ENCLOSURE 2

ATTACHMENT 1

"Potential Lost Parts Analysis for Quad Cities Generating Station Unit 2 Installed Dryer Installation," GE-NE-0000-0035-4745-R2, Non-Proprietary, dated April 2005

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Potential Lost Parts Analysis

For Quad Cities Generating Station Unit 2

Installed Dryer Instrumentation

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Summary

The potential lost part(s) are from the various instrumentation installed on a newly designed replacement steam dryer for the Quad Cities Generating Station Unit 2. This evaluation addresses the safety and operational concerns for plant operation with the potential lost part(s) becoming real lost part(s) during a full operating cycle of 24 months.

This evaluation, conducted for the Quad Cities Generating Station Unit 2, concludes that safe reactor operation will not be compromised with the presence of the potential lost part(s) in the reactor vessel. There is no safety concern for flow blockage to the fuel bundles, interference with the control rod scram function, corrosion or adverse chemical reaction with other reactor materials, interference with nuclear boiler or neutron monitoring instrumentation, interference with MSIV, RWCU or RHR isolation valves, or interference with RHR pumps and heat exchangers. There is moderate operational concern related to an increased probability of fuel clad damage due to fretting, and partial bottom head drain plugging, all of which can be detected and mitigated through existing procedures. For bottom head drain plugging, monitoring the top and bottom head temperature prior to starting of an idle loop is recommended. There are no operational concerns relative to interference with operation of the RWCU pumps, heat exchangers, and filter demineralizers. There is no operational concern relative to interference with operation of the HPCI, RCIC, ERVs, Safety Valves or Target Rock SRV systems. It is recommended that the Station implement periodic monitoring (three times per week) of the dryer instrumentation. If there is any indication of a catastrophic failure of the dryer instrumentation (sudden loss of all instrument readings), the Station should enter the event into its corrective action program. The Station should take the necessary actions based upon the indications, which could be the shutdown of the unit to inspect the instrumentation. The possibility of the lost part(s) acting in conjunction with another lost part to cause or aggravate a safety or operational concern is considered an extremely low probability event and is not further evaluated.

1.0 INTRODUCTION

GE is designing and installing replacement steam dryers for Quad Cities Units 1 and 2. The first of these replacement steam dryers will have pressure sensors, strain gages and accelerometers installed in order to gather data for confirming the steam dryer design and collecting data to be used for GE and industry initiative with respect to fluctuating loads on steam dryers. This evaluation addresses the safety and operational concerns during plant operation with potential of lost part(s) from the installed dryer instrumentation.

2.0 LOST PART DESCRIPTION

The descriptions of the potential six lost parts are as follows:

- Outer hood and inner hood pressure sensors and mounting brackets –P8 & P27 [[

  ]].
- Inside dryer skirt pressure sensor – P23 (tubular shaped Inconel 600 material with maximum 0.43 inch diameter and minimum diameter of sheath cable being 0.0775 inch, for a total length of 7.45 inches. Cable insulation material is Magnesium Oxide).
- Accelerometers on top of the hood and on the skirt – A1 & A6 (Tubular shaped sensor with maximum diameter 0.62 inch and minimum diameter of sheath cable being 0.0775 inch, for a sub- total length of 8.34 inches mounted to a 0.79 inch thick 1.46 inches square block with a center mounted 0.91inch diameter cylinder that is 0.82 inch high. Overall total length of part is 9.8 inches. The part materials are, Inconel 600 with the exception of the cable insulation material, which is magnesium oxide).
- Instrument mast –[[

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Stainless steel and Inconel are ductile alloys such that brittle failure modes resulting in many small pieces are highly unlikely. Fatigue forces generally produce relatively long cracks without much branching, such that the production of very small pieces is unlikely. Likewise, impact damage, such as passing through the recirculation pump, would not generate small pieces such as would occur from shattering a brittle material.

3.0 SAFETY AND OPERATIONAL CONCERNS

The following safety and operational concerns are considered in this evaluation:

3.1 Safety Concerns

- Potential for Interference with Main Steam Isolation Valves,
- Potential for fuel bundle flow blockage and consequent fuel damage,
- Potential for interference with control rod operation,
- Potential for corrosion or adverse chemical reaction with other reactor materials,
- Potential for interference with RWCU or RHR isolation valves,
- Potential for interference with operation of the RHR pumps and heat exchangers,
- Potential for interference with the In Core Monitoring Instrumentation,
- Potential for impairment of HPCI, RCIC and SRVs

3.2 Operational Concerns

- Potential for fuel fretting,
- Potential for interference with operation of the RWCU pumps, heat exchangers and filter demineralizers,
- Potential for flow blockage of the reactor vessel bottom head drain,
- Potential for impairment of recirculation system performance.

4.0 ASSUMPTIONS

1. It is assumed that for the Atrium 9 fuel, the Lower Tie Plate (LTP) maximum opening is [[ ]], with the Upper Tie Plate (UTP) maximum opening being [[ ]]. It is assumed that the Atrium 9 fuel spacers would only pass objects smaller than [[ ]]. Exelon will verify these assumptions prior to applying this report.

2. Use of the term "approximate": If any of the data (e.g. dimensions) are reported as approximate and the exact value is not stated or known, the approximate data will be used. In these cases the dimensions have been judged to be non-critical, and the conclusions of this report would not be affected by variations within the expected range around the approximate value.

3. The possibility of the lost parts acting in conjunction with another lost part to cause or aggravate a safety or operational concern is considered an extremely low probability event and is not further evaluated. This is justified because the reactor environment is kept generally free of foreign material, and the lost parts volume is small enough that

they could not distribute throughout the reactor in sufficient concentration to act in conjunction with each other.

4. The following piping dimensions and configuration, will be verified by Exelon prior to applying this report:

   Main Steam – 20 inch schedule 80, ID 17.938 inches
   RHRSDC- 20 inch, 0.840-inch min wall
   RWCU - 6 inch schedule 80S, ID 5.761 inches
   HPCI steam feed - 10 inch schedule 80, ID 9.562 inches
   RCIC steam feed - 3 inch schedule 80, ID 2.90 inches
   Recirculation suction - 28 inch, 1.113 inches min wall

   RHRSDC comes off vertical recirculation pipe
   RHR heat exchanger tubes 3/4 inch OD 18 gage
   RWCU comes off top of horizontal RHRSDC pipe
   HPCI steam feed comes off top of horizontal main steam line
   RCIC steam feed comes off side of horizontal main steam line
   FW sparger 6 inch Schedule 40, with 1 1/4 inch holes in 56 places

Exelon will verify these assumptions prior to applying this report.

5. This evaluation does not consider the consequences of a lost part coincident with an accident or a transient.

5.0 POSSIBLE LOST PART MIGRATION PATHS

This section analyzes the transport of the potential lost part(s) in the reactor vessel and associated systems. This is used as input to the safety and operational evaluation in section 6. Transport involves weight, lift, and buoyancy forces on the components. Thus, if a part fell in a region where there is significant flow during reactor operation, the part might be lifted and carried by the flow.

It is assumed that if pressure sensor P27 and its mounting bracket become potential lost part it would drop down between the dryer banks "D" and "E" and remain in that position. Also, if the instrument mast gets separated and becomes a lost part it would stay on top of the dryer or between dryer banks and will not travel to a steam line or the reactor annulus.

The Potential lost part(s) could become dislodged from the various points of the steam dryer after it is installed in the reactor vessel. The possibility of the part(s) dropping in the annulus region, steam separator and traveling to steam lines will be considered. All parts are not expected to be able to migrate to all areas, because of their mounting location. For example,

only two parts are expected to migrate to the lower plenum, and only one of them may migrate to the upper plenum.

5.1 Migration Path from Steam Separator

Only the potential lost part P23 (located inside the dryer skirt) could be dropped onto the steam separator. It could potentially go into one of the steam separator tubes and drop past the turning vanes and migrate to the upper plenum area. The P23 part may alternately drop on the shroud head and then into the reactor annulus. None of the other identified potential lost parts could fall on top of the steam separator and migrate to the upper plenum. [[

]]. It could also drop into the bypass region where it will land on top of a control blade, but it cannot clear the gap between the blades and the fuel channel wall. [[

]]. Also, it could drop in the bypass region to the core plate area in the peripheral region, where it would most likely stay. The part may also stay on the top guide until the next outage and drop in an empty fuel cell during fuel shuffle. The potential lost part could just stay inside the steam separator area, but would most likely drop into the annulus, which is discussed below.

5.2 Migration Path from the Annulus Region

If the potential lost part(s) P8 and P23 pressure sensors and/or A1 and A6 accelerometers were dropped into the reactor annulus region, the part(s) would most likely come to rest on the jet pump support plate. Because the flow velocity in this region is low, the lost parts would likely remain there. None of the other identified potential lost parts are expected to migrate to the reactor annulus.

It is possible that the part(s) could be drawn into the recirculation suction line, pass through the recirculation pump, and then enter the lower plenum entrained in the jet pump drive flow. However, the diameter of the lost part(s) are smaller than the diameter of the jet pump nozzle (3.315 inches) and if it reaches the nozzle, it can pass through and into the jet pump. The part could also be drawn directly into the jet pump suction, also a likely path for entering the lower plenum.

In the lower plenum, the part could come to rest between the tubes penetrating into the lower plenum, or be swept over to the bottom head drain opening. The vertical components of the velocities in the lower plenum are up to 10 ft/s (Reference 1) and can lift the part, horizontally, toward a fuel support inlet orifice. The probability of the part negotiating a path

through the "forest" of control rod guide tubes (in a horizontal position) and finding the way to a fuel bundle orifice is small. Most likely, the intact part would settle out in a low flow area at the bottom of the vessel. Nevertheless, this possibility is evaluated. Because of the orientation of the side entry orifices on the fuel support piece, the part would have to align itself in a stable position in order to block the orifice. With the lift force on the part in a horizontal orientation and the turbulent flow in the area, the part will not be stable while blocking a side entry orifice. [[

]]

5.3 Migration path through the Steam Lines

The potential lost part(s) P8 and A1, mounted respectively on the side and on top of dryer bank "F", are the only two identified parts that might be expected to migrate to a steam line. They are mounted at a location between the steam nozzles; of the "D" and "C" steam lines. The flow on each side of a dryer outer hood is pulled into the nearest nozzle. Recognizing the flow field, the chance of a part from the top or side of the outer bank going upstream and moving across the dome to the other side is highly unlikely, because it would need to move against the gravity and against the strong flow field toward the nozzles. Therefore, it is highly unlikely that the potential lost part would enter the "A" or "B" steam lines. The potential lost part could enter the "D" or "C" steam line.

The possibility of the lost part(s) traveling in the RWCU, RHR, or recirculation lines is addressed in Section 6.0.

6.0 SAFETY AND OPERATIONAL EVALUATIONS

6.1 Potential for Interference with Main Steam Isolation Valves

The potential lost part(s) P8 pressure sensor and mounting bracket and/or A1 accelerometer could potentially enter the "D" and "C" steam lines. Even if these lost part(s) do get into a steam line, the safety concern is not significant because the main steam isolation valves (MSIVs) are redundant. The likelihood of blocking one valve and failure of the remaining valve to close is remote. Similarly, the likelihood of both valves to be blocked (multiple loose parts) is remote. The failure scenario is one isolation valve blocked by a part with another valve in a different line failing to close (single failure). Since the lost parts are smaller than these valves, significant obstruction is not likely, because if it does not hang up at a pipe fitting, it most likely will not stay in the valve. Therefore, it would not be

expected to interfere with the safety or normal operation of the valves such that valve closure would be impaired.

Therefore, it is concluded that there is no safety concern associated with the potential for blockage of the MSIVs due to the presence of the potential lost part(s).

6.2 Potential for Fuel Bundle Blockage and Consequent Fuel Damage

Consistent with assumption 3, the potential lost part(s) P23 and P8 pressure sensor and/or A1 and A6 accelerometers will not act together or with another lost part to block a single central fuel inlet. As noted above, the migration path of the potential lost part(s) to the lower plenum is possible through a jet pump suction opening from the annulus or through a jet pump nozzle.

Although highly unlikely, the flow in the lower plenum may lift a part to a fuel orifice (Reference 1). The A1 or A6 parts can pass through the central orifice, but not through the peripheral side entry or bottom entry orifices, [[

]]. If the orifice for a peripheral bundle is completely blocked, adequate cooling is expected by reverse flow from the lower tie plate bypass flow holes and the fuel channel clearances. If the potential lost parts A1 or A6 can position itself to block the side entry orifice of a high-powered bundle, the maximum percentage of area blockage would be less than [[ ]]. The A1 or A6 parts blockage of a lower tie plate would be [[ ]], which is much less than the [[ ]] blockage at the onset of boiling transition. The P8 and P23 parts blockage of the lower tie plate is even lower than the A1 and A6 blockage.

Analyses to determine the orifice and lower tie plate blockage necessary to cause boiling transition for GE14 and Atrium 9B fuels have been performed. The results of these analyses show that the highest power channel will experience the onset of boiling transition when the blocked area at the inlet orifice is [[ ]]. The maximum possible blockage at the inlet orifices due to a potential lost part area is less than that required to cause boiling transition.

Therefore, it is concluded that there is no safety concern for potential significant fuel bundle flow blockage and consequent fuel damage due to clad heat up.

6.3 Potential for Interference with Control Rod Operation

The potential lost part P23 may enter the bypass region from the upper plenum, if it passes through a steam separator tube. If the part gets to the bypass region, it would most likely land on top of a control rod blade. Since it cannot clear the gap between the blades and the channel wall, the part cannot cause binding of the control rod blades. The part may drop into a guide tube when the rod is fully withdrawn. If the part dropped into the guide tube, it would pass the velocity limiter and fall to the bottom of the guide tube where it would remain.

Therefore the potential lost part (P23 pressure sensor, the only one that could reach the upper plenum) will not interfere with the scram function of the control rods.

6.4 Potential for Corrosion or Adverse Chemical Reaction with Other Reactor Materials

Stainless steel and Inconel are used in many components in the reactor pressure vessel. Stainless steel and Inconel has been in the reactor environment for many years without corrosion or adverse chemical reaction with other reactor materials. The insulation material from the inside of the instrumentation cabling is magnesium oxide with no organic compounds. The total quantity of magnesium oxide [[ ]] is expected to be of no concern.

In the BWR NSSS system, the low conductivity demineralized water does not contain significant quantities of ions that would accelerate galvanic corrosion effects. In addition, stainless steel is used for many components in the NSSS and at many locations (for example, the Quad Cities 2 recirculation inlet and outlet nozzle safe ends) is directly welded to low alloy steel or carbon steel. These dissimilar metal welds have seen hundreds of reactor operating years that have included frequent inspections, and no evidence of accelerated general corrosion has been reported. Therefore galvanic corrosion is not a concern.

It is concluded that there will be no significant corrosion or adverse chemical reaction with other reactor materials from the potential lost part(s).

6.5 Potential for Interference with RWCU or RHR Isolation Valves

6.5.1 RWCU Isolation Valves

If the potential lost part(s) P8, P23, A1, and/or A6 enter the RWCU line, they may lodge in a fitting and will not reach the RWCU isolation valves. These valves are

redundant normally open isolation valves (inboard and outboard) that close during an accident such as a LOCA. If the potential lost part(s) enters the RWCU line, and do not hang up at a pipe fitting, like an elbow, it most likely will not stay in the isolation valve. Since these isolation valves are normally open when the part(s) could be lost and need to be closed during an accident such as a LOCA, a lost part could prevent the isolation valve from performing the complete isolation function as required. If the part hangs up in one valve and prevents full closure, the other valve would provide the isolation function.

Therefore, it is not expected that the potential lost part(s) would interfere with the safety or normal operation of the valves such that the valve isolation function would be impaired.

6.5.2 RHR Isolation Valves

The RHR isolation valves are redundant isolation valves (inboard and outboard) closed during normal operation and are open with flow through the piping when the system is in shutdown mode. The isolation valves close during a LOCA or drain down event.

The RWCU system is normally operating and taking suction from the vessel through the RHR line. Because of the large diameter of the RHR pipe compared to the RWCU line, the RHR line velocities (during normal operation) are too low to carry the lost part through the RHR piping.

If the part were drawn into the RHR line, and does not hang up at a pipefitting, it most likely will not stay in the valve. If the potential lost part(s) hangs up in one valve and prevents full closure, the other valve would provide the isolation function. Therefore, the potential lost part(s) are not expected to interfere with the safety or normal operation of the valves such that the valve isolation function would be impaired.

It is concluded that there is no safety concern associated with the potential for blockage of the RWCU or RHR isolation valves due to the presence of the potential lost part(s).

6.6 Potential for Interference with the In Core Monitoring Housing

The potential lost part(s) P8, P23, A1, and/or A6 could migrate into the lower plenum and with normal reactor flow and impinge upon the In Core Monitoring Housing (ICMH)

tubes. The impingement by these Potential lost part(s) would be of no consequence because of the small sizes of the potential lost part(s).

Therefore, there is no safety concern for the potential lost part(s) on the ICMH tubes.

6.7 Potential for Damage to the Fuel Due to Fretting

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]] from the lower plenum and there could be possible fretting wear of the fuel rods. If there were fuel-cladding leakage it would be detected by the off-gas system so that appropriate actions could be taken to maintain the off-gas radiation release within acceptable limits. All identified Technical Specification actions will be complied with as required. Additional information and recommended actions are provided in SIL Number 552, "Fuel Failures Caused By Metal Debris

Therefore, there is some possible damage to the fuel due to fretting, which is not a safety problem, but an operational concern.

6.8 Potential for Interference with Operation of the RWCU or RHR Pumps, RWCU or RHR Heat Exchangers and RWCU Filter Demineralizers

6.8.1 RWCU Pumps, Heat Exchangers and Filter Demineralizers

The potential lost part(s) P8, P23, A1, and/or A6 can migrate to an RWCU pump and may pass through without causing any pump damage. The RWCU pumps operate in parallel configuration and if a part reached a pump and caused pump damage, operation of the other pump will not be affected.

If a part did pass through a pump, it would then be discharged into a pipe leading to the associated heat exchanger, where it most likely would be trapped and cause minimal blockage. If the lost part passed through the heat exchanger tubes, it would collect on the filter demineralizer. Blockage at these locations would be similar to leaking tubes that are plugged or to the collection of corrosion products on the RWCU filter demineralizer. Because of the relatively large demineralizer area in comparison to the lost part area, the blockage would not be expected to change the demineralizer pressure drop.

6.8.2 RHR Pumps and Heat Exchangers

The RWCU system is normally operating and taking suction from the vessel through the RHR line. Because of the large diameter of the RHR pipe compared to the RWCU line,

the RHR line velocities (during normal operation) are too low to carry the potential lost part(s) P8, P23, A1, and/or A6 through the RHR piping to a pump.

Therefore, there is no safety concern for operation of the RHR pump and heat exchanger, and no operational concern for the operation of RWCU pump, heat exchanger, or filter demineralizers.

6.9 Potential for Flow Blockage of the Reactor Vessel Bottom Head Drain

If the potential lost part(s) P8, P23, A1, and/or A6 were to enter the lower plenum, they may migrate to the bottom head drain opening. The part(s) could enter the drain line opening. If the part partially blocked the bottom head drain line, lower temperature measurement in the drain line may indicate a line blockage. In addition, the temperature differences between the top and bottom of the reactor vessel would need to be monitored so as not to violate Technical Specifications if startup of an idle loop is desired.

Therefore, there is a slight possible operational concern for partial flow blockage of the reactor vessel bottom head drain, which may require additional monitoring of the bottom head drain line temperature and temperature difference at startup time of an idle recirculation loop.

6.10 Potential for Impairment of Recirculation System Performance

The potential lost part(s) P8, P23, A1, and/or A6 could be drawn into the recirculation system. In view of their size, the lost part(s) would pass through the recirculation pump, based on past experience where larger and heavier items have passed through the pump and the jet pump nozzles without causing damage. The lost part(s) are relatively small and are not expected to cause any detectable flow reduction in jet pump drive flow. Therefore there is no potential for recirculation system performance impairment.

6.11 Potential for Impact Damage on Reactor Internals

Potential lost part(s) (P23 pressure sensor and/or A6 accelerometer) could migrate into the lower plenum through the jet pumps. The high downward velocity component in the jet pumps will tend to drive the parts to the bottom of the lower plenum. The factor that will determine whether the part will sweep up off the bottom is dependent on the radial component of the velocity. These radial velocities are approximately 7 ft/s at the periphery and drop significantly approaching the center and bottom of the vessel, which causes parts to initially be pushed toward the vessel center where they would be expected to remain.

The lost parts could lodge in the shroud support legs or between 4 CRD stubs and an incore instrument housing, where there is essentially no clearance.

Except for the nuclear instrument guide tubes, the components at the bottom of the lower plenum are relatively thick and are not expected to wear through. Therefore fretting wear by lost part(s) is less likely to occur in the lower plenum. The nuclear instrument guide tubes are vulnerable to fretting, but they do not form a pressure boundary in the lower plenum.

The impingement by the these part(s) on the shroud, shroud hardware, recirculation lines, jet pump assemblies, jet pump instrumentation lines, core spray piping, and other reactor internals would normally be of minimal or no consequence because of the relative small size of the part(s). In rare cases, a part may become stuck or trapped in an area like a jet pump nozzle or the jet pump assembly and cause wear of the equipment hindering its expected performance. Performance deterioration would not be a safety issue and would be something that can be monitored so that corrective action could be taken if necessary. There are no thermal consequences due to a fretted hole in the jet pump nozzle during normal operation because the water is at the same temperature as the downcomer.

Therefore, the lost part(s) are not expected to cause significant damage to the reactor internals or to negatively impact safe shut down and offsite dose.

6.12 Potential for Interference with HPCI, RCIC and SRV Operation

The potential lost part(s) P8 and/or A1 accelerometer could potentially enter the "D" or "C" steam lines. Since the HPCI taps off the "B" and RCIC taps off the "A" main steam lines, the potential for the lost parts to enter the HPCI and RCIC steam lines and interfere with system operation must be addressed. It is unlikely for the potential lost part(s) to enter the "A" and "B" main steam lines. During normal operation both systems are idle, so there is no flow to draw the lost parts into the system piping. If the systems were initiated, the initiation signal would be coincident with or would follow a reactor scram signal. The flow in the main steam line will fall off rapidly following scram, which will allow the potential lost parts to settle out on the bottom of the steam line. In addition, the HPCI and RCIC steam demand is controlled to allow the systems to come up to speed without tripping. This ramping of the steam demand will also provide time for the parts to settle out. The HPCI steam line is connected to the top of the main steam line and it is unlikely that the HPCI steam flow will be sufficient to draw the lost part(s) up from the bottom of the main steam line. Similarly, the RCIC steam line is a small pipe connected to the side of the main steam line and it is unlikely that the RCIC steam flow will be sufficient to draw the small parts up from the bottom of the main steam line. The ERVs, Safeties and Target Rock Safety Relief Valves (SRVs) come off the top of the steam line and the steam is stagnant during normal operation. It is unlikely that the lost part(s) will be lodged in the relief valve

inlet or get sucked in. Because of the flow velocity in the steam lines, it is unlikely that the part will be at rest under the inlet waiting to be pulled into valves.

Therefore, the potential lost parts are not expected to interfere with HPCI, RCIC or SRV operation.

7.0 CONCLUSION

This evaluation, conducted for the Quad Cities Generating Station Unit 2, concludes that safe reactor operation will not be compromised with the presence of the potential lost part(s) in the reactor vessel. There is no safety concern for flow blockage to the fuel bundles, interference with the control rod scram function, corrosion or adverse chemical reaction with other reactor materials, interference with Nuclear Boiler or Neutron Monitoring Instrumentation, interference with MSIV, RWCU or RHR isolation valves, or interference with RHR pumps and heat exchangers. There is moderate operational concern related to an increased probability of fuel clad damage due to fretting, and partial bottom head drain plugging, all of which can be detected and mitigated through existing procedures. For bottom head drain plugging, monitoring the top and bottom head temperature prior to starting of an idle loop is recommended. There are no operational concerns relative to interference with operation of the RWCU pumps, heat exchangers, and filter demineralizers. There is no operational concern relative to interference with operation of the HPCI, RCIC, ERVs, Safety Valves or Target Rock SRV systems. It is recommended that the Station implement periodic monitoring (three times per week) of the dryer instrumentation. If there is any indication of a catastrophic failure of the dryer instrumentation (sudden loss of all instrument readings), the Station should enter the event into its corrective action program. The Station should take the necessary actions based upon the indications, which could be the shutdown of the unit to inspect the instrumentation. The possibility of the lost part(s) acting in conjunction with another lost part to cause or aggravate a safety or operational concern is considered an extremely low probability event and is not further evaluated.

8.0 REFERENCES

1. "Consequences of a Postulated Flow Blockage Incident in a Boiling Water Reactor", NEDO 10174, Rev. 1, October 1977.