SAFETY GUIDE 14—REACTOR COOLANT PUMP FLYWHEEL INTEGRITY

A. Introduction

General Design Criterion 4 requires that structures, systems, and components of nuclear power plants important to safety be protected against the effects of missiles that might result from equipment failures. This guide describes an acceptable method of implementing this requirement with regard to the flywheels of reactor coolant pump motors in water cooled power reactors.

B. Discussion

The flywheels on reactor coolant pump motors provide inertia to assure a slow decrease in coolant flow in order to prevent fuel damage as a result of a loss of power to the pump motors. Because they have large masses and rotate at speeds of 900 rpm or 1200 rpm during normal reactor operation, a loss of flywheel integrity could result in high energy missiles and excessive vibration of the reactor coolant pump assembly. The safety consequences could be significant because of possible damage to the reactor coolant system, the containment, or the engineered safety features.

Reactor coolant pump flywheels are of a simple geometric shape, and normally are made of a ductile material. Their quality can be closely controlled, and their service conditions are not severe; therefore, the use of suitable material, and adequate design and inservice inspection can provide a sufficiently small probability of a flywheel failure that the consequences of failure need not be protected against.

C. Regulatory Position

1. The flywheel material should be produced by a process that minimizes flaws in the material and improves its fracture toughness properties, such as the vacuum-melt and degassing process. The material should be examined and tested to meet the following criteria:
   a. The nil-ductility transition (NDT) temperature of the flywheel material, as obtained from the dropweight tests (DWT) performed in accordance with the specification ASTM E-208, should be no higher than 10° F.
   b. The Charpy V-notch (C_V) upper-shelf energy level in the "weak" direction (WR orientation in plates) of the flywheel material should be at least 50 ft-lb. A minimum of three C_V specimens should be tested from each plate or forging, in accordance with the specification ASTM A-370.
   c. The minimum fracture toughness of the material at the normal operating temperature of the flywheel should be equivalent to a dynamic stress intensity factor (K_{Ic} dynamic) of at least 100 ksi in . Compliance can be demonstrated by any of the following:
      (1) Testing of the actual material of the flywheel to establish the K_{Ic} (dynamic) value at the normal operating temperature.
      (2) Testing of the actual material of the flywheel by means of C_V specimens oriented with respect to the "weak" direction (WR orientation in plates). The C_V impact tests should be conducted to define the C_V test curve up to at least 50 ft-lb fracture energy value. The C_V curve should then be adjusted for the NDT temperature and size effect, as described in the proposed AEC "Fracture Toughness Requirements", 10 CFR Part 50 § 50.55a, Appendix G, Section III B. The adjusted fracture energy, as read from the adjusted C_V curve at the normal operating temperature of the flywheel, should be demonstrated to be equivalent to a K_{Ic} (dynamic) value of at least 100 ksi in by using appropriate correlation data. The test data and the correlations used should be submitted to the regulatory staff for review.
      (3) Use of a lower bound fracture toughness curve obtained from tests on the same type of material. Such

a curve should be translated along the temperature coordinate until the K_{Ic} (dynamic) value of 45 ksi in is indicated at the NDT temperature of the material, as obtained from the DWT tests. The proposed lower bound fracture toughness curve should be submitted to the regulatory staff for review.

d. Each finished flywheel should be subjected to a 100% volumetric ultrasonic examination using procedures and acceptance critiera equivalent to those specified for Class 1 vessels in the ASME Boiler and Pressure Vessel Code, Section III-Nuclear Power Plant Components.

e. If the flywheel is flame cut from a plate or forging, at least 1/2 inch of stock should be left on the outer and bore radii for machining to final dimensions.

f. Finish machined bores, keyways and drilled holes should be subjected to magnetic particle or liquid penetrant examination.

2. The flywheel should be designed to withstand normal conditions, anticipated transients, the design basis loss of coolant accident, and the design basis earthquake without loss of structural integrity. The design of the pump flywheel should meet the following criteria:

a. The combined primary stresses at the normal operating speed, due to centrifugal forces and the interference fit of the wheel on the shaft, should not exceed 1/3 of the minimum specified yield strength, or 1/3 of the measured yield strength in the weak direction of the material if appropriate tensile tests have been performed on the actual material of the flywheel.

b. The design overspeed of a flywheel should be at least 10 percent above the highest anticipated overspeed. The anticipated overspeed should include consideration of the maximum rotational speed of the flywheel if a break occurs in the reactor coolant piping in either the suction or discharge side of the pump. The basis for the assumed design overspeed should be submitted to the regulatory staff for review.

c. The combined primary stresses at the design overspeed, due to centrifugal forces and the interference fit, should not exceed 2/3 of the minimum specified yield strength, or 2/3 of the measured yield strength in the weak direction if appropriate tensile tests have been performed on the actual material of the flywheel.

d. The shaft and the bearings supporting the flywheel should be able to withstand any combination of the normal operating loads, anticipated transients, the design basis loss of coolant accident and the design basis earthquake loads.

3. Each flywheel assembly should be tested at the design overspeed of the flywheel.

4. The inservice inspection program for each flywheel should include the following:

a. An in-place ultrasonic volumetric examination of the areas of higher stress concentration at the bore and keyway at approximately 3 year intervals, during the refueling or maintenance shutdown coinciding with the inservice inspection schedule as required by the ASME Boiler and Pressure Vessel Code Section XI.

b. A surface examination of all exposed surfaces and complete ultrasonic volumetric examination at approximately 10 year intervals, during the plant shutdown coinciding with the inservice inspection schedule as required by the ASME Boiler and Pressure Vessel Code Section XI. Removal of the flywheel is not required to perform these examinations.

c. Examination procedure, and acceptance criteria in conformance with the requirements specified in C.1.d.