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Investigation of free and forced flows of relevance to fast reactor thermohydraulics using the ultrasonic Doppler method.

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Extended Abstract

This extended abstract describes two experimental investigation of general interest to the convective heat transfer community, but of particular interest to those engaged in the design of liquid metal-cooled, energy intensive facilities such as the liquid metal fast breeder reactor.

1. Thermal Striping

Thermal striping refers to the phenomenom of fluid-structure interactions in nuclear reactors (specifically liquid-metal cooled reactors), the result of which reactor structures and components incur undesireable thermal stresses. The thermal-hydraulics aspects of this problem concern the random streams of poorly mixed hot and cold coolant. One critical area is the above-core structure of a LMFBR, which due to flow of hot/cold jets out of the core, may experience thermal striping. Since the thermal fatigue behavior of above-core components and their locations are generally known, understanding the convective mixing (or non-mixing) of buoyant and forced-flow is important to the safe design of the reactor. In the present case a basic experiment using a water test facility and consisting of LDA, UVP and recently PIV velocity measurement techniques, as well as temperature measurement has been initiated. The flow geometry is a central cold jet surrounded by two hotter jets, each exiting out of of a rectangular nozzle.

In **Figure 1** we a show a schematic of the test section and a magnified view of the probe orientation with respect to the jet nozzles. The UVP transducer was set at a 10° incline with respect to the horizontal and measurements were taken from both the left and right sides. Unless noted the vertical transverse increments were 5 mm. In the cases shown here, the central jet was set at 30°C while the two adjacent jets were at 35°C. All three jets had equal flowrates out of the nozzle and an exit average velocity of 0.5 m/s.

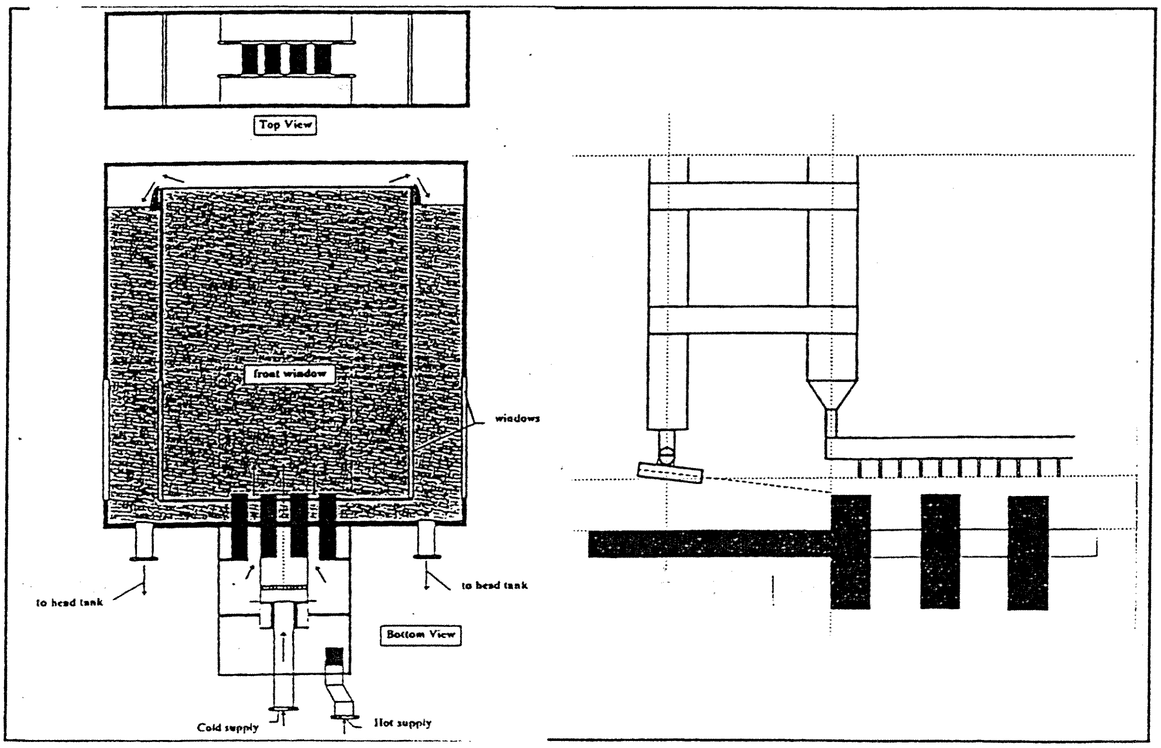
Figure 2, 3, 4 and **5** show some typical results and these are summarized as follows. They are:

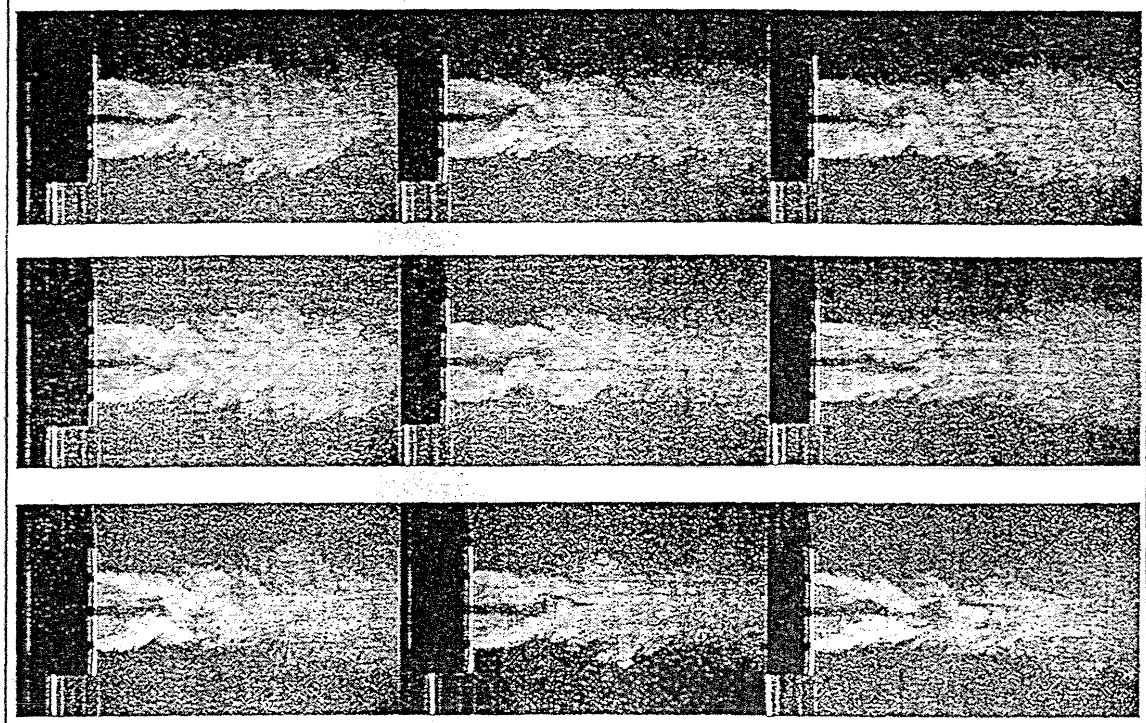
Figure 2. A sequence of four consecutive images as digitized from video pictures during an experimental run. A laser sheet was introduced from the right of the image in order to enhance visualization of the flow.

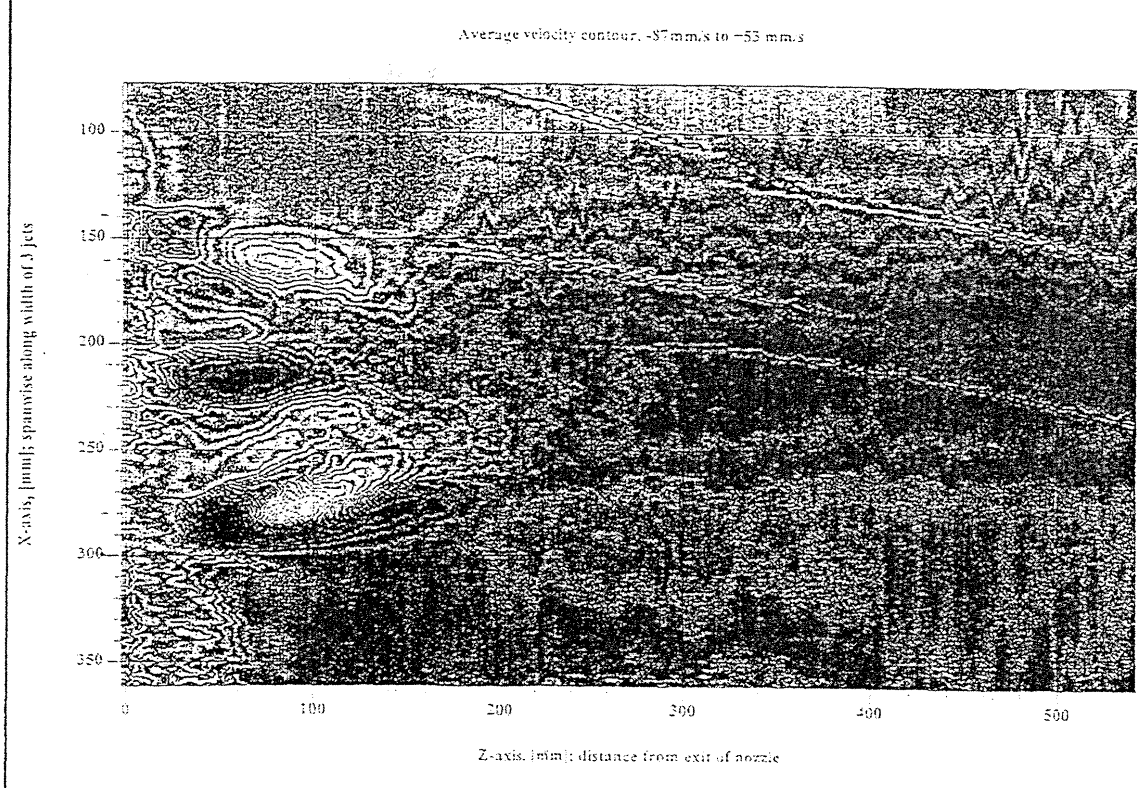
Figure 3. A grayscale image of the temperature fluctuation distribution as taken with a spanwise array of 35 thermocouples positioned on a traversing mechanism. Two spanwise profiles at z ~ 45 and 200 mm from the exit are inset. The vertical and horizontal axes are respectively, the spanwise width covering the exit of the three jets and the axial distance along which temperature measurements were made.

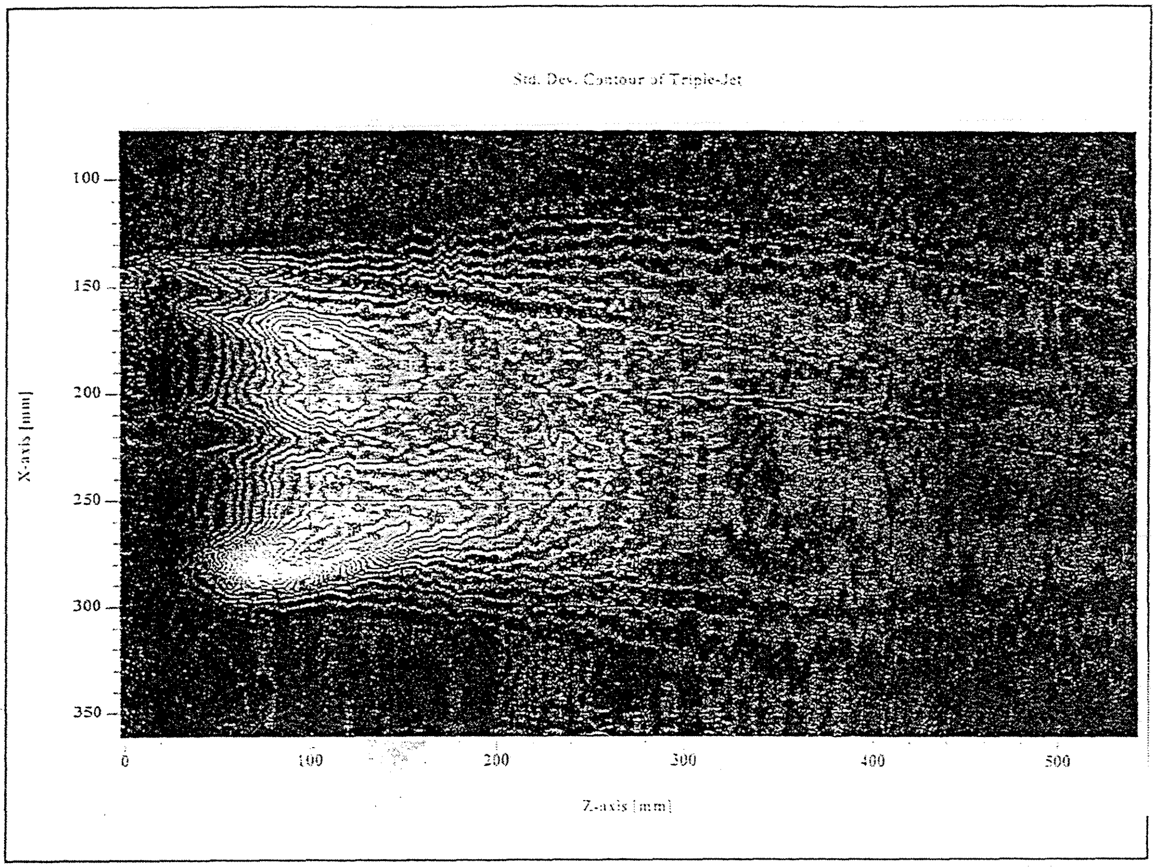
Figure 4. A grayscale image of the velocity fluctuation distribution that nearly corresponds to w'. The vertical and horizontal axes are respectively, the spanwise width covering the exit of the three jets and the axial distance along which UVP measurements were made.

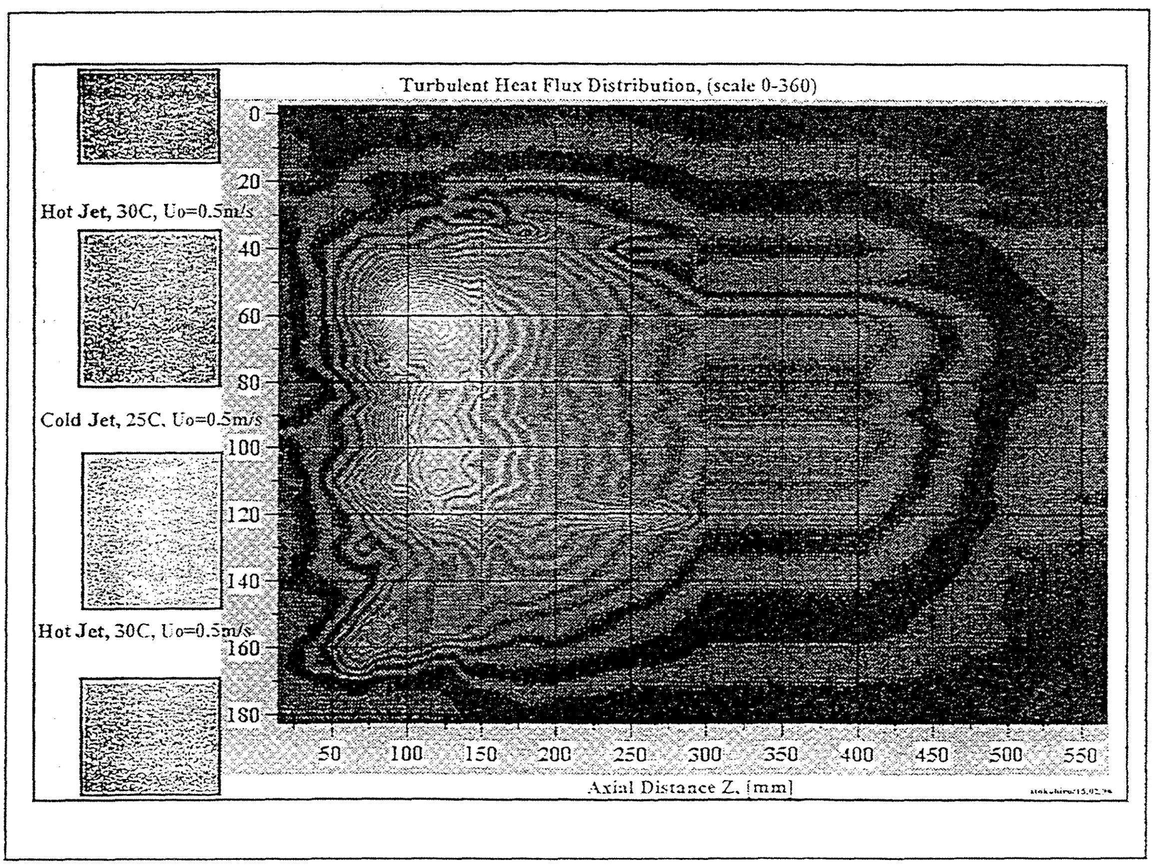
Figure 5. The *constructed* turbulent heat flux distribution, $w't' = f(x,z)$, where w' and t' are respectively, the fluctuating component of velocity, as measured using the UVP, and that of the temperature, as measured using a thermocouple array. The distribution shows that under these condtions, most of the thermal mixing takes place within the first z ~ 200 mm from the exit of the jets and that spanwise, the regions with the highest calculated fluxes are approximately those in between the cold and hot jets.






Average velocity contour, -87mm/s to -53 mm/s
X-axis, [mm]; spanwise along width of 3 jets
100
150
200
250
300
350
0
100
200
300
400
500
Z-axis, [mm]; distance from exit of nozzle


Std. Dev. Contour of Triple-Jet
X-axis [mm]
100
150
200
250
300
350
0
100
200
300
400
500
Z-axis [mm]


Turbulent Heat Flux Distribution, (scale 0-360)
Hot Jet, 30C, Uo=0.5m/s
Cold Jet, 25C, Uo=0.5m/s
Hot Jet, 30C, Uo=0.5m/s
0
20
40
60
80
100
120
140
160
180
50
100
150
200
250
300
350
400
450
500
550
Axial Distance Z, [mm]