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FACIL:50-315 Donald C. Cook Nuclear Power Plant, Unit 1, Indiana M 05000315

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SUBJECT: LER 98-011-02:on 980305,steel containment liner pitting was is excess of design.Caused by lack of procedural controls. Seals were removed,containment liner plate was prepared & coated & new seals applied.W/980831 ltr.

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August 31, 1998

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In accordance with the criteria established by 10 CFR 50.73 entitled Licensee Event Report System, the following report is being submitted:

98-011-02

Sincerely,

John R. Sampson

J. R. Sampson
Site Vice President

/mbd

Attachment

c: J. L. Caldwell (Acting), Region III
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NRC Form 366 (4-95) U.S. NUCLEAR REGULATORY COMMISSION	APPROVED BY OMB NO. 3150-0104 EXPIRES 04/30/98
LICENSEE EVENT REPORT (LER) (See reverse for required number of digits/characters for each block)	ESTIMATED BURDEN PER RESPONSE TO COMPLY WITH THIS MANDATORY INFORMATION COLLECTION REQUEST: 50.0 HRS. REPORTED LESSONS LEARNED ARE INCORPORATED INTO THE LICENSING PROCESS AND FED BACK TO INDUSTRY. FORWARD COMMENTS REGARDING BURDEN ESTIMATE TO THE INFORMATION AND RECORDS MANAGEMENT BRANCH (T-6 F33), U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, DC 20555-0001, AND TO THE PAPERWORK REDUCTION PROJECT (3150-0104), OFFICE OF MANAGEMENT AND BUDGET, WASHINGTON, DC 20503

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TITLE (4)

Steel Containment Liner Pitting in Excess of Design Basis Results in Unanalyzed Condition

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 NAME	DOCKET NUMBER
03	05	98	98	-- 011 --	02	08	31	98	FACILITY NAME	DOCKET NUMBER

OPERATING MODE (9)	5	THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: (Check one or more) (11)			
		20.2201 (b)	20.2203(a)(2)(v)	50.73(a)(2)(i)	50.73(a)(2)(viii)
POWER LEVEL (10)	0	20.2203(a)(1)	20.2203(a)(3)(i)	X 50.73(a)(2)(ii)	50.73(a)(2)(x)
		20.2203(a)(2)(i)	20.2203(a)(3)(ii)	50.73(a)(2)(iii)	73.71
		20.2203(a)(2)(ii)	20.2203(a)(4)	50.73(a)(2)(iv)	OTHER
		20.2203(a)(2)(iii)	50.36(c)(1)	50.73(a)(2)(v)	Specify in Abstract below or in NRC Form 366A
		20.2203(a)(2)(iv)	50.36(c)(2)	50.73(a)(2)(vii)	

LICENSEE CONTACT FOR THIS LER (12)

NAME	TELEPHONE NUMBER (Include Area Code)
Mr. Pat Mangan, Structural Engineering Manager	616/697-5535

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)		EXPECTED SUBMISSION DATE (15)	MONTH	DAY	YEAR
YES (If Yes, complete EXPECTED SUBMISSION DATE).	X NO				

Abstract (Limit to 1400 spaces, i.e., approximately 15 single-spaced typewritten lines) (16)

On March 5, 1998, with Unit 1 in Mode 5, an inspection of the steel containment liner identified pitting resulting in the thickness of the steel containment liner being less than 0.250 inches. The location of the pitting is at the bottom of the containment near where the vertical section of the liner joins the horizontal section and is in close proximity to the seal located between the concrete floor slab and the steel liner. With pitting of this magnitude the steel containment liner could potentially not meet the stress assumptions made in the design basis. This event was reported in accordance with 10 CFR 50.72(b)(2)(i), as a condition which was found while the reactor was shutdown, which if it had been found while the reactor was operating, would have resulted in the nuclear power plant being in an unanalyzed condition, outside the design basis. The ENS notification was made at 1522 hours EST on March 5, 1998. This LER is being submitted in accordance with 10 CFR 50.73(a)(2)(ii).

The root cause for the above events can be attributed to the lack of procedural controls that require rigorous inspection of the liner plate. The existing seal has been removed and the surface on the containment liner plate prepared, coated and new seals applied. Appropriate VT-3 and VT-1 visual examinations have been performed on the accessible floor-liner seal surface area, and the liner in the area of the seal removal.

An engineering analysis has been performed which evaluated the effect of the corrosion on the structural and the leaktight integrity of the containment. The structural integrity of the as-found liner to withstand normal and accident loads satisfies design basis assumptions and the leaktight integrity of the containment has not be impaired. Therefore, this condition was determined to be of no safety significance.

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TEXT *(If more space is required, use additional copies of NRC Form (366A)* (17)

Conditions Prior to Event
Unit 1 was in Mode 5, Cold Shutdown

Description of Event
In response to NRC IN97-10, "Liner Plate Corrosion in Concrete Containments", a visual inspection of the Unit 1 containment liner plate in the floor seal area was performed in March 1998. On March 5, 1998, during visual examination, corrosion was measured to a depth of 0.171 inches, resulting in the thickness of the steel containment liner being less than 0.250 inches. With pitting of this magnitude the steel containment liner could potentially not meet the stress assumptions made in the design basis. The examination identified more than 40 occurrences where the thickness of the steel containment liner was less than 0.250 inches. Engineering had evaluated the pitting/corrosion and developed acceptance criteria used during the inspection. Based on calculations it was concluded that the liner plate would stay within the design basis provided the wall thickness was 0.250 inches or greater.

Cause of Event
The root cause for the above events can be attributed to the lack of procedural controls that require rigorous inspection of the liner plate. The following discussion provides background information.

From the original installation of the liner plate until 1991, no inspection procedure existed. In December 1989, the NRC issued IN89-79 and IN89-79 Supplement 1 describing the potential for corrosive deterioration of steel containment liners. In response to these notices, inspections were performed of Unit 1 and Unit 2 liner plate coatings in upper and lower containment and found them acceptable. That inspection did not include inaccessible areas such as those where the current pitting was discovered.

In May 1991, Engineering Guideline EC-CE-001, Protective Coating Surveillance Inspections, was developed for containment coating inspection. The engineering guide provided adequate information on assessing the condition of the protective coatings; however, the product of the survey focused on a listing of future coating maintenance and not on an assessment of the integrity of the existing protective coating. The engineering guide did not delineate the need to apply engineering rigor to the assessment of the containment coating condition on the containment system. In short, the engineering guideline provided general simplified inspection criteria but did not provide a specific detailed program for more vulnerable areas.

Analysis of Event
This event was reported in accordance with 10 CFR 50.72(b)(2)(I), as a condition which was found while the reactor was shutdown, which if it had been found while the reactor was operating, would have resulted in the nuclear power plant being in an unanalyzed condition, outside the design basis. The ENS notification was made at 1522 hours EST on March 5, 1998. This LER is being submitted in accordance with 10 CFR 50.73(a)(2)(ii).

An engineering analysis has been performed to evaluate the structural and leaktight integrity of the containment structure taking into account the corrosion damaged condition of the 3/8-inch thick steel liner in the annular space near the containment cylinder base. The maximum thickness loss at the deepest pit is 0.172 inch or 44 percent of the actual thickness of the liner at this location. A conservative estimate of the average effective thickness of the corroded liner plate in the annular space near the containment cylinder base is 0.241 inch. In this evaluation the effect of corrosion on the mechanical properties of the liner was accounted for by a 50 percent reduction in the design basis allowable strain in the liner.

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Analysis of Event (cont'd)
The steel liner is not considered a structural strength element in the design of the containment to resist the design loads. Therefore, the sole function of the liner is to serve as a leaktight pressure boundary.

The liner thickness of 3/8-inch was originally established from constructability considerations even though a thinner liner is adequate to function as a leaktight membrane.

The effect of corrosion on the mechanical properties of the liner were evaluated based on results of experimental studies investigating the effect of corrosion damage on mechanical properties of steel liner reported by J. L. Cherry, in "Analysis of Containment Structures with Corrosion Damage," Sandia National Laboratories Report prepared for the USNRC under contract DE-AC04-4AL85000, December 1997. In these studies, several samples of ASTM A 516 plates were intentionally corroded and then tested to failure in uniaxial tension. The corrosion damage inflicted on the plates included general corrosion and pitting. The test results obtained from the corroded specimens were compared with those from uncorroded control specimens.

Test coupons from corroded liner plates reached the same yield and ultimate tensile stress levels as uncorroded test specimens, leading to the conclusion that corrosion damage does not adversely affect the yield and ultimate tensile strength of the liner plate.

Even though the ultimate stress reached by the corroded and uncorroded specimens were the same, corroded test specimens showed considerable reduction in the total elongation at failure indicating the adverse effect of corrosion on ductility due to stress/strain concentrations around pits and on the rough uneven corroded surfaces. Necking of the corroded specimens began around 12 percent strain and reached an ultimate strain of only 14 percent. In contrast, uncorroded test specimens exhibited necking at 24 percent strain and reached an ultimate strain of 28 percent.

From this information the following conclusions are made. The yield stress and ultimate tensile stress of a liner plate with general and pitting corrosion would be the same as that of an uncorroded plate and corrosion reduces the ductility of a liner plate by 50 percent.

A strain-based acceptance criterion is used in the industry as the measure of leaktight integrity of an uncorroded liner plate. In a corroded liner, the metal loss is typically very irregular in both depth and distribution. It is not feasible to determine the actual strain in a corroded plate even with a finite element model analysis since the pitted and corroded surfaces consist of micro discontinuities that are much smaller than the practical size of a finite element mesh. Therefore, it is more practical to account for the effect of corrosion by reducing the allowable strain in the corroded liner by applying a reduction factor based on test results.

Based on the experimental results described in the previous section, it is judged appropriate to apply a 50 percent reduction factor to the design basis allowable liner strain of 0.005 inch/inch. Therefore, the allowable strain in the liner near the cylinder base shall be limited to 0.0025 inch/inch in this structural evaluation to account for the effect of corrosion.

Since the original design basis of the containment structure does not take any credit for the steel liner as a structural strength element, the design basis structural integrity of the containment structure to resist Normal Operating and Design Basis Accident loads is not affected by the corroded condition of the liner.

For Severe Accident, the ultimate internal pressure capacity of the reinforced concrete containment structure, including the portions not backed by concrete, was evaluated. The ultimate internal pressure capacity of the containment is governed by the capacity of the personnel airlock door and is equal to 32.3 pounds per square inch gage (psig) based on the specified

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Analysis of Event (cont'd)
minimum material strength and 45.1 psig based on the mean actual material strength. The ultimate internal pressure capacity of the reinforced concrete portion of the containment is governed by flexural bending and shear in the basemat and is equal to 45.8 psig based on the specified minimum material strength and 54.5 psig based on the mean actual material strength. The minimum internal pressure capacity of the reinforced concrete cylinder near the base in the meridional direction based on the specified minimum yield stress of 40,000 pounds per square inch (40 ksi) in the reinforcing steel and neglecting the strength of the liner is 72.15 psig.

Therefore, the design basis structural integrity of the containment to withstand Normal Operating, Design Basis Accident, and Severe Accident loads is not impaired by the observed corrosion damage to the liner in the annular space near the cylinder base.

The evaluation of leaktight integrity of the corroded liner began with an evaluation of thermal buckling. Design basis evaluation of the potential for thermal buckling of the containment shell steel liner shows that containment shell liner panels directly exposed to the design accident temperature are not likely to buckle.

The liner in the annulus space is not directly exposed to the design accident temperature but is thermally shielded by the concrete fill slab. It is judged that thermal buckling of the cylindrical band of liner in the annular space is not feasible because the filler material and the moisture barrier seal filling the annular space between the liner and the concrete fill-slab act as a continuous brace against buckling of the liner. Additionally, the fill-slab acts as a thermal shield and protects the liner from direct exposure to the design accident temperature in the containment atmosphere and, therefore, the average temperature rise in the liner in the annular space would be significantly smaller than in the liner directly exposed to the accident temperature. The liner is circumferentially stiffened and anchored at El 598 feet 9 3/8 inches, the elevation of the top of the fill-slab annular floor, where annular space liner would experience the maximum temperature rise.

However, since the critical buckling strength of a liner panel is a function of the thickness of the liner and since loss of thickness due to corrosion tends to reduce the critical buckling strength, the potential for buckling of the corroded liner panels with reduced effective thickness in the annular space near the cylinder base was evaluated. This evaluation conservatively neglects the bracing effect of the preformed filler and moisture barrier seal in the annular space.

The design basis accident temperature in the lower compartment of the containment atmosphere, provided in the updated Final Safety Analysis Report, is 256 degrees Fahrenheit with 1.5 times the containment maximum design pressure (P), 250 degrees Fahrenheit with 1.25 P, and 244 degrees Fahrenheit with 1.0 P. In the thermal buckling evaluation presented, the average accident temperature experienced by the liner is assumed to be 244 degrees Fahrenheit. This is a conservative assumption considering the thermal shielding provided by the concrete annular floor. The actual yield strength of the liner is 48.3 ksi as provided in "Evaluation of D.C. Cook Containment to Determine Limiting Internal Uniform Pressure Capacity" by Structural Mechanics Associates, Report No. 80C129-1, March 16, 1981. This corresponds to a yield strain of 0.001666 inch/inch. Therefore, elastic buckling of the corroded liner panel could occur if the compressive strains imposed exceed the critical buckling strain (0.001370 inch/inch).

Strains imposed on the liner near the cylinder base were calculated using the following assumptions. The temperature rise in the liner under Normal Operating condition is less critical for thermal buckling of liner than under Design Basis Accident conditions and, therefore, is not considered for evaluation.

Meridional compressive strain due to seismic overturning is neglected since this is a transient short duration strain and is not of consequence to leakage under sustained accident pressure.

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Analysis of Event (cont'd)

Dead load effects near the cylinder base are neglected for the following reasons: dead load induces meridional tensile strain on the interior face of the containment wall due to the combined effect of membrane compression and discontinuity meridional moment near the cylinder base, and hoop compressive strain induced in the containment wall near the cylinder base due to restraint to the Poisson lateral strain from dead load meridional compression of 7,000 pounds per inch of circumference is negligible.

Meridional tensile strain in the liner due to meridional tension and bending moment near the cylinder base due to Design Accident Pressure occurring concurrently with accident temperature is conservatively neglected.

Using the information and assumptions from above the total biaxial compressive strain imposed on the liner was calculated to be 0.001296 inch/inch. Conservatively determined biaxial compressive strain (0.001296 inch/inch) imposed on the liner is less than the critical buckling strain of the corroded liner panel near the cylinder base (0.001370 inch/inch).

Leaktight integrity of the liner under Normal Operating condition is less critical than under Design Basis Accident and Severe Accident conditions.

Under Design Basis Accident condition, load combinations 'a' (DL+1.5P+TL') and 'd' (DL+1.0P+T'''+TL'''+E') are the most critical with respect to the containment structural integrity.

Since the design basis earthquake E' in load combination 'd' is a transient of short duration load and since the accident pressure in this load combination is less than the factored accident pressure in load combination 'a', load combination 'a' is the most critical for leaktight integrity evaluation.

Under load combination 'a', the liner in the annular space experiences compressive strain due to restrained concrete shrinkage and thermal and tensile strain due to 1.5 P. In this evaluation, the tensile strain in the liner is maximized by conservatively neglecting the concurrent compressive strain in the liner and the maximum tensile strain in the liner is assumed to be the same as that in the reinforcing steel near the interior face of the containment cylinder at the cylinder base.

Under Severe Accident condition (ultimate internal pressure), the maximum tensile strain in the liner near the cylinder base is conservatively assumed to be equal to the normal yield strain of the reinforcing steel.

The conservatively determined maximum compressive and tensile strains in the liner under critical Design Basis Accident and Severe Accident loading are well below the reduced allowable strain (50 percent of design basis allowable strain) employed in this evaluation to account for the effect of corrosion.

The minimum design margin in the corroded liner near the containment cylinder base is at least 80 percent.

Based on the results of this evaluation the following was concluded. The structural integrity of the containment to withstand Normal Operating, Design Basis Accident, and Severe Accident loads is not effected by the as-found corrosion damage of the liner. Compressive strains imposed on the liner in the annular space near the cylinder base is less than the critical buckling strain of the corroded liner. Conservative maximum strains in the liner under Design Basis Accident and Severe Accident conditions do not exceed the reduced allowable strain used in the evaluation. The design margin available in the corrosion damaged liner near the cylinder base is at least 80 percent. The leaktight integrity of the containment will not be impaired and the liner as-found will continue to fulfill its function as an effective leaktight membrane. Therefore, the pitting of the steel containment liner has been determined to be of no safety significance.

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Corrective Actions

The existing seal was removed which extended from approximately the floor level to the top of the filler material. A visual inspection of the containment liner plate was performed. The area inspected went from approximately one foot above the annulus floor slab and covered the liner down to the top of the filler. In five areas the annulus floor concrete was excavated up to 8 inches in depth and filler material was further excavated to determine the extent of the corrosion. The pitting over 0.125 inches in depth was mapped and the severity of the pitting determined by depth measurements of the pits and ultrasonic wall thickness measurements of the liner in the areas of the pitting. The visual examinations revealed that the deepest corrosion was located in the area of the seal material above the top of the filler material and near the floor grade. The corrosion was noted to be less severe at the lower grades and it was noted to stop in two areas (10 inches and 15 inches below floor grade) where the filler material was removed.

The existing seal has been removed and the surface on the containment liner plate at the seal area directly above and below the annulus floor slab has been prepared and coated with the self-priming Carboline-890 Epoxy. New seals were then applied.

To determine the effectiveness of the new seal, a VT-3 visual examination will be performed on the accessible floor-liner seal surface area. The inspections will be made approximately every three years for the next three consecutive 3-year periods. During each three-year inspection, the floor-liner seal will be removed in two sections, one foot in length, where heavy corrosion was noted during this inspection. A VT-1 visual examination will be performed on the liner in the area of the seal removal. The areas of seal removal will be different for each three-year inspection, and distributed across the seal area to the extent practical.

The inspections are based on the flaws discovered and the guidance provided in the 1992 Edition and Addenda of ASME Section XI, Subsection IWE. This commitment will be made as part of the Containment ISI Program, which is currently under development and will be completed by March 1, 1999.

Failed Component Identification

Not Applicable

Previous Similar Events

None