Health Physics Problems of Power Operation with Failed Fuel

Alan Orchard, Sizewell B Power Station, England

INTRODUCTION.

Sizewell B Power Station is one of the most modern PWR stations in the world and is generally regarded as having some of the best safety design features of any nuclear power station. It is also probably one of the most monitored plants in the world, providing one of the most powerful tools available to the operational Health Physicist. This is the Engineering Computer System (ECOS). The ECOS computer records readings from around 20000 different sensors around the plant every two seconds. Of immediate interest to the Health Physicist are the area gamma radiation monitors, containment activity levels, stack activity levels and activity levels in HVAC ducts. But also available is information about system temperatures, pressures, tank and sump water levels, valve positions and pump running states. All of this information is available live time or can be retrieved for historical review.

Figure 1 shows a typical output from the ECOS system. In this case, the large peak corresponds to the release of noble gas activity into the HVAC ducting during sampling of the Reactor Coolant System. By placing the two cursors at different locations on the chart it is possible to interrogate plant parameters at any given instant. It is also possible to superimpose several plant parameters on the same time scale.

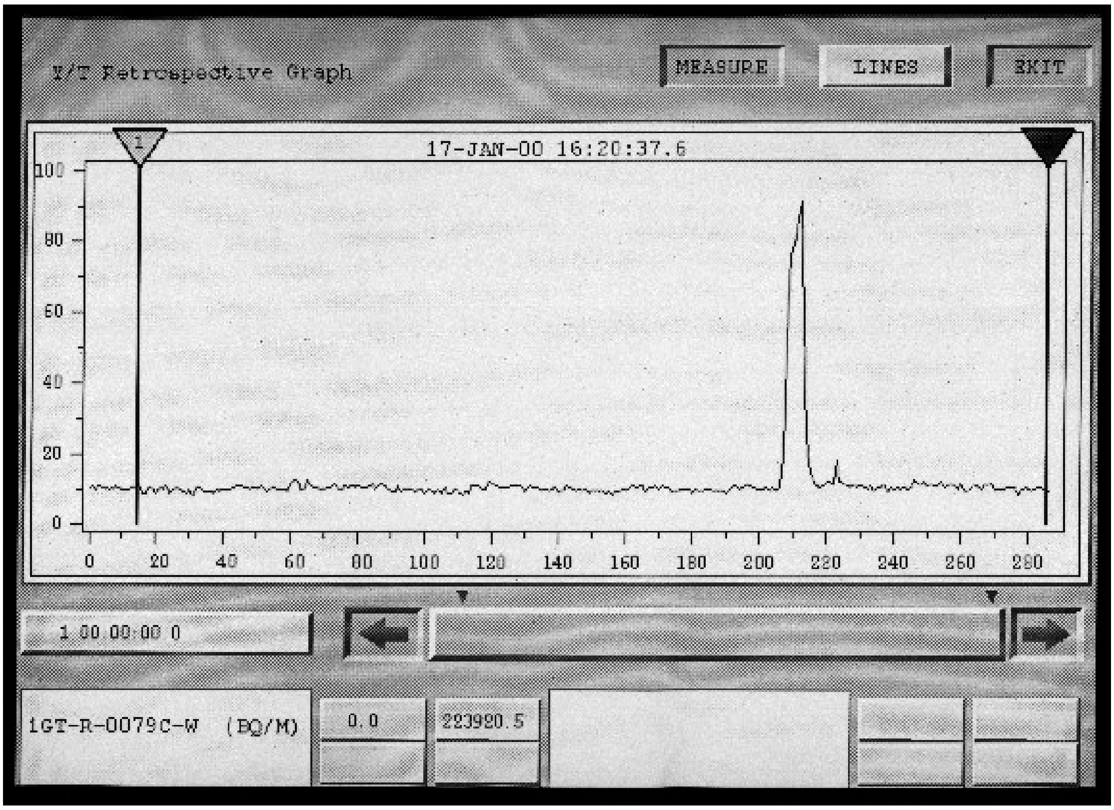

Figure 1

On several occasions this has proved invaluable to the Health Physics staff in understanding what occurred during some event. However the diversity and redundancy of the safety systems, together with some of the conservatisms that the designers made have led to some abstract operational difficulties. This paper describes one such difficulty that has been experienced at Sizewell B.

RADIOLOGICAL MONITORING.

The sub-sets of ECOS that deal with Radiological Monitoring are known as the Process & Effluent Activity Monitoring System (PEAMS) and the Health Physics Instrumentation System (HPIS). The role of the PEAMS is to provide the necessary information to allow monitoring and control of the flow of liquid and gaseous streams containing radioactive materials resulting from normal operations. It will also initiate automatic termination of discharges which exceed specified limits. The requirements of the PEAMS can be further identified, for individual monitors, as satisfying one of the following categories:

i) System monitoring – general monitoring associated with specific equipment within a system and contributing to the condition monitoring of that system.

ii) Limits of Operation Monitoring (LOOM) –monitoring to provide assurance that the station is operating within safe limits.

iii) Post-fault monitoring – Direct monitoring of nuclear safety functions and systems which are significant to nuclear safety.

The alarm set point for an individual instrument was derived depending on which of these three categories was being fulfilled by the instrument. For instruments in the first category the alarm set point was defined by the designer as 'the lesser of 10 x the best estimate specific activity or the conservative specific activity' during normal operation.

These instruments have proven to be very sensitive and have frequently provided the operator with early indication that a plant parameter is drifting off normal. The problem with this approach however, is 'what do you do when an alarm initiating fault cannot be resolved until a plant outage'. As is the case when operating with minor fuel pin defects.

AUXILIARY BUILDING HVAC.

The HVAC system at Sizewell B contains radiation monitors for particulate, halogen and noble gas specific activity. The intention is to alert the control room staff to an abnormal condition, which is giving rise to a potential radiological hazard in an area to which staff have access. However, the HVAC systems also provide forced ventilation to tanks and sumps and this led to the first problem that Sizewell B experienced following minor defects occurring in a single fuel assembly.

Shortly after the occurrence of the fuel pin failures the noble gas channel of Auxiliary Building HVAC radiation monitor started to alarm on high activity. Exhaustive surveys failed to locate elevated levels of noble gas in any of the rooms where systems connected to the primary circuit were located. The surprising thing was that this alarm always seemed to go off at about the same time and on the same days of the week. This prompted an investigation to determine what operation was occurring at these times.

During routine sampling of the reactor coolant, the sample line is left to run for several minutes to ensure that the sample lines are well flushed and that the samples are representative. The sample line runs to a sump in the basement of the Auxiliary Building and the sump is then pumped to the radwaste building for treatment. It was quickly realised that during this routine the entrained noble gases were being released into the sump and then being swept directly into the HVAC. Because of the direct collection of the activity into the HVAC system there was no dilution occurring in the much larger volume of the building rooms. Typical levels in the HVAC during sampling were around 40 kBq/m^3. This is less than one DAC in the duct and with negligible leakage into the building did not in itself present any hazard to personnel on the station.

Later on as the levels of noble gas in the RCS increased, the background level of noble gas in the HVAC also increased. Soon we found that the alarm would also initiate at the weekends and last for exactly four hours. This coincided with a routine operations surveillance to test the emergency exhaust system. During this test the HVAC is realigned through charcoal filters and the flow falls to approximately half the normal flow. The effect of this was that with a constant release of activity into the HVAC the specific activity would double in the reduced flow and this caused the alarm to be initiated. The final straw came when the standing level of activity in the HVAC exceeded 70% of the alarm set point. The monitor is set such that the alarm will only reset after the activity drops to 70% of the alarm set point. Now when the instrument went into alarm due to either sampling or emergency exhaust testing we not able to reset the alarm when the levels dropped back.

Also station personnel were starting to divide into two factions. Some were genuinely concerned about high radiation alarms at the entrance to the Auxiliary Building and required reassurances about the radiological hazard. Others were becoming nonchalant to the alarm leading to concerns that they would fail to take appropriate action should the alarm be initiated by some other event. Eventually the situation was resolved by increasing the alarm set point for the instrument. Unfortunately this was not the end of our problems.

It was easy to understand why there were peaks of activity in the HVAC during sampling and during the emergency exhaust surveillance test but we were struggling to explain why the background level was increasing in the interim periods. Most attention was focused around the area in the auxiliary building associated with the Chemical & Volume Control System. This suite of rooms is situated at the 6.5m level at the north end of the building. Despite several surveys and attempts to take grab samples of the air in these rooms for gamma spectrometry analysis, no significant levels of noble gas were detected.

PERSONAL CONTAMINATION EVENTS.

At Sizewell B, in common with most of the UK nuclear industry, the radiological controlled area (RCA) is considered a clean area with small areas where contamination controls are exercised. This means that for most of the radiological controlled area, plant personnel wear either the normal clothes or personal coveralls, and these are not removed at the exit from the RCA. At about the same time as we were experiencing the high levels of noble gas in the HVAC, we were using large quantities of borated water. This meant that the operations staff were spending a significant amount of time batching fresh boric acid solution to replenish the boric acid storage tanks (BATs). We soon found that we were experiencing a large number of incidents where these people were bringing up the contamination alarms on the RCA personnel exit monitors. The contamination was characterised as covering the whole body and with a short half-life. Clearly the noble gases were present in this room but where were they coming from. The obvious suspect was the nuclear sampling suite in the adjacent room. However, tests established that the HVAC was balanced in such a way that the sampling room was at a slightly lower pressure than the BATs room. Also there was no indication of noble gases in the sampling room.

Typically the batching was carried out on the night shift. Despite several surveys by the Health Physics staff on the morning following these events we were never able to identify any noble gas in the batching room. This seemed to point to the batching process but this involved dissolving fresh boric acid into water from the Reactor Make-up Water Supply. This water in clean reactor grade water, and as we do not run evaporators at Sizewell B is not even contaminated by tritium.

The final piece to the jigsaw fell into place when we were mixing up a batch of lithium hydroxide in the chemical addition tank room. Again an operator became contaminated with noble gases.

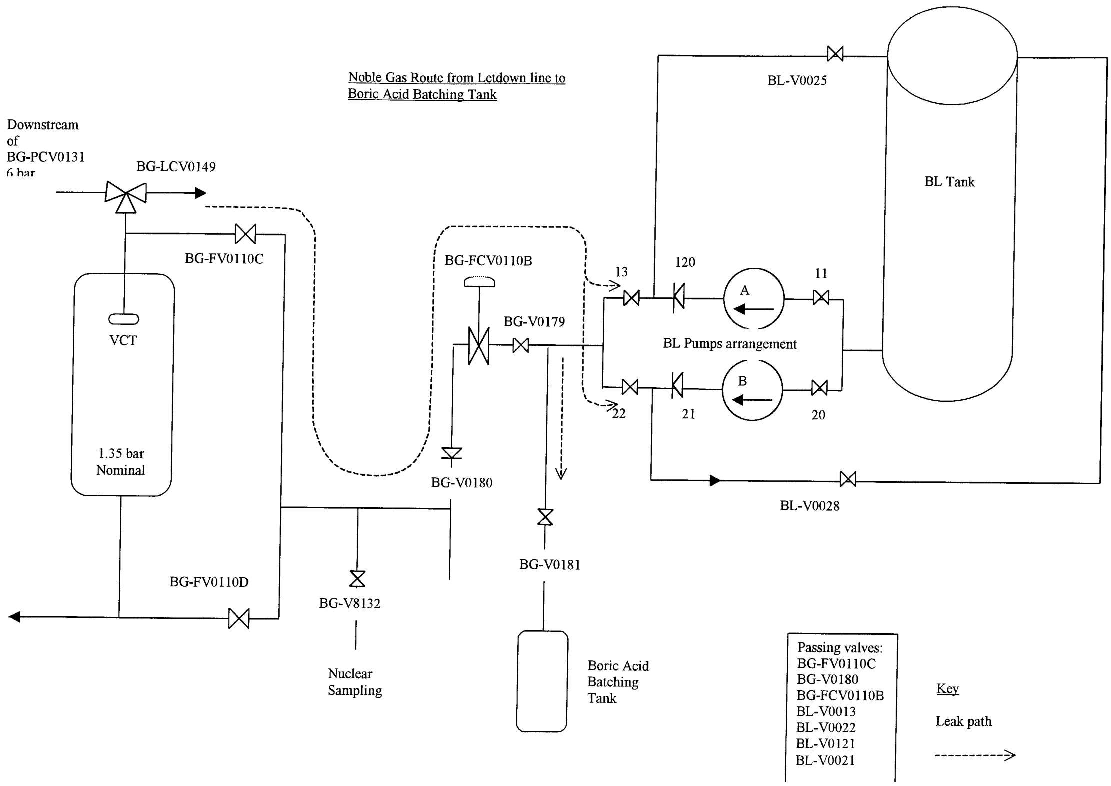

Figure 2

This clearly pointed to noble gas in the reactor make-up water. The activity was degassing into the tanks and was being expelled into the room as water was added to the tank during the batching process. Now that we knew where the noble gas was coming from it was only a short time before we were able to demonstrate that a non-return valve on the make up line from the water store to the CVCS was passing slightly. We now knew how noble gas from the reactor coolant was getting out of the containment building, into a ‘clean’ water system and ultimately into the rooms where operators were working. This is shown in figure 2.

ACTIONS TAKEN

As previously noted, the alarm set point has been increased on the detector that monitors the HVAC ducting from the sump. This has had a significant effect in decreasing the frequency of noble gas generated alarms. Personnel have become used to wearing additional paper coveralls in the batching tank rooms and in addition have developed a habit of finding other work in the RCA following work in these areas. They have realised that by delaying their transit through the installed personnel monitors by as little as thirty minutes the noble gases have time to decay to insignificant levels. These actions have removed the psychological problems of numerous alarms for which little or no action is required. However, they do nothing to remove the root cause of the problem.

The single most influential factor in reducing the levels of noble gas is the operation of the gaseous radwaste plant. Whereas, previously it was common practice to operate with out the gas treatment in service, it is now seen as an essential tool in controlling noble gas activity throughout the entire plant. Plans are in place to overhaul the defective non-return valve at the next outage and it is expected that these measures will remove the nuisance alarms. But, at the root of the problem is the small number of fuel pin failures that are allowing the gases to be released into the reactor coolant. This is seen as a feature beyond the control of the station and relies on fuel manufacturers to seek further improvements in fuel reliability.