



GOLDEN PRINCESS
AMMONIA REMOVAL TRIAL
SCENARIO 1 – PROGRESS REPORT No.3

September 2009

Golden Princess Ammonia Removal Trial

Summary

Hamworthy carried out a further progress review on board from 12 to 19 September, by W Chen and K Cooksley. The purpose of the visit was to ensure that the trial was continuing with good progress and that all parameters were being maintained. Further adjustments were recognised during the visit, which will be highlighted in this report.

Personnel directly involved in the visit: Pietro Donato (Staff Engineer), Carmine Parisi (Hotel Engineer), Wilfredo Saavedra (1st Plumber), Hector Tapdasan (1st Plumber), Roy Van Acuzar (2nd Plumber) and Jovy Abellonar (Plumber). A review of the progress and the test results was carried out with Chief, Staff and Hotel Engineer, and separately with HAL representatives and Marin (Environmental engineer) on board on 19/09.

No.	Subject	Action
1	<p>General</p> <p>Very good progress has been made, recognising the operational constraints and pressures ship's staff perform under, especially during the Alaska season. Snags and all previous actions in the previous update reports (Appendix B&C) were addressed. The process performance is far more stable than during July and August. Hamworthy appreciate the continued huge support by the ship staffs.</p> <p>There are factors to further lengthen the trial period, such as 1) the need to unblock the anoxic zone mixing pipe; and 2) MBR No.3 aeration diffuser maintenance requirement that will waste the nitrifying biomass, which will have to be re-established.</p> <p>Hamworthy encourages the PCL head office to review the technical progress and the trial results together with Hamworthy and the ship staffs, so that the targets and the outcome of Scenario 0 and Scenario 1 are implemented and understood to the best degree. Hamworthy will explore possible arrangement with PCL.</p>	HWS
2	<p>MBR No.3 Feed System and MBR Capacity</p> <p>The Feed Tank level was further increased to 70% to balance the ammonia fluctuations in the influent. The ratio between grey and black water, controlled by Feed Tank levels, is now deemed acceptable, with resultant ammonia concentration varied between 100 and 200 mgN/l. The attached graphs show the ratio of Grey to Black has been oscillating around the 2:1 from September. The difficulties of maintaining this ratio are also evident. Additional regulating hand valves may be provided to the black water feed line, if so required by any worsening of the ammonia fluctuations.</p> <p>MBR No.3 capacity was running at 90-100 m3/day during Sept., and any excess water was sent to MBR 1 or 2. The target is now 80 m3/day, to improve nitrification efficacy - considering the ammonia achieved so far is still nowhere near the GP limit. There will be no attempt to further reduce the feed flow, because this will render the solution further away from being feasible due to the required tankage.</p> <p>The detrimental impact of the increased flow to MBR No.3 during Mid August, as a result of MBR No. 1 planned maintenance, was all too clear in the graphs. The effluent reflected a significant increase in ammonia.</p> <p>The mixing air provided to Tank 5 was reduced to 1 minute on 5 minutes off, in order to reduce the aerobic biodegradation of carbon source in the wastewater (see note B in P&IDs). Carbon is needed for denitrification process in the Anoxic zone. This will be an interesting element to adjust in the future.</p>	(HWS)

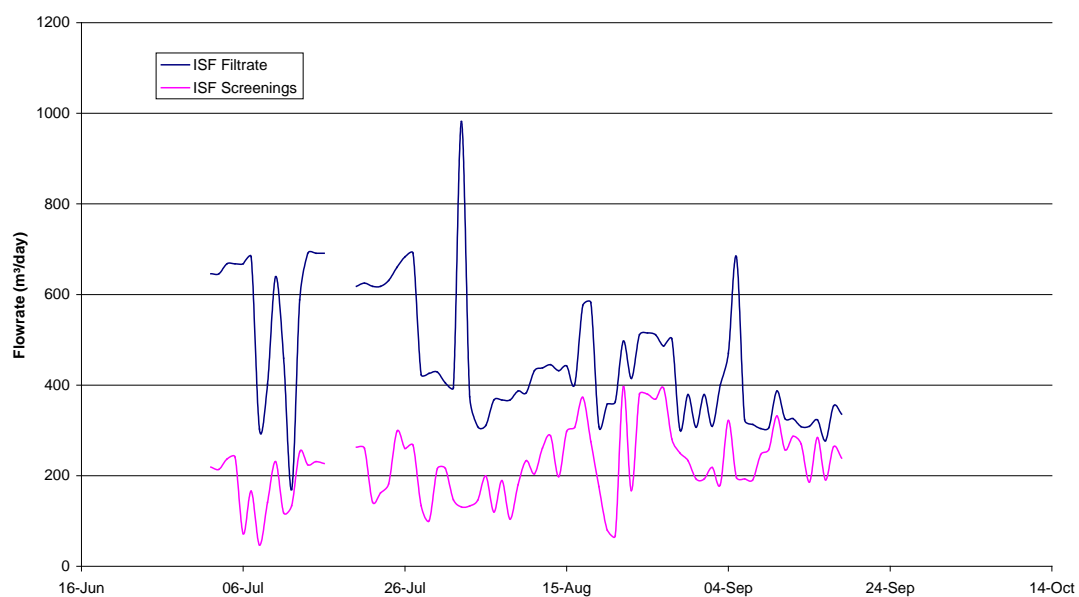
3	<p>Mixing in the Anoxic Zones</p> <p>The mixing pipe in the Anoxic zone was evidently blocked. This renders the anoxic zone ineffective for denitrification process (see note C in P&IDs). Operators were encouraged to visually observed the mixing via the viewing hatch.</p> <p>Anoxic zones need to be emptied and cleaned. Detailed instructions were provided separately to the ship. The task will be done while en-route to LA.</p> <p>There is also a planned maintenance to MBR No.3 aeration diffusers in early Oct. The nitrifying biomass has to be wasted as there is no mean of transferring the biomass back from any holding tank. It will be a lengthy process to re-establish the nitrifying bacteria. Ship staffs may combine this task with the task above, so that the trial system is ready from the first LA cruise.</p>	<p>Ship</p> <p>Ship</p>
4	<p>Dissolved Oxygen (DO) in the aerobic reactor</p> <p>DO has now increased to 1.5-2.0 mg/l which is satisfactory. The spray nozzles to the Anoxic zone were closed during the visit to reduce the amount of entrained air (and the associated DO in the spray water) into this zone (see note A in P&IDs). The nozzles may be turned on if there is evident of foaming or scum build-up in the anoxic zones.</p>	
5	<p>ISF flows</p> <p>The ISF Filtrate flow has been set to 300-350 m³/day. This is acceptable. Screening flow cannot be reduced further. This element is considered less important, and will not be pursued further.</p> <p>The filtrate pump flow may be attenuated in order to improve the nitrate return into the anoxic zone. At present, the filtrate flow (less permeate production) is batched into the anoxic zone. By throttling filtrate pumps, the batch flow into anoxic zone will have less flow rate, but over a longer duration. This shall in theory improve the process. This element may be investigated in the near future when conditions are ready.</p>	(HWS/ Ship)
6	<p>Sludge Age</p> <p>The sludge age is currently maintained at 21 days, by a daily desludge of 6% of the second stage (2.02m³). Although this is in theory sufficient, a longer sludge age may be attempted in the near future aiming to improve process stability.</p>	(HWS/ ship)
7	<p>Preliminary comments on on-line Instrumentation</p> <p>Comparisons between the on-line measurements and the laboratory test results were made, as shown in the attached graphs. During July, the figures showed significant discrepancies in permeate ammonia. The discrepancy reduced after the sensor was calibrated at the end of July. However, the calibration had to be repeated at the end of August. A calibration on ammonia probe takes 1 to 2 hours.</p> <p>Greater uncertainties were found with ammonia probes in Tank 5, and in Anoxic zone. The probe in Tank 5 requires daily cleaning to prevent blockage, the probe in anoxic zone has to be cleaned 3 times per week.</p> <p>The NOx probe in the permeate tank is performing reasonably stable, although there is a level of discrepancy to lab results.</p> <p>The NOx probe in the anoxic zone was proved in-effective. Much effort (and expenses) had been made to this probe in the past 2 months. Hamworthy sourced a second probe with 1mm sensor spacing to replace the previous probe (with 2 mm spacing). The outcome was not positive. For future applications, it may not be recommendable to use NOx probe within a MBR bioreactor.</p>	

	<p>It can also be concluded that the reliability of ammonia and NOx probes are reasonably satisfactory for process indication, but may not be reliable enough for compliance purpose.</p>	
8	<p>Resources and training</p> <p>With the support by PCL, Jovy Abellonar will extend his contract to Jan 2010. A new 1st plumber is also allowed to overlap with the existing crew.</p> <p>Hamworthy encouraged the ship staffs to take increased interests in the daily trial results. A set of training material on biological nitrification and denitrification was distributed to Chief, Staff and the Hotel Engineer.</p> <p>Allowance of an additional technical resource on board was considered by Hamworthy. No conclusion is drawn at present. Setting aside the issue on funding of such resource, Hamworthy believes it is useful to continue the trial with realistic resource input that typical to a cruise ship operation. CCP may be consulted on the subject.</p>	HWS
9	<p>Performance analysis</p> <p>It is still early days, as the process is just starting to stabilise. The attached graphs clearly indicated the gradual process of improvement, including</p> <ul style="list-style-type: none"> - the feed flow rate being stabilised towards 80-100 m³/day - the grey to black mixing ratio being stabilised towards 2 - the DO being increased to 1.5 – 2 mg/l - the mixing tank (Tank 5) level being increased to 70% (not shown in the graph) - the ISF filtrate flow being reduced towards the target set in Scenario 0 - etc., <p>The above improvements were made with great efforts from the ship staffs, in a period longer than we anticipated, but Hamworthy agrees that this is a true reflection of the operational constraints and pressures ship's staff perform under, especially during the Alaska season.</p> <p>Good nitrification and denitrification processes were observed, albeit not yet reliable. Specially, during the running in September, significant nitrification can be seen, along with relatively low effluent ammonia levels.</p> <p>There are signs of uncertainties such as indicated by a high nitrite level. This could be due to unfavourable conditions to certain nitrifying bacteria.</p>	

(K Cooksley/W Chen 22-09-09)

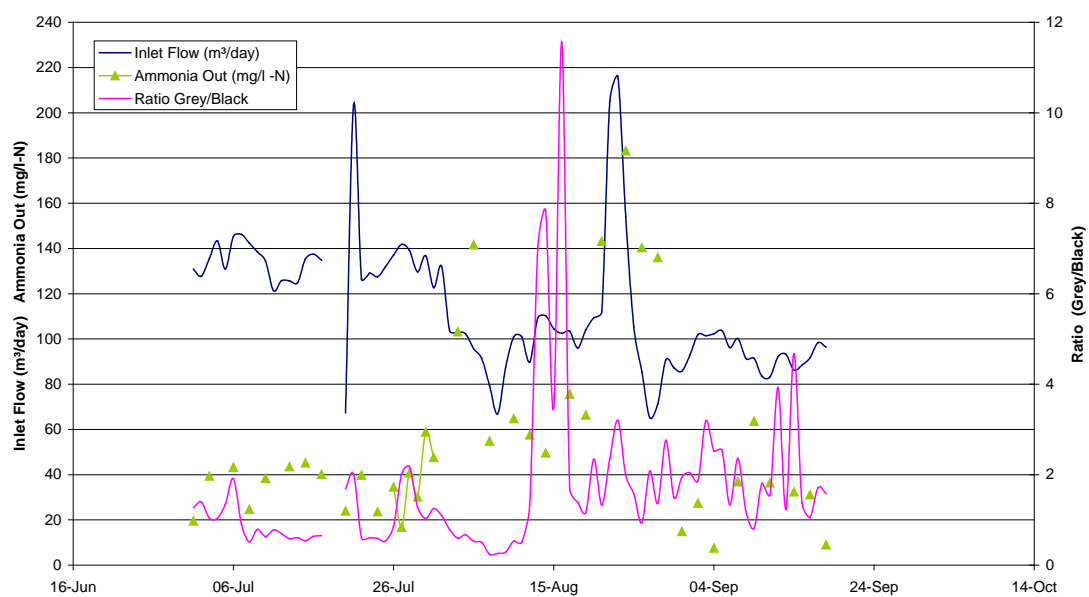
MBR 3 ISF Flows

Appendix 4



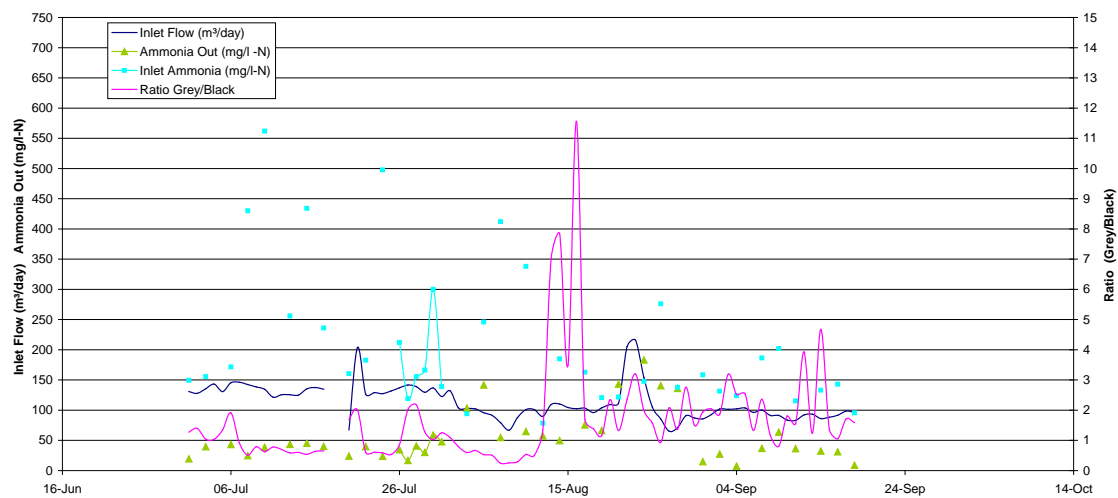
MBR3 Influent Details

Appendix 1



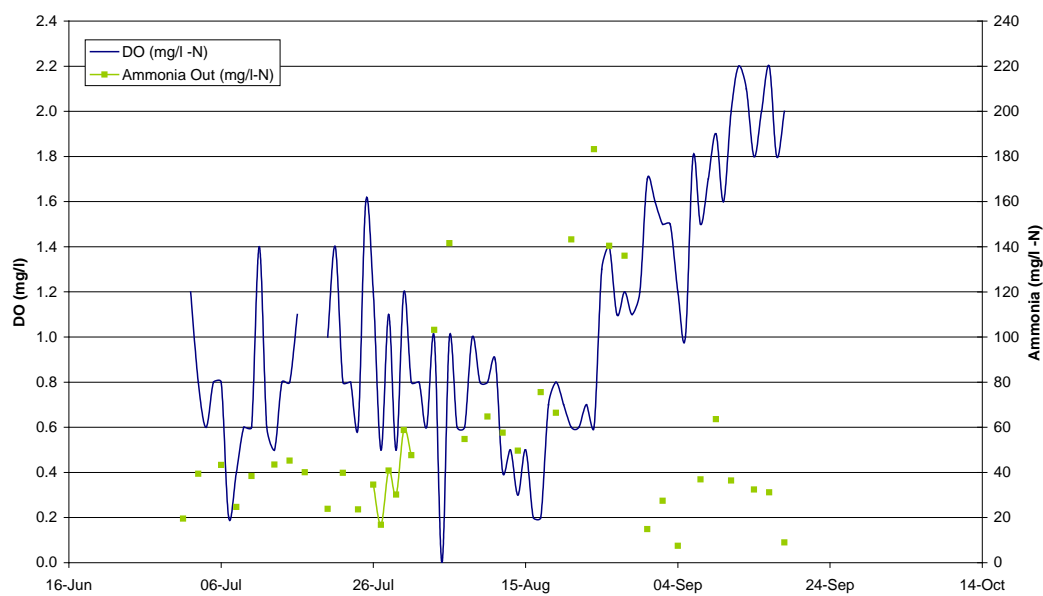
MBR3 Influent Details

Appendix 1b



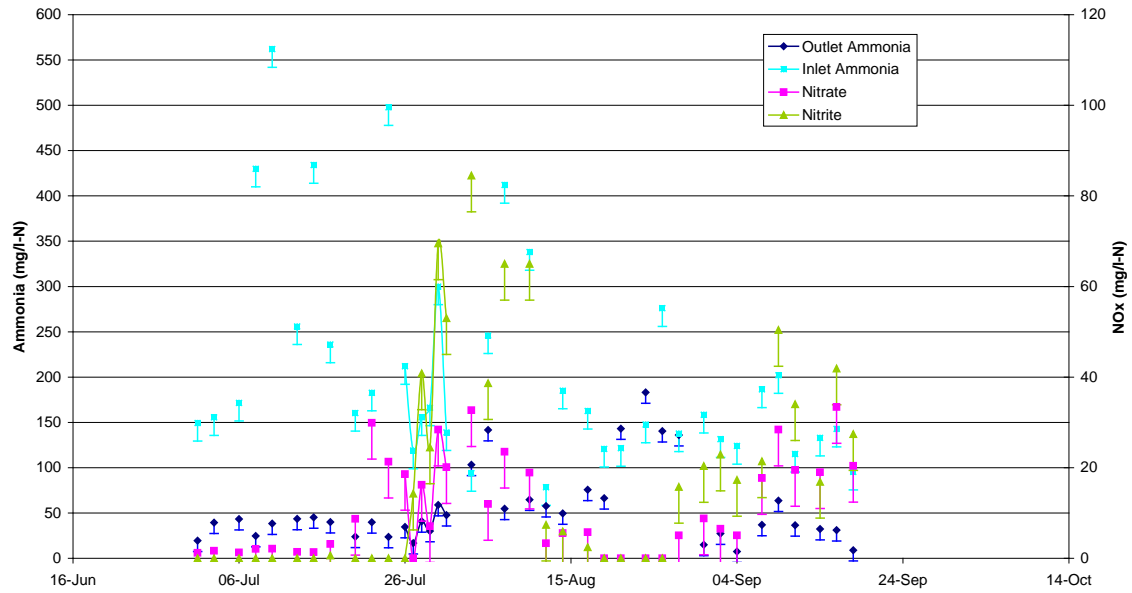
MBR 3 DO

Appendix 2



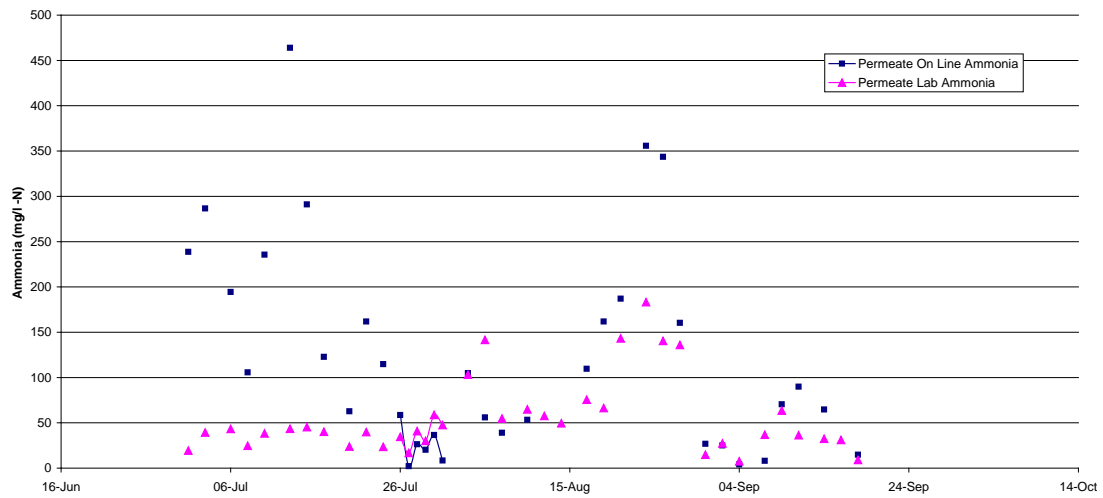
MBR 3 Permeate/ Influent

Appendix 3b



MBR3 On line Comparison

Appendix 5



Appendix C: Scenario 1 Progress Report No. 2

Hamworthy carried out a further progress review on board on 28/08/2009, by W Chen, after his visit a week before (Appendix B). The visit was accompanied and supported by Giuseppe Farris (Hotel Engineer), Wilfredo Saavedra (1st Plumber), Roy Van Acuzar (2nd Plumber) and Jovy (Plumber). Some progresses were made between the visits, and the key findings are summarised below.

No.	Subject	Action
1	<p>MBR No.3 capacity</p> <p>The operator believes the MBR No.3 capacity cannot be reduced to 80 m3/day. The reason is the MBR 1&2 membrane banks rely on the extended back flush procedures to remove blockage. The modification to prevent membrane blockage was not yet implemented. This item must be concluded asap. In the mean time, Hamworthy agrees to a compromise of 100 m3/day.</p>	HWS
2	<p>Black and grey water mix</p> <p>The mixing ratio is more stable now. The water level in Tank 5 is now 66%. Hamworthy agreed to not to increase the level further, until Hamworthy engineer can stay on board again to examine the situation over a number of days.</p>	HWS
3	<p>Dissolved Oxygen (DO)</p> <p>DO has now been increased to 1.1-1.5 mg/l– which is encouraging. Operator reported foaming problem – which is contained and managed. The leaking seal of the spray pump is not yet replaced. Hamworthy emphasised the purpose of the spray system provided for this trial.</p>	Ship
4	<p>Anoxic zone and Swing zone</p> <p>During the visit, it was found the half-opened aeration down pipe observed in the last visit remained the same. It was closed immediately during this visit. Mixing within the anoxic zone and the swing zone was further adjusted during the visit.</p>	
5	<p>ISF flows</p> <p>The ISF flows remained too high. Action is needed immediately.</p>	Ship
6	<p>Communications</p> <p>It was found that Jovy had not seen the Hamworthy instructions (Appendix A). Hamworthy raised the concern over this situation.</p>	
7	<p>Resources</p> <p>It was revealed that Jovy will leave the ship in Oct, and 1st and 2nd plumber on duties will leave in Dec. Considering the progress so far, further operational resource, and the associated trainings, must be allowed for.</p>	PCL
8	<p>Program</p> <p>A further visit by both Ken Cooksley and W Chen may be planned in mid September. The aim will be to assist implementing the scenario 1 conditions to that the trial can start. Hamworthy will also observe the operational resource to ensure progress.</p>	HWS

(W Chen 08/2009)

Appendix B: Scenario 1 Progress Report No. 1

Hamworthy carried out a progress review on board. The visit was accompanied and supported by (Farris Giuseppe, Hotel Engineer) and (Saavedra Wilfredo, 1st Plumber). It was concluded that the Test Scenario 1 (and some elements within Scenario 0) has not progressed substantially in accordance to the Plan (Appendix A). The key findings are summarised below.

No.	Subject	Action
2	<p>MBR No.3 capacity</p> <p>Scenario 1 calls for MBR No. 3 daily capacity of 80 m³/day. This is considered too low during the Alaska Season. The reason is that for MBR No. 1 and No. 2, extended membrane bank back flush is required to prevent blockage or membrane bank high pressure. Hence:</p> <ul style="list-style-type: none"> - Hamworthy must implement the MBR No. 1 and 2 membrane bank fail-safe controls (to automated the actuated valves on the membrane bank feed lines) which is now long overdue. - In the mean time, Hamworthy agrees to keep the MBR No. 3 capacity to 100 m³/day. 	HWS
3	<p>Black and grey water mix</p> <p>The situation has improved. The level in Tank 5 has been increased to 66%. Further increase can not be agreed upon due to concerns of possible overflowing. It is agreed that no further increase is attempted until Hamworthy engineer is on board again to observe and examine the situation.</p>	
5	<p>Dissolved Oxygen (DO)</p> <p>The importance of DO to a good nitrification process was again emphasised. While the target DO is 1.5 mg/l, the actual DO has been merely 0.2 to 1.0 mg/l.</p> <p>During the visit, the operator indicated concerned about foaming when aeration is increased. It was found that the spray pump and the spray system, specifically designed to cope with possible foaming, was actually not running. When the operator attempted to run the spray pump, the seal was found leaking when isolation valves were opened.</p> <p>The pump seal shall be replaced, and the spray system shall be made functional. This shall give operator a peace of mind in maintaining the required aeration. Prior to a satisfactory DO level is maintained, a stable nitrification process cannot be established.</p>	
6	<p>Anoxic zone and Swing zone</p> <p>During the visit, it was observed that at least one of the aeration down pipes into the anoxic zone was half open, with air bubbles visible in the reactor content (from side low level viewing hatch). It was emphasised that air shall not be supplied to the anoxic zone.</p> <p>It was also observed that the mixing line to the swing zone was closed. It was recommended to keep it open so that the mixing is sufficient in both the anoxic zone and the swing zone.</p>	
7	<p>Alkalinity</p> <p>Sodium hydroxide solution is being dosed to the system. Two dosing systems are made available to provide sufficient dosing capacity. It was advised that the permeate alkalinity shall be maintained between 100~200 mg/l CaCO₃. The dosing of sodium hydroxide shall be adjusted to suit.</p>	
8	<p>ISF flows</p> <p>The importance of ISF flows was emphasised. ISF screening flow was in some cases as</p>	

	high as 300 m ³ /day, comparing to a target of 100 m ³ /day or less.	
9	<p>Tank 5 Ammonia on-line meter</p> <p>The ammonia on-line meter showed weak agitation within the flow cell. It was recommended to increase the flow through the cell to prevent accumulation of solids that cause un-reliable readings or blockage.</p>	
10	<p>Program</p> <p>A short visit by W Chen is planned in Victoria on 28/08 (in the evening).</p> <p>A further visit by both Ken Cooksley and W Chen may be planned in mid September.</p>	

(W Chen 08/2009)

Appendix A: Scenario 0 and Scenario 1 (July 2009)

Background – Progress so far

The ammonia removal trial on Golden Princess is now ready to start. The key activities so far, achieved with full support by Carnival Corporation and Princess Cruises, are summarised below:

- Ship survey completed	Nov 2008
- Scope of work and contract agreement	Jan 2009
- Allocation of one plumber for this trial by Princess	Mar 2009
- Wastewater characterisations (Phase 1) completed	Mar 2009
- Phase 1 report submitted	Apr 2009
- Trial plant installation and commissioning (Phase 2) completed	Jun 2009
- Trial period starts (Phase 3)	Jul 2009

Ammonia removal trial plan - general

Over the next few months, *ammonia and phosphorus removal* performance will be investigated using the modified MBR No.3. Hamworthy relies primarily on a strictly structured communication regime with the ship staffs to implement all trial scenarios. Additional resource, including one additional plumber, had been allowed for by Princess Cruises.

Recognising the fundamental importance of keeping good communications for this project, Hamworthy decided to allow a 'Scenario 0' prior to starting the nitrification process (Scenario 1). The subsequent test scenarios will be developed based on the outcome of the previous scenarios. This technical note outlines Scenario 0 and scenario 1, in a very simplified way. Detailed communication are carried out separately with ship staffs, which are on-going.

Scenario 0

The objectives are:

- To establish a rigid communication regime so that data are complete, and correct;
- To establish a stable operational condition to the new feed system and MBR3;
- To clear any snags.

No.	Tasks
1.	Data to be received by Hamworthy on every Monday and Thursday morning: <ol style="list-style-type: none"> 1) Ammonia Removal Trial Log Sheets 2) Golden Princess Log Sheets 3) Feed Panel PLC data down load 4) SC1000 data down load
2	Tank 5 and MBR3 operational parameters required (to be implemented from 18/07): <ol style="list-style-type: none"> 1) MBR feed rate ~100 m³/day, with grey:black ratio 2:1 – by adjust Tank 5 level settings (reducing the black water level bend). 2) MBR sludge age 10 days – by desludge 3-4 m³ <u>daily</u>. 3) ISF filtrate ~400 m³/d, screenings ~100 m³/d – by throttling ISF feed valve. 4) Stop Nutrient solution (Hepburn) dosing into MBR3 during the trial period.
3	Program Start date: 01/07, and expected to last for a period of 4 weeks. Ken Cooksley of Hamworthy will attend the ship by the end of July to resolve any snags.



Scenario 1

The objectives are:

- To establish nitrification and denitrification in the system;
- To stabilise nitrification and denitrification in the system;
- To clear any snags.

No.	Tasks
1	<p>Tank 5 and MBR3 operational parameters required (implementation date TBA, expected on 01/08):</p> <ol style="list-style-type: none">1) Create Anoxic Zone – by switch off air supply to Anoxic and Swing zones;2) Maintain DO 2.0 mg/l – by running a maximum of two blowers;3) MBR feed ~ 80 m3/d; grey:black = 2:1;4) MBR sludge age 20 days – by desludge 1-2 m3 <u>daily</u>;5) ISF filtrate ~300 m3/d, screenings ~80 m3/d;6) Introduce AMMO1000 (Hepburn) to MBR3.
2	<p>Program</p> <p>Start date: TBA, and expected to last for a period of 8 weeks.</p> <p>W Chen of Hamworthy will attend the ship in early August to support the trial.</p>

(Wei Chen, July 2009)