Remote Removal of an Obstruction from FFTF In-Service Inspection Camera Track

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REMOTE REMOVAL OF AN OBSTRUCTION FROM FFTF IN-SERVICE INSPECTION CAMERA TRACK

ABSTRACT

Remote techniques and special equipment were used to clear the path of a closed-circuit television camera system that travels on a monorail track around the reactor vessel support arm structure. A tangle of wire-wrapped instrumentation tubing had been inadvertently inserted through a dislocated guide-tube expansion joint and into the camera track area. An externally driven auger device, mounted on the track ahead of the camera to view the procedure, was used to retrieve the tubing.

INTRODUCTION

The Fast Flux Test Facility (FFTF), a U.S. Government-owned, 400 MWth, sodium-cooled fast reactor, employs a Surveillance In-Service Inspection (SISI) closed-circuit television (CCTV) camera system that travels on a monorail track around the reactor vessel support arm structure to periodically verify the physical integrity of the support arm welds. On one occasion, the track was found to be obstructed by a 12-m (40-ft) long tangle of wire-wrapped instrumentation tubing (Figures 1 and 2) that had been inserted through a dislocated guide-tube expansion joint. The obstruction was some 20 m (60 ft) from the nearest access, down a narrow, tortuous path along the CCTV track (Figure 3). The environment in the area of the obstruction was in a 120 °C (250 °F) nitrogenous atmosphere with an approximately 1 Gray (100 R/h) gamma field.

A probe (Figures 4 and 5) was mounted ahead of the camera and transported to the area of the obstruction to measure the actual ambient temperature and determine the maximum available envelope for passage of obstruction removal equipment. Using this information, the work group constructed a mock-up of the CCTV trolley track, complete with envelope restrictions and a representative tubing snarl to test the equipment design and to develop operating techniques.
Figure 1. Diagram of 0.47 cm (0.18 in.) Diameter Wire-Wrapped Tubing.

Figure 2. Diagram of the SISI Trolley Obstruction.
Figure 3. Diagram of the SISI Trolley Track.
Figure 4. Diagram of the SISI Probe Target.
The work group designed and built a remotely operated obstruction removal tool to travel along the CCTV trolley track, grip the tubing, twist and pull portions of tubing free, and draw the obstruction out of the camera path (Figure 6). The tool was mounted ahead of the camera so removal operations could be visually directed. The obstruction removal system was designed to be fail-safe, with no single mechanical failure or snag point to prevent withdrawal of the CCTV or tooling. Failure to withdraw this equipment would prevent the installation of a reactor cavity shield plug, which in turn would prevent further reactor operations.

PROBLEM DESCRIPTION

The SISI program at the FFTF requires a number of periodic inspections of critical reactor vessel components at specified intervals. One of these inspections concerns the steel arms that support the reactor vessel. These arms are welded directly to the reactor vessel and carry its full weight. The inspection is performed periodically to verify the support arm-to-reactor vessel
Figure 6. Final SISI Obstruction Removal Equipment Configuration.
weld integrity. Because of the high radiation levels, inert nitrogen environment, and physical inaccessibility around the reactor vessel/support arm annulus, the inspection must be remotely performed using the trolley-mounted SISI CCTV camera system.

During the scheduled inspection on November 10, 1987, the CCTV camera would not move past the last five support arms on its monorail track. The unknown obstruction could not be seen because the 90° mirrored lens required for the weld inspection prevented viewing along the track. A subsequent inspection using a forward-looking camera lens revealed that a snarled mass of reactor guard vessel leak-detector tubing had become entangled with the SISI CCTV track (Figure 2). An expansion joint in the detector guide tube had disengaged, causing the full length of the leak-detector tubing [approximately 12 m (40 ft)] to be inserted into the support arm annulus instead of down into the guard vessel. The wire wrap became snagged, which prevented pulling the tubing up through its guide tube. To continue operating the reactor, the obstructing tubing had to be removed and the required inspection completed as part of the American Society of Mechanical Engineers Pressure Vessel Code surveillance inspection plan for FFTF.

CHARACTERIZATION OF ENVELOPE AND ENVIRONMENT

To determine the actual clearance envelope available, the SISI CCTV trolley path had to be characterized to allow for maximum flexibility in tool size selection and accurate construction of the trolley track mockup. The actual ambient temperature had to be measured so that the proper materials could be selected. If the actual temperature was less than the CCTV design temperature of 200 °C (400 °F), a broader selection of materials could be considered.

An external thermocouple was mounted to the camera to measure the ambient temperature in the support arm annulus. The temperature was found to be 120 °C (250 °F); this was considerably less than earlier estimates.

A crossed set of flexible steel scales cut from a tape measure and oriented horizontally and vertically was mounted on rods ahead of the camera, but in its field of view (Figures 4 and 5). By positioning these scales near objects of restrictive clearance, the location of the objects relative to the known location of the monorail was shown along the length of the track; these measurements were recorded on video tape through the CCTV. The final operating envelope was determined by superimposing these measurements onto a computer layout of the measuring scales. Using this method, the group determined that the most restrictive location was at an opening in an insulated thermal baffle surrounding the support arm annulus.
REQUIREMENTS OF OBSTRUCTION REMOVAL EQUIPMENT

The job required a remotely operated device that could reach the support arm annulus via the CCTV track, engage the tubing, fatigue portions of it to failure by twisting, and remove these portions of tubing. The removal tool design had to be fail-safe--no single mechanical failure or snag point could prevent withdrawal of the CCTV or the tooling. In addition to the potential loss of an expensive, radiation-hardened CCTV system, tooling or the camera train left on the track would prevent closeout of the reactor cavity and could prevent further reactor operations. Other design objectives included avoiding the following:

- Loosening the sheet metal surrounding the trolley access opening that leads through the thermal baffle located around the support arm area in a way that would prevent future access of the CCTV into the support arm annulus

- Bending the trolley rail so that the CCTV camera could not pass

- Engaging the tubing with the removal tooling such that the tubing could not be released

- Relocating the tubing snarl during removal operations in a way that would still prevent the passage of the CCTV camera.

DESIGN OF OBSTRUCTION REMOVAL EQUIPMENT

The obstruction removal equipment consisted of a remotely-operated system attached to the front of the SISI CCTV trolley (Figure 6). A double helical auger would "screw into" and grip a portion of tubing. The auger-engaged tubing could then be twisted free from the remainder and pulled out. If the tubing could not be broken loose, the auger could still be disengaged from the tubing by simply reversing its direction of rotation. The auger was mounted on a trolley car in the CCTV camera's field of view for visual direction of removal operations. The existing, unmodified SISI CCTV trolley drive was used to move the auger car along the track and withdraw the separated tubing.

In anticipation of pull forces on the CCTV trolley train in excess of original design loads, the CCTV umbilical train-connecting links were doubled in strength. The actual tubing-removal pull forces were further separated from the CCTV train by the addition of twin wire ropes clipped to and running along the train cars. These wire ropes connected the auger car to the CCTV umbilical takeup drum. All tubing pull forces would be transmitted along these wire ropes directly to the drum.

Power to rotate the auger was transmitted through a manually driven, flexible drive shaft tied along the umbilical train. A planetary-gear torque
multiplier, which increased the torque at the auger, was mounted on a special
trolley car with a replaceable auger on its output shaft. The drive shaft could be
turned by a hand crank or an electric drill motor. This allowed the drive input
to be on the operating floor level and eliminated the need for a locally mounted
electric, hydraulic, or pneumatic motor, all of which are potentially unreliable in
a high-temperature environment. This also resulted in a much smaller and
streamlined package, which proved vital to viewing the auger during the actual
operation.

In the event that the auger car became entangled, the camera train could
still be withdrawn by pulling the drive line free at a breakaway coupling on the
car, releasing the twin wire ropes at the operating deck, and pulling the train
free. While this would not improve the inspection situation, it would allow the
reactor cavity to be closed for continued reactor operation.

MOCK-UP TESTING

The obstruction removal equipment was tested on a mock-up of the SISI
CCTV trolley track that was constructed to duplicate the turns, space
restrictions, support arm annulus envelope, and the simulated tangle of leak
detector tubing along the CCTV camera track. The purpose of the mock-up
testing was to demonstrate that (1) the obstruction removal equipment properly
interfaced with the CCTV system, (2) the auger car would fit into the annulus,
(3) tubing could be severed and pulled from the annulus, and (4) both the CCTV
and the auger car were retrievable under the postulated fault conditions. These
tests established the final auger configuration and operating parameters such as
rotation speeds, torques, and pull force. Several potential snags and interference
points on the removal equipment were discovered and subsequently eliminated.
In addition, operating techniques were developed that made best use of the
equipment.

CONCLUSION

On April 19, 1989, the device was inserted into the reactor vessel support
arm annulus. The equipment functioned as designed and the obstruction was
removed. The support arm welds were inspected within a week, and the
surveillance program requirements were met. During this operation, no
personnel were exposed to radiation or other hazardous conditions. The
equipment, made from available spare parts and off-the-shelf hardware, resulted
in a cost-effective, timely, and safe solution to a difficult, remote-maintenance
situation.
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