Steam Generator Tube Rupture

Chapter 4.6
Objectives

1. Discuss why operator intervention is necessary to limit or prevent radiological releases during a Steam Generator Tube Rupture (SGTR) event.

2. Discuss the primary-side and secondary-side indications of an SGTR in the control room.

3. Discuss how the affected SG may be identified either prior to or following the reactor/turbine trip.
Objectives (Cont)

4. List the initial actions taken by the operator once the affected SG has been identified.

5. Discuss the actions required to stop the primary-secondary leakage.

6. Discuss the problems associated with the following: Secondary-to-primary leakage, SG Overfill.

7. List the principal systems/components affected by a loss of offsite power (LOOP).
Objectives (Cont)

8. Discuss how plant cooldown and pressure control are accomplished with an SGTR and LOOP.

9. Discuss what affect the following events had on the SGTR transient at the Ginna Plant:
   - Tripping of the reactor Coolant Pumps,
   - Failure of pressurizer power-Operated relief valve,
   - Automatic operation of letdown valves,
   - Pressurizer relief tank failure, and
   - Steam generator Safety Valve Failure.
SGTR

• Most frequent occurring major accident.
• Provides a direct release path for primary coolant to environment via SG and its safety/relief valves (Containment Bypass).
• Timely operator involvement is required to prevent SG overfill and limit radiological releases.
Figure 4.6-1 Closeup View of SGTR
## Past Steam Generator Tube Rupture Accidents at Pressurized Water Reactors

<table>
<thead>
<tr>
<th>Plant</th>
<th>Date</th>
<th>Leak Rate (gpm)</th>
<th>Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point Beach Unit 1</td>
<td>February 26, 1975</td>
<td>125</td>
<td>wastage</td>
</tr>
<tr>
<td>Surry Unit 2</td>
<td>September 15, 1976</td>
<td>330</td>
<td>PWSCC in U-bend</td>
</tr>
<tr>
<td>Doel Unit 2</td>
<td>June 25, 1979</td>
<td>135</td>
<td>PWSCC in U-bend</td>
</tr>
<tr>
<td>Prairie Island 1</td>
<td>October 2, 1979</td>
<td>390</td>
<td>loose parts</td>
</tr>
<tr>
<td>Ginna Unit 1</td>
<td>January 25, 1982</td>
<td>760</td>
<td>loose parts and tube wear</td>
</tr>
<tr>
<td>Fort Calhoun</td>
<td>May 16, 1984</td>
<td>112</td>
<td>ODSCC at a crevice</td>
</tr>
<tr>
<td>North Anna Unit 1</td>
<td>July 15, 1987</td>
<td>637</td>
<td>high cycle fatigue in a U-bend</td>
</tr>
<tr>
<td>McGuire Unit 1</td>
<td>March 7, 1989</td>
<td>500</td>
<td>ODSCC in the free span</td>
</tr>
<tr>
<td>Mihama Unit 2</td>
<td>February 9, 1991</td>
<td>700</td>
<td>high cycle fatigue</td>
</tr>
<tr>
<td>Palo Verde Unit 2</td>
<td>March 14, 1993</td>
<td>240</td>
<td>ODSCC</td>
</tr>
<tr>
<td>Indian Point Unit 2</td>
<td>February 15, 2000</td>
<td>150</td>
<td>PWSCC in U-bend</td>
</tr>
</tbody>
</table>
Industry Improvements

• Secondary Side Inspections
• Improved Steam Generator Designs
• Water Chemistry Control
• More Reliable Eddy Current Techniques
Primary-Side Indications of SGTR

- Decreasing Prz level
- Decreasing Prz Pressure.
- Increasing charging flow.

These indication would also occur for a LOCA, how could the operator differentiate between the two?
- Lack of degraded containment conditions.
- Abnormal secondary side indications.
RCS pressure drop is one indication of SGTR or LOCA.

Trip from 0T ΔT or If reducing Turb Load, Low Prz Press.

Figure 4.6-2(a) Initial Pressurizer Pressure Response

4.6-35
Prz level drop is another indication of SGTR or LOCA.

Figure 4.6-2(b) Initial Pressurizer Level Response

1 tube

10 tubes
Figure 4.6-3 RCS Temperature Following Reactor Trip

Figure 4.6-3  RCS Temperature Following Reactor Trip

4.6-37
Secondary-Side Indications of SGTR

- Chemistry Samples.
- Condenser Off Gas RM.
- SGBD Rad Monitor Alarms.
- Main Steam Line RM’s
- SF/FF mismatch on affected SG.
- SG level rise on affected SG.
Figure 4.6-4(a) Steam Generator Response Following Reactor Trip
Figure 4.6-4(b) Steam Generator Response Following Reactor Trip
4.6-39
Figure 4.6-4(c) Steam Generator Response Following Reactor Trip

4.6-39
Initial Operator Actions

• Isolate the affected SG.
  1. Isolate Feedwater & AFW.
  2. Close MSIV.

• These actions help minimize radiological releases & prevent SG overfill.

• Isolating the affected SG also allows use of the non-affected SG for cooling down RCS.
Recovery Actions

• Following isolation of the effected SG the intent is to match RCS pressure with affected SG pressure to stop the leak.
• 1\textsuperscript{st} step cooldown RCS using intact SG’s.
• 2\textsuperscript{nd} step depressurize RCS using Prz sprays or PORV if RCPs unavailable.
• 3\textsuperscript{rd} Step terminate SI to prevent re-pressurization of RCS.
Figure 4.6-5  Equilibrium Break Flow

(1) (2) (4) (10)

BREAK FLOW
(N) = # of FAILED TUBES

SI FLOW

FLOW (LB/SEC)

RCS PRESSURE (PSIG)
Figure 4.6-6 RCS Response - Offsite Power Available

RCS COOLDOWN INITIATED

Cooldown RCS to less than Saturation Temp for affected SG pressure.

i.e. SG Press 800-899 Core Exit TC 470° Saturation for 899# is ~532°

This will allow depressurization of RCS to SG press and stop the leak with the RCS sub-cooled.
Figure 4.6-11  RCS and Ruptured SG Pressure Following SI Termination
As Primary is depressurized, Break flow decreases and SI Flow increases refilling Pzr.

Figure 4.6-8  SI Flow and Break Flow

4.6-47
SI Termination:
RCS Sub Cooling >25°
SG FF >720gpm or 1 Intact SG >7%
RCS Press stable or increasing
Pzr level >5%

Figure 4.6-10 Pressurizer Level Response - RCS Cooldown and Depressurization
When several tubes fail RCS pressure can drop below SG pressure during recovery. This can result in secondary – to – primary leakage which will dilute RCS boron concentration thus effecting SDM.
Figure 4.6-79(b) Multiple Tube Failure Response

- AFFECTED SG
- INTACT SG

Time (Mins): 0 10 20 30 40 50 60

SG Water Level (% Narrow Range):
- 0%
- 20%
- 40%
- 60%
- 80%
- 100%
Affected SG level recovers faster and higher for feedflow.

Figure 4.6-12 Steam Generator Levels

4.6-55
SGTR with LOOP

- No RCPs – natural circulation cooldown required, slows recovery.
- No Steam Dumps to condenser – must use SG PORVs.
- Prz Sprays unavailable – must use Prz PORVs or Aux Spray.
- Overall this results in increased potential for rad releases and SG overfill.
Figure 4.6-13  Steam Generator Pressure Following Reactor Trip With and Without Offsite Power

Offsite Power Available

Loss of Site Power

Steam Dumps 1092#

Higher SG pressure SG PORV (1125#), or Safeties (1st @ 1170#). Can result in rad release from affected SG.
Higher no-load Tave (1125#) 
Slower Pressure Decrease

Figure 4.6-14 RCS Pressure Following Reactor Trip 
With and Without Offsite Power
Figure 4.6-15  RCS Temperature Following Reactor Trip Without Offsite Power 4.6-61
Without RCPs running upper head becomes inactive. Stays hot and prone to voiding during subsequent cooldown.

Figure 4.6-16 Natural Circulation Flow Following Loss of Offsite Power

4.6-63
Cooldown done with PORV on SG vs Steam Dumps

When the affected SG is isolated
That loop may stagnate.
Figure 4.6-18 RCS Pressure Response, Without Offsite Power

During Depressurization
Head may void causing rapid Increase in pressurizer level.
Questions
Fig 4.6-19  GINNA OVERVIEW
Figure 4.6-20  Ginna RCS Piping and Instrumentation
47% Normal Pzer Level

Increase Charging and Load reduction stabilize Press and Level decrease
This indicates leak ~750gpm

47% Normal Pzer Level

Plant Computer Data Available

Tube Rupture at ~09:25

Rx Trip on low Press at 1900#

Figure 4.6-22 Ginna SGTR - Initial Pressurizer Pressure and Level Response
4.6-75
SI pumps recover RCS pressure to about 1350# and with S/G at about 1050 there is ~400 gpm going into “B” SG.

Figure 4.6-23  Ginna SGTR - SI and Break Flow
At 9:40 "B" SG is isolated. B coolant loop stagnates. B loop reverse flow out the Ruptured tube.

Cooling down on "A" SG

Attempt to depressurize Using PORV and it sticks Open on 4th cycle and is Isolated. Rapidly filling Pzr.
SI Termination Criteria exists

Tube Leak increasing “B” S/G Pressure

“B” S/G ISOL.

FIRST PORV LIFT

“B” S/G SAFETY OPEN

“B” S/G SAFETY RE-SEATS

2 Chg Pps no letdown
Maintains RSC ~40#>SG
Break Flow continues

Heat removal changed to PORV

Break Flow Reverses

Figure 4.6-25 Ginna SGTR - RCS and SG Pressure 4.6-81
Letdown relief open
Control break-flow by keeping RCS pressure ~25# < SG press
Ginna Lessons Learned

• Tripping RCPs slowed down and complicated recovery actions.
• PORV failure resulted in sec-to-pri leakage, RCS steam void formation, and Prz overfill.
• Opening of letdown iso valves resulted in overpressure of PRT.
• PRT rupture disc burst resulting in release of Reactor Coolant to Containment.
• Failure of SG Safety resulted in Rad releases & complicated recovery actions (lower SG pressure.)
Objectives

Obj-1 Discuss why operator intervention is necessary to limit or prevent radiological releases during a Steam Generator Tube Rupture (SGTR) event.

Without operator action the affected SG and associated steam line will fill with water solid. S/G PORVs and Safety valves are not designed to pass water and may fail open. The steam lines may fail due to the weight of water in the lines. These failures could result in a containment bypass event releasing radiation directly to the environment.
Obj-2 Discuss the primary-side and secondary-side indications of an SGTR in the control room.

- **Primary**
  - Decreasing pressurizer level
  - Decreasing RCS pressure

- **Secondary**
  - Condenser Offgas rad-monitor
  - SGBD rad-monitor
  - Main Steam rad-monitor
  - SG Steam flow / feed flow mismatch
  - SG water level deviation alarms
Obj-3  Discuss how the affected SG may be identified either prior to or following the reactor/turbine trip.

- Feedflow / Steam Flow mismatch
- Water level in affected SG returns on scale before other SGs
- Water level in affected SG higher than other S/Gs
- SGBD rad-monitor (if not common)
- Main Steam Line rad-monitor
Obj-4 List the initial actions taken by the operator once the affected SG has been identified.

- Isolate the affected SG.
  1. Isolate Feedwater & AFW.
  2. Close MSIV.
  3. Raise Setpoint on Affected SG ASDV
- These actions help minimize radiological releases & prevent SG overfill.
- Isolating the affected SG also allows use of the non-affected SG for cooling down RCS.
Obj-5 Discuss the actions required to stop the primary-secondary leakage. Isolate the affected SG

- Cooldown RCS to saturation temp below affected SG pressure
- Depressurize RCS down to SG Pressure
- When pressurizer level is restored and SI termination criteria are meant stop SI pumps.
- Pressurizer level will slowly decrease as RCS depressurizes to SG Press and break flow stops
Obj-6 Discuss the problems associated with the following: Secondary-to-primary leakage, SG Overfill.

• Secondary to Primary Leakage
  – Dilution of primary (SD Margin)

• SG Overfill
  – Safety Valves and PORVs are not designed to pass water and may fail.
  – SG Lines fill with water to the MSIV and main steam line may fail.
Obj-7 List the principal systems & components affected by a loss of offsite power (LOOP).

- No RCPs – natural circulation cooldown required, slows recovery.
- No Steam Dumps to condenser – must use SG PORVs.
- Prz Sprays unavailable – must use Prz PORVs or Aux Spray (backup).
Obj-8 Discuss how plant cooldown and pressure control are accomplished with an SGTR and LOOP.

- Cooldown using SG PORV vs Stm Dumps
- Depressurize using PORV vs Normal or Aux Spray
OBJ-9 Discuss what affect the following events had on the SGTR transient at the Ginna Plant:

- Tripping of the reactor Coolant Pumps,
- Failure of pressurizer power-Operated relief valve,
- Automatic operation of letdown valves,
- Pressurizer relief tank failure, and
- Steam generator Safety Valve Failure.
The End