BWROG-TP-12-013
Revision 0
August 2012

Containment Accident Pressure Committee

Task 5 – Effects of Non-Condensible Gases on Seals (CVDS Pump)

Author:	Ankur Kalra (Sulzer Pump)
Project Manager:	Kenneth Welch (GEH)
Committee Chairman:	John Freeman (Exelon)

INFORMATION NOTICE

BWROG Utility Members	
CENG – Nine Mile Point	Chubu Electric Power Company
DTE – Fermi	Chugoku Electric Power Company
Energy Northwest – Columbia	Comisión Federal de Electricidad
Entergy – FitzPatrick	Hokuriku Electric Power Company
Entergy – Pilgrim	Iberdrola Generacion, S.A.
Entergy – River Bend/Grand Gulf	Japan Atomic Power Company
Entergy – Vermont Yankee	J-Power (Electric Power Development Co.)
Exelon (Clinton)	Kernkraftwerk Leibstadt
Exelon (D/QC/L)	South Texas Project
Exelon (Oyster Creek)	Taiwan Power Company
Exelon (PB/Limerick)	Tohoku Electric Power Company
FirstEnergy – Perry	Tokyo Electric Power Company
NPPD – Cooper	
NextEra – Duane Arnold	
PPL – Susquehanna	
PSEG – Hope Creek	
Progress Energy – Brunswick	
SNC – Hatch	
TVA – Browns Ferry	
Xcel – Monticello	

Executive Summary

This BWROG Technical Product provides an evaluation of the effect of non-condensable gases which come out of solution and migrate to a pump seal purge piping. The evaluation is based on the seal purge piping arrangement of the Monticello RHR pump (model CVDS).

Implementation Recommendations

This product is intended for use to address (in part) issues raised in the NRC Guidance Document for the Use of Containment Accident Pressure in Reactor Safety Analysis (ADAMS Accession No. ML102110167). Implementation will be part of the BWROG guidelines on the use of Containment Accident Pressure credit for ECCS pump NPSH analyses.

Benefits to Site

This product provides a technical response to the NRC concerns raised in the reference document above about the potential pump seal damage resulting from gases which come out of solution and migrate into the pump seal purge piping.

SULZER

QUALITY LEVEL

- ☐ Direct
- ☐ Indirect

SULZER PUMPS (US) INC. DOCUMENT

DOC. NO: E12.5.1913

ORDER NO:

TITLE: Task 5 – Effect of Non-Condensable Gases on Seals
Sulzer Pumps (US) Inc.
Monticello - 12x14x14.5 CVDS RHR Pump

ASME CODE SECTION

CLASS NO.

CODE EDITION (YEAR)

SEASON YEAR

CUSTOMER GE-HITACHI Nuclear Energy Americas LLC

PROJECT Monticello Nuclear Power Station, Monticello, MN

CUSTOMER P.O. NO. 437054820

CONTRACT NUMBER

SPECIFICATION NO.

ITEM / TAG NUMBER

CUSTOMER APPROVAL NUMBER:

SPACE FOR CUSTOMER APPROVAL STAMP
(when applicable/available)

CUSTOMER APPROVAL REQUIREMENT

☐ Yes ☐ No ☑ Information Only

CERTIFIED AS A VALID SULZER PUMPS (US) INC. DOCUMENT

☐ For Outside Vendor

☒ For Manufacture at Sulzer Pumps (US) Inc.

☐ Risk Release Inspection Report # ______

☐ Other (specify) ______

APPROVALS (SIGNATURE)		Date
Engineering	[signature]	04/23/12
Quality Assurance		

CERTIFICATION (when applicable)

This Document is certified to be in compliance with THE APPLICABLE PURCHASE ORDER, SPECIFICATIONS, PROCEDURES, AND ADDITIONAL REQUIREMENTS LISTED IN THE APPENDICES.

______
Professional Engineer

______ ______
State Registration No.

Date ______

Originating Dept: Advance Engineering

By: Ankur Kalra

Title: Hydraulic Design Engineer

Date: 11/7/2011

APPLICABLE S.O. NUMBERS:
100072780

DOCUMENT IDENTIFICATION	Rev.
E12.5.1913	0

TABLE OF CONTENTS

1.0 PURPOSE

The purpose of this report is to evaluate the potential impact of the evolution of non-condensable gases on the mechanical seals of Monticello RHR pumps.

2.0 BACKGROUND

Dissolved gases are present in water depending on the fluid temperature, gas solubility, pressure, and duration of contact. For extended time duration, the gas and liquid will come to an equilibrium state according to Henry's Law. As a liquid passes through a centrifugal pump, the reduced pressure at the pump inlet can result in some of the dissolved gas coming out of solution as gas bubbles. Since the pump seals are continuously cooled using flush water from the pump discharge, the flush water will contain small amounts of gas bubbles. In addition, it is also possible that air bubbles can migrate within the pump casing into the pump seals.

3.0 SCOPE

The following are evaluated in this report.

- Froude number and critical flow calculation are used to determine the possibility of bubble accumulation in the discharge end and mechanical seal piping.
- Mechanical seal flush piping orientation, seal flush, and internal bearing flush injection system's role in permitting entrained air to accumulate in the stuffing box region of the pump.

4.0 ANALYSIS

This report evaluates the potential for the accumulation of the non-condensable gases at the mechanical seal faces that could cause the lack of lubrication and cooling of the seal faces leading to damage and eventual seal failure. To predict gas accumulation it is important to understand the piping configuration and the flow characteristics of the two-phase (liquid along with the entrained gas) fluid. Figure 1 shows examples of two phase flows. The Froude number, a ratio of inertial force on a liquid to gravitation force, is a useful parameter for predicting non-condensable gas dynamics in a fluid carrying duct.

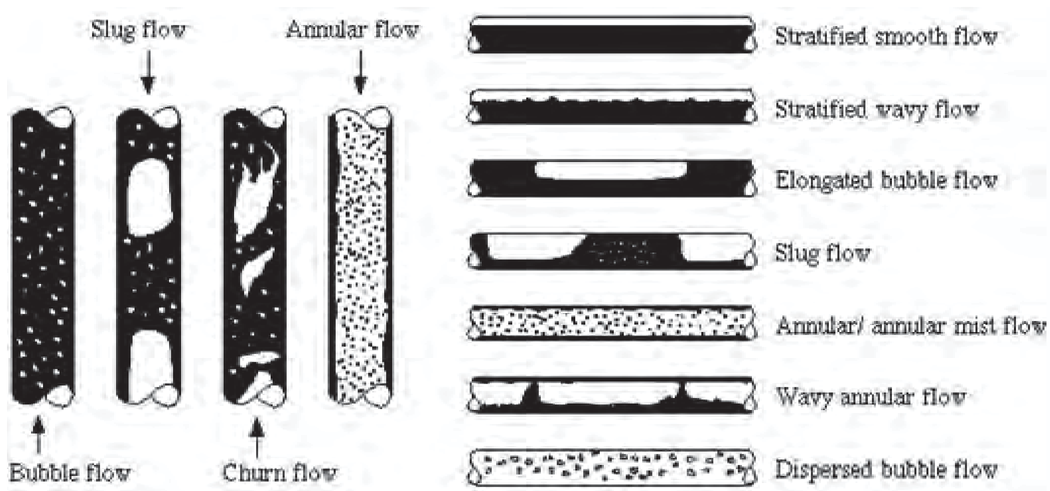

Figure 1: Entrained Air in Pipes [Ref 1]

4.1 According to BWROG, The suppression pool water is normally at a range of [[ ]] to [[ ]] and is at equilibrium with the suppression pool air space, which is composed of [[

]]

4.2 In the case of the Monticello RHR pumps the mechanical seals are lubricated and cooled by pumpage (flush) that is tapped off from the discharge nozzle (See Fig. 2). Water at high pressure enters the cyclone separator where any debris in the flush is separated out.
A Froude number calculation for the discharge and the seal piping can show if the bubbles trapped in the fluid will travel through the mechanical seal flush piping and reach the internal bearings. It is important to note that;

Froude number (Fr) > 1 → Supercritical Flow

Froude number (Fr) < 1 → Subcritical Flow

According to several studies done on bubble propagation in circular water pipes it is found that in a supercritical flow a bubble will travel with the fluid in its direction of flow [4]. In other words, bubble/entrained air will not stagnate and accumulate which may block the flow path. Following is a calculation of the froude number for the RHR pump discharge side.

$Froude(Fr) = V / \sqrt{g \times D}$ Where, → Equation 1 [5]

V = Flow velocity, ft/sec
g = Acceleration due to gravity = 32.2 ft/sec^2
D = Pipe ID, ft
For RHR Pump, discharge ID is [[ ]]

$$FlowVelocity(V) = \frac{FlowRate}{Cross - SectionalArea},$$

At the flow rate of [[ ]], and cross sectional area of [[ ]],

V = [[ ]] and Fr = [[ ]].

In case of RHR pump mechanical seals, pipe used is [[ ]], with an ID of [[ ]].

Flow is typically [[ ]], which is [[ ]]

and $Cross - SectionalArea = \frac{\Pi \times D^2}{4}$ = [[ ]]

V = [[ ]] and Fr = [[ ]].

Since Fr is above 1 the flow is supercritical in both the discharge and the mechanical seal piping. This shows that bubbles will not accumulate in the piping and block the flow of flush through the discharge end or the mechanical seal piping.

In addition to the above calculation, another equation derived from experimental tests predicts the flow below which the air bubbles will accumulate in the discharge piping and the seal piping. This flow is called the critical flow (Qc).

$$Q_c = 0.38 \times (D)^{\frac{5}{2}} \times g^{\frac{1}{2}}$$ → Equation 2 [4]

Where,
D = Pipe ID, in
g = 32.2 ft^2/sec

Using the above equation, critical flow for the discharge piping equals [[ ]] and for the seal piping [[ ]]. Hence, blockage of flow due to bubble accumulation is possible if flow rate in the discharge piping falls below [[ ]] or below [[ ]]in the seal piping. The expected flow through the discharge piping is [[ ]] and seal piping is [[ ]], both of which are well above the critical flow values.

4.3 After passing through the mechanical seal flush piping, entrained air would reach the internal bearings. However, due to the vertical orientation of the pump and the seal, the less dense entrained air entering from point A (See Fig 3) would rise up in the stuffing box outlet to connection point B located above the seal faces and exit to the pump suction. Arrows (Fig 3) show anticipated bubble flow path.

4.4 As long as the flush flow is above the critical flow, the possibility of air accumulation in the seal piping is not present. Also, stagnation or accumulation of air around the seal faces is unlikely due to the orientation of the seal and the location of the stuffing box outlet B. Therefore, due to the above reasons the likelihood of the seals running dry is negligible.

[[

]]

Figure 2: Monticello - RHR Mechanical Seal Layout

[[

]]

Figure 3: Mechanical Seal Connections

5.0 RESULTS AND CONCLUSIONS

Two methods; Froude Number and Critical Flow calculations indicate that air bubbles will not stagnate and accumulate in the seal piping. The vertical orientation of the pump and the location of the flush inlet and outlet on the seal stuffing box significantly reduce the possibility of air accumulation in the vicinity of the mechanical seals.

Some of the concerns, regarding air entrainment in mechanical seals, raised in the NRC guidelines can be addressed through this report.

a) Entrained air released due to NPSH margin reduction – As explained in this report, the vertical setup of the mechanical seal system will flush out the bubbles, and therefore, as long as a minimum flow through the mechanical seal piping is maintained, the possibility of void fraction accumulating at the seal faces is negligible.
b) Use of Dual Mechanical Seals – For a vertical mechanical seal setup with seal flush outlet located at the top of the seal, dual mechanical seals with external flush system will not provide an additional benefit. Vertical setup ensures constant flushing of the seal faces.
c) Excessive entrained air centrifuged inward to the shaft – Forced lubricated bearings are located between the impeller inlet and the mechanical seals. This high pressure liquid will prevent any bubbles to flow from the impeller inlet to the mechanical seal faces.

Therefore, the entrained air that may be present in the suction line of the RHR pumps following a LOCA has no significant impact on the performance of the mechanical seals.

6.0 BIBLIOGRAPHY

[1]: Gas entrainment at a propagating slug front, Ruben Shulkes, Hydro Oil and Energy

[2]: Centrifugal Pumps, Johann Gulich, 2nd Edition.

[3]: Centrifugal Pumps Book, Stepanoff.

[4]: Air in Water Pipes, A manual for designers of spring supplied gravity driven rural water delivery system, Gilles Corcos, 2nd Edition.

[5]: Froude Number, Wikipedia, http://en.wikipedia.org/wiki/Froude_number

[6]: Henry's Law Calculation. http://www.engineeringtoolbox.com/air-solubility-water-d_639.html