RESEARCH ON CRITICAL HEAT FLUX OF PWR FUEL ASSEMBLY IN NPIC

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ABSTRACT

One of the important limitations in nuclear reactor design is to avoid departure of nucleate boiling (DNB) and dry-out (DO), which may cause fuel assembly cladding failure. Critical heat flux (CHF) under different condition is a complicated physical phenomenon which could not be predicted by analytical method. Experiment is the common way to acquire the CHF correlations for complicated geometry like bundle channels. To simulate the thermal hydraulic condition in an actual reactor, different scaling and geometry rod bundles are applied. The facility named Large Scale Thermal Hydraulics Test Facility (LS-THTF) of NPIC (Nuclear Power Institute of China) which carried out the CHF experiments of full length rod bundle is introduced in the article, and also with the primary results of benchmark experiment including two test configurations.

KEYWORDS
Fuel Assembly; CHF; Benchmark Experiment

1. INTRODUCTION

The one of most important components in fuel assembly of Pressurize Water Reactor (PWR) is grid space r, which can improve the performances of thermal hydraulics, increase safety and economics of reactor co re besides supporting and positioning functions. Therefore many great nuclear power manufacturers spen d a great deal of human source and cost on improving its design.

In recent years, thermal hydraulic researches related PWR fuel assembly were carried out in NPIC, and full-length rod bundle CHF experiments play an important role on the research. The facility named Large Scale Thermal Hydraulics Test Facility (LS-THTF) of NPIC (Nuclear Power Institute of China) which carried out the CHF experiments of full length rod bundle is introduced in the article, and also with the primary results of benchmark experiment including two test configurations.

2. EXPERIMENTAL FACILITY

LS-THTF consists of pump, test channel, the purification system, feed water supply and pressure system, cooling water system, DC power system and the data acquisition system. The Schematic of the facility is shown in figure 1. The important T-H parameters are measured by calibrated instruments, including temperature, flow rate, pressure and power. The inlet and outlet fluid temperature are measured by high precision resistance temperature detectors (RTD). The inlet mass flow rate is measured by Venturi flow meter. The inlet and outlet pressures are measured with capacitance pressure sensors. The DC current is measured by Hall Effect sensors, and DC voltage is directly measured across the positive and negative plates of the bundle.

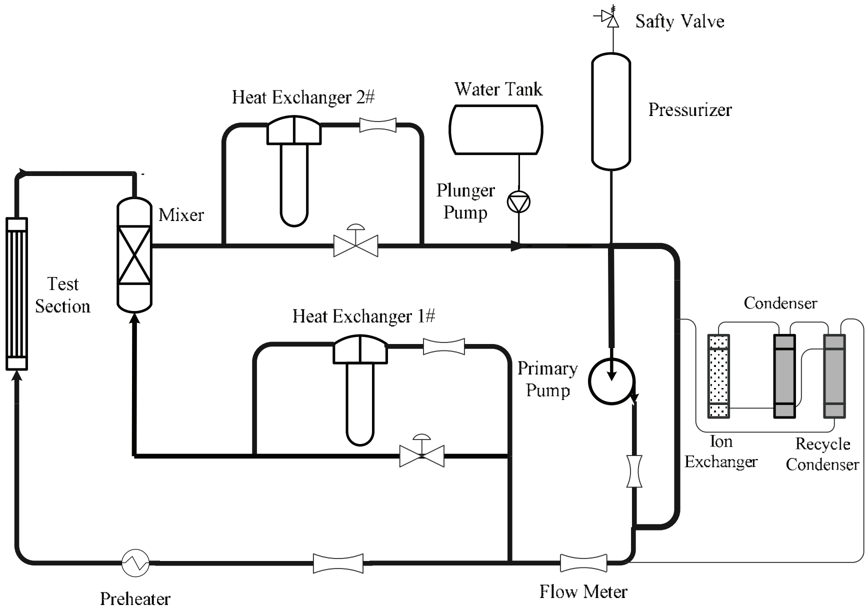

Figure 1 Schematic of large scale thermal hydraulics test facility

3. BENCHMARK EXPERIMENT

The primary benchmark experiments were carried out using two test configurations. The bundle configuration consisted of a 5×5 typical cell rod array with cosine axial power shape and 12fts heated length. The outer diameter of directly heated rods is 9.5mm. Test Configuration 1 was installed with mixing vane grids (MVG), middle span mixing grids (MSMG) and support grids (SG), and benchmarked with the Heat Transfer Research Facility (HTRF) of Columbia University. The results of Test Configuration 2 without MSMG were compared with the FC-CHF correlation of Framatome. The configurations are shown in figure 2.

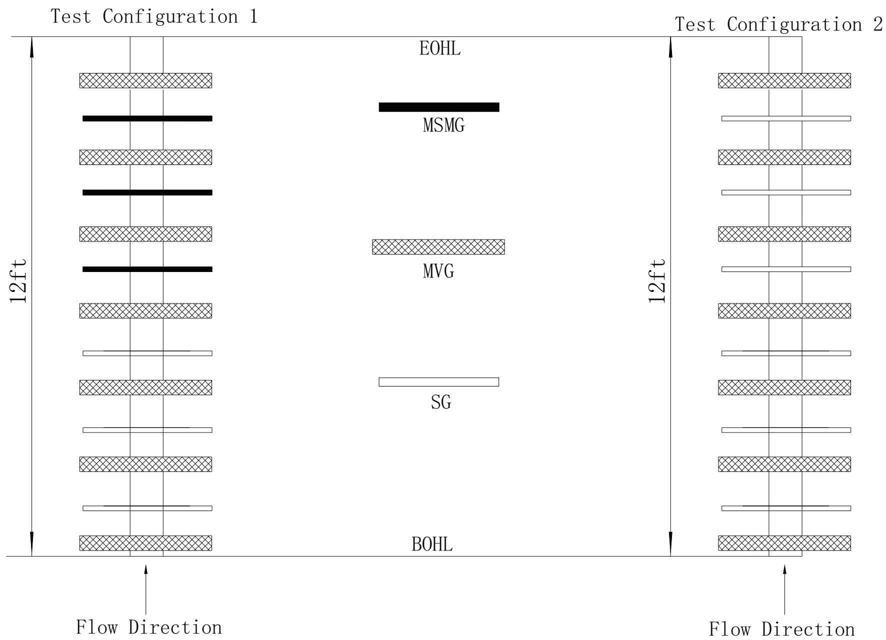

Figure 2 Schematic of test configurations

The procedure of CHF experiment was as follow. Firstly, the presetting thermal condition is established, and the initial power of the bundle is about 80%~90% of the expected CHF power level. Secondly, the bundle power is increased slowly with the inlet parameters keeping almost constant, until a temperature excursion is observed in one or more TCs of the rods. Finally, a rapidly cut of the power about 10% is executed to protect the rods. The typical process is illustrated by Figure 3.

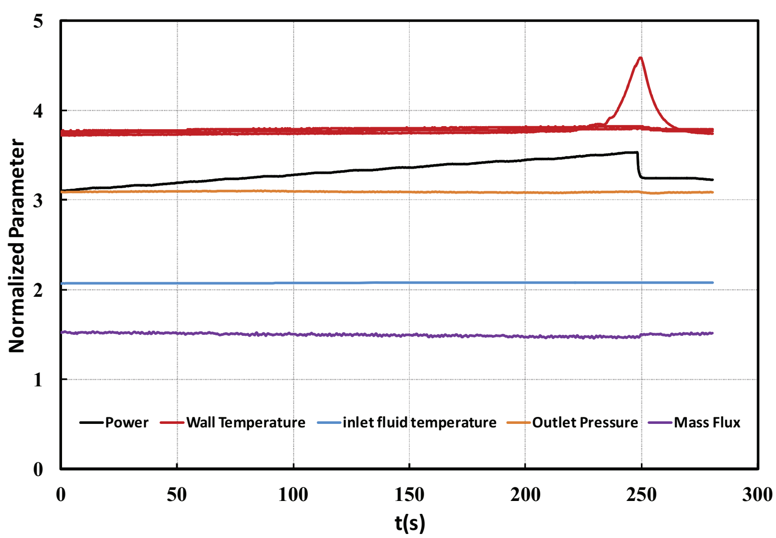

Figure 3 Typical curves of CHF process

3.1. Primary results of Test Configuration 1

In order to making a direct comparison of CHF data, the presetting thermal hydraulic condition of each CHF point was set to the reference CHF point. The tolerance criteria and maximum bias in the benchmark experiments are shown in Table 1.

Table 1 Tolerance criteria and maximum differences

Parameter	Tolerance	Maximum bias
inlet fluid temperature	1.5℃	0.9℃
inlet mass flux	2%	1.7%
outlet pressure	0.2MPa	0.15MPa

A set data of Test Configuration 1 was compared with HTRF reference test data. The inlet and outlet parameters for each CHF point were within the tolerances given in Table 1. The results are shown in Figure 4. A good agreement of experiment results from LS-THTF and HTRF is shown.

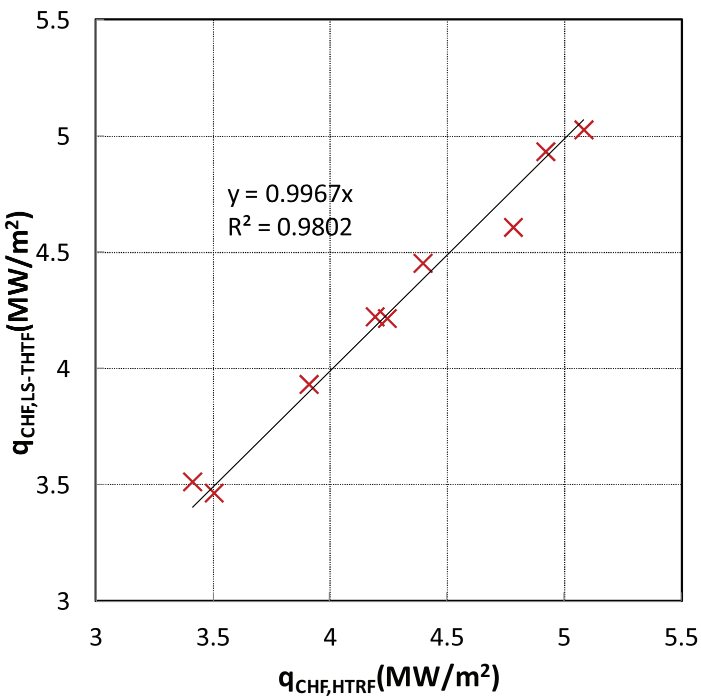

Figure 4 Comparison of CHF power between LS-THTF and HTRF

3.2. Primary results of Test Configuration 2

An indirect comparison of Test Configuration 2 CHF data was carried out with the FC-CHF correlation of Framatome. The distribution of M/P under different mass flux and local quality are shown in Figure 5 and Figure 6, respectively, and a good agreement is indicated.

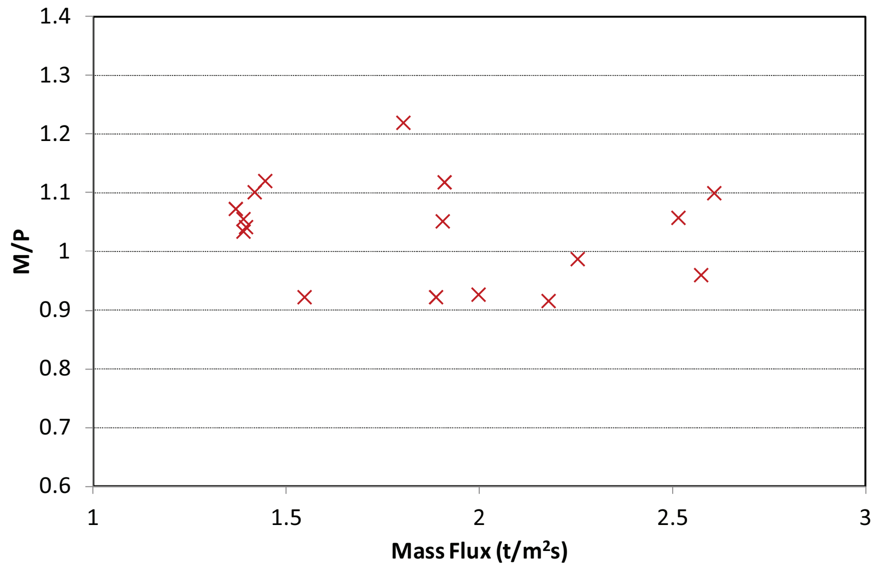

Figure 5 Distribution of M/P under different mass flux

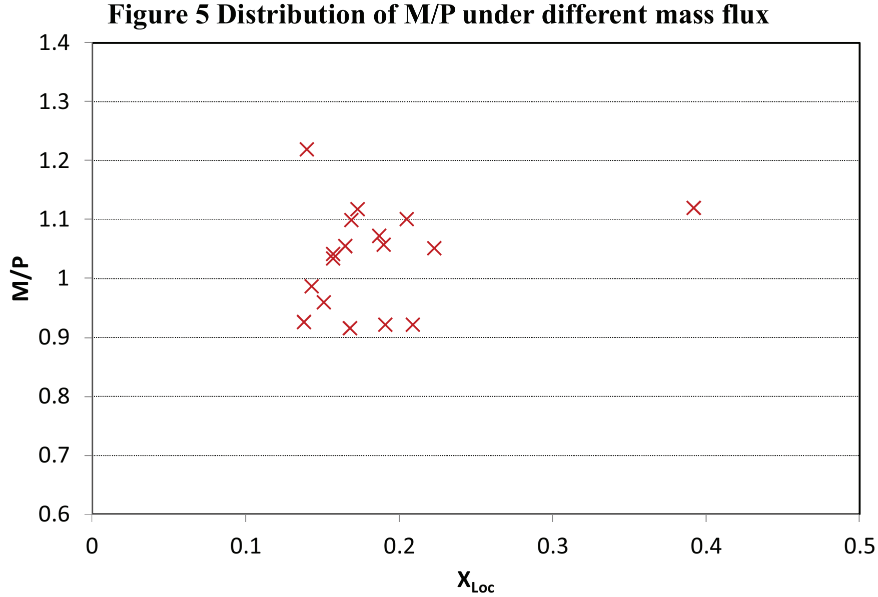

Figure 6 Distribution of M/P under different local quality

4. CONCLUSIONS

Primary benchmark experiments show that the LS-THTF is consistent in CHF data with the Heat Transfer Research Facility in Columbia University. A complete benchmark experiment is underway, and the intensive analysis of the result will be shown in the future.