Replacement of a Leaking Beam Port Bellows in the UT-Austin TRIGA Reactor

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Abstract

During routine maintenance in November 2013, a small amount of water was discovered coming from inside a beam port at the University of Texas at Austin (UT-Austin) TRIGA reactor. An investigation revealed the source of the water to be a pin-hole in a convolution of a metal bellows (thermal expansion joint) in the beam port. The beam port was plugged and flooded as a temporary solution while a plan was developed to replace the failed bellows. Since there are two bellows of identical age and construction in the beam port, it was decided to replace both the failed bellows and the second intact bellows. Because of the significant radiation shielding provided by the pool water, divers were used to remove the old bellows and installed the new bellows. To reduce dose to the divers, the reactor fuel was moved to storage and shielding was placed around activated components in the reactor pool. After leak testing the newly installed bellows and cleanup of the pool water, the reactor fuel was moved from storage to the core and operations resumed.

Introduction

Rust was noted on the bearings supporting the lead shutter for beam port five (BP5) during routine maintenance. Further investigation showed water in the track in which the bearings ride. With a history of a roof leak in this area of the facility, it was assumed that the water in the track was coming from the roof leak. However a path from the roof leak to the bearing track could not be identified. A search for the source of the water was launched and it was determined to be originating from within BP5. Again, due to the history of roof leak in the area, a path from the roof leak to the interior of BP5 via an electrical conduit or other similar route was investigated. However, no path from the roof leak to BP5 could be found. At that point, it was assumed that there was a leak in the beam port allowing pool water to enter the interior of BP5. A radiological analysis was performed on the water and it was confirmed to be originating from the reactor pool due to the tritium content of the water.

With the reactor pool water leak confirmed, it was evaluated for impact on operations. The operations schedule was full until the normal holiday shut-down at the end of December. A routine maintenance period was scheduled immediately following the holiday shut-down. The leak rate was determined to be about two liters per day which is less than the normal evaporative losses from the surface of the pool. It was determined that reactor operations could continue as scheduled while capturing the water from the leak. Further investigation would be performed once the maintenance period was reached.

Detailed Investigation

During the scheduled maintenance shut down in January 2014, the collimator was removed from BP5 to determine where in BP5 the water was originating. A remote camera system was used to inspect the interior of BP5. BP5 is actually one half of a through port tangential to the reactor core with BP1 as the other half. A graphite scattering block is located at the midpoint of BP1/BP5 adjacent to the core. The inspection of the interior of BP5 up to the scattering block showed that the water appeared to be originating from the BP1 side.

The investigation was refocused to the BP1 side and no water was initially noted at BP1. An attempt was made to remove the collimator from BP1 in order to investigate the interior of BP1. However, the collimator was stuck apparently due to oozing of the tar sealant between joints in the beam port pipe. A device similar to a gear puller was devised to extract the collimator from BP1. Once the collimator was removed, there was no immediate indication of water on the BP1 side.

A spotting scope was used to view the interior of BP1 and initially, it appeared that there was a crack in the lens as a diagonal line was noted across the image. However, it was then noted that the diagonal line did not move with the scope as the scope was repositioned but remained at the same place in the beam port. Further investigation revealed that the diagonal line was inside the beam port. The remote camera was used to investigate the diagonal line and it was discovered that the line was actually a jet of water originating from a pinhole leak in a convolution of the bellows.

Initial Corrective Actions

With the leak being in a curved, thin-walled, flexing portion of the beam port, it was determined that a patch was not feasible. Thus, the only permanent solution was to replace the leaking bellows. However, funding was not readily available for such an action. So a temporary solution was devised using expanding pipe plugs. Pipe plugs were placed in BP1 and BP5 at approximately the location of the tank wall and the leak was allowed to slowly flood the beam port. The pipe plugs had a central tube to allow thermal expansion, purging, and monitoring of the water flooding the beam port.

Once the beam port flooded and the plugs were confirmed to be leak tight, operations resumed. However, with BP1/BP5 flooded and out of service, the neutron radiography system located on BP5 had to be relocated. The radiography system was moved to BP3 and placed downstream from the prompt gamma neutron activation analysis system located on BP3. While BP3 was not designed to optimize imaging, the move allowed radiography operations to continue with the flooded beam port. In addition to the need to relocate the radiography system, it was noted that the flux profile of the core shifted due to the flooded beam port. While noticeable, it had a relatively minor effect on operations as determined by power level and control rod worth calibrations.

Final Corrective Actions

After approximately eighteen months of operation with the flooded beam port, funding was acquired to replace the leaking bellows. As there are two identical bellows, one each on BP1 and BP5, it was decided to replace both bellows. Even though 6061 aluminum is favorable for activation product reduction, it is a poor choice for an assembly which will be undergoing repeated flexing. So the new bellows were fabricated from 321 stainless steel. Even though the stainless steel will have more activation products than 6061 aluminum, it is not considered significant when compared to the total reactor structure.

It was decided the replacement should be done with divers to take advantage of the significant radiation shielding provided by water. UT-Austin has a research dive team which routinely supports underwater research operations. Replacement of bellows underwater was a very straightforward operation for them. The unusual part of the dive was the radiation environment. In preparation for the dive, the divers were trained as radiation workers.

To reduce the radiation level in the tank, the fuel in the core and in storage in the pool was removed and placed in storage outside the pool. Even with the fuel removed, the activated reactor structure was a significant radiation source in the tank. To reduce this radiation level, shielding curtains were suspended in the tank between the reactor structure and the location of the divers. In addition, various specialized tools were fabricated to facilitate ALARA during the dive.

In September 2015, dive operations took place over three days. The leaking bellows (BP1) was removed and the replacement installed. Then the second bellows (BP5) was removed and a replacement installed. The water was purged from the flooded beam port and the new bellows were confirmed to be leak tight. Total radiation dose to the divers was much less than the 1 rem administrative limit for the operation.

Lessons Learned

Introducing Foreign Material Into The Pool Results In Poor Water Quality

Following dive operations, the pool water quality was greatly reduced. Visibility was reduced to about four meters and conductivity was greater than the maximum range of the coolant conductivity meter (30 microsiemens). Introduction of divers and equipment not normally found in a reactor pool also introduced contaminants not normally found in a reactor pool. Analysis of the water revealed cyanobacteria; the pool was experiencing an algal bloom. A supplementary water treatment system incorporating ultraviolet light was assembled and treatment of the biological contamination was initiated. As the treatment of the biological component progressed, pool water visibility did not improve.

It appeared that there was a large amount of gas (air) dissolved in the pool water causing the cloudy appearance. Further investigation revealed that the ion exchange resin was disintegrating and introducing particulates into the water. Additional filtration was added to the water treatment system and conditions slowly improved.

Once the water quality was within the technical specification requirements, fuel was moved from storage back to the pool and into the core. After required surveillances were performed, the reactor was run at high power for extended periods. This resulted in evolution of the dissolved gas as the water temperature increased and destruction of the remaining biological material due to the radiation dose. Water quality improved a bit more until reaching a plateau. At that point, the old ion exchange resin was removed and replaced with fresh resin. Once the new resin was installed, water quality improved rapidly to a level not achieved in the facility in quite some time.

There Is Always Room For Improvement

The move of the fuel from the reactor pool to storage was accomplished using a TRIGA shipping cask basket with an improvised lifting system. This basket could hold three fuel elements and had two inches of lead shielding on the sides (none on top and bottom). Dose rates on the surface of this basket with three elements inside were as high as 500 rem/hr. This dose rate required the use of shadow shielding and remote manipulation (working from atop scaffolding) when moving fuel in this basket. Because of the remote handling, it also required multiple people in multiple stations along the path of the basket from the pool to storage to perform all the required tasks. The improvised lifting system required that once the basket was in the pool, one of the lifting chains be disconnected and the basket repositioned in the pool to allow loading of fuel elements into the basket. The entire process was cumbersome and inefficient.

Concurrent with preparations for the bellows replacement, a new fuel transfer cask was designed and fabricated. The new cask held four fuel elements and had substantially more shielding (surface dose rates of less than 200 mrem/hr with four elements inside). The lifting system allowed loading and unloading of fuel elements without having to disconnect rigging or reposition the cask. The lower dose rates and specially designed rigging reduced the number of people required to perform a fuel move and was much more efficient.

First Responders Request Access to the Facility for Training

There is a specialized military weapons of mass destruction (WMD) response unit stationed near the UT-Austin TRIGA facility. Part of their mission is response to radiological and nuclear incidents. We were contacted by this unit to see if they could monitor the facility while the fuel move was taking place. Monitoring the fuel move would allow them to perform activities with their specialized equipment that they normally do not get to perform. In essence, the fuel move provided a “real world” nuclear event for them to monitor.

When we agreed to have this specialized military unit present during fuel moves, they informed their colleagues. So in addition to the military unit, a Federal Bureau of Investigation WMD response unit and the Austin Fire Department special operations division were on site for training. All the first responders agreed that they were able to see and do things during the fuel move that they had never experienced in prior training.

Return To Normal Operations

As described previously, once the bellows were replaced, there was significant effort needed to return to normal operations. Pool water cleanup took several weeks and required specialized water treatment methods be used. Final assembly and testing of the fuel transfer cask was performed in preparation for moving the fuel from storage to the pool. And planning meetings with first responders took place to ensure that their mission could be accommodated while the fuel move was being performed. Finally, in November 2015, the reactor returned to normal operation.