SMOKE AND MIRRORS:
Analysis of the Nuclear Regulatory Commission's
Augmented Inspection Team Report on the San Onofre Crisis

Friends of the Earth | July 24, 2012

On July 19, the U.S. Nuclear Regulatory Commission (NRC) issued its final Augmented Inspection Team (AIT) report on the multiple steam generator failure at the San Onofre nuclear plant, operated by Southern California Edison. The AIT confirmed the serious problems previously identified in three technical reports commissioned by Friends of the Earth. Yet the press release and executive summary of the report distorted the findings to spread the notion – unsupported by the report itself – that Edison has been exonerated and that the utility complied with the required licensing procedures for the replacement steam generators.

The press release directly contradicts a statement in the report's cover letter from NRC Regional Administrator Elmo Collins: "It is not the responsibility of an AIT to determine compliance with the NRC rules and regulations or to recommend enforcement actions, this will be done through subsequent NRC inspection or review."[1]

The NRC's press release is crafted to provide cover for the failure of both Edison and the agency. It excuses the utility's intentional misrepresentation of the replacement steam generators and the failure by of NRC staff to enforce their own regulations which put public safety at significant and unnecessary risk.

The notion that Edison was in compliance is *not* what the NRC AIT report reveals, nor what it concludes. Instead, the AIT reveals that:

- Edison designed defective and significantly altered replacement steam generators – which in 2006 they represented to the NRC as a "like for like" exchange – in order to sidestep the rigorous license amendment process and public adjudicatory hearing required for such changes under NRC regulations.

- Edison not only designed, but also was intimately involved in, the construction and installation of this critically flawed equipment. These defective components within months of operation earned the dubious distinction as the most severely damaged of comparable replacement steam generators in the history of the U.S. nuclear industry.[2] According to the AIT, the flawed design led to "the loss of steam generator tube integrity [which] is a serious safety issue that must be resolved prior to further power operations." [3]

  Edison's negligence and the identical design specifications for the steam generators in reactor Units 2 and 3 mean that this equipment in both reactors has the same design faults, has exhibited the same types of problems, and poses significant risks to public safety.

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[1] See, SAN ONOFRE NUCLEAR GENERATING STATION – NRC AUGMENTED INSPECTION TEAM REPORT 05000361/2012007 and 05000362/2012007, Elmo E. Collins Regional Administrator to Peter Dietrich Senior Vice President and Chief Nuclear Officer Southern California Edison Company, July 18th 2012, http://www.nrc.gov/info-finder/reactor/songs/ML12188A7

[2] Fairewinds Associates (2012, July 11). SAN ONOFRE'S STEAM GENERATORS: SIGNIFICANTLY WORSE THAN ALL OTHERS NATIONWIDE. Retrieved from: http://fairewinds.org/content/san-onofre's-steam-generators-significantly-worse-all-others-nationwide

[3] Opcit. SAN ONOFRE NUCLEAR GENERATING STATION – NRC AUGMENTED INSPECTION TEAM REPORT 05000361/2012007 and 05000362/2012007, see Executive Summary, i.

- The NRC definitively stated in the report that the 50.59 licensing issue requires further assessment. It by no means exonerates Edison nor is compliance a closed or decided matter.

- The report reveals that the NRC staff –having failed in their regulatory and enforcement responsibilities when the significantly altered and now crippled steam generators were initially proposed in 2006 and installed– are now trying to create a tortuous justification for their regulatory failure. The NRC staff suggests that since Edison chose to misrepresent what they were doing, and therefore followed the wrong licensing process, the failure of the NRC to ensure they followed the *right* process is okay. The staff justify this failure by stating that they ensured the utility followed all the right steps of a perfunctory and incorrect process. The statements in the AIT press release and the executive summary reveal the NRC attempting to exonerate themselves .

NRC Has Concluded It Must Do Further Analysis of 50.59 Licensing Issue

AIT Report:

> However, the 50.59 screening evaluation identified three methods of analysis described in the updated final safety analysis report that were affected by the proposed steam generator replacement and required further evaluation against the criteria in 10 CFR 50.59.[4]

Friends of the Earth Analysis:

Whether Edison's design and evaluation of the replacement steam generators was, in fact, in compliance with the 50.59 process is unresolved. Three methods used by Edison for evaluating areas of concern in the updated FSAR for the replacements may constitute a violation of the 50.59 process, FOE believes that this is just the tip of the iceberg, and that many other 50.59 violations have occurred.

Edison Made Major Design Changes

AIT:

> Initially, the licensee reviewed the following cause contributors:
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> • Departure from original steam generator u-bend/anti-vibration bar configuration - highly probable
> • Departure from original steam generator stay cylinder configuration - possible
> • Departure from original steam generator tube support plate configuration - possible
> • Replacement steam generator anti-vibration bar structure too flexible - possible
> • Additional 300 rotations of Unit 3 replacement steam generator due to divider plate repair work - possible
> • Thermal-hydraulic and flow induced vibration models used in replacement steam generator design incorrectly predicted replacement steam generator tube bundle behavior – possible
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> The team observed that the licensee performed a detailed analysis and attempted to address all probable causes. The team observed that some of the conditions which were eliminated as potential contributors may need further evaluation.[5]

Analysis:

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[4] Ibid, see page 34
[5] Ibid, see pages 17-18

Edison's replacement steam generators contained significant alterations of the original equipment design. The utility DID NOT perform an analysis of all the probable causes for the accelerated and pervasive wear of the steam generator tubes, including many of the major design changes in the replacement components. While the NRC claims that Edison considered removal of the stay cylinder and other departures from the original design as "possible" causes, the Edison report leaked to FOE shows that Edison never addressed these changes to the original design in their analysis. Edison's evaluation was inadequate, and design modifications that may be contributing to the dangerous, rapid wear were inappropriately eliminated and need to be re-evaluated.

AIT Report:

> The replacement steam generator design developed by Mitsubishi for SONGS Unit 2 and Unit 3 in accordance with the licensee's design specification was translated into the same set of design and fabrication drawings[6] . . . During the inspection, it was identified that all design and manufacturing changes proposed by Mitsubishi required review and approval from a SCE representative. . . The team assessed whether these differences could be considered as contributing factors for the cause of the tube-to-tube wear issue in Unit 3. The team also reviewed Engineering Change Packages 800071702 and 800071703 for the Unit 2 and Unit 3 replacement steam generators, respectively, with emphasis on changes made to the design methodology described in the updated final safety analysis report for the original steam generators to verify that the evaluation was performed in accordance with licensee procedures and the provisions of 10CFR 50.59, "Changes, Tests, and Experiments" . . . The team identified two unresolved items for which additional information is required to determine if performance deficiencies exist or if the issues constitute violations of NRC requirements.[7]

Friends of the Earth Analysis:

Responsibility for designing the most severely defective and damaged steam generators in the history of the U.S. nuclear industry falls squarely on the shoulders of Southern California Edison. Any alterations to Edison's design specification by the manufacturer were approved by Edison. There remain unresolved questions regarding the design and fabrication that may yet constitute violations of NRC regulations.

AIT Report:

> Part of the SONGS oversight plan of Mitsubishi included the placement of SCE quality assurance/quality control personnel (residents) at the Mitsubishi facility. Plan SGR-A10183, "Replacement Steam Generator Resident Oversight Plan," described the roles and responsibilities of the resident management, engineering, and quality oversight implementation strategy for the replacement steam generators. This oversight plan was created to provide reasonable assurance that the design, licensing, fabrication, delivery, and acceptance of the SONGS replacement steam generators were performed in accordance with specified SCE, industry, regulatory, and Code requirements.[8]

Analysis:

Edison not only specified the design of the replacement steam generators and approved any proposed deviations from their design, but also installed an Edison representative at the Mitsubishi facility who actively oversaw all aspects of the fabrication and the shipping of these components. As such, Edison is

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[6] Ibid, see page 26
[7] Ibid, see page 23
[8] Ibid, see page 38

explicitly responsible for all aspects of these critically-flawed and exorbitantly expensive replacement steam generators.

Edison's Major Design Changes Led To Steam Generator Degeneration And Tube Failure

AIT Report:

> The licensee's evaluation for the engineering design package determined that although the original steam generators had a number of plugged tubes, the reactor coolant system flow rate of the original steam generators was near the design requirement. Because the replacement steam generators has 377 more tubes than the original steam generators, and contained tubes with u-bends versus "square bends", the pressure drop of the replacement steam generators with no plugged tubes would be much less than the original steam generators resulting in a higher flow rate.[9]

Analysis:

The 377 extra tubes and the change in the radius and the broached tube support plates created the fluid elastic instability on the outside of the tubes which altered the flow outside the tubes. This created the excessive vibrations that led to the severe damage in the newly replaced steam generators.

AIT Report:

> Mitsubishi's preliminary explanation of the failure mechanism started with the combination of two factors: (1) a relatively small tube pitch to tube diameter ratio (P/D), and (2) high void fraction in the tube bundle area where the tube-to-tube wear was identified. The small pitch to diameter ratio was a fixed parameter in the replacement steam generators established by the nominal center-to-center distance between adjacent tubes (P) and the nominal outside diameter of the tubes (D). The failure mechanism model also considered a fluid dynamic effect associated with the spreading of the tubes in the U-bend region during normal operating conditions. This effect was informally referred to as "flowering," due to the characteristic shape in which the tube bundle spreads transverse to the plane of the u-bends at normal operating conditions. "Flowering" was described as the elastic deformation of the anti-vibration bar structure and the tube bundle in the U-bend region, as a result of thermal expansion and fluid dynamic pressure acting on the secondary side of the tubes. . . Mitsubishi considered that the collective contribution of the factors described above resulted in conditions in the U-bend that were highly susceptible to excessive tube vibration.[10]

Analysis:

Edison's design changes in the steam generators, particularly the addition of nearly 400 more steam generator tubes and the more narrow radius of the tubes, resulted in conditions that created a high likelihood of the excessive vibration and collision that led to the unprecedented, rapid degradation of the steam generator tubes.

Flaws Could Create Catastrophic Accident– Neither Edison nor NRC Has A Solution

AIT Report:

> 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. The baseline core damage frequency of a steam generator tube rupture, according to the SONGS SPAR model, is 4.26E-7/yr. Because of an unmitigated bypass of containment, the large early release frequency is also 4.26E-7/yr. Assuming conservatively that the steam generator tube rupture

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[9] Ibid, see page 30

[10] Ibid, see pages 18-20

> frequency would at least double, the increase in large early release frequency attributable to the degraded tubes would be approximately 2.13E-7/yr (taking into account a 6-month exposure period).[11]

Analysis:

Although the significant problems related to the steam generators manifested in a small radioactive leak on January 31st, there was a real possibility that the problems could have been initially revealed by a catastrophic, cascading tube rupture accident and massive release of radiation into the environment.

Additionally, given the unprecedented number of damaged tubes, the probability of this kind of massive nuclear accident is likely far greater than the NRC assumes in this analysis. The consequences of a tube break would also significantly exceed the design basis for San Onofre. The bottom line: the likelihood of such a catastrophic accident is substantially greater and the consequences far more severe than the NRC has put forth in this report. Restarting either reactor with such damaged and defective equipment poses enormous and unacceptable risk to surrounding communities.

AIT Report:

> It should be noted, this is a preliminary assessment of the risk requiring additional information and inspection to ascertain whether a performance deficiency exists. This does not include or preclude regulatory or enforcement action by the NRC.[12]

Analysis:

If a steam line break accident were to occur, the depressurization of the steam generator caused by the steam line break coupled with the lack of water at the top of the steam generators would cause cascading tube failures, involving hundreds of tubes. The cascading tube failures would pop like popcorn, and the cascading failures would cause excessive offsite radiation exposures.[13]

AIT Report:

> SCE determined that the best solution to prevent tube-to-tube wear was to conservatively plug and stabilize the affected areas. By taking the impacted tubes out-of-service, SCE determined that this should reduce the potential for localized fluid velocities reaching critical velocity. In addition, in order to ensure sufficient margin to preclude the onset of fluid-elastic instability, SCE determined that reactor power would also have to be reduced. At this time SCE is still developing additional corrective actions to prevent tube-to-tube wear. The actions have not been finalized and no determination has been made concerning the appropriate power level. The NRC has not made any conclusions on the proposed corrective actions. Once the corrective actions have been finalized, they will be inspected as part of the Confirmatory Action Letter followup inspection."[14]

Analysis:

Plugging the tubes only eliminates the radioactive water inside the tubes, but it does not eliminate the vibration, so the plugged tubes will continue to vibrate and damage adjacent tubes. Plugging the tubes will

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[11] Ibid, see page 57
[12] Ibid, see page 57
[13] See, http://www.foe.org/news/blog/2012-05-san-onofres-steam-generator-failures-could-have-been
[14] Opcit. SAN ONOFRE NUCLEAR GENERATING STATION – NRC AUGMENTED INSPECTION TEAM REPORT 05000361/2012007 and 05000362/2012007, see page 56.

never solve the underlying problem because vibration is the result not the root cause of the steam generator problems at San Onofre. The actual problem is that design changes have caused too much steam and too little water at the top of the steam generators. Edison's solution of plugging the inside of the tubes will not lessen the risk of an accident or stop the ongoing vibrational damage that is occurring to the inaccessible outside of the San Onofre steam generator tubes.[15]

AIT Report:

> The team identified one unresolved item associated with the non-conservative FIT-III thermal-hydraulic model results.
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> Based on independent NRC thermal-hydraulic analysis, the team concluded that the SONGS replacement steam generators were not designed with adequate margin to preclude the onset of fluid-elastic instability. Therefore unless changes are made to the operation or configuration of the steam generators, high fluid velocities and high void fractions in localized regions in the u-bend will continue to cause excessive tube wear and accelerated wear that could result in tube leakage and/or tube rupture . . .[16]

Analysis:

The NRC and Edison have yet to work out a way to operate the San Onofre reactors without continued risk of severe damage to the thousands steam generator tubes. They have failed to conduct a root cause analysis and are instead focusing on the consequences of decisions taken by Edison and inaccurate computer modeling codes run by Mitsubishi, reviewed and approved by Edison. As above, reduced power operations as is being considered by Edison will not prevent vibration inside the steam generators and therefore risk of continued severe damage and accident.

Edison's Negligence Means Reactor Units 2 And 3 Have Same Design Problems & Equipment Failures

AIT Report:

> The team focused on differences in fabrication, manufacturing, operation, and eddy current data results between Units 2 and 3 steam generators . . . Since generator physical dimensions and design are identical, the operational parameters are basically the same between the Unit 2 and 3 steam generators; therefore, the hydraulic forcing function that caused tube-to-tube wear and accelerated anti-vibration bar and tube support plate wear should also be same . . .[17]
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> Conclusion
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> Based on the review of actual operating data and independent thermal-hydraulic modeling analyses, the team determined that there were no major differences in the thermal hydraulic phenomena at normal full power operation.[18]

Analysis:

– As FOE has repeatedly stated, there is no meaningful difference between the wear in Unit 2 and the wear

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[15] see , http://www.foe.org/news/blog/2012-05-san-onofres-steam-generator-failures-could-have-been
[16] Opcit. SAN ONOFRE NUCLEAR GENERATING STATION – NRC AUGMENTED INSPECTION TEAM REPORT 05000361/2012007 and 05000362/2012007, see page 56.

[17] Ibid, see page 58
[18] Ibid, see page 59

in Unit 3. The NRC appears to finally agree. Moreover, there is no scientific basis to compare the damage at either San Onofre unit to any of the damage at any other steam generator that has experienced tube plugging anywhere in the United States. San Onofre is in a class by itself for steam generator damage. Yet Edison and the NRC seem to believe they can extrapolate from experience elsewhere to allow San Onofre to operate in the future. This approach will turn San Onofre into a science experiment.

The AIT Report Attempts to Whitewash the NRC'S Regulatory Failure

AIT Report:

> One of the major enhancements of the replacement steam generators was the use of Alloy-690 tubing versus Alloy-600 for corrosion resistance. Alloy-690 has lower heat conductivity so, to achieve the same power, the heat transfer surface area must be increased by at least 10 percent. This required more tubes to be used in the replacement steam generators. The increased number of tubes resulted in a more tightly compacted tube bundle and elimination of the stay cylinder. The increase in the number of tubes could lead to increases in primary reactor coolant flow through.[19]

Analysis:

The Augmented Inspection Team is arguing that the simple change in tube alloy from 600 to 690 – a common alteration in all replacement steam generators – *necessitated* the other major design changes for which Edison should have been required to undergo the license amendment process. Edison's own report in January 2012 says this was not the reason extra tubes were added. According to independent expert review from Fairewinds Associates, no such changes were required from the simple alteration of the tube alloy. This is supported by the fact that the significant design changes in the San Onofre replacement steam generators are not replicated in the design of comparable equipment at other reactors despite the altered tube alloy in the replacements of those reactors.

AIT Report:

> With regard to the major design changes between the original and replacement steam generators, the updated final safety analysis report did not specify how the original steam generators relied on special design features such as the stay cylinder, tubesheet, tube support plates, or the shape of the tubes to perform the intended safety functions.[20]

Analysis:

The AIT concedes that Edison failed to flag these "major design changes" but then makes a completely irrelevant excuse that "the NRC licensing process does not require the licenses to presume deficiencies in the design or fabrication." The AIT thus confirms that Edison misled the NRC and failed to disclose these major design changes in the 50.59 process. It confirms that the changes Edison failed to identify were in fact major changes which of course required a thorough review and a license amendment.

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[19] Ibid, see page 47
[20] Ibid, see page 36