Figure 7.1: Flow Diagram and Mass Balance for SBR

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Figure 7.1: Mass Balance for SBR (Option A)

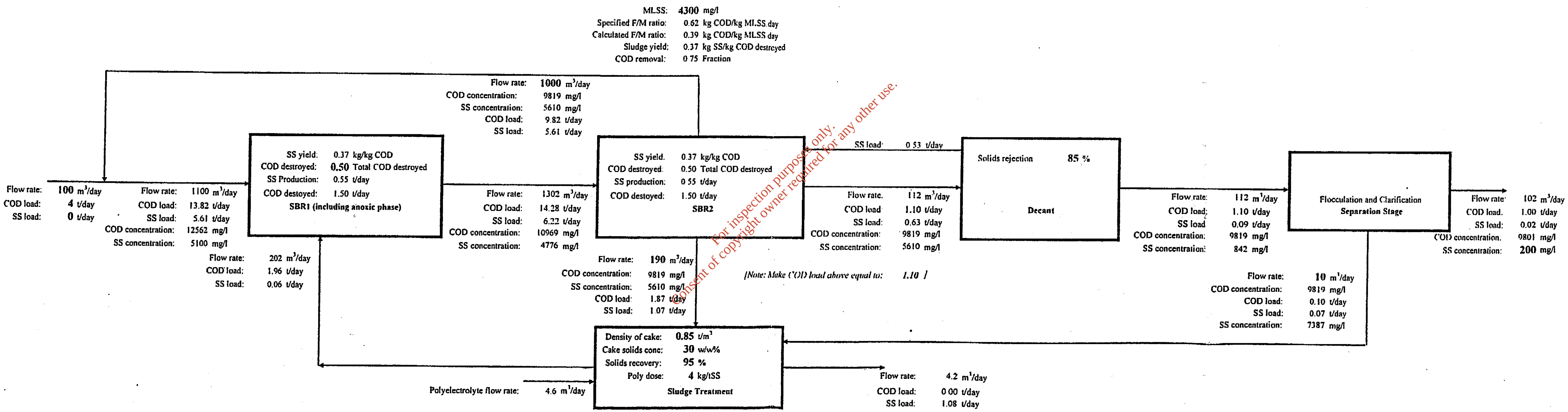

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Figure 7.2: Flow Diagram and Mass Balance for Activated Sludge with Gravity Separation

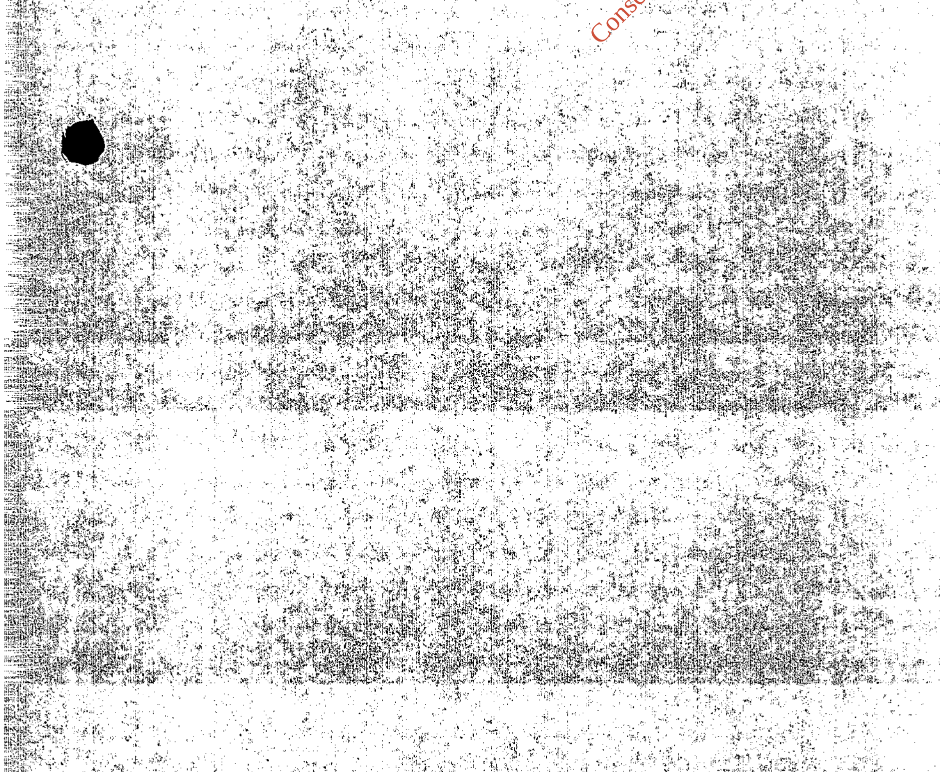

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Figure 7.2: Mass Balance for Activated Sludge with Gravity Separation (Option B)

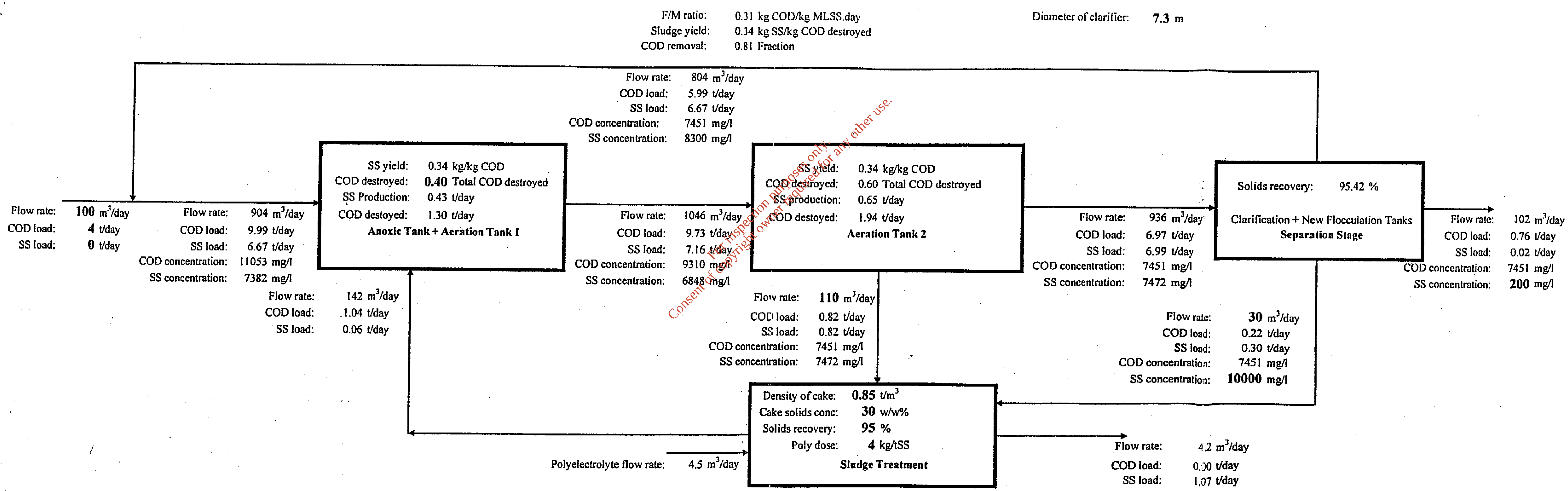

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Figure 7.3: Flow Diagram and Mass Balance for Activated Sludge with Membrane Separation

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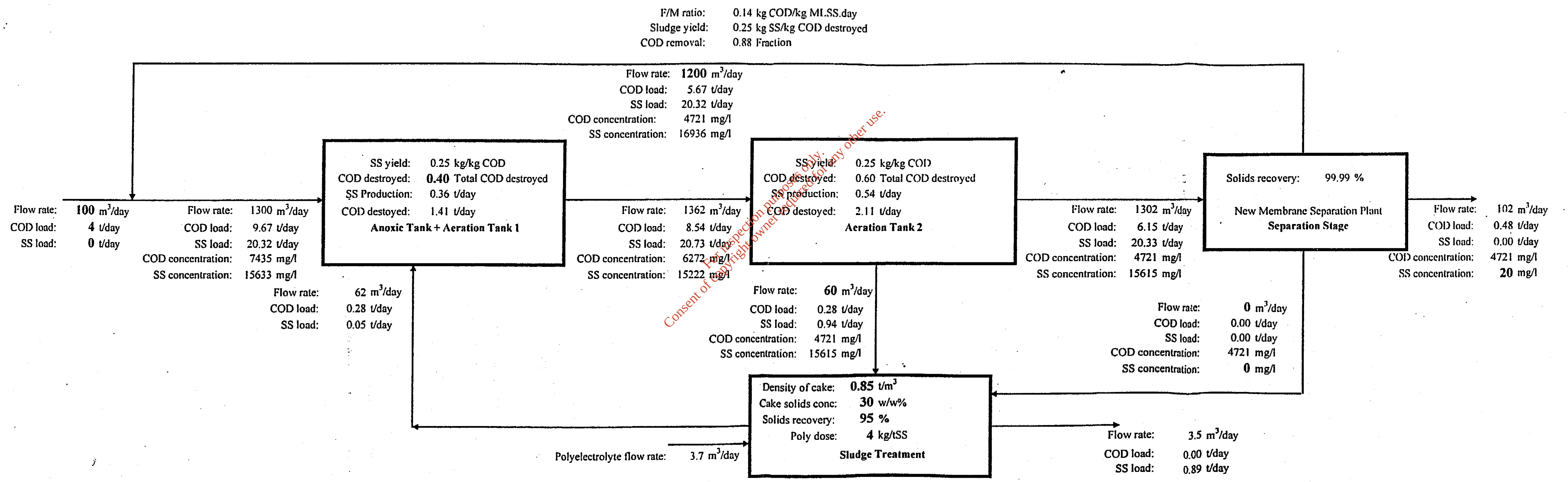
Figure 7.3: Mass Balance for Activated Sludge with Membrane Separation (Option C)



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8 Common Issues

There are three major issues common to all the treatment options, namely:

- odour control
- cooling requirements
- capacity of the aeration system.

This chapter reviews these issues.

8.1 Odour Control

8.1.1 Extent of Odour Control

With regard to odour control, a system based on, for example, a Bord na Mona biofilter should be provided for the dewatering building. However, it would not be rational to provide odour control for the wastewater treatment units since, as explained in Section 2.3, these units are unlikely to produce emissions capable of causing public odour nuisance.

Mild chemical odours are detectable on-site owing to emissions from the production units and the equalisation tank. However, such odours have not historically caused public odour nuisance and should not cause nuisance in the future.

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8.1.2 Contingency

In the unlikely event that the biological reactors in the upgraded WWTP cause odour nuisance, an odour control system could readily be retrofitted. New induction fans would generate a small negative pressure in the headspaces of the biological reactors and digester and transfer the odorous air vented from these spaces to an odour scrubber. Any odorous air produced by an aerobic biological system is unlikely to be treatable by a scrubber working on an aerobic biological principle. Given the high flow rate of the odorous air (it includes the aeration air), a chemical scrubber would be the best option in terms of performance and cost. An example of such a scrubber would be a single-stage hypochlorite scrubber with a nickel catalyst, of the type known as 'OdorGard™'. Several companies, including Jones & Attwood of Stourbridge in the UK, design and supply such scrubbers.

The cost of an odour control system, incorporating on OdorGard™ scrubber, for the biological reactor and digester would be around €450 000. An alternative would be a solid-bed filter containing activated carbon or a similar compound. However, since the odour load would be potentially high, this type of scrubber would not be cost-effective owing to the comparatively high cost of replacing the medium.

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8.2 Cooling Requirements

The biological oxidation of the organic chemicals in the biological reactors will release heat, causing mixed-liquor temperature to rise. For chemicals containing little nitrogen, the amount of heat liberated is, to a good approximation, directly proportional to the COD of the chemical. Biological systems convert some of the organic chemicals to biomass and the remainder is oxidised. Assuming a 50% conversion, the heat liberated is equal to:

7.5 MJ per kg of COD biologically destroyed.

If more of the COD is oxidised rather than converted to biomass, then the heat liberated per kg of COD destroyed increases.

Assuming no heat losses from the system, the destruction of 10 000 mg/l of COD has the potential to raise the temperature of the wastewater by 18°C. Such a large temperature rise is hypothetical since heat losses are inevitable but it indicates the significant heating potential of the biological reactors. The highest temperature measured in the mixed liquor seems to have been about 40°C, measured in early 1999, a few weeks after commissioning.

The performance of the aerobic biological reactors at site will be maximised when the mixed-liquor temperature is in the optimum mesophilic range that is from 25°C to 38°C. The thermophilic range, existing above the mesophilic range, has an optimum temperature range of 45°C to 60°C. Generally, biological reactors operate optimally when in either the mesophilic range or the thermophilic range, but crossing from one range to another leads to reduced performance and treatment instability. Accordingly, temperature of the liquor in the biological reactors at site should be maintained within the mesophilic range. The following investigates the characteristics of a cooling system needed to prevent the liquor temperature exceeding a value of 35°C.

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8.2.1 Cooling System

The only available method of cooling at site is to transfer the excess heat to the atmosphere using a cooling tower. The main components of the cooling system would be as follows:

- spiral heat exchanger with 12 mm channels to transfer heat from the mixed liquor to the cooling water
- pumping station to re-circulate mixed liquor from the downstream biological reactor, through the heat exchanger, to the upstream biological reactor
- cooling tower containing media for transferring heat from the cooling water to the atmosphere
- pumping station to re-circulate cooling water through the heat exchanger and the cooling tower
- make-up water system with softening system, if necessary.

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8.2.2 Heat Balance

The heat balance around the biological reactors is given by:

Heat in wastewater	=	Heat in treated effluent
+ Heat from biological reaction		+ Heat losses through reactor walls
+ Heat from compression of aeration air		+ Heat losses from compressor and delivery pipes
+ Sensible heat in air intake to compressor		+ Sensible heat in spent aeration air from reactors
		+ Latent heat in water vapour in spent aeration air

Notes: The heat balance does not consider radiation transfers which are negligible by comparison.

The sludge withdrawn from the biological reactors is a source of heat loss. However, much of this heat is recycled to the reactors in the sludge liquors. Although the sludge handling gives a net heat loss, the amount is assumed to be small compared with the other heat losses and gains.

Table 8.1 gives the calculations and the assumptions used to determine the cooling requirement; the particular values in this table relate to a wastewater flow rate of 100 m^3/day and a COD of 40 000 mg/l, which is the worst case.

Figure 8.1 shows the relationship between the cooling requirement and the flow rate and COD of the site wastewater fed to the WWTP.

The worst-case cooling requirement is 154 kW; this is increased to 180 kW to provide a safety factor to cover for fouling of the heat exchanger and other efficiency reductions. Appendix F and Appendix G present quotations from Balcke-Marley for a 180 kW cooling tower and from Alfa Laval for a 180 kW heat exchanger respectively.

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Table 8.1: Calculation of Cooling Requirements

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Table 8.1: Calculation of Cooling Requirements for Wastewater Flow Rate of 100 m³/day.

Parameter	Unit	COD = 40000 mg/l		COD = 35000 mg/l		COD = 30000 mg/l		COD = 25000 mg/l		COD = 20000 mg/l		COD = 15000 mg/l		COD = 10000 mg/l		COD = 5000 mg/l	
		Input	Calc	Input	Calc	Input	Calc	Input	Calc	Input	Calc	Input	Calc	Input	Calc	Input	Calc
Streams																	
Air temperature	°C	20		20		20		20		20		20		20		20	
Wastewater temperature (used as datum)	°C	25		25		25		25		25		25		25		25	
Wastewater flow rate	m³/day	100		100		100		100		100		100		100		100	
Wastewater COD	mg/l	40000		35000		30000		25000		20000		15000		10000		5000	
Wastewater COD load	t COD/day		4.00		3.50		3.00		2.50		2.00		1.50		1.00		0.50
Removal of COD	%	75		76		77		78		79		80		76		76	
Temperature of Mixed Liquor	°C	35.0		35.0		35.0		35.0		35.0		35.0		35.0		35.0	
Net Heat Balance (+ve denotes excess)	kW		153.6		127.3		100.3		72.5		43.9		14.6		-19.4		-48.7
Dimensions																	
Width of tank	m	12.15		12.15		12.15		12.15		12.15		12.15		12.15		12.15	
Length of tank	m	15.64		15.64		15.64		15.64		15.64		15.64		15.64		15.64	
Wall depth	m	6.50		6.50		6.50		6.50		6.50		6.50		6.50		6.50	
Water depth	m	5.50		5.50		5.50		5.50		5.50		5.50		5.50		5.50	
Aerator submergence	m	5.20		5.20		5.20		5.20		5.20		5.20		5.20		5.20	
Nr of tanks	Nr	2		2		2		2		2		2		2		2	
Heat Input from Biological Activity																	
COD oxidised	%	60		60		60		60		60		60		60		60	
COD load oxidised	t COD/day		1.8		1.596		1.386		1.17		0.948		0.72		0.456		0.228
Biological heat	MJ/kg COD oxidised	14.5		14.5		14.5		14.5		14.5		14.5		14.5		14.5	
Biological heat produced	kW		302.1		267.8		232.6		196.4		159.1		120.8		76.5		38.3
Heat Input from Aeration																	
Percentage of O2 removed from air	%/m	1.4		1.4		1.4		1.4		1.4		1.4		1.4		1.4	
Aeration efficiency (mech-to-water)	kg O2/kWh		0.99		0.99		0.99		0.99		0.99		0.99		0.99		0.99
Air flow rate	t/day		106.0		94.0		81.6		68.9		55.8		42.4		26.8		13.4
Air flow rate	m3/day at ambient		88456		78431		68111		57496		46587		35382		22409		11204
Specific heat of air	cals/g.°C	0.24		0.24		0.24		0.24		0.24		0.24		0.24		0.24	
Pressure losses in air delivery pipe	mwg	1		1		1		1		1		1		1		1	
Total air delivery pressure	mwg		6.2		6.2		6.2		6.2		6.2		6.2		6.2		6.2
Isentropic constant for air (n)		1.4		1.4		1.4		1.4		1.4		1.4		1.4		1.4	
(n-1)/n			0.29		0.29		0.29		0.29		0.29		0.29		0.29		0.29
Isentropic compression power	kW		53.0		47.0		40.8		34.5		27.9		21.2		13.4		6.7
Mechanical efficiency (Rootes type blowers)	%	70		70		70		70		70		70		70		70	
Shaft compression power	kW		75.7		67.2		58.3		49.2		39.9		30.3		19.2		9.6
Isentropic temperature of compressed air	°C		63.3		63.3		63.3		63.3		63.3		63.3		63.3		63.3
Isentropic heat in compressed air (relative to atmos)	kW		53.3		47.2		41.0		34.6		28.1		21.3		13.5		6.7
% of shaft power lost as heat from air delivery pipes etc	%	30		30		30		30		30		30		30		30	
Heat lost from air delivery pipes	kW		22.7		20.1		17.5		14.8		12.0		9.1		5.8		2.9
Net heat gain to mixed liquor	kW		53.0		47.0		40.8		34.5		27.9		21.2		13.4		6.7
Conduction Losses																	
Thermal conductivity of concrete	W/m.°C	1.45		1.45		1.45		1.45		1.45		1.45		1.45		1.45	
Thickness of concrete	mm	250		250		250		250		250		250		250		250	
Thermal resistance of concrete	m².°C/W		0.17		0.17		0.17		0.17		0.17		0.17		0.17		0.17
Thermal outside surface resistance	m².°C/W	0.065		0.065		0.065		0.065		0.065		0.065		0.065		0.065	
Thermal inside surface resistance	m².°C/W		0.0325		0.0325		0.0325		0.0325		0.0325		0.0325		0.0325		0.0325
Total thermal resistance	m².°C/W		0.27		0.27		0.27		0.27		0.27		0.27		0.27		0.27
Heat transfer coefficient of walls	W/m².°C		3.70		3.70		3.70		3.70		3.70		3.70		3.70		3.70
Thermal resistance of floor	% of wall resistance	50		50		50		50		50		50		50		50	
Heat transfer coefficient of floors	W/m².°C		1.85		1.85		1.85		1.85		1.85		1.85		1.85		1.85
Heat transfer coefficient of roofs	W/m².°C	0		0		0		0		0		0		0		0	
Surface area of walls	m²		611		611		611		611		611		611		611		611
Surface area of floors	m²		380		380		380		380		380		380		380		380
Surface area of roofs	m²		380		380		380		380		380		380		380		380
Heat lost through walls	kW		22.7		22.7		22.7		22.7		22.7		22.7		22.7		22.7
Heat lost through floors	kW		7.0		7.0		7.0		7.0		7.0		7.0		7.0		7.0
Heat lost through roofs	kW		0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0
Total conduction losses	kW		29.7		29.7		29.7		29.7		29.7		29.7		29.7		29.7
Heat Losses in Treated Effluent																	
Flow rate of effluent	m³/day		100		100		100		100		100		100		100		100
Heat in effluent	kW		48.4		48.4		48.4		48.4		48.4		48.4		48.4		48.4
Evaporative Heat Losses																	
gradient		0.0277		0.0277		0.0277		0.0277		0.0277		0.0277		0.0277		0.0277	
constant		0.7899		0.7899		0.7899		0.7899		0.7899		0.7899		0.7899		0.7899	
Relative humidity of atmosphere	%	80		80		80		80		80		80		80		80	
Water content of atmospheric air	g/m³		17.7		17.7		17.7		17.7		17.7		17.7		17.7		17.7
Relative humidity of aeration air	%	100		100		100		100		100		100		100		100	
Water content of spent aeration air	g/m3		57.5		57.5		57.5		57.5		57.5		57.5		57.5		57.5
Water load in input air	t/day		1.6		1.4		1.2		1.0		0.8		0.6		0.4		0.2
Water load in spent aeration air	t/day		5.3		4.7		4.1		3.5		2.8		2.1		1.4		0.7
Latent heat of water evaporation	Cals/g	574		574		574		574		574		574		574		574	
Evaporation losses	kW		105.0		93.1		80.9		68.3		55.3		42.0		26.6		13.3
Sensible heat in spent aeration air	kW		18.5		16.4		14.2		12.0		9.7		7.4		4.7		2.3
Total heat in spent aeration air	kW		123.5		109.5		95.1		80.2		65.0		49.4		31.3		15.6
Overall Heat Balance																	
Heat input from biological activity	kW		302.1		267.8		232.6		196.4		159.1		120.8		76.5		38.3
Heat input from aeration	kW		53.0		47.0		40.8		34.5		27.9		21.2		13.4		6.7
Heat losses by conduction through reactor	kW		29.7		29.7		29.7		29.7		29.7		29.7		29.7		29.7
Heat losses in treated effluent	kW		48.4		48.4		48.4		48.4		48.4		48.4		48.4		48.4
Heat losses in spent aeration air	kW		123.5		109.5		95.1		80.2		65.0		49.4		31.3		15.6

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Figure 8.1: Relationship between Cooling Requirement and Wastewater Characteristcs

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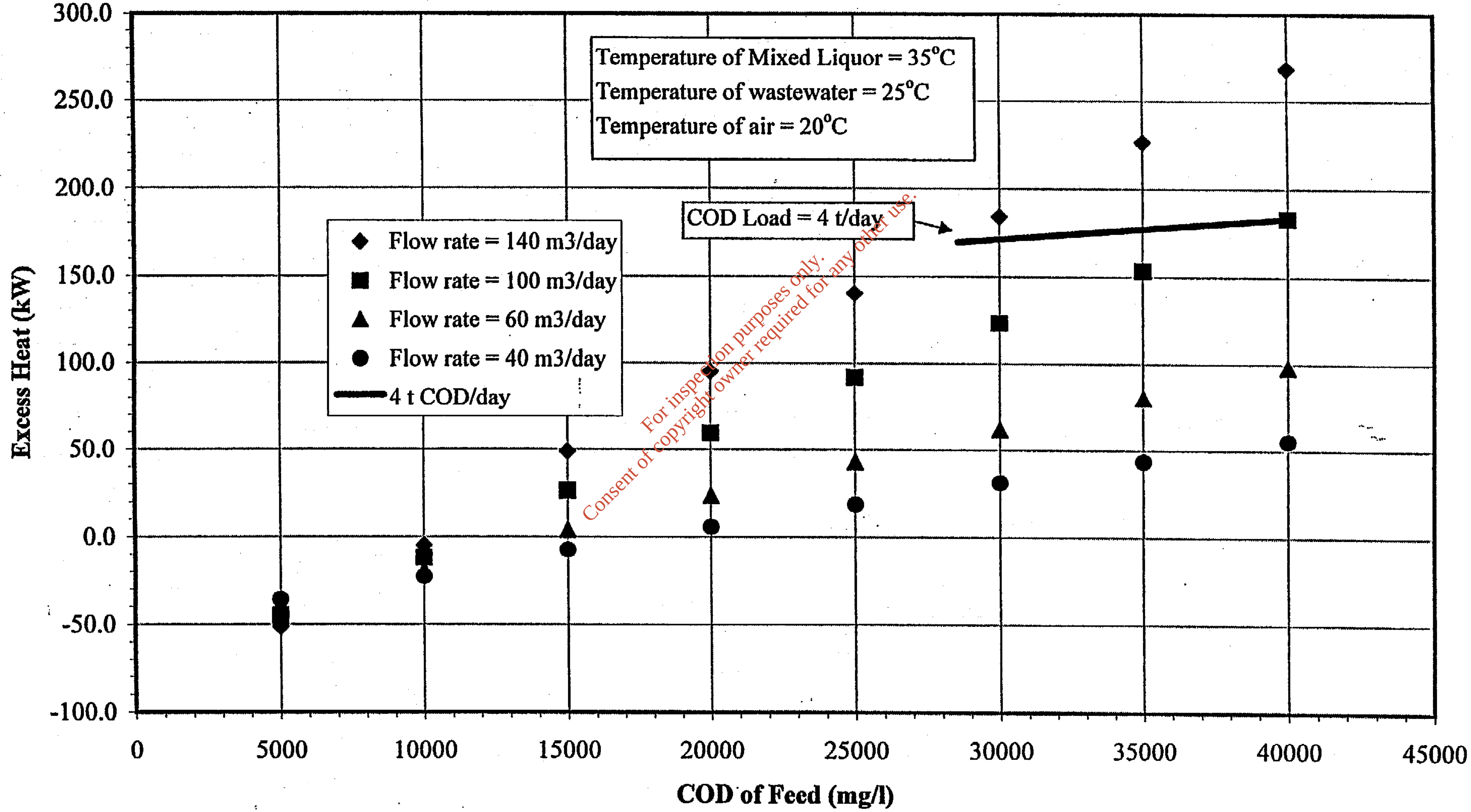
Figure 8.1: Relationship between Cooling Requirement and Wastewater Characteristics



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8.3 Review of Aeration System

This section was prepared to determine whether:

- the existing aeration system has sufficient capacity to satisfy the biological demand
- the aeration system could be cost-effectively replaced by a more efficient system.

8.3.1 Existing Plant

Currently the biological reactors are provided with an aeration system using "Helixor" proprietary aerators, supplied with air from a common set of five Rootes type blowers comprising two different sizes. The information obtained from site indicates that the aeration system comprises:

- 3 No. Hick Hargreaves model 4264, 110 kW motor, blower speed 2 696rpm, each 4 300 m^3/h @ 600 mbar
- 2 No. Hick Hargreaves model 4342, 30 kW motor, blower speed 4 083rpm, each 1 000 m^3/h @ 600 mbar
- 90 No. Helixor aerators in each biological reactor, ECL type 300-3, arranged in five sets in each reactor.

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The aeration system also supplies air to the aerobic digester, which also contains Helixor aerators. The blowers are configured so that the two 30 kW blowers normally serve the aerobic digester and the three 110 kW blowers the biological reactors. A cross-connection between the air delivery manifolds allows, in emergencies, the two smaller blowers to provide air to the biological reactors instead of the aerobic digester.

The Helixor aerator has a long history in industrial wastewater treatment and a relatively low capital cost. Significantly for some wastewaters, it is less likely to block with coarse solids arising in the feed wastewater. At site, there are little if any coarse solids in the feed wastewater and therefore other types of aeration systems could be used, particularly if they are more cost effective or have other advantages over the Helixors.

There is another aeration system in the Equalisation Tank, but this only mixes the contents and its air requirements are nominal and independent of the system serving the biological reactors.

8.3.2 Review of Aeration Capacity

(i) Process Oxygen Demand

The maximum oxygen demand from the biological system has been determined assuming:

- COD load is equal to the maximum (4 t COD/day)
- 75% of the COD is removed
- 70% of the COD removed is oxidised (rather than converted to biomass).

These assumptions give an oxygen demand from the aeration system of 2.1 t O_2/day (87.5 kg O_2/hour). This estimate is the worst case for two reasons. First, it assumes the maximum COD load and, second,

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it takes no account of the 'oxygen' that will be recovered through the denitrification of the nitrate in the wastewater. The average oxygen demand is expected to be around 60% to 70% of the worst-case value.

(ii) Adequacy of Existing Aeration System

There are 90 Nr Helixors in each SBR tank that has dimensions of 15.6 m by 12.2 m by 5.5 m working depth. This corresponds to about 2 m^2 floor area per Helixor, which is satisfactory.

The Helixor aerator is a coarse bubble system with typical aeration efficiency of 1.0 kg O_2/kWh to 1.2 kg O_2/kWh into 'clean' water. Because the aerator produces coarse bubbles, the α factor when aerating wastewaters is comparatively high, within the range 0.9 to 1.0.

The air requirements and the power consumed by the blowers were estimated for the worst-case oxygen demand and a range of mixed-liquor temperatures from 20°C to 40°C. Table 8.2 shows the steps in the calculation of these estimates.

The results of the calculations indicate that air flow rate and power consumption are insensitive to mixed-liquor temperature. The required air flow rate and power consumption are 120 000 m^3/day (5 000 m^3/h) and 108 kW, respectively. By comparison, each aeration blower is rated at 4 300 m^3/h and fitted with a 110 kW motor. For most of the time, therefore, only one of the three available blowers will meet the duty.

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However, the aeration system will need to be modified, especially if the SBRs are converted to operate in the activated sludge mode. The modification will allow the aeration air to be appropriately distributed between the two reactors so that the DO concentration is accurately controlled. This modification will include installing control valves on the aeration lines to each reactor and a PLC to control the valve openings.

Another modification that should be considered is to install frequency inverters on two of the blower motors (it is assumed that motor size is sufficient to accept a frequency inverter). One of the modified blowers would serve as standby. This modification could substantially reduce aeration costs.

(iii) Mixing Requirements

Generally, the power input from aeration systems should be greater than 10 W/m^3 to prevent settlement and less than 100 W/m^3 to prevent damage to instruments and possible loss of liquid from the reactors.

At the maximum power input of 108 kW, the specific power input would be 50 W/m^3, which is in the middle of the normal range.

(iv) Conclusion

The review indicates that the existing aeration system has sufficient capacity, requiring only one of the three available blowers to operate for most of the time. Improved control, involving the installation of control valves on the aeration lines is necessary. Frequency inverters could be installed on two of the blowers to reduce aeration costs.

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Table 8.2: Aeration Requirements

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Table 8.2: Aeration Requirements

Parameter	Unit	Test conditions		Site conditions @ 20C		Site conditions @ 25C		Site conditions @ 30C		Site conditions @ 35C		Site conditions @ 40C	
		Input	Calc	Input	Calc	Input	Calc	Input	Calc	Input	Calc	Input	Calc
Streams													
Air temperature	°C	25		20		25		25		25		25	
Temperature of wastewater	oC	20		15		20		25		30		35	
Wastewater flow rate	m^3/day	100		100		100		100		100		100	
Wastewater COD	mg/l	40000		40000		40000		40000		40000		40000	
Wastewater COD load	t COD/day		4.00		4.00		4.00		4.00		4.00		4.00
Removal of COD	%	75		75		75		75		75		75	
Depth													
Wall depth	m	6.50		6.50		6.50		6.50		6.50		6.50	
Water depth	m	5.50		5.50		5.50		5.50		5.50		5.50	
Aerator submergence	m	5.20		5.20		5.20		5.20		5.20		5.20	
COD removed													
COD oxidised	% of COD removed	70		70		70		70		70		70	
COD load oxidised	t COD/day		2.1		2.1		2.1		2.1		2.1		2.1
Aeration Power													
SOTE (Helixor) @ 20oC	%/m	1.51		1.51		1.51		1.51		1.51		1.51	
Alpha factor		1		0.95		0.95		0.95		0.95		0.95	
Reduction in saturation concentration due to TDS	Factor	1		0.95		0.95		0.95		0.95		0.95	
Saturation concentration of oxygen at 20oC	mg/l		9.18		9.18		9.18		9.18		9.18		9.18
Saturation concentration of oxygen at mixed liquor temp.	mg/l		9.18		10.20		9.18		8.29		7.52		6.88
Effective aeration depth correction	mwg		1.17		1.17		1.17		1.17		1.17		1.17
Dissolved oxygen concentration in water	mg/l	0		0.5		0.5		0.5		0.5		0.5	
Oxygen concentration correction	mg/l		1.00		1.01		0.90		0.81		0.73		0.67
Rate constant		1.024		1.024		1.024		1.024		1.024		1.024	
Rate correction			1.00		0.89		1.00		1.13		1.27		1.43
OTE @ site conditions	%/m		1.51		1.29		1.30		1.31		1.33		1.36
Air flow rate	t/day		114.6		141.6		141.2		140.6		139.3		137.0
Air flow rate	m3/day at ambient		97313		118183		119899		119357		118273		116279
Specific heat of air	cals/g.°C	0.24		0.24		0.24		0.24		0.24		0.24	
Pressure losses in air delivery pipe	mwg	1		1		1		1		1		1	
Total air delivery pressure	mwg		6.2		6.2		6.2		6.2		6.2		6.2
Isentropic constant for air (n)		1.4		1.4		1.4		1.4		1.4		1.4	
(n-1)/n			0.29		0.29		0.29		0.29		0.29		0.29
Isentropic compression power	kW		58.3		70.8		71.9		71.5		70.9		69.7
Mechanical efficiency (Rootes type blowers)	%	70		70		70		70		70		70	
Shaft compression power	kW		83.3		101.2		102.7		102.2		101.3		99.6
Motor efficiency	%	95		95		95		95		95		95	
Power consumption	kW		87.7		106.5		108.1		107.6		106.6		104.8
Aeration efficiency (wire-to-water)	kg O2/kWh		1.00		0.82		0.81		0.81		0.82		0.83

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8.3.3 Review of Alternative Aeration Systems

(i) Description of Alternatives

Two particular types of aeration systems are extensively used in the treatment of pharmaceutical industry wastewaters. These are:

- fine-bubble diffused-air (FBDA)
- jet aeration.

In a FBDA system, the air passes through fine slots in chemically-resistant rubber membranes located near the floor of the mixed-liquor tank. Like the Helixors, FBDA systems provide mixing and oxygen transfer by the upflow of air bubbles. When there is no air flow, there is no mixing.

Contrastingly, a jet-aeration system pumps the mixed liquor from the reactor and re-circulates it through venturi injectors into which air from blowers is also introduced. Jet aeration systems provide mixing even in the absence of aeration. The recirculation of the mixed liquor can be arranged to disperse the influent wastewater more quickly throughout the mixed liquor, as a means of reducing the impact of toxic components on the biomass.

Both FBDA and jet aeration systems produce small air bubbles, about 1 to 2 mm in diameter, compared to the 4 to 8 mm diameter bubbles produced by Helixors. FBDA and jet aeration systems therefore have higher aeration efficiencies. However, the difference in aeration efficiency is not as great as might be expected from the difference in bubble size because surfactants in wastewater reduce the value of the mass transfer coefficient controlling the transfer of oxygen from the bubbles to the mixed liquor, and this reduction is higher for smaller bubbles. The wastewater at site contains high concentrations of surfactants, such as sodium acetate, and the effect of these surfactants on the mass transfer coefficient of the bubbles, particularly those produced by a FBDA system, could be comparatively high. Before replacing the Helixor system with a FBDA or jet-aeration system, it would be expedient to test the site wastewater to determine the mass transfer characteristics (as indicated by the α factor).

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For this study, we have assumed that the site aeration efficiencies of the FBDA and jet-aeration systems are a factor of two greater than the efficiency of the Helixor system, in line with our general experience. In the case of the jet-aeration system, the aeration power in this assumption does not include the power consumed by the recirculation pumps. Tests at site could indicate that the FBDA and jet-aeration efficiencies are lower than assumed for this study but are unlikely to indicate significantly higher values.

(ii) Cost Comparison

Assessments of power consumption, conversion costs and operating costs, as appropriate, have been made for the three types of aeration systems for the two biological reactors at site. Table 8.3 lists the main tasks involved in converting the Helixor system to the other two systems. In addition, there may also be control issues, but these would be similar in each case.

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Table 8.3: Main Conversion Tasks

Helixor	FBDA	Jet aeration
None	Remove Helixors and aeration grids. Install new aeration grid and membrane diffusers.	Remove Helixors and aeration grids. Install jet manifolds in SBRs. Install recirculation pumps and make connections through SBR walls.

Table 8.4 lists the aeration powers and the capital conversion costs and the electricity costs of the three systems. The electricity costs were derived from the following assumptions:

- The cost of electricity is 6 cents/kWh.
- Continuous aeration power of the Helixor system is 95 kW.
- Continuous aeration power of the FBDA system is 48 kW.
- Continuous aeration power of the jet aeration system is 48 kW plus the power for the water-jet recirculation.

The assumed values of the continuous aeration power imply that the systems would be operating continuously at their maximum capacities. This assumption favours the economics of the Helixor system.

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The capital costs for the new aeration systems were obtained as budget estimates from Veolia, a major company in the field of industrial and domestic wastewater treatment. Veolia specialise in both FBDA and jet aeration systems.

The data in Table 8.4 show that an FBDA system costing € 50 000 would have a payback period of 6 years, for the stated assumptions. A jet aeration system would not be economically attractive.

A disadvantage of FBDA would be the replacement cost of the membrane diffusers, which would increase the payback period. Also, the reactor would have to be emptied to replace broken diffusers. Typical life of a membrane diffuser is 5 to 10 years.

(iii) Conclusions

The results of this review suggest that it would be neither cost-effective nor expedient (owing to maintenance requirements) to replace the Helixors. Only if the Helixors have deteriorated and are in need of replacement could a FBDA system be considered. The most cost-effective way of reducing aeration power consumption would be to improve the control of dissolved oxygen in the reactors, which will require the fitting of frequency inverters on the blower motors.

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Table 8.4: Relative Costs of Aeration Systems

Aeration System	Conversion Capital Cost (€)	Absorbed power (kW)	Annual power cost at typical maximum load (€/year)	Annual power cost at average load (€/year)	Payback period (years)
Helixor	0	95	30K	15K	N/A
FBDA	50K	48	15K	7K	6
Jet Aer^n	330K	123	47K	23K	-

Notes: The absorbed power for Jet Aeration also includes mixed liquor recirculation pumps.
Blowers operate about 14 hours/day and Jet Aeration pumps operate 24 hours/day.

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