The use of a buoyant wall jet to improve the dilution of a submerged outfall

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Professor Sharp provides some thought provoking ideas on the use of a re-attachment principle for submerged outfalls. However, the outfalls proposed and the flow patterns described relate to the case where the effluent is discharged into still water. Designers, of course, normally seek sites for outfalls where there are ambient currents to provide subsequent dispersion of the effluent. What does the Author think the possible performance of the proposed outfalls in an ambient current would be? It seems likely that turbulence caused by the pipe section may cause early mixing of the effluent, particularly in situations where the current reverses in direction.

9. An ambient current can be used to enhance the re-attachment characteristics of a submerged jet if the device is flush with the sea bed. Anwar¹¹ reported favourably on the performance of a plain long slot set at right angles to an ambient current where it was shown that the effluent travelled some distance along the sea bed before being entrained within the bulk of the moving fluid.

Fig. 7. Longitudinal section through model

DISCUSSION

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A research project similar to that described in the Paper is at present under way in my department under the supervision of Professor I. R. Wood.

11. An experimental study is being made of a two dimensional jet discharging under a gate at the top of a slope (Fig. 7). The jet is observed to cling to the slope and then to leave the bed as a buoyant plume at some distance from the gate. A dimensionless plot similar to Fig. 4 has been obtained (Fig. 8). Mean point temperatures have been measured and temperature distributions plotted. Further testing is to be performed to obtain velocity distributions, thus enabling an estimate to be made of the entrainment of the ambient fluid into the top of the jet.

12. A model study of a cooling water discharge device using a similar arrangement of gate and slope was performed by the State Electricity Commission of Victoria, Australia, in 1974 for the proposed Newport Power Station in Melbourne. The results of this model study suggest that a large amount of mixing will be achieved for a small loss in head across the gate.

Mr A. R. Agg, Water Research Centre, Stevenage Laboratory

The Author's proposal involves the discharge of effluent immediately above the sea bed in order to achieve attachment of the jet by the Coanda effect. There could be practical objections to such an arrangement because of the possibility of scouring of bed material from around the outlet and, conversely, the danger of the outlet being blocked by bed material in the event of temporary or long-term accretion. Recent practice in the UK has been to position outlets at least one metre above the bed in order to avoid such difficulties; these would be most likely to occur with intermittent discharges into comparatively shallow water and where tidal velocities are sufficiently high to disturb bed material. Areas subject to substantial ground swell are also subject to short-term variations of bed profile.

14. It is interesting to compare the Author's preliminary observations with results obtained by Anwar¹² in similar model experiments with round buoyant jets in still water. He observed no significant effect of the floor of the model when comparing results for centre line dilution of the jet obtained with outlets of diameter 0.5 in. and 1.0 in. placed 8 in. and 0.25 in. above the floor and discharging horizontally. It is thus important to establish the limitation on the position of the outlet in relation to the floor in order to achieve attachment of the jet.

15. Anwar¹² also obtained results with jets discharging at 30° below the horizontal. These indicated significant increases in centre line dilution over the performance of similar horizontal jets. Corresponding data for $Y_0/D=8$ indicate that the ratio between dilution factors for the downward-inclined jet and the horizontal jet increases from 1.7 at $F_d=6$ to 3.5 at $F_d=15.8$. For a constant value of $F_d=8$, the ratio varies from approximately 2.3 at $Y_0/D=8$ to 1.7 at $Y_0/D=30$. These increases in dilution appear to be of the same order as those suggested by the Author's experiments.

16. The practical application of downward-inclined jets, however, is open to the objections outlined. In a given depth of water the resulting dilution at the surface would also depend on the height of the outlet above the bed. Anwar¹² found that the centre line of the jet extended about five pipe diameters below the discharge origin for $F_d=8$ and ten pipe diameters for $F_d=15.8$. Thus the effective values of Y_0/D would be considerably reduced if the outlet were sited to take account of the penetration of the jet below the horizontal.

17. The Author's preliminary observations have been made in still water. In view of the tidal situation at most outfall sites it would be desirable to extend further investigations of buoyant wall jets to include their behaviour in moving water.

Fig. 8

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The Author's experimental research has shown that the buoyant wall jet increases the surface dilution beyond that of a free buoyant jet.

18. The surface dilution S_0 of a buoyant jet is a function of both the relative depth Y_0/D and the densimetric Froude number F_d , i.e.

$$S_0 = \phi \{F_d, Y_0/D\}$$

or

$$\phi \{F_d, Y_0/D, S_0\} = 0$$

Thus an alternative non-dimensional functional equation can be formed

$$\phi \{F_d, (Y_0/D)/F_d, (Y_0/D)/S_0\} = 0$$

or

$$F_d = \phi \{(Y_0/D)/F_d, (Y_0/D)/S_0\}$$

19. I have checked, using the data of Abraham,¹⁰ that when the ordinate and abscissa of Fig. 2 are adopted there is still separation relating to the value of F_d . The Author's data show some sign of systematic sequences. Has the Author sought to resolve his data further in this manner?

DISCUSSION

20. Some of the devices for attachment of the buoyant wall jet to the sea bed seem to have considerable promise. The Paper serves a useful purpose in showing the possibilities which exist for improvement of the dilution ratio.

Dr Sharp

The research programme is still in a development stage and all experiments to date have been in still water. However, as **Dr White** and **Mr Agg** suggest, the effects of turbulence and ambient currents are important. It would appear likely that any movement of the receiving water would increase dilution factors but it is uncertain to what extent.

22. Scouring of the sea bed, or blockage of the exit ports, for an outfall laid with the ports at bed level is an obvious danger but I should have thought that the problems would be significantly reduced if the outfall were laid above the bed and the jets inclined downwards. Experiments are under way to determine the relationship between angle of inclination, densimetric Froude number and the depth (relative to diameter) to which the jet will penetrate and cling to a horizontal floor. These experiments have given similar results to those obtained by Anwar¹² and quoted by Mr Agg. For an angle of 30° and $F_d=8$, the jet will touch and begin to cling to a horizontal floor eight diameters below the nozzle. The same Froude number with a more steeply inclined jet (45°) extends the depth to almost thirteen diameters.

23. If scouring were still thought to be a problem it would be relatively simple to attach a flat plate under the outfall port such as would cause attachment of the jet. The cost would probably be as low or lower than other pre-dilution devices. There would be no danger of scour and, with the outfall raised above the bed, little danger of blockage.

24. The distance between outfall and floor at which reattachment ceases to occur has not been precisely identified. However, there is little doubt that the height, relative to diameter, is a function of the densimetric Froude number and that, at medium values of F_d , it is very small. Initially experiments were run using ordinary pipe nozzles laid on the floor and it was noticed that the thickness of the pipe wall itself was sufficient to prevent reattachment at values of F_d just greater than 1.0. Thereafter the wall of the nozzle was shaved so that the fluid was ejected on the floor.

25. Comparison of Figs 4 and 7 is interesting and shows, as might be expected, that the two-dimensional jet penetrates further along the floor than the three-dimensional jet reported in the Paper. There is also much less scatter on Fig. 4 and this may indicate a basic difference in the two phenomena. In obtaining results for length of cling (Fig. 4) it was noticed that considerable gusting occurred. The point at which the jet left the floor moved to and fro, varying by as much as 20 diameters with a small nozzle and high Froude numbers.

26. As **Mr Morrow** suggests the normal arrangement of parameters for providing dilution results is not that given in Fig. 2. However, the format of Fig. 2 was chosen in this case to show quickly and easily the increased dilution obtained by the effect of the floor. The results have previously been presented in the more usual form.⁴

References

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