A WATER COMPANY STW

REPORT INTO AN INVESTIGATION

ON THE AERATION AIR BLOWERS

E C Harding CEngMIMechE

Air Technology Limited
1 Oaks Industrial Estate
Festival Drive
Loughborough
Leicestershire LE11 5XN

(Telephone: +44 (0)1509 264900
(Facsimile: +44 (0)1509 264800

Email: office@airtechnology.co.uk

Date: 01 May 2008

Quote reference: 012525

Revision: 01

CONTENTS

1 BACKGROUND:

This large sewage treatment works uses low pressure blown air for aerating the treatment lanes. It is an essential service vital to the operation of the facility.

The works consists of the existing aeration lanes and a recently installed biological phosphate removal plant, known as the P-plant. The load is currently split 40/60 between the P-plant and the existing plant. This is due to be changed to a 50/50 split in the near future.

The aeration air for the existing plant is supplied by two Howden Donkin SG65A-CVC single stage centrifugal blowers each rated at 34,800m^3/hr @ 560mbarg. The actual delivered flow from the blowers in terms of normal conditions (1,013mbarA, 0^{o}C 0%RH) will vary with the inlet conditions.

These blowers are located in the main blower house to the north of the works. The blower's discharge into a common header from where it runs underground to the five sets of treatment cells

The aeration air for the P- plant is supplied by two Howden Donkin SG30A-CVC single stage centrifugal blowers each rated at 9,480m^3/hr @ 750mbarg. The actual delivered flow from the blowers in terms of normal conditions (1,013mbarA, 0^{o}C 0%RH) will vary with the inlet conditions.

These blowers are located in a purpose built blower house adjacent to the P-plant. The blower's discharge into a common header from where it is routed at high level to the three sets of treatment cells.

The blower output is controlled by inlet guide vanes and variable vane outlet diffusers. This allows the blowers to be output to be reduced without too much loss in efficiency to approximately 50% of the full load capacity. When the demand is less then 50% of capacity, a bypass valve on the blower discharge vents the excess air to atmosphere.

Surge detection is by a pressure transmitter on the compressor outlet, which opens the bypass valve when a pulsation greater than a preset amplitude is detected.

The demand of both plants is usually met by one of the blowers operating with the inlet guide vanes at the minimum open position and bypass valve opening slightly to prevent surge.

Given that both systems are operating at the lower and less efficient end of their capacity, there are believed to be excellent energy and maintenance cost saving opportunities by combining the systems. These savings would come from operating the blowers at more efficient higher flows, and eliminating losses from the blow off valves.

In order to identify the potential savings and determine the costs of combining the systems, a measurement-based investigation is required. The client has commissioned

Air Technology Ltd, an independent company specialising in this work to undertake such an investigation

2 TERMS OF REFERENCE:

Client purchase order number:

- To establish the aeration air demand and pressure from the main plant.
- To establish the aeration air demand and pressure from the P-plant.
- To determine the energy used to provide aeration air to the existing plant.
- To determine the energy used to provide aeration air to the P-plant.
- To determine the feasibility of combining the systems.
- To determine the cost savings from combining the two systems.
- To determine the pipework sizing required when combining the systems.
- To provide an estimate of the costs of combining the systems.
- To make any recommendations for improvements from observations made on site.
- To report in writing.

3 THE REPORT:

3.1 The results of the measurements.

3.1.1 The blown air demand and pressure

Insertion turbine flow meters and pressure transducers were installed as follows:

- In the 24"NB feed from the main blower house.
- In the 24"NB feed from the P-plant blower house.

The outputs from these instruments were fed to data recorders and the airflows and pressures were measured over an eight-day period. The results of these measurements are shown in Table 1.

Sample chart recordings and corresponding turbine flowmeter calculation sheets are included in Appendices A & B.

STW
Table 1. Summary of Blown Air Demand and Pressure

Date	Main Plant Demand (Nm^3/hr)			P- Plant Demand (Nm^3/hr)			Total Demand (Nm^3/hr)			Pressure Range (barg)	
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Main	P-Plant
7/11	19,216	21,736	26,461	4,066	6,160	9,659	23,279	27,896	36,042	0.49	0.68 – 0.74
8/11	19,531	23,311	25,201	3,080	5,791	11,459	22,602	29,102	36,652	0.49	0.65 – 0.71
9/11	19,216	20,791	21,421	3,080	5,708	7,103	22,294	26,499	28,518	0.49	0.70 – 0.74
10/11	14,499	18,091	20,476	3,019	5,708	7,393	18,516	23,799	27,549	0.49	0.72 – 0.76
11/11	15,324	18,091	22,366	3,019	6,342	9,487	18,341	24,433	31,532	0.47 – 0.52	0.68 – 0.77
12/11	15,751	18,271	22,051	3,327	6,342	8,878	19,075	24,613	26,662	0.46 – 0.51	0.71 – 0.75
13/11	17,285	17,780	18,064	3,327	5,962	7,483	20,610	23,742	24,715	0.45 – 0.48	0.72 – 0.75
14/11	15,645	17,400	17,903	3,327	5,962	7,357	18,970	23,362	25,169	0.46 – 0.49	0.72 – 0.77
15/11	15,121	17,285	18,271	3,327	5,580	8,625	18,445	22,865	25,116	0.46 – 0.52	0.71 – 0.74

3.1.2 Main plant demand

The mean demand during the investigation was 19,156Nm^3/hr.

The maximum demand during the investigation was 26,481Nm^3/hr.

The minimum demand during the investigation was 14,499Nm^3/hr.

The demand was met by one blower throughout the investigation. The actual turndown of the blower was not determined by measurement, though taking a figure of 50%, the mean demand should be met without the blower having to vent.

The reports of blower venting continually are probably due to the passing vent valve as described in section 3.1.3 below.

Had the bypass valve been operating correctly, and assuming a turndown of the 50%, the blower should have been venting for less than 20% of the time.

The demand pattern shows that the changes in demand are very gradual, with no major step changes in demand.

3.1.3 Main plant pressure control

Pressure control to the main plant was initially good with the pressure being closely controlled at 490mbarg, irrespective of the demand. The pressure trace showed some small fluctuations of ±5mbar. At 08:45 on 11th November the pressure control became more erratic with the pressure fluctuating by up ±20mbar.

From 11:00 on 12th November there was a noticeable drop in the delivery pressure at a demand of 17,641Nm^3/hr. The pressure only recovered to the set point pressure when the demand reduced to less than 16,500Nm^3/hr.

It was observed on 15th November that there was a considerable amount of air flowing through the bypass line on the No.1 Blower. The blower controllers indicated that the bypass valve should have been closed for most of the time air was observed flowing through the bypass.

Further observations showed that from 12th November, the blower was unable to maintain the set point pressure even at an indicated full load. The demand at this time was between 17,000 Nm^3/hr and 18,000Nm^3/hr. As the demand was around 50% of the rated capacity of the blower, this suggests that a considerable amount of air is being lost through the passing bypass valve.

As the blower had been operating at between 40% and 60% of its capacity for most of the investigation, there is the possibility that the inlet guide vanes are sticking at a part open position, further limiting the capacity of the blower.

The indicated power consumption showed the blower was pulling between 280 and 310kW during this period. This suggests that the blower was not coming on full load, where the power should be approximately 600kW. There is also the possibility that the power meter is not working correctly and this needs to be checked out.

These problems were reported to the customer. Given the very large losses, it is recommended that the other blower is brought on line whilst the faults are rectified.

3.1.4 P-plant demand

The mean demand during the investigation was 5,961Nm^3/hr.

The maximum demand during the investigation was 11,459Nm^3/hr.

The minimum demand during the investigation was 3,019Nm^3/hr.

The demand was usually met by one of the blowers. A second blower was required for nine hours, which is less than 5% of the time.

At the quoted turndown figure of 50%, the blower should have been venting for approximately 25% of the time.

The demand pattern shows that the changes in demand are more noticeable, with the demand rapidly increasing and decreasing by several thousand Nm^3/hr over periods of less than an hour. These sinusoidal cycles would last several hours before settling down to a more gradual change in demand.

The sinusoidal cycles could also show a gradual increase or decrease in the base demand. The period were the second blower was required can be clearly seen on the recordings.

3.1.5 P-plant pressure control

Pressure control to the P-plant was very good with the pressure being controlled for most of the investigation between 710 – 750mbarg. The pressure trace was very smooth with gradual changes in pressure

Air was observed flowing through the bypass line on No.7 Blower on 15th November. Checks made on the blower controllers showed that the bypass valve was indicating that it was fully closed.

The above suggests that the bypass valve is either passing or not closing correctly. This was reported to the customer and it is recommended that the faults are identified and rectified at the earliest possible opportunity.

3.1.6 Total site demand

The mean combined demand during the investigation was $25,117Nm^3/hr$.

The maximum combined demand during the investigation was $36,652Nm^3/hr$.

The minimum combined demand during the investigation was $18,341Nm^3/hr$.

The mean site demand measured during the investigation is greater than the capacity of the three P-plant blowers, each of which delivers $8,250Nm^3/hr$ at the design inlet conditions of 1,013mbarA, 30^oC, 65%RH.

The mean demand is within the capacity and theoretical throttle range of one of the main plant blowers, each of which delivers $32,250Nm^3/hr$ at the design inlet conditions of 1,013mbarA, 20^oC, 60%RH.

The blower would have to run at an increased speed to enable the air to be generated at the higher pressure required for the P-plant. This would require changing the gearing and as the absorbed power would be approximately 800kW, the motor and power supply would need to be uprated.

A second blower would be required to meet the maximum demand, during which time both the blowers would be running at very close to the minimum turndown position.

3.2 The aeration air economics

3.2.1 Blower running hours and energy consumption

Readings from the blower running hour and kilowatt-hour meters were taken at the start and the end of the investigation. These are summarised in Table 2.

STW
Table 2. Blower Running Hours and Energy Consumption Summary

Date	07/11/01 11:00		15/11/01 09:30		Hours Run	Energy Used (kWhr)	Mean Power (kW)
	Indicated Hours	Energy Meter (MWhr)	Indicated Hours	Energy Meter (MWhr)			
Main Plant Blowers							
1	7,506	47722	7,695	47781	189	59,000	312.2
2	8,945	2,664	8,945	2,664	0	0	0
P-Plant Blowers							
5	7,430	1109.376 775	7,439	1110.653 776	9	1,277 1,000	141.9 111.1
6	3,664	513.236 417	3,664	513.236 417	0	0	0
7	5,440	818.307 838	5,630	847.944 863	190	29,637 25,000	156.0 131.6

3.2.2 Main plant energy costs

Using the quoted electricity cost of 3.8pence /kWhr the annual energy costs based on the demands measured during the investigation are £104,000.

The specific power consumption equates to 1.63kW/100Nm^3/hr. This is considerably better than the quoted figure at full load of 1.85kW/100Nm^3/hr. Though the pressure was slightly lower, this cannot account for the difference; hence, the accuracy of the power meter has to be called into question.

Given that the blower was running at less than full load and was reported to be venting for most of the investigation, it is unlikely that the specific power consumption would be much better than 2.0kW/100Nm^3/hr. Using this figure, the annual energy costs increase to at least £128,000.

3.2.3 P-plant energy costs

There are two power meters on each the P-plant blowers. As the Maxim meters do not read the below one megawatt hour, the readings from this meter will consequently be +/-2MWhr (2,000kWhr). Even taking this account, there is a considerable difference in the readings on No.7 blower.

For the purposes of the investigation the readings from the kilowatt-hour meters, not the maxim meters will be used.

Using the quoted electricity cost of 3.8pence /kWhr the annual energy costs based on the demands measured during the investigation are £54,200. This gives a total energy costs for the site of an estimated £182,200.

The specific power consumption equates to 2.73kW/100Nm^3/hr. This compares reasonably well to the quoted figure at full load of 2.58kW/100Nm^3/hr. Given that the bypass valve was passing slightly, the blowers appear to be operating close to their design efficiency.

3.3 Recommendations for improvements

3.3.1 Reducing the aeration air demand

The results show that there is a considerable difference in the blown air demand between the two plants. During the investigation the sewage loading was 60/40, which means that the main plant was doing approximately 50% more sewage treatment than the P-plant. However it was using 3.2 times more aeration air than the P-plant.

The reason for this is that the main plant requires a minimum amount of aeration air to hold the domes open when all the lanes are in use. The excess air results in over aeration of the sewage as well as wasting considerable amounts of energy.

It has been suggested that some of the main plant aeration lanes are shutdown, though in the current operating regime, this would mean the blower would vent more air. The situation will worsen when the sewage load split is change to 50/50.

Had the main plant been using the aeration air as efficiently as the P-plant, than the mean demand would have been in the order of 9,000Nm^3/hr, which is just over half the existing mean demand. The maximum demand increases to approximately 17,000Nm^3/hr.

3.3.2 Combining the plants

With the existing demands, it is not feasible to combine the two systems. This is because the extra energy required to generate all the air at the higher pressure required for the P-plant would far outweigh the savings with reduced venting. The estimated annual energy costs in this instance would increase to £216,000.

Closing down a number of lanes on the main plant and using the revised figures for the main plant demand, the total site demand would give a mean of approximately 15,000Nm^3/hr with a maximum of approximately 28,500Nm^3/hr.

Provided that the passing bypass valve on No.7 blower is repaired, then the reduced mean demand is now within the capacity of two of the P-plant blowers. Though the maximum demand is outside the total capacity of the three P-plant blowers, these high demands occur for relatively short periods, and it is likely that the P-plant blowers could meet the demand for all but a few days a year.

One of the main plant blowers will still be required for periods of high demand. The control system will need to capable of identifying these periods of high demand and bring on one of the main plant blowers and shutdown P-plant blowers as required.

Generating the majority of the air from the P-plant would result in an estimated mean power consumption of 410kW. This equates to an annual energy cost of £136,500, which represents a saving of £45,700.

3.3.3 Pipework sizing

The link line should be sized to optimise installation cost and pressure drop. At the current 60/40 sewage load split and the proposed 50/50 split, the pressure drops at mean and maximum demands are summarised in Table 3.

STW
Table 3. Summary of Pipework Pressure Drops

Pipe Size	60/40 Load Split		50/50 Load Split	
	Pressure Drop at Mean Demand (mbar)	Pressure Drop at Max Demand (mbar)	Pressure Drop at Mean Demand (mbar)	Pressure Drop at Max Demand (mbar)
10"NB	105	375	72.9	263
12"NB	47.2	169	32.8	118
14"NB	25.5	91.0	17.7	63.9
16"NB	12.2	43.4	8.5	30.8

As the P-plant blowers operate at approximately 200mbar higher pressure than required by the main plant, the minimum pipework size is therefore 12"NB. However to allow for some margin, it is recommended that the costs of 12"NB and 14"NB are obtained.

Ideally a 12"NB or 14"NB connection should be provided, though two 10"NB connections will be adequate. The amount of control available on the inlet valves to each of the aeration lanes needs to be checked to identify whether a pressure reducing valve is required to reduce the pressure to what it is at present.

3.4 Cost benefit analysis

3.4.1 The installation costs

We have obtained the budget quotations from the site contractors, they are included in Appendix C, and the total cost estimate is shown below.

The routing is from the high level stainless line at P-Plant to an underground tie-in at the main blower house adjacent to the entry point of the air main to the five cells. This route incorporates 3 no. road crossings.

Final routing and tie in position would be subject to agreement with Anglian Water.

Cost Estimate	£	£
Civil Works		
Road Crossings	7,500	
Pipe Supports	5,500	
Tie In Excavations	1,000	
O/H & Profit (15%)	2,100	16,100
Mechanical Works		
14" pipework materials	16,667	
Labour	19,215	
Plant	12,411	
Management	5,500	
O/H & Profit (12%)	6,455	60,248
Sub Total		**76,348**
Additional Costs		
Control Valve 14"		5,000
Contingency 10%		8,135
Total		**89,483**

3.4.2 The payback period

With an estimated annual cost saving of £45,700 available by combining the systems the payback period is just under 2 years.

4 CONCLUSIONS:

Our conclusions are that:

1. The mean demand from the main plant was 19,156Nm^3/hr.
2. The maximum demand from the main plant was 26,481Nm^3/hr.
3. The minimum demand from the main plant was 14,499Nm^3/hr.
4. The mean demand from the P-plant was 5,961Nm^3/hr.
5. The maximum demand from the P-plant was 11,459Nm^3/hr.
6. The minimum demand from the P-plant was 3,019Nm^3/hr.
7. The mean combined demand during the investigation was 25,117Nm^3/hr.
8. The maximum combined demand during the investigation was 36,652Nm^3/hr.
9. The minimum combined demand during the investigation was 18,341Nm^3/hr.
10. No.1 blower was unable to maintain main plant system pressure from 12th November.
11. The bypass valve on No.1 blower was found to be passing.
12. The accuracy of the power meter on No.1 blower is questionable.
13. The bypass valve on No.7 blower was found to be passing.
14. The energy costs for providing air to the main plant are estimated at £128,000.
15. The energy costs for providing air to the P-plant are estimated at £54,200.
16. The main plant uses considerably more aeration air than the P-plant. This is to maintain a minimum flow to the aeration domes.
17. It is not practical to provide aeration air for the P-plant from the main plant.
18. Reducing the number of lanes running on the main plant such that the aeration air is used as efficiently as the P-plant results in the mean site demand being within the capacity of two P-plant blowers
19. Closing down a number of lanes on the main plant and providing the aeration air from the P-plant will provide estimated savings of £45,700.
20. The cost of installing a 14"NB link line and controls is estimated at £89,483.

5 RECOMMENDATIONS:

Our recommendations are:

1. The passing bypass valve on No.1 blower is repaired.

2. The operation of the inlet guide vanes on No.1 blower is checked to ensure they are not sticking.

3. The calibration of the power meter on No.1 blower is checked.

4. The passing bypass valve on No.1 blower is repaired.

5. A 14"NB link line is installed between the main plant and P-plant blowers and the P-plant blowers used to provide the aeration air to the main plant.

6 APPENDICES

Appendix A Sample chart recording and calculation sheet for the 24" NB feed main from the main plant blower house.

Appendix B Sample chart recording and calculation sheet for the 24" NB feed main from the P- plant blower house.

Appendix C Cost Estimate received from onsite contractors.