Executive Summary

The Tubular Filter Press Unit (TFP) at the Umgeni Water H.D. Hill Waterworks has been in operation since 1987. During an evaluation of the unit for the application of dewatering waterworks sludges, it was decided that there were significant weaknesses in the design, causing tube blockages and other operating problems, which need to be rectified in order to produce a reliable process. It was concluded that an important factor in the successful operation of the Tubular Filter Press, was the availability of a full-scale or pilot plant for experimental and development purposes.

In addition to its application for the dewatering of waterworks sludge, the tubular filtration process can provide potable water quality water (without the addition of chemicals) at high fluxes and low energy consumption. It was on this basis that a submission was made to the Water Research Commission (WRC) for a project to pursue further experimental work at the Umgeni Water Process Evaluation Facility. Following the resolution of licensing agreements between the WRC and Hi-Tech Water the project was initiated in 1994.

OBJECTIVES

The Aims of the Project were to :

- Develop and demonstrate the Exxpress Process for the dewatering of water works sludges.
- Apply the Exxpress Process to the production of potable water from river water.

In order to achieve the objectives and improve the design of the Tubular Filter Press, a number of specific areas were identified that required attention. These included :

1. Improving the design of the Tubular Filter Press to reduce the occurrence of cloth splits and tube blockages, and addressing aspects of the manifold layout to improve the flow distribution and cleaning.
2. Developing a commercially operational unit for waterworks sludges and providing a detailed design of the new plant.
3. Monitoring the capital and operating costs and comparing these to similar processes in industry.
4. Assessing the performance of the new design by extended operation during the project.
5. Assessing the use of the new design for potable water production.

6. Developing techniques for determining design parameters for the Tubular Filter Press by extending the filtration model proposed by Dr. Rencken and incorporating these into a design procedure.

DESIGN OF A VERTICAL TUBULAR FILTER PRESS

A design sub-committee was convened to address specific aspects of the design, and it was proposed that a vertically mounted tube, shorter in length and of a larger tube diameter be used. A single tube pilot plant was constructed at the Umgeni Water Process Evaluation Facility to demonstrate the proposed configuration. Following successful small-scale vertical tube trials, detailed mechanical drawings were approved for the manufacture and assembly of a full-scale demonstration unit at the Umgeni Water Wiggins Waterworks.

Construction of the unit was completed during September 1995 and was successfully demonstrated to delegates attending the International Water Supply Association (IWSA) Conference in Durban. As the supply of curtain fabric material had to be negotiated with Gelvenor Textiles, the plant was initially operated using single tubes of another material. This material eventually split and when replaced with curtains manufactured by Gelvanor Textiles, no further tube splitting was experienced. The operation of the Vertical Tubular Filter Press is detailed by the following stages.

Filtration Cycle - Feed sludge is pumped into the tubes under pressure. The formation of a filter cake occurs rapidly on the inside of the tubes, and the permeate is directed to a collection tank. The highly resistive nature of the filter cake results in a reduction in filtration rate (flux) until an operating limit is reached.

Tube Discharge - Once a final permeate flux has been achieved the tube discharge is initiated. The discharge valve at the bottom of the tubes is opened and the tubes are emptied onto a conveyor belt. In this way, dilute sludge is returned to the feed tank and filter cake is separated for waste disposal.

Flush Cycle - Sludge from the feed tank is then pumped at a high flowrate through the tubes and any remaining cake is washed onto the conveyor belt. The efficiency of the removal is dependent on the amount of solids deposited in the tubes and the nature of the dewatered solids. Under certain operating conditions the flush cycle may not totally clean the inside of the tubes which will result in a decrease in the performance of the unit with time.

Roller Action - A double roller is provided which squeezes the double row of tubes together, creating a restriction through which the flushing fluid is pumped. The increase in velocity through the restriction ensures a reliable and consistent cleaning of the tubes. It has been found that under certain operating conditions the rollers may not be necessary. Once complete, the operating cycle is repeated.

EXPERIMENTAL OPERATION TO DATE

Laboratory-scale compression-permeability cell (C-P cell) tests were performed to evaluate these tests as an effective means of obtaining sludge characteristics. The experimental method was investigated and found to be reliable, but some difficulties were experienced. A new C-P cell was manufactured to measure the transmitted pressure, to determine whether the effect of wall friction is significant when compressing highly resistive waterworks sludge.

The operation of a single tube pilot plant demonstrated the use of the vertical tubular technology for the dewatering of waterworks sludges. The effects of varying the operating parameters of feed solids concentration, operating pressure and final permeate flux were examined.

Once the new large-scale plant had been installed a number of practical problems were experienced, including losses of sludge from the conveyor during flushing, unstable roller movement, power tripping during flushing, inefficient mixing in the feed tank and the collection of solids from the conveyor. Other safety related issues have also been addressed by the inclusion of a high pressure switch on the feed pump and the installation of a splash cover around the material tubes.

The Vertical Tubular Filter Press was operated intermittently in a batch mode of operation where the recovery of the solids and dewatering performance were monitored. During the pilot-plant operation, 150 m^3 of sludge was filtered and the feed solids concentration varied between 7 and 30 g/l (0,7 and 3,0 % m/v). By varying the operating parameters of operating pressure and final flux before cleaning, and monitoring the feed solids concentration some interesting trends were observed.

The filtration model proposed by Rencken was extended to include a new theory of *Area Contact* between particles in the filter cake. A method was also developed to use pilot-scale or full-scale operating data to obtain parameters to describe the sludge characteristics. These parameters would normally be obtained from laboratory tests. The solution methodologies that have been developed

are being incorporated into user-friendly Windows based software. This work is still to be completed.

SUMMARY OF RESULTS

The deficiencies in the operation of the Tubular Filter Press at the Umgeni Water H.D. Hill Waterworks were identified and modifications to the design were proposed. A single-tube pilot plant was constructed and successfully operated in a new vertical configuration, demonstrating that the proposed design was feasible. The single tube pilot plant was found to accurately represent the filtration and cake removal, and can be used effectively to obtain design information for the sizing of dewatering applications.

A Vertical Tubular Filter Press was manufactured and constructed at the Umgeni Water Wiggins Waterworks in Durban, and was demonstrated to delegates of the IWSA conference during September 1995.

The performance of the filter has been reasonable producing cake concentrations between 20 and 32 percent solids (m/m), at cake recoveries up to 75 %. Although a trend of increasing cake solids with increasing pressure and increasing feed concentration was observed, the nature of the sludge from Wiggins was variable during the period of operation. The suspended solids in the raw water, the amount of bentonite, lime, hypochlorite and coagulant addition all have an affect on the nature of the sludge which will impact on the performance of the unit for sludge dewatering.

The cake recovery during cleaning was found to be dependent on the filtration time (or the final filtration rate before cleaning) as a sludge which has been allowed to reach compression equilibrium, will be more resistant to the vigorous effects of flushing. A cake which has not been compressed sufficiently will reslurry more easily and will pass through the conveyor belt thereby lowering the cake recovery, or more significantly the solids will remain on the inside of the filter tubes resulting in a shorter filtration time during subsequent plant operation, and hence poorer plant performance. The solids dewatering rate was found to depend on the filtration pressure, feed solids concentration and final permeate flux allowed before flushing.

The plant operation was found to be highly dependent on the sludge characteristics, not only with regard to the filtration cycle (cake formation) but also the flush cycle (cake removal). Cake recovery is a complex function of operating pressure, final flux and feed solids concentration. In order to optimally operate a tubular filter not only should the filtration characteristics be determined, but also the recovery *characteristic function*. It was found that under certain operating

conditions, flushing without the use of a roller may be sufficient to effectively remove the cake from the tubes. This may not always be the case as the sludge characteristics were found to vary considerably during the operation of the plant.

Tube blockages (previously experienced at the H.D. Hill Waterworks) were completely eliminated by increasing the tube diameter to 60 mm and decreasing the tube length. The increased tube diameter did not result in any occurrences of tube splitting or failure using the fabric produced by Gelvanor. Cake release and conveyance out of the tubes improved as the vertical orientation of the tubes assisted this by collapsing during the flush cycle.

The addition of lime to a waterworks sludge was found to improve the filterability of the sludge by altering the sludge characteristics. This was determined by C-P Cell tests, and evident during the continuous operation of the Vertical Tubular Filter Press. The addition of lime can have a negative impact on the plant operation as the pH of sludge and permeate increases significantly, and fouling of the woven tube fabric may occur due to the precipitation of calcium carbonate. Wall friction in the C-P Cell tests was investigated to determine if this was significant for waterworks sludges, and whether the standard C-P cell test was accurate in determining sludge characteristics. Although wall friction was observed the difference in the sludge characteristics obtained did not appear to be significant.

A new generalised *Area Contact Model* has been proposed for the constant pressure compressible cake filtration. Solution methodologies have been developed to regress for cake characteristics from operating plant data and to account for the period of pressurisation at the start of the filtration cycle. Once the software has been totally developed the accuracy of the *Area Contact Model* can be determined.

A pilot plant (comprising a single vertical tube) was operated in dead-end filtration mode to assess the use of the new design in raw water filtration for the production of potable water. It was shown that a precoat of limestone is required to reduce the turbidity of the raw water to below 1 NTU, but the efficiency of pre-coating in dead end mode (in a vertical tube) was poor. This process was clearly not adequate when compared to the Crossflow Microfiltration process for potable water production.

In meeting the objectives of the project a Vertical Tubular Filter Press was designed and developed for the dewatering of waterworks sludges. The limitations of the previous design, especially tube

blockages were totally eliminated and provided the process can operate without the use of rollers for sludge removal and tube cleaning a reliable and inexpensive process has been developed.

The use of the new vertical configuration operating in dead-end filtration mode is not recommended for potable water production as the effectiveness of pre-coating using limestone is poor, and the turbidity of the final water occasionally exceeds the SABS guidelines for potable water (<1 NTU).

RECOMMENDATIONS

It is recommended that this technology be actively marketed for dewatering of sludges where few problems are likely to occur. Areas to be avoided are organic effluents and highly variable industrial effluents where problems may arise as a result of inadequate information. To achieve this purchasing agreements need to be set up with the curtain supplier, and a small business could be initiated for the manufacture of curtains.

The Vertical Tubular Filter Press at the Wiggins Waterworks should be moved to a site where it can be optimised and then operated on a continuous basis for an extended period of time in order to fully demonstrate and market the technology. The application should be specifically chosen where the sludge supply and characteristics are more consistent (more particulate in nature). Sufficient instrumentation should be installed to adequately monitor the continuous operation.

A limitation of the single tube pilot plant is that it can only be operated in a batch mode. It is also recommended that this be automated such that it can be utilised for process investigations of new applications and together with the computer model form a total design package.

Further investigations into the aspects of cake removal are recommended with the objective to develop a mathematical recovery function based on the parameters that have been identified.

It is recommended that the software be completed and fully evaluated before being developed into a marketable product that will compliment the technology.

The single-tube pilot plant should be maintained by Umgeni Water, and hired to the licensed companies for pilot-plant studies to promote the use of the vertical tubular technology. The hiring charges should be sufficient to adequately maintain and repair, as well as improve or modify the operation of the pilot plant.