

18 months - Regular  
40 month - <sup>filling</sup> lubrication  
items

# Need for and Timing of Steam Generator Replacement

BOR

5/16/03

# Background

- 2001 – SONGS commenced feasibility and replacement evaluations
  - Although the 50% (best estimate) cases supported operation through end of life, SONGS observed the forecasts do not quantify all risks
  - Replacement timing would be reviewed following the Cycle 12 refueling outages
- Updated historically-based, quantitative forecasts have not appreciably changed; however,
  - Forecasts do not quantify significant risks,
  - Trends of regulatory required shutdowns are increasing, and
  - Many other changes in the industry are now occurring
- After carefully examining all relevant risks to continued availability, SONGS is seeking to confirm the selection of the Cycle 16 refueling for replacements

# SG Replacement Experience

- Following graphs depict the operating history of all the US steam generators with tubing similar to SONGS 2 and 3.
- SONGS 2 and 3 are shown with planned replacements during the Cycle 16 refueling outages scheduled to occur in the 2009-2010 timeframe (depending on capacity factor).
- Remedial actions at SONGS have resulted in SG life well above average
- If steam generators are not replaced in 2009, SONGS may be the only plant with original 600 Mill Annealed (MA) tubing

# SG Replacement History MA600

|                  | Corn Ops | replaced | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |
|------------------|----------|----------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| surry 2          | 1973     | 1979     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| surry 1          | 1972     | 1980     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| turkey point 3   | 1972     | 1981     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| turkey point 4   | 1973     | 1982     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| cook 2           | 1978     | 1988     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| summer           | 1984     | 1994     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| braidwood 1      | 1988     | 1998     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| catawba 1        | 1985     | 1996     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| watts bar 1      | 1996     | 2007     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| stp 1            | 1988     | 2000     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| point beach 1    | 1970     | 1983     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| robinson         | 1971     | 1984     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| indian point 3   | 1976     | 1989     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| mcguire 2        | 1984     | 1997     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| byron 1          | 1985     | 1998     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| shearon harris   | 1987     | 2000     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| north anna 2     | 1980     | 1994     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| stp 2            | 1989     | 2003     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| trojan           | 1976     |          |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| north anna 1     | 1978     | 1993     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| millstone 2      | 1975     | 1992     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| mcguire 1        | 1980     | 1997     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| palo verde 2     | 1986     | 2003     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| comanche peak    | 1990     | 2008     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| palisades        | 1971     | 1990     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| palo verde 1     | 1986     | 2005     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| palo verde 3     | 1988     | 2007     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| saalem 1         | 1977     | 1997     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| ano 2            | 1980     | 2000     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| farley 2         | 1981     | 2001     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| callaway         | 1985     | 2005     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| st lucie 1       | 1976     | 1998     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| maine yankee     | 1972     |          |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| farley 1         | 1977     | 2000     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| sequoyah 1       | 1980     | 2003     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| diablo canyon 2  | 1986     | 2009     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| diablo canyon 1  | 1985     | 2009     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| point beach 2    | 1972     | 1997     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| san onofre 3     | 1984     | 2009     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| waterford 3      | 1985     | 2010     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| indian point 2   | 1974     | 2000     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| kewaunee         | 1974     | 2000     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| cook 1           | 1975     | 2001     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| calvert cliffs 2 | 1977     | 2003     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| saalem 2         | 1981     | 2007     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| san onofre 2     | 1983     | 2009     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| calvert cliffs 1 | 1975     | 2002     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| st lucie 2       | 1983     | 2010     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| ginna            | 1970     | 1998     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| sequoyah 2       | 1982     | 2010     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| beaver valley 1  | 1976     | 2006     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| prairie island 1 | 1973     | 2004     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| fort calhoun     | 1973     | 2007     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| prairie island 2 | 1974     | 2013     |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

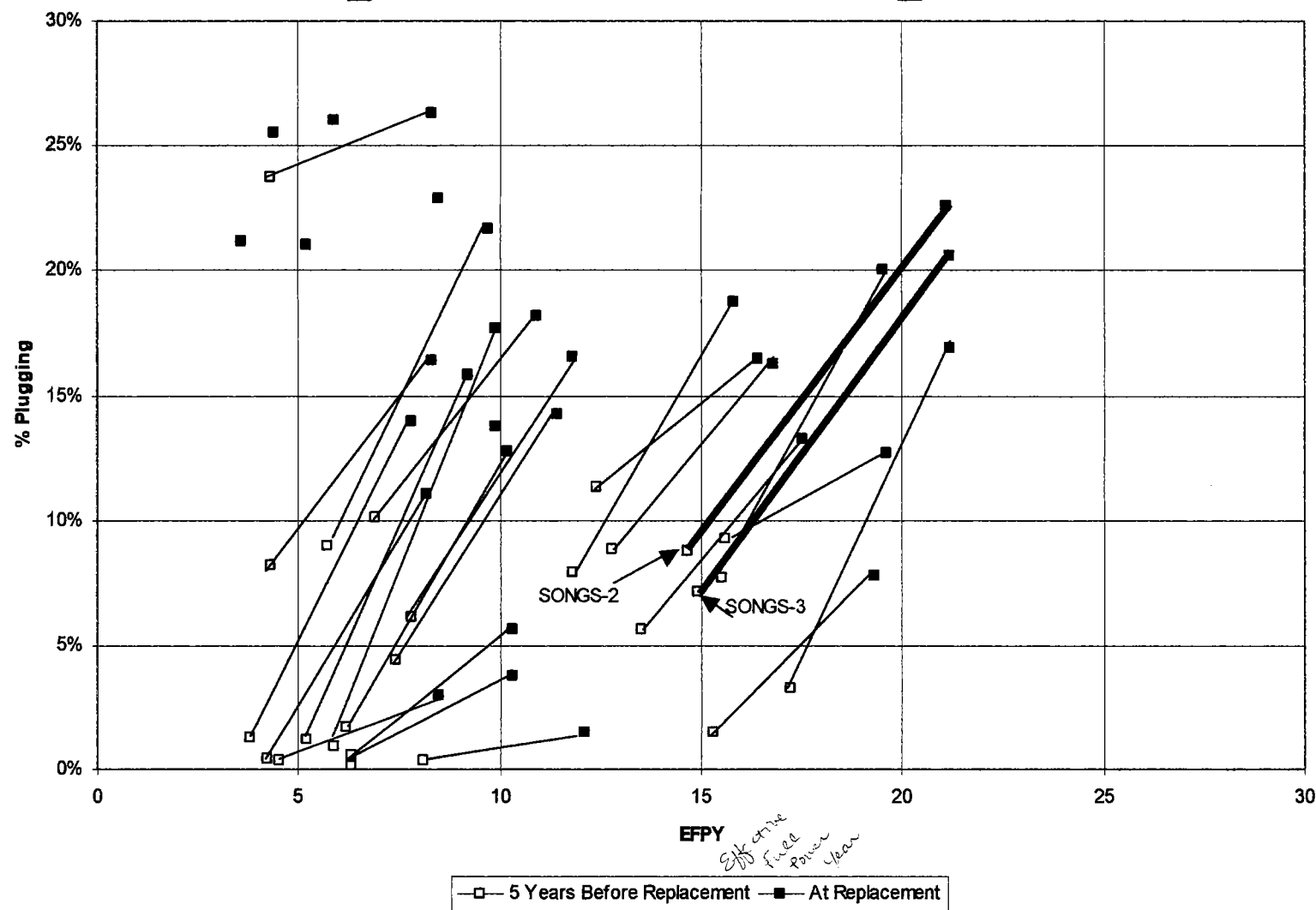
# SG Replacement History MA600

[illegible]

# Industry SG Replacement Decision Experience

- If SONGS experience follows an average industry trend, replacement will be required during the Cycle 16 refueling outage.
- Industry experience would dictate that a SG replacement decision be made now.
- SONGS Original Steam Generators (OSG) cannot be assured to provide plant availability and meet the needs of the grid beyond the Cycle 16 refueling outage.

# SG Replacement Experience



# Replacement Decision

- The historically-based, quantitative forecast does not include certain real, but non-quantitative risk factors
- These risk factors must be incorporated into SG replacement decision making
- Today's Objective
  - Confirm the necessary timing of steam generator replacement to assure plant availability



# Historically-based, Quantitative Forecast Limitations

- Uncertainty is not statistically developed
- No allowance for changes in:
  - Tubing environment from SG chemistry, etc
  - Regulatory environment
  - Inspection technology and industry standards
  - Ability to meet structural integrity requirements
- No allowance for new degradation types or sleeve degradation

# Determination of Replacement Timing

- Started with the Historically-based Quantified Forecasts
- Developed four risk elements
- Applied expert judgment to assess each risk element
- Risk assessed independently for each element and unit
- Included industry experience
- Reviewed by independent consultants
- Resulted in a realistic assessment of replacement timing

## Probabilities of San Onofre Unit 2 Operation (with existing Steam Generators)

| Risk Element*   | 2009 | 2012 | 2016 |
|---|------|------|------|
| Historically-based, Quantitative Forecast   | 99%  | 87%  | 70%  |
| Unfavorable Evolution (regulatory expectations, industry guidance and NDE technology) | -10% | -15% | -25% |
| Impact of Sleeving becoming non-viable  | -5%  | -10% | -10% |
| Unanticipated degradation, including further eggcrate degradation                     | -5%  | -5%  | -10% |
| Variability in Historically-based, Quantitative Forecast                              | -3%  | -5%  | -8%  |
| <b>Total</b> (rounded to nearest 5%)  | ~75% | ~50% | ~15% |
| *Risk assessed independently for each element and unit                                |      |      |      |

## Probabilities of San Onofre Unit 3 Operation (with existing Steam Generators)

| Risk Element*   | 2009 | 2012 | 2016 |
|---|------|------|------|
| Historically-based, Quantitative Forecast   | 99%  | 99%  | 99%  |
| Unfavorable Evolution (regulatory expectations, industry guidance and NDE technology) | -10% | -15% | -25% |
| Unanticipated degradation, including further eggcrate degradation                     | -5%  | -10% | -15% |
| Variability in Historically-based, Quantitative Forecast                              | -3%  | -5%  | -8%  |
| Impact of Sleeving becoming non-viable  | 0    | 0    | -2%  |
| <b>Total</b> (rounded to nearest 5%)  | ~80% | ~70% | ~50% |
| *Risk assessed independently for each element and unit                                | ~75% | ~50% | ~15% |

Unit 3  
Unit 2

# Unfavorable Evolution in Requirements

- Current issues
  - Inability to detect circumferential degradation with bobbin
    - A finding of circ indications at dented support intersections would put further pressure on the inspection program
  - Industry noise standards
  - Inspection limitations have forced plugging of 3% of low row tubes - extrapolation to whole bundle would shorten SG life by 1-2 cycles
  - Some probability that all low row tubes will require plugging
  - Absence of agreement on regulatory expectations
    - Technical specification revision has been in progress for years
  - Severe accidents
    - This addition to design basis will be required to obtain NRC staff approval of continued operation
    - Avoided in 1997 cracking and support thinning issues
    - Unlikely we could avoid if those issues or issues of similar regulatory interest arise

# Unfavorable Evolution in Requirements

- Not just a matter of increasing costs - evolution in requirements is capable of making existing SG's non-viable
- Regulatory oversight for the last units operating with 600MA tubing would make continued operation impractical. This also makes single unit operation at SONGS unsupportable.
- Examples:
  - Diablo Canyon, SONGS, others – significant increase in tubesheet inspection has occurred and additional increases in bends likely (100% of bends is 15-16 days and \$4-5M)
  - Diablo Canyon recently tested new noise standards – most tubes failed

# Unanticipated Degradation

- Structural Integrity is measured by Probability of Burst (POB) and Leakage during Normal Operation and Accident Conditions
  - Not addressed in Quantitative Forecast
  - U2 POB has doubled since Cy 10 and will double again by 2009
    - 90% confidence POB
    - Current level is 1% → 2%  
2009
- Unanticipated degradation
  - Not included in historically-based, quantitative forecast
  - Developed based on experience in CE SG fleet
  - Additional repairs to address new degradation advance SG end of life 1 cycle (high confidence)
- Example:
  - Diablo Canyon – circumferential cracks in U-bend (discovered 2/2003)

could  
cause  
mid  
cycle  
inspections

Inspection  
would  
find a  
month to the  
outage

# Impact of Sleeving Becoming Non-Viable

- Historically, installed sleeves have exhibited a finite service life
  - 35 US plants have installed 64,700 sleeves
  - 2 US plants plugged all sleeves, 6 US plants plugged 10% or more
- In 2009 oldest U2 sleeves will have been in service for 10 EFPY
- 2009 Best Estimate Forecast
  - 12% plugs/10% sleeves
  - Relies on sleeves to maintain plugging below end of life limit
- 2009 High Confidence Forecast
  - 16% plugged/18% sleeved
  - If sleeves installed through 2004 require plugging – end of life is reached
- Combined assessment of:
  - Likelihood that all sleeves require repair in best estimate case, or
  - Significant portion of sleeves require repair in high confidence case



# Historically-based, Quantitative Forecast Variability

- Statistical treatment
  - Going back to early 90's, forecast repair level is +/-5% after 6 EFPY (2009) and +/-10% after 9 EFPY (2012)
  - Assumes about 50% of repairs are sleeved hence impact on plugging level is ~50% of the variability
- Additional factors contributing to uncertainty
  - Small sample sizes (for many degradation mechanisms only a few tubes have failed – particularly Unit 3)
  - Long extrapolation compared to data period
    - 4 to 5 inspections over 6.3 EFPY extrapolated up to 20 EFPY
- Best estimate forecast is based on most recent SONGS data
- High confidence forecast is based on CE fleet experience but excludes outliers (Maine Yankee and ANO2) – non-statistical treatment

# Summary

- The historically-based, quantitative forecast does not include certain real, but non-quantitative risk factors that must be incorporated into SG replacement decision making
- Industry experience would dictate that a SG replacement decision be made now.
- Steam generator life is not just a matter of increasing costs - evolution in regulatory requirements is capable of making existing SG's non-viable
- Regulatory oversight for the last units operating with 600MA tubing would make continued operation impractical. This also makes single unit operation at SONGS unsupportable.
- SONGS Original Steam Generators (OSG) cannot be assured to provide plant availability and meet the needs of the grid beyond the Cycle 16 refueling outage.

# Conclusion

- The SG replacement decision needs to be made now to adequately ensure unit availability beyond 2009