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Biological Aerated Filters

BAF 2

Cranfield University
12th June 1996

Organised by:
The School of Water Sciences, Cranfield University
In conjunction with The IChemE Water Subject Group

Editors – Professor Tom Stephenson and Dr Bruce Jefferson

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**2nd Symposium on Biological
Aerated Filters (BAF2)
12 June 1996**

Following the success of the first BAF symposium held here in 1993, Cranfield University's School of Water Sciences is holding a second one day symposium on Biological Aerated Filters.

Over the last three years there has been a great deal of work on the development and optimisation of what has become one of the leading processes in wastewater treatment. The aim of this second symposium is to introduce recent work carried out in this field, bringing together many of the world's leading exponents of BAF technology and its application.

BAF2 represents an ideal opportunity to update your knowledge of these developments.

BAF2 Programme

- 9:30 Registration and coffee
- 10:25 Chairman's morning introduction
- 10:30 Trouble shooting and optimisation of BAF systems.
A Smith, Thames Water
- 11:00 Pilot scale comparisons of floating/sunken media and up/downflow BAFs.
A Mann, School of Water Sciences, Cranfield University.
- 11:20 Combined treatment of dairy and municipal wastewater in BAFs.
Howard Rundle, Tetra (Europe) Ltd.
- 11:40 North European experience of BAFs.
P Sagberg, Veas, Norway.
(to be confirmed)
- 12:00 The Poole Harbour wastewater treatment works.
P Brewer, Wessex Water Engineering.

- 12:30 Lunch
- 2:00 Chairman's afternoon introduction
- 2:10 The moving bed biological aerated filter
T Stephenson, School of Water Sciences, Cranfield University
- 2:30 Operational trials of different proprietary Lamella and BAF systems.
F Budge, Halcrow Consulting Engineers and D Gorrie, Grampian Regional Council.
- 3:00 Aeration optimisation in biological aerated filters.
P Pearce, Thames Water.
- 3:30 Operating performance and future development of the Biobed system.
A Cantwell, Brightwater Engineering.
- 4:00 *Close of Meeting and Tea*

The School of Water Sciences

The School of Water Sciences is the UK's only academic centre to specialise in process technologies for water and wastewater treatment. The school has considerable experience in research and development, working with many of the world's leading water companies and organisations concerned with water and effluent treatment. This experience ensures that the school is well positioned to offer consultancy and research and development related to these process technologies. The School has particular expertise associated with biotechnological applications including BAFs.

In addition to research and development and consultancy, the School of Water Sciences is recognised as a leading centre for the training of process technologies with funding from the EPSRC and approval of its programmes from the IChemE and CIWEM.

BAF and the biotechnology short courses have been developed to advance the understanding and implementation of these technologies.



OPERATIONAL TRIALS OF DIFFERENT PROPRIETARY LAMELLA AND BAF SYSTEMS

F Budge: Director, Halcrow Scotland

D Gorrie: Principal Engineer, North of Scotland Water Authority (formerly Grampian Regional Council)

1 The Background

Halcrow Scotland were appointed by Grampian Regional Council (now North of Scotland Water Authority) in April 1993 to carry out the Aberdeen Wastewater Treatment Feasibility Study. The study started with a verification of the flows and polluting loads generated within the catchment followed by a review of the treatment technologies available. The purpose of examining the available technologies was to ascertain the land areas required. Different technologies had different land requirements, and it was important to evaluate this for the site selection stage. Inevitably, conventional activated sludge treatment processes required the greater land take, but it was the only proven technology as far as the client was concerned.

Other treatment processes, loosely termed "small footprint", could be accommodated within a much smaller area. The most promising of these processes was Biological Aerated Flooded Filters (BAFF), but at that time there were very few plants operating in the UK and none in Scotland. Halcrow recommended that the client establish pilot plant trials of the BAFF process. For minimal land take lamella plate separators would be required in the primary treatment stage and it was decided to include this compact settlement process (with or without chemical assistance) in the pilot plant trials.

Lamella and BAFF pilot plant trials thus were set up to evaluate the following:

- *To prove that lamella and BAFF processes are suitable for the conditions found in Aberdeen*
- *To assess the operational and maintenance aspects*
- *To demonstrate to the public the advantages of the processes*

The trials were extended later to examine the following:

- *Test different chemicals for assisted settlement*
- *Test the thickening characteristics of the BAFF sludges*
- *Test the treatability of the BAFF sludges (digestion and dewatering)*
- *Examine the effects of different loading rates and operating regimes*

Following extensive enquiries by Halcrow, two manufacturers were chosen; Degremont UK (DUK) for a six month period and John Brown Engineering (JBE) for a three month period. Final selection was made on the basis of BAFF type, availability and cost. Two plants were used to ensure that different types of BAFF plant work with Aberdeen sewage. The DUK plant is an upflow system using granular media, whereas the JBE



plant is a downflow, fully mixed system using a fixed plastic media. Two different lamella plate settlement pilot plants were used as compact primary treatment systems to suit each BAFF unit.

2 Public Relations

It was recognised from the outset that consultation with the public and statutory consultees, including departments of Aberdeen District Council, would play a major part in determining the site location and acceptance of the technology to be utilised in the works. The lamella and BAFF pilot plant trials offered the opportunity to provide information and background detail to the public and the other parties involved.

As the site selection process was still to be completed it was also important that the public understood that the location of the pilot plant did not pre-empt the location of the final works. The public information exercise also had to take account of the fact that the pilot plant would require planning permission from the District Council before the trials could take place.

Thus the trials not only included the technical assessment of the performance and operation of the BAFF process but also:

- *A public information meeting to coincide with lodging of the planning application for the pilot plant*
- *Visits from planning and environmental health officers of the District Council*
- *Visits from elected members of the Regional and District Councils*
- *Public open days with guided tours of the existing headworks and the pilot plants*
- *Guided tours for professional groups, statutory consultees, and interested bodies*

One of the major public concerns with waste water treatment plants is the potential for odour. This therefore was an area of great interest to planning and environmental health officers of the District Council.

A public meeting was held in a school near to the existing headworks on 2 December 1993 and as expected there was concern regarding odour potential and the pilot plant being a precursor to the site selection. These concerns were however successfully addressed and the opportunity for the public to visit the pilot plant was particularly welcomed.

The pilot plant was given planning permission on 16 December 1993. The Degremont UK pilot plant was installed on site in February 1994; the John Brown Engineering Plant was installed in April 1994.

The first open day at the plant took place on 23 April 1994 and was successful in not only providing a demonstration of modern waste water treatment technology but raised



public awareness of waste water treatment and disposal. Throughout the pilot trials the plants were visited as detailed above and the successful operation and openness of the trials was a contributory factor to the achievement of the planning consent for the full scale works being awarded with no objections being received.

3 Establishing the Test Units

Both treatment units were to be fed from the same source of sewage. A pump was suspended in the discharge sump of the screw lift pumps in the existing headworks building serving the Aberdeen Long Sea Outfall. The pump drew sewage up to a common header tank which had draw-off points serving each of the test units. The sewage had been screened and degritted, but the screenings were returned to the flow after maceration to 5mm maximum size (see Figure 1).

The Degremont UK plant was first installed in February 1994 and became fully operational on 14 March 1994 when sufficient bacteria had grown on the granular media.

The JBE pilot plant was brought onto site on Tuesday 5 April 1994 and was fully installed by 26 April 1994. After the 'seeding' and commissioning phase it was formally handed over to trained GRC/Halcrow operatives on Friday 27 June 1994.

The maintenance requirements detailed by the manufacturers did not indicate any specific requirements over and above general inspection and servicing of the major components at regular intervals.

4 Degremont UK Pilot Plant Arrangement

Figure 2 illustrates the various stages of treatment provided by the DUK pilot plant. Raw wastewater was pumped from a sump in the Headworks to a fine screening unit (Prepazur) above the main treatment units, the lamella clarifier (DENSEDEG) and the biological aerated flooded filter (BIOFOR).

The flow passed from the Prepazur (A) to the mixing tank (B) and then to the DENSEDEG lamella (C&D). The Densadeg was designed for chemical settlement and sludge recycling and contained tilted hexagonal tubes (D). The tilted tubes allowed the fine particles suspended in the wastewater to settle out. The settlement can be further enhanced by adding chemical flocculators and coagulants to the flow (B&C). Sludge, a by-product of the settlement process, was collected at the base of the tank whilst the wastewater passed on for further treatment.

The next stage of treatment was provided by the BIOFOR BAFF(E) which was filled with filter media of 5mm nominal size expanded shale, similar to fine gravel. Settled wastewater from the Densadeg was pumped from an intermediate holding tank (as the flow throughputs were different) through the BAFF unit and was purified by the bacteria which grow on the granular media. The bacteria required air to keep them alive and



this was blown through the granular bed. This was an upflow treatment where the treated water, suitable for discharge to the river or sea, emerged at the top of the tower. As the BIOFOR BAFF treats the wastewater, the media gradually traps impurities within it. Some of the treated water was stored (F) and used to clean (or backwash) the unit. Backwashing was required for a period of 45 minutes each day.

Control systems on the plants meant that the Densadeg operated diurnally whilst the BIOFOR BAFF operated on a fixed rate unless altered manually. A trained DUK employee was employed on site full time to operate the pilot plant.

An extensive monitoring regime was put in place to assess the capabilities of the pilot plant. This involved composite samples being taken at three points in the process by automatic samplers at the following sampling points:

- *raw wastewater from the header tank*
- *primary treated effluent from the Densadeg lamella process*
- *secondary treated (final) effluent from the BIOFOR BAFF process*

Samples were taken as 24 hour composite samples, gained from mixing samples taken at two hour intervals over the period. There was also diurnal sampling on different weekdays when two hourly samples were taken and tested individually. This was to highlight variations in effluent quality and plant performance during the day.

Samples were collected by Grampian Regional Council's (GRC) Scientific Services and analysed at their Whitemyres Laboratory. The parameters monitored were:

- *Biochemical Oxygen Demand (BOD)*
- *Suspended Solids (SS)*
- *Chemical Oxygen Demand (COD)*
- *Ammonia (NH₃)*
- *pH*
- *Chloride (Cl)*
- *Total Oxidised Nitrogen (TON)*

The minimum standard agreed for the single stage BAFF unit was that the treated effluent should meet a 40mg/l BOD and 60mg/l SS standard. A full scale plant would consist of a two stage arrangement to meet the Scottish Office guidelines standard of 25mg/l BOD and 35mg/l SS.

5 The Trials on the Degremont UK Pilot Plant

During the trials at Nigg the flow to the DENSADeg was controlled by a Magflo-PID control valve loop. The pilot plant had the capacity to operate at flows up to 35m³/h, but the unit at Aberdeen operated with a diurnal flow between 5 and 15m³/h.

Normal operation represented the operational regimes used to investigate the performance of the lamella and BAFF processes with Aberdeen wastewater.



The Densadeg lamella separators were tested with the following operating regimes:

Normal Operation	Steady and diurnal flow with chemical dosing
Regime 1	Diurnal flow simulation without chemical dosing
Regime 2	Diurnal flow simulations with ferric sulphate dosing
Regime 3	Diurnal flow pattern ceased
Regime 4	Treated effluent recycled to upstream of Densadeg

Some of the early plant failures were exacerbated by variability of loadings and high initial levels of suspended solids in the flow. To counteract these effects sludge recycling was stopped and the chemical dosing regime was optimised.

The flow rate to the BIOFOR was controlled manually at between 4 and 8 m³/h by means of a variable speed positive displacement feed pump. This method of flow control had the limitation that the true diurnal flow pattern to the headworks could not be replicated. This resulted in a 'smoothing' of the flows and loadings to the plant.

Process air for the BIOFOR was supplied from a Roots type air blower at a constant rate. The air flow rate was adjusted manually to suit changes in load in the effluent feed to the BIOFOR. Once the air flow rate was set under reasonably stable load conditions it was necessary to make adjustments only when a significant change in flow/load occurred, which was approximately every two weeks during the trials.

Under normal conditions the BIOFOR cell was backwashed once per day. About 11m³ of washwater was used in each backwash. However, due to occasional high load conditions (when septic tank contents were discharged at the Headworks inlet), the pilot BAFF unit was washed twice daily.

The results during the normal operating period revealed that the BAFF process consistently achieved a good percentage reduction of BOD and SS. The final effluent, however, did not always meet the target consent level. Analysis of these failures revealed that the majority of the pilot plant problems were associated with the chemically assisted lamella settlement process. This had a knock-on effect on the BIOFOR plant performance. In general, a DENSADEG lamella failure resulted in overloading of the BAFF process and a final effluent failure.

The Degremont UK plant did not perform well under the no-chemical dosing regime. This regime resulted in overloading of the BIOFOR causing final effluent failures. The contractor did express reservations about this regime as the unit at Nigg was designed for chemical dosing. It was noted by the contractor during the no-chemical regime that the lamella reduction rate of SS was more constant than at any other time in the trials.

The DUK plant performed satisfactorily under the final test regime which introduced effluent recirculation within the DENSADEG. Under this regime, the raw sewage flow



to the DENSADeg was reduced to $6.5\text{m}^3/\text{d}$, with a reduced BOD loading being passed to the BIOFOR averaging $1.11\text{kg BOD}/\text{m}^3/\text{d}$ up to a maximum of $2.35\text{kg BOD}/\text{m}^3/\text{d}$.

6 John Brown Engineering Pilot Plant Arrangement

The JBE pilot plant is represented in schematic form in Figure 3. Raw wastewater was taken from the header tank and then fed into JBE's control cabin where certain parameters were measured before it was pumped into the lamella unit (1). This is the primary treatment stage which, by a series of horizontal baffle plates, allowed the fine particles suspended in the wastewater to settle out. JBE designed their lamella plant to run without a flocculating polymer to enhance the settlement process. There was a stirrer in the bottom of the tank to aid sludge thickening whilst the treated wastewater flowed to the BAFF unit (BIOPUR).

A sample of the treated wastewater was returned to the control cabin to allow monitoring and automatic adjustment of critical parameters such as dissolved oxygen (DO) in the effluent. Air is critical to the BAFF process and this monitoring ensured the most effective use of the air supply available.

The BIOPUR BAFF tanks (2) and (3) were filled with a structured plastic filtering media. The settled wastewater from the lamella plates flowed down through this media whilst air was blown through the filtering media. Backwashing was required twice daily for the first BIOPUR BAFF tank (2) and once daily for the other tank (3). Each backwash took approximately 15 minutes.

This process was designed as a fully mixed system rather than a more conventional flow-through system. Mixing occurred within the tanks due to the upflow of air versus the downflow of effluent. Turbulence was created by the media within the tank, thus allowing mixing through the full fixed media column. This meant that the plant could cope more easily with shock loads as their effect was dissipated by the mixing that takes place. Twin BIOPUR BAFF tanks were used to attain the depth of media required to meet treated effluent consent standards.

A similar monitoring regime to that of the DUK plant commenced when the pilot plant became fully operational. Samplers were placed at three locations:

- *Primary treated effluent from lamella plate settlers*
- *Secondary treated effluent from Stage 1 BIOPUR BAFF*
- *Secondary treated (final) effluent from Stage 2 BIOPUR BAFF*

In addition, the results from the sampler at the header tank were used for both DUK and JBE tests. The samples were analysed for the parameters given above, and a similar daily composite sampling regime adopted. The two hourly sampling regime was not necessary for the JBE plant as this was a fully mixed system linked to the existing headworks inlet flume measurement electric and automatically followed the hydraulic loading of the headworks.



7 The Trials on the John Brown Engineering Pilot Plant

The sewage from the header tank flowed by gravity through the lamella plate separators and the BIOPUR (BAFF) process and then through to the washwater tank. After each BAFF stage, the flow was returned to the control cabin where it was sampled for control purposes. Normal operation related to the assessment of the performance of the lamella and BAFF processes with Aberdeen sewage. Under this regime the variations of the incoming flows at the headworks inlet were matched.

The lamella plate clarifier was fed sewage screened to 5mm, including macerated screenings, and produced SS removal efficiencies averaging in excess of 70% and BOD removal efficiencies of between 40% and 50% throughout the duration of the trial. These removal rates were achieved without the use of any chemicals.

Sludge was produced from the lamella plates at consistencies up to 10% dry solids. This high figure was due to the failure of the sludge withdrawal valve serving the picket fence thickener within the unit. Dry solids contents of between 5 and 6% were normal after this problem was rectified.

Trials with the lamella plate clarifier are summarised below:

Max Flowrate (m ³ /hour)	SS Loading (mg/l)	SS Reduction (%)
1.5	674	88
3.0	401	54
4.5	830	56
5.25	512	44
6.0	484	47

The design criteria for the lamella is 50% reduction in SS at a DWF of 1.5m³/h and peak flow rate of 5.0m³/h. By comparing these values with those obtained in the trials, it can be seen that the lamella exceeded its design criteria by producing a 56% reduction in SS at a constant flow rate 4.5³/h (3 times the design DWF). Even when the plant was loaded beyond its peak flow rate, SS reductions of just below 50% were achieved.

The amount of air required for each stage of the BIOPUR process varied with time and strength of influent. The amount of air delivered to each stage was controlled automatically. The following control philosophy was used during the trials:

- *Pre-determined set points were entered into each stage's process air controller.*
- *The Dissolved Oxygen (DO) sensor in each stage's discharge pipework recorded the value of DO in the sewage and transmitted this to the convertors.*



- *The convertors sent the value of DO to the corresponding controller where it was compared to the set point.*
- *Depending on whether more or less air was required, a signal was sent to open or close the air control valves which were located in the air delivery pipework.*

Excess biomass in the BIOPUR cells was removed by periodic backwashing using scouring air and washwater. During the trials, three backwashes were undertaken every 24 hours with two for the 1st stage BAFF cell and one for the second stage BAFF cell. A backwash required approximately 15 minutes of downtime. About 5-6m³ of washwater was used in each backwash.

The JBE BAFF plant was designed for a maximum of 2.5 kg BOD/m³ media to achieve the consent standard. The plant consistently passed the consent standard, often at loadings much greater than the design maximum. During the initial trials with the variable Aberdeen sewage, the plant coped very well with shock loads and achieved a 96 percent pass rate of the consent levels.

The operational regimes were changed to increase the loading on the BIOPUR and investigate the operational limitations of the plant. During this period a number of different flow regimes were tested as follows:

REGIME	FLOW TO BIOPUR (m ³ /d)		
	Average	Maximum	Minimum
Normal	60	94	37
1	93	97	81
2	120	141	110
3	158	160	150

These trial regimes were used to investigate the operational limitations of the plant. These proved that the plant achieved the final effluent standard when the media loading was beyond the design maximum. The JBE pilot plant functioned well throughout the trial period. The achievement of the 95 percentile for the 40:60 consent level demonstrated that these processes work under Aberdeen conditions. The BIOPUR plant easily dealt with 1.75kg BOD loading/m³ whilst passing the trials consent standards.

8 Conclusions

The two very different lamella plate separators and BAFF processes were shown to be suitable for consideration for the Aberdeen Wastewater Treatment Scheme. In fact confidence in the BAFF treatment process generally was greatly enhanced.

The two BAFF systems trialled were designed for very different loading rates, which



reflected the choice of media. The lower design loading rate of 2.5kg BOD m³/d for the JBE two-stage BAFF system was compensated for by the greater depths of 4.5m and 5.0m of plastic media in each stage respectively. The Degremont UK design loading rate of 4.0kg BOD m³/d was easily attained by 3.5m depth of expanded shale media, but the system was designed to be preceded by chemical assisted primary settlement. Thus the two systems would have similar 'footprint' sizes in a full scale treatment plant.

The trials with and without chemicals to assist settlement in the lamella clarifier confirmed a preference for a system which avoided the use of chemicals.

Maintenance involved cleaning the DO probe daily, lamella separators/plates monthly, checking the air blowers and backwash pumps routinely. Many of these maintenance activities would be automated in a full scale plant. No particular maintenance issues arose.

The importance of having an operator fully conversant with the equipment and processes involved was highlighted during the trials. Inevitably a pilot plant lacks the sophistication of a full scale installation and trial results were quickly affected by minor changes which may not have been significant otherwise. Several breakdowns of ancillary equipment caused effluent standard failures, masking the overall good performances.

After backwashing the media bacteria required 30 to 45 minutes to recover effectiveness. This would not be significant in a multi-cell arrangement.

Odours were a public concern prior to the trials, but the visits to the pilot plant trials by the public, statutory bodies, planners and other interested parties were effective in allaying fears. The trials became a very important part of the public relations for the overall feasibility study.



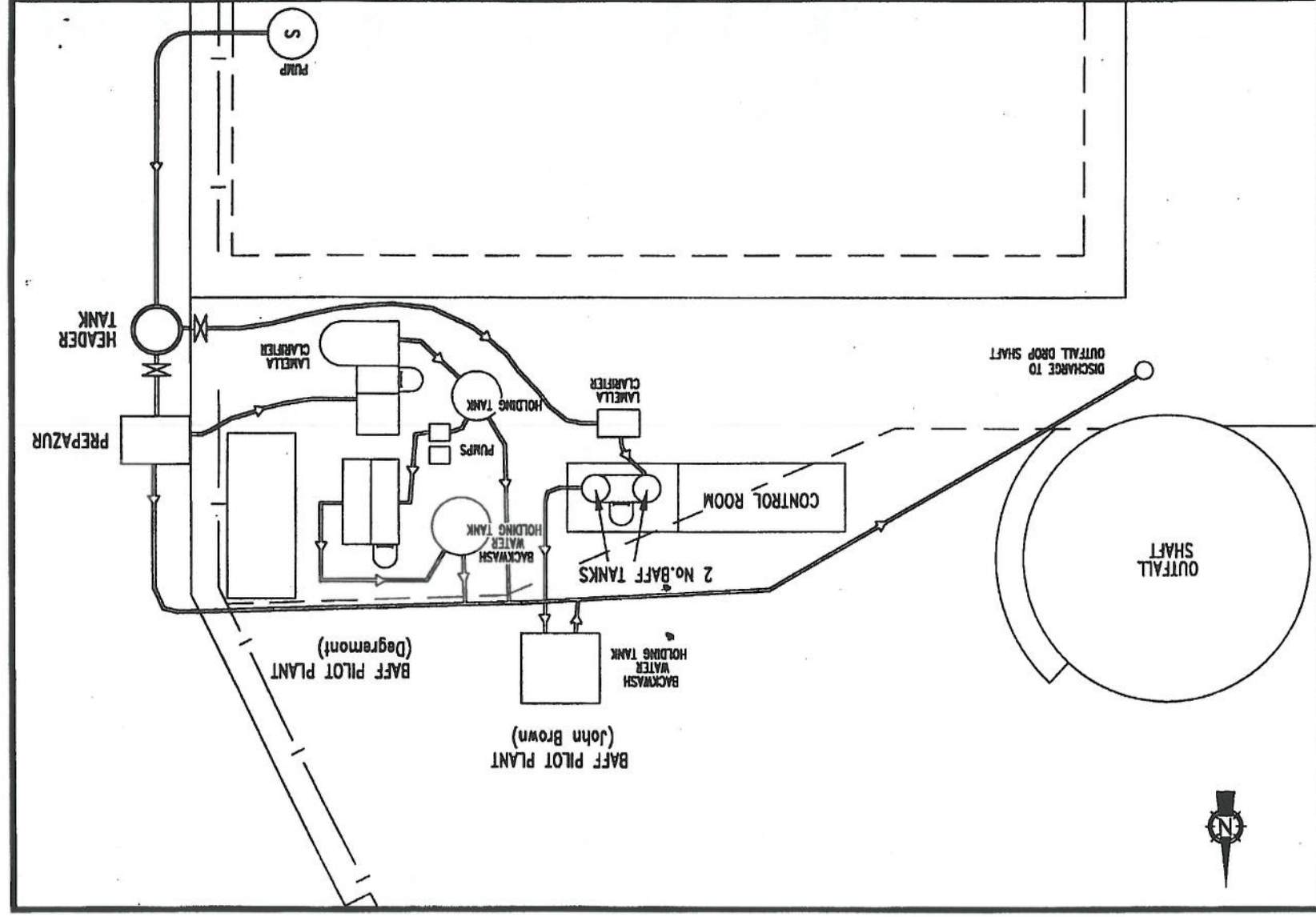


Figure 1 General Arrangement



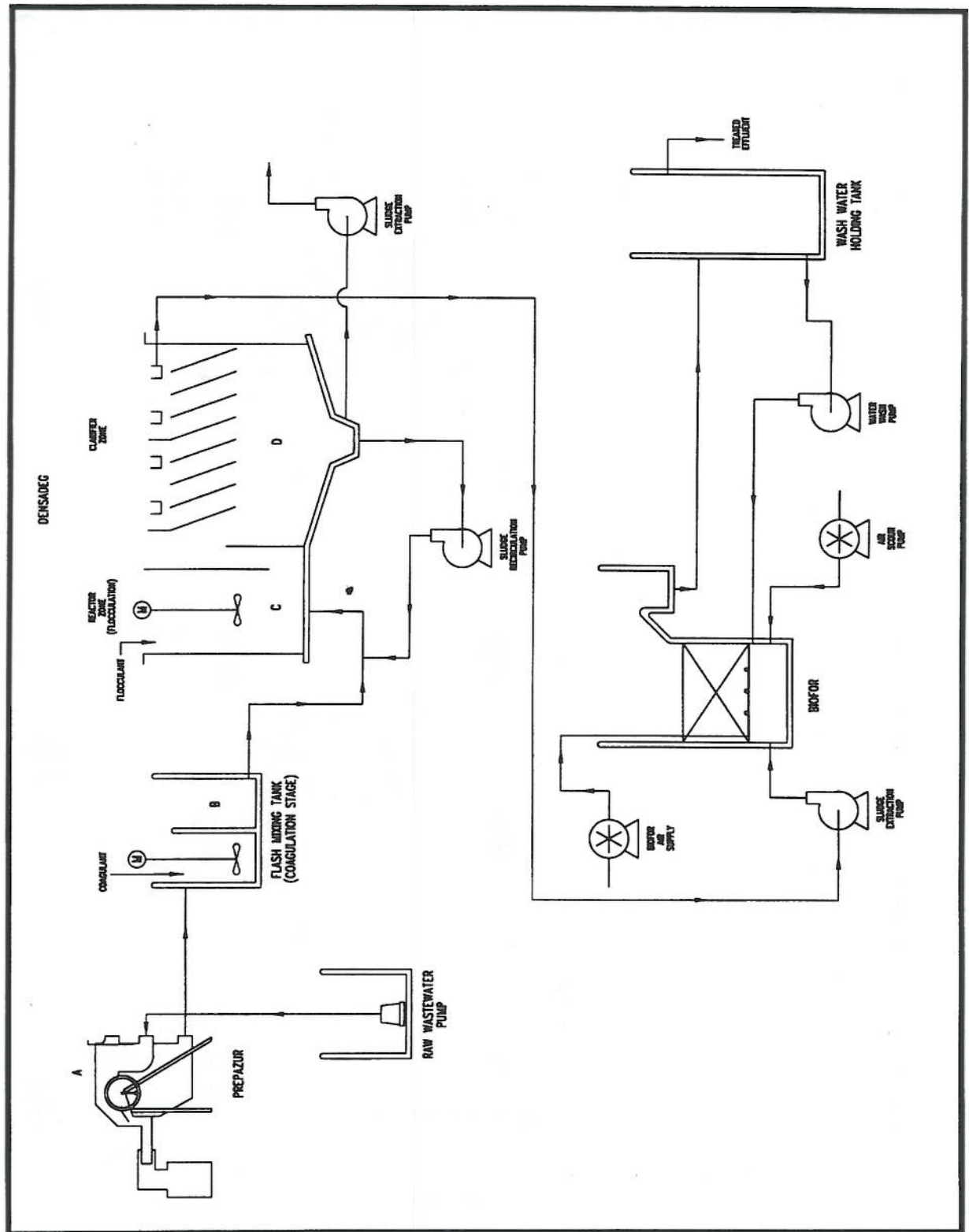


Figure 2 Schematic of D.U.K. pilot plant



LAMELLA AND BIOPUR DEMONSTRATION PLANT

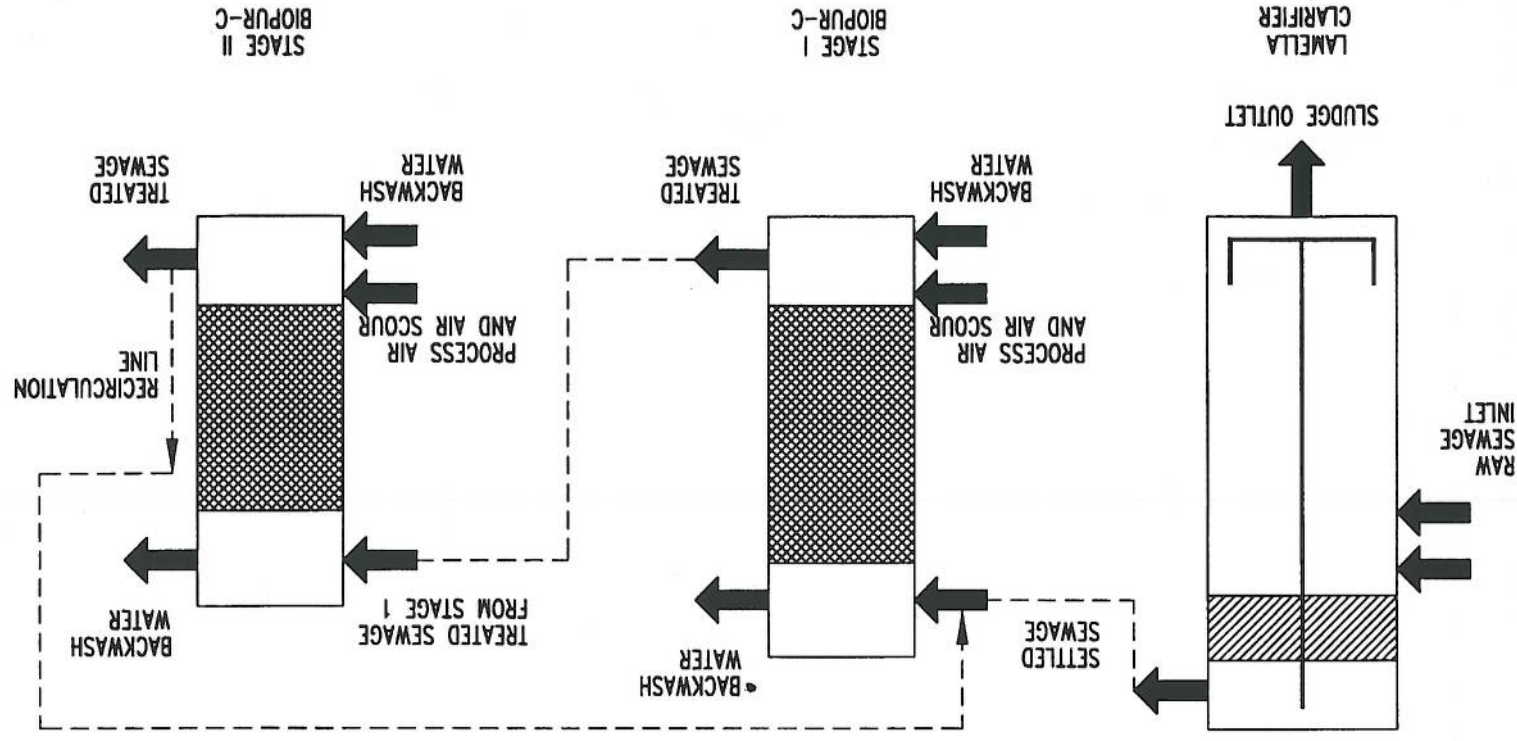


Figure 3 Schematic of John Brown Engineering Pilot Plant

