1717.52	Total >	2214.83	Total >	2753.31
Total		Total >	3315.55	Total >	4030.74	Total >		Total >		Total >	

INTERNAL DISTRIBUTION

- 1-30. B.F. Lyon
- 31. Central Research Library
- 32. Document Reference Center
- 33. ORNL Patent Section
- 34-35. ORNL Laboratory Records
- 36. ORNL Laboratory Records, RC

EXTERNAL DISTRIBUTION

- 37. Office of Assistant Manager, Energy Research and Development, DOE-ORO, P.O. Box 2008, Oak Ridge, TN 37831-6269.
- 38-39. Office of Science and Technical Information, P.O. Box 62, Oak Ridge, TN 37831.