TOPICAL REPORT
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WSTG-1-NP

PROCEDURES FOR
ESTIMATING THE PROBABILITY OF STEAM TURBINE DISC RUPTURE FROM STRESS CORROSION CRACKING

Submitted to:
NUCLEAR REGULATORY COMMISSION
May, 1981

Westinghouse Steam Turbine Generator Division

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ABSTRACT

This report discusses the procedures used for estimating the probability of disc rupture and missile generation. Specifically, the probability of a given nuclear turbine experiencing a low pressure disc rupture due to stress corrosion cracking on the bore or in a keyway of a disc is estimated as follows:

1) The probability of a crack initiating in a given disc is estimated from Westinghouse turbine [ ]^{b,c}

2) The rate at which a crack could grow is estimated as a function of disc [ ]^{b,c} the estimate is obtained from an analysis of crack statistics obtained from turbine inspections.

3) The critical crack depth for a disc is estimated from its calculated tangential bore stress at the speed of interest and the measured toughness; allowance is made for [ ]^{b,c}

4) Special conditions such as existing cracks or overbored keyways are taken into account.

5) A probability of disc rupture resulting from the initiation and propagation of a stress corrosion crack is estimated for each disc; this information is combined to give an estimate of the probability that the turbine will experience a disc rupture from stress corrosion cracking.

6) The probabilities are estimated for both running speed disc rupture and design overspeed disc rupture; they are further modified to estimate the probability of generating a turbine missile from the unit.

I. INTRODUCTION

A typical nuclear turbine arrangement is shown in Fig. 1 It consists of a high pressure rotor and two or three low pressure rotors in tandem. Because of the massive sizes of these low pressure rotors, it has not been possible to procure them as a single piece forging. Instead, individual discs are shrunk-on to a shaft (Fig. 2) and keyed in place so that discs cannot spin independently of the shaft should they come loose. Details of the disc and common terms used are shown in Fig. 3

In 1979 Westinghouse first observed radial cracks in the bores and keyways of certain low pressure discs of a nuclear turbine. The cracks are environmentally assisted cracking. Subsequent inspections of operating nuclear turbines have revealed this to be a condition that manifests itself with irregularity. Pre-service inspection of several units has shown no cracking thus establishing that cracking occurs during operation.

It is important to note that cracking has been found only on some discs on some turbines. Further, discs that have cracks may have 1, 2 or 3 keyways cracked and may, instead of or in addition to the keyway cracks, have cracks emanating directly from the bore surface. Further still, crack depths vary within a disc, among discs on one turbine, and among machines. Because of these variabilities a probabilistic approach has been taken to effect a risk analysis for this class of turbines. Such an approach is expected to yield two benefits:

1) It will allow two aspects: turbine missiles and disc rupture to be addressed quantitatively.

2) It should provide additional insight into the mechanisms for the cracking.

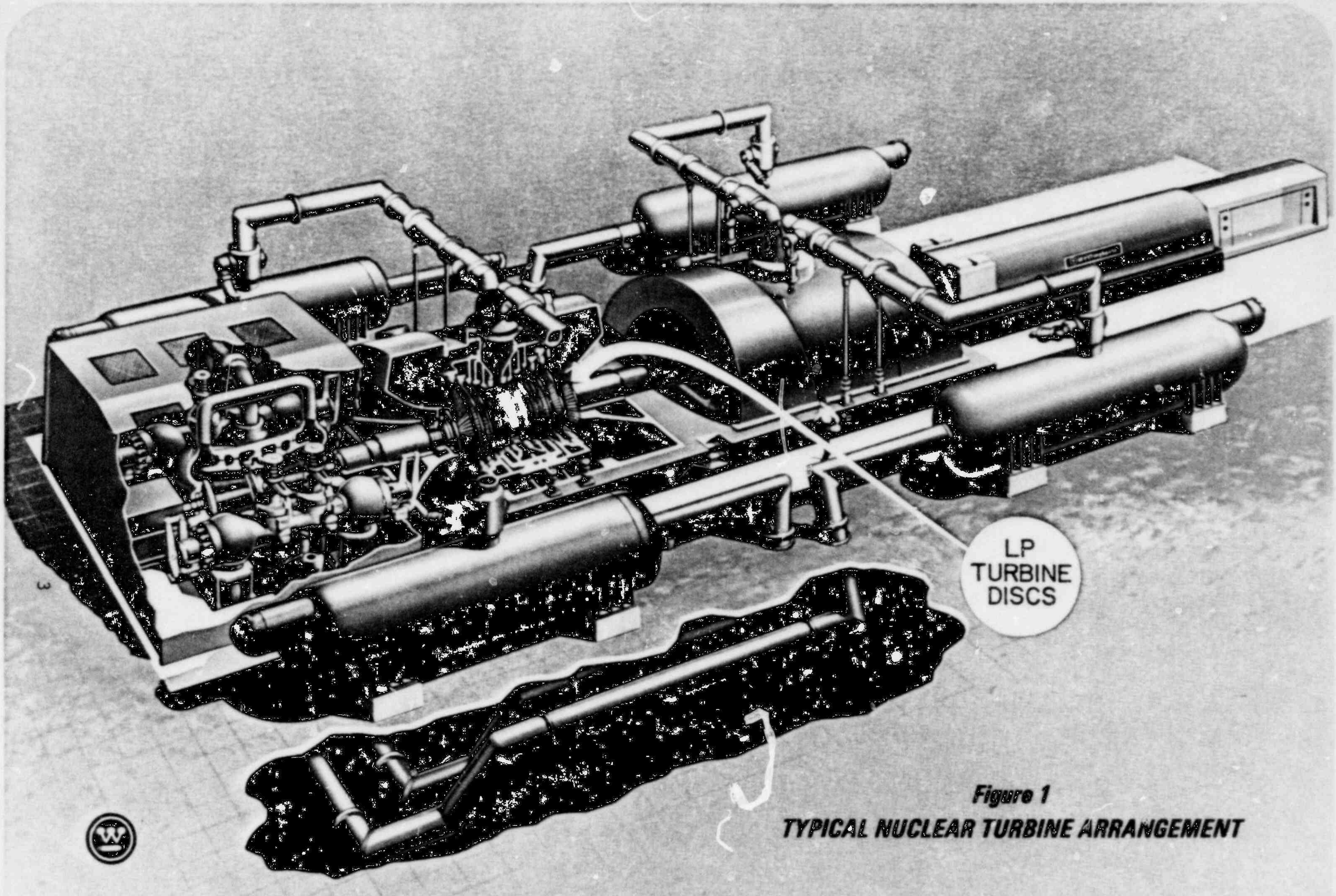

Figure 1
TYPICAL NUCLEAR TURBINE ARRANGEMENT

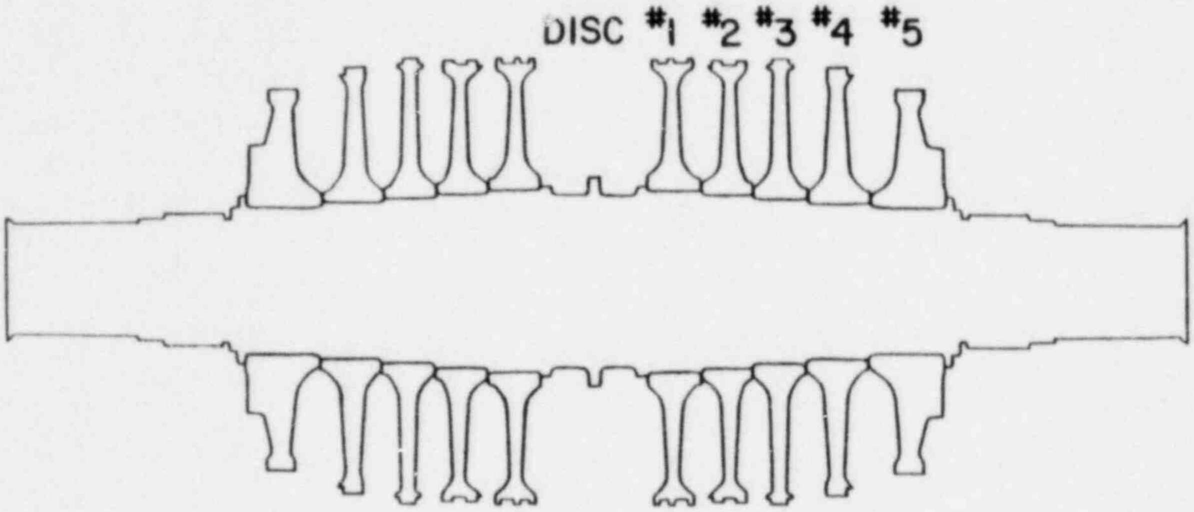

Figure 2
TYPICAL LOW PRESSURE ROTOR

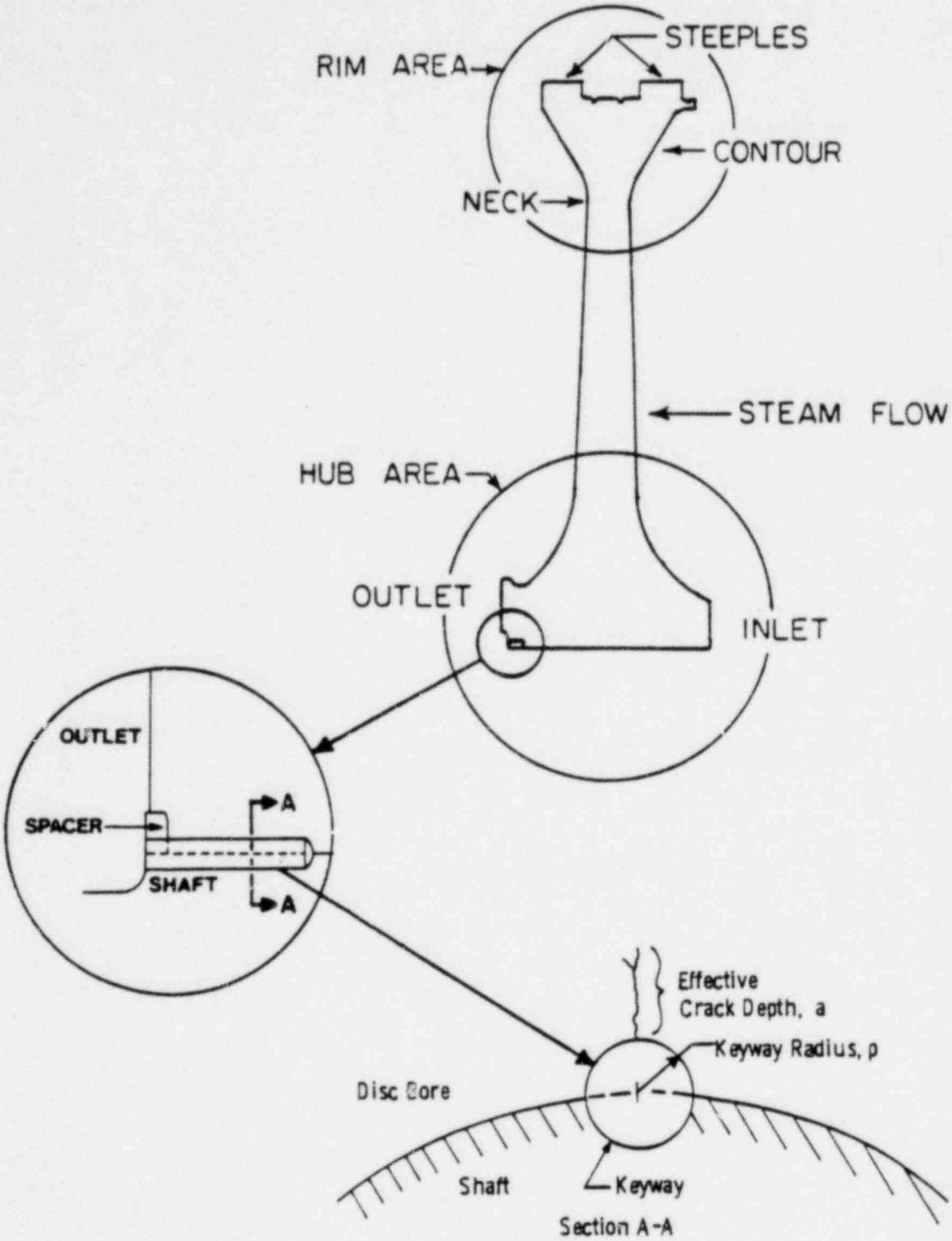

Figure 3

DETAILS OF A TYPICAL SHRUNK-ON DISC

Earlier experiences of environmentally enhanced cracking have been reported for other turbines and other areas in turbines. The best known example is the cracking in the Hinkley Point (U.K.) turbine that led to the rupture of one LP disc and the consequential rupture of three more. Within Westinghouse, the closest related phenomenon is the steeple cracking and outer rim cracking that has been observed on some LP turbine discs. Neither the steeple and rim cracking, nor the Hinkley Point failure appear to provide sufficient information relative to the current investigation. It was therefore decided to confine investigation strictly to observed cracks in the hubs of Westinghouse LP nuclear turbines.

Section II of this report describes briefly the facts and tendencies that have been established about the disc cracking insofar as the probabilistic analysis is concerned. Section III contains the details of the modeling of crack growth as a random variable; similar work for critical crack depth is given in Section IV. The full procedure for the risk assessment, including estimation of the probability of cracking, is described in Section V. Section VI contains the extension to the estimation of the probability of generating turbine missiles.

The appendix contains various tables of supporting data for the several parts of the analysis.

II. FACTS AND TENDENCIES

In the midst of the extensive variability of the cracking process, two facts do seem to be holding, and they support the hypothesis that this is a form of stress corrosion cracking. The first of these is that no cracking has been observed in dry steam, i.e., no discs in the superheat region upstream from the moisture transition zone have been found cracked. The second is that all cracks that have been examined in detail have been wholly or partly intergranular and exhibit some branching.

There are also some characteristics that manifest themselves as tendencies; i.e., are generally operative but not always. The rate of crack growth appears to be related to [ ]^{b,c} in a consistent way (rate increases [ ]^{b,c} Finally, there are distinct differences among [ ]^{a,b,c} with respect to their tendency to crack; part of these differences may be due to differing [ ]^{a,b,c}

The risk assessment methodology being reported here recognizes the branching nature of the cracks, relates the crack growth rate to [ ] ^{b,c} treats the crack initiation probability separately for each [ ],^{a,b} and estimates initiation probabilities directly by [ ]^{b,c}

III. MODELING OF CRACK GROWTH

It must be noted at the onset of this work that the crack growth model that has been developed is primarily descriptive rather than causal. Where possible, causal interpretation of model parameters are given, but the model as a whole is empirical and derives most of its support from the [ ]b,c

Two decisions were made in selecting the data base for this development: (1) Only Westinghouse data have been used; i.e., the related British experience is not incorporated in this work. (2) The [ ]b,c have been used. It is thus possible for a single disc to contribute as many as [ ]b,c cracks to the data base.

The first of the above decisions was reached early in 1980 when the Westinghouse experience included 28 keyway and 4 bore cracks. An independent fitting of the Westinghouse data and the British data (by procedures and models to be discussed shortly) revealed that a common linear relationship between ℓn (growth rate) and reciprocal temperature over the full temperature range covered by the combined data set was inappropriate; this is shown on Figure 4. Since the British data covered [ ]b,c than those of interest to Westinghouse, it was decided that use of the Westinghouse data alone was appropriate.

The second decision was reached in an effort to have the largest and most comprehensive data base possible consistent with the constraint that its members be statistically independent. Since most discs with cracked keyways do not have all keyways cracked, it appears that some yet unidentified factors may be operative in the cracking mechanism. Bore cracks appear in clusters on the bore surface so it must be concluded that cracks near each other cannot be regarded as independent. Then, in order to achieve some semblance of independence,

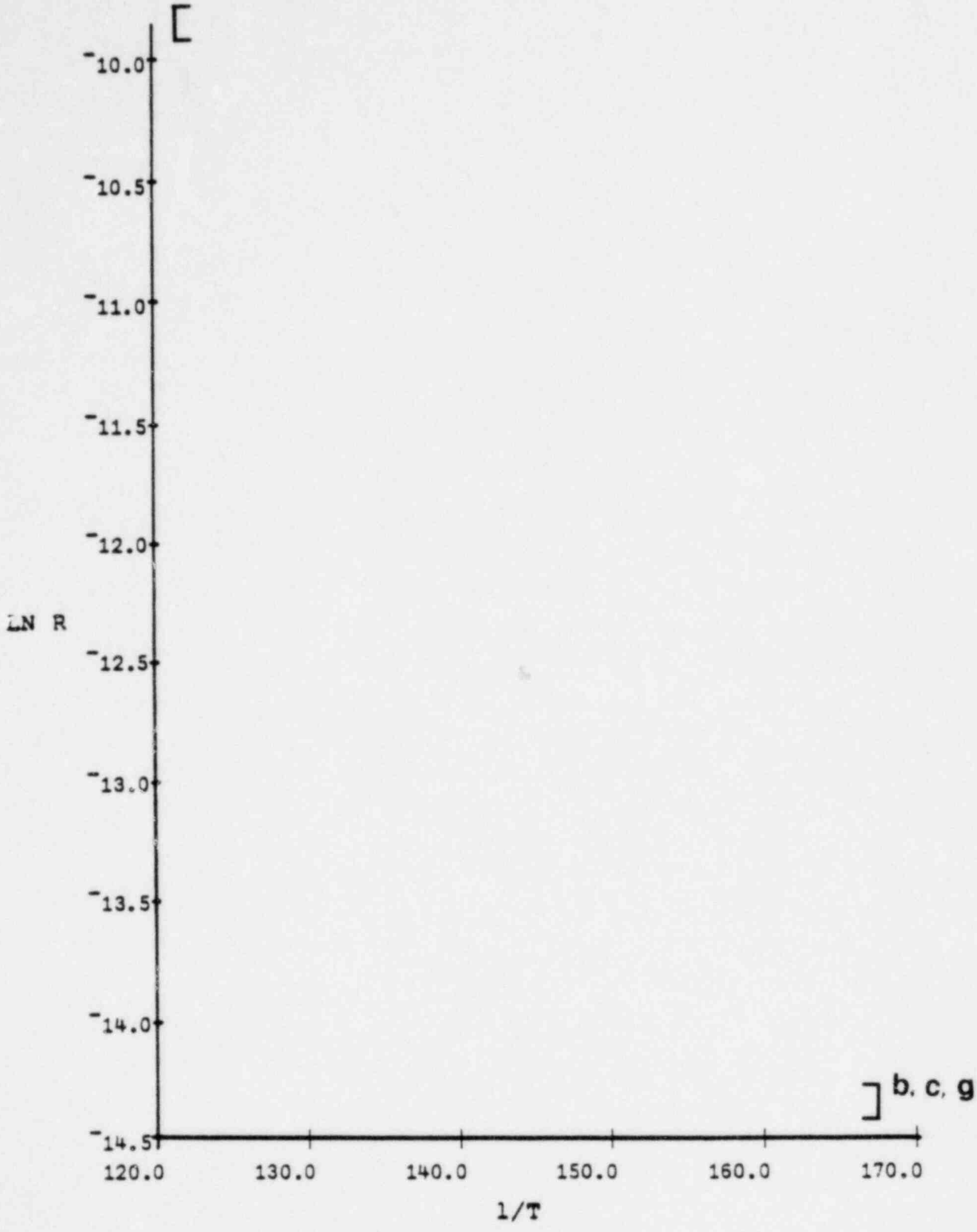

Figure 4

COMPARISON OF MODEL 2 FITTED TO EARLY WESTINGHOUSE DATA (TABLE A1) AND BRITISH DATA (TABLE A2)

the decision was made to accept, from any one disc, [ ]^{b,c}

The impact of the second decision just discussed has been investigated; the results of that investigation are reported later in this section.

Each observed disc crack carries with it two pieces of information: the estimated crack depth (from Ultrasonic Testing, UT) and the service hours at inspection. In order to obtain an estimate of the rate of growth of the crack it is necessary to establish another point on the depth vs. time record; this was done by assuming that a crack, if it initiates and propagates in a disc, does so very early in the service life of that disc. Operatively, we assumed that all cracks have a [ ]^{b,c} There are two justifications for this assumption: First, this assumption is consistent both with the British experience and with limited laboratory data. Second, since the approach is to build an empirical model, a statistical demonstration of validity, as has been done and will be presented shortly, should be adequate.

It was decided to seek a model to relate observed crack growth rate to [ ]^{b,c} taken at the disc bore. Other candidates for independent variables were considered and rejected for various reasons; e.g., [ ]^{b,c} is too highly correlated with [ ]^{b,c} Four model forms were investigated:

$$\ln r = [\quad]^{b,c} \qquad (1)$$

$$\ln r = [\quad]^{b,c} \qquad (2)$$

$$\ln r = [\quad]^{b,c} \qquad (3)$$

$$\ln = r = [\quad]^{b,c} \qquad (4)$$

where r = estimated crack depth/service time,
[ ]^{b,c} The

estimated crack depth in this and all subsequent parts of the analysis is taken to be the depth from the UT indication increased by [ ]b,c mils to account for any reasonable uncertainty in the UT estimation; actual depths, where known, were used instead of UT estimates.

Each of the 4 models above were fit by the method of least squares and the resulting fits interpreted statistically. It was found that model (2) was a significant improvement over model (1), while models (3) and (4) showed only a very marginal improvement over model (2); it was decided to use the model that related the logarithm of the crack growth rate to the [ ]b,c as shown.

The result of fitting on the 32 data available earlier was

$$\ln \hat{r} = [\quad]^{b,c}$$

$$\hat{s} = [\quad]^{b,c}$$

$$R^2 = [\quad]^{b,c}$$

where $\hat{s}$ is the estimated standard deviation for a single observation and R^2 is the multiple correlation coefficient, sometimes called the coefficient of determination. (R^2 measures the fraction of the total variation in the data that is explained by the regression.) The question of significant difference between bore and keyway cracks was raised because the bore cracking rate appears to be higher. This question was unresolved at this point because of the small number of bore cracks (4) in the data base. A probability plot for the residuals was made and [ ]b,c (Fig. 5).

Early in 1981, with the data base augmented by the disc cracks found during 1980, the crack growth rate model was reexamined for two purposes: To verify the model form and to generate improved parameter estimates. Concurrent with this investigation the modified data bases

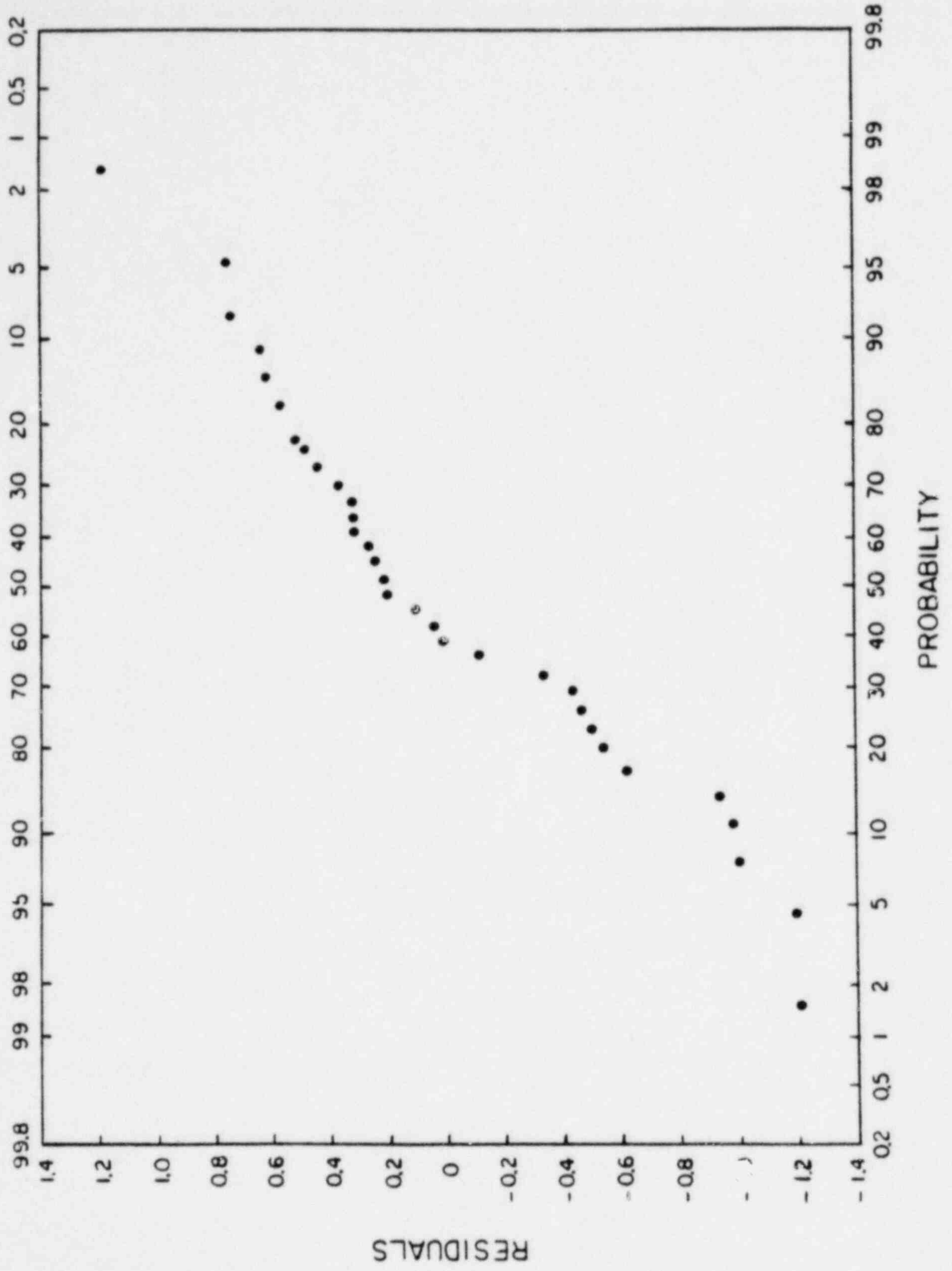

Figure 5

NORMAL PROBABILITY PLOT OF RESIDUALS FROM FIT OF MODEL 2 TO EARLY WESTINGHOUSE DATA (TABLE A1)

were used to learn the stability of the model with reference to the earlier decision to include up to [ ]b,c per disc in the data base. Modifications examined were:

[

]b,c

The results of these regressions are shown in Table 1. The results for model 0 using augmented data are compared with the model using the 32 data on Fig. 6.

Table I

[ ]b,c

[

]b,c

An examination of these regressions showed that

[

]b,c However, the lack of range for temperature and yield strength in the bore cracks precluded doing a meaningful regression on those data, so a [

]b,c

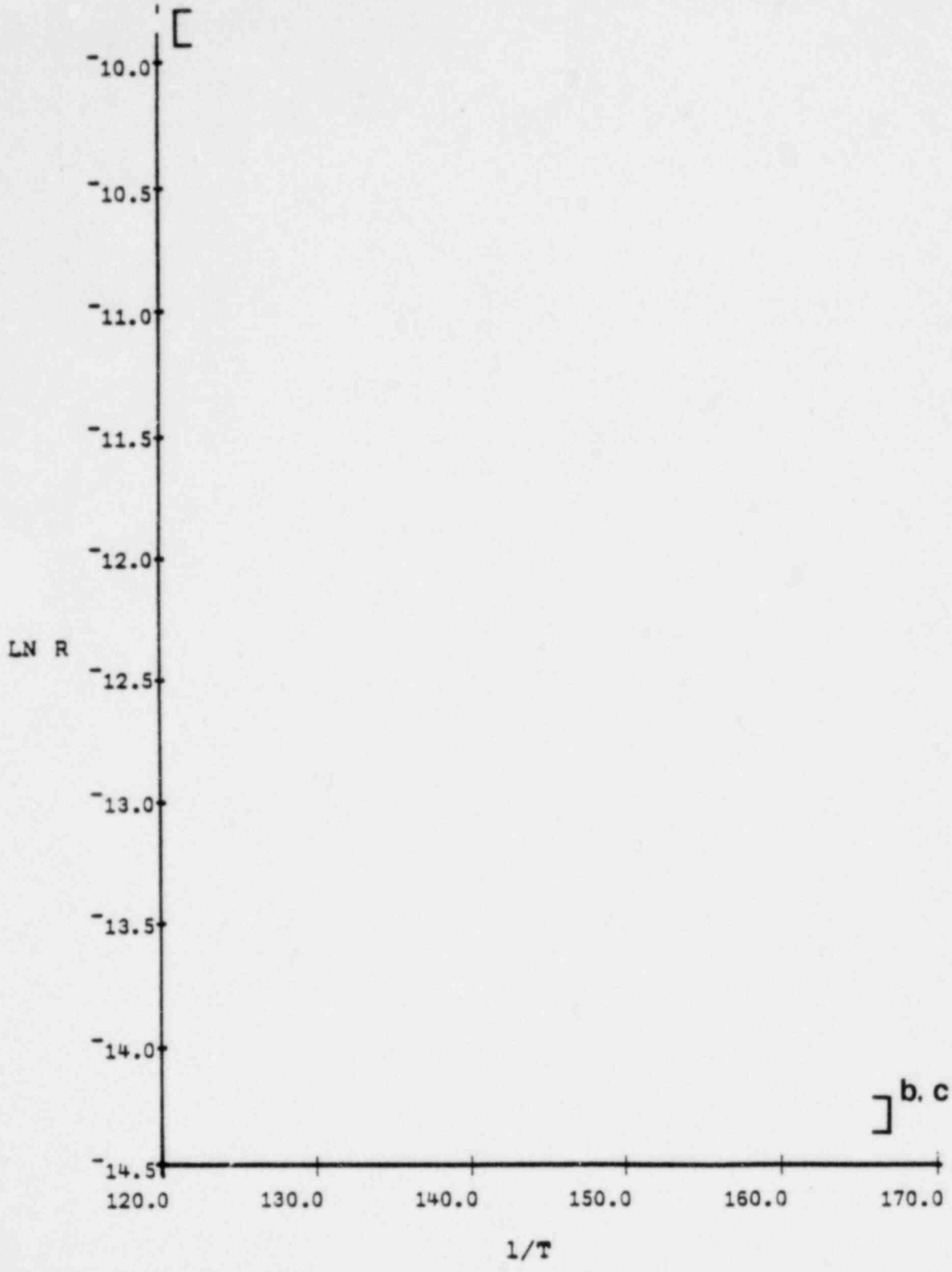

Figure 6

COMPARISON OF EARLY WESTINGHOUSE DATA (TABLE A1) AND LATER WESTINGHOUSE DATA (TABLE A3) FITTED ACCORDING TO MODEL O

The procedure was to fit the keyway and bore crack data simultaneously under the constraint that the [

]^{b,c} for the two types of data. Formally, the following regression model was used:

[

]^{b,c}

With the augmented data base of 60 keyway cracks and 9 bore cracks, the following was obtained:

[

]^{b,c}

Fig. 7 displays the growth rate curves for bore and keyways using the above method against the combined bore and keyway data (model 0) for the latest data.

Fig. 8 shows the comparison of crack growth rates using the above method for the latest Westinghouse data against the model 0 using the early Westinghouse data.

The form of model chosen to reflect dependence of crack growth rate on [ ]^{b,c} is believed to be appropriate. It is recognized that some variability remains unexplained by this regression, but until other operative mechanisms can be included in the model, the present descriptive form is used.

There are two consistencies that should be noted as further support of the regressions obtained here. First, although no direct evidence has been obtained to support the [ ]^{b,c} assumption, the

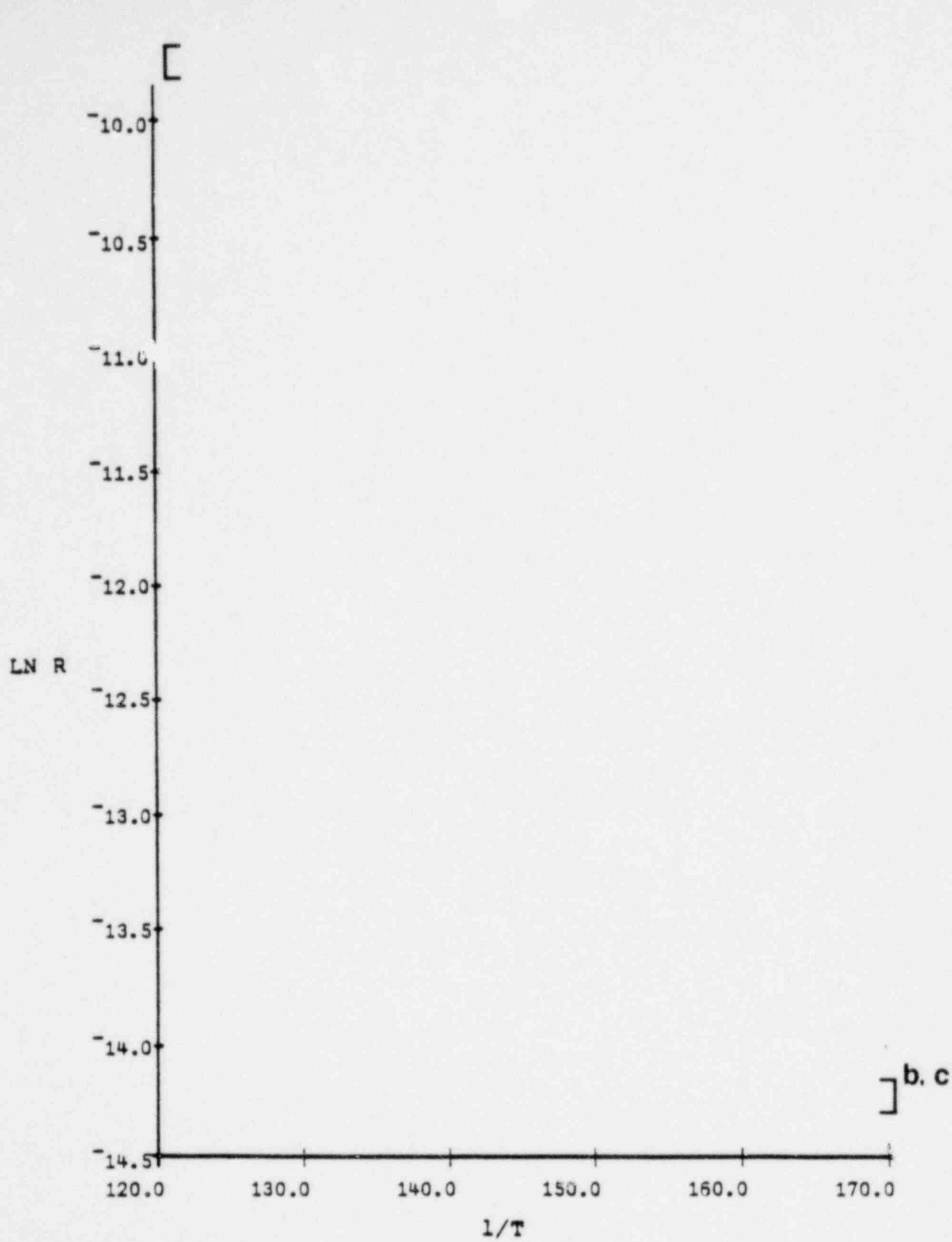

Figure 7
COMPARISON OF MODEL 0 AND PROPOSED MODEL FITTED TO LATER WESTINGHOUSE DATA (TABLE A3)

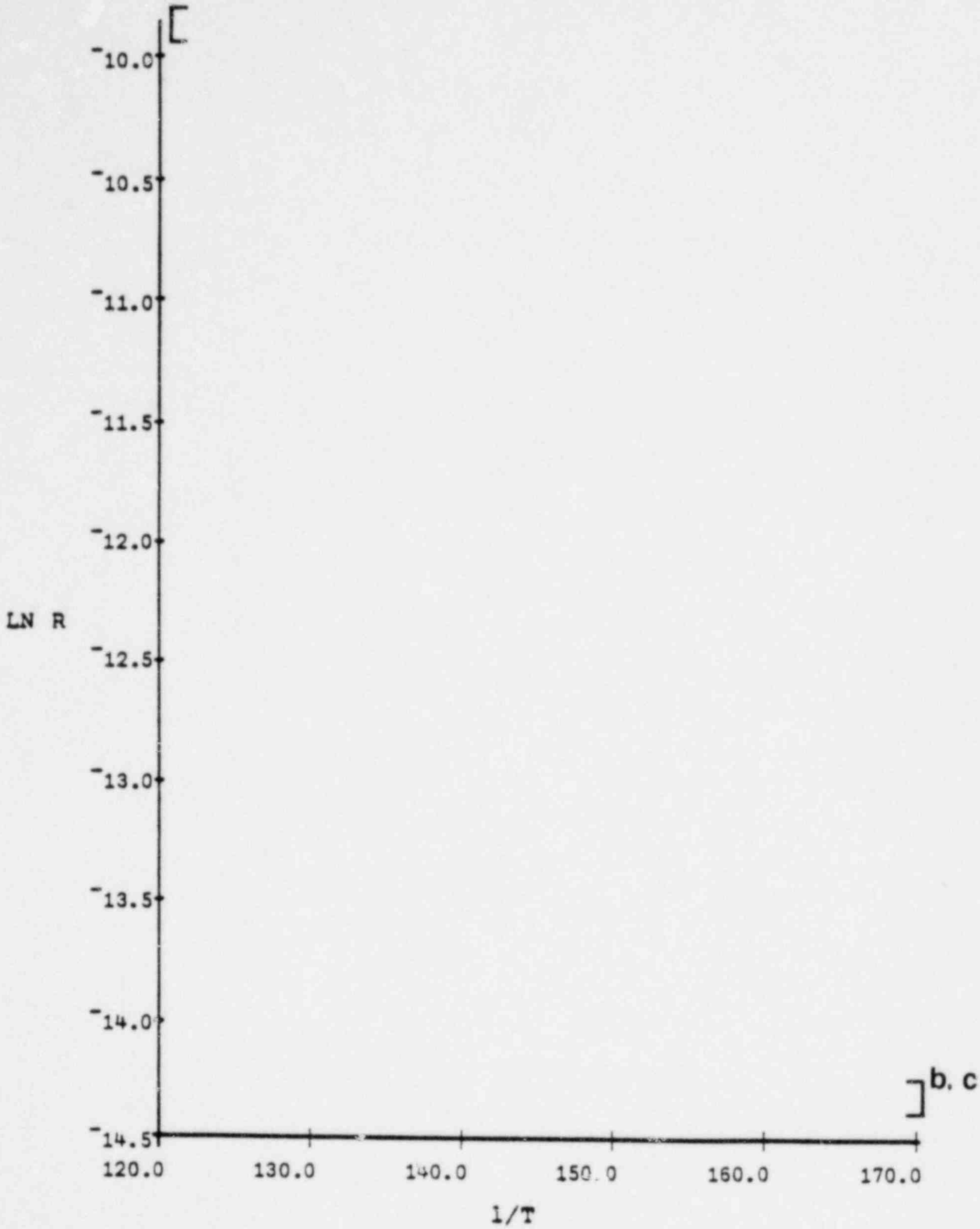

Figure 8

COMPARISON OF EARLY WESTINGHOUSE DATA (TABLE A1) FITTED TO MODEL 0 WITH PROPOSED MODEL FITTED TO LATER WESTINGHOUSE DATA

quality of fit has actually improved with the data augmentation and the parameter estimates have changed little. It is felt that this supports the stability and appropriateness of the model without requiring that the [ ]b,c assumption be physically justified.

Secondly, work reported recently indicates that the coefficient of the temperature term should be about 7000, this value coming from consideration of the activation energy for a water-steel surface reaction. All variations of the model and data base produced estimates of the temperature coefficient [ ]b,c

IV. MODELING OF CRITICAL CRACK SIZE

There are two types of cracks of concern: radial cracks emanating from the apex of a keyway and radial cracks emanating directly from the bore surface of the disc. The stress intensity at the tip of a keyway crack will be calculated by considering the keyway as [ ]^{b,c} The simplified formula used is not valid if the crack is too small compared to the radius of the keyway; we consider the formula valid only if the crack depth exceeds [ ]^{b,c}

The basic formula for critical crack size a_{cr} (in.) is

$$a_{cr} = \frac{Q}{1.21\,\pi} \left(\frac{K_{Ic}}{\sigma}\right)^2$$

where K_{Ic} is the relevant fracture toughness (KSI-IN $^{1/2}$), σ the tangential bore stress (KSI), and Q the flaw shape parameter. This must be modified slightly to allow a better incorporation of the variability in its several factors as follows:

$$a^{*}_{cr} = \frac{1}{1.21\,\pi} \left(\frac{K_{Ic}}{\sigma}\right)^2 \text{, the lower critical crack size (in.)}$$

and

$$a_{cr} = G\, a^{*}_{cr}$$

where G is a quantity called the flaw geometry factor and reflects [ ]^{b,c} near the crack tip.

A number of actual cracks have been examined for their shape. The observed flaw shapes have varied to produce values of the traditional flaw shape parameter from [ ]^{b,c} The effective toughness, in the presence of service induced cracks, has been observed to be as much as [ ]^{b,c} the value obtained in the presence of laboratory fatigue cracks; this increase in K_{Ic} would [ ]^{b,c}

the actual critical flaw size over its calculated value, presumably because of branching at the crack tip. Based on these two facts it was decided to take G as a uniformly distributed random variable on the range [ ]^{b,c} The [ ]^{b,c} was chosen to be conservative (the actual distribution form is, of course, unknown) since it makes the unfavorable tail probabilities as large as is reasonable. The range [ ]^{b,c} reflects the variability due to flaw shapes or due to crack branching [ ]^{b,c} By not claiming [ ]^{b,c} favorable flaw shape and branching, even though they [ ]^{b,c} further conservatism (underestimate of a_{cr}) has been introduced.

Supporting data indicate that K_{Ic} may vary by [ ]^{b,c} due to variability in the Charpy data and correlations. It is also estimated that each of the principal stress components (centrifugal modified for shrink fit and thermal) may vary by [ ]^{b,c} so conservatively a [ ]^{b,c} variation in σ was allowed.

Combining these estimates of variability a_{cr} can be represented by a random variable with mean

[ ]^{b,c}

where K_{Ic} and σ represent the calculated values of toughness and stress, and variance

[ ]^{b,c}

The distribution of a_{cr} was represented by a [ ]^{b,c} with mean m, variance v, and [ ]^{b,c} The lower [-

]^{b,c}

When the crack growth rate model that [
$]^{b,c}$ is used, it is necessary to treat critical crack depths for bore and keyway cracks [$]^{b,c}$ It has been observed that bore cracks have a [$]^{b,c}$ than do keyway cracks, and this manifests itself in the model through G, the flaw geometry factor. Instead of using a [
$]^{b,c}$ to represent G, the following are taken:

[$]^{b,c}$

[$]^{b,c}$

These ranges are consistent with experience to date, and adequately reflect the effect of crack branching.

For additional background information on crack growth rate modeling and critical crack size calculations, see Ref. (2).

V. RISK ASSESSMENT

A probabilistic risk assessment for a given turbine unit requires an estimate of p_i, the probability of failure of disc i under the conditions it sees in the turbine. The probability of turbine failure is then

$$P = 1 - \prod_i (1 - p_i)$$

where the product is taken over all discs in the turbine. The generation of the (p_i) for disc failure at normal running speed is discussed below:

For a given disc, the probability of failure (disc rupture) from a keyway or bore crack is broken into two parts, as

$$p_i = \Pr\text{ (a crack initiates in disc i) x}$$

$$\Pr\text{ (crack grows beyond critical size/initiation)}$$

More formally, let

q_i = Pr (a crack initiates in disc i)
$X_i(t)$ = crack depth in disc i after time t
Y_i = critical crack depth for disc i

Then

$$p_i = q_i \cdot \Pr\ (X_i(t) > Y_i)$$

For a given disc the following information is provided:

[

]b,c

estimated crack growth rate parameters, including $\hat{s}$

A computer program has been written to evaluate

$$Pr\ (X_i(t) > Y_i)$$

[

]b,c

The q_i are obtained from [ ]b,c
and are calculated for each [ ]b,c
Suppose that N Number [ ]b,c have
been inspected and a total of K have been found with one or more cracked keyways or bore cracks. Then we take

[

]b,c

for any Number [ ]b,c

The standard risk assessment takes six values of time, 1 year, 2 years, 3 years, 4 years, 5 years, 10 years and, for each, computes p_i for each disc and, from those,

$$P = 1 - \prod_i (1 - p_i)$$

If all p_i are very small, P is approximately given by

$$P \simeq \sum_i p_i$$

The estimation of disc rupture at design overspeed requires the inclusion of an additional factor for the probability of a control system failure that would lead to such overspeed. If load is unexpectedly shed while operating at or near full load, a failure of the Overspeed Protection Controller (OPC) would result in the turbine reaching design overspeed (120% of rated speed for most turbines, 128% to 132% for the others). Service years have been gathered on the use of the OPC. Using the fact that no OPC failure has ever been reported, upper 50% confidence bounds have been computed as estimates of the failure probability. These estimates are

[ ]b,c for turbine with EH controls
[ ]b,c for turbine with 300 lb. controls

The risk assessment proceeds as before, using the stress at design overspeed to calculate m. The final result is

$$P' = f \cdot [1 - \prod_i (1 - p_i)]$$

where P' = probability of disc rupture at design overspeed. Calculations are made for the same six intervals of time.

In both the calculation of P and P' two corrections must be made to m before the $Pr(X_i(t) > Yi)$ is computed. First m is reduced by [ ]b,c a step taken to allow for a possible inaccuracy in UT indications. Secondly, the density function is [

]^{b,c} This reflects the inclusion of the keyway in the depth of any crack; it is this feature that makes keyway cracks a greater hazard than bore cracks, given that they have equal initiation probabilities and equal growth rates. If either of those assumptions are abandoned in the future, it will be necessary to make a risk assessment for [

]^{b,c}

When a risk assessment is run on a turbine that has been modified by overbored keyways or is running with known cracks, simple adjustments to the program will accommodate these anomalies:

A. Overbored keyways. Simply [
]^{b,c} by the distance the new keyway extends into the disc instead of the [ ]^{b,c} used norm ly.

B. An existing crack in a keyway. Suppose that disc i had a known keyway crack of depth d when the turbine was returned to operation after inspection. The probability calculations are modified in two ways: [
]^{b,c}

C. An existing bore crack. Suppose that disc i has a known bore crack of depth d when the turbine was returned to operation after inspection. It is necessary to do two risk assessments and accept the one that yields the larger P. First, do a standard probability calculation for possible keyway cracks; in this the bore crack is ignored. Second, do a probability calculation in which the density of Y_i is not translated downward [
]^{b,c} The reason for the two calculations is that one cannot tell in advance which is worse - a known crack in the bore or a potential crack from a keyway.

Recently, the accumulation of additional crack data has allowed another refinement in the methodology just described. With a data base of 69 cracks (60 keyway and 9 bore), the following estimates were obtained for the means of ℓnr:

[

]^{b,c}

The risk assessment proceeds as before except that disc rupture probabilities are evaluated separately for keyway and bore cracks and then summed to obtain the probability of disc burst. The bore and keyway analyses differ in 3 respects:

[

]^{b,c}

Above (1) simply requires that the [ ]^{b,c} be separated into the bore and keyway components and the related [ ]^{b,c} The reason for the change in the distribution of G in (3) above is that bore cracks have consistently been found to have a [ ]^{b,c} than keyway cracks. The range for this [ ]^{b,c} is, as before, chosen to reflect the variability in the crack shape <u>or</u> the effect of branching at the crack tip, [ ]^{b,c}

Finally, in the risk assessment to use the crack growth model that distinguishes between bore and keyway cracks, it is necessary to modify the procedure described above as follows:

1. A separate risk assessment is done for bore and keyway cracking, leading to estimates P_b and P_k as the probabilities of disc rupture from bore cracking and keyway cracking respectively. Then $P = P_b + P_k$.

2. In the estimation of P_k, generate initiation probabilities from keyway cracking above. Also take [ ]b,c for generating the critical crack density.

3. In the estimation of P_b, generate initiation probabilities from bore cracking alone. Also take [ ]b,c for generating the critical crack density.

VI. TURBINE MISSILES

The methodology of the preceding sections allows the estimation of the probability of disc rupture in a given turbine. To estimate the probability of generating a turbine missile from that unit one must further account for the fact that not every disc can, upon rupturing, produce fragments of sufficient energy to perforate the turbine structure and exit the turbine housing. Energy calculations for disc fragments and resulting missile energies are done independently of this study and are discussed elsewhere[2].

If a particular disc is known to have insufficient energy to produce missiles after bursting, the program sets the crack initiation probability, q_i, equal to zero for that disc. In other words, no distinction is made between the case in which a disc bursts but is contained and the case in which no burst is possible, as far as evaluating the risk of missiles is concerned. Missile probabilities are generated for both running and design overspeed. Generally, the probability of missile generation is higher at running speed because of the low probability of ever seeing the design overspeed condition.

Prior to separating the keyway and bore crack growth rates, the probabilities for most units had been calculated considering only the keyways and the crack growth rate derived from the combined data base of 28 keyway cracks and 4 bore cracks. In order to determine whether these calculations should be redone considering both bore and keyways, calculations were repeated for three typical units. The comparisons of probabilities as a function of inspection intervals shows (Fig. 9-11) that the old calculations and new calculations differ by only a factor of about two or less. It is believed that this difference is insignificant and that no need exists to recalculate probabilities obtained by considering only the keyways. The reason for this insignificant effect is that the probabilities of crack initiation in the bore are relatively small.

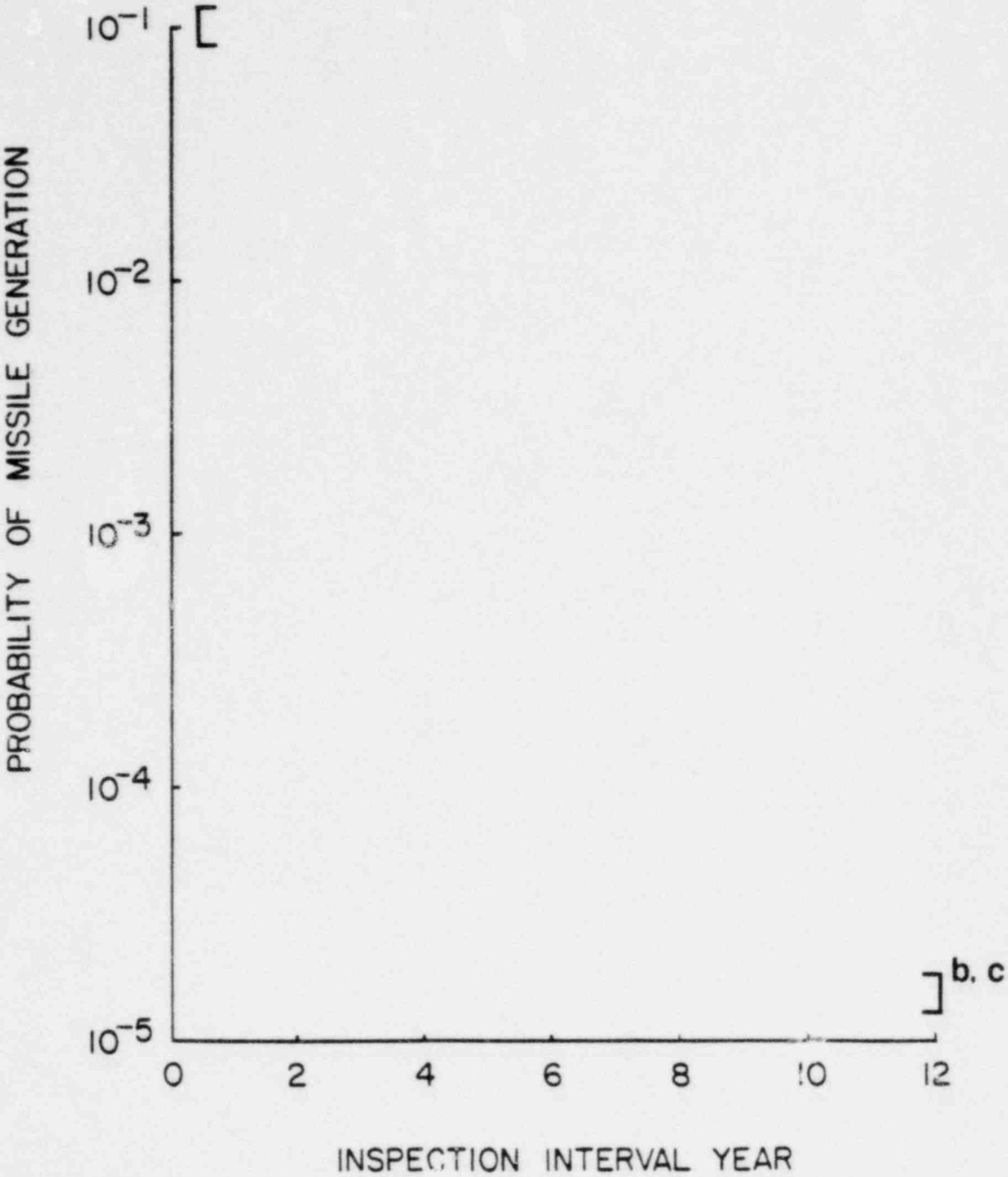

Figure 9

UNIT I

PROBABILITY OF MISSILE GENERATION AS A FUNCTION OF INSPECTION INTERVAL YEAR

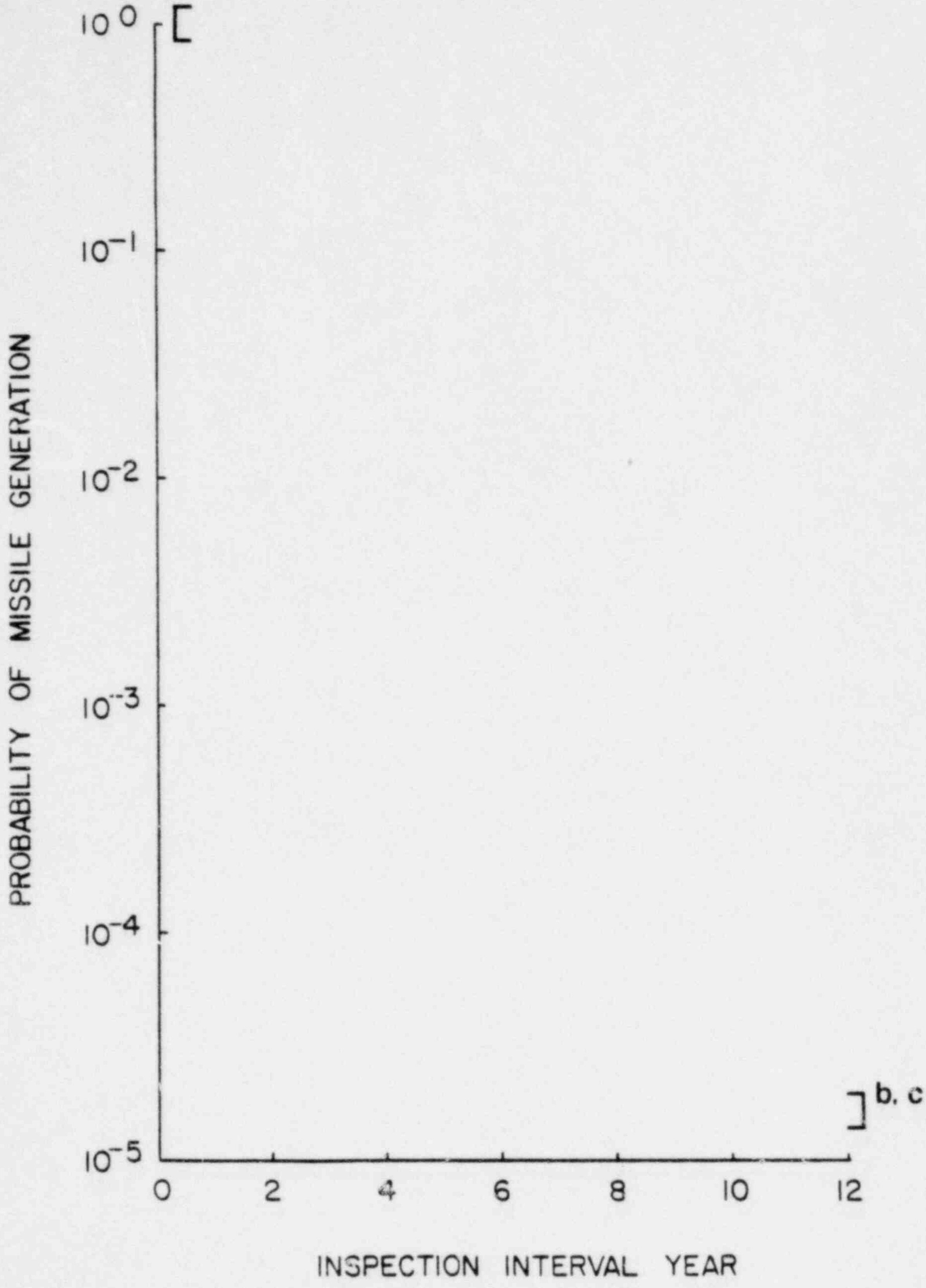

Figure 10

UNIT II

PROBABILITY OF MISSILE GENERATION AS A FUNCTION OF INSPECTION INTERVAL YEAR

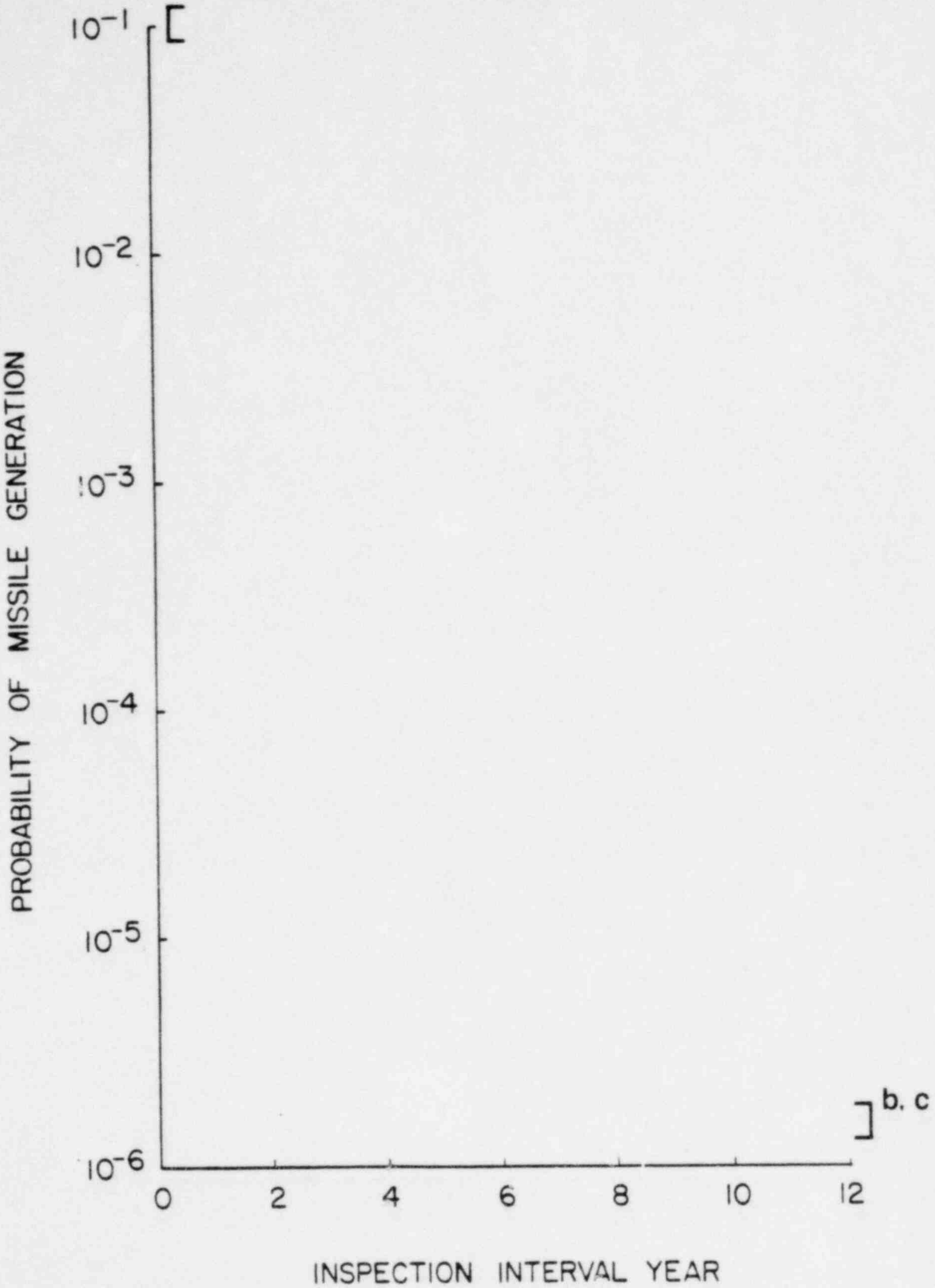

Figure 11

UNIT III

PROBABILITY OF MISSILE GENERATION AS A FUNCTION OF INSPECTION INTERVAL YEAR

VII. REFERENCES

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2. Missile Energy Analysis Methods for Nuclear Steam Turbines - Steam Turbine-Generator Division, Westinghouse Electric Corporation, May, 1981.

Table A1. Early Westinghouse Data

ID	[ ]b,c	Growth Rate (IN/HR) x 10^6
1	[	10.3
2		10.1
3		8.9
4		4.8
5		4.1
6		7.9
7		4.9
8		4.6
9		8.8
10		19.3
11		8.8
12		17.4
13		20.8
14		4.1
15		36.1
16		70.6
17		58.8
18		19.3
19		11.2
20		3.8
21		9.1
22		8.8
23		20.8
24		19.3
25		4.6
26		18.3
27		13.0
28		11.4
29		29.3
30		32.6
31		41.9
32	]b,c	42.0

Table A2. British Data

ID	[ ]b,c	Growth Rate (IN/HR) x 10^6
1	[	1.60
2		2.00
3		3.10
4		1.30
5		0.45
6		0.91
7		0.91
8		1.20
9		3.50
10		1.60
11		1.20
12		1.60
13		1.30
14		3.70
15		1.30
16		0.80
17		0.54
18		0.80
19		0.26
20		0.39
21		0.28
22		1.60
23		0.20
24		0.42
25		0.67
26		0.69
27		1.10
28		1.40
29	]b,c	0.33

Table A3. Later Westinghouse Data

ID	[ ]b,c	Time (HRS)	Crack Depth (IN)	Bore Cracks (b)
1	[	44139	0.057	b
2		44139	0.500	
3		64440	0.250	
4		60009	0.120	
5		42141	0.410	
6		42141	0.100	
7		42141	2.130	
8		42141	0.750	
9		42141	0.320	
10		42141	1.465	
11		42141	1.840	b
12		30032	0.126	
13		30032	0.378	
14		35662	0.580	
15		35662	0.395	
16		23040	0.126	
17		23040	0.126	
18		23040	0.345	
19		23040	0.315	
20		23040	0.347	
21		23040	0.378	
22		38760	0.095	
23		38760	0.236	
24		38760	0.126	
25		38760	0.113	
26		15447	0.290	
27		15447	0.180	
28		15447	0.360	
29		15447	0.300	
30		15447	0.250	
31		15447	0.200	
32		15447	0.190	
33		15447	0.150	
34		35088	0.300	
35		35088	0.250	
36		45960	0.500	
37		44282	0.120	
38		44282	0.180	
39		44282	0.529	
40		44282	0.913	
41		44282	0.913	
42		44282	0.283	
43		44282	0.126	
44		44282	0.283	
45	]b,c	14352	0.440	

Table A3. (Cont.)

46	[	14352	0.520	b
47		39672	0.120	
48		39672	1.220	b
49		38194	0.756	
50		38194	0.630	
51		38194	0.760	
52		38194	0.360	
53		38194	0.640	
54		16800	0.790	
55		16800	0.760	
56		16800	1.150	
57		16800	2.080	b
58		16800	0.630	b
59		16800	0.260	b
60		16800	0.470	
61		16800	0.350	
62		16800	0.110	
63		16800	0.400	b
64		16800	0.450	
65		16800	0.400	
66		16800	0.040	
67		16800	0.680	b
68		17040	0.200	
69	][b,c]	17040	0.360	