Black Cell Operations - UK National Nuclear Laboratory Experience – 14049

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ABSTRACT

Black Cell inspection and intervention has been carried out at the Sellafield nuclear site in the United Kingdom over the last 30+ years. Staff within the UK National Nuclear Laboratory have been continuously involved with this work, and have successfully designed, built, tested and deployed numerous inspection devices and specialist equipment over this period of time. This paper describes a variety of devices containing closed-circuit television, lighting, and ultrasonic thickness measurement capability, and provides evidence of the value that these devices have provided. Bespoke equipment with cutting, welding, unblocking and analytical functionality is also described, and details of the operational constraints that such devices have alleviated is discussed.

INTRODUCTION

The UK National Nuclear Laboratory (NNL) is a Government owned organization that helps support UK nuclear operations and carries out research and development work on behalf of UK and international customers. NNL was formed as part of the transformation of the UK nuclear industry over the last decade, and has it’s roots as the Research and Technology division within the now obsolete British Nuclear Fuels plc (BNFL). In its various guises, NNL has been involved in black cell projects over a number of decades, and continues to provide new and innovative solutions to deal with present day challenges.

NNL has a unique expertise in carrying out Closed-Circuit TV (CCTV) inspection of a number of the black cells present on UK nuclear sites, particularly at the Sellafield reprocessing and waste treatment site in North West England. This includes the development of new cameras and deployment methods to increase coverage of the black cell areas, and the use of new technologies, where appropriate, to support the ever changing needs of operational nuclear facilities. New inspection and measurement devices are continually under development, and existing devices are often modified and improved to enhance their performance and maximise their flexibility to be used in a variety of applications.

Periodically it becomes necessary to break black cell containment in order to make operational improvements to plants where the requirement for access had not been foreseen and therefore not accounted for during the design and build of the facility. NNL have expertise in successfully carrying out projects of this type, where bespoke devices or robotic manipulators have been designed, built and tested in full scale testing facilities prior to deployment.

When early plants such as Magnox reprocessing and Highly Active Liquor and Storage (HALES) were built at the Sellafield site, limited consideration was given as to the long-term inspection requirements that would be required in order to support the continued operation of these facilities. Inspection ports were installed at various locations, through which cameras can be deployed from man-access areas into the black cells, but their coverage is somewhat limited. As new facilities such as the Thermal Oxide Reprocessing Plant (THORP) and HALES Evaporator D (which is currently under construction) have been built, careful consideration of the ongoing inspection requirements has been made, hence enhanced infrastructure to support inspections is in place.

This paper describes a number of inspection devices and other specialist equipment that has been deployed in black cells within various operational plants on the Sellafield site. This ranges from relatively simple camera systems to complex robotic manipulators, cutting and welding equipment, thus giving a good indication of the range of black cell intervention work carried out by NNL. Development of inspection devices and equipment often requires input from a number of specialist teams within NNL, including designers, remote engineering experts and experienced plant inspectors. Many of the inspection devices and remotely deployable equipment developed by NNL was built in order to carry out specific tasks, some of which were unexpected prior to the need being identified. In addition to the deployments, NNL is also able to carry out the design, build and full functional testing of equipment, making use of full scale rigs built to replicate the appropriate black cells within the operating plant.

DESCRIPTION

Closed-circuit TV (CCTV) Inspection Devices

Many of the CCTV inspection devices used to carry out black cell inspections consist of readily available cameras incorporated within specially developed shielding, to preserve the operating lifetime of the camera. Potential worst case dose rates in black cells at Sellafield are in the region of 40 kGy/hr. Such cameras are then mounted on a variety of vehicles, from modified scaffolding poles to specially designed equipment, depending on the application and complexity of the inspection. In order to support continued operations a number of the plants on the Sellafield site are subject to statutory inspection within pre-determined time intervals, typically every 3 to 5 years. The intent of these inspections is to observe the condition of the pipe work, vessels and supporting infrastructure, in order to identify any changes over time and mitigate against any potential operational issues. This approach has proved successful in helping to support continued operation of facilities on the Sellafield site. Figure 1 shows a typical image from a statutory CCTV inspection of a highly active evaporator vessel.

Fig. 1. Highly Active Evaporator CCTV Image

It often becomes necessary for bespoke camera inspection devices to be built on order to carry out difficult inspections in hard to reach places. One such inspection device is that shown in Figure 2, where the camera had to be placed at the end of a hinged unit, to allow deployment past black cell obstructions to obtain images of the area below a vessel within the cell. This device was successfully deployed, and provided clear images of the target area.

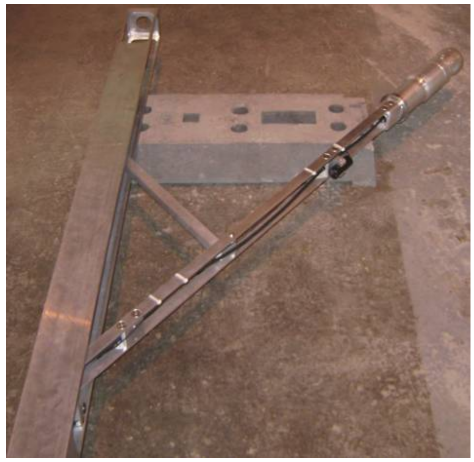

Fig. 2. Hinged Camera Inspection Device

Ultrasonic Thickness Measurement Devices

Ultrasonics is a tried and tested technique, and is thus a methodology that NNL often uses to measure the remaining thickness of vessels and pipe work when this becomes necessary to support continued operations. Some of the operating plants on the Sellafield sites have been operating for up to 40 years, hence some of the components have corroded and require monitoring to understand the remanent life of these components. In addition to simple thickness measurements, where the component can be reached via man access in low activity areas, NNL has developed a number of devices, with ultrasonic capability, for deployment into black cells. These devices have been deployed into heating/cooling coils and resistance thermocouple lines in order to measure the thickness of these components, thus allowing the calculation of associated corrosion rates and prediction of the remanent life of the plant. Figure 3 is a schematic of a highly active evaporator showing a coil down which the device shown in Figure 4 has been deployed. Maximum coil deployment distances of around 45m have been achieved, and a device has been developed that can be deployed into various coils within three different highly active evaporators. Figure 5 shows thickness measurements obtained using the inspection device shown in Figure 4.

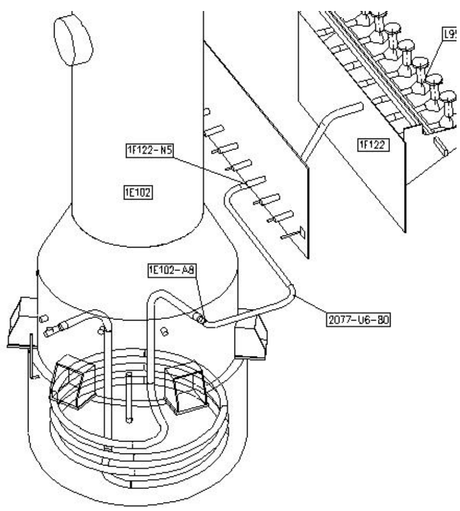

Fig. 3. Highly Active Evaporator Showing Coil

Fig. 4. Coil Inspection Device

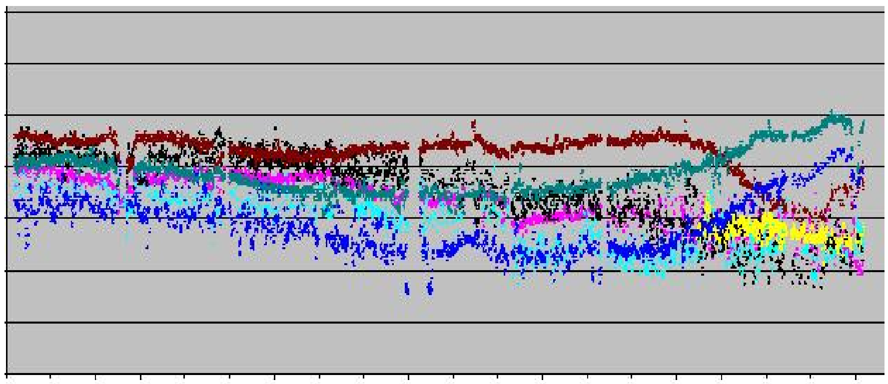

Fig. 5. Ultrasonic Thickness Measurements

Black Cell Interventions

The reprocessing and waste treatment/storage plants on the Sellafield site typically operate well due to their robust design and the undeniable skill of the associated operational and technical support staff. Nonetheless, on occasion it is necessary for intervention into black cell areas to be carried out, in order to carry out upgrades to key components. One example of such an occasion was when the through wall power supply cables to a melter in the Sellafield vitrification plant were replaced. In this project a complicated remote deployment system was successfully developed and deployed, allowing fully functional melter operation to be maintained.

A second example of a black cell intervention was when raffinate feed lines to dissolvers within the Magnox reprocessing plant required re-routing, and this required black cell containment to be temporarily modified. Various pieces of equipment such as a pipe grip, cutting tool and remote welder had to be deployed into the dissolver cell using newly cut deployment routes. Pieces of pipe were cut and welded into place, and obstructions were carefully negotiated, helping to ensure the success of this project over an 18 month "concept to completion" timescale. Figure 6 shows a test rig containing some of the equipment used in this project, and a mock up of some of the pipe work involved.

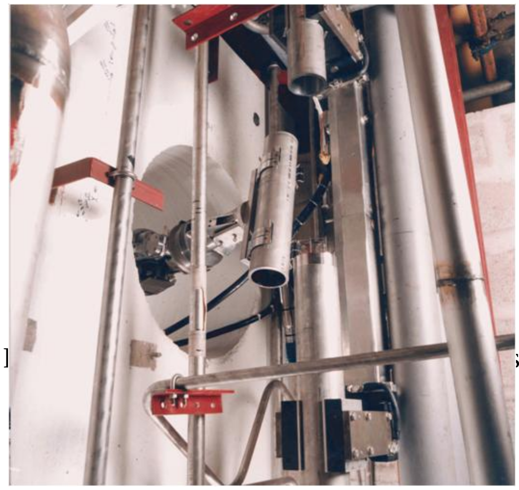

Fig. 6. Magnox Dissolver Cell Intervention Test Rig

Pipe Unblocking

Some of the liquors that are treated at Sellafield have high solids contents, and a significant amount of work has been done over the years to understand how these solids behave, and how blockages can be mitigated and/or avoided. Wash procedures have been developed in order to support this approach. However, there are a small number of occasions when pipe work is blocked with solids, and remote intervention is one method that can be used to clear such blockages. NNL staff were involved in the development of a device that was used to clear a blockage in one of the Sellafield Waste Vitrification Plant (WVP) feed lines. This device required deployment down 30m of 2 inch pipe work, while passing a number of 908 bends and negotiating a two way diverter vessel. This device contained a camera, lighting and the capability to add wash liquors to the piping to erode the solid blockage. It was also known that this device would pick up contamination during deployment, so it was sacrificial in nature and contained shielding to allow safe retrieval after use. Figure 7 shows images of this device, its original control panel and a schematic if the route down which it was deployed.

Fig. 7. Pipe Unblocking Equipment

Analysis and Monitoring

NNL has recently developed specialist instrumentation that is able to detect and measure the level of radiation within nuclear facilities. The primary developments in this area are Rad-Line® and Rad-Ball®, which have both been successfully deployed in radioactive facilites. In particular, Rad-Line® has recently been deployed within black cells in the Sellafield vitrification plant, in order to identify the radioactive content of solids technical waste, to allow classification of the waste and thus identification of the required disposal routes. Further work is ongoing to integrate the Rad-Line® technology into pre-existing inspection devices, to allow deployment into additional black cell areas. The primary aims of this work are to identify solids present in vessels, using their radiation signature, and to monitor the effectiveness of the removal of solid compounds from tank waste, thus driving efficiency into post operational clean out waste treatment operations.

CONCLUSIONS

Primarily through involvement with reprocessing and waste treatment operations at Sellafield, NNL staff have developed a number of bespoke inspection devices and other specialist equipment. This has been a key contribution in enabling ongoing plant operation, giving an improved understanding of operational constraints and allowing operational improvements to be made.

With careful consideration of the technologies available deployment challenges can be overcome, providing access to hard to reach areas of black cells, thus dispelling the myth that black cells cannot be accessed once active operations have commenced.

ACKNOWLEDGEMENTS

The author would like to thank Sellafield Ltd for their agreement in allowing this paper to be published, and for the operational plant support provided that has allowed black cells devices and equipment to be successfully and safely deployed. The author would also like to thank NNL colleagues, too numerous to mention. Who have worked diligently to design, build, test and deploy the equipment described herein.