SAFETY EVALUATION REPORT

Criteria For Low Pressure Nuclear
Turbine Disc Inspection

Westinghouse has prepared a proprietary report covering their investigation and analysis of turbine disc cracking. This report includes a statistical analysis of all turbine disc cracks found to date and recommends criteria for scheduling disc inspections that provide a very low probability of disc failure prior to inspection.

We have evaluated each of the criteria presented in the report and are in agreement with either the Westinghouse position or with one of the positions in those cases where they suggest alternatives. These criteria and our evaluation of each is described below.

There are several major criteria involved in setting inspection schedules. Basically, the approach used is to make a conservative prediction of how fast a presumed or actual crack will grow and then schedule an inspection prior to the time the crack grows large enough to be of concern. Analytic components of this approach are:

A. Crack Growth Rate

B. Critical Crack Size

C. Fraction of Critical Crack Size Allowed.

The Westinghouse criterion for establishing each of these factors and our evaluation is discussed below.

A. Crack Growth Rate

Westinghouse has performed statistical studies using the field data on crack sizes and shapes as related to temperature of operation, location (bore or keyway), material strength, and environment. They have selected a conservative

upper bound basis and developed equations that define a conservative crack growth rate for each disc. We have reviewed the Westinghouse methodology and find the growth-rate equations to be acceptable.

B. Critical Crack Size

Westinghouse has used the usual LEFM model to calculate critical crack size, taking into consideration effects of crack shapes expected in different locations (bore or keyway). The fracture toughness values used in the calculations are determined from actual charpy V tests on each disc, using the common Rolf-Novak correlation. Westinghouse also presented test results, obtained from both fracture mechanics specimens and a spin test, to show that this correlation yields over-conservatively low values of the toughness related to actual disc cracks because the cracks are irregular and branched. We therefore prefer the alternative proposed; i.e., to increase the estimate of fracture toughness derived from the Rolf-Novak expression by 20% to reflect the effect of the irregular nature of actual service-induced disc cracks. This 20% increase is still very conservative, as all of the test data show even larger increases.

C. Fraction of Critical Size Allowed

Westinghouse has proposed two methods for applying this factor. One involves a very conservative critical crack size calculation using the Rolf-Novak value of toughness, and then permitting operation until a crack grows to a predicted maximum of 75% of the critical size. An alternative approach is to use the more realistic (but still conservative) augmented toughness value (discussed in B above) that gives a larger and more realistic crack

size and then permitting operation until a crack grows to a predicted maximum of 50% of critical crack size. We prefer this latter approach. A growth limit of 50% of critical crack size has been the NRC criterion; consequently, an acceptable inspection schedule criteria is maintained as follows:

1) New discs should be inspected at the first refueling outage, or before any postulated crack would grow to more than 1/2 the critical depth.

2) Discs previously inspected and found to be free of cracks or that have been repaired to eliminate all indications should be reinspected using the same criterion as for new discs, calculating crack growth from the time of the last inspection.

3) Discs operating with known and measured cracks should be reinspected before 1/2 the time calculated for any crack to grow to 1/2 the critical crack depth.

4) These inspection schedules may be varied to coincide with scheduled outages. Westinghouse recommendations in this regard should be followed.

Summary and Conclusions

A. We agree that the Westinghouse crack growth rate equations for bore and keyway cracks are acceptable.

B. We agree with the alternative Westinghouse critical crack size calculational method, using a value of fracture toughness increase of 20% above the Rolf-Novak value.

C. We will retain a criterion of relating allowable running time before inspections to the time to reach 1/2 of the critical crack depth.

D. The NRC staff will no longer monitor each turbine inspection except through the normal activities of the Office of Inspection and Enforcement.