JAPAN

JAPC provides Tsuruga-2 leak findings to NSC

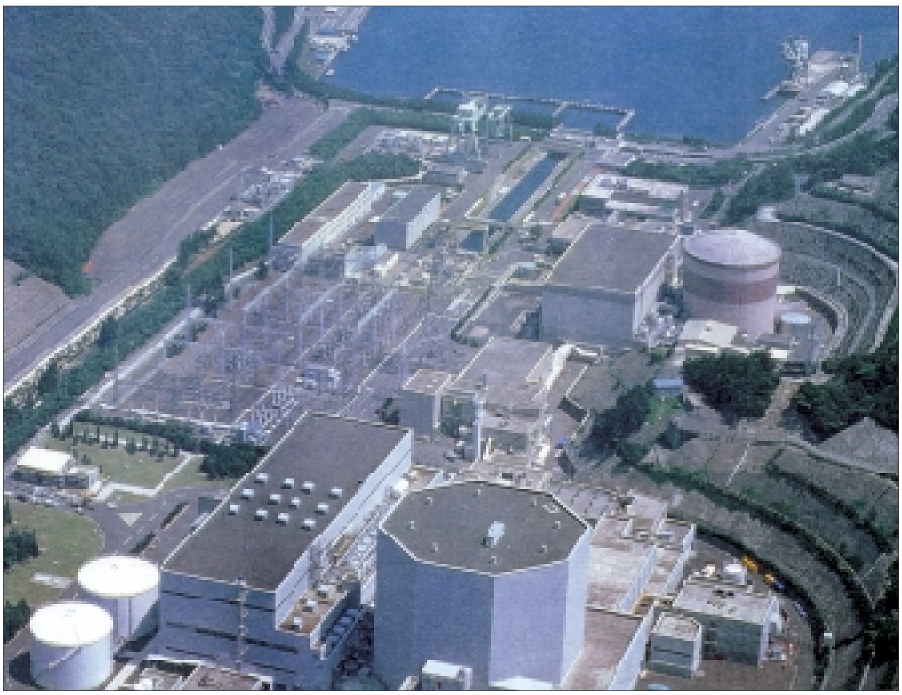
Thermal stresses were determined to be the cause of cracks in a pipe elbow and a regenerative heat exchanger connected to the top of the elbow.

On August 30, the Japan Atomic Power Co., Ltd. (JAPC) reported its findings to the Nuclear Safety Commission on the cause of the July 12 pipe leak at its Tsuruga-2 nuclear power plant (*NN,* p. 18, Aug. 1999). The incident was classified as a Level 1 (anomaly) on the International Nuclear Event Scale (INES).

The utility concluded that 11 cracks inside the leaking pipe elbow (including the 47-mm-long and 0.2-mm-wide penetrating crack) and five other crack-like marks inside a regenerative heat exchanger connected to the top of the elbow were caused by thermal stresses from hot-and-cold water cycling in the heat exchanger.

That heat exchanger is the second in a series of three that are part of the unit's chemical and volume control system (CVCS). The elbow, which spilled about 51 tons of primary coolant water, routes incoming reactor coolant from the second to the third heat exchanger for successive temperature reduction of the coolant.

Other possible causes for the cracking, such as manufacturing defects and stress corrosion from mechanical forces, were considered but not found to be involved.



Japan Atomic Power Co., Ltd.'s Tsuruga-2 nuclear power plant, at bottom center, with its octagonal reactor building. Tsuruga-2 is an 1115-MWe pressurized water reactor. Tsuruga-1, a 341-MWe boiling water reactor, is nearby—above and to the right, with the cylindrical reactor building. (JAPC photo)

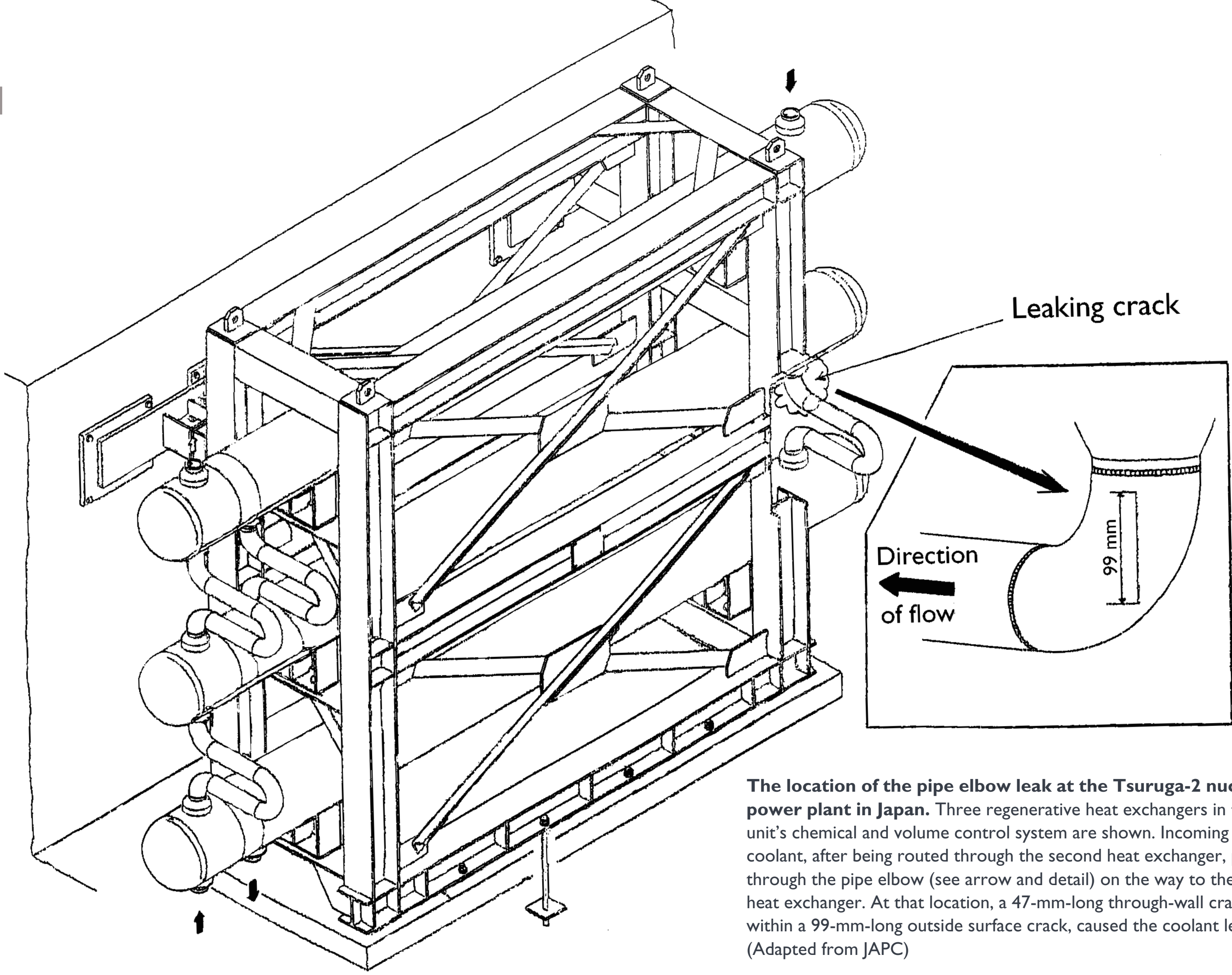
The pipe elbow with the vertical crack that caused the July 12 leak at Tsuruga-2 in Japan (JAPC Photo)

The three stainless steel heat exchangers have a unique inner cylinder design. The heat exchangers step down the temperature of the incoming coolant in three stages, to protect the CVCS purification unit, and then heat the coolant water being returned to the primary circuit. Each heat exchanger has a 5.2-m length, 0.4-m inside diameter, and 39-mm wall thickness. All pressure parts and heat exchange tubes, and also the pipe elbow, are made of SUS316 stainless steel.

While flowing through the shell-side of each heat exchanger, the incoming higher-temperature coolant gives heat off to the outgoing lower-temperature coolant through heat exchanger tubes, at each heat-exchanger stage. Entering the shell-side of each heat exchanger, the incoming coolant is divided by the inner cylinder (which surrounds the heat exchanger tubes) into two flows, one moving outside the inner-cylinder and another inside the inner-cylinder.

The inner cylinder is provided to focus flow along the heat-exchanger tubes to gain greater heat transfer. The water traveling *inside* the heat exchanger tubes is coolant being heated on its way back to the reactor primary system. (This inner cylinder design, however, is no longer used in the latest PWR models.)

The five crack-like marks were on the inside surface of the second heat-exchanger shell, around the outlet of the inner cylinder. JAPC has found that the inner cylinder was positioned more than 1 mm off center at support ring number 2 near the end of the inner cylinder, thus providing more space for wa-



The location of the pipe elbow leak at the Tsuruga-2 nuclear power plant in Japan. Three regenerative heat exchangers in the unit's chemical and volume control system are shown. Incoming reactor coolant, after being routed through the second heat exchanger, passed through the pipe elbow (see arrow and detail) on the way to the third heat exchanger. At that location, a 47-mm-long through-wall crack, within a 99-mm-long outside surface crack, caused the coolant leak. (Adapted from JAPC)

ter flow on one side of the flow pass between the shell and cylinder, and, accordingly, less space on the other side. In its technical evaluation, JAPC noted that if the wider space allows more flow and thus more heat, the cylinder wall on that side accordingly would expand more than the other side, choking the flow accordingly. If the flow were choked, it then would lead to less flow, less heat, and thus less expansion of the wall and a net movement of the wall in a direction back to creating a wider space—then, again more flow and more heat, etc. The resulting hot-and-cold mixed flow, produced at the end of the inner cylinder, entered the pipe elbow in question.

This cycling phenomenon of flow is believed to have occurred at a frequency of once every 10 to 20 minutes, resulting in thermal stress of about 11 kg/mm^2 in the affected areas on the heat exchanger and its connecting elbow, for 10^6 cycles over the period of plant operation to date. Tsuruga-2, an 1115-MWe pressurized water reactor, began commercial operation in February 1987.

To correct the situation, JAPC plans to replace the heat exchangers with a new design, without inner cylinders—if and when its ongoing technical evaluation recommends this, and the licensing authority concurs—during a year-end scheduled plant inspection. Originally set for December 1999–January 2000, this inspection has been moved up to November–December 1999. The plant will remain shut down until that inspection is completed.

As a result of the Tsuruga-2 incident, the Natural Resources and Energy Agency instructed the operator utilities of Takahama-3 and -4 (Kansai Electric Power Co., Inc.), Sendai-2 (Kyushu Electric Power Co., Inc.), and Tomari-1 and -2 (Hokkaido Electric Power Co.)—all pressurized water reactors—to check their heat exchangers of the same design (but not necessarily the same dimensions), using nondestructive testing.

The Mitsubishi research laboratory in Takasago has begun testing the Tsuruga-2 inner cylinder–type heat exchanger to examine mixed flow and temperature distributions, using a full-size mockup of the heat exchanger and the elbow. JAPC will conclude its technical evaluation of the Tsuruga-2 pipe leak, and corrective actions, when the mockup testing is successfully completed. NN