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WESTINGHOUSE CLASS 3

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INDIAN POINT UNIT 2

INFORMATION PRESENTED TO THE NRC RELATIVE TO THE INDIAN POINT UNIT 2 STEAM GENERATOR SECONDARY SIDE LOOSE OBJECTS

NOVEMBER, 1989

WESTINGHOUSE CLASS 3

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WESTINGHOUSE CLASS 3

On Thursday, November 2, 1989 a meeting was held between Consolidated Edison Company, Westinghouse and the NRR staff in One White Flint North Building, Rockville, Md to discuss the status of the Indian Point Unit 2 steam generators. The overall presentation focussed on the maintenance of steam generator tube integrity and the 1989 refueling outage steam generator tube inservice inspection. The meeting agenda included discussions on:

1. Licensing Activities
2. Inspection Activities and Results
3. Steam Generator Secondary Side Loose Objects Evaluation
4. Steam Generator Tube Wear Calculation

The Westinghouse presentation on the steam generator tube wear calculation is provided herein.

INDIAN POINT UNIT 2 EVALUATION OF POTENTIAL FOR TUBE WEAR DUE TO LOOSE OBJECTS

LOOSE OBJECT TUBE WEAR EVALUATION METHODOLOGY

- Potential Mechanisms for Tube Degradation
- Tube Excitation Mechanisms
- Tube Wear Evaluation Conservatisms
- Material Wear Coefficients
- Archard Wear Equation

QUALIFICATION OF VIBRATION AND TUBE WEAR METHODOLOGY

- Tube Vibration Analytical Methods
- Archard Wear Equation
- Field Experiences With Loose Objects

EVALUATION OF INDIAN POINT 2 LOOSE OBJECTS

- Loose Objects In General
- Loose Objects From 1989 Accountability Logs
- Other Loose Objects Found in 1989

POTENTIAL MECHANISMS FOR TUBE DEGRADATION

- **Fretting Wear**
  - loose object and tube remain in contact
  - tube vibrates relative to loose object

- **Impact-Sliding Wear**
  - loose object and tube occasionally lose contact
  - tube vibrates relative to loose object
  - fluid removes loose material from wear site
  - [ ]a,b,c

- **Impacting Without Sliding**
  - loose object is lifted away from tube and collides with tube repeatedly
  - energy imparted to tube causes tube deformation

TUBE EXCITATION MECHANISMS

- **Fluidelastic Excitation**
  - large vibration amplitudes
  - self-excited vibration mechanism characterized by a critical flow velocity above which vibration amplitudes increase rapidly
  - vibration is sinusoidal and occurs at natural frequency of the tubes in the fluid

- **Turbulence-Induced Excitation**
  - small vibration amplitudes which vary randomly in time and direction
  - narrow-band random vibration at natural frequencies of the tubes in the fluid

- **Vortex Shedding**
  - forced vibration which is significant only when vortex shedding frequency is near tube frequency
  - excitation is insignificant in tube bundle region
  - not believed to contribute significantly to loose object tube wear

- [ ]a,b,c

TUBE WEAR EVALUATION CONSERVATISMS

- **Location of Loose Objects**
  - tubesheet region has highest cross flow velocities and drag forces
  - tube vibration amplitudes are largest in the span between the tubesheet and first TSP

- **Wear Time Calculations**
  - loose object considered to wear continuously on one location on the tube
  - only the tube is considered to experience wear
  - [ ]a,b,c
  - maximum approach and gap velocities for tubesheet region are used regardless of object's location

- **Impacting Without Sliding Calculations**
  - Upper bound tube deformations estimated based on Westinghouse tube dent experiments
  - Deformation due to maximum expected energy imparted to tube during a collision

MATERIAL WEAR COEFFICIENTS

- Wear coefficients relate work rate to wear volume
- Test programs utilize known tube motions and contact forces to produce a measurable wear volume
- Westinghouse test programs are performed in a range of environments including water and AVT steam
- Carbon steel, stainless steel, and Inconel materials have been tested in contact with Inconel tubes
- Wear tests performed under constant load sliding conditions and impact-sliding conditions
- [ ]a,b,c
- [ ]a,b,c
- [ ]a,b,c
- For loose objects of unknown composition, Inconel on Inconel wear coefficients are used for conservatism

LOOSE OBJECT TUBE WEAR EVALUATION METHODOLOGY

ARCHARD WEAR EQUATION

$$V = KFD$$

V = volume of material worn from the tube

K = wear coefficient for two material in contact

F = contact force between tube and object

D = total distance over which contact force acts

- Volume worn from tube is dependent on loose object geometry and orientation with respect to the tube
- Wear coefficient based on Westinghouse test programs
- [ ]a,b,c
- [ ]a,b,c

TUBE VIBRATION ANALYTICAL METHODS

- Equations and parameters used to analyze SG tube vibration behavior are based on results of extensive experimentation and testing

- Special purpose computer program incorporates equations and parameters necessary to model tube behavior in secondary side flow field

- Frequently utilized by Westinghouse to predict the behavior of SG tubes in both the straight leg and U-bend regions for applications such as:

  - analysis of cut tubes
  - tube stabilization
  - U-bend fatigue analysis
  - loose object evaluations

ARCHARD WEAR EQUATION

- [ ]a,b,c,e

- Provides a straightforward relationship between wear related parameters used in the interpretation of wear test data

- Basis for wear predictions in conjunction with nonlinear tube vibration model analytical solutions

- [ ]a,b,c,e

- [ ]a,b,c,e

- [ ]a,b,c,e

Successful application has been achieved for interaction between SG tubes and:

- *tube support plates*
- *anti-vibration bars*
- *loose objects*

FIELD EXPERIENCES WITH LOOSE OBJECTS

- Weld rod
  - plugged tube due to wear scar which formed in one operating cycle
  - wear time evaluation indicated that wear time to minimum allowable wall thickness was on order of one cycle
- Anti-rotation block
  - tube leak occurred when loose object migrated from feedwater line to tubesheet region
  - wear occurred in a 4 month period
  - analysis indicated that wear to minimum allowable wall thickness could occur in 3 months
- Westinghouse experience with loose objects at 33 different plants

Year	Number of Loose Object Evaluations
1983	4
1984	5
1985	9
1986	14
1987	7
1988	13
1989	8
Total	60

- No leakage events attributable to known stationary objects in SG's which were returned to service

TABLE 1

S/G	DESCRIPTION	SIZE	LOCATION	CURRENT CONDITIONS	UP-RATED CONDITION	PARTS CATEGORY
21	WIRE	1/8" Dia. x ?	Hot Leg, R45 C50-C52	16.1	15.2	1
	BLOCK	3/4 x 3/4 x ?	Not observed this Inspection (Formerly Hot Leg, between R35 C17 & R34 C16-17 Tubes)	14.4	13.6	2
	HALF MOON SHAPED OBJECT	3/8" Dia. x ?	Not observed this Inspection (Formerly Hot Leg, in Annulus beside R26 C9, R27 C10, & R28-29 C11 Tubes).	28.9	27.3	2
	PLATE	0.25 x 1.5 x ?	Hot Leg, between R15 C3 & P16 C3	7.7	7.3	1
	MACHINE CHIP	7/8" Dia. x ?	Not observed this Inspection (Formerly Cold Leg, Among R40 C67-68 & R41 C66 Tubes).	12.4	11.7	2
	WIRE	1/16" x 1/8" x ?	R38 C21 (Hot Leg)	2.7	2.5	4
22	DIGIDOSE	1" x 3" x 4" Aluminum Case (Contains a 9V battery).	UNKNOWN*	33.0	31.2	3
	TLD BADGE	1" x 1.25" x 0.38" Plastic	UNKNOWN*	NOT APPL.	NOT APPL.	3
	POCKET ION CHAMBER	0.5" Dia. x 4", Aluminum	UNKNOWN*	21.0	19.8	3
	LADDER LOCK PIN	1/8" Dia. x 8" Iron	UNKNOWN*	3.7	3.5	3
	CAMERA HEAD	1.25" Dia. x 4.12"	Stuck in wrapper Annulus	13.1	12.4	3
	WIRE	1/8" Dia. x 8"-12" Long	Between R42-R43, Tubes, extending into Annulus towards shell	10.2	9.6	4
	PIECE OF BAR	3/8" x 3/8" x 4"	Between R42-43, C31-C33 Tubes (Cold Leg)	12.6	11.9	1
	PIECE OF WELD ROD	1/8" Dia. x 4"	In Annulus adjacent to R42-43 (Stuck to Tubesheet, Cold Leg).	2.8	2.6	1
	WIRE AROUND FOUR TUBES	1/16" Dia. x ?	Hot Leg, wrapped around R44 C35-36	2.7	2.5	1
	ELECTRICAL WIRE	1/16" Dia. x ?	Hot Leg, between R1 C40-41 Tubes	2.4	2.2	1
	UNKNOWN OBJECT	3/4 x 7/8 x 1/4	Cold Leg, between R45 C53-54 Tubes	6.5	6.1	1
	PIPE TAP	11/32 Max. Dia.	Cold Leg, between R22-23 C7 Tubes	2.3	2.2	1
	ROD	1/8" Dia. x 10"	Cold Leg, Back in bundle between R14-15, C5-6 Tubes	20.5	19.4	1

* THESE OBJECTS ARE POSTULATED TO BE IN THE INDIAN POINT UNIT 2 STEAM GENERATORS AS THEY HAVE NOT BEEN VISUALLY OBSERVED.

TABLE 1

S/G	DESCRIPTION	SIZE	LOCATION	ESTIMATED IMPACT-SLIDING WEAR TIMES (years) CURRENT CONDITIONS	UPRATED CONDITION	PARTS CATEGORY
23	PLATE	0.25" x 1.5" x ?	Not observed this Inspection (Formerly Hot, R35 C17)	7.7	7.3	2
	CYLINDER	0.4" Dia. x 1" (Reported as 0.75" Dia. During Previous Outages)	Hot Leg, between R35-36 C16 Tubes	13.1	12.3	1
	ROD	0.25" Dia. x ?	Not observed this Inspection (Formerly Hot Leg, between R44 C35-36).	5.2	4.9	2
24	WIRE	1/16" Dia. x ?	Not observed this Inspection (Formerly Cold Leg, R45 C44-45).	2.8	2.6	2
	UNIDENTIFIED OBJECT (POSSIBLY HARD SLUDGE)	1" Dia. x 0.5"	Not observed this Inspection (Formerly Cold Leg, R43-44 C58).	5.1	4.8	2
	THREE (3) TIE WRAPS	0.25" Dia. x 18" Plastic	UNKNOWN*	NOT APPL.	NOT APPL.	4
	MASKING TAPE	Various Pieces	UNKNOWN*	NOT APPL.	NOT APPL.	4
	SAND PAPER	1" x 1" Piece	UNKNOWN*	NOT APPL.	NOT APPL.	4
	DYLO MARKER	1" Dia. x 7" Long	UNKNOWN*	18.5	17.4	3
	GASKET MATERIAL (RED SEAL OFF PLATE MATERIAL)	Approx. 2" x 1/8" x 8"	UNKNOWN*	NOT APPL.	NOT APPL.	4

* THESE OBJECTS ARE POSTULATED TO BE IN THE INDIAN POINT UNIT 2 STEAM GENERATORS AS THEY HAVE NOT BEEN VISUALLY OBSERVED.

CATEGORY #1- OBJECTS UNRETRIEVABLE IN 1987 OR BEFORE, REMAINING IN S/G IN 1989

#2- OBJECTS UNRETRIEVABLE IN 1987 OR BEFORE, NOT SEEN IN 1989

#3- OBJECTS MISSING OR REPORTED LOST IN 1989 BUT NOT OBSERVED

#4- NEW OBJECTS IN 1989, NOT PREDICTED FROM QC LOGS