William J. Cahill, Jr.
Vice President

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March 28, 1980

Re: Indian Point Unit No. 2
Docket No. 50-247

Mr. Darrell G. Eisenhut
Division of Operating Reactors
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Eisenhut:

In response to your February 25, 1980 letter regarding turbine disc integrity in operating Westinghouse nuclear low pressure turbines, the "generic" information which you requested was transmitted by letter dated March 14, 1980 from J. M. Schmerling, Westinghouse Disc Integrity Program Manager to Darrell G. Eisenhut, NRC. This "generic" information was prepared by Westinghouse and presented by Westinghouse to Con Edison and other licensees using Westinghouse Turbines at the March 12-13, 1980 meeting of the Turbine Disc Integrity Task Force. The Task Force reviewed the Westinghouse information and approved the consensus responses to each of your generic questions. Attachment 1 is the generic information prepared by Westinghouse and approved by the Task Force.

Additional comments regarding the generic information requested is presented in Attachment 2.

We understand that this information accurately describes Westinghouse's program for design, fabrication, quality control and inspection of low pressure turbines, and Westinghouse's theories about the possible effects of stress and chemicals, if any, on disc cracking. We are confident that the recent turbine inspection of the Indian Point Unit No. 2 LP turbines and the corrective actions taken provide ample assurance of safe turbine operation. As a member of the Task Force, Con Edison will continue to evaluate turbine disc cracking.

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Should you or your staff have any questions, please contact us.

Very truly yours,

William J. Cahill, Jr.

William J. Cahill, Jr.
Vice President

attach.

cc: Mr. Boyce H. Grier, Director
Office of Inspection and Enforcement
U. S. Nuclear Regulatory Commission
Region I
631 Park Avenue
King of Prussia, Pennsylvania 19406

U. S. Nuclear Regulatory Commission
Office of Inspection and Enforcement
Division of Reactor Operations Inspection
Washington, D. C. 20555

Mr. T. Rebelowski, Resident Inspector
U. S. Nuclear Regulatory Commission
P. O. Box 38
Buchanan, New York 10511

Generic Information Prepared by Westinghouse and Approved by the Turbine Disc Integrity Task Force

GENERIC QUESTIONS - TO BE COMPLETED IN 20 DAYS

I. Describe what quality control and inspection procedures are used for the disc bore and keyways.

ANSWER:

Chemical analyses are made from each heat of steel. During manufacture mechanical tests are made from the disc bore region. These include tensile and Charpy v-notch impact tests. Each disc bore region is subject to ultrasonic and magnetic particle inspections. On later units, the disc keyways are inspected after machining, using liquid penetrant techniques.

For in-service inspection two ultrasonic techniques, namely the tangential aim and radial aim scans, have been developed to detect and determine the depth of disc keyway and bore cracks. The in-service ultrasonic inspection does not require unshrinking discs from the rotor.

The tangential aim scan is used to locate cracks. The technique requires sound energy to be coupled and directed tangentially towards the keyway from a precalculated position on the hub. This is accomplished by means of a compound angled plexigalass wedge. The wedge is machined to provide a contoured face which makes complete contact with the disc hub, while aiming the sound energy at the disc bore/keyway. Crack indications occuring in the vicinity of the keyway apex and at the bore will reflect the sound energy. The tangential aim scan is performed both in the clockwise and counterclockwise directions to permit locating crack indications with respect to the keyway apex.

A radial aim technique is used to confirm cracks located by the tangential aim scan. The technique is also used to determine the crack depth by comparing the time lapsed in obtaining a ultrasonic reflection from the crack with the time to obtain a reflection from the keyway or bore.

II. Provide details of the Westinghouse repair/replacement procedures for faulty discs.

ANSWER:

When cracks are found by an inservice inspection their severity is evaluated by means of an allowable life calculation. The allowable life is relatable to the time required for the crack to grow to critical size for fracture. Based upon the results of this calculation, the following actions may be taken:

A. If the affected disc has a calculated allowable life greater than zero a reinspection of the disc is recommended at approximately one-half of the allowable life.

B. If the affected disc has an allowable life less than or close to zero, one or more of the following may be employed:

1. The affected disc is removed by "machining", and is replaced with a collar and pressure drop baffle.

2. Upstream keyways may be drilled oversize to remove cracks after the downstream disc is removed.

3. The affected disc may be replaced . This requires unstacking and restacking several discs on the rotor.

III.A. What immediate and long term actions are being taken by Westinghouse to minimize future stress corrosion problems with turbine discs?

ANSWER:

The following short range actions are being taken:

1. Those discs which have been observed to be most susceptible to stress corrosion cracking are being redesigned. The new designs will achieve lower bore stresses and utilize lower yield strength material. These changes will increase the margin against stress corrosion cracking.

2. Designs that will eliminate spacers and bore keyways are being explored.

The following long range solutions are being examined:

1. Bore Heating - Ways and means to keep the disc keyways dry are being explored.

2. Sealing - Ways of sealing the hub and bore from the steam environment are being studied.

3. Coatings - Another method of sealing is to apply a protective coating. We are continuing to experiment with different coatings, but extensive work is still required to develop processes for their application and to demonstrate their benefits.

4. Partial Integral Rotors - Since one piece forgings cannot be procured at this time, we are exploring the possibilities of partial integral rotors where the first two or three discs are made a part of the shaft. Only the last few discs will have to be shrunk on.

5. Integral Rotors - A welded rotor design is being evaluated as a means to produce an integral rotor.

III.B. What actions are being recommended to utilities to minimize stress corrosion cracking?

ANSWER:

Westinghouse has developed recommended limits for steam purity. When these limits are exceeded corrective actions should be taken.

IV.A. Identify the impurities known to cause cracking in the low pressure turbines, and their sources.

ANSWER:

The main chemical species known to cause or contribute to stress corrosion of steam turbine materials in steam environments are:

Sodium hydroxide
Sodium chloride
Sodium sulfate
Oxygen

The sources of these impurities are under study.

IV.B. Discuss the relationship between steam generator chemistry and steam chemistry relative to the introduction of corrosive impurities into the turbine, including phosphate, AVT, and BWR chemistry.

ANSWER:

Analyses of material within LP disc cracks from PWR units shows the presence of Na, K, Ca, Si, Cl, OH, and C together with Fe, Co, V, Al and Ni ions.

In PWR units with recirculating steam generators, the total carry-over of non-volatile dissolved solids, such as NaOH and NaCl depends mainly on the mechanical carry-over. However, where ammonia is used for pH control such as with the all volatile water treatment, carry-over of anions may increase due to a formation of volatile ammonium salts.

In the PWR units with once-through steam generators, the high pressure turbine steam purity is similar to the feedwater purity. Most impurities entering the steam generator are carried directly into the turbine.

The published information on BWR systems indicates the concentration of oxygen in the steam is in the range of 10 to 30 ppm. With respect to other elements, however, it is likely that high steam purity standards will be maintained for control of radioactivity. To achieve this, BWR reactor water is generally double demineralized.

IV.C. Discuss the mechanism of deposition of these impurities that can lead to their concentration in certain areas of keyways and bores.

ANSWER:

The impurities from steam can get into shrunk-on disc bores and keyways in several possible ways:

1. After deposition in the steam path during operation, corrodents can wash into disc keyways during layup due to moisture condensation.

2. In the wet steam regions, the moisture can dry on hot metal surfaces.

3. As long as the disc retains its shrink fit we are not aware of any mechanism which can concentrate impurities on the bore.

V. What role does the refluxing action in the steam separation portion of the steam generator have on scrubbing corrosive impurities from the steam?

ANSWER:

Two modes of transport of corrosive impurities from the steam generator to the turbine are mechanical entrainment and volatility.

The non-volatile chemical species are transported by mechanical entrainment which is normally expected to be small.

The steam generator scrubbing equipment has minimum effectiveness in preventing the transport of volatile impurities, such as ammonium chloride, to the turbine. The concentration of volatile impurities in turbine steam is determined by their concentration in the steam generator bulk water and their specific volatility coefficient which differs with each species.

VI. To what extent can the buildup of corrosive impurities in the LP turbine be alleviated? What would be the effects of the following action:

A. Pumping moisture separator condensate to condenser?

ANSWER:

Pumping moisture separator condensate to the condenser would be beneficial in units with condensate polishing . In units without condensate polishing, there will be no effect.

B. Periodically moving (the) point of condensation to prevent locallized buildup of corrosive impurities.

ANSWER:

Conceptually, dilution of contaminants by increased levels of moisture and their subsequent transport to the condensate system could substantially reduce the buildup of impurities. However, the effectiveness of this technique and the means for successful control of the local environment of particular turbine parts must be developed and experimentally verified.

Several of the less volatile active corrodants, such as sodium chloride and sodium sulphate precipitate as concentrated liquid solutions in a region slightly above the equilibrium saturated vapor line of pure water. This region occurs locally within a given stage during normal operation and migrates toward the turbine exhaust as load reduces. Control of the zone can be affected by changes in load and moisture separator reheater (MSR) outlet temperature.

VII Describe fabrication and heat treatment sequence for discs, including thermal exposure during shrinking operation.

ANSWER:

The typical sequence for producing a disc forging includes the following operations, not all of which are necessarily applicable to any given disc.

A. Melting and casting of Ingot. Most discs manufactured since the early 1960's are made using basic electric furnace steel which is vacuum stream degassed or vacuum-carbon-deoxidized.

B. Forging The ingot is heated to forging temperature, block forged and cut into 2 to 4 pieces from which the individual disc forgings are made.

C. Preliminary Heat Treatment This step consists of austenitizing and tempering the forging to promote structure uniformity, grain refinement, and good machineability.

D. Preliminary Machining The forging is machined to the disc contour.

E. Preliminary Ultrasonic Inspection Typically the supplier makes a partial ultrasonic inspection of the forging to assure that the quality warrants continued manufacturing effort.

F. Heat Treatment for Properties The forging is austenitized and tempered at appropriate temperatures to achieve the desired mechanical properties. Cooling from the austenitizing treatment is achieved by water quenching. After tempering the forging is cooled in the furnace at a controlled rate.

G. Mechanical Properties Tensile properties are tested to determine if the required strength level has been achieved. Since about 1960, Charpy v-notch impact tests are made on each forging.

H. NDE Inspection The forgings are rough machined to the Westinghouse drawing requirements and an ultrasonic inspection of the flat surfaces of the hub, web, and rim of the disc is performed.

I. Stress Relief This treatment is required when a significant amount of metal is machined off of the forging after it has been heat treated for properties. The stress relief treatment is 50-100° F below the tempering temperature. Cooling is accomplished by a controlled furnace cool.

J. Mechanical Properties When a stress relief is used, the mechanical properties are tested after the stress relief treatment. (Reference Step G)

K. Dimensional Check The forging is machined to a clean surface, the balance of test prolongations are removed, and the dimensions checked. The forging is then shipped to Westinghouse for final machining and assembly onto the rotor.

L. NDE Inspection A fluorescent magnetic particle inspection is performed after finish machining (This inspection was not applied during the early 1970's.)

M. Shrinking Discs On the Rotor Shaft The assembly operation consists of four parts; namely, preparation of the shaft, preparation of the discs, assembly of the rotor and pinning of the discs to the shaft.

1. Preparation of the Shaft After final shaft machining and inspections are complete the shaft is cleaned with degreaser and dry lint-free cloths, and is mounted in a vertical position. The surface of the rotor that will be in contact with the disc is coated with lubricant.

2. Preparation of the Disc. After final machining and inspections are complete the disc surfaces and blades are cleaned to remove foreign material. Prior to heating for assembly the disc bore diameter is measured and compared to that of the drawing to assure a correct shrink fit. The disc is placed on an assembly fixture, leveled and loaded into a furnace which is at $300^{\circ}F$ or less.

3. Assembly of the Rotor The disc is slowly heated to the required shrink temperature between 600° and 750° F. When the shrink temperature is reached the disc is removed from the furnace and lowered onto the shaft.

4. Axial Aligning and Pinning of Discs. Liners are placed at the exhaust face of each disc to assure the proper axial location. The keyways are then drilled. Since the early 1970's, a penetrant inspection is performed in the keyway prior to inserting the key.

VIII Discuss the effect of any local residual stresses on the cracking mechanism.

ANSWER:

Depending on their nature and magnitude, residual surface stresses can have an effect on crack initiation. Proper control exercised in the selection of machining parameters results in compressive stresses which are usually beneficial. At the apex of the keyway, the residual stresses may be influenced by local yielding as a result of the stress concentrating action of the keyway.

Con Edison Supplement to the Generic Responses

III B. What actions are being recommended to utilities to minimize steam corrosion cracking?

Answer

Westinghouse has developed recommended limits for turbine steam purity. Steam purity of PWR's is well within these limits because the limits for chemical constituents in recirculating steam generator water have been progressively reduced over the years. Now the recommended chemical concentrations in steam generator water are so low that the mechanical carryover of $\leq$ 0.25% results in minimal concentration in steam. The steam generator water limits should be strictly observed.

IV B. Discuss the relationship between steam generator chemistry and steam chemistry relative to the introduction of corrosive impurities into the turbine, including phosphate, AVT, and BWR chemistry.

Answer (insert as para. 2)

At the present time there is no known correlation between water chemistry and cracks in the turbine discs. "Plain stressed samples of disc steel can crack by stress corrosion in normal power station wet steam. No chemical concentration mechanism need be invoked." (Ref. J. M. Hodge and I. L. Mogford", "UK Experience of Stress Corrosion Cracking in Steam Turbine Disc", Procedures of the Institution of Mechanical Engineers, Vol 193, No. 11, p. 93, 1979).

VI. To what extent can the buildup of corrosive impurities in the L.P. turbine be alleviated? What would be the effects of the following action:

A. Pumping moisture separator condensate to condenser?

Answer Pumping moisture separator condensate to the condenser in units with condensate polishing would probably permit meeting steam generator water purity limits with less continuous blowdown. Units without condensate polishing would still be required to maintain the same continuous blowdown as required with forward pumping.