DAF FOR WASTEWATER TREATMENT

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ABSTRACT

As part of the determination of a strategy for the upgrade of Shepparton Wastewater Treatment Complex, Goulburn Valley Water have undertaken a Dissolved Air Flotation (DAF) trial on secondary effluent from the plant. The trial aimed to determine the suitability of the DAF process as a tertiary treatment method for reduction of phosphorus to levels acceptable for future discharge to the Goulburn River. The trial was conducted between December 1997 and June 1998. This paper presents the major operational problems encountered through the duration of the DAF trial, and some of the main results.

KEY WORDS

Dissolved Air Flotation (DAF), Induced Air Flotation (IAF), Ferric Chloride, Alum, tertiary treatment, phosphorus reduction.

1.0 INTRODUCTION

1.1 Shepparton Wastewater Treatment Plant

The Shepparton Wastewater Treatment Complex currently receives and treats domestic wastewater from the local community of around 30,000 people, and trade waste from numerous sources. The Shepparton Preserving Company (SPC) produces the most significant trade waste load on the plant, contributing flows of 1,400 ML/year out of a total inflow to the plant of around 7,000 ML/year. Other major trade waste contributors are Campbell's Soups, Pental Soaps, Shepparton Saleyards, Stuarts Meats, Ducats Milk Products, and Midland Milk. The proportions of flow from the various sources is detailed in Table 1.

Table 1: ***Inflow characterisation at Shepparton Wastewater Treatment Complex***

Type of Flow	Percentage of Total Flow
Domestic wastewater	71.6%
Cannery waste	19.2%
Dairy waste	0.7%
Saleyard waste	0.7%
Meat processing waste	0.5%
Vegetable processing waste	6.9%
Soap manufacturing waste	0.4%

The treatment process is essentially through lagoon treatment, comprising six anaerobic lagoons and thirteen facultative / aerobic lagoons. During the peak fruit canning season, nitrogen is added to the raw waste to assist in maintaining stability in the biological treatment process. Lime is also used to control pH and odour. Operation of the plant through the various lagoons is extremely flexible, and effluent may be diverted depending on available capacity and treatment requirements.

Disposal of treated effluent from the plant is by irrigation of Goulburn Valley Water land during the summer and discharge to the Goulburn River during winter.

1.2 Need for Tertiary Treatment

Recently there has been growing concern in the region about the issue of nutrient discharges to rivers from various sources. In responding to this concern, EPA have indicated that all wastewater treatment plant licences will be updated in the near future, and will include limits for phosphorus and nitrogen concentrations in effluent being discharged to surface water bodies.

Nutrient loads discharged from the Shepparton plant to the Goulburn River are currently significant. In the 1997/98 financial year, total phosphorus concentrations of the discharge water ranged from 3.2 mg/L to as high as 9.8 mg/L. These concentrations equated to an annual of load of 15,000 kg phosphorus and 53,000 kg nitrogen discharged to the river.

If discharges are to be maintained, there is a need to reduce the nutrient concentrations. Re-use trials undertaken in recent years have indicated that complete land disposal of effluent is not likely to be sustainable in the long term, at this site. The main problems identified are the rising regional water table and associated salinity as well as problems with loss of soil structure and productivity caused by sodicity. Although not yet set, future licence limits for discharges to inland waterways may be as low as a median of 0.5mg/L and 90th percentile of 1.0mg/L for phosphorus.

In addition to the principal need for nutrient removal, particularly phosphorus, it is not likely that the Shepparton plant will be able to meet more stringent licence requirements using the existing lagoon technology. Parameters such as BOD and suspended solids may also have to be reduced in the future to meet new licence requirements. High BOD_5 and suspended solids loads in secondary treated wastewater are experienced in many lagoon based systems due mainly to elevated levels of algae in the terminal lagoons. Tertiary treatment will be required to reduce these parameters to acceptable future levels.

1.3 Objectives of Pilot Trial

The pilot trial at the Shepparton Treatment Plant had three main objectives. The first of these was to determine whether an air flotation system could provide tertiary treated effluent that would be likely to achieve future EPA requirements for discharge to the Goulburn River. Not only did DAF need to be capable of removing phosphorus and algae in the effluent, but it also had to be able to do this in an economically viable manner.

The second objective of the trial was to compare the performance of dissolved air flotation with that of induced air flotation.

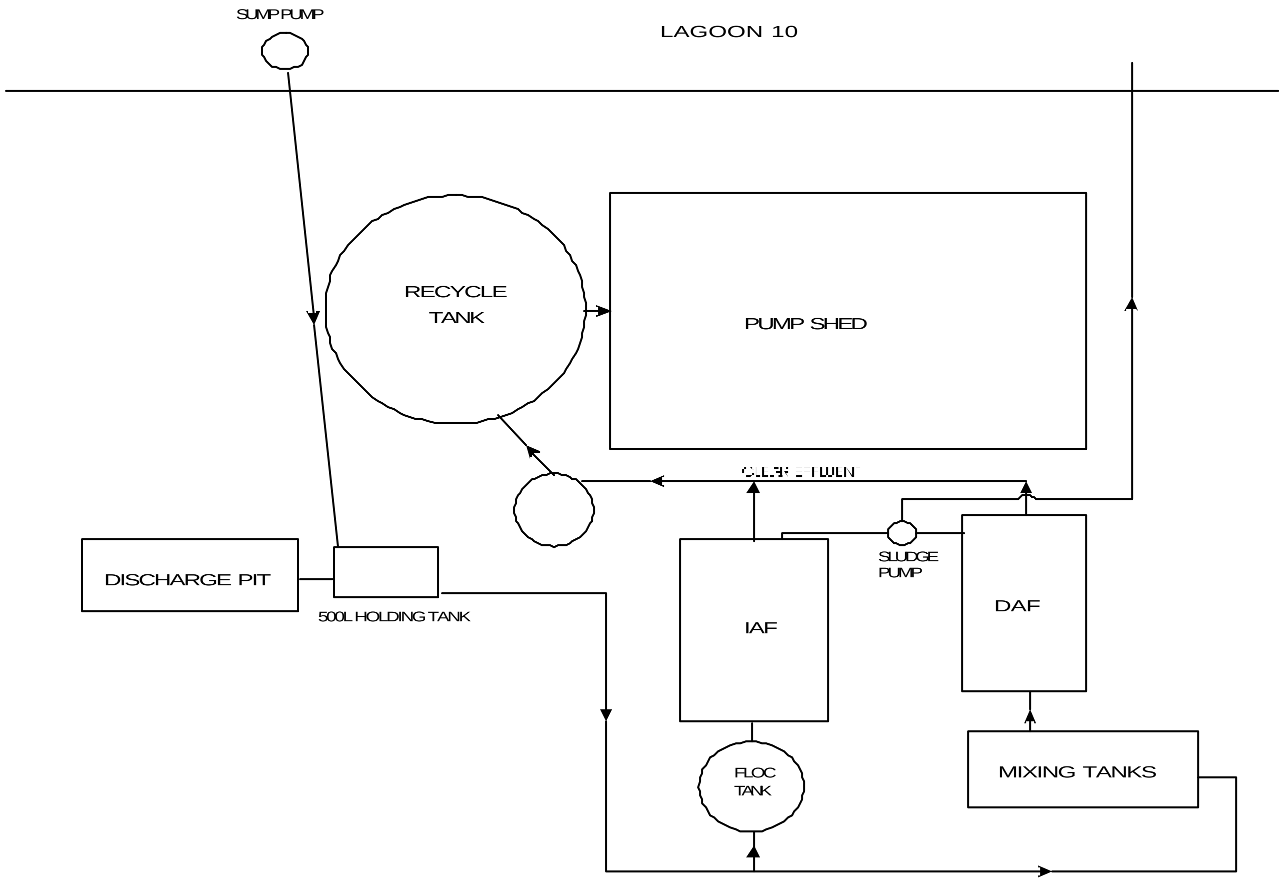
Lastly, the selection of an appropriate chemical for coagulation was required. The pilot trial tested four different coagulants - ferric chloride, ferric sulphate, alum and PFS (hydroxylated ferric sulphate). The selection of an appropriate polymer to aid flocculation was also investigated.

2.0 DISCUSSION

2.1 Pilot Plant Set-up

A site along side Lagoon 10 was selected as appropriate for the pilot plant due to the availability of electricity, and its proximity to the pipeline allowing discharge to the River. A drawback of this site was a lack of a fresh water supply. A schematic of the layout of the pilot plant site is shown in Figure 1.

Figure 1***: Schematic of Trial Plant Layout***



The trial was due to commence in December, but there was no effluent being discharged to the river at this time. It was proposed to draw effluent for the trial from terminal Lagoons 17, 18 and 19, some distance away from the trial site. To allow this, an inflatable sewer plug (650mm) was installed in the river discharge pipeline which meant that with careful adjustment of flows, effluent could be backed up in the pipeline and pumped out of an air vent pit at the trial plant site using a sump pump. Initially, it was established that Lagoon 10 effluent was close in quality to the effluent usually discharged during winter, therefore the sump pump was placed directly into Lagoon 10.

The Induced Air Flotation (IAF) plant was supplied with effluent from the holding tank using a diaphragm pump. Coagulant was pumped into the pipeline just prior to an elevated 700L flocculation tank. Coagulation mixing was assisted by the upflow of effluent in the tank and rapid mixing was not required. The flocculated effluent overflowed into the IAF unit, where it flowed over a number of baffles before coming in contact with the induced air bubbles. If polymer dosing was required it was to be pumped into the IAF tank prior to the first baffle to allow sufficient contact time before flotation. Floated sludge was removed by a longitudinal scraper followed by a smaller lateral scraper at the end of the tank.

The conventional DAF plant was substantially more complicated than the IAF unit. Effluent was pumped from the holding tank into the first of two 1500L mixing tanks which were used for chemical dosing, mixing and flocculation. Both mixing tanks were supplied with rapid mixers, neither of which had variable speed. From the mixing tanks the effluent flowed under gravity into the DAF unit. Clarified effluent is recycled at a rate of around 15% and is compressed to a saturation pressure of 450kPa being returned to the head of the DAF unit. Floc becomes attached to the dissolved air bubbles and is floated to the surface and scraped to a sludge collection tank from where it is pumped back into Lagoon 10. Clarified effluent flows under the sludge collection tank and is discharged back to the lagoon.

2.2 Proposed Trial Schedule

The pilot trial was originally supposed to proceed for approximately three months, form the start of December 1997 to the start of March 1998. During this time, several variables were to be investigated. The first and main objective was to investigate which of four coagulant chemicals (ferric chloride, ferric sulphate, alum and hydroxylated ferric sulphate) was most effective on this particular effluent. Once this coagulant was identified, the plant was to be used to determine the dose required to reduce the phosphorus concentration to various levels, namely 2mg/L, 1mg/L and 0.5mg/L. A cationic polymer had been selected for use in the trial, and the next step was to investigate the effects of adding various doses of polymer to the flocculated effluent.

The effects of operational variations were also to be assessed. The configuration of the plant was to be assessed by moving dosing points and in the case of the conventional DAF unit, varying the operation of the two mixing units. The feed rates into the two trial plants was to be varied, as was the DAF pressure and recycle rate on the DAF unit.

The final stage of the trial was to bring all these components together, and determine in detail the optimum conditions for achieving the required phosphorus removal.

2.3 Problems Encountered

A number of unforseen problems were encountered during this trial, which caused both delays to the trial process and the need for extended experimentation. These included a large variation in the quality of the secondary treated effluent, several mechanical breakdowns and the requirements for variation to the pilot plant configurations.

♦ **Variability of Effluent**

It had been assumed that the quality of effluent in the treatment lagoons would be relatively constant, and any changes would occur gradually. We were therefore unprepared for the large and sudden variations in effluent quality that occurred throughout the trial.

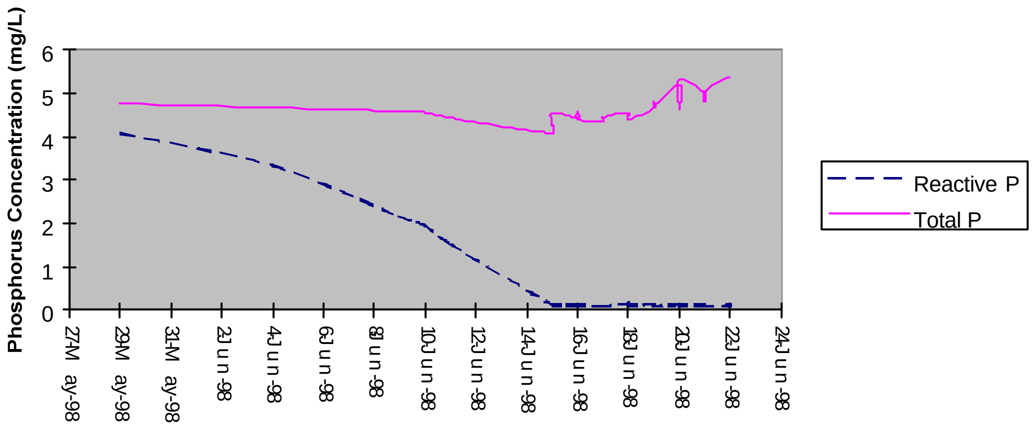
Prior to commencement of the trial, jar tests were performed by the consultants to determine approximate starting doses for each of the chemicals using the effluent from Lagoon 10. These jar tests indicated that relatively low doses would be required for adequate phosphorus removal, in the order of 20mg/L as aluminium or iron. At this time the effluent was relatively free of algae, and much of the phosphorus was in a reactive form.

A delay of several weeks in between the initial jar tests and commencement of the trial occurred, partly due to late delivery of the plant and other equipment. At the commencement of the trial, the proportion of reactive phosphorus to total phosphorus was substantially lower, and even with doses of up to 50mg/L (as Fe or Al) the total phosphorus could only be reduced to 2mg/L. The addition of the selected cationic polymer only marginally improved this situation.

As the trial progressed, more of the phosphorus became bound up in algae or bacterial biomass. Seemingly overnight, the lagoon twice dramatically changed its characteristics. Early in the trial, the effluent became bright green indicating a build up the algal population. Later in the trial the lagoon turned pink, which was the result of the presence of large concentrations of Chromatium, a type of bacteria usually associated with anaerobic conditions and elevated sulphate levels. When this bacteria was present, a chemical dose of around 110 mg/L as Fe was required to achieve good results.

At the start of winter, the trial was recommenced using the terminal lagoons from which effluent is normally discharged to the Goulburn River. Initially the lagoons were green with relatively high loads of algae, and up to 85% of the phosphorus in the effluent was in reactive form. This meant that the chemical dosing worked well, with jar tests showing that an average dose of 40mg/L as Fe or Al would reduce the phosphorus to below 1mg/L, and around 80mg/L was required to reduce the total phosphorus to below 0.5mg/L. When the pilot plants were restarted on the 15th June 1998, the reactive phosphorus component in Lagoon 17 had reduced to virtually nothing, meaning that a dose of around 120mg/L as Fe was now required to reduce the phosphorus lower than 1mg/L. A comparison of total and reactive phosphorus versus time is plotted in Chart 1.

Chart 1 - ***Changes in Total Phosphorus and Reactive Phosphorus with Time in Lagoon 17***



♦ **Changes in Chemical Requirements**

During the first month of the trial, it was determined that the polymer initially selected was virtually ineffective. The original polymer was a low strength cationic polymer, which was mixed to a 0.3% solution using a remote polymer batching unit located at a potable water supply. Polymer was carted to the pilot plant site in drums as required. Further jar testing during the trial showed that a 10% cationic polymer with a high molecular weight achieved a much more stable floc blanket and lower supernatant turbidities than the original polymer.

This discovery brought about significant delays. Firstly, two to three weeks of the trial had to be repeated using the new polymer. In addition, the polymer batching unit was not able to be used with the new polymer, and an alternative mixing arrangement had to be found. Due to the lack of clean water supply at the pilot plant site, it was not possible to install another batch unit there. Ultimately the simplest method proved to be mixing small quantities (each batch was 32 litres) by hand at the nearby laboratory on a daily basis, or as required.

The lack of efficient phosphorus removal during the trial suggested that pH correction to within the range 5.5 - 6.0 may be required to optimise the flocculation. Jar tests part way through the trial seemed to confirm this suspicion. It was decided to introduce sulphuric acid dosing into the trial to investigate this possibility. The acid was set up to be dosed into the first mixing tank of the DAF unit at the same point as the coagulant. Acid dosing commenced on the 12th of March 1998, and continued until the end of April.

The pilot trials and later jar tests showed very little improvement due to the acid dosing. It has been presumed that this is due to the lack of reactive phosphorus in the effluent for much of the time, as acid dosing only assists in optimising the reaction between the coagulant and the reactive phosphorus component.

- **Problems with Induced Air Flotation Plant**

The Induced Air Flotation unit had some problems with the structure of the unit itself. A large proportion of the delays were caused by faulty electrical connections on the scraper and its variable speed drive, which meant that electricians had to be arranged several times to rectify the problem. The plant was completely enclosed with steel plates, which meant that it was virtually impossible to view the flocculation process, the clarity of the subnatant, and whether excessive sludge accumulation in the base of the tank was occurring. In addition, there was no provision for settled sludge removal, and it was suspected that some of that sludge was becoming resuspended into the effluent.

The process itself turned out to be inappropriate for this type of effluent. Very little float was produced unless excessive polymer doses were applied, and even then a stable float could not be consistently produced. It is probable that the bubbles induced into the effluent were too large, and are more appropriate for readily floatable wastes such as raw dairy wastes and wastes with very high algal content where no metal salts were to be added.

Despite the inability of the IAF unit to float the floc, it was observed that very little floc was formed in the final effluent, but the effluent was highly turbid. This was due to a combination of floc settlement and floc breakup throughout the process. The overflow from the flocculation tank into the IAF unit was quite turbulent, and the floc seemed to have broken up by the time it had reached the induced air bubbles. The bubbles themselves and the turbulence created by the mixer may have broken up more of the floc.

The accuracy of inflows and chemical doses was also of concern. There was no regulation on the inflow to the unit except for adjusting a simple valve on the pumping line, which would have required calibration each time it was set. The chemical dosing pumps supplied with the unit were also hard to regulate, as there was no gauge and again calibration was constantly required. In addition, these pumps were not able to reliably pump the small doses required during the trial, and on occasion, on return to the plant they would have been found to have stopped altogether.

- **Problems with the Dissolved Air Flotation Plant**

The Dissolved Air Flotation plant was also found to be less flexible than was desirable. The main issue with this plant was that the mixing tanks were supplied with two rapid mixers, and there was no way of using one of the mixers as a slow mix tank for polymer contact. For the main part of the trial it was attempted to overcome this by leaving the mixer in the second tank off and relying on the natural mixing process within the tank itself. Every two hours after a sample had been taken, the mixer was briefly turned on to resuspend any settled material in the base of the tank. This was not considered a satisfactory method of flocculation, and in the final stages of the trial the second mixer was removed and a large paddle mixer with a variable speed drive was temporarily installed.

This plant also had no provision for settled sludge removal, and there were also no viewing panels to determine whether substantial settlement was occurring. As with the IAF unit, it was possible that settled matter was being resuspended in the tank. This issue was not able to be resolved during the trial.

The pumps supplied with this unit were also difficult to calibrate, and the minimum pumping rates were not low enough for some of the doses that were required. This was particularly true when acid dosing was introduced, and it became necessary to dilute the acid on site. For some of the lower doses, it was also necessary to dilute ferric chloride on-site to accommodate for these pumps. pH probes and automatic pH correction facilities were included on the unit, however it was found that these were inoperable and portable pH probes were required on site.

Despite all efforts to optimise the DAF plant, it was observed that the jar tests consistently returned better results than the DAF unit. For example, in the winter tests on the terminal lagoons, one set of results showed 60mg/L as Fe was capable of an 84% phosphorus removal int he jar tests, however the DAF plant was only capable of 48% removal. It is supposed that the inflexibility of this plant meant that optimum conditions were not obtained.

2.4 Treated Effluent Quality

The trial results showed that the lagoons experience a high variation in secondary treated effluent quality, and this in turn leads to high variations in dosing requirements. Table 2 shows maximum and minimum doses required to achieve total phosphorus concentrations of 2mg/L, 1mg/L, and 0.5mg/L for the jar tests, DAF and IAF units. A comparison of indicative chemical costs as determined from the jar tests are shown in Charts 2 and 3.

Table 2: ***Dose of Fe or Al required to reduce total phosphorus***

	Jar Test			**DAF Plant**		
	2mg/L	**1mg/L**	**0.5mg/L**	**2mg/L**	**1mg/L**	**0.5mg/L**
Ferric Chloride as Fe (mg/L)						
Maximum	90	>120	>120	80	160	>160
Minimum	10	30	70	25	57	>57
Alum as Al (mg/L)						
Maximum	20	40	90	>80	>80	>80
Minimum	10	20	30	50	50	80

Chart 2 - ***Maximum and Minimum Alum Costs for Various Phosphorus Targets***

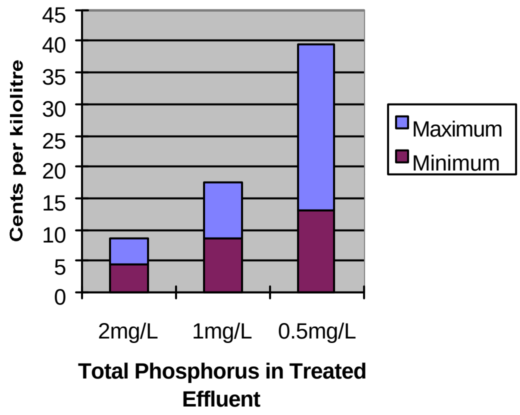
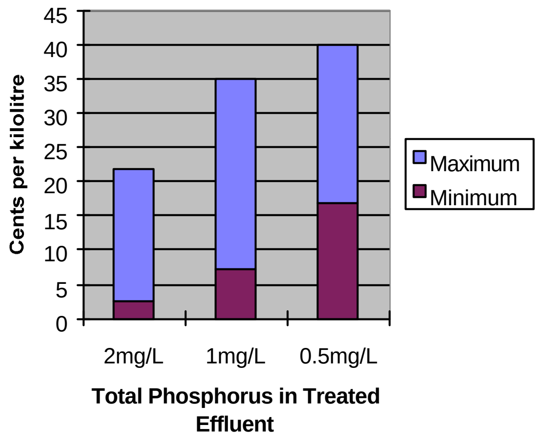


Chart 3 – ***Maximum and Minimum Ferric Chloride Costs for Various Phosphorus Targets***



Note that the jar tests for ferric chloride showed that doses in excess of 120mg/L (which corresponds to a ferric chloride cost of 29 cents per kilolitre) may be required to remove phosphorus to 1mg/L or 0.5mg/L. The maximum costs in Chart 3 have been assumed to be at greater than this to allow for a safety margin.

It can be seen from Table 2 that under certain conditions low phosphorus levels can be obtained with quite low doses of iron or aluminium. For example, the jar tests show that under conditions of low algae and bacteria content, 0.5mg/L phosphorus can be obtained with doses of 70mg/L Fe or 30mg/L Al. Note that although less aluminium is required to achieve certain doses than iron, the cost of the alum per unit aluminium is substantially greater than that of ferric chloride per unit iron. Cost analyses of these two coagulants are currently underway.

In addition to the main goal of phosphorus removal, DAF treatment will also remove BOD, suspended solids, E.coli and nitrogen to varying degrees The average removal of these parameters is outlined in Table 3.

Table 3: ***Average removal of various quality parameters using DAF technology.***

Parameter	Average Removal					
	mg/L as Fe			mg/L as Al		
Dose	**30**	**80**	**120**	**30**	**80**	**120**
Biochemical Oxygen Demand	47%	50%	25%	31%	26%	-
Suspended Solids	7%	58%	75%	0%	55%	-
Total Kjeldhal Nitrogen	12%	66%	63%	14%	59%	-
E.coli	38%	-	86%	-	96%	-

3.0 CONCLUSIONS

The jar tests performed during this trial show that dissolved air flotation technology can be successfully used for tertiary treatment of wastewater, depending on the dose of coagulant used. Further work on plant optimisation is required to bring the phosphorus removal to the level achieved in the jar tests.

The economic viability of this treatment process is still being assessed, but is dependent on the coagulant and polymer doses required, the secondary treatment effluent quality, and the quality limits to be achieved.

A high level of understanding of individual lagoon characteristics is required to determine the suitability of dissolved air flotation for municipal wastewater treatment. Prior to any pilot plant being implemented, it is advisable to do an extensive series of jar tests to determine variations in amount and form of phosphorus.

5.0 ACKNOWLEDGMENTS

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6.0 REFERENCES

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