A MTR FUEL ELEMENT FLOW DISTRIBUTION MEASUREMENT PRELIMINARY RESULTS

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ABSTRACT

An instrumented dummy fuel element (DMPV-01) with the same geometric characteristics of a MTR fuel element was designed and constructed for flow distribution measurement experiments at the IEA-R1 reactor core. This dummy element was also used to measure the flow distribution among the rectangular flow channels formed by element fuel plates. Two probes with two pressure taps were constructed and assembled inside the flow channels to measure pressure drop and the flow velocity was calculated using pressure drop equation for closed channels. This work presents the experimental procedure and results of flow distribution measurement among the flow channels. Results show that the flow rate in the peripheral channels is 10 to 15% lower than the average flow rate. It is important to know the flow rate in peripheral channels because of uncertainties in values of flow rate in the open channel formed by two adjacent fuel elements. These flow rates are responsible by the cooling of external fuel plates.

1. Introduction

The IPEN IEA-R1 is a 5 MW pool type research reactor that uses MTR (Material Testing Reactors) fuel elements in the core. Each fuel element has 18 fuel plates assembled on two lateral support plates, forming 17 independent flow channels. Actually, the reactor core has 20 fuel elements, 4 control fuel elements and a central irradiator, assembled in a square matrix 5x5. The safe operation of the reactor is guaranteed maintaining suitable safety margins in any operational conditions. These safety margins (DNBR, ONB, CHF and maximum surface temperature) are verified in the thermal-hydraulic analysis (THA) of the core. To perform the THA it is necessary to know some parameters, such as: heat flux distribution, geometric characteristics, material properties and flow rates through the fuel elements. The uncertainties of these parameters are also necessary for the THA.

The flow rate through the fuel elements is an important parameter and it is difficult to determine due to the geometric complexity of the core. The IAEA (International Atomic Energy Agency) TECDOC 233 [1] suggests that the flow rate through the fuel elements is the total reactor primary flow rate divided by the number of fuel elements. This value is not completely true because the core has fuel elements and other components such as: reflectors, irradiators, plugs and still secondary bypass holes, gaps and couplings. A dummy fuel element (DMPV-01) [2] was designed and constructed to measure the flow rate distribution among the fuel elements at the IEA-R1core. It is made of aluminium in natural size and has static pressure taps at inlet and outlet region, and has a dynamic pressure tap at outlet nozzle. The measured values show that the flow distribution is approximately uniform (difference of 4% between maximum and minimum measured values) and that the actual flow through the fuel elements is lower than the values based on TECDOC 233, indicating bypass flow through secondary paths [3]. The total primary flow rate of the IEA-R1 is 681.3 m^3/h (0.1893 m^3/s) and the calculated individual fuel flow rate, based on TECDOC 233, is 28.4 m^3/h (0.0079m^3/s), while the average measured value using DMPV-01 is 19.8 m^3/h (0.0055m^3/s).

Usually, THA considers uniform flow rate through the fuel elements on the reactor core and also uniformly distributed flow rate among the fuel flow channels. This is not completely true, e.g., there is a flow distribution in both cases. In the first case, was observed a small experimental difference (4%) among the fuel elements of the IEA-R1. In the second case, an experiment was also performed and the procedure and results are subjects of this work.

2. Experiment

Dummy fuel element DMPV-01, Fig.1, was used to perform an experiment to measure the flow rate distribution among the flow channels. It was assembled in the experimental circuit, Fig. 2. A calibrated orifice plate and a calibrated differential pressure transducer (DPT1) were used to measure the total flow rate through the dummy element and a type K thermocouple measured the fluid temperature during the experiment for properties corrections.

Two probes were constructed with 2.5 mm diameter tube in stainless steel with two pressure taps 475 mm distant. They were assembled inside the flow channels of the DMPV-01 in central region to measure pressure drop together with two calibrated differential pressure transducers (DPT2 and DPT3). Figure 3 shows two adjacent fuel elements and dimensional details of the flow channels. The experiments were performed in three flow rates: 21.9, 18.7 and 14.4 m^3/h. The channel flow velocities and flow rates were calculated using pressure drop equation for closed channels.

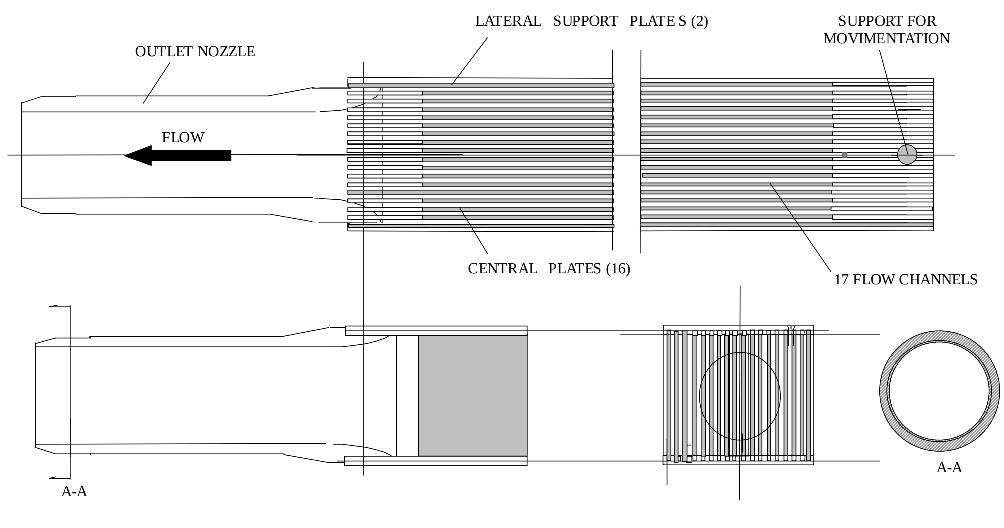

Figure 1. Instrumented dummy fuel element DMPV-01.

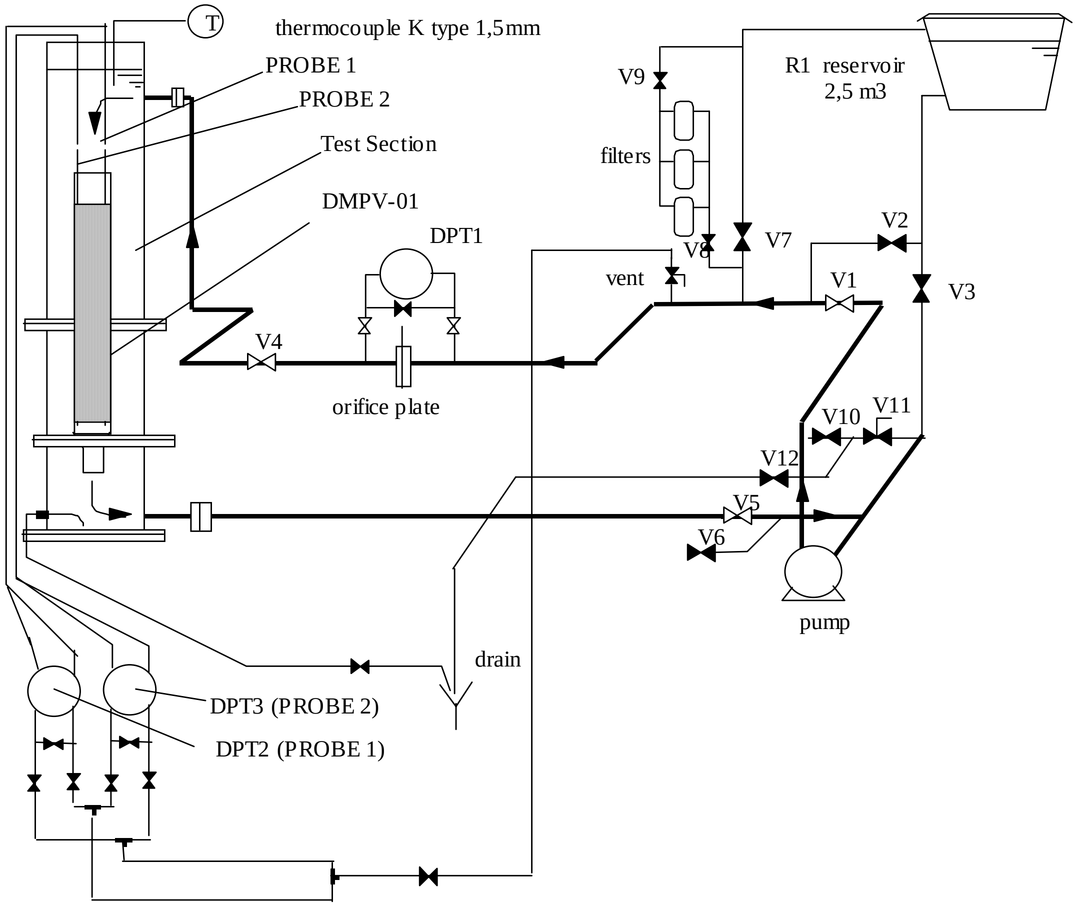

Figure 2. Experimental circuit and DMPV-01.

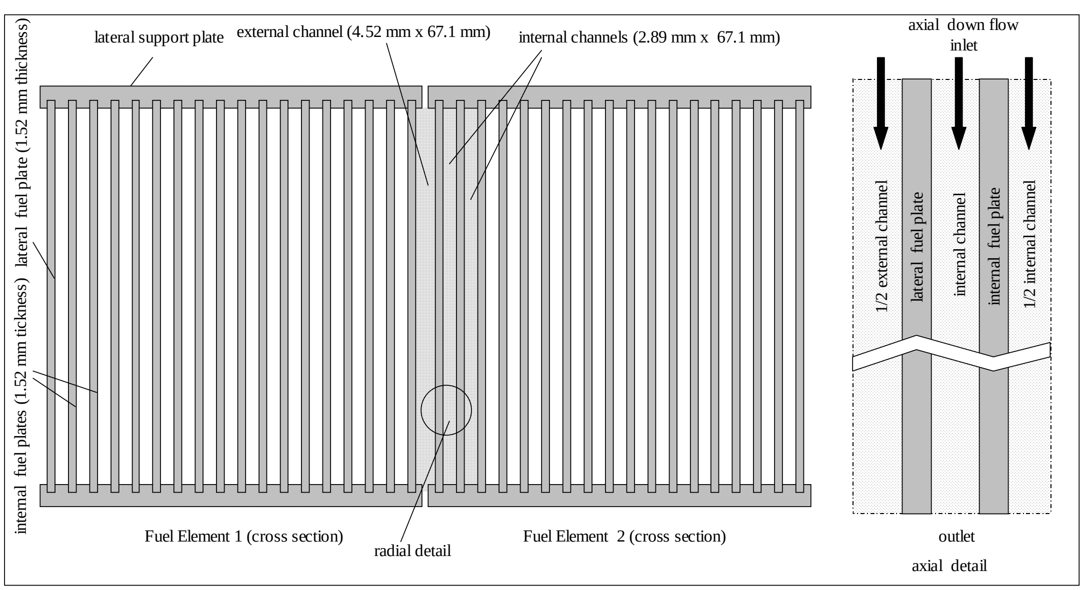

Figure 3. Cross section of two adjacent fuel elements

3. Results

The flow velocities (V) were calculated using the pressure drop equation for closed channels, Eq. 1, and the smooth tube friction factors (f) were calculated by Eqs. 2 and 3 for turbulent flow. Eq. 4 calculate the channel flow rate. It was considered the following conditions in the calculations: a) the channel geometry is the same for all channels and b) the probe influence on channel flow area is negligible.

$$\Delta P = 0.5 \,.\, f \,.\, (L/Dh) \,.\, \rho \,.\, V^2 \qquad (1)$$

$$f = 0.3164 \,.\, Re^{-0.25} \qquad \text{(smooth tube)} \qquad (2)$$

$$Re = \rho \,.\, V.\, Dh / \mu \qquad (3)$$

$$Q = V \,.\, A \qquad (4)$$

where ΔP is the pressure drop measured by the probe (N/m^2), L is the channel distance between probe pressure taps (0.475 m), Dh is the channel hydraulic diameter (5.541×10^{-3} m), ρ is the fluid density (kg/m^3), V is the average flow velocity (m/s), f is the friction factor, Re is the Reynolds number, μ is the fluid dynamic viscosity (kg/m.s), Q is the channel flow rate (m/s) and A is the channel flow area (1.94×10^{-4} m^2). The total flow area (A_{total}) in channel region is 0.0033 m^2.

Figure 4 shows the channel pressure drop as a function of the volumetric flow rate in dummy element. Pressure drop in external channels (1 and 17) is lower than in the others, indicating a lower flow rate in these channels when compared to the internal channels.

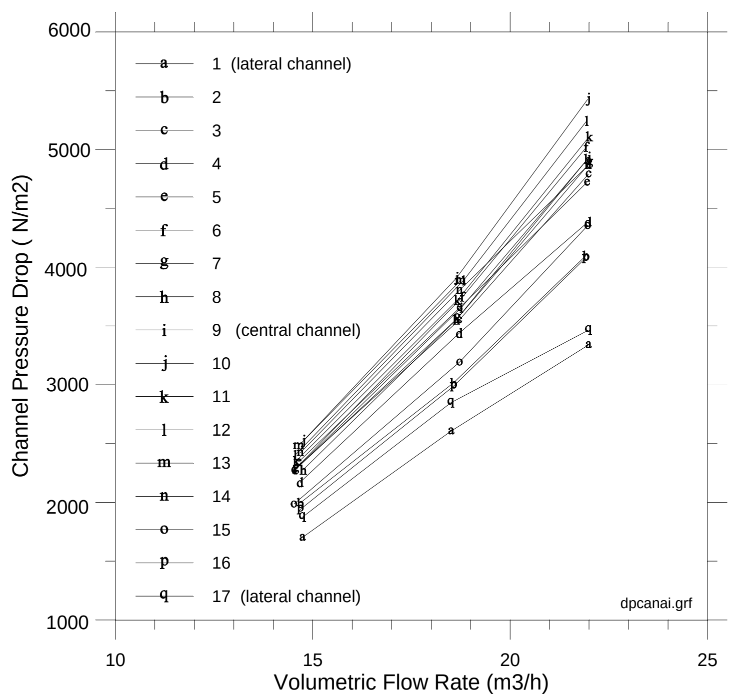

Figure 4 – Channel pressure drop versus volumetric flow rate.

Figure 5 shows the flow distribution among the flow channels for the three different flow rates. We can observe that the flow rate in the peripheral channel is lower (10 to 15%) than the average value and depends on flow rate through the fuel element. This difference is due to inlet and outlet effects in the element.

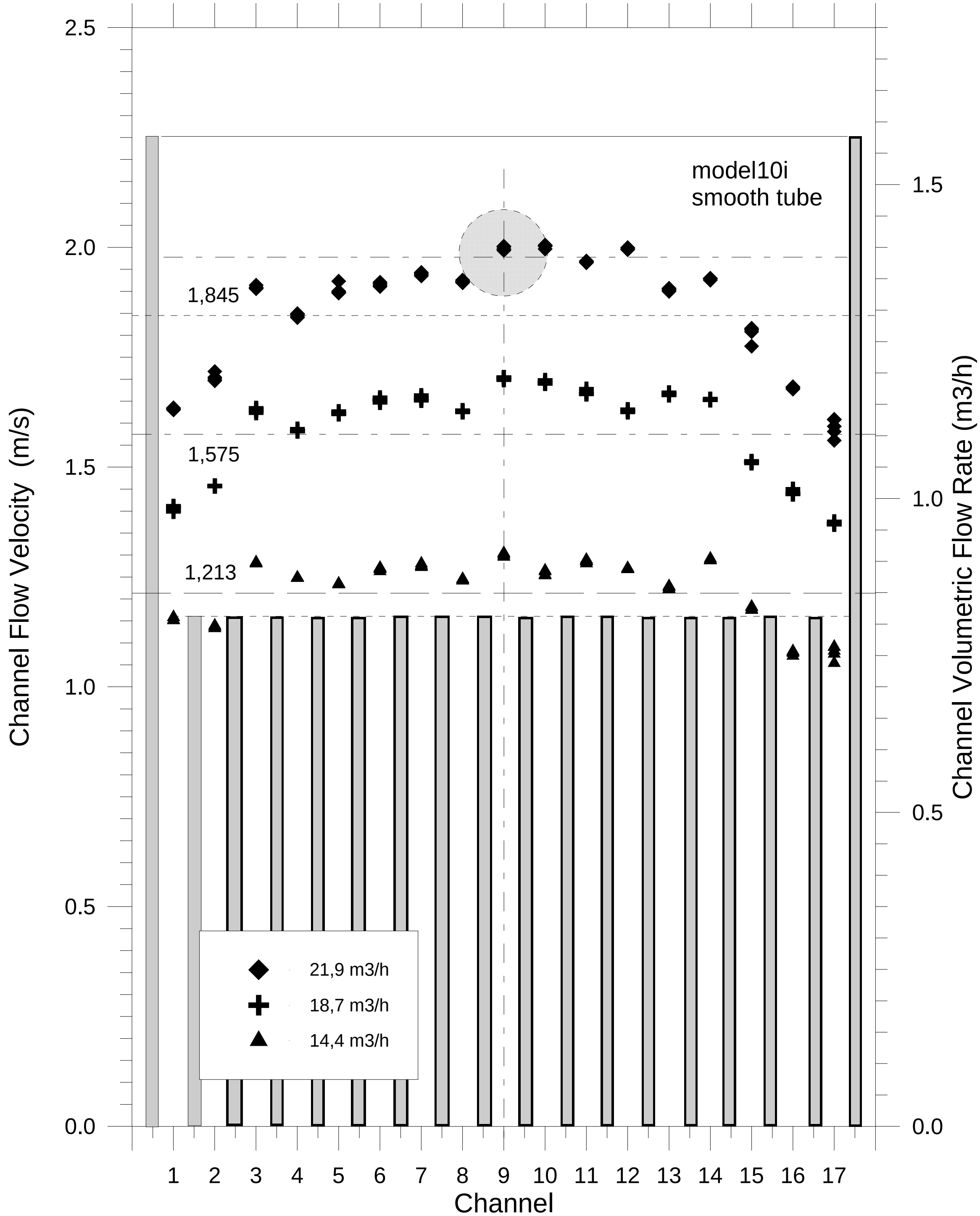

Figure 4 – Flow rate distribution among flow channels.

4. Conclusions

The flow distribution among the fuel flow channels was calculated using experimentally measured data of pressure drop and pressure drop equation for closed channels. The results show that the flow rate in peripheral channels is 10 to 15% lower than central ones. This difference is due to inlet and outlet effects. The cooling of the external fuel plates is provided by the flow rate in internal channel and the flow rate in the open channel formed by two adjacent fuel elements. The last one is a difficult parameter to determine and to measure, and usually an estimated value is used. Therefore, the flow rate in internal channel is an important input parameter in thermal-hydraulic analysis. Future works will be performed to reduce mainly the inlet effect by the reduction of the external plate size to the same height of the internal plates.

5. References

[1] IAEA – TECDOC – 233, "Research Reactor Core Conversion from Use of High Enriched Uranium to Use Low Enriched Uranium Fuel Handbook", International Atomic Energy Agency, Vienna, Austria, 1980.

[2] Lima, R. M., Oliveira, F. S., "Relatório Descritivo de Fabricação do Elemento DMPV-01", IPEN Internal Report No.RDF-DMPV-01/01, 2000.

[3] Torres, W. M., Umbehaun, P. E., Baptista F^{o}, B. D., Almeida, J. C., Souza, J. A. B., Silva, D. G. " Distribuição de Vazão no Núcleo do Reator de Pesquisas IEA-R1", Proceedings Brazilian Congress of Mechanical Engineering, Uberlândia, Minas Gerais, Brazil, 2001.