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U. S. Nuclear Regulatory Commission
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Subject: Docket No. 50-361
Voluntary Report
Licensee Event Report No. 95-003
San Onofre Nuclear Generating Station, Unit 2

During the Unit 2 Cycle 8 refueling outage, Edison inspected the low pressure turbine and discovered some cracking in the rotor discs. This voluntary report discusses this finding and the methods used to repair the turbine. Neither the health nor the safety of plant personnel or the public was affected by this occurrence.

If you require any additional information, please so advise.

Sincerely,

R.W. Krieger for R. Krieger

Enclosure: LER No. 95-003

cc: L. J. Callan, Regional Administrator, USNRC Region IV
A. B. Beach, Director, Division of Reactor Projects, NRC Region IV
K. E. Perkins, Jr., Director, USNRC Region IV Walnut Creek Field Office
J. Sloan, USNRC Senior Resident Inspector, Units 2 & 3
M. B. Fields, NRC Project Manager, San Onofre Units 2 & 3
Institute of Nuclear Power Operations (INPO)

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LICENSEE EVENT REPORT (LER)

Facility Name (1)	Docket Number (2)	Page (3)
SAN ONOFRE NUCLEAR GENERATING STATION, UNIT 2	0 5 0 0 0 3 6 1	1 of 0 7

Title (4)

UNIT 2 LOW PRESSURE TURBINE ROTOR CRACKING

EVENT DATE (5)			LER NUMBER (6)			REPORT DATE (7)			OTHER FACILITIES INVOLVED (8)	
Month	Day	Year	Year	Sequential Number	Revision Number	Month	Day	Year	Facility Names	Docket Number(s)
0 2	2 5	9 5	9 5	0 0 3	0 0	0 6	2 3	9 5	NONE	

OPERATING MODE (9): 6

POWER LEVEL (10): 0 0 0

THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10CFR (Check one or more of the following) (11)

___ 20.402(b)	___ 20.405(c)	___ 50.73(a)(2)(iv)	___ 73.71(b)
___ 20.405(a)(1)(i)	___ 50.36(c)(1)	___ 50.73(a)(2)(v)	___ 73.71(c)
___ 20.405(a)(1)(ii)	___ 50.36(c)(2)	___ 50.73(a)(2)(vii)	X Other (Specify in Abstract below and in text)
___ 20.405(a)(1)(iii)	___ 50.73(a)(2)(i)	___ 50.73(a)(2)(viii)(A)	
___ 20.405(a)(1)(iv)	___ 50.73(a)(2)(ii)	___ 50.73(a)(2)(viii)(B)	
___ 20.405(a)(1)(v)	___ 50.73(a)(2)(iii)	___ 50.73(a)(2)(x)	

VOLUNTARY REPORT

LICENSEE CONTACT FOR THIS LER (12)

Name	TELEPHONE NUMBER
R. W. Krieger, Vice President, Nuclear Generation	AREA CODE 7 1 4 3 6 8 - 6 2 5 5

COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT (13)

CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS	CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS

SUPPLEMENTAL REPORT EXPECTED (14)

___ Yes (If yes, complete EXPECTED SUBMISSION DATE)

X NO

Expected Submission Date (15): Month ___ Day ___ Year ___

ABSTRACT (Limit to 1400 spaces, i.e., approximately fifteen single-space typewritten lines) (16)

In February 1995, with Unit 2 in Mode 6 during a refueling outage, Edison performed nondestructive examination of all stages of the Unit 2 Low Pressure (LP) turbine. The extensive examination was performed in response to stress corrosion cracking (SCC) found recently in other similar General Electric Company (GEC) turbines. The inspection included the disc rim blade attachment area, disc rim closing blade locking pin holes, and the steam balance holes. Cracking was found in each of these areas. Edison removed the cracks by excavation (milling) and/or machining. Additionally, all affected surfaces were shot peened.

Edison performed a structural and fracture mechanics evaluation of the stage 4 discs. This evaluation included several finite element models stress analyses and confirmed that the discs, as repaired, will operate without failure through Cycle 8 (Edison plans to develop a reinspection plan for the LP turbine to be implemented during future refueling outages). GEC, the turbine vendor, independently reviewed and concurred with the analysis results and the adequacy of the repair work performed. Therefore, Edison considers the safety significance of the turbine disc cracking to be minimal.

Edison is providing this voluntary report due to NRC and industry interest.

Plant: San Onofre Nuclear Generating Station, Unit 2
Reactor Vendor: Combustion Engineering
Event Date: February 25, 1995
Mode: Unit 2, Mode 6, Refueling Outage in Progress

BACKGROUND INFORMATION:

Low Pressure Turbines

San Onofre Units 2 and 3 have steam turbines manufactured by General Electric Company (GEC, England). The low pressure (LP) portion of the turbine [TA] [TRB] has three double flow rotors (LP1, LP2, and LP3). Each of the rotors consists of a spindle with six discs forming eight blade stages in both front and rear flows of the rotor. Both the spindle and discs of stages 1-6 are made of nickel-chrome-molybdenum-vanadium (NiCrMoV) steel. The built up rotor is assembled by joining the turbine spindle and discs together. The manufacturer: 1) expands the rotor discs by heating; 2) "shrinks" the spindle by cooling it with liquid nitrogen; and 3) slides the discs onto the spindle. This process is called "shrink-fitting." At the time of the Unit 2 Cycle 8 refueling outage, the Unit 2 LP rotors had been operated for approximately 77,000 hours. The Unit 3 LP rotors currently have been operated for approximately 77,000 hours and a refueling outage for Unit 3 is scheduled to begin in July 1995.

DESCRIPTION OF EVENT:

In February 1995, with Unit 2 in Mode 6 during a refueling outage, Edison performed nondestructive examination of all stages of the Unit 2 LP turbine. The extensive examination was performed in response to stress corrosion cracking (SCC) found recently in other similar GEC turbines. (See additional information section below.) The inspection included the disc rim blade attachment area, disc rim closing blade locking pin holes, and the steam balance holes (see attached figures). This inspection identified cracks primarily in the following areas:

Disc Rim Blade Attachment Area

Cracking was discovered in some of the stage 4 discs of LP1, LP2, and LP3 in the disc rim blade attachment area. The cracks extended in the tangential direction of the disc. In addition, some very minor cracks were identified in the stage 3 blade attachment area.

Closing Blade Locking Pin Holes

The closing blade on the LP turbine is attached to the stage 1-6 discs by a set of locking pins inserted through the base of the blade (blade root) and the disc rim parallel to the axis of the rotor. Cracking was found in the closing blade locking pin hole area on the LP3 stage 4 front disc. Cracks were found extending between the pin holes, and from the outermost (top) hole to the rim of the disc. Cracks were also found extending from the innermost (bottom) hole in the radial direction toward the disc hub. In addition, minor cracks were identified in the pin holes on other LP rotor stage 4 discs.

Steam Balance Holes

Each of the stage 4 discs has 17 equally-spaced steam balance holes. Cracks were found emanating from some of the steam balance holes in the stage 4 discs extending radially toward the disc rim and hub. A larger number of cracks were found on the discs in LP1. In addition, less significant cracking was identified in some of the stage 5 steam balance holes.

The Unit 2 & 3 LP turbines are nonsafety-related. The discovery of the cracks discussed above did not affect safe operation of the plant and did not meet the reporting criteria of 10 CFR 50.72 or 50.73; however, Edison is submitting this voluntary report due to NRC and industry interest in this issue.

CAUSE

Edison determined the likely cause of the Unit 2 LP turbine cracking to be SCC; however, the formal root cause analysis has not been issued. The cracks were primarily centered around higher stress locations in the stage 4 discs. The fourth stage is the first stage where the quality of the steam is below the Wilson line (the point at which superheated steam becomes saturated steam). The cracks appear to be typical of SCC found in turbines manufactured with the "shrink-fit" process as evidenced by industry experience. Detailed analysis of the fracture surface at the closing blade area of one disc revealed intergranular branching SCC. Surface analysis of the steam balance hole cracking revealed branching cracking associated with pitting typical of SCC.

CORRECTIVE ACTIONS

As detailed below, Edison removed the cracks in the LP turbine by excavation (milling) and/or machining. Additionally, all affected surfaces were shot peened. Shot peening is a cold working process in which the surface of a part is bombarded with small spherical steel media called shot. Benefits obtained by shot peening are the result of the effect of the compressive stress and the cold working induced. Compressive stresses are beneficial in increasing the resistance to fatigue failures, corrosion fatigue, and SCC.

Disc Rim Blade Attachment Area Repairs

All cracks found in the disc rim blade attachment area were removed by excavation. The surface material was removed until MT examination confirmed the cracks had been completely removed. After repairs, all root surface areas were shot peened. Crosskeys (see attached figure) were used to attach adjacent blades at some locations to allow some blade load to be shared by adjacent blades.

Closing Blade Pin Hole Repairs

The significant cracks in the disc rim closing blade pin holes were removed by excavation followed by shot peening. The disc rim pin holes were also enlarged to eliminate interference between the mating pin and disc rim pin hole surface. In addition, crosskeys were added in the blade root of the locking blade and two adjacent blades (total of four pins interconnecting five blades). This was done to transfer the load created by the locking blade to the adjacent blades. Thus, the disc rim pin hole no longer carries the loads imposed by the locking blade.

Steam Balance Hole Repairs

Cracks in steam balance holes were removed by excavation and/or machining. In most cases, cracks were first removed by local milling until they were completely excavated as indicated by MT examination. The holes were then machined to circular shape for the least stressed configuration. When cracks were shallow and did not extend the entire width of the disc, a combination of machining and/or excavation was used to remove these cracks. The surfaces of all steam balance holes were also shot peened.

SAFETY SIGNIFICANCE

The Updated Final Safety Analysis Report (UFSAR) Section 3.5.1.3 and NUREG-0712 (Safety Evaluation Report for SONGS 2/3) Section 3.5.1.3 evaluated the effects of turbine generated missiles on plant safety. These evaluations considered that any of the shrunk-on LP turbine discs could be a source of missiles. The conditions noted above remained bounded by the UFSAR evaluation.

Edison also evaluated the safety significance of the as-repaired condition of the stage 4 discs in engineering calculation M-DSC-315. This analysis confirmed that, with a turbine overspeed of up to 120 percent, local yielding can occur at the steam balance holes and disc rim area, but this will not result in a catastrophic failure of the turbine. The turbines are provided with redundant overspeed protection systems which ensure the turbine speed will not exceed 120 percent of nominal speed. In the unlikely event that a stage 4 turbine disc does fail, UFSAR Table 3.5-4 shows that disc failure at 120 percent overspeed would not have sufficient energy to escape the casing and become a missile.

The existing missile analysis (UFSAR Section 3.5.1.3) concluded that the stage 8 disc is the bounding disc with respect to the bursting speed (i.e., the rotational speed at which missiles will be generated). The bursting speed of stage 8 was determined to be 167 percent of normal operating speed (1800 rpm = 100 percent), while stage 4 was previously analyzed to have a bursting speed of 190 percent (UFSAR Table 3.5-4). Calculation M-DSC-315 has determined the burst speed of the stage 4 disc, following the Unit 2 Cycle 8 outage repairs, to be 170 percent.

To evaluate the structural integrity of the repaired Unit 2 LP turbine, Edison performed a structural and fracture mechanics evaluation of the stage 4 discs. This evaluation included several finite element models (FEM) stress analyses and confirmed that the discs, as repaired, will operate without failure through Cycle 8 (Edison plans to develop a reinspection plan for the LP turbine to be implemented during future refueling outages). GEC, the turbine vendor, independently reviewed and concurred with the analysis results and the adequacy of the repair work performed.

Upon review of the stress calculations for the LP1 stage 4 rear disc with enlarged steam balance holes, it was considered that overspeed testing would result in unnecessary high stresses. Although this would not cause a failure, there is a chance that some localized yielding may occur. Accordingly, Edison lowered the overspeed trip setpoint for the low pressure turbines from 110 percent to 107 percent plus or minus 1 percent.

Edison also contracted with Aptech Engineering Services, Inc. (APTECH), a company with extensive industry experience and expertise with LP turbines, to perform an additional review of Edison's evaluation. The primary objective of their evaluation was to provide an independent verification of input data, analysis assumptions, stress modeling methods, and results. Several detailed FEM and theoretical analyses were performed by APTECH to confirm reported hoop and radial disc stresses. The conclusions of the APTECH review indicated that Edison's technical evaluation, computed stresses, and repair methodology were correct.

Because Unit 3 was not scheduled to shutdown until July 1995, Edison management considered the impact the Unit 2 discoveries could have on operation of Unit 3. Based on the findings at Unit 2, the results of the stress analyses completed, discussions with the turbine vendor, and the time left in the current operating cycle, Edison concluded that Unit 3 operation until the end of the current cycle was acceptable. Edison will perform detailed examinations of the Unit 3 LP turbine and will implement repairs, if required, during the Cycle 8 refueling outage.

Edison considers the safety significance of the turbine disc cracking to be minimal.

ADDITIONAL INFORMATION

In the past three years, Edison has not reported any occurrences of LP turbine disc cracking.

As noted above, the LP turbine cracking found at San Onofre Unit 2 has been found at other plants that have turbines manufactured with the "shrink-fit" process using NiCrMoV discs. Cracking was discovered in LP rotors (similar to SONGS 2 and 3 rotors) in a Korean nuclear station, KORI Unit 1, operated by Korea Electric Power Company. Other less severe SCC has been found in similar disc steels in both nuclear and fossil LP steam turbines.

Industry studies have concluded that SCC is affected primarily by a combination of various factors including:

1) Material chemical composition (such as Chromium content),

2) Material mechanical properties,

3) Environmental factors (operating temperature, steam oxygen content, pH, impurities),

4) Steam quality, and

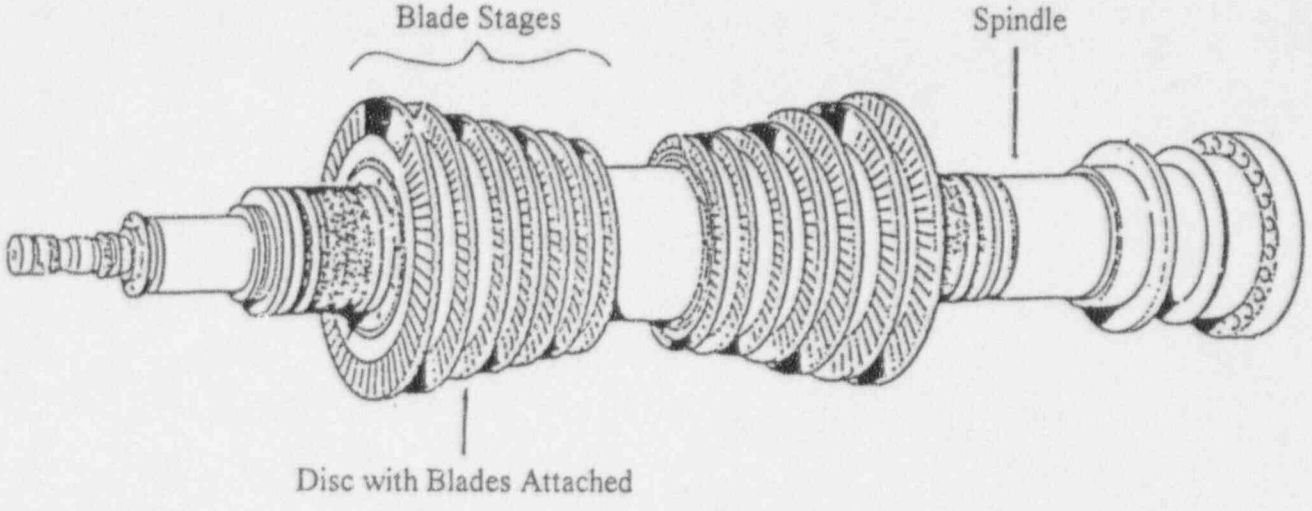
5) Stresses applied to the disc.

To follow the Industry activities associated with this issue, Edison is participating in industry groups and seminars whose topics relate to the management and solution of electric utility turbine blading and rotor issues. Edison has also formed a team to assess the long-term corrective actions for the LP turbines, which may include welding and/or component replacement.

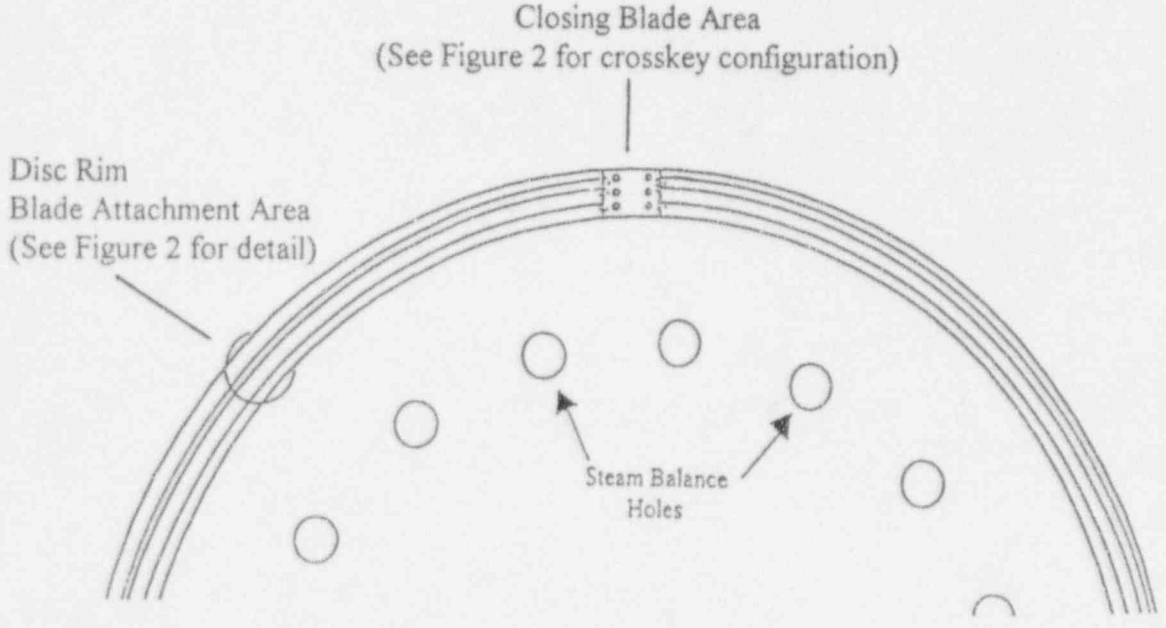
Enrico Fermi Nuclear Station recently experienced a turbine blade ejection event. While the turbines at Fermi and San Onofre are produced by the same manufacturer and are of the same design, the blade failure mechanism that occurred at Fermi is not related to the SCC found at San Onofre.

FIGURE 1

LOW PRESSURE TURBINE (TYPICAL)



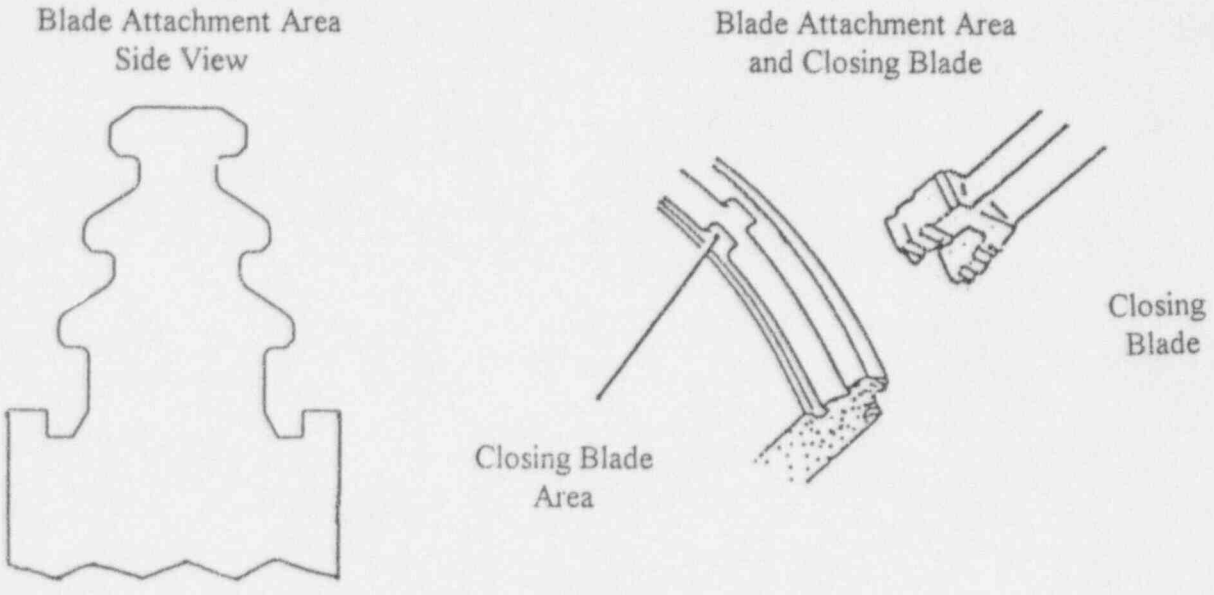
FOURTH STAGE DISC



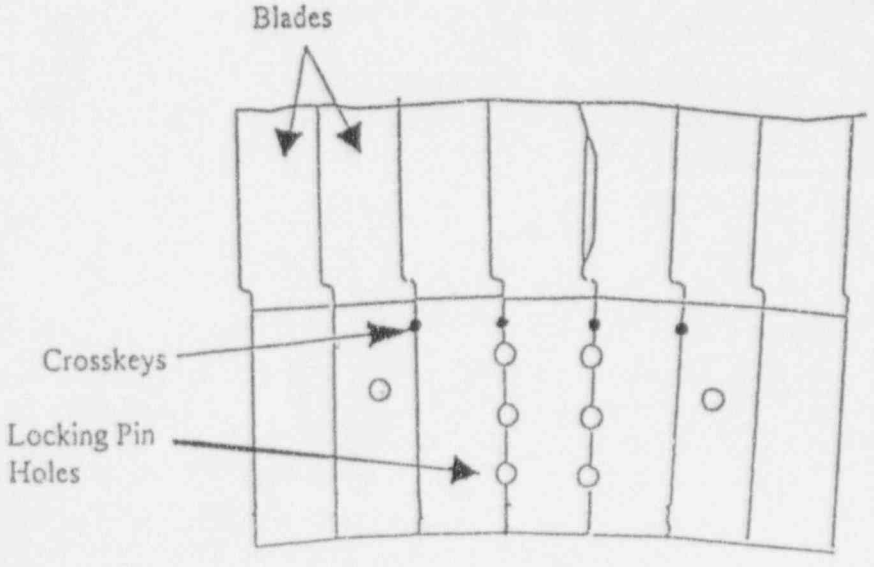
NOT TO SCALE

FIGURE 2

DISC RIM BLADE ATTACHMENT AREA DETAIL



CLOSING BLADE CROSS KEY CONFIGURATION



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