U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

RIC 2017





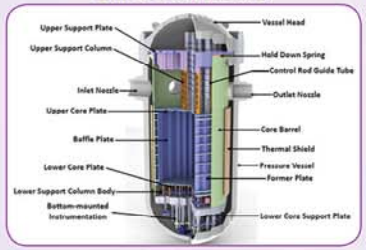
Office of Nuclear Reactor Regulation

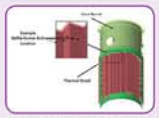
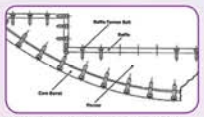
Baffle-Former Bolt Degradation

Introduction

The primary function of the baffle-former assembly is to direct coolant flow through the core and provide lateral support for core internals, especially during seismic events and loss-of-coolant accidents. As part of the license renewal process, licensees have committed to periodically inspect reactor vessel internal components, including baffle-former bolts. During their spring 2016 refueling outages, two pressurized-water reactors discovered and reported large numbers of degraded bolts; much larger than what was anticipated.

Baffle-Former Assembly



The vertical baffle plates are bolted to the edges of horizontal former plates, which themselves are bolted to the inner surface of the core barrel. Typically, there are eight levels of former plates distributed along the height of the core barrel. The baffle-former bolts secure the baffle to the former plates.

Bolt Types

Material	Plant	Details
Type 347 stainless steel	Westinghouse (older)	Sharper head-to-shank radius and shorter shank than Type 316
Type 316 cold-worked stainless steel	Westinghouse (newer)	All replacement bolts
Type 304 stainless steel	B&W	
Type 316 stainless steel	CE	

Potential Bolt Failure Issues

Resulting Issue	Description	Consequence
Baffle plate movement	Plates detach or deflect and impact with control rods	Grid crush, fuel cladding damage, and altered rod insertion challenges core cooling
Baffle jetting	Flow leakage between baffle plates impinging on fuel	Radioactivity leak to coolant
Loose parts	Bolt heads or locking bars falling into the reactor coolant system	Minor fuel damage

Early History

- Degradation was first found in European plants in late 1980s.
- Ultrasonic (UT) examinations of French and Belgian plants found up to 11 percent of bolts degraded.
- The NRC issued Information Notice 98-11 alerting plant operators of this operating experience (OE).
- Consequently, U.S. industry initiated a program that included pilot inspections of baffle-former bolts at several plants.
- Two 2-loop downflow plants with Type 347 bolts (1998–1999) found 7–10 percent of bolts degraded and replaced them.
- Two 3-loop downflow plants with Type 316 bolts (1998–1999) and one B&W plant (2005) were examined with no indications found.

Fuel Assembly Damage due to Baffle Jetting

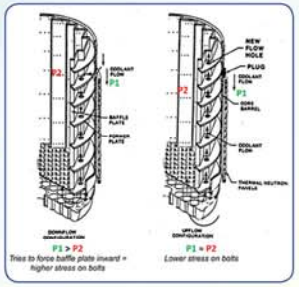
Replacement Bolt

External Bolt

Internal Hex

Factors Influencing Baffle-Former Bolt Degradation

- Irradiation-assisted stress-corrosion cracking
- Areas of high fluence
- Stresses
  - Preload
  - Irradiation
  - Void swelling
  - Bolt per area ratio
  - Bolt geometry
- Fatigue (fluctuating stresses) due to thermal cycles or flow-induced vibration
- Differential pressure due to upflow or downflow configuration
- Type 347 stainless steel bolts



	Tier 1a	Tier 1b
Design	4-loop plants operating in a downflow configuration	4-loop plants operating in a downflow configuration
Bolts	Type 347 bolts	Type 316 bolts
Plants	D.C. Cook 1, D.C. Cook 2*, Diablo Canyon 1, Indian Point 2*, Indian Point 3, Salem 1*, Salem 2	Sequoyah 1, Sequoyah 2
Recommendations	Complete UT volumetric inspection of baffle-former bolts next outage. Develop bolting pattern analysis and plan to replace damaged bolts before starting back up. Consider mitigating strategies like an upflow conversion and preemptive bolt replacements.	Complete VT3 inspection of baffle-former bolts next outage. If visual indications are found, complete UT volumetric inspection of baffle-former bolts. If no visual indications are found, complete UT volumetric inspection prior to completion of the second outage after issuance of the NSAL. Monitor baffle-former bolt OE to determine if further or more rigorous inspection is warranted.

** Completed initial UT examinations and replacement of degraded bolts.*

NRC Risk-Informed Evaluation (LIC-504)

The NRC Staff identified and evaluated four options for the Tier 1 plants against the five principles of risk-informed regulation:

1. Immediate shutdown and inspection
2. Continued operation until next refueling outage, then inspection
3. Generic communication
4. Maintenance of status quo

Options 3 and 4 were eliminated due to more risk uncertainty.

Option 1 was eliminated because it places an unnecessary burden on licensees.

Interim industry guidance effectively implements Option 2.

Baffle-Former Bolt Inspections Performed 2011–2015

NRC-approved reactor internals inspection guidelines for aging management (MRP-227-A) specify UT exams for baffle-former bolts.

- Initial (baseline) exams:
  - Westinghouse and CE: 100 percent of bolts between 25-35 effective full power years (EFPY).
  - B&W: 100 percent of accessible bolts no later than two refueling outages from the beginning of the license renewal period.
- Default reinspection in 10 years.

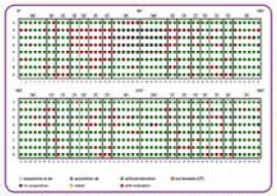
Design	Bolts	EFPY	# of Reactors Inspected	Results
Westinghouse 2-loop	Type 347	34	5	Maximum percentage of defective bolts was 10.3 percent.
Westinghouse 3-loop	Type 347	30–32	4	0–8 degraded bolts were found per unit.
B&W	Type 304	30–32	3	No more than four bolts were found degraded in each plant.
CE	Type 316	27–28	0	

Recent Inspection OE

- Indian Point Unit 2, Salem Unit 1, and D.C. Cook performed UT exams in 2016.
- UT exams found 21–27 percent of bolts were potentially degraded.
- Majority of degraded bolts were found in clusters.
- Degraded bolts were replaced with Type 316 stainless steel.
- Selected bolts are being tested to confirm the root cause of degradation.
- Indian Point Unit 2 and Salem Unit 1 completed analysis to determine replacement scope and justify continued operation.
- D.C. Cook Unit 2 found broken bolts visually in 2010, replaced 52; UT in 2016 found more degraded bolts, including six replacement bolts.
  - Also found five degraded baffle-edge bolts.
- Indian Point Unit 3 and Salem Unit 2
  - Operability evaluations of baffle-former assemblies considered information from Indian Point Unit 2 and Salem Unit 1.
  - UT inspection of all bolts is scheduled for spring 2017.

NRC Current and Future Actions

- Follow root cause investigation at D.C. Cook Unit 2, with focus on cause of degradation of replacement bolts and baffle-edge bolts.
- Will determine if LIC-504 requires revision based on new developments at D.C. Cook Unit 2.
- Continue to engage with industry focus group, especially on root cause from the three plants. Discuss with industry if changes to interim guidance are necessary.
- Developing information notice.
- Document assessment of Materials Reliability Program (MRP) interim guidance.
- Determine whether changes to MRP-227-A guidance are needed.



D.C. Cook Unit 2 Baffle-Former Bolts