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AXIAL FLUX DATA FOR FUEL MEASUREMENT

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Process Analysis Unit
Process Technology Subsection
Research and Engineering Section

MASTER

AXIAL FLUX DATA FOR FUEL MEASUREMENT

A survey of the PITA-18 nonpoisonous spline program¹ was conducted in conjunction with a study to determine the best method of eliminating the variability of axial flux on the fuel performance parameter, q . The results of this survey and the conclusions reached in the rupture coefficient study were found to be interdependent such that both are presented in this report.

The data from the PITA-18 nonpoisonous spline program, as received, is the output of the NOLA-2 computer program.² One quantity of interest is the rupture potential relative to a cosine, commonly referred to as the relative rupture potential. As

¹Albertson, D.G., and Bowers, C.E., Final Report - PITA-18, Use of Nonpoisonous Splines for Longitudinal Flux Traversing, HW-77403, May 1, 1963. [REDACTED]

²Bailey, G.F., The NOLA-2 Code, HW-69486 Rev1., October 31, 1961.

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programed, the relative rupture potential, which was derived by applying the rupture model to individual fuel elements, might be expected to vary linearly with the rupture rate as in the following expression.

$$RR = k (RRP) P^a T^b E^c \quad [1]$$

where

RR is the rupture rate, ruptures per charge exposed

k is a proportionality constant

RRP is the relative rupture potential

P is the tube power

T is the temperature

E is the exposure

a, b, c are constants currently estimated to be 3.3, 8.7 and 5.0.

In terms of expected ruptures for some period, this may be approximated by:

$$\epsilon(R) = q (RRP) \Delta RI \quad [2]$$

where

$\epsilon(R)$ is the expected ruptures

q is the fuel performance parameter

RRP is the relative rupture potential

ΔRI is the change in rupture index, or $\sum^n [(P^a T^b E^c)_{end} - (P^a T^b E^c)_{start}]$, for n charges.

The present control chart basis is to calculate expected ruptures by:

$$(R) = q \Delta RI \quad [3]$$

Therefore, if the method of calculating control chart points is modified to the form of equation [2], the variability of axial flux will be removed from the fuel performance parameter, provided RRP does indeed account for axial flux effects linearly as had been expected.

The use of the relative rupture potential in the form of equation [2] was studied over the period of July, 1962, through December, 1963. The results of this study are presented in Table 1 and Figure 1.

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TABLE 1

(1)	(2) Average RRP	(3) <u>(ARI)_n</u>	(4) <u>(ARI)_n(RRP)</u>	(5) Observed Ruptures	(6) Distribution of Ruptures (Column 4)	(7) Distribution of Ruptures (Column 3)
7/62-12/62						
B	2.269	28.7	65.1	9	9.6	7.1
D	1.595	35.1	56.0	10	8.2	8.7
DR	1.905	22.1	42.3	5	6.2	5.4
F	1.316	32.2	42.4	7	6.2	7.9
H	1.226	<u>15.7</u>	<u>19.2</u>	<u>2</u>	<u>2.8</u>	<u>3.9</u>
Avg. or Sum	1.662	133.8	225.0	33	33.0	33.0
1/63-6/63						
B	1.539	26.0	40.0	7	4.6	3.1
D	1.274	57.3	73.0	7	8.3	6.8
DR	1.213	37.3	45.2	8	5.1	4.4
F	1.224	32.3	39.5	1	4.5	3.8
H	0.533	<u>74.1</u>	<u>39.5</u>	<u>4</u>	<u>4.5</u>	<u>8.9</u>
Avg. or Sum	1.157	227.0	237.2	27	27.0	27.0
7/63-12/63						
B	1.803	51.2	92.3	5	5.2	3.0
D	1.333	69.4	92.5	7	5.2	4.1
DR	1.352	47.9	64.8	3	3.6	2.8
F	1.020	34.5	35.2	2	2.0	2.0
H	0.449	<u>121.7</u>	<u>54.6</u>	<u>2</u>	<u>3.0</u>	<u>7.1</u>
Avg. or Sum	1.191	324.7	339.4	19	19.0	19.0
Total						
7/62-12/63						
B	1.870	105.9	197.4	21	19.5	12.2
D	1.401	161.8	221.5	24	21.8	18.6
DR	1.490	107.3	152.3	16	15.0	12.4
F	1.186	99.0	117.1	10	11.5	11.4
H	0.736	<u>211.5</u>	<u>113.3</u>	<u>8</u>	<u>11.2</u>	<u>24.4</u>
	1.337	685.5	801.6	79	79.0	79.0

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Figure 1. Observed Ruptures Versus $(RRP) (\Delta RI)_n$
(Data for 18 Month Period 7/62 to 12/63)

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The headings of Table 1 are defined as follows. Column one represents the reactors within each time period. Column two represents the numerical average of all spline traverses taken during each six-month period. Column three represents the sum of the change in rupture index for each period normalized to 03N nonbumper material. Column four represents the product of the two previous headings within the six-month periods, and a summation of the three individual periods for the 18-month period. Column five represents the total ruptures incurred during each period except for those caused by mechanical damage. Column six represents the distributions of the total number of observed ruptures between reactors according to the numerical values of $(\Delta RI)_n(RRP)$, in column four, i.e., the ruptures one would expect had they occurred exactly in accordance with equation [2]. Column seven represents the distribution of the total number of observed ruptures between reactors according to the numerical values of $(\Delta RI)_n$ in column three. This represents the distribution of ruptures had they occurred exactly in accordance with equation [3].

The Chi-Square Goodness-of-Fit Test was applied to see if the observed distributions of ruptures in column 3 was adequately represented by the expected distributions in columns 6 and 7. From standard practice, a 90 per cent confidence interval was selected as the acceptance level. On this basis, the distributions obtained during the four time intervals using equation [2], column 6, did adequately represent the observed distributions. Using equation [3], column 7, the distributions obtained during the time periods 1/63-6/63 and 7/62-12/63 did not adequately represent the observed distributions. Therefore, equation [3] is rejected and equation [2] is selected as an adequate description to the observed data.

Figure 1 illustrates the graph of equation [2] for the data of the total period. It is seen that, for this period, a well defined linear relationship results.

However, irrespective of the linear relationship observed in Figure 1, the presently available data does not lend itself to a month-by-month correlation which is the desired result. This is because of several difficulties which do not seriously affect the average results of an 18-month period.

One such difficulty is the insufficient quantity of data available. As seen in Table 2, the reactors differ considerably in the frequency and number of flux traverses taken. The conclusions reached in the PITA-18 final report were "routine longitudinal flux traverses should be made at all reactors, using the spline traverse method, at a minimum frequency of 5-7 traverses per equilibrium month per reactor at the old reactors...."¹ Table 2 indicates that, in many instances, these conclusions have not been followed.

¹ibid.

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TABLE 2

NUMBER OF SPLINE TRAVERSES REPORTED PER REACTOR PER MONTH

<u>Reactor</u>	Month	<u>1962</u>						<u>1963</u>						<u>Total</u>							
		<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>	<u>12</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>		<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>	<u>12</u>	
B			9	5	5			6			6	3	5	3	3		8	7		60	
D			11					7				3			6		3		2	32	
DR			10		7	6		5	5	3	4			4						44	
F			7	6	8		8		6	6	5	6	8			8				68	
H			<u>6</u>	<u>7</u>	<u>—</u>	<u>—</u>	<u>9</u>	<u>—</u>	<u>4</u>	<u>—</u>	<u>—</u>	<u>1</u>	<u>—</u>	<u>9</u>	<u>—</u>	<u>—</u>	<u>12</u>	<u>—</u>	<u>—</u>	<u>48</u>	
Total			6	44	11	20	15	8	22	11	9	16	12	22	7	9	20	11	7	2	252

Another difficulty encountered is the locations of the flux traverses on the reactor face. An analysis of the 68 F reactor traverses by location is illustrated in Figure 2. The reactor face is arbitrarily divided into quadrants with the total number of traverses taken in each quadrant shown. From this it is evident that any analysis of F reactor flux traverses would favor the conditions which prevailed in the upper left quadrant.

FIGURE 2

SPLINE TRAVERSES REPORT PER QUADRANT OF THE REACTOR FACE

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One cannot simply "weight" the results to account for the uneven distribution. This is because, on any particular day, there may not be any traverses taken in the upper right quadrant, and, since the flux concentrations shift with time, there would be no basis with which to weight the flux traverses available. This effect is illustrated in Figure 3 on which the relative rupture potential is plotted against time for various locations on the reactor face. It is seen that the relative rupture potential in a particular location can change considerably and in opposite directions relative to other locations.

Both of the adverse conditions mentioned above can be corrected. If this were done, a steady influx of reliable data would be available which could be used on either a one, two, or three-month basis in the calculation of the control chart points. Of course, the length of time required for a basis is dependent on the frequency and reliability of the data and will be determined at a future date. Therefore, with these objectives as our goal, the following improvements in the PITA-18 program are suggested:

1. Routine longitudinal flux traverses should be made at all reactors, using the spline traverse method, at a minimum frequency of five traverses per equilibrium month per reactor. Additional sets of five should be taken whenever significant axial flux shifts can be predicted.
2. Every set of five traverses should consist of one near the center of each of the four quadrants, and one near the geometric center of the reactor face.
3. If practical, the complete set of five or more should be taken in a short period during equilibrium operation to obtain an instantaneous flux picture.
4. Each month the spline traverse data from each reactor should be forwarded to Process Analysis for use in the Rupture Memo control chart calculations. Delays in data handling and computation should be held to a minimum.

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Relative Rupture Potential

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Figure 3. Relative Rupture Potential Versus Time for F Reactor at Various Locations on the Reactor Face

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