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SUPPRESSION OF DENSITY WAVES IN CLARIFIERS

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ABSTRACT

Experiments on a 4-ft (1.2-m) diameter model circular clarifier operating at overflow rates and suspension concentrations corresponding to municipal treatment practice show that baffles designed to function as wave traps suppress low-frequency, large-amplitude density waves observed in these units. Simultaneous measurements of solids removal show substantial improvement. This work establishes the relationship between density waves and the deviation from ideal clarifier performance that earlier papers on internal waves by our research group suggested. The power spectrum of the internal waves and the effect of operating variables such as overflow rate, scraper speed, and suspended solid on the spectrum and solids removal are discussed.

INTRODUCTION

Existence of internal, density waves in clarifiers has been demonstrated in a series of research papers published by our group [1,2,3]. We have attributed part of the deviation from ideal clarifier performance to the presence of these waves. In the 1980 IAWPR meeting, we showed that a baffle which accelerates the effluent just in front of the outlet weir increases significantly the solids recovery in a model rectangular clarifier[2]. At that time we proposed that the baffle acted as a wave trap by preventing the reflection of density waves from the clarifier outlet.

EXPERIMENTAL

This study was performed using a 122 cm (4 ft) diameter, circular clarifier, with a 1:10 slope from the periphery to the center well. The vessel was dimensionally similar to a full-scale centre-feed, horizontal flow circular clarifier. Inlet and outlet pipes, inlet baffle spacing, and weir design were scaled down from commercial designs but do not preserve exact similitude. A rotary scraper was employed. Although the scrapers were kept small to avoid interference with the wave analysis, no attempt was made to maintain dimensional similitude with full scale scrapers.

Fibre optics probes or turbidimeters were used to monitor inlet and outlet suspended solids concentrations, as well as density waves within the clarifier. The material used for all the experiments was a diatomaceous earth, "Celite 545". Its particle size and density provide suspended solids removal typical of municipal treatments plants operating at conventional overflow rates.

DENSITY WAVE OBSERVATIONS

The large concentration fluctuations of about 50 to 200 mg/L at irregular intervals of about 2 to 5 minutes were found with the conventional circular clarifier design. These large fluctuations were imposed on a background of much more rapid changes of 10 to 20 mg/L. Even smaller fluctuations in the 1-Hertz range were visible in the probe traces. Although taken in the same vessel under ostensibly identical operating conditions, no two traces were alike. Variation in replicate observations was typical of runs made in the conventional clarifier; it was seen to a much less extent with the baffled unit.

Wave traps effectively removed the large fluctuations. The higher frequency background fluctuations were less affected.

Density wave data were processed through a Fourier transformer and reexamined as a power (in decibels) vs. frequency plot. Comparison of these plots shows that wave traps reduces the "power" across the frequency spectrum. The highest power was almost 10 decibles lower when traps are used. This is significant because fluctuations with the largest concentration differences contain the most energy and probably result in the greatest mixing. We believe it is mixing which reduces the solids removal. Furthermore, power dropped off much more rapidly with increasing frequency. With the 30° trap, a 10-decibel reduction occurred by 0.03 Hz, whereas with a conventional clarifier an increase of about 0.07 Hz was needed. The curves drew together as the frequency exceeds 0.3 Hz. Above 1 Hz, fluctuations probably result from turbulence generated by the density current. This turbulence seemed unaffected by the traps.

SOLIDS REMOVAL MEASUREMENTS

Fractional removal of inlet suspended solids in the clarifier when plotted vs. overflow rate for an inlet concentration of about 500 mg/L and scraping frequency of 0.3 rpm showed consistently higher solids removal for a clarifier equipped with a conical trap sloped 30° from the horizontal. These traps increase solid removal by about 9% at 65% removal, but this becomes a dramatic 45% when the removal sinks to about 35% at high overflow rates. The effect is even more pronounced if one focuses on clarifier capacity. At an overflow rate of 0.0175 cm/s basin capacity may be increased by 32% while maintaining 60% solids removal. If 50% solids removal is satisfactory (overflow rate of 0.027 cm/s), capacity may be increased by nearly 60%. These results are similar to those reported in our earlier IAWPR paper [2] for a rectangular clarifier.

As in our earlier study, the curve for the modified clarifier lies close to the ideal clarifier performance. This, together, with the reduction in amplitude of the large low frequency density waves suggests that is is indeed these density waves arising unavoidably in stratified flow that are responsible for deviation from ideal clarifier performance.

Limited experiments were made using a 500 mg/L feed and a conical trap sloped at 60° to the horizontal. Wave suppression and solids removal were similar to those obtained with a 30° trap.

Quite a wide range of inlet suspended solids concentrations were explored. Concentrations below 500 mg/L gave results similar to those just described. However, with concentrations above 2500 mg/L, little or no improvement was found with the modified clarifier. The high concentration measurements were undertaken to perserve Froude number similitude between the model clarifier and full scale units. Unfortunately, the high concentrations resulted in heavy solids buildup which seemed to interfere with solids removal.

REFERENCES

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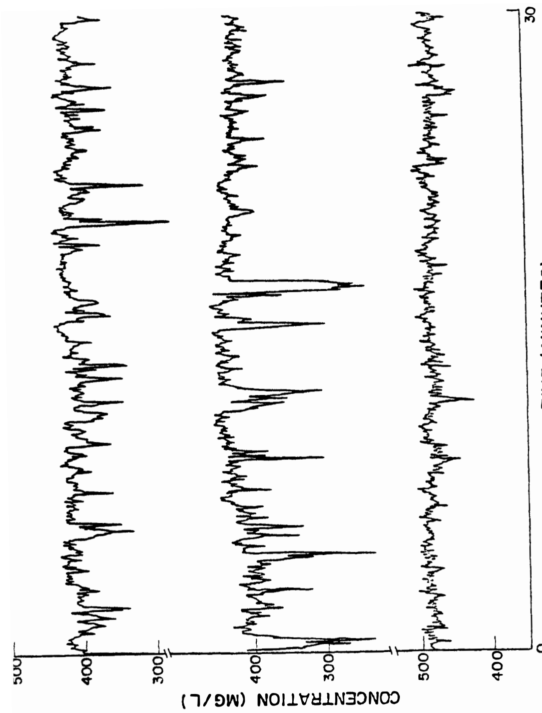
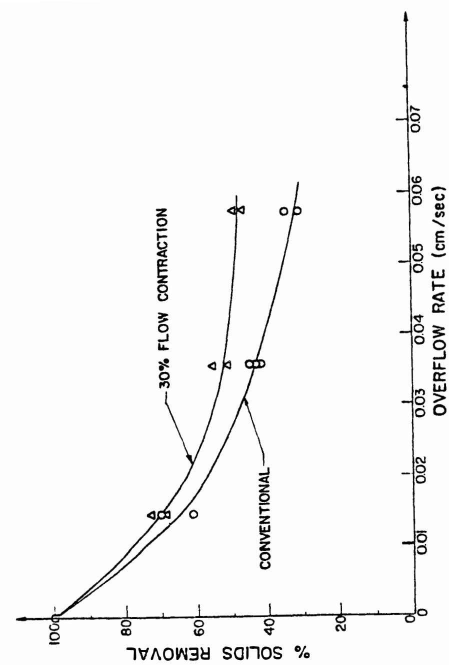
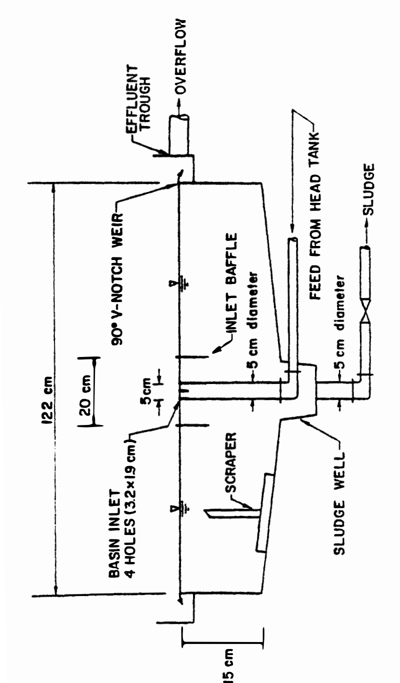
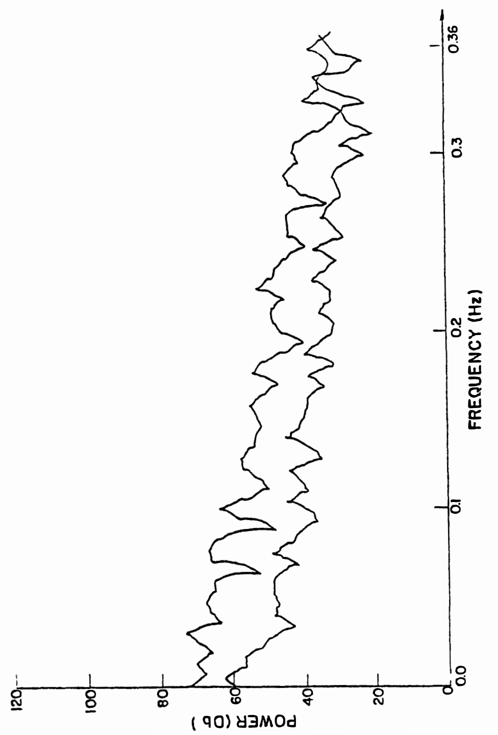

CONCENTRATION (MG/L)
TIME (MINUTES)
500
400
300
400
300
500
400
0
30


% SOLIDS REMOVAL
OVERFLOW RATE (cm/sec)
30% FLOW CONTRACTION
CONVENTIONAL
100
80
60
40
20
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07


122 cm
20 cm
15 cm
5cm
90° V-NOTCH WEIR
EFFLUENT TROUGH
OVERFLOW
BASIN INLET
4 HOLES (3.2×1.9 cm)
SCRAPER
INLET BAFFLE
5 cm diameter
FEED FROM HEAD TANK
SLUDGE WELL
5 cm diameter
SLUDGE


POWER (Db)
FREQUENCY (Hz)
120
100
80
60
40
20
0
0.0
0.1
0.2
0.3
0.36