# II－50 A Study on Surface Velocity Distribution of the Buoyant Surface Jet

## 温排水の表層流速分布に関する実験

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## I. INTRODUCTION

The operation of a power plant calls for a large amount of cooling water to remove the waste heat. This is most commonly done to discharge the heated water horizontally at the water surface from a large-diameter pipe or an open channel terminating near the shoreline. In addition to possess the general characteristics of nonbuoyant jets, heated surface discharges are greatly affected by the buoyancy of the discharge; lateral spreading is enhanced and vertical entrainment is reduced. (see Fig. 1)

Experiments have been performed to investigate the effect of the buoyancy on the velocity distribution. By using the assumption of Gaussian distribution the half-width of the velocity is obtained and the experiment results are compared with the Gaussian profile. Finally, the trajectory of heated water near the outlet is presented.

The velocity component in $x$-direction and density deficit distributions are described by[1]:

$$U(x,y,z) = U_c(x,0,0)Exp(-\frac{y^2}{b^2})Exp(-\frac{z^2}{a^2}), \tag{1}$$

$$\Delta\rho(x,y,z) = \Delta\rho_c(x,0,0)Exp(-\frac{y^2}{\lambda_h b^2})Exp(-\frac{z^2}{\lambda_v a^2}). \tag{2}$$

Here the $x-axis$ is located at the surface in the jet axis, $y$ is the lateral coordinate and $z$ is taken positive downwards. $U_c$, $\Delta\rho_c$ are centerline velocity and density deficit, respectively.

The integration of Eqs.(1) yields:

$$U_c(x,0,0) = U_o\frac{2}{\sqrt{\pi}}(\frac{B_oH_o}{ab})^{\frac{1}{2}}, \tag{3}$$

## II. EXPERIMENT PROCEDURE

The experiments were carried out in a $2.00m$ long, $0.45m$ wide and $0.45m$ deep tank. The discharge channel with $0.01*0.01m^2$ section was placed in the center of the upstream side. An overflow over the whole length of the opposite side was provided. Another constant head tank is used to supply water through horizontal slots on the whole bottom of the main tank, thus cancelling the entrained water and establishing quasi-steady flow condition. The surface velocities were measured by photograhing floating spheres. The experiments were performed for nine situations listed in *Table 1.*

*Table 1. experiment conditions and* $c_{0\,5} = Db_{0.5}/Dx$, $T_a = 20°C$

| Run No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Temperature($°C$) | 21.40 | 23.00 | 30.01 | 25.05 | 30.01 | 48.03 | 30.01 | 38.68 | 67.58 |
| Velocity($m/s$) | 0.10 | 0.10 | 0.10 | 0.20 | 0.20 | 0.20 | 0.30 | 0.30 | 0.30 |
| $F'_o$ | 21.29 | 14.19 | 7.10 | 21.29 | 14.19 | 7.10 | 21.29 | 14.19 | 7.10 |
| $c_{0\,5} = Db_{0.5}/Dx$ | 0.4232 | 0.5249 | 0.6376 | 0.5340 | 0.6099 | 0.7336 | 0.5200 | 0.5976 | 0.6691 |

## III.EXEPERIMENTAL RESULTS AND DISCUSSIONS

### 3.1. Half width of the surface plume

By fitting the Gaussian profile to the measured data, half width $B$, at an arbitray distance $x$ is determined. Collecting these data for one given condition, Fig.2 is drawn to give the width $B$ as a function of $x$. It can be said that $B$ increases linearly to $x$, in the neighbourhood of the outlet, as long as no effect of side walls appears.

As the buoyancy increases, the discharged water tends to move upward, thus expanding of the plume width at the surface. Fig.3 shows this situation clearly. With the large value of $F_r$, $B$ becomes smaller. The angle of spread is nearly proportional to $F_r^{\frac{-1}{3}}$, within the range of the present experiments.

3.2 Velocity distribution

If some of theoretical works is refered, the spatial distribution of velocity is usually assumed to be of the Gaussian profile. In Fig.4 the surface velocity distribution is with the work by *Jirka* et al., for the condition of Run 6 of the authors. As immediately known from the figure, even in the neighbourhood of the outlet, out-going velocity is given by the theory. This always contradict to the experimental results which show the inward-coming water velocity at the side of the jet. It is due to the entrainment effect of jets or plumes.

Due to buoyancy, we showed the width of plume widens. Accordingly, the velocity profile may differ from the Gaussian profile.

In order to see these effect, Fig.5 are provided. The velocity along the $x$-axis can be calculated with Eq.(3) inserting the relationships in Fig.2. This formula is obtained by one of the authors.

Velocity profiles differ from the Gaussian distribution to some extent. With a smaller $F_r$, scattering of plots is considerable. This means that the effect of buoyancy acts to spread the plume horizontally and brings the interaction with side wall into effect. With the small $F_r$., scattering becomes smaller but still the deviation from the Gaussian profile is recognized.

REFFERENCE:

[1] *Stefan, H., andVaidyaraman, P.*, "Three-Dimensional Surface Plumes"

[2] *Jirka, G.H., Adams, E.E., andStolzenbach, K.D.*, " Buoyant Surface Jets", *Journal of the Hydraulics Division, ASCE, Vol. 107, No. HY11, Nov., 1981, pp. 1467-1487*

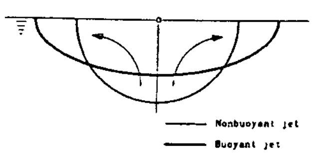


Fig.1-Deformation of cross section of plume by buoyance—(schematic)

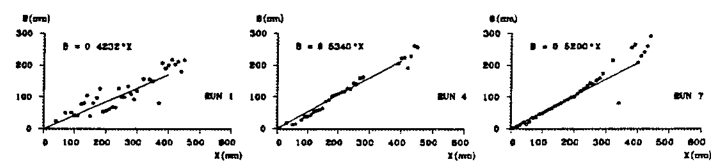


Fig.2- relation of half width and centerline distance

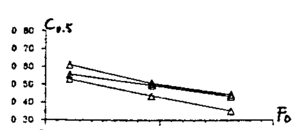


Fig.3 Relation of spreading angle

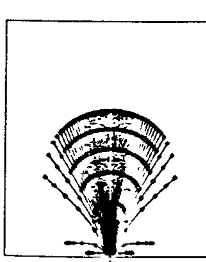
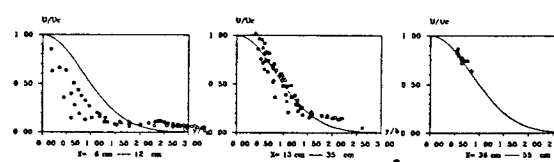
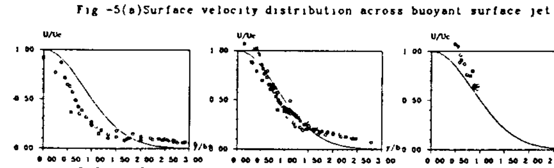


Fig 4-Jet trajectory (Run 6)



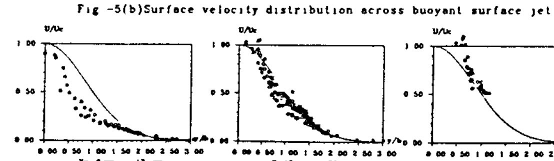
RUN 9 F = 7 0960

Fig -5(a)Surface velocity distribution across buoyant surface jet



RUN 8 F = 14 1920

Fig -5(b)Surface velocity distribution across buoyant surface jet



RUN 7 F = 21 2879

Fig -5(c)Surface velocity distribution across buoyant surface jet