2.206 PRESENTATION
San Onofre Units 2 and 3
Replacement Steam Generators

MEETING WITH PETITIONER FRIENDS OF THE EARTH, REQUESTING ENFORCEMENT ACTION AGAINST SOUTHERN CALIFORNIA EDISON UNDER 10 CFR 2.206

January 16, 2013

Presented For Friends of the Earth
By Fairewinds Associates Inc, Burlington VT

Based Upon Non-Proprietary Information
Sequence of Presentation

SECTION 1: Chronology of Events
SECTION 2: Magnitude of Design Changes
SECTION 3: Conclusions
SECTION 1

CHRONOLOGY OF EVENTS
Prior To Analysis And Design Of RSGs, Edison Applied To CPUC For RSG Permits

According to Southern California Edison’s 2004 Annual Report, its application for its Unit 2 and 3 Replacement Steam Generators was filed with the State of California’s PUC on February 27, 2004, which was prior to the contract with MHI on September 30, 2004.
In 2004 Edison Contract Language Directed MHI That CFR§50.59 Would Not Apply

An Edison Whistleblower released the San Onofre Design Specification for RSG. This specification required that CFR§50.59 would not apply to the San Onofre RSG’s even though an analysis had not yet been completed.

EXCERPTS FROM SONGS Replacement Steam Generator Design & Performance Specifications_SO23-617-1

Originator – James Chan
IRE – Jun Gaor
FLS – David Calhoun
SLS – Craig Herberts
PE Tom Pierno
NO& A Bill Kotekkaskos
3.6.1.1
“Edison intends to replace the steam generators under the 10 CFR 50.59 rule.”

3.6.1.2
“...the Supplier shall guarantee in writing that the RSG design is licensable and provide all support necessary to achieve that end.”

3.6.1.3
“Any deviations from these requirements shall require Edison’s approval.”
3.6.2 Licensing Topical Report:

“The Supplier shall prepare and submit for Edison’s approval a Licensing Topical Report demonstrating compliance of the RSG design with all SONGS licensing requirements. The report shall include an engineering evaluation, including all necessary analyses and evaluations, justifying that the RSGs can be replaced under the provisions of 10 CFR 50.59 (without prior NRC approval). …The 10 CFR 50.59 evaluation shall be performed by Edison.”
Edison Notified NRC of 50.59 Decision in June 2006

“A meeting was held on Wednesday, June 7, 2006, between the Nuclear Regulatory Commission (NRC) staff and the SCE, the licensee for SONGS 2 and 3. The meeting was held at the request of the licensee to provide to the NRC staff an overview of the various aspects of its steam generator (SG) replacement project.”

(ML061670140)
Licensing

- Will Be Implemented Under 10CFR 50.59
- No Power Uprate
- Associated Technical Specification Changes
  - Identification 2007
2006 NRC Informed of “Improvements”

Some Key Design Improvements

- Larger Surface Area
- Alloy 690 Thermally Treated Tubing
- Improved AVB Design
- Integral Steam Nozzle
- Improved Material for Tube Supports
- Forged Shell

S/G 3A Lower and Middle Shell
S/G 2A Balance Ring, Extension Ring, & Tubesheet
2006 Edison Accepts Responsibility

Oversight

- Design Reviews
- Technical Meetings (SONGS, Kobe)
- SCE Resident Personnel @ Kobe
- Special Engineering Visits
- Readiness Reviews
- Independent Inspections
- Audits
Mitsubishi Heavy Industries Was Constrained By The Contract

Between the contract award in 2004 and NRC kickoff meeting in 2006, Mitsubishi Heavy Industries had to force fit the RSG analysis and design in order to support Edison’s earlier decision determining that 10CFR§50.59 did not apply.
The 10CFR§50.59 Process

In its January 9, 2013 Response to the NRC, Edison said

“As discussed in Section 1.3 of NEI 96-07, changes are evaluated under 10 CFR 50.59 using a multi-step process. First, a licensee must determine that a proposed change is safe and effective through appropriate engineering and technical evaluations.” Page 5

• Fairewinds agrees with Edison that this is the correct approach, and it should have been implemented.

• However, this approach was not applied during the RSG Project. Rather this "multistep process" was thwarted by Edison.

• No “appropriate engineering and technical evaluation” was performed by Edison when the contractual decision was made that 10CFR§50.59 would not apply.
2009: During the San Onofre Standard Technical Specification License Amendment, Edison identified many areas where the San Onofre Replacement Steam Generator was dramatically different than the Original Steam Generator.
San Onofre RSG’s Were Not Like-For-Like

<table>
<thead>
<tr>
<th>Modification</th>
<th>Design Parameter Ratio RSG / OSG*</th>
<th>Percent Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam Generator (SG) Volume</td>
<td>23,100 / 22,803</td>
<td>1% Increase</td>
</tr>
<tr>
<td>Secondary Volume to Cover Tubes in One SG</td>
<td>3825 / 3349</td>
<td>14% Increase</td>
</tr>
<tr>
<td>Flow Restrictor Area</td>
<td>2.8 / 7.87</td>
<td>65% Decrease</td>
</tr>
<tr>
<td>Total SG Mass</td>
<td>1,334,393 / 1,242,369</td>
<td>7% Heavier: Increase of 100,000 pounds</td>
</tr>
<tr>
<td>Cold Pipe Coolant Mass</td>
<td>68,235 / 60,073</td>
<td>13% Increase</td>
</tr>
<tr>
<td>SG Tube Active Volume</td>
<td>2,898 / 2,523</td>
<td>14% Increase</td>
</tr>
<tr>
<td>Hot Plenum Volume</td>
<td>2,998 / 3,055</td>
<td>2% Decrease</td>
</tr>
<tr>
<td>Cold Plenum Volume</td>
<td>3,701 / 3,974</td>
<td>7% Decrease</td>
</tr>
<tr>
<td>Tube Mass Specific Heat</td>
<td>48,512 / 50,182</td>
<td>3% Decrease</td>
</tr>
</tbody>
</table>

*Note: RSG (Replacement Steam Generator) to OSG (Original Steam Generator)
Edison Identified Numerous San Onofre Design Changes

2011 Edison and MHI Report tout all the design changes implemented in the San Onofre RSG:

- Remove Stay Cylinder
- Add 377 Tubes
- Change Tube Support Structure
- Add New Anti-Vibration Bars
- Dozens More Changes…
SECTION 2
MAGNITUDE OF DESIGN CHANGES
In and of themselves, Edison’s design changes to the Replacement Steam Generators should have triggered the 10 CFR §50.59 process.
• The San Onofre tubes and tube sheets are part of the containment boundary and are safety related.

• San Onofre claimed to the NRC that new improved **anti-vibration bars** would reduce wear on these important components and would not adversely impact their design function.
Table 1
Steam Generator Design Changes Identified By Fairewinds Compared With The NRC’s Like-For-Like Criteria

<table>
<thead>
<tr>
<th>50:59 Criteria (A)</th>
<th>(B) Remove stay cylinder</th>
<th>Change tube sheet</th>
<th>Tube alloy change</th>
<th>Add tubes</th>
<th>Change tube support</th>
<th>Add flow restrictor</th>
<th>Additional water volume</th>
<th>Feed water distribution ring</th>
</tr>
</thead>
<tbody>
<tr>
<td>i – Accident Frequency Increase</td>
<td>Yes (1)</td>
<td>Yes (1)</td>
<td>No</td>
<td>Yes (3,4)</td>
<td>Yes (3,4,8)</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>ii – Increase in SSC Malfunction occurrence</td>
<td>Yes (1)</td>
<td>Yes (1)</td>
<td>No</td>
<td>Yes (3,4)</td>
<td>Yes (3,4,8)</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>iii - Accident consequent increase</td>
<td>Yes (1)</td>
<td>Yes (1)</td>
<td>No</td>
<td>Yes (3,4)</td>
<td>Yes (3,4,8)</td>
<td>Yes (2)</td>
<td>Yes (2,5,6)</td>
<td>No</td>
</tr>
<tr>
<td>iv - Increase in SSC consequence of malfunction</td>
<td>Yes (1)</td>
<td>Yes (1)</td>
<td>No</td>
<td>Yes (3,4)</td>
<td>Yes (3,4,8)</td>
<td>Yes (2)</td>
<td>Yes (2,5,6)</td>
<td>No</td>
</tr>
<tr>
<td>v - Create unanalysed accident</td>
<td>Yes (1)</td>
<td>Yes (1)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes (2)</td>
<td>Yes (2,5,6)</td>
<td>Yes (3,7,8)</td>
</tr>
<tr>
<td>vi – Create new malfunction</td>
<td>Yes (1)</td>
<td>Yes (1)</td>
<td>No</td>
<td>No</td>
<td>Yes (3,8)</td>
<td>Yes (2)</td>
<td>No</td>
<td>Yes (3,7,8)</td>
</tr>
<tr>
<td>vii – Alter fission product barrier</td>
<td>Yes (1)</td>
<td>Yes (1)</td>
<td>No</td>
<td>Yes (3)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>viii – Change design basis evaluation method</td>
<td>Yes (2)</td>
<td>Yes (2)</td>
<td>No</td>
<td>Yes (2)</td>
<td>Yes (2,8)</td>
<td>Yes (2)</td>
<td>Yes (2,5,6)</td>
<td>No</td>
</tr>
</tbody>
</table>

http://www.fairewinds.com/content/san-onofre’s-steam-generator-failures-could-have-been-prevented
Mitsubishi Heavy Industries Should Not Be The Scapegoat

“If the RSGs had been designed and manufactured in accordance with the procurement specification, the leak and tube wear would never had occurred.” Page 12, 1/9/13 Edison Letter to NRC

• The replacement steam generator design developed by Mitsubishi … in accordance with the licensee’s design specification was translated into the same set of design and fabrication drawings. AIT Report, Page 27

• No matter who fabricated the RSG’s for San Onofre, the tube damage would have occurred. The root cause of this problem was the design, not the fabrication.
San Onofre Identical To Palo Verde

Palo Verde Steam Generators

“The steam generators at the Palo Verde Nuclear Generating Station (Palo Verde), in which SCE owns a 15.8% interest, have the same design and material properties as the San Onofre units. During 2003, the Palo Verde Unit 2 steam generators were replaced.”

(Edison 2003 Annual Report, Page 21)
Stay Cylinder: Retained On Palo Verde And Eliminated On San Onofre
Egg Crate Design Retained On Palo Verde/
Eliminated On San Onofre

BROACHED TUBE SUPPORT

EGG CRATE TUBE SUPPORT
San Onofre Problem Was Foreseeable

- Stay Cylinder removal and Tube addition placed too much heat in the center of San Onofre’s Replacement Steam Generators
- San Onofre added 4% more tubes at the center of its RSGs
- Palo Verde added 10% to the periphery and added 2.9% more heat
- Palo Verde has no FEI problems
- Edison’s Design destroyed San Onofre’s RSGs
Contour Of Steam Quality

Condition Report: 201836127, Revision 0, 5/7/2012, Figure 2: Contour of steam quality at the height of the maximum quality in U-bend region for T-hot = 598°F (Figure 8.1-2 (a) in Reference [2]), Page 74.
What Did The 10CFR§50.59 Review Say? Edison is parsing its words!

• “At the time the RSGs were designed, MHI evaluated the flow patterns and determined that fluid elastic instability (FEI) would not occur.” 1/9/13 Edison brief to NRC, page 14

• “MHI provided a thermal-hydraulic analysis as part of the original design of the RSGs that showed there would be no FEI.” page 17

• Removing the stay cylinder allowed 377 extra tubes into the center void, creating more interior heat

• The riser column water void above the tube sheet was also eliminated

• There was nothing on the steam side to facilitate and bias the flow direction. The steam side flow patterns were never established.

• The 10CFR§50.59 analysis should identify high void fractions and confused in/out-of-plane FEI.
Friends Of The Earth Consultants Reached A Different 10CFR§50.59 Conclusion

"... design changes may be screened out under 10 CFR 50.59 if the changes do not adversely affect a design function” Page 9, Edison Response, 1/9/13

"The adverse condition that later resulted in the tube leak was a deficiency associated with the design and was not known at the time the 50.59 evaluation was performed.” Page 9, Edison Response, 1/9/13

• Fairewinds agrees with this approach, but it is not the approach used by Edison at San Onofre.
• The totality of RSG changes Edison proposed in 2004 created an unacceptable void fraction at the top of the hot side of the tubes that then created the FEI.
• Fairewinds and John Large both agree that it should have been foreseeable to Edison in 2004 that this combination of changes would cause FEI to occur.
Edison’s Cause Report Was Wrong

- Former NRC Chairman Gregory Jaczko promised Senator Boxer and the public a complete Root Cause Analysis. This has not been conducted.

- Kepner Tregoe Cause Analysis is severely flawed.

- “If they can get you asking the wrong questions, they don’t have to worry about answers.” Thomas Pynchon, Gravity’s Rainbow

- Statement upon which Edison based its Cause Report: “What is different or has changed when comparing SONGS Replacement SGs to Another US plant’s Replacement SG” (page 43, Condition Report)
What Root Cause Question Should Edison Have Asked?

There are no changes to compare among Edison’s RSG and other RSGs nationwide. It’s an apples and oranges comparison.

The changes Edison should have analyzed and compared are those between the OSG and the RSG or between San Onofre and Palo Verde, since Edison has acknowledged that Palo Verde’s RSG is identical to San Onofre’s OSG.
<table>
<thead>
<tr>
<th>Possible Causes</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Departure from the OSG design in terms of tube U&quot; bend configuration and U&quot; bend support configuration</td>
<td>Changing design from the original SG to the Replacement SG, is not causal factor in itself for tube to tube wear.</td>
</tr>
<tr>
<td>Departure from the OSG design in terms of replacing the stay cylinder with the divider plate and separator configuration</td>
<td>Changing design from the original SG to the Replacement SG, is not causal in itself for tube to tube wear.</td>
</tr>
<tr>
<td>Departure from the OSG design in terms of tube straight leg support configuration</td>
<td>Changing design from the original SG to the Replacement SG, is not causal in itself for tube to tube wear.</td>
</tr>
</tbody>
</table>

Extracted from the Edison Kepner Tregoe Exclusion Table: Condition Report: 201836127, Revision 0, 5/7/2012, Root Cause Evaluation: Unit 3 Steam Generator Tube Leak and Tube-to-Tube Wear, San Onofre Nuclear Generating Station, Page 52
SECTION 3

CONCLUSIONS
During the past eight years, the NRC had extensive evidence from multiple sources that the replacement steam generators at San Onofre were not the like-for-like replacements for the original designs, as Edison committed during the 10 CFR 50.59 processes. And, as demonstrated by the significant damage in the San Onofre Replacement Steam Generators, the design changes did have a significant impact upon key design functions and in fact degraded the containment boundary.

Edison should have notified the NRC that the significance of all the changes required a 10 CFR 50.59 license amendment.
San Onofre Was A ‘Near Miss’

The tube failures at San Onofre are the worst nuclear equipment failures since the near miss at Davis Bessie in 2002.
San Onofre Technical Specifications

San Onofre Technical Specifications states that the limiting design basis accident is a "double ended rupture of a single tube".

Page 510
Edison’s San Onofre: Operating Outside Design Basis

Eight Tubes failed their pressure test, not one!

The evidence shows that San Onofre was operating outside of its design basis and the NRC has done nothing to address this major violation.

“Although in this case the degraded condition of the tubes was manifested as a small primary to secondary leak, it is possible that a full-blown rupture could have been the first indication.” Page 57, NRC AIT Report
Arnie Gundersen, Chief Engineer
Fairewinds Associates, Inc

Nuclear Engineering, Safety, and Reliability Expert
42-years of nuclear industry experience and oversight

ME NE  Master of Engineering Nuclear Engineering
Rensselaer Polytechnic Institute, 1972
U.S. Atomic Energy Commission Fellowship
Thesis:  Cooling Tower Plume Rise

BS NE  Bachelor of Science Nuclear Engineering
Rensselaer Polytechnic Institute, 1971, Cum Laude
James J. Kerrigan Scholar

RO  Licensed Reactor Operator
U.S. Atomic Energy Commission
License # OP-3014