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TVA-88-689
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W GO CO
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Tennessee Valley Authority
Sequoyah Nuclear Plants
Ice Condenser Surveillance Techniques

Dear Mr. Hosmer:

At TVA's request Westinghouse has evaluated two surveillance techniques for complying with the Sequoyah Plant Tech Spec Ice Condenser surveillance requirement (4.6.5.1). These techniques are explained in the attached letter report. They are:

1. The acceptance criterion for number of flow passages that may be blocked as a function of sample size such that there is 95 percent confidence that the ice blockage in all flow passages is less than 15 percent.

2. The acceptance criterion for the number of flow passages that may be blocked, based on a 33 percent sample size and ice blockage categorized as 25 percent blocked, 50 percent blocked, 75 percent blocked and 100 percent blocked.

As we have discussed with your staff, the second methodology is preferred as it facilitates quantitatively evaluating the condition of the entire flow channel passage area.

Very truly yours,

WESTINGHOUSE ELECTRIC CORPORATION

T. A. Lordi, Manager
TVA Sequoyah Project

cc: W. R. Mangiante

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ATTACHMENT TO TVA-88-689

Sample Size Calculations for the Ice Condenser

This letter report documents the results of two sampling analyses for the surveillance of ice blockage in the flow passages of each bay in the ice condenser.

The first analysis is to determine the sample size of flow passages for surveillance of ice blockage in each bay of the ice condenser. The acceptance criterion is that there is no Tech Spec violation if there is less than or equal to 15 percent ice blockage in the bay. The number of flow passages blocked with ice that may be observed during surveillance as a function of sample size was determined such that there is 95 percent confidence that the total ice blockage in 164 flow passages will not exceed 15 percent.

The second analysis is to determine the acceptance criterion for a 33 percent sample size with ice blockage counted as: 25 percent blocked, 50 percent blocked, 75 percent blocked and 100 percent blocked. The number of flow passages observed in each category of ice blockage was determined (for all possible combinations). These combinations are reported in tables for easy reference. If the surveillance of 54 flow passages (based on 162 flow passages) finds less than the number of failures in the tables, then there is 95 percent confidence that the total ice blockage in 162 flow passages will not exceed 15 percent.

The results of these two analyses are presented in the following sections.

I. Calculation of Sample Sizes For Ice Condenser Flow Passage Surveillance

The results of the statistical analysis for the acceptance criterion for surveillance on less than 100% of the flow passages in each bay of the ice condenser are reported in Table 1.1. The number of failures that can be observed over a range of sample sizes was determined. Failure is defined as a flow passage blocked with ice. The range of sample sizes (from 40 to 110 bays sampled) is reported in Table 1.1.

The following values are calculated for each sample size listed in the table:

1. percent of passages. The sample size as a percent of all flow passages.

2. Mean (or Proportion). The mean number of failures is calculated as the number of failures divided by the sample size (proportion of sample). Only integers were used in the calculation. This is the mean number of failures observed in the sample that will exceed the acceptance criterion that less than or equal to 15 percent of all the flow passages are blocked with ice with 95 percent confidence.

3. 95 percent Upper Bound. This is the calculated 95 percent upper bound on the mean number of failures in all of the flow passages, based on the mean failures in the sample.

4. Number of Failures. These are the number of failures used to calculated the mean and 95 percent upper bound. These calculated failures represent the number of failures that may be observed in each sample size such that the 95 percent upper bound on the population mean (all failures in the bay) will exceed the criterion that less than or equal to 15% flow blockage exists in the bay. If the observed number of failures in the sample is less than the number of failures listed, then the criterion that all the flow passages in the bay have less than 15 percent flow blockage is accepted.

Table 1.1

Number of Failures per Sample Size to Exceed 95 Percent Upper Bound

Sample Size	Percent of Flow Passages	Mean (Proportion)	95 Percent Upper Bound	Number of Failures
40	24.4	0.1000	0.1703	4
45	27.4	0.0889	0.1504	4
50	30.5	0.1000	0.1599	5
55	33.5	0.1091	0.1670	6
60	36.6	0.1000	0.1520	6
65	39.6	0.1077	0.1579	7
70	42.7	0.1143	0.1626	8
75	45.7	0.1067	0.1507	8
80	48.8	0.1125	0.1548	9
90	54.9	0.1222	0.1610	11
100	61.0	0.1200	0.1539	12
110	67.1	0.1273	0.1577	14

As an example: a sample size of 55 represents 33.5% of the flow passages. If this sample size is used, then failure of 6 flow passages (6/55) will be a failure of the 0.15 criterion (the bound of 0.1660 exceeds 0.15). Five failures will not exceed 0.15.

The variance on the mean proportion of a sample size is a function of the size of the sample. The smaller the sample, the larger the variance, and the confidence intervals are less stable. The power of the test is less and accepting the hypothesis that the mean proportion of failures is similar to the proportion of failures in the total population of flow passages will have an increasing probability of being the wrong decision (Beta Error) as the size of the sample is decreased. A sample size of less than 55 to 60 is not recommended.

The sample size was calculated under the following assumptions.

1. A random sample is obtained from the 164 ice passages.

2. The distribution of the blocked flow passages is random, i.e., the blocked passages are not dependent upon their position in the ice condenser. If there is any indication that the blockage of flow passages occurs more frequently as a function of position, then the sampling scheme must be changed from random to either proportional or stratified sampling.

3. The sampling is without replacement.

Methodology

There are only two possibilities for the flow passages: blocked (failure = 1) or open (failure = 0). The number of blocked passages will be counted during the surveillance. Only one failure per passage is possible. This is a set of Bernoulli trials, or the distribution is Binomial.

The sample mean proportion of failures is: $p' = \frac{\text{number of failures}}{\text{number of trials}}$

The sample variance of p' with replacement is:

$$s^2 = (1-n/N)*p'(1-p')/(n-1)$$

Where N is the number in the total population (164 flow passages) and n is the number in the sample (number of trials).

For a 95 percent upper bound (alpha = .05) on p (the proportion blocked in the total population of flow passages):

$$p' + s*t$$

t is from the table of the Student's T distribution for a one sided limit at 95 percent. The T distribution approaches the normal distribution for sample sizes over 200.

s is the standard error necessary to calculate the upper bound and is the square root of the sample variance

Sample sizes from 40 to 110 were assumed. One to twenty failures were assumed for each sample size. The proportion, p', sample variance s^2 and upper bound were calculated for each of the assumed failures. The acceptance criterion was set at 0.15. If the upper bound exceeds 0.15, the the calculated p' is the proportion that cannot be exceeded. Since p' is calculated as number of failures/sample size n, np' is the number of failures in the sample size that will exceed the criterion of 0.15

The upper bound is a function of the sample variance. The number in the total population is known, therefore, the sample variance will converge to 0 at 164 and the upper bound will be 0, or the mean proportion of failures is exact.

II. Acceptance Criteria for Surveillance of Ice Condenser Flow Passages with 25 Percent, 50 Percent, 75 Percent and 100 Percent Ice Blockage in the Flow Passages, Based on a 33 Percent Sample Size.

The results of the calculations to provide the acceptance criteria for surveillance of ice condenser flow passages are presented for the following conditions.

1. One third of the flow passages will be randomly selected for surveillance.

2. The flow passages selected for surveillance will be examined for ice blockage and the percent of blockage in each passage estimated. The blockage of the ice passage will be listed as number of flow passages with: 0 blockage, 25 percent blockage, 50 percent blockage, 75 percent blockage and 100 percent blocked.

3. Based on the total percent of ice blockage in these passages in this sample, the criterion for acceptance is that the total ice blockage in the passages must be less than 15 percent.

The mean proportion, variance and upper bound of all of the possible combinations of blockage were calculated. The mean proportion of the sample that will exceed the allowable 15 percent acceptance limit was determined for each combination as well as the mean number that would be calculated for each combination of failures. The results of these calculations are provided in the following tables.

1. Table 2.1 is all of the combinations of 25%, 50% and 75% blocked passages with no passages having 100% blockage recorded.

2. Table 2.2 is all of the combinations of 25%, 50% and 75% blocked passages with one passage having 100% blockage recorded.

3. Table 2.3 is all of the combinations of 25%, 50% and 75% blocked passages with two passages having 100% blockage recorded.

4. Table 2.4 is all of the combinations of 25%, 50% and 75% blocked passages with three passages having 100% blockage recorded.

5. Table 2.5 is all of the combinations of 25%, 50% and 75% blocked passages with four or five passages having 100% blockage recorded.

Methodology

The mean proportion, p', of blockage over the sample is:

0.0 times the proportion with 0 blockage (Po)+ 0.25 times the proportion with 25 percent blockage (P1) + 0.50 times the proportion with 50 percent blockage (P2)+ .75 times the proportion with 75 percent blockage (P3) + the proportion with 100 percent blockage (P4), or,

$$p' = .25*P1 + .50*P2 + .75*P3 + 1.0*P4$$

The proportions, Po, P1, P2, P3 and P4 are calculated as the number of flow passages (ni) in each of the percentile blockage categories divided by the sample size n, or Pi = ni/n.

The variance, s^2, of this sample mean is:

$$s^2 = \frac{(1-n/N))*(.25^2*P1 + .5^2*P2 + .75^2*P3 + 1.0*P4) - p'^2]}{(n-1)}$$

where n is the sample size and N is the population size. The sample size for this calculation is 1/3 of the flow passages; with 162 flow passages in each bay (N). Therefore the sample size n is 54.

The 95th percent upper bound on the true mean proportion of the population is:

$$p' + st$$

where t is from the student T tables (1.673, for n = 54 and 95 %) and s is the standard error (square root of the variance).

How to Use Tables

After the sample is chosen, the passages inspected, and the number of passages with 25%, 50%, 75% and 100% blockage recorded, this combination is compared with the numbers in the tables in the following manner.

1. Chose the table based on the number of passages with 100% blockage (0, 1, 2, 3, 4 & 5). If five or more passages are recorded with 100 percent blockage, then the criterion of less than 15 percent total blockage is exceeded (the total population of 162 passages are then assumed to have more than 15 percent blockage).

2. Find the number in this table that corresponds to the number of passages with 75 percent blockage. The possible combinations are listed in order for 75 percent blockage (column 3). If the number of passages with 75 percent blocked is greater than the numbers listed in the specific table, the criterion is exceeded.

3. If the number of passages blocked is matched with the 75% blockage recorded, then match the number with 50% blockage (column 2) and 25% blockage (column 1).

Each combination listed in the tables will yield the 15% upper bound on the mean proportion of all of the flow passages. The number of passages blocked in each category must be less than the numbers listed in the table.

For example, if 1 passage is recorded with 100% blockage, 2 passages with 75 percent blockage, none with 50 percent blockage and 2 with 25 percent blockage, Table 2 for one passage blocked would be used. The column under 75 percent blocked is then found. The table is entered in the row with 2's in column 3. The first row has 0 blocked in the column for 50% blockage. In this case the criterion would be exceeded if 13 passages were counted with 25% blocked. But only 2 passages were counted with 25 percent blockage, therefore, the acceptance criterion has not been exceeded and the surveillance indicates that the mean proportion is less than 15 percent blocked.

TABLE 2.1 - NO PASSAGES BLOCKED 100%

PERCENT BLOCKED 25%	50%	75%	100%	MEAN (P')	VARIANCE	95TH BOUND	MEAN NUMBER
27	0	0	0	0.125	1.965E-04	0.15	6.75
24	1	0	0	0.120	2.254E-04	0.15	6.50
22	2	0	0	0.120	2.545E-04	0.15	6.50
20	3	0	0	0.120	2.836E-04	0.15	6.50
17	4	0	0	0.116	3.119E-04	0.15	6.25
15	5	0	0	0.116	3.410E-04	0.15	6.25
13	6	0	0	0.116	3.702E-04	0.15	6.25
11	7	0	0	0.116	3.993E-04	0.15	6.25
8	8	0	0	0.111	4.271E-04	0.15	6.00
6	9	0	0	0.111	4.562E-04	0.15	6.00
4	10	0	0	0.111	4.853E-04	0.15	6.00
2	11	0	0	0.111	5.144E-04	0.15	6.00
0	12	0	0	0.111	5.433E-04	0.15	6.00
23	0	1	0	0.120	2.836E-04	0.15	6.50
20	1	1	0	0.116	3.119E-04	0.15	6.25
18	2	1	0	0.116	3.410E-04	0.15	6.25
16	3	1	0	0.116	3.702E-04	0.15	6.25
14	4	1	0	0.116	3.993E-04	0.15	6.25
11	5	1	0	0.111	4.271E-04	0.15	6.00
9	6	1	0	0.111	4.562E-04	0.15	6.00
7	7	1	0	0.111	4.853E-04	0.15	6.00
5	8	1	0	0.111	5.144E-04	0.15	6.00
2	9	1	0	0.106	5.416E-04	0.15	5.75
0	10	1	0	0.106	5.708E-04	0.15	5.75
19	0	2	0	0.116	3.702E-04	0.15	6.25
17	1	2	0	0.116	3.993E-04	0.15	6.25
14	2	2	0	0.111	4.271E-04	0.15	6.00
12	3	2	0	0.111	4.562E-04	0.15	6.00
10	4	2	0	0.111	4.853E-04	0.15	6.00
8	5	2	0	0.111	5.144E-04	0.15	6.00
5	6	2	0	0.106	5.416E-04	0.15	5.75
3	7	2	0	0.106	5.708E-04	0.15	5.75
1	8	2	0	0.106	5.999E-04	0.15	5.75
0	9	2	0	0.111	6.309E-04	0.15	6.00
15	0	3	0	0.111	4.562E-04	0.15	6.00
13	1	3	0	0.111	4.853E-04	0.15	6.00
11	2	3	0	0.111	5.144E-04	0.15	6.00
8	3	3	0	0.106	5.416E-04	0.15	5.75
6	4	3	0	0.106	5.708E-04	0.15	5.75
4	5	3	0	0.106	5.999E-04	0.15	5.75
2	6	3	0	0.106	6.290E-04	0.15	5.75
0	7	3	0	0.106	6.581E-04	0.15	5.75

TABLE 2.1 - NO PASSAGES BLOCKED 100%

PERCENT BLOCKED 25%	50%	75%	100%	MEAN (P')	VARIANCE	95TH BOUND	MEAN NUMBER
11	0	4	0	0.106	5.416E-04	0.15	5.75
9	1	4	0	0.106	5.708E-04	0.15	5.75
7	2	4	0	0.106	5.999E-04	0.15	5.75
5	3	4	0	0.106	6.290E-04	0.15	5.75
3	4	4	0	0.106	6.581E-04	0.15	5.75
0	5	4	0	0.102	6.848E-04	0.15	5.50
8	0	5	0	0.106	6.290E-04	0.15	5.75
6	1	5	0	0.106	6.581E-04	0.15	5.75
3	2	5	0	0.102	6.848E-04	0.15	5.50
1	3	5	0	0.102	7.139E-04	0.15	5.50
0	4	5	0	0.106	7.455E-04	0.15	5.75
4	0	5	0	0.102	7.139E-04	0.15	5.50
2	1	6	0	0.102	7.430E-04	0.15	5.50
0	2	6	0	0.102	7.721E-04	0.15	5.50

TABLE 2.2 - ONE PASSAGE BLOCKED 100%

PERCENT BLOCKED 25%	50%	75%	100%	MEAN (P')	VARIANCE	95TH BOUND	MEAN NUMBER
21	0	0	1	0.116	3.702E-04	0.15	6.25
19	1	0	1	0.116	3.993E-04	0.15	6.25
16	2	0	1	0.111	4.271E-04	0.15	6.00
14	3	0	1	0.111	4.562E-04	0.15	6.00
12	4	0	1	0.111	4.853E-04	0.15	6.00
10	5	0	1	0.111	5.144E-04	0.15	6.00
7	6	0	1	0.106	5.416E-04	0.15	5.75
5	7	0	1	0.106	5.708E-04	0.15	5.75
3	8	0	1	0.106	5.999E-04	0.15	5.75
1	9	0	1	0.106	6.290E-04	0.15	5.75
0	10	0	1	0.111	6.600E-04	0.15	6.00
17	0	1	1	0.111	4.562E-04	0.15	6.00
15	1	1	1	0.111	4.853E-04	0.15	6.00
13	2	1	1	0.111	5.144E-04	0.15	6.00
10	3	1	1	0.106	5.416E-04	0.15	5.75
8	4	1	1	0.106	5.708E-04	0.15	5.75
6	5	1	1	0.106	5.999E-04	0.15	5.75
4	6	1	1	0.106	6.290E-04	0.15	5.75
2	7	1	1	0.106	6.581E-04	0.15	5.75
0	8	1	1	0.106	6.872E-04	0.15	5.75
13	0	2	1	0.106	5.416E-04	0.15	5.75
11	1	2	1	0.106	5.708E-04	0.15	5.75
9	2	2	1	0.106	5.999E-04	0.15	5.75
7	3	2	1	0.106	6.290E-04	0.15	5.75
5	4	2	1	0.106	6.581E-04	0.15	5.75
2	5	2	1	0.102	6.848E-04	0.15	5.50
0	6	2	1	0.102	7.139E-04	0.15	5.50
10	0	3	1	0.106	6.290E-04	0.15	5.75
8	1	3	1	0.106	6.581E-04	0.15	5.75
5	2	3	1	0.102	6.848E-04	0.15	5.50
3	3	3	1	0.102	7.139E-04	0.15	5.50
1	4	3	1	0.102	7.430E-04	0.15	5.50
0	5	3	1	0.106	7.746E-04	0.15	5.75
6	0	4	1	0.102	7.139E-04	0.15	5.50
4	1	4	1	0.102	7.430E-04	0.15	5.50
2	2	4	1	0.102	7.721E-04	0.15	5.50
0	3	4	1	0.102	8.013E-04	0.15	5.50
3	0	5	1	0.102	8.013E-04	0.15	5.50
0	1	5	1	0.097	8.274E-04	0.15	5.25
0	0	6	1	0.102	8.886E-04	0.15	5.50

TABLE 2.3 - TWO PASSAGES BLOCKED 100%

PERCENT BLOCKED 25%	50%	75%	100%	MEAN (P')	VARIANCE	95TH BOUND	MEAN NUMBER
15	0	0	2	0.106	5.416E-04	0.15	5.75
13	1	0	2	0.106	5.708E-04	0.15	5.75
11	2	0	2	0.106	5.999E-04	0.15	5.75
9	3	0	2	0.106	6.290E-04	0.15	5.75
7	4	0	2	0.106	6.581E-04	0.15	5.75
4	5	0	2	0.102	6.848E-04	0.15	5.50
2	6	0	2	0.102	7.139E-04	0.15	5.50
0	7	0	2	0.102	7.430E-04	0.15	5.50
12	0	1	2	0.106	6.290E-04	0.15	5.75
10	1	1	2	0.106	6.581E-04	0.15	5.75
7	2	1	2	0.102	6.848E-04	0.15	5.50
5	3	1	2	0.102	7.139E-04	0.15	5.50
3	4	1	2	0.102	7.430E-04	0.15	5.50
1	5	1	2	0.102	7.721E-04	0.15	5.50
8	0	2	2	0.102	7.139E-04	0.15	5.50
6	1	2	2	0.102	7.430E-04	0.15	5.50
4	2	2	2	0.102	7.721E-04	0.15	5.50
2	3	2	2	0.102	8.013E-04	0.15	5.50
0	4	2	2	0.102	8.304E-04	0.15	5.50
5	0	3	2	0.102	8.013E-04	0.15	5.50
2	1	3	2	0.097	8.274E-04	0.15	5.25
0	2	3	2	0.097	8.565E-04	0.15	5.25
1	0	4	2	0.097	8.856E-04	0.15	5.25
0	1	4	2	0.102	9.177E-04	0.15	5.50
0	0	5	2	0.106	9.784E-04	0.16	5.75

TABLE 2.4 - THREE PASSAGES BLOCKED 100%

PERCENT BLOCKED 25%	50%	75%	100%	MEAN (P')	VARIANCE	95TH BOUND	MEAN NUMBER
10	0	0	3	0.102	7.139E-04	0.15	5.50
8	1	0	3	0.102	7.430E-04	0.15	5.50
6	2	0	3	0.102	7.721E-04	0.15	5.50
4	3	0	3	0.102	8.013E-04	0.15	5.50
1	4	0	3	0.097	8.274E-04	0.15	5.25
0	5	0	3	0.102	8.595E-04	0.15	5.50
7	0	1	3	0.102	8.013E-04	0.15	5.50
4	1	1	3	0.097	8.274E-04	0.15	5.25
4	0	2	3	0.102	8.886E-04	0.15	5.50
1	1	2	3	0.097	9.148E-04	0.15	5.25
0	0	3	3	0.097	9.730E-04	0.15	5.25

TABLE 2.5 - MORE THAN THREE PASSAGES BLOCKED 100%

PERCENT BLOCKED 25%	50%	75%	100%	MEAN (F')	VARIANCE	95TH BOUND	MEAN NUMBER
5	0	0	4	0.097	8.856E-04	0.15	5.25
3	1	0	4	0.097	9.148E-04	0.15	5.25
1	2	0	4	0.097	9.439E-04	0.15	5.25
0	3	0	4	0.102	9.760E-04	0.15	5.50
2	0	1	4	0.097	9.730E-04	0.15	5.25
0	1	1	4	0.097	1.002E-03	0.15	5.25
0	0	2	4	0.102	1.063E-03	0.16	5.50
0	0	0	5	0.093	1.057E-03	0.15	5.00