Time ratio in radial flow sedimentation tanks

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Experiments carried out on model tanks at Birmingham University⁹ and elsewhere have shown that even quite small density differences between influent and effluent can radically influence the flow pattern. Surface streaming similar to that obtained in the Authors' experiments without a baffle can be achieved by having a relatively warm influent. The usual bottom flow density current is easily demonstrated if a dense influent having a high suspended solids concentration is used, without the necessity of providing baffles. The Authors' flow patterns may be considerably modified in a real tank by density effects. With typical density differences of, say, 200 ppm the optimum 'inlet ratio' and tank shape may differ from those put forward in the Paper.

74. The Authors make use of a parameter 'inlet ratio' defined in § 32 as the depth at inlet, D' , divided by the depth of flow under the baffle, D_1 . This term is also used in Fig. 7 to denote D' divided by the depth of flow over the inlet pipe. However, these two cases do not appear to be sufficiently similar to warrant the same term 'inlet ratio', since the baffle imparts a vertical thrust to the flow, whereas without the baffle the flow is initially horizontal, causing the surface streaming. I would have thought that in conjunction with the 'inlet radius', the radius of the inlet pipe would have some effect on flow patterns. In the figures it appears rather larger than one would find in practice.

75. Perhaps a more obvious parameter than the Authors' 'inlet ratio' to describe the extent of baffling is the simple ratio baffle depth:total depth, which might be called 'baffle ratio'. This is used by the Authors in Fig. 8, but thenceforward has been abandoned. The relationship between them is

$$\text{baffle ratio} = 1 - \frac{1}{\text{inlet ratio}}$$

and inlet ratios of 1, 2, 3 and 4 correspond to baffle ratios of 0, 0.5, 0.66 and 0.75. If time ratios in Figs 9–12 are plotted against baffle ratios instead of inlet ratios, it can be shown that the distinct peak apparent in most of these figures becomes a very much smoother curve, showing that the depth of baffle immersion is not so critical, and in most cases may vary between 0.15 and 0.40 of the tank depth without significantly affecting the time ratio.

76. The theory section (§§ 6–18) is an extension of Mr Clements's previous paper on rectangular tanks and, as is explained, does not include the effects of mixing or flocculation. A theoretical model incorporating the effects of mixing and reverse flow has been devised,^{9, 10} the resulting equations being somewhat complex. I feel sure that these equations could be extended to accommodate circular tanks.

77. The model results generally show that the most effective tank shape in terms of time ratio is No. III, closely followed by No. V. Tank shape V might well appeal to design engineers since excavation is much reduced and the flat bottom enables the reinforcement and construction of the base to be simplified. De-sludging could be carried out using an air lift sludge scraper. Perhaps the Authors could recommend an optimum wall height for circular tanks in view of their model experience.

Mr Clements and Dr Khattab

We were glad to read the contribution from Dr March which raised several points of interest.

79. Baffles were used in some of the tests since they provide a very convenient

Paper published: *Proc. Instn civ. Engrs*, 1968, 40 (Aug.) 471–494.

DISCUSSION

means of producing vertical patterns of the bottom flow type. Their advantage is that the patterns, similar to those produced with density currents as described by Dr March, can be reproduced easily in the models and in those of other workers. It is perhaps unfortunate that illustrations of these vertical patterns serve to stress their importance, whereas the theory examines their effect in some detail and emphasizes the fact that they are unimportant to the settling of the particles. Their importance lies in their potential effect on the scouring of previously settled particles if care is not taken.

80. With suspended solids contents of 600 mg/l (much higher than the figure of 200 ppm which Dr March described as 'typical') it would be seen from the tests (Figs 9 and 15) that the optimum inlet ratios do *not* differ from those obtained with clean water. The inference is therefore drawn that, although the vertical pattern may be modified by density differences, the distribution around the tank is affected but little and the time ratio is therefore hardly altered.

81. Recent support has been obtained from tests in rectangular tanks at Sheffield where distinct changes in vertical pattern due to density differences caused by warm influent have produced modifications to the time ratio of the order of only 5%.

82. Regarding Dr March's preference for 'baffle ratio' instead of 'inlet ratio', this is not a vital matter—as he pointed out they are very simply related. We have continued to use 'inlet ratio' (as originally introduced for the rectangular tank tests) because of the advantage that it can be applied as a general term both with and without baffles, whereas in the latter case 'baffle ratio' can have no meaning. It is agreed that the precise optimum depth of baffle is not important and has been given as 'about one quarter'.

83. From the model results it appears that the inlet pipe radius may have a significant effect, but in order to obtain a high enough flow for Reynolds number similarity the inlet pipe has to be rather bigger in proportion than is usual in practice. These 'no-baffle' cases are difficult to model geometrically when neither radius nor inlet ratio can be made small enough for some examples. A similar difficulty has been pointed out concerning weir inlets in rectangular tanks.

84. Unfortunately the velocity distribution assumed by Takamatsu and Naito does not accord with that found in practice in either model or full-size tanks by workers at Sheffield. Although turbulent mixing has been omitted, it should be pointed out that the case of reverse flow was included in the Authors' theory for both vertical and horizontal velocity variations (Figs 2 and 3).

85. We feel diffident about recommending a best shape of tank (§ 60) but it appears that tanks with floor slopes greater than 10° are at a disadvantage in every respect except that of ease of sludge removal.

86. Regarding optimum wall height, this can be approached logically by considering the risk of scour at the tank floor in a similar manner to that proposed for rectangular tanks.^{1, 11} When we recorded the maximum velocities near the floor (§ 36) the radius at which these occurred was omitted; this should have been given as $R/2$. It is hoped that suggestions on tank depth, too long to include here, will be offered in a future design paper.

References

9. MARCH R. P. The performance of rectangular sedimentation tanks. University of Birmingham, PhD Thesis, 1967.
10. TAKAMATSU T. and NAITO M. Effects of flow conditions on the efficiency of a sedimentation vessel. *Water Res.*, 1967, (1) 1.
11. CLEMENTS M. S. Design of rectangular sedimentation tanks on velocity principles. *Surveyor*, 19 October 1968, 41–45.

Corrigenda

p. 477, § 20, line 2: the expression to read $Q/\pi(R+R_c)^2$

p. 488, § 55, line 4: insert f after 'friction coefficient'.