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Flow mapping of the mercury flow

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1. Introduction

Measurement of a flow, a velocity at any point or its spatial and temporal distribution, has been one of the most difficult tasks in using liquid metals and, because of it, its application to the study in physics and to industrial devices has been largely limited. Also for many of the rheological liquids which are mostly opaque, investigation of their flow behaviour was limited only to a measurement of total volume flow and pressure. For overcoming such difficulty, a new measuring method has been developed using ultrasound technique, Ultrasonic Velocity Profile method (UVP), and has been established in the field of fluid mechanics and fluid engineering[1][2]. The UVP has been developed at Paul Scherrer Institut(PSI) in Switzerland for investigating liquid metal flow in the geometry of the target of the neutron spallation source (SINQ). This method uses a pulsed echography of ultrasonic beam. In this paper, we present our latest results of the measurement of mercury flow.

2. Experimental set-up

2.1 Mercury loop A full scale mock-up container of the lower part of the SINQ target geometry has been installed in the Hg loop of the Institute of Physics of the Latvia University (IPLU) at Riga, Latvia. The mercury is a model liquid to Pb-Bi-Eutectic (LBE) to be used in the SINQ liquid target. The SINQ target test section is illustrated in Fig.1. It consists of double coaxial cylinders and has two buffle chambers at the top for inlet and outlet flow respectively. The mercury is fed into this chamber through 6 inlet tubes connected to it. It then flows down in an annular channel toward the bottom part called "window" which has a hemispherical shape. The fluid turns there into a inner circular channel inside the inner guide tube and flows up to the second chamber for outlet. The diameter of the outer tube is 207 mm and the total length of the test section including these chambers is ca. 2.3m[2]. Since the geometry of the bottom part such as the shape of the bottom plate and of the edge of inner tube as well as the gap distance between inner tube and bottom plate is most important in designing the target, investigation of the flow in various geometry for this part is under progress. In this paper, we present results of experiments for the axisymmetric configurations of inner tube and for the flow configuration under the different gap distance and different flow rate.

2.2 Instrumentation Flow measurement was made using UVP method. Based on the results of ultrasound transmission[3], the wall thickness of stainless steel was selected as 2.87mm. The ultrasound transducers(TDX) were set on the outside of the container wall. Figure 2 shows the test window region with transducers that were fixed by a special transducer holder. With this holder we can measure maximum on 20 measuring lines. Prior to the measurement, gas bubbles were injected as a tracer, which reflect the ultrasound pulse. By this method, the measurement was successful to observe the spatial and temporal behaviour of the flow. When many measuring lines are aligned non-parallel, it is possible to obtain two velocity components at the crossing points of measuring lines, so that we can obtain the vector field

3. Results

In the present experiment we made two different types of flow mapping; time-averaged flow mapping and time-dependent flow mapping. Fig. 3 shows the typical measuring lines for time-averaged and time-dependent flow mapping. For the time-averaged velocity profiles, the data set for one measurement consists of 512 instantaneous velocity profiles. The vector field was then computed for a series of measurements which consists of 36 measuring lines. This generates in total 126 vectors in the field, when eliminating the points where the crossing angle is less than 15°. The computed vector field is plotted in Fig. 4. It is seen that the flow is not necessarily symmetric with respect to the target axis especially to gap:8. It is considered to be due to the generation of large vortex and its time dependent nature as a chaotic flow. The effect of flow rate is seen in Fig. 4 such that it becomes more symmetric for the large flow rate, although it is not a strong effect. A feature in the vector fields appears similar for three flow rates studied here when the gap distance is constant. Again the flow is very non-symmetric for 8 cm gap distance,

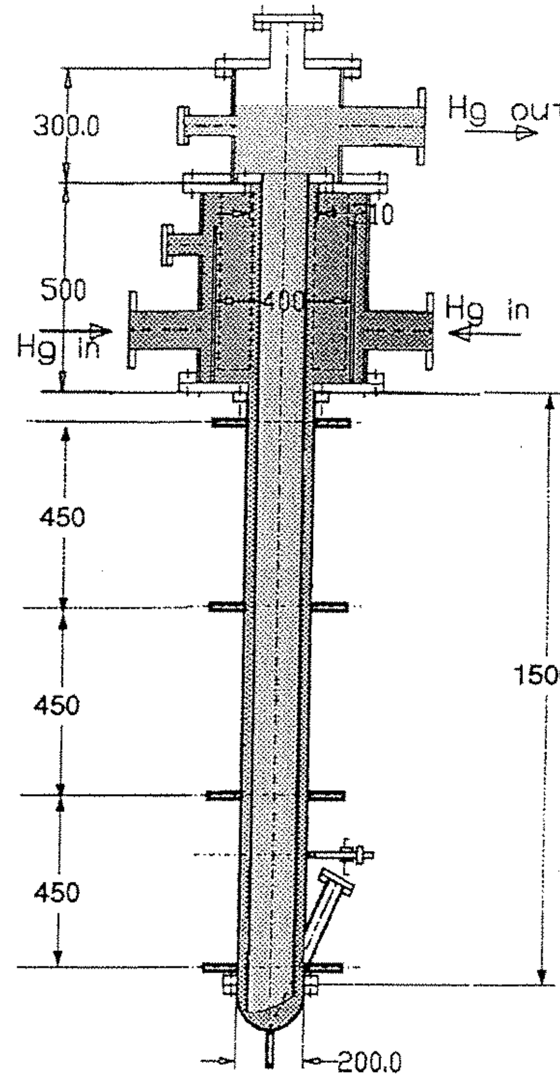


Fig.1 Test section

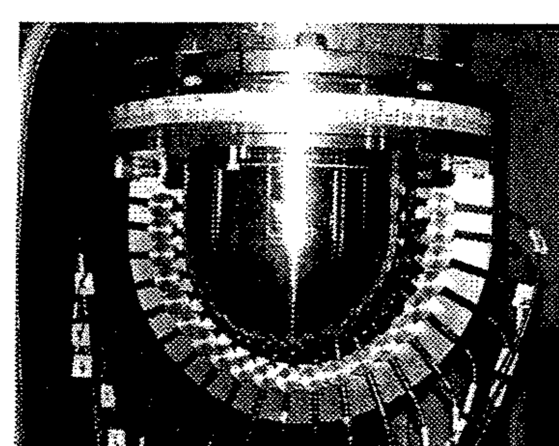
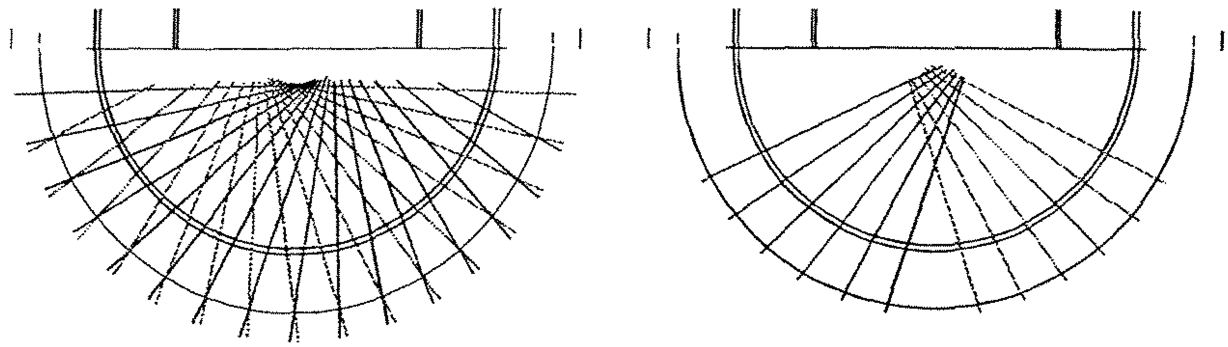


Fig.2 The hemispherical window



(a) Time averaged (b) Time dependent

Fig.3 Measuring lines

but it is similar to other cases. The effect of gap distance is significantly large as seen above. Even for the smallest flow rate with gap distance 2 cm, the flow appears quite symmetric. It is also seen that the region of very low velocity (dead layer) becomes smaller. It is obvious because the inlet flow velocity at the exit of the annular channel is larger.

Using the high speed measuring mode of present equipment, we can obtain the time-dependent flow mapping. Unfortunately, for the time-dependent flow mapping, present measuring area is very small because of restricted alignment of the measuring lines. Fig. 5 shows the flow field for the cases of two different gap distances in the hemispherical window. In these cases, measuring time for one line was 44ms and total measuring time for a vector map was 0.525 sec. In this figure, we also found that the gap distance has a very strong influence on the flow behaviour.

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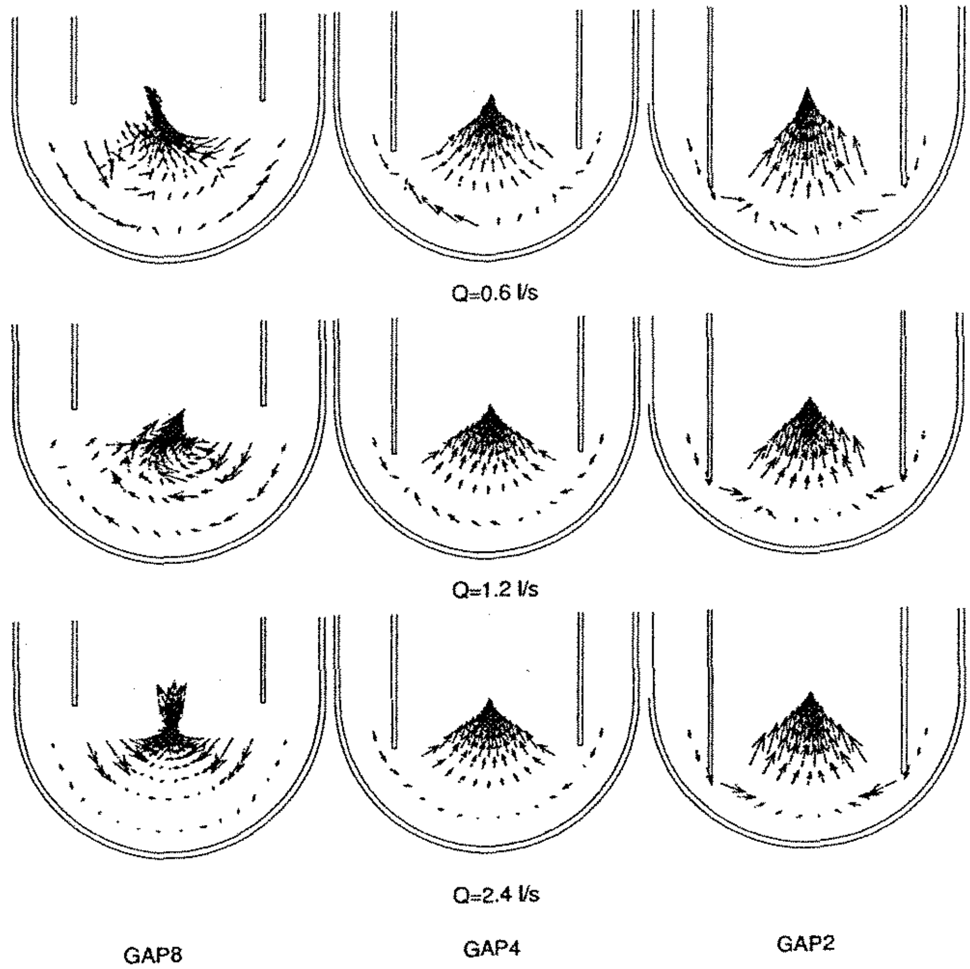

Fig.4 Vector fields for different gap distance

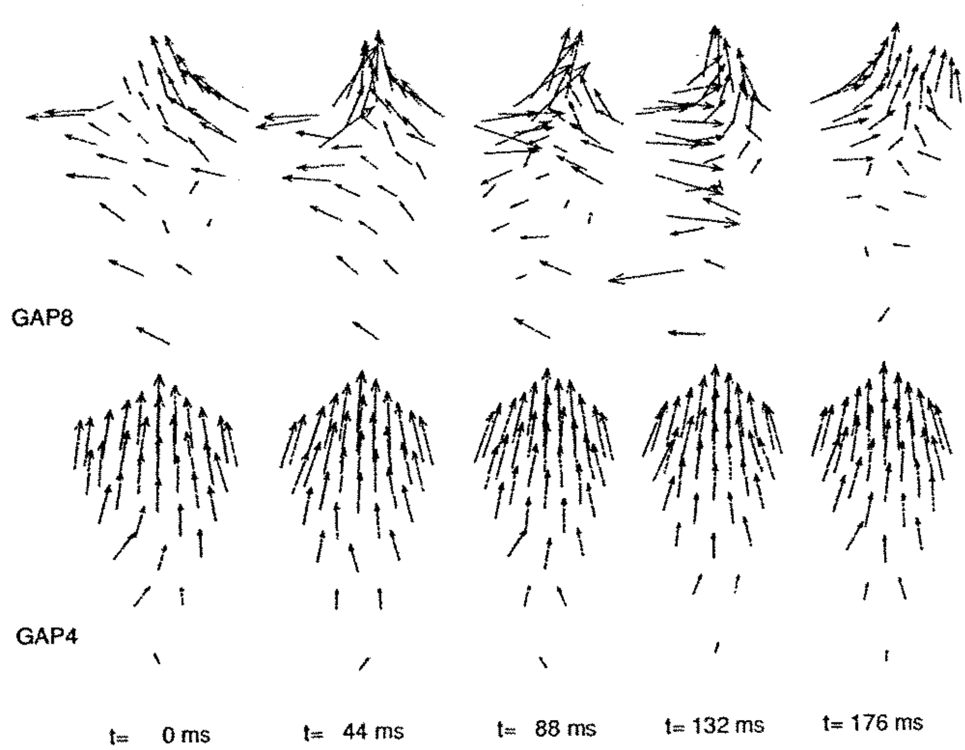

Fig.5 time dependent flows