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Up-rating underground sedimentation tanks subject to hydraulic overloading

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By designing the plates as self-supporting and removable by hand from the unit makes the maintenance of the plates very easy. Such plates can be cleaned using a scraper. Another alternative is withdrawing sludge very rapidly. This causes sludge which is resting on the plates to dislodge. Spraying the plates with a jet of water has the same effect.

2.3.6 FLOCCULATING IN LAMELLA SETTLERS.

It is well known that the ability of particles to settle out effectively in a suspension is dependent only on the clarifying surface area available. However, where flocculants are used to enhance settling the effectiveness of the settling is determined by the height through which the particles fall. Through the coagulation of the flocculant with the particles the settling velocity becomes faster and faster. The coagulation process requires a certain amount of time (conventional flocculation basins have a 30 to 45 minute holding time). The longer the time allowed, the better the flocculant suspensions so formed. There is insufficient time for floc to form in lamella settlers because the retention time is so short (less than 10 minutes on average).

It is therefore important that the flocculating process is separated from the sedimentation process and that proper flash mixing and coagulation take place outside before the influent enters the lamella settler (see figure 17).

Natural flocculation without the addition of chemicals also takes place in lamella settlers. This happens when the particles fall to the lower wall of each plate and come into contact with previously settled particles. The additional contact of the falling particles in the plates with the upflow of wastewater also facilitates the formation of denser, more readily settleable solids.

2.4 UP-RATING EXISTING HYDRAULICALLY OVERLOADED SEDIMENTATION TANKS USING INCLINED PLATES

The use of inclined tubes and plates to up-rate existing installations has been reported by Culp(1968), Gray(1975) and Van Vliet(1976). Up-rating an existing installation can be done for various reasons:

- Plant extensions can be avoided if plates are introduced into the settler, whilst still maintaining the desired effluent qualities.
- The cost of chemicals used to flocculate can be reduced.
- Improved effluent qualities may be required from the clarifier.

Culp(1968) used small tubes with a diameter of only a few centimetres as the up-rating mechanism. Such tubes have a large wetted perimeter relative to the wetted area and therefore readily create laminar flow conditions within them, a fact borne out by the very low Re numbers measured in tube settlers. A tube module that was developed is shown in figure 18.

By alternating the direction of inclination of each row of channels forming the tube passage ways, the module becomes a self-supporting beam which needs support only at it's ends. These tube modules were installed into one sixth of an existing circular clarifier to evaluate their performance (see figure 19).

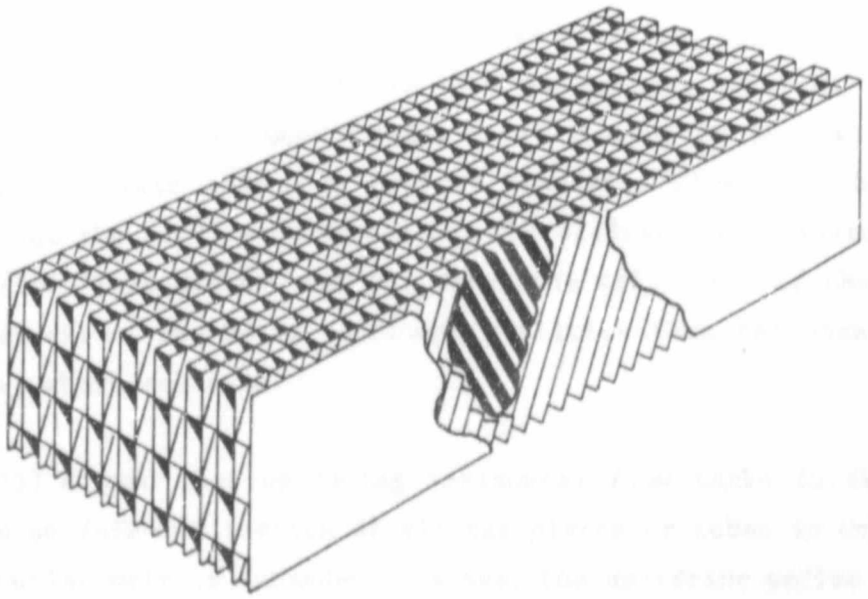


Figure 18. Tube module for installation into existing clarifiers.

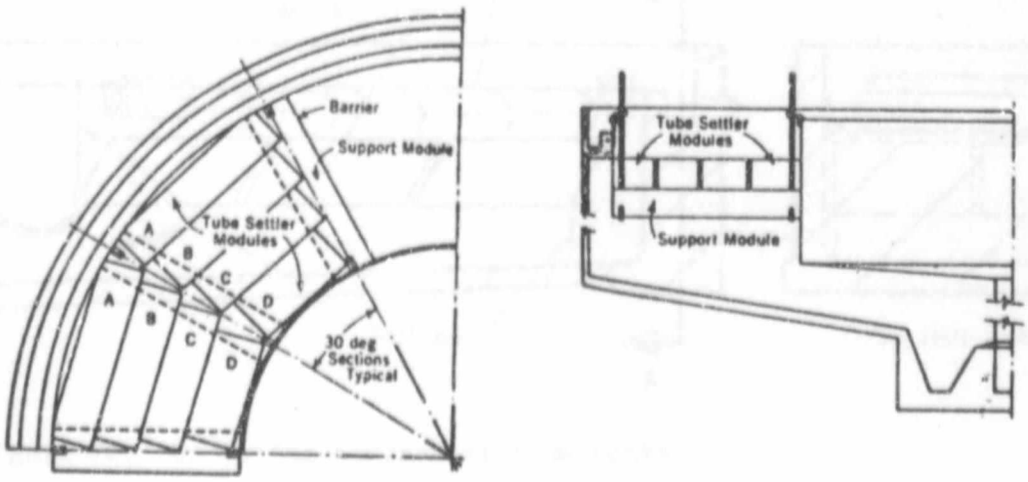


Figure 19. Installation of tube modules into circular clarifier, Culp(1968).

Tube modules were also used as support beams for the upper modules so that none of the clarifier surface was lost due to some other type of support structure. The radial support beams were attached to the inlet well and the effluent weir with PVC support brackets. Flow distribution tests showed that the outer modules nearest the effluent weir received the bulk of the flow. This did however not deter the efficiency of the modules to any great extent and better effluent qualities than had been previously obtained, where achieved.

Gray(1975) showed that up-rating horizontal flow tanks is feasible but that the uniform utilisation of all the plates or tubes is only possible if the outlet weir is extended back over the up-rating medium in the form of a channel or gutter. This adds to the cost but ensures maximum efficiency of the installed system (see figure below).

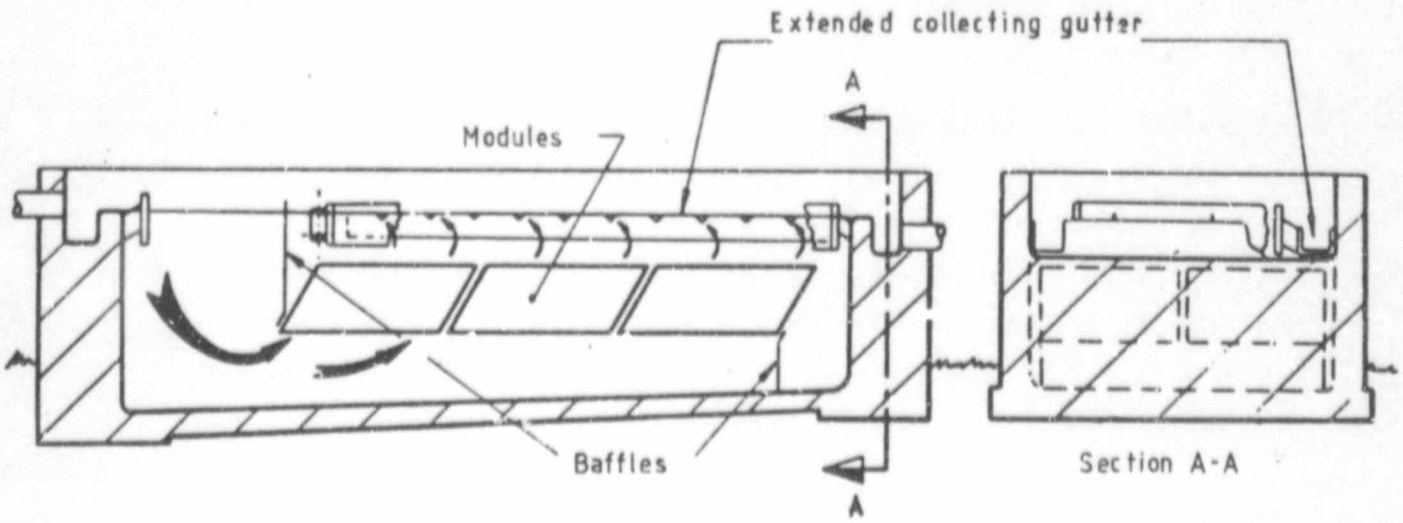


Figure 20. Up-rating horizontal flow tanks.

Gray(1975) also reports that a sedimentation tank becomes less sensitive to changes in temperature and differences in temperature between the incoming suspension and the bulk liquid already in the tank if the tank is fitted with plate or tube modules. Modules installed into an existing upward flow humus tank were supported at a level in the tank which avoids

interference from surface winds. Tube modules are reported to increase the capacity of existing tanks by 50 to 150 percent.

The cost of the steel support structure for the modules (if required) must be examined carefully. For the design of the supporting beam it must be assumed that the tank is emptied, that the module weight may have doubled due to sludge and that a man may walk across it. Experience has shown that a substantial beam is necessary.

Van Vliet(1976) showed that in general the performance of plate modules are slightly better than that of tube modules and that both types of modules inclined at 60° to the horizontal exhibit a self-cleaning effect. He also showed that both types of modules are relatively insensitive to hydraulic loading which means that effluent qualities remain almost constant as the overflow rate increases. This phenomenon would make the modules particularly useful in up-rating existing clarifiers.

2.5 CLARITY OF EFFLUENT REQUIRED IN MINING OPERATIONS.

It is the opinion of practical engineers in the mining industry that it is impractical as well as uneconomical to achieve an effluent of extreme purity and that an effluent which is "cloudy" is quite satisfactory. The feeling is that this type of effluent does not greatly effect the operational life of high-lift water pumps.

It has however been shown that a high concentration of suspended solids in the effluent leads to the settling out of the solids in the inaccessible clear water sumps, giving rise to problems in sump cleaning. Solids in suspension also promote pump wear. Pump wear due to suspended solids is dependent on the following:

- the fact that pump wear is directly proportional to the turbidity of the water,

- the hardness of the particle relative to that of the metal from which the pump components are manufactured,

- the head against which the pump is operating. This influences the packing ring wear which is proportional to 1.5 times the power of the seal pressure provided the particle size is less than 37µm. Larger particle sizes produce higher packing ring wear.

- the particle mass and size, there being an increase in wear rate when the particle size reaches 40% of the gap clearance between the impeller and the housing.

Where the clarified water is to be used for underground human consumption and in refrigeration circuits, suspended particles can adversely affect the chlorination process and create scaling on condenser and evaporation tubes. For such water usage the clarity of the effluent should approach the Rand Water Board specifications of 5 mg/l. This is however difficult to achieve without secondary filtering. An effluent with a turbidity of

10 mg/l is considered practical for drilling and other mining purposes as well as keeping pump wear down to acceptable levels. The following turbidity counts are also specified:

SERVICE WATER IN MINES

TURBIDITY 10^6 particles/cm^3	REMARKS
10	Maximum acceptable
5	Fair
2	Good

3.0 EXPERIMENTAL PROCEDURE FOLLOWED

From the literature, it is evident that some form of tube or plate modules are commonly used to up-rate existing hydraulically overloaded sedimentation tanks. Hence it was envisaged that parallel plates of some form would be used in the experimental procedure. The approach in up-rating existing settling tanks was therefore as follows:

- Batch settling tests carried out under quiescent conditions on the sludge that was tested, were done for a range of SS concentrations, namely 500 - 3000 mg/l. Dehydrated mine sludge originating from the drains in a mine was used throughout the experimental procedure. The results from these tests would indicate the maximum % SS removals which are physically possible for a certain overflow rate.

- An existing model sedimentation tank was tested in the laboratory for it's % SS removal efficiencies over a range of overflow rates. The sedimentation tank was a conventional upward flow tank (see APPENDIX B) and was subjected to overflow rates which resulted in extreme hydraulic overloading as well as underloading. The same range of SS concentrations was used as was tested in the batch settling tests.

- The results obtained from the upward flow tank were then compared with the batch settling results and the discrepancy between theory and practice is quantified in the form of an upscale factor (safety factor). The upscale factor is a measure of the short-circuiting and turbulence which occurs in conventional sedimentation tanks. The upscale factor was calculated for the range of influent SS concentrations and overflow rates tested.

- Ways of up-rating the upward flow sedimentation tank at the overflow rates where hydraulic overloading occurs were looked at. The conventional forms of up-rating, namely using plate or tube modules were discarded for reasons discussed in CHAPTER 5. A unique type of conical

lamella settler was designed, which would optimally utilise the surface area of the upward flow model tank. The cones were constructed and then installed into the same model previously used as an upward flow tank.

- The conical lamella settler was then subjected to the same flow rates and influent SS concentrations as was the upward flow tank. A comparison of the % SS removals was made to see whether any improvement in effluent qualities was obtained. Any variation in the sludge concentrations at the bottom draw-off was monitored for both systems.

- Theory of settling between parallel plates is based on the creation of laminar flow conditions between the plates and is only valid for rectangular plates. This theory is modified to accommodate the geometry of cones as parallel plates. A comparison is made to see whether the theory fits the actual results obtained in the laboratory. This step was undertaken since it was realised that the results obtained in the laboratory are of academic interest only and that some means is required to extrapolate these results to a full-scale practical situation. This is done in CHAPTER 7 and a typical procedure is given which may be followed if it is envisaged that a sedimentation tank is to be up-rated using cones of the type used in the laboratory. The upscale factor which is a measure of the efficiency of the conical lamella settler is also calculated for design purposes.

- The size and the number of spacings between the cones was varied to try and establish how sensitive the performance of the conical lamella settler is to changes in it's physical parameters. The performance was once more compared with the theory.

- A qualitative observation of the flow patterns in the two types of tanks was attempted by introducing potassium permanganate into the influent as a tracer and observing the flow patterns through the perspex walls of the model tank.

4.0 PERFORMANCE OF THE UPWARD FLOW SEDIMENTATION TANK

In an ideal settling tank it is assumed that all particles settle discretely and that all particles which have a settling velocity greater than the design velocity v will be completely removed. The design velocity or overflow rate v can be calculated from:

$$v = g(S_s-1)d^2/(18\nu)$$

which is better known as Stoke's Law (Re < 0,5) for discrete settling,

and where S_s - particle specific gravity
d - diameter of the particle
ν - kinematic viscosity of the fluid

In practice however, discrete settling seldom occurs. The suspended solids encountered in industrial wastes and domestic sewages are usually of a flocculant nature. This phenomenon was directly observed in Imhoff settling tests done on the mine water used in all the experiments. In flocculant settling, particles coagulate while settling. This changes the diameter, shape and density of the particle and hence also it's settling velocity.

Batch settling tests where carried out (see APPENDIX A for results) to obtain design overflow rates which take into account the flocculating nature of the mine water. Since the flocculating effect of any waste increases with increasing initial concentration, a series of tests should be carried out for the anticipated range of SS concentrations envisaged for the prototype tank. The SS concentration range tested on the mine water was from approximately 500 - 3000 mg/l.

The perspex upward flow settling tank model (see APPENDIX B for details) was tested for it's removal efficiencies of SS using the same range of influent concentrations as the batch settling tests (see APPENDIX C). From these results the increasing flocculating nature of the waste with in-

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creasing initial concentration is evident in the rise of % SS removed with an increase in feed SS. This trend is similar for all the overflow rates applied to the settling tank.

The graphs in APPENDIX C also show a clear discrepancy between the predicted tank performance obtained from batch settling tests and it's actual performance. This "error" between predicted and actual results increases with increasing overflow rate. The drop in efficiency of the settling process in an actual tank is due to several factors:

- Turbulence and eddy currents due to high inlet velocities,
- Density currents caused by a change in temperature of the inflowing water compared to the water already present in the tank,
- Temperature currents due to temperature gradients in and around the tank,
- Surface currents caused by wind. These effects can be significant in large exposed tanks.

When % SS removed is plotted vs overflow rate (see figure 21 below), it can be seen that the discrepancy increases with increasing overflow rate for a particular influent concentration. This can be ascribed to higher air entrainment and turbulence at high overflow rates. The increase in air entrainment was visible through the perspex model and is also responsible for the bigger scatter in the settling tank results of graphs 98 and 99 in APPENDIX C.

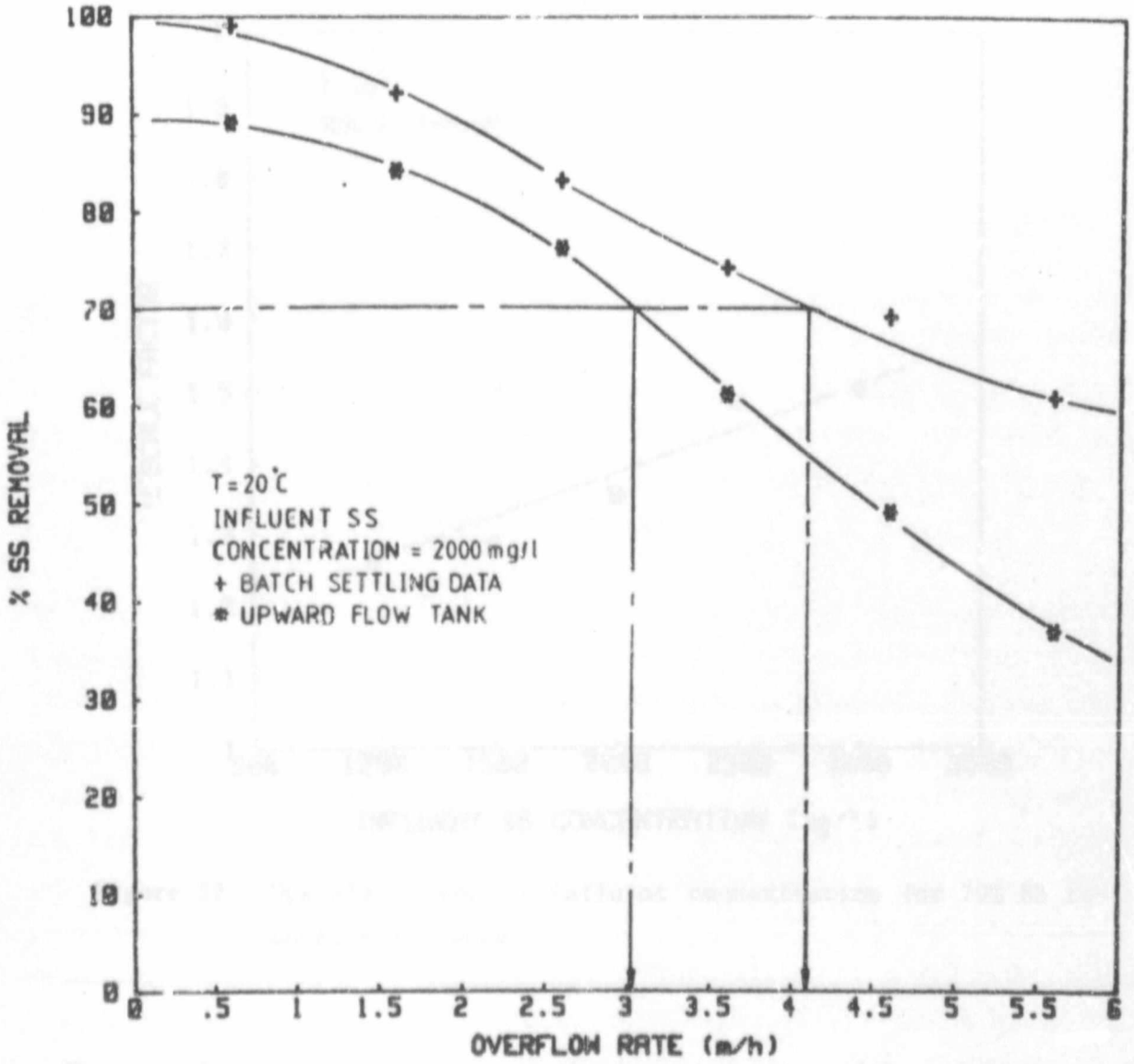


Figure 21. % SS removal vs overflow rate for a constant feed concentration.

To account for the turbulence and air entrainment, appropriate corrections are made to the batch settling data which can then be used in the design of a prototype tank. Figure 21 can be reproduced for the range of influent concentrations tested to produce figure 22 below. Overflow rates for a 70% removal in SS is usually chosen for the design of upward flow sedimentation tanks.

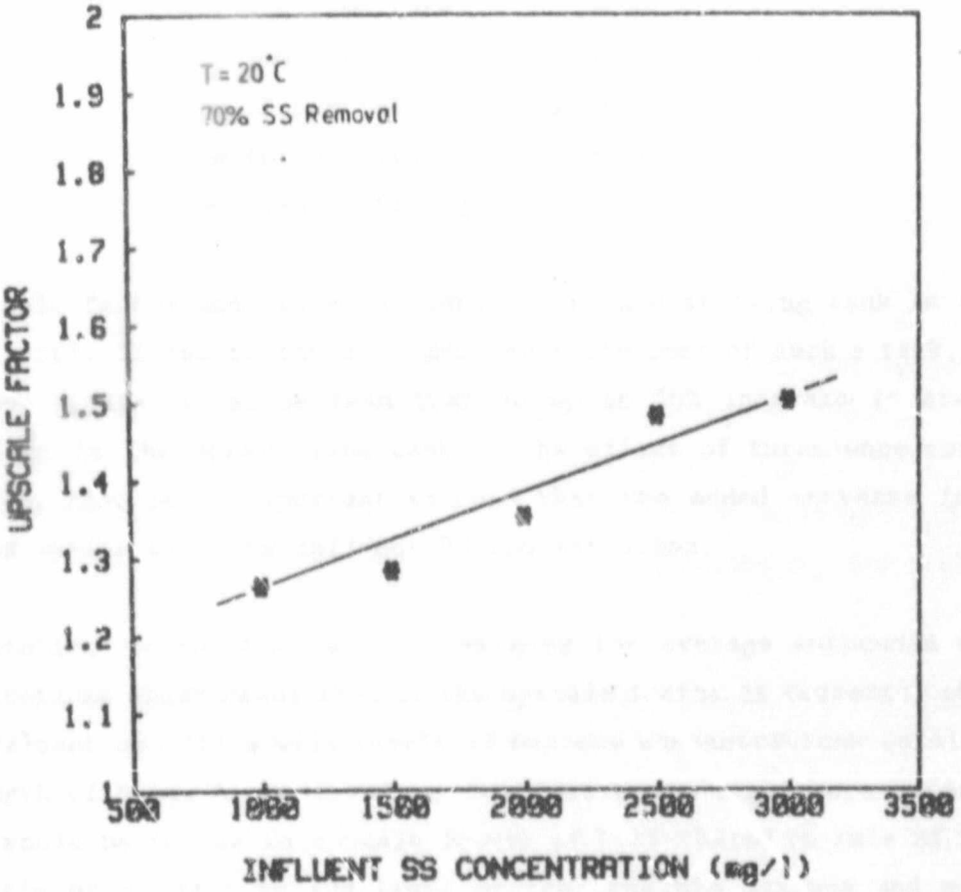


Figure 22. Upscale factor vs influent concentration for 70% SS removal efficiency.

The upscale factor = (batch overflow rate/settling tank overflow rate) and varies with the initial concentration. Typical rule of thumb values for the upscale factor are 1,25 to 1,75 for the overflow rate and 1,5 to 2 for the detention period. The upscale values for the model settling tank agree well with this general rule.

The upscale factor results in an increase in the effective settling area of a sedimentation tank since clarification requires a certain minimum area as indicated by overflow rate and the incoming flow:

$$A = Q/v$$

where A - sedimentation area required
Q - influent flow rate
v - overflow rate for a critical particle size in discrete settling or overflow rate for a certain % SS removal in flocculant settling.

The upscale factor and hence the turbulence in a settling tank is therefore directly linked to the size and hence the cost of such a tank. From the above figure it can be seen that an up to 50% increase in area can be avoided in the upward flow tank if the effect of turbulence could be neglected. Also it is important to note that the added increase in area required varies with the influent SS concentration.

Sedimentation units are usually designed for average suspended solids concentrations which means that if the upscale factor is correctly chosen, poor effluent qualities will result if maximum concentrations persist for any length of time. A conservative (but correspondingly more expensive) design would be to use an upscale factor of 1,75 (based on rule of thumb) if little or no data is available on the possible maximum and minimum concentrations that can be expected. Accurate design is therefore not possible for a single unit since the upscale factor can only be determined once the prototype tank is in operation. Upscale factors would also vary for different types of sedimentation tanks since inlets and shape vary considerably. It would thus be advantageous and more cost effective if the effect of turbulence can be excluded in the design of sedimentation tanks.

A qualitative observation of the turbulence was made by introducing potassium permanganate into the perspex model tank. From the photographs in APPENDIX D it can be seen that plug flow conditions are non-existent and that considerable mixing takes place in the settler.

5.0 DESIGN AND DEVELOPMENT OF THE CONICAL LAMELLA SETTLER

5.1 SOME CONVENTIONAL UP-RATING CONFIGURATIONS

The most common and extensively tested method of up-rating settling tanks is to install tube or plate modules which cover the settling surface area of the tank. The modules usually come in rectangular blocks (see LITERATURE REVIEW) and are installed in sections into the tank. This however poses some practical problems when the intention is to install them into circular clarifiers. Culp(1968) suggested the following arrangement of modules in a circular sedimentation tank:

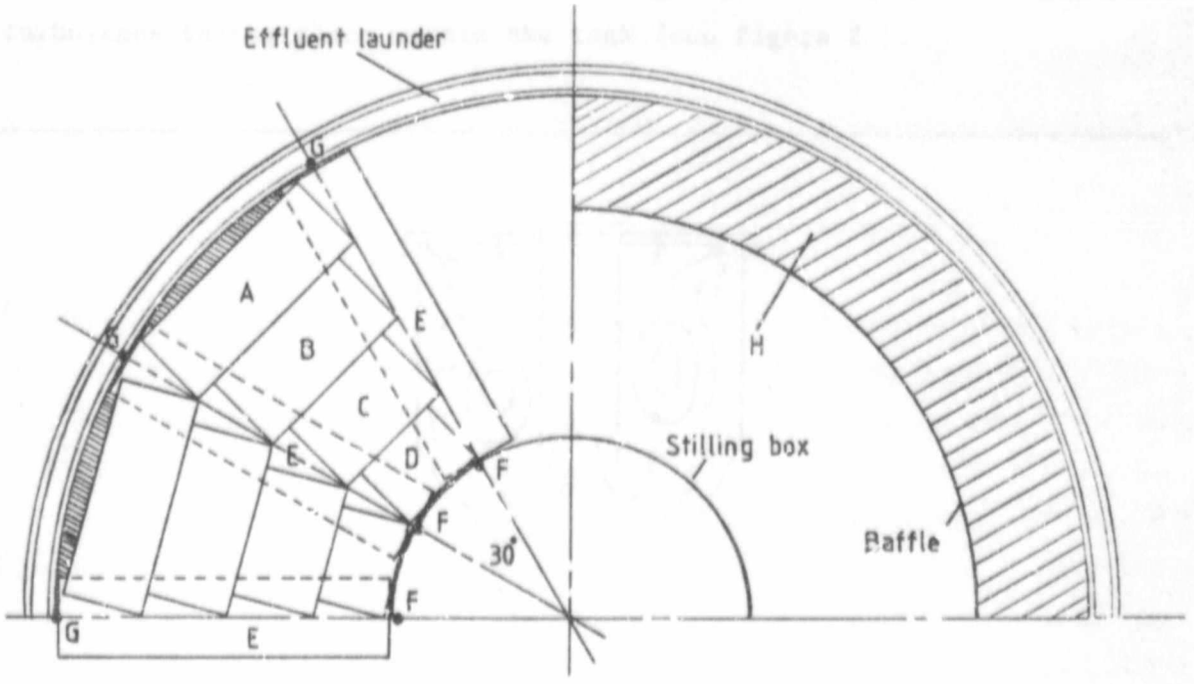


Figure 23. Plan view of module arrangement in a circular sedimentation tank.

The above figure shows the lower support module E with modules A, B, C and D resting on top of the radial support modules. This arrangement is possible since the modules are designed in such a way as to act as self-supporting beams requiring only a support at their ends. This type of arrangement however results in an inefficient utilization of the surface area of the tank since portions of module E are covered with twice the amount of tube module due to the edges of A, B, C, and D lying on top of E. Also since the sedimentation tank is circular, certain areas, notably adjacent to the effluent weir are not covered with tube modules (shaded area in above figure). This would be the critical area to cover since velocities are the highest here and directly next to the effluent weir. Small areas near the stilling box are also not covered but are less critical since they are more distant from the weirs. These uncovered areas would have to be closed if short-circuiting is to be prevented.

The velocity distributions in a circular sedimentation tank are anything but uniform with velocity gradients being highest at the weirs and much turbulence taking place within the tank (see figure 24).

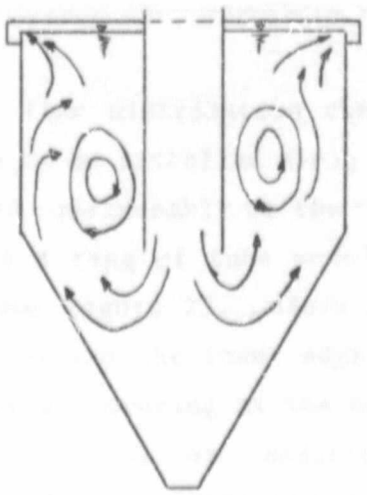


Figure 24. Flow pattern in a conventional upward flow tank.

Culp(1968) was aware of this problem and measured the flow rates through the modules A, B, C, and D. As was expected, the outer modules received

the bulk of the flow and were operating at 3 times the overflow rates as compared to the modules near the stilling box. This did not however affect the turbidities of the various modules to any great extent since inclined tubes and plates are well known to be fairly insensitive to hydraulic loading (see figure 25).

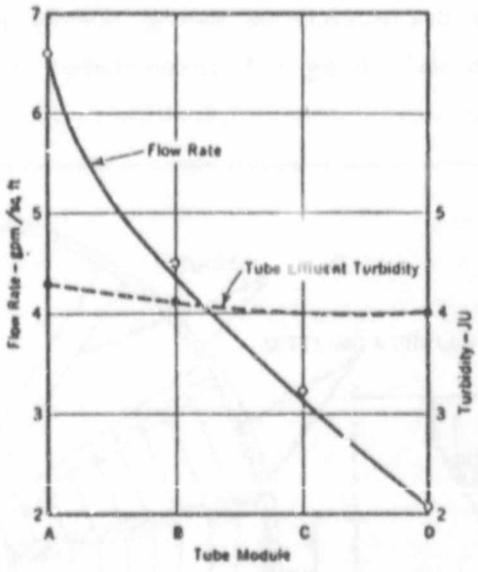


Figure 25. Flow distribution and turbidities of modules installed into a circular clarifier.

To obtain a more uniform flow distribution through the modules, radial effluent weirs would have to be installed along lines FG (see figure 23). This modification will add considerably to the cost of up-rating. Another alternative is to install a ring of tube modules completely around the periphery of the basin (see figure 2? module H). This approach would however require a baffle around the inner edge of the module to prevent short-circuiting. Any further covering of the basin with tube modules up to the stilling well, will necessitate additional effluent collection weirs to distribute the flow more uniformly and to realize the full potential of the tube modules. Therefore the problems encountered in covering the surface area of a sedimentation tank with tube modules are not insurmountable but do not lend themselves to general design.

The modules A to E are easily manufactured but the arrangement loses it's attractiveness when the wide variation in diameter of settling tanks in practice is taken into account. This means that every situation is a specific one and will require a separate detailed design and hence mass production of modules A to E is not feasible. The design of a module H is even more specific to the diameter of the sedimentation tank as is the design of any additional effluent collection weirs and baffles. Figure 26 (Culp and Culp; 1974) gives an indication of the extensive effluent launder arrangement requirement for good flow distribution.

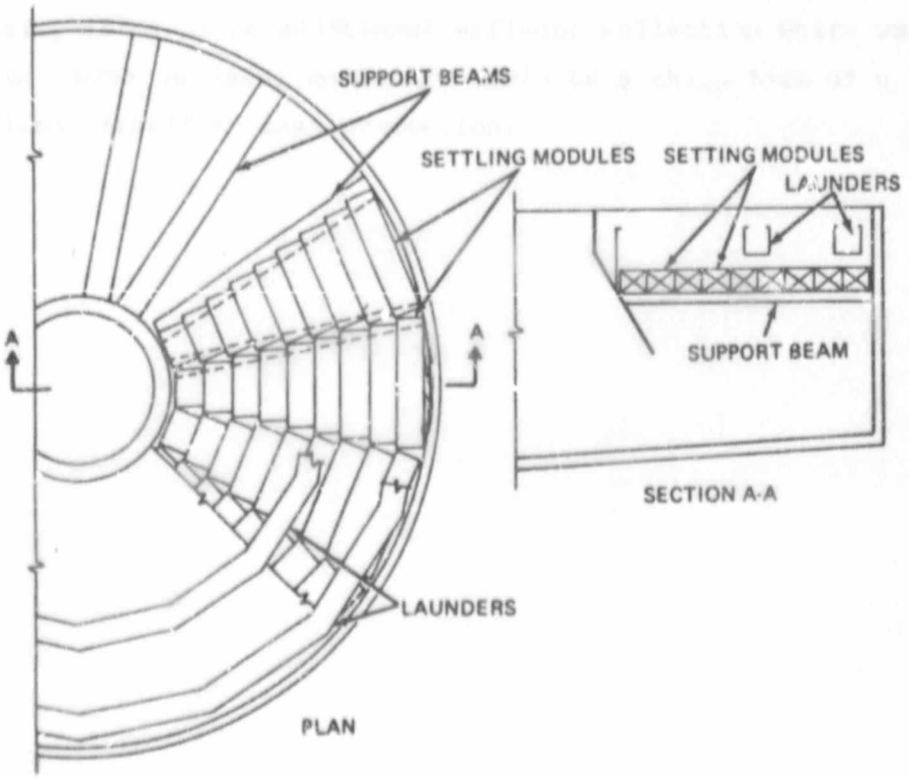


Figure 26. Tube installation and launder arrangement in a circular basin.

To overcome the problems problems caused by the non-uniform flow distribution present in settlers Culp and Culp(1974) recommend that tube modules are not located too close to the inlet where turbulence would reduce the effectiveness of the tube modules as clarification devices. In radial flow basins, the modules are placed in a ring around the pe-

riphery leaving an open area around the stilling box to dissipate inlet turbulence. The physical dimensions of the tube modules and the uneven distribution of velocities within the tank result in up-rating configurations which do not fully implement the clarification capabilities of the tubes or the entire available surface area which could be covered with tube modules. Often additional costs in the form of effluent launders and baffles are also incurred.

What would therefore be ideal is some type of mechanism which is not influenced by the velocity gradients formed by the inlet and is also totally reproducible for any type of tank shape or size. Also the design procedure would be simplified since additional effluent collection weirs would not be required. Such an ideal mechanism would be a cheap form of up-rating since it lends itself to mass production.

5.2 THE CONICAL LAMELLA SETTLER

The conical lamella settler is designed bearing the previously ideal up-grading conditions in mind. The problem of the turbulence caused at an inlet is addressed right where it starts, ie. at the inlet. It is proposed to insert a series of truncated cones around the inlet and in so doing a conical lamella settler is utilized to up-rate an existing installation (see figure 27).

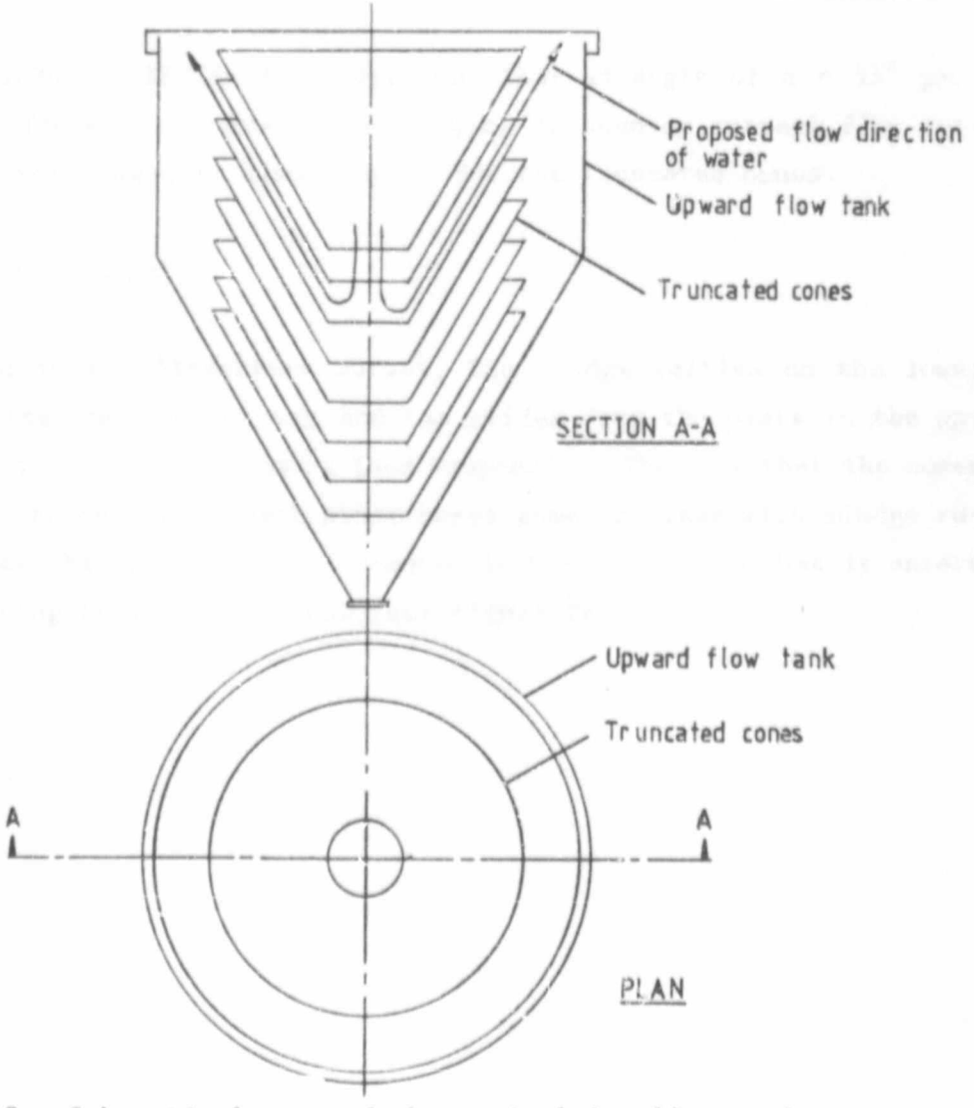


Figure 27. Schematic layout of the conical lamella settler.

The above arrangement makes optimal use of the available settling surface area of a sedimentation tank but raises a number of questions:

- Water flow direction

As the inlet is in the center and the weirs on the periphery, a counter current flow regime between influent and sludge is established. This type of system was deemed as the most advantageous for reasons given in the LITERATURE REVIEW.

- Angle of inclination of cones

From the LITERATURE REVIEW it is apparent that an angle of $\alpha = 55^{\circ}$ provides for efficient continuous de-sludging in counter current flow systems. Hence this angle is also adopted for the truncated cones.

- Removal of sludge

As described in the literature survey, the sludge settles on the lower surface of the inclined plates and the slides down the plate in the opposite direction to the incoming feed suspension. The fact that the cones are stacked one on top of each other poses some problems with sludge removal. Assume that particle A is removed in the system and that it enters the top spacing between the cones (see figure 28).

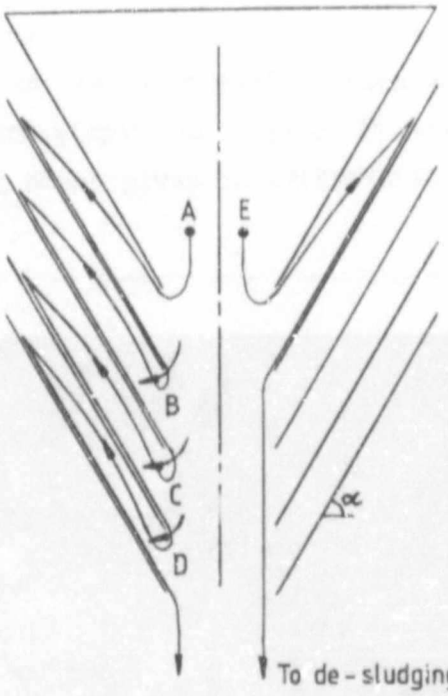


Figure 28. Flow paths of particles between conical plates.

The particle will settle on the lower surface of the the first cone spacing and will then slide down this surface due to the action of gravity. As it falls past the next plate spacing (B) it will again be washed between the cones by the incoming suspension of spacing B. Once again the particle will settle on the surface of the lower cone just to be re-suspended into spacing C. Hence the particle will only be removed from the system once it passes plate spacing D.

Such a system of sludge removal has the potential to work but problems will be experienced in the lower plate spacings since these will have to remove the SS from the water of the top spacings as well as from their own incoming suspension. This will result in a rapid progressive blocking from the lower cone to the upper cone and hence the system has failed as a continuous de-sludging system. Ideally therefore, once a particle has settled it should not be re-suspended but must be completely removed from the system. Such a completely removed particle would follow a typical flow path such as particle E, as indicated in the above figure.

The flow path of particle E is achieved in the conical lamella settler by channeling the sludge into a series of gutters to the bottom where it is de-sludged. This results in a model to the shape of the cone as shown in the photographs in Figure 29 and 30 and in the working drawings of the model cones given in APPENDIX E.

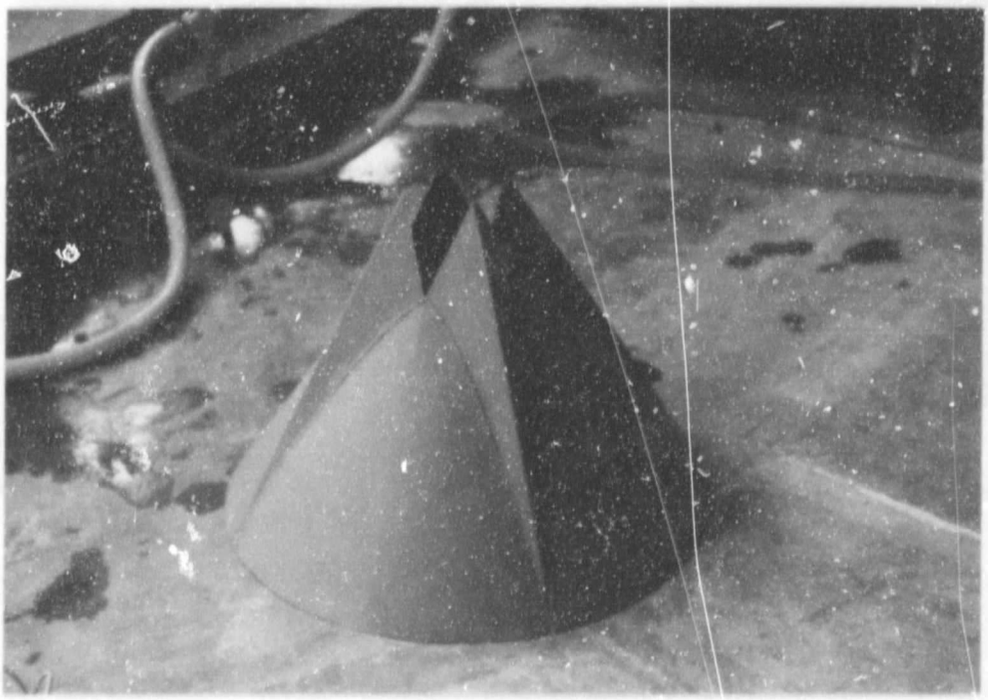


Figure 29. Photograph showing the lamella cone with triangular gutter arrangement.

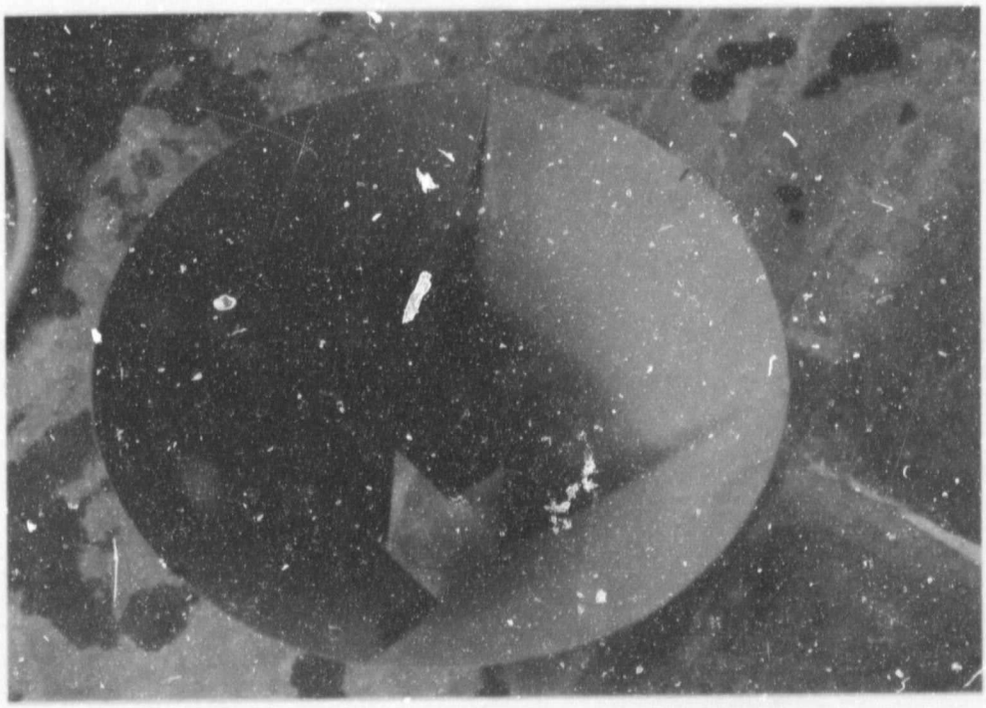


Figure 30. Photograph showing the lamella cone with triangular gutter arrangement.

The photographs show four triangular gutters attached to the cones. The angle of the gutter to the horizontal is 60° and is therefore inclined at 5° more to the horizontal than the cones. Thus any sludge collecting in these gutters is removed at a greater speed than that sliding down from the cones. This prevents any build up of sludge within the triangular gutters. Once the sludge has collected in the trough of the triangular gutter it is channeled to the bottom where it is de-sludged by means of vertical semi-circular gutters which run along the entire length of the plate spacings (see figure 31).

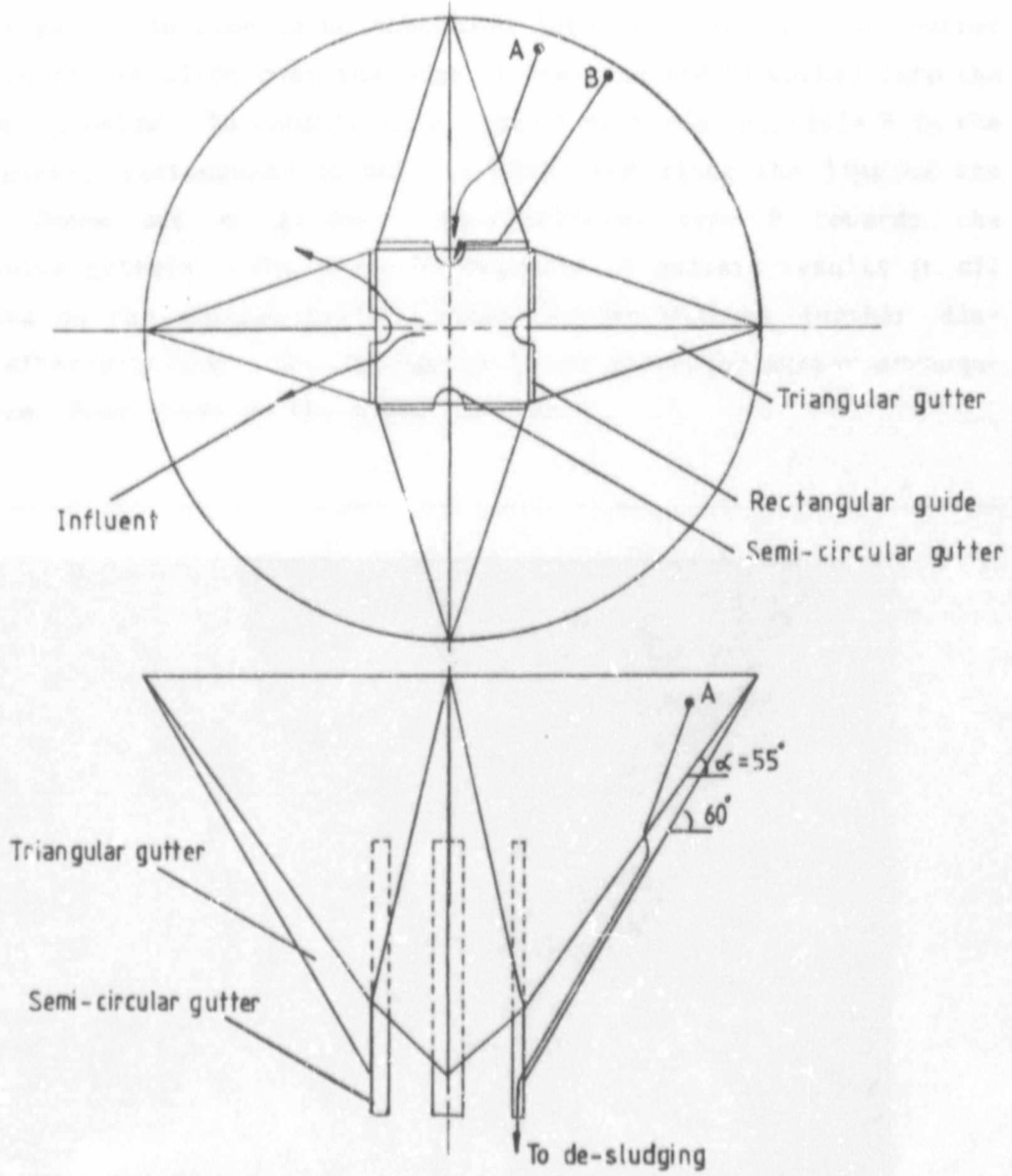


Figure 31. Gutter arrangement of conical lamella settler.

In this way the settled sludge is not re-suspended since it is protected from the influent by the semi-circular gutters which face with their backs to the feed flow (see figure 31, plan view). Now assume that particle A settles on the conical surface as shown above and slides down the inclined lower surface of the cone spacing. As soon as it reaches the triangular gutter it will accelerate downwards (since the gutter is at a steeper angle) and will be channeled into the vertical semi-circular gutter.

A particle settling on the conical surface might however not reach the triangular gutter in time to be channeled into the semi-circular gutter and will therefore slide over the edge of the cone and be washed into the plate spacing below. To capture this type of particle (particle B in the above figure), rectangular guides are installed along the lips of the entrance. These act as guides for particles type B towards the semi-circular gutters The above arrangement of gutters results in all SS settling on the conical surface being removed without further disturbance after settling. The photograph below shows the gutter arrangement as seen from above in the model settler.



Figure 3.2 Triangular and circular gutters, with guides.

It should also be noted that the central opening of the cone is square. This allows for easy attachment of the semi-circular gutters which is important since it is envisaged that these will be the main supports of the cones, keeping them their specified distance apart. The model lamella settler in the laboratory had the cones hanging from the semi-circular

gutters which had teeth cut into them into which the cones where slotted. In practice the cones would be supported by the vertical connecting plates (see APPENDIX E) and the central semi-circular gutters which would act as struts. The gutters and the connecting plates would slot into the cones which makes the changing of the plate spacing a simple process of just sliding the cones up or down as required.

Apart from channeling sludge, the triangular gutters also serve other purposes. Without the triangular gutter arrangement, sludge would concentrate at the inlet since it is all sliding down towards this focal point. The triangular gutters however increase the surface area on which the sludge can settle and remove it faster than the cones. In this way any possible blocking problems at the inlet are prevented. The triangular gutters also serve an important structural function in that they act as a beam which simplifies the support of the cones by connection to these gutters.

- Plate spacing and arrangement of cones

From the literature a plate spacing of d = 40mm seems to be a recognized optimum for counter current flow lamella systems. This was the first plate spacing tested. Later d = 32mm was experimented on.

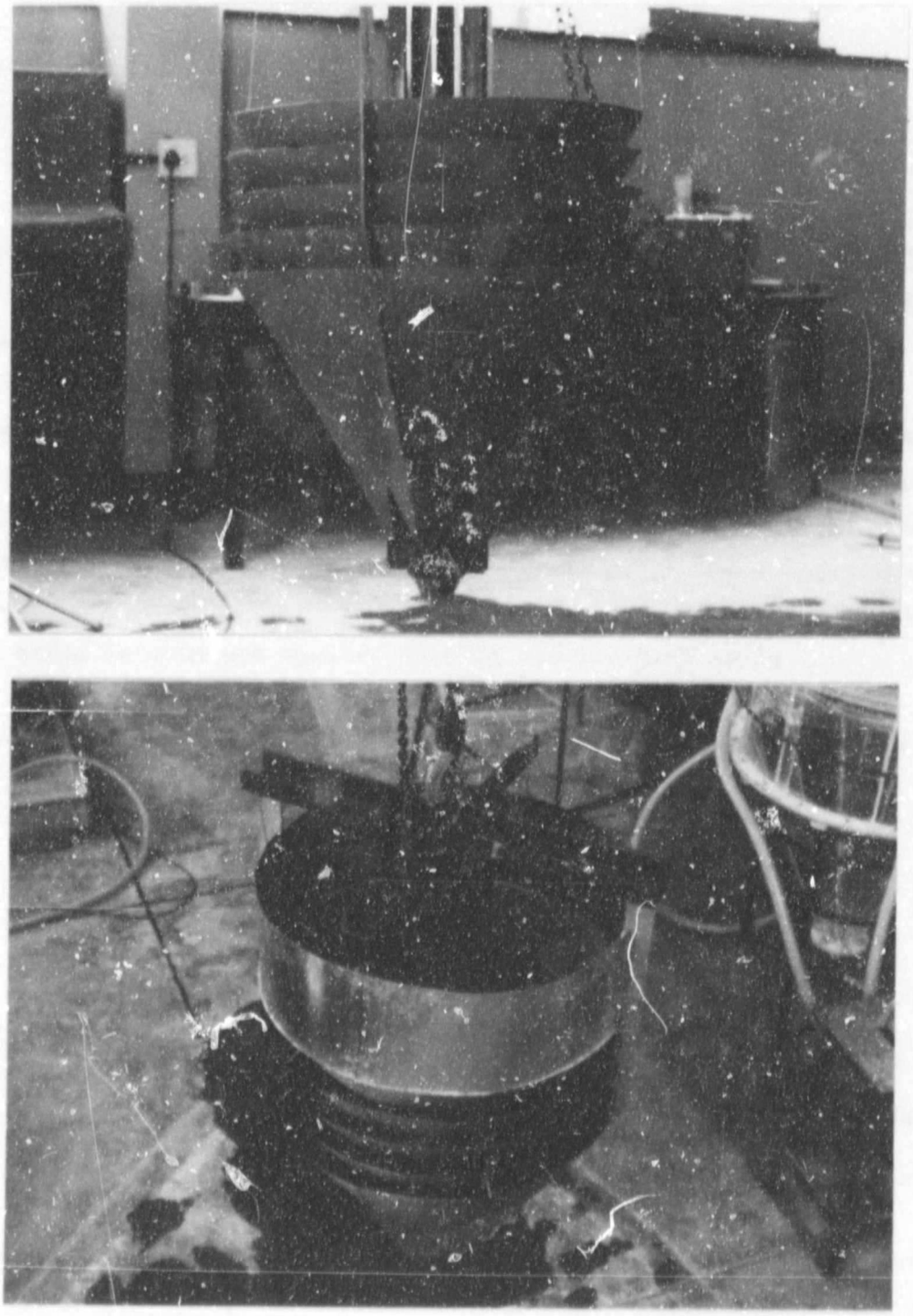


Figure 33. Stacking of the lamella cones.

The above two photographs show the cones stacked on top of each other and in so doing they form the spacings through which the water is to flow from the center to the periphery. The above figure also shows the stilling well which consisted of a sheet plate around the edge of the upper cone. The function of the stilling well is to prevent short circuiting that might occur from the inside of the cones to the outside without first passing through the plate spacings. This would be an important feature for cones installed over a certain depth of a sedimentation tank. It is recommended that if it is envisaged that cones will only be installed over a certain of the tank, that they are installed near the bottom and not at the top (see figure 34). This will result in the sludge being removed immediately and also the support of the cones by means of the gutters is simplified. The positioning of the cones at the bottom of the tank increases the distance from the outer edge of the cones to the weirs and particles which have not been captured in the plates will have the chance to settle down the sides between the conical lamella and the tank walls.

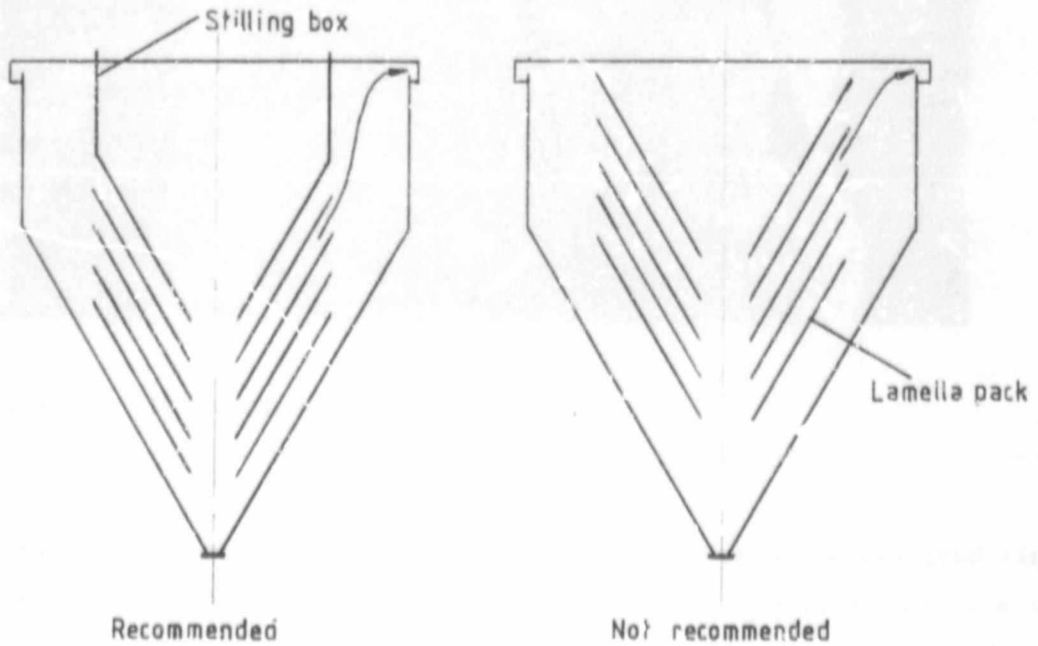


Figure 34. Recommended position of cones for a limited depth of conical lamella.

- Inlet pipe

This is the critical item in the design of the conical lamella settler. It is important not to overload one of the plate spacings and hence an even velocity distribution is required over the length of the plate spacings for the conical lamella settler to operate as theorized. To achieve this an inlet pipe was designed with a slot along the length of the plate spacings. To direct the flow from a horizontal to an inclined flow in the direction of the plates a series of small cones at 60° were installed around the slot (see figure 35 and APPENDIX E).



Figure 35. Inlet pipe.

The change in direction from horizontal to inclined flow is required since flow in a horizontal direction will strike the inclined surface and re-suspend sludge at the inlet. Inclined flow however, will result in minimal turbulence at the inlet (see figure 36).

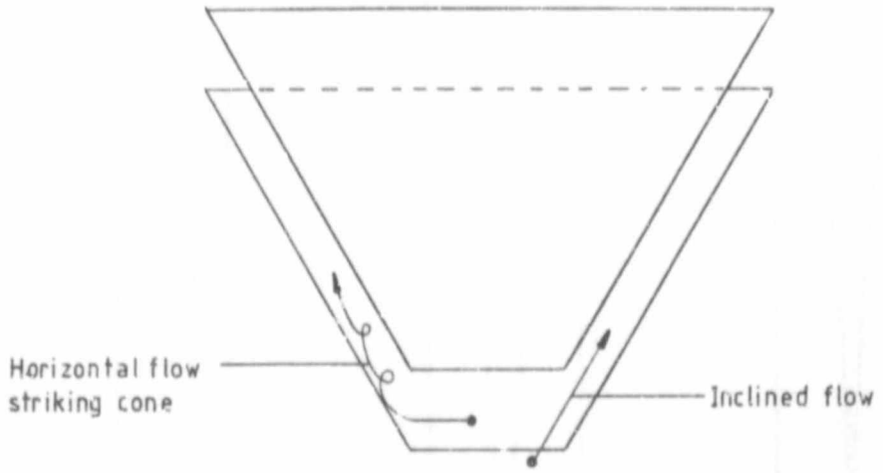


Figure 36. Modification of the inlet flow direction.

Initially the slot was designed as rectangular (see APPENDIX E). Introduction of potassium permanganate into the influent however showed an uneven velocity distribution with the bulk of the tracer being ejected from the bottom of the pipe. This is because the influent acts as a jet in the pipe which is dissipated against the base plate of the lowest cone. Hence it was decided to change the slot to a triangular one with it's apex at the bottom (see figure 37). This slot resulted in a much more even velocity distribution along it's length.

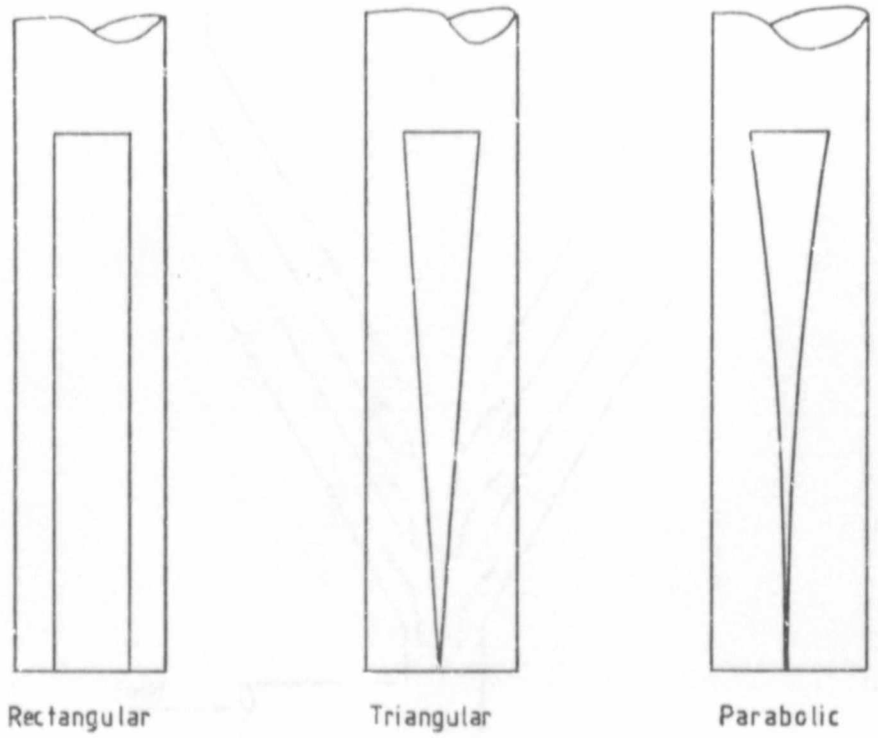


Figure 37. Pipe slots.

The triangular slot configuration was chosen through trial an error. Other shapes that could be tried is a parabolic slot (see figure 37) or some arrangement of orifices. Only further research can determine whether they will produce better results than a triangular slot. Another possible type of entrance configuration is the introduction of the feed from the bottom of the cones. This would alleviate the need for the intricate pipe arrangement used in the laboratory model (see figure 38).

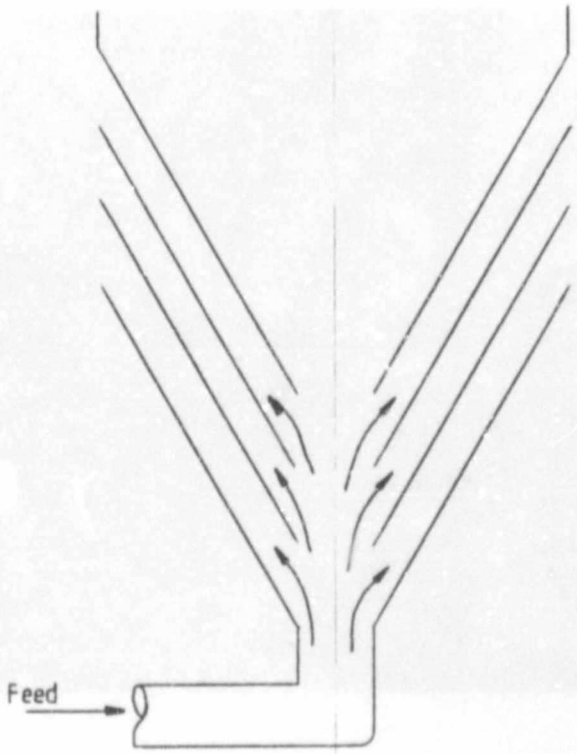


Figure 38. Inlet arrangement with feed from the bottom.

Similarly the introduction of the feed from the top without the inlet pipe could be tried. Once again only further research will establish the success of such inlet configurations.

The previous photograph shows a mesh around the cones of the inlet pipe. The mesh was 1,18mm square and it's function was that of an energy dissipater for reducing some of the turbulence resulting from the feed pipe. The photograph below shows the inlet pipe installed in the center of the cones.

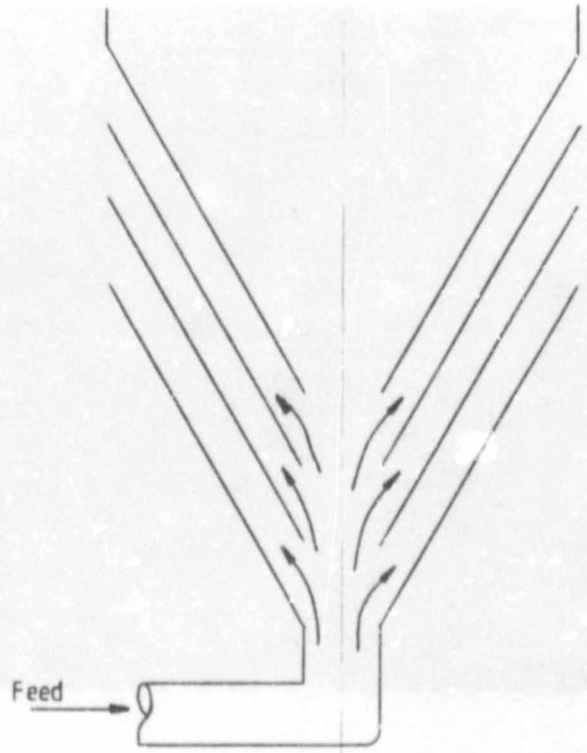
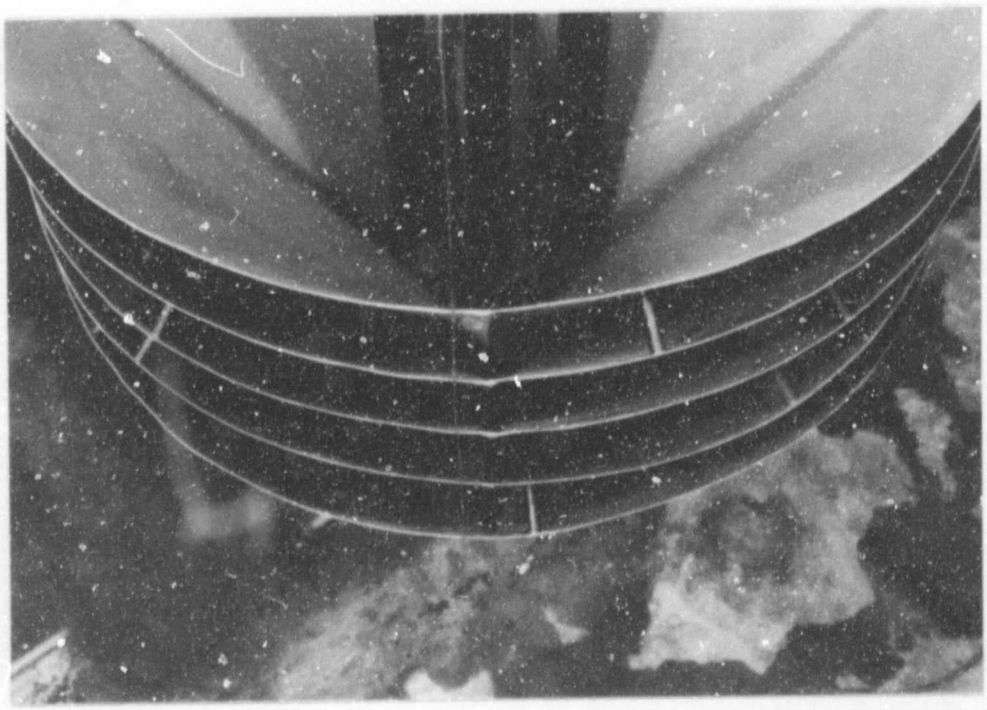


Figure 38. Inlet arrangement with feed from the bottom.

Similarly the introduction of the feed from the top without the inlet pipe could be tried. Once again only further research will establish the success of such inlet configurations.

The previous photograph shows a mesh around the cones of the inlet pipe. The mesh was 1,18mm square and it's function was that of an energy dissipater for reducing some of the turbulence resulting from the feed pipe. The photograph below shows the inlet pipe installed in the center of the cones.



ure 39. Inlet pipe and cone arrangement.

- Installation of cones into the model sedimentation tank

The two photographs below show the lamella cones installed into the perspex settling tank. The flow path of the water is the same as that used for the upward flow tank namely: influent in the 70 liter bucket, pump, throttle valve, flow meter and through the lamella cones. Effluent and sludge are continuously returned to the bucket to close the loop. The flow rates and influent SS concentration range were the same as that used in the upward flow tank. The de-sludging rate was kept constant at 0.45m^3/s, the same as used in the upward flow tank. Influent, effluent and sludge samples were tested for their SS concentrations (see APPENDIX J for method) and hence the % SS removed for a particular influent SS concentration and flow rate was calculated (see APPENDIX F).

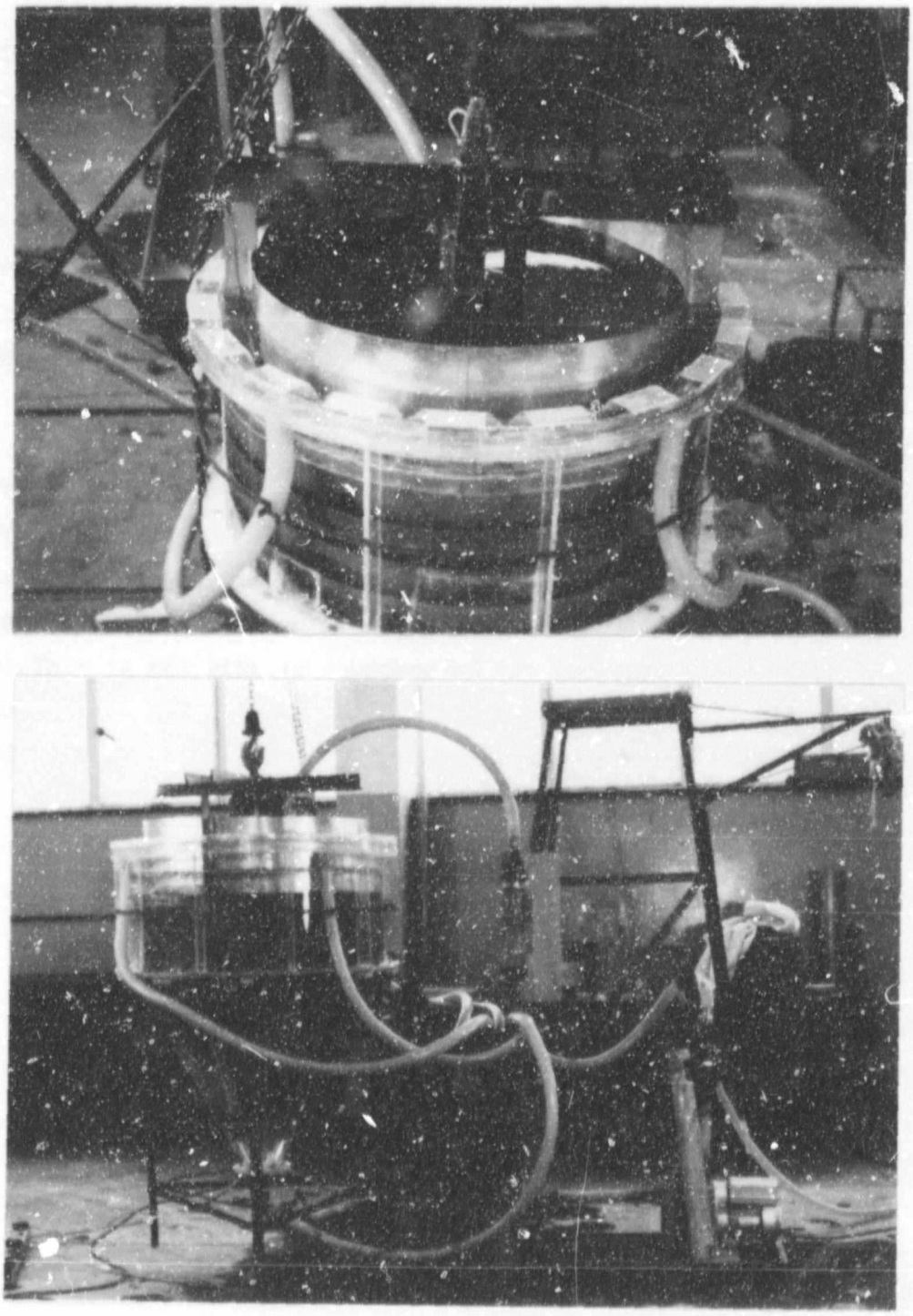


Figure 40. Cones installed in perspex sedimentation tank.

Author Barthelme Sven-Helmut
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