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Failure analysis of branch connection on the reactor primary pipeline

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ABSTRACT

A shut down event occurred in one pressurized heavy water reactor unit due to primary loop heavy water leakage. Failure analysis was hence performed in order to develop the following pertinent actions. The sampling plan was developed via visual inspection and analysis of the defective connection. Physical and chemical tests were conducted by means of stereo microscope, metallurgical microscope, scanning electron microscope (SEM) and energy dispersive spectrometer (EDS). The results revealed that the main crack initiated at the weld root inside the connection and eventually progressed throughout the pipe wall. The fracture and metallographical morphology showed the typical character of stress corrosion cracking. It is concluded that the failure was caused by transgranular stress corrosion cracking (SCC) on the stainless steel side of the dissimilar metal weld. The root causation could be bad weld forming due to inappropriate welding process.

1. Introduction

The primary pipeline is the main coolant pressure boundary of the nuclear reactor. Nuclear safety is directly influenced by the primary pipeline integrity. In December 2007, a shutdown event occurred in one pressurized heavy water reactor unit due to heavy water leakage of the primary loop. The leakage point was located on the primary pipe branch connection of the primary heat transport system. It cost 182 h to replace the defective branch connection during the unscheduled maintenance outage and resulted in a total generation loss of 11,242 kWh relatively. This nuclear power unit began to service in December 2002 and the primary pipeline has been in operation for five years before this leakage. In order to prevent the similar case, the failure analysis should be performed.

2. Experimental procedure

The leakage point was finally identified on a branch connection of the reactor primary loop, as shown in Fig. 1. It located on a primary pipe, which is a hot leg of a steam generator. Table 1 shows the basic information of the connection. Fig. 2 shows the connect structure of the branch connection. The leakage was on the stainless steel side of the dissimilar weld. The metallurgical samples were

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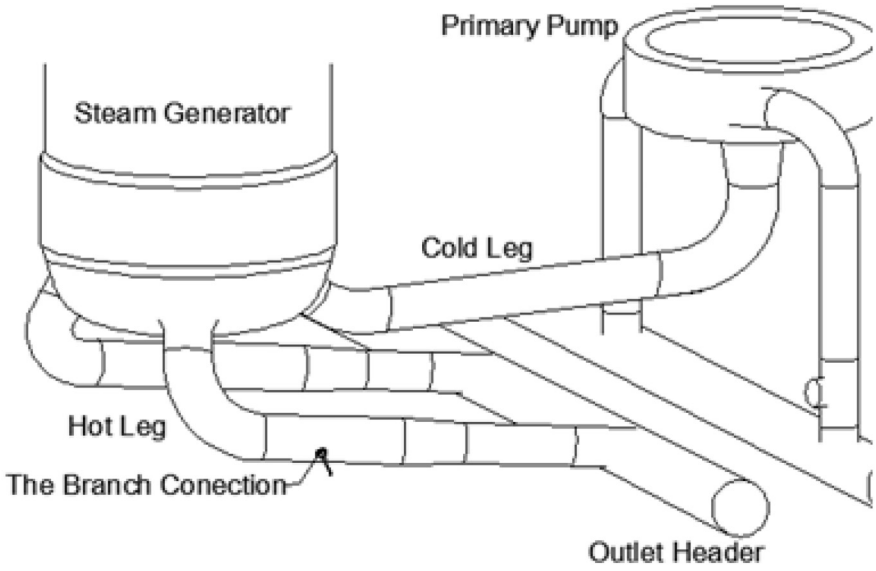

Fig. 1. The location of the branch connection.

Table 1
Basic information of the branch connection.

Item	Parameter
Connecting structure	3/4 in to 20 in, wedeled 3/8 in to 3/4 in, tube adapter
Design pressure/operating pressure	17.24 Mpa/11.15 MPa
Design temperature/operating temperature	315.6 °C/260 °C
Inner medium	Primary loop heavy water
Flow rate	0.3 m/s
Parent material	SA 182F 304L + SA 105N
Welding technic	Tungsten inert-gas arc welding
Welding material	ERNiCr3 Φ3.2 mm
Welding thickness	3.9 mm
Welding direction	30° fixed

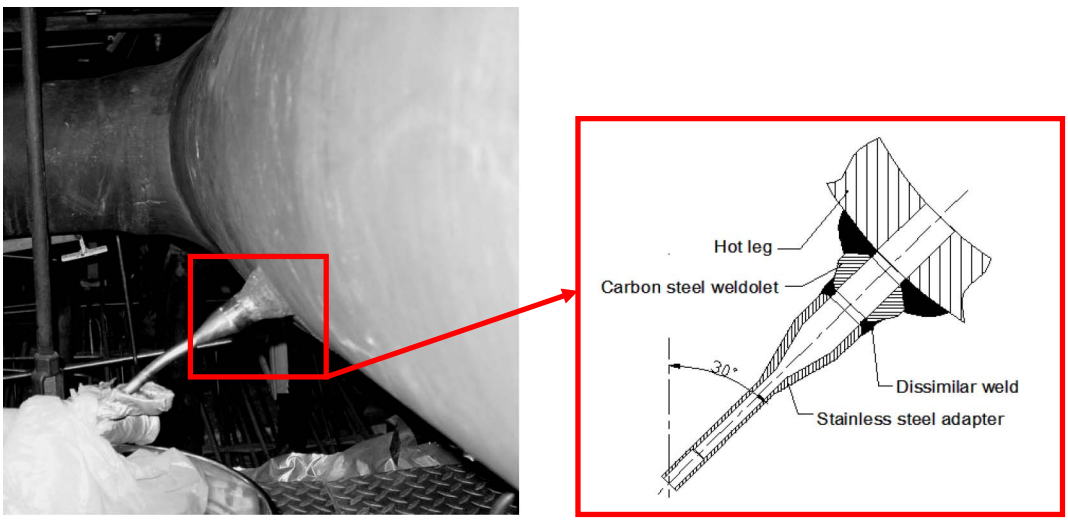

Fig. 2. The structure of the branch connection.

cut from the carbon steel weldolet. The sampling locations and incision direction are shown in Fig. 5. Table 2 shows the sampling order and test items. The metallography samples were prepared by using standard metallographic techniques and etched electrochemically in 10% oxalic acid solution according to standard ASTM A262 Practice A.