(NR)

From: Stuart Rubin (RES)
To: Joseph Muscara
Date: Tue, Feb 26, 2002 1:53 PM
Subject: Fwd: Air Ingress Questions from George Lanik on White Paper Review

FYI

CC: Amy Cubbage; Donald Carlson; Undine Shoop; Yuri Orechwa

T/51

From: George Lanik
To: Stuart Rubin
Date: Tue, Feb 26, 2002 1:40 PM
Subject: Air Ingress Questions

Stu,
I looked at the PBMR system for potential air ingress and water ingress. Attached is a copy of the file of air ingress considerations you might want to consider. Since I was not present at any of the prior meetings which discussed PBMR concepts or the training sessions, some of these questions may have already been answered to NRC staff satisfaction. As you informed me in earlier discussions, the system is complicated by the concentric configuration of the piping and the implications for break locations and propagation. Let me know if you need more on this or if I can contribute in other ways.
Thanks,
George

CC: Charles Ader; John Flack; Jose Ibarra

Potential Air and Water Ingress Scenarios in PBMR

prepared by George Lanik

REAHFB/DSARE/RES

System Characteristics With Potential to Impact Air Ingress

It is argued that the PBMR reactor is protected from air ingress by the so-called "diving bell" characteristic. Helium is lighter than air and the flowpaths to the core enter the reactor vessel at the bottom; consequently, the helium will tend to stay inside the reactor vessel, preventing air ingress. The argument continues that air ingress to the graphite core via natural circulation is delayed until sufficient air diffuses into the core. Discussions of this phenomena generally refer to a condition where the geometry is like an inverted manometer with the helium, which is significantly lighter than air, trapped in the upper part and air diffusing in from below.

The attached figure shows relative system elevations (not necessarily to scale) and locations of various heat sinks (coolers) of the PBMR piping. Note, the actual piping of the PBMR is pipe within a pipe (concentric) with hot gas on the inside and cooler gas on the outside. The attached figure was an attempt to lay this out in a linear fashion to better visualize the flow path and elevations.

A potential concern is that differential heating and cooling, perhaps combined with a "loop seal" formed by dense air in a low point in the piping could create a mechanism for induced flow of air into the core. Unexpected behavior of "loop seals", relatively simple piping configuration problems, and unanalyzed temperature differences had been major factors in the TMI accident, the Brown's Ferry partial scam failure events, and other risk significant events. Given the limited experience with the gas flow characteristics of the PBMR reactor, lessons learned from past experience could be relevant.

It is not obvious that the "diving bell" characteristic or the inverted manometer with equal pressure at the bottom openings of the hot leg and cold leg is always the correct assumption. Given the complicated piping system of inner and outer pipes, and the large elevation differences within the piping system, these factors need to be addressed.

The following questions relate to potential air ingress scenarios:

What primary system rupture locations present the potential for the most air ingress to the core?

Following a rupture of the primary system, temperatures within the primary system could range from very high in the core to near ambient within heat exchangers (coolers). Is air ingress increased in some scenarios due to these temperature differentials.

Cold air collecting at a low point in the power conversion unit (PCU) and creating a "loop seal" might result in a configuration where cooling of the helium in the PCU would result in a mechanism to displace helium from the core more quickly than would be the case with simple diffusion. Have all potential scenarios related to heat sinks and "loop seals" been considered when analyzing for air ingress?

Have the implications of a break in the CCS piping been thoroughly considered, including the impact of the heat exchangers in the CCS?

What are the potential impacts on air ingress to the core of pressure changes within the citadel as a result of opening or closing rupture disks and blow out panels following a pressure boundary rupture accident? Does the elevation of the rupture disc and blow out panels impact air ingress potential?

Given a pipe break, forced circulation could introduce air into the core quickly. Once air is introduced into the core, the "diving bell" characteristic is no longer applicable. Continuation of pumping action by the system turbo-compressors following a system rupture could potentially introduce air during turbo-compressor coast-down. Also, spurious equipment operation or inappropriate operator actions could pump air through the system through inadvertent start of the SBS or CCS electrically powered blowers. Design features to prevent these scenarios may be needed.

Questions related to potential equipment operation:

What is the potential for introduction of air to the core following a system rupture due to continued pumping action due to coast-down of the turbo-compressors.

What is the impact of inadvertent or spurious operation of pumps and valves in the power conversion unit on potential air ingress scenarios?

What interlocks and permissives prevent start of the startup blower system helium circulator?

What interlocks and permissives prevent start of the core conditioning system helium circulator?

Questions related to potential for inappropriate operator actions:

What specific operator actions are required to respond to pressure boundary ruptures at different locations?

What instrumentation is available to operators to determine the status of system pressure boundaries?

What are the potential improper operator actions in response to air ingress accidents which could result in larger volumes of air ingress? Could these actions include inadvertent start of the CCS or SBS blowers.

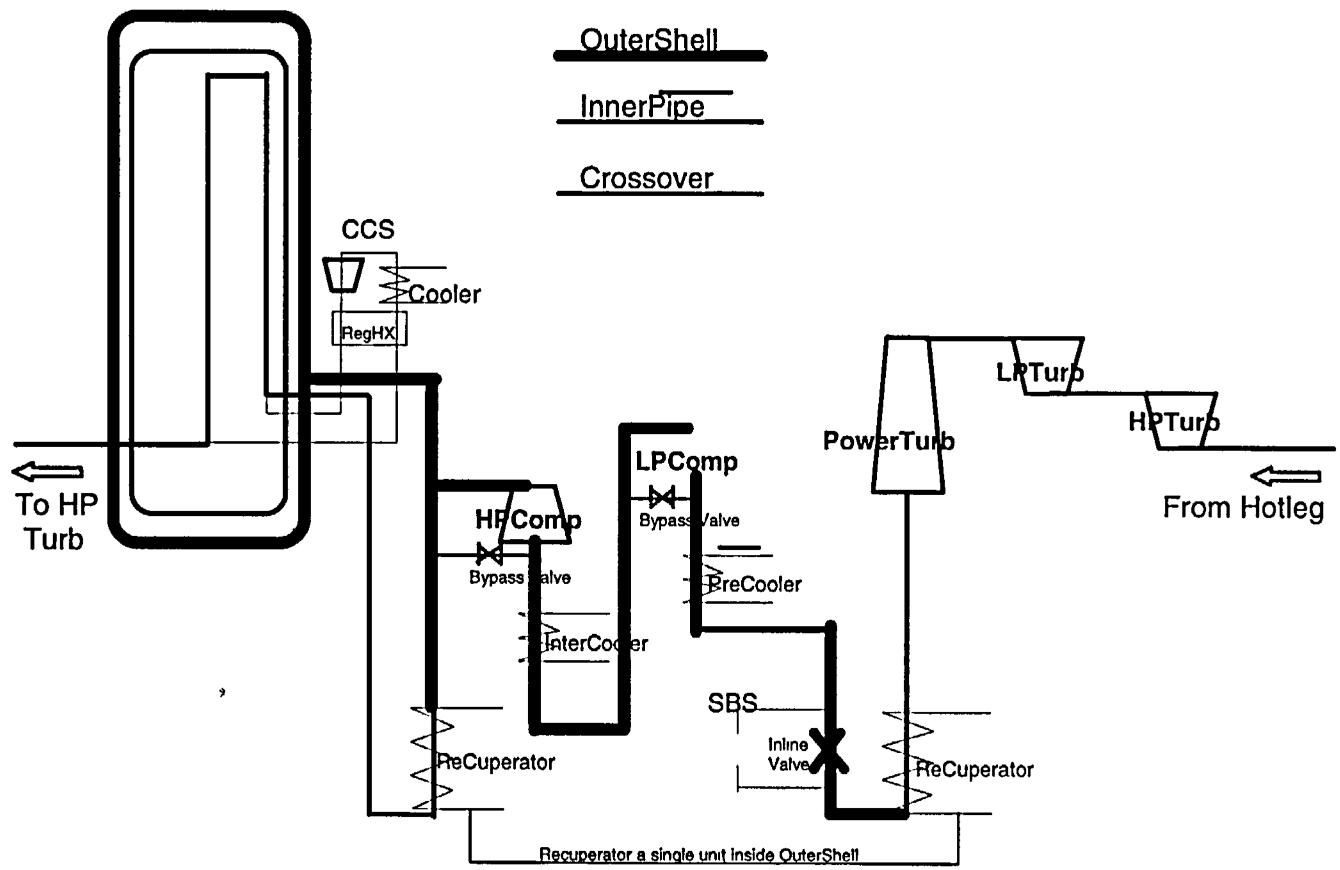
Do operator actions vary depending on the location and size of the primary system rupture location? And what is the potential for increased air ingress if the operator responds to the wrong scenario ?

System Characteristics With Potential to Water Ingress

Water is present in the primary system turbo-compressor coolers and the CCS heat exchanger. During normal operation, the helium pressure is higher than the water pressure in the coolers so that leakage would occur from the helium system to the water system. Also, the elevation of the turbo-compressor coolers is below the active part of the core. However, previous experience with Ft. St. Vrain water ingress events indicates that the potential for water ingress may still need to be addressed.

What operating limits are placed on primary system water vapor or humidity measures; and what instrumentation is available in the primary system to detect water ingress?

What provisions exist during low helium pressure conditions in the primary system to prevent or limit water ingress in the event of rupture of cooler or heat exchanger water line?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