

# Robotic plumber repairs pipes in nuclear power plants

## SITUATION

The remedy for a leak in residential plumbing often is as simple as calling a local plumber. However, when the leak is in a nuclear power plant's cooling system, the remedy is likely to be a lot more complicated.

Like any plumbing system, the water circulation system in a nuclear power plant can develop leaks when welds crack or when pipes are stressed by high-pressure fluid. In this case, the problem concerned not just one reactor, but a class of nuclear reactors built in Sweden; after 15 to 20 years of service, the reactors exhibited metal fatigue when cracks developed in the emergency shutdown valve nozzles on the control rod housings.

The repair steps were:

1. Polish the workpiece to remove scale and oxidation.
2. Survey the workpiece with a custom-made touch probe to establish its position.
3. Part the pipe on either side of the damaged section and leave a locating register on the ends of the pipe to help position the new pipe.
4. Profile the OD of both the pipe and the nozzle for proper heat distribution during welding
5. Deburr the ID, OD, and ends of the pipe and nozzle.
6. Survey the workpiece after machining to determine if anything changed, so a custom-fit pipe can be machined to fit exactly into the gap.
7. Bore the ID of the pipe and nozzle to size after the repair.

Although the repair concerned only one pipe size, it had to be performed 650 times (on 130 pipes in each of the five reactors in this class).

One more catch: The machine that would perform the repairs would have limited access to the work area. It would have to work from the inside of the pipe.

## RESOLUTION

Concept Systems Inc., Climax Portable Machine Tools, and Swedish engineering firm Uddcomb Engineering AB teamed up to develop a robotic pipe repair system that uses a mobile CNC machine tool in conjunction with a robotic arm.

Two of the main challenges of the project were manipulating different cutting tools into the gap in the pipe and onto the spindle of the CNC robot, and changing tools by remote control (because each operation in the repair process

required a different tool). Because the robot had to work inside the pipe, precise tool manipulation was critical to prevent damaging the pipe threads that hold a high-pressure check valve.

The individual machining processes vary from 20 minutes for deburring to 4.5 hours for tapering the profile on the nozzle OD. A typical repair takes approximately 48 hours, which is half the time the utility company originally estimated.

During part of the repair process, the machine's head spindle had to pass through the high-pressure nozzle, then machine the outside surface of the nozzle with a tool that was twice the size of the nozzle's ID. The manipulator arm replaced tools without



**Figure 1**

*The base of the CNC machine is located in the equipment area below the piping at the power plant.*



**Figure 2**

*The CNC tool spindle operates inside the pipe.*



**Figure 3**

*The system's robotic arm removes a cut section of pipe.*

removing the spindle head or repositioning it in the nozzle. Project specifications required a 0.005-mm positioning tolerance.

Concept Systems programmed all of the probing, polishing, and machining operations into the machine. The machine operator mounted the machine on the control rod housing, probed the workpiece, entered the offset values to align the machine with the workpiece, installed the tool on the spindle, and started the program. After the operator started the program, all the spindle motion was automatic. After each process, the machine returned the tool to the park position and was ready for a tool change and execution of the next process.

### **MORE WORK FOR THE ROBOT**

After the initial repairs were completed, the machine's role was expanded. Climax and Concept Systems retrofitted the machine with a shorter spindle and provided tooling and programming for a completely new task.

A check valve that threads into the

opening of each of the pipes has a locking pin, and it was discovered that this pin often damages the first 6 mm of the threads, preventing the valves from being removed. Technicians must remove the check valve to perform the weld repair, and occasionally to repair or replace the check valve itself. Using a shorter spindle than the original, the machine parts off the check valve housing and removes the damaged threads. This enables removal of the remaining portion of the check valve housing with no further damage or subsequent repairs required to the nozzle.

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