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FAC and Current Status of Two-phase FAC Test Facilities

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1. Introduction

Flow-accelerated corrosion (FAC) causes wall thinning in carbon steel piping, vessels, and components when these parts are exposed to flowing water (single-phase) or wet steam (two-phase). FAC has plagued Nuclear Power Plants (NPPs) and fossil power plants for many years [1]. Undetected, FAC will cause an abrupt rupture of components without a warning of leaks. Due to FAC, fatalities and a considerable economic loss occurred at Surry Unit 2 in 1986 in the USA and at Mihama Unit 3 in 2004 in Japan [1]. As a result, FAC became a major issue for NPPs. FAC occurs under both single and two-phase flow regimes. This paper describes FAC and the current status regarding global two-phase test facilities.

2. Methods and Results

2.1 FAC

FAC is a process during which a protective oxide on carbon or low-alloy steel becomes thinner and less protective. FAC is a very complex, and its rate depends on several parameters, such as the temperature, pH, water chemistry, electric potential, material composition, and thermal-hydraulic characteristics [1]. In single-phase flow, a scalloped, wavy, or orange-peel phenomenon is observed, whereas in two-phase flow, tiger striping or a shotgun pattern is observed.

2.2 Two-phase FAC

Two types of FAC in a two-phase flow can occur; one is erosion-corrosion and the other is liquid droplet impingement (LDI) [1]. It occurs in components carrying wet steam and not those with dry steam, and is associated with annular/droplet flow regimes of the types found in NPPs. The water-steam flow, flow type, steam quality, temperature, and pressure influence the FAC rate. In the early stages, theoretical and experimental investigations concentrated on identifying the mechanisms associated with two-phase FAC. Many researchers have studied the flow and thermal hydrodynamic behaviors, water chemistry, and degradation phenomena pertaining to FAC under two-phase conditions using small-scale facilities [1].

For a realistic simulation of the environments in NPPs, large-scale FAC test facilities operating at high pressures and temperatures have been developed for FAC tests (two-phase condition), such as the BENSON test rig, the CRIEPI test loop, the TEPCO system, and the CIROCO loop [2-5]. The experimental data obtained from the above facilities were used to develop computer codes that can be employed to predict the future corrosion damage caused by FAC and LDI.

2.3 Large-scale FAC test facilities

The high-pressure test facility known as the BENSON test rig was installed in an accredited laboratory at Framatome ANP in Erlangen, Germany [2]. The design data are as follows:

- System pressure 330 bar
- Temperature 600 ℃
- Mass flow 28 kg/s
- Heating capacity 2000 kW

The test facility, as shown in Fig. 1, is made of austenitic stainless steel and is thermally insulated a 50mm thick layer of rock wool. It has a wide range of operating conditions for two-phase tests. The results obtained from the BENSON test rig were used to develop the COMSY code. This program can be applied to NPPs to predict the FAC, LDI, and cavitation types of degradations.

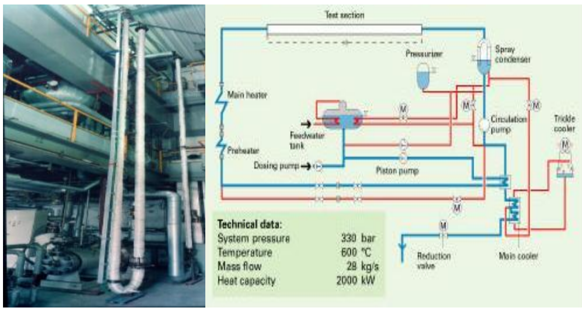

Fig. 1. View and flow diagram of the BENSON test rig [2].

Fig. 2 shows a multipurpose steam test apparatus for the LDI experiments (250℃, 0.01~1.6MPa, 833kg/h, 20% wet) at CRIEPI in Japan. In order to simulate actual conditions at NPPs, a high speed steam-water flow was utilized in the LDI tests. The principal parameters during these tests are the inlet pressure and the degree of wetness. The results were used to develop a new thinning rate prediction model (the LDI model) [3].

The TEPCO R&D center in Japan owns a large-scale mock-loop test system. The test conditions with pure water equipment are as follows:

- System pressure Max. 7.45 MPa
- Temperature Max. 288 ℃
- Flow rate Max. 26 t/h
- Heating capacity 1130 kW
- Steam quality 0~50 %

This facility conducts various studies of two-phase FAC, with the obtained data used to develop the wall-thinning management codes targeting FAC and LDI [4].

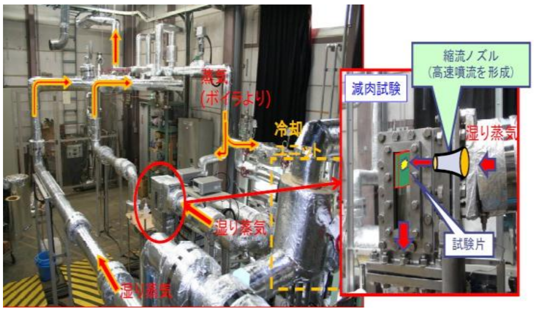

Fig. 2. Steam experiment apparatus for the LDI wear tests [3].

The EDF R&D center in France constructed the CIROCO loop to study FAC in 1978. This loop consists of high and low-pressure loops and it has been continually improved. The EDF has developed the BRT-CICERO^{TM} code using laboratory tests conducted on the CIROCO loop for predicting both single and two-phase FAC [5]. The recent EPRI report provides results conducted on the mechanics and factors influencing two-phase FAC. For this test, a test loop was developed to simulate steam-water mixtures.

3. Conclusions

An overview of the characteristics of FAC, including the type known as two-phase FAC, was presented here. Several small-scale test loops have been developed to investigate the parameters which influence FAC. A number of large-scale FAC test facilities capable of simulating NPP conditions have been developed, such as the BENSON test rig, the CRIEPI test loop, the TEPCO system, and the CIROCO loop. The results obtained from these facilities have been used to develop computer codes to predict two-phase FAC.

Acknowledgements

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