

## A RISK REDUCTION EXERCISE AT BNFL SELLAFIELD

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### ABSTRACT

This paper discusses one of the old facilities at BNFL Sellafield, England and the risks it posed. These were both safety, in terms of potential releases of radioactivity to the environment, and commercial, in terms of disruption of production activities.

The facility is the drainage and effluent management system from an old storage pond. The potential risk was spontaneous failure of this system. The pond itself still contains substantial inventories of old and damaged fuel and of corrosion products. A failure of the drainage system would:

- a) release 10,000m<sup>3</sup> of pond water onto site, and
- b) leave the pond solid contents uncovered.

The paper describes BNFL's initial response to regulatory demands to remove this risk, which was the provision of an emergency response and a consequence mitigation scheme. Why this policy was adopted is explained. Current plans for removing the risk are described.

### INTRODUCTION

This paper describes a risk reduction exercise at an old facility at BNFL Sellafield, Cumbria, England. The facility operated from 1959 to 1987 and was the principal facility for the receipt, storage and decanning of Magnox fuel (metallic uranium clad in a magnesium alloy material). The storage pond was equipped with a drainage system to manage the pond water, and with a sludge removal system to remove particulate material arising from the corrosion of the Magnox canning material. These two systems were cross connected and are collectively known as the South Active Drain Trench (SADT) system. Operation of the SADT system proved to be troublesome since arisings of solids from the pond and decanners far exceeded what the systems designers had anticipated, both for amount particulate arisings and for their levels of radioactivity.

At the end of the facility operational life the pond was left with a significant inventory of radioactive material, most of which is still there. The main components are unreprocessed fuel, some 400 tonnes, most of which has now lost its cladding material due to corrosion; and sludges formed by corrosion products of fuel and cladding with a volume of, some 1,000m<sup>3</sup>. The pond is open to the air and relies on the maintenance of pond water level to contain the active inventory and to provide shielding.

Likewise at the end of operational life the SADT was partially blocked with solids whose activity characterised them as intermediate level waste (ILW) and operating valves were jammed and unmaintainable. The system is potentially still connected to the pond and its hydrostatic head of pressure of approximately 20 feet of water.

## **DESCRIPTION**

The risk reduction scheme is a £6m (\$ 9m) project involving the SADT. The SADT is actually three trenches, two to the south and one to the west of the decanning plant. These trenches contain two 8" diameter pipes made of cast iron and mild steel with a flanged construction. There are numerous connections to systems which manage pond water (high level take off points) and sludges (low level take off points). The SADT system is forty years old has been redundant for fifteen years.

The pipes are in a corroded state and their supporting brackets are vulnerable to impact damage. The system has the potential failure for spontaneous failure. A full bore breach of the main 8" sections would release pond water at up to 1200 m<sup>3</sup>/hr, with a total pond inventory of 10,000m<sup>3</sup>.

The trench was 10 feet deep and 4 feet wide. Numerous leakages had contributed to an inventory of radioactivity on the floor of the trench and the pipes themselves contain radioactive residues. The dose rate on the floor of the trench and around the pipes is of the order of 2 – 5 mSv/hr (gamma) (200 – 500 mrem/hr). There are local hot spots at up to 7 Sv/hr (700 rem/hr) so some sections of the trench cannot be entered by personnel. The trench was littered with debris and being outside collected rainwater which is removed by small submersible pumps lowered into the trench.

Connecting pipework runs through the decanning building from take off points in the building and in the pond. Most of these take off points are now inaccessible because

- low level take off points for the sludge line are buried under significant depths of sludge, and
- many take off points are in areas covered with shielding and containment improvements made in the decanning building to try improve the radiological conditions on the plant.

The true state of the system pipes and control valves is not known and thus every pessimistic assumption has had to be made. Thus

- when considering the potential for spontaneous failure it is assumed that the pipes are full of liquor exposed to the hydrostatic head of pressure from the pond, some 20 feet of water. Pond water and sludges are assumed to be fully mobile.
- when considering the potential for flotation during encapsulation the pipes are assumed to be empty of liquors and solids.

There has been previous work attempting the remediation of the SADT system. The system is physically isolated at the effluent treatment station that it fed and one spur of pipework had been partially removed. This removal was done using remote cutting technique but even so was abandoned because the limited occupancy that was required led to excessive radiation exposures.

## **ACCIDENT CONSEQUENCES**

Analysis of accident conditions proved to be problematic. Because of the limited knowledge of the physical conditions of the pipework systems bounding values were used to provide some probabilities for failure of the system. A greater unknown was what volumes of sludge

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or pond water would be released. In the end the accident model was based on unit releases, per m<sup>3</sup> of either sludge or pond water.

- Three consequences emerged:
  - radiological consequence to on site worker
  - radiological consequence to a member of the public off-site
  - plant and site operability problems

For the radiological consequence to a worker the assessed dose easily exceeded the legal annual dose limit. For the off-site radiological consequence the dose to the most exposed member of the public was within the legal limit but took up a large part of the site's overall risk allowance. For plant and site operability problems there were two consequences – the release onto the site of a significant volume of contaminated pond water and the removal of shielding over the pond inventory. Either of these would have severely disrupted the economic activities of the Sellafield site, where the annual turnover is some £600M (\$1,000M) per year.

The first two of these three consequences attracted the attention of the NII, the site's safety regulator, who applied pressure on BNFL to make safety improvements to the SADT system.

### **INITIAL EMERGENCY PREPARATIONS**

The initial emergency preparations at the SADT consisted of:

- improved impact protection for the SADT system pipes by providing high quality, thermally insulated trench covers. This, however, could not address the numerous in-feeds that run through the decanning building.
- provision of self-powered pumps capable of removing the arisings from a double open ended fracture of both of the main 8" pipes in the SADT. Returns from these pumps were directed back to the pond so that in the event of a pipe failure the pond water level would be maintained.

The provision of these measures did nothing to remove the source of the risk from the SADT, so while the regulator approved of them, there was no let up in the pressure on BNFL to make substantial risk reductions.

### **ENGINEERED SOLUTIONS - 1**

With the failure of the pipe removal project – the SADT and with the increase on pressure from the regulator BNFL re evaluated its options. The outcome was a decision to encapsulate the pipework systems in the trench *in-situ*. The option of doing nothing scored almost as high.

Potential encapsulating materials were:

- cementitious material
- dry granular material
- glass
- foamed polymers

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- sand
- expanded polymer media

Structured decision making processes identified a cementitious grout as the material most likely to provide an acceptable solution. The material had to satisfy a wide range of criteria, some of the key ones are listed below with reasons:

- self compacting – access not available to all areas of the SADT because of dose rates
- high flow capability – for the same reasons
- low density – to minimise pipe buoyancy
- low strength – to satisfy seismic and decommissioning requirements
- good impact resistance – to protect the pipework from collision damage
- durability – ultimate decommissioning of the pipework might not be for 20 years after encapsulation
- proven technology – to ease safety licensing problems
- available in large volumes – the free volume in the SADT is about 300m<sup>3</sup>
- repeatable and consistent – so that batches will give predictable results
- compatible with the pipework and its support bracketry – to ensure it will not accelerate corrosion of the pipework, and ideally to reduce corrosion
- porous – so that any minor leakage that might occur would make its way to engineered sumps in the SADT

To construct a credible safety case it was necessary to show that the risks of encapsulating the SADT pipes were acceptable. These risks came from:

- buoyancy of the pipes
- heat of hydration causing expansion of the pipes so that flange seals or pipe brackets fail
- lack of durability of the encapsulant

The first of these was addressed easily by a phased programme of controlled pours such that the pipes were never surrounded by enough fluid cement to give a buoyant lift that exceeded the weight of the pipes.

The second was not so easily addressed. Demonstration of safety came from the use of a full scale mock up of the SADT. Instrumentation was fitted to simulant pipework and the temperature transient from the heat of hydration was compared to a prediction from model using a finite element analysis. In fact several FEA codes were used. The main motive for doing this was to avoid a situation where BNFL and its regulators could be in disagreement because each side was using a different FEA code which gave different predictions.

To demonstrate the integrity of the pipework, both during the pour and after, a water management system was installed in the SADT. This consisted of collection sumps, pumping systems and sampling arrangements. Water arising in the SADT, whether from rain or from leakage in the trench will make its way to the sumps from where it will be pumped.

The final point proved more problematic, as the type of foamed concrete BNFL wished to use was relatively newly developed. There was no application of it more than 7 years old, so

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longevity could not be demonstrated. Arrangements were made to collect samples of each pour, to be kept in representative conditions and periodically tested to destruction.

### **ENGINEERED SOLUTIONS – 2**

The sections above describes how BNFL reduced the immediate risk from the SADT by making parts of it less vulnerable to damage. Other, minor, sections remain exposed and the pipework remains connected to the pond and its head of hydrostatic pressure.

Future work is now being planned and scoped out to:

- identify and protect remaining minor infeeds to the SADT pipework.
- identify, locate, expose, and seal the various sumps and take off points that feed into the SADT from the pond. This will isolate the from the pond and will finally remove the risk from the SADT. There is a large inventory of sludge in the pond and sump sealing must be integrated into the overall pond work programme.
- remove and dispose of the SADT pipework

### **CONCLUSIONS**

One of the major safety risks at he BNFL Sellafield site came from the possibility of a failure of the SADT pipework. This risk has been reduced by approximately 100 times by the short term measures described above. There is a similar reduction in the commercial risk to the operations of this site.

Removal of the residual risk is planned, by sealing the connections between the pond and its drainage system.