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Prepared by: Richard Mayoh
Rycam Industrial Pty Ltd

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Meat & Livestock Australia Limited
Locked Bag 991
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Learnings from the Burrangong Meat Processor covered anaerobic lagoon

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1 Introduction

Anaerobic lagoons are a critical component of modern wastewater treatment plants treating raw meat processing wastewater in a highly cost effective manner. Their weaknesses include:

- A risk of offensive odour production, especially where a naturally forming floating crust does not form, or erodes, and
- The release of very significant quantities of methane which is an important greenhouse gas.

Innovation has come in the form of covered anaerobic lagoons (CAL) in which a synthetic plastic membrane is laid across the lagoon surface. The impermeable cover captures the energy-rich methane biogas which can be combusted to destroy greenhouse emissions with associated energy capture. This process also destroys unpleasant odours. This offers a way in which the cost effectiveness of anaerobic lagoons can be retained for the industry while minimising the weaknesses.

Unfortunately there have been serious teething troubles for CAL technology applied to meat processing facilities in Australia. Some of these have been recently explored in the MLA report “Anaerobic Cover Material Vulnerability (2009)”. Several early CALs built for abattoirs have suffered problems in the design and operation of their covers and associated biogas handling. Burrangong Meat Processing (BMP) constructed a covered pond at its Young (NSW) facility in 2007 with plans to capture the biogas and run it through its engines for cogeneration. It experienced many of the difficulties common to the use of CAL technology in the red meat industry.

The objective of the project was to debrief the author concerning the CAL built for BMP, especially relating to gas flows, composition and lessons that can be learned from its design, construction and operation. This information can then be available to the red meat processing industry and assist in informing their decision making.

2 Plant Operation

This section describes the BMP Young facility operation and the wastewater treatment context for the CAL operation. The meat processing plant is a medium-sized, multi-species facility operated with a US listing export license and a full range of ancillary operations including a low temperature rendering facility.

2.1 Processing

2.1.1 Animal throughput

The plant had 3 separate processing lines for pig, cattle and small stock. The lines all ran independently, with a processing capacity of 3.5 pigs/min, 8 smalls/min and 30 cattle/hr. Typical average HSCW produced weekly over the preceding 3 years was:

Maximum: 940 tonne comprising:

- 7,000 pigs (ave. 70 kg HSCW)
- 16,000 smalls (ave. 18.75 kg HSCW)
- 750 cattle (ave. 200 kg HSCW)

Minimum: 510 tonne comprising:

- 4,000 pigs
- 12,500 smalls
- 500 cattle.

2.1.2 Offal collection

The site was a major offal collector for all species for human consumption and pet food, including tripe, honey combs, runners, maws and sweet intestine. Typical large weeks were:

- Pig offal, 30 tonne
- Smalls, 10 tonne
- Beef, 5 tonne for human consumption
- Combined, 30 tonne for pet food.

2.1.3 Rendering

The facility incorporated an on-site Low Temperature Rendering plant (LTR) processing all on site raw material, local butcher shop fat and bone, and material from another small domestic abattoir totalling less than 5% of the total through-put. The rendering plant also had a caustic hydrolyser to process woollen pieces for further rendering including heads, hocks, belly wool and no commercial value (NCV) skins.

2.1.4 Additional processing

The plant also included a skin shed for salting of small stock skins and a minor boning operation.

2.2 Wastewater

2.2.1 Volume and source

Typical daily water usage ranged from 900 kL to 1.2 ML. A wide variety of streams contributed to the wastewater. Major streams include:

- lairage for 2,000 pigs, 300 cattle and 4,000 smalls,
- Red and green offal,
- LTR stickwater (cooled),
- LTR waste stream,
- Caustic hydrolyzer effluent,
- Combined red streams from processing floors,
- General wash down of hard areas.

Although there was separation of streams within the plant the final destination was the same. The majority of stormwater was diverted to a separate stormwater system.

2.2.2 Effluent system

The treatment of effluent was conducted in a relatively modern wastewater treatment facility retrofitted significantly in the mid-2000s and comprising some primary treatment followed by biological treatment consisting of both anaerobic and aerobic systems. The treated effluent was irrigated onto a 60 ha farm sown typically with lucerne.

The primary treatment area combined 3 wedge wire rotary screens where the wastewater was rudimentarily screened. The wastewater then flowed into the 12 ML covered anaerobic dam, followed by treatment in a 4 ML Sequencing Batch Reactor (SBR) both designed by Johns Environmental Pty Ltd and installed during 2003-04. After further treatment in maturation and final irrigation dams, the treated effluent was irrigated to land.

This system is relatively common in the Australian red meat processing industry.

3 Pond Cover and Biogas Capture

3.1 Anaerobic Pond

The anaerobic pond that was covered was originally built and commissioned in 2003 with dimensions approximately 70m x 70m x 6m to top of wall and centre of the bank. It was designed with the option of covering at some later point in mind, which involved ensuring the pond was of a regular geometric shape and had sufficient top of wall width to allow cover anchorage. It operated with approximately 500 mm free board.

The facility then burnt down in 2004 and it was not until January 2006 that the anaerobic pond was recommissioned. A crust was reformed within 2 months and the pond started up well with no significant odour emissions.

At about that time BMP opted to cover the anaerobic pond with a synthetic cover with biogas capture for cogeneration. The company had a view to selling electricity back to the grid. This decision was driven in part by the restriction of access to sufficient electrical power from the local utility (Country Energy) for the plant, and there was the added lure of minimising carbon dioxide equivalent emissions from the facility and the capture of the associated carbon credits for the cogeneration equipment operator. The pond was covered by mid 2007, after some difficulty removing the existing natural crust. No additional primary treatment was installed.

3.2 Anaerobic Pond Cover Design

The cover was designed and installed by Fabtech (South Australia) and was a 3 layer laminate. The top white layer was designed to resist UV, the middle layer for strength and the bottom layer (that was in contact with the effluent) was supposed to resist degradation by the effluent. The materials are unknown.

The cover and biogas system were complicated by relatively poor knowledge of the wastewater flows and quality. The design biogas flow estimated by Fabtech was 300 m^3/h which was found to be reasonably accurate once commissioned.

3.3 Fabrication and Installation of the Cover

3.3.1 Crust removal

The anaerobic pond had formed a natural crust which was approximately 1 metre thick in the centre. This had to be removed prior to cover installation. The approach was to use two long arm excavators to remove the crust from the edges where it could be accessed while others in boats dragged the floating crust towards the walls. This process required the services of 20 people for 14 days and was challenging.

3.3.2 Fabrication and installation

The cover was fabricated on site by welding 8m wide strips together and then pulling/floating them over the surface of the dam. The cover was secured in place via a 300 mm wide by 1 metre deep trench, where the cover was inserted and back-filled with compacted natural ground.

The cover was a positive pressure design in the range 5 – 30 Pa.

3.3.3 Stormwater Removal

The cover was fitted with 150 mm dia PVC pipes filled with salt water to weight the cover and direct stormwater to a sump in the cover (Figure 1).

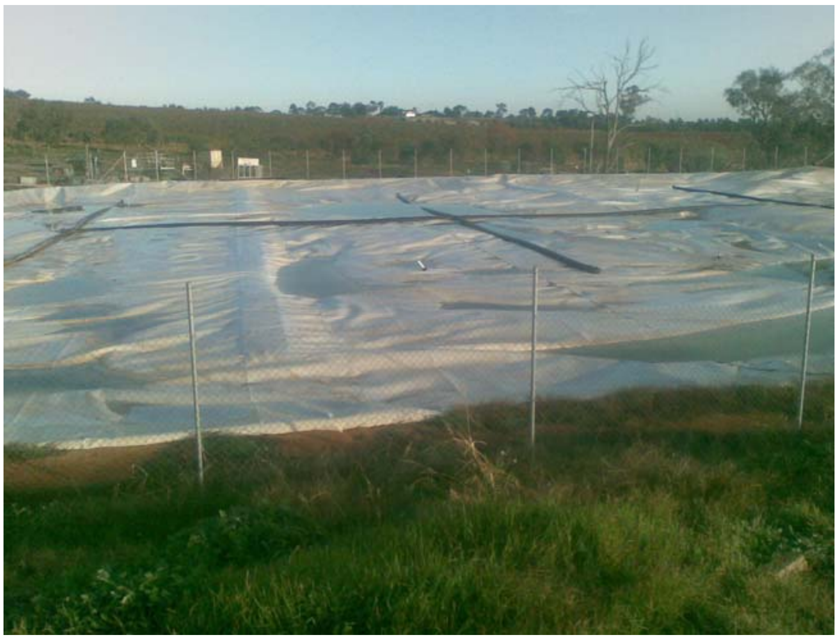

Figure 1 BMP CAL with weight pipes

From the sump a pipe, under the cover and exiting through the pond wall, directed captured stormwater to an external sump for disposal (Figure 2). However, the weighted pipes tended to obstruct the flow of stormwater on the cover to the sumps.

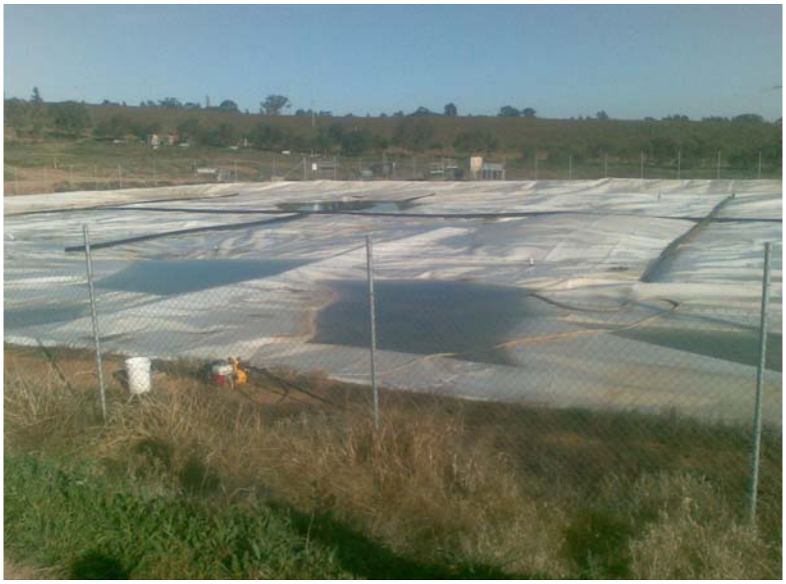

Figure 2 BMP CAL stormwater removal via portable pump.

3.3.4 Biogas Capture Main

A 200 mm dia HDPE pipe was installed around the perimeter of the pond, under the cover to capture the gas. The pipe was fitted with 20 mm dia holes 300 mm apart to allow gas ingress. This collector was held in place during the pond-covering process with wire tied to star pickets embedded in the soil on the pond side of the pipe.

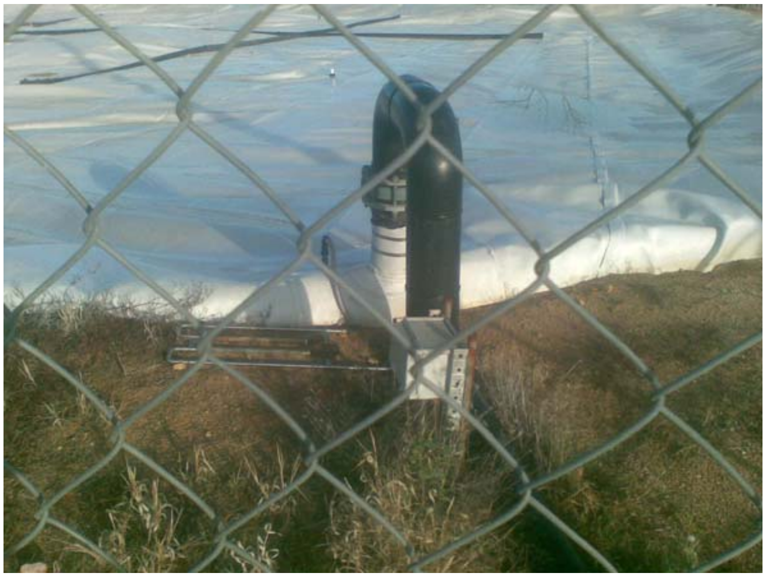

Figure 3 BMP gas off-take

3.3.5 Emergency Biogas Venting

There were two systems for ensuring that excess biogas was vented to protect cover integrity:

- Safety spears comprising 32 mm dia pipes placed vertically in the cover were installed. These tended to fill with crust under the cover and blocked.

- An emergency 200 mm dia HDPE vent pipe was installed with a manual valve to permit gas release if cover height was excessive. However opening this vent with the biogas blowers still in operation risked sucking oxygen (air) under the cover and into the biogas system, which posed a hazard. Consequently the vent was disabled.

As a result excessive biogas production caused the cover to rise to heights of up to 5 metres above top of wall, which exposed it to wind stresses.

3.4 Biogas Treatment Train

The biogas train consisted of the following elements:

- A 200 mm dia HDPE feed pipe from the manifold under the cover to the knockout pot (Figure 3);
- A knock out pot;
- A 150 mm dia stainless steel pipe to the flare(Figure 4);
- A blower set controlled by pressure transducers originally installed upstream in the biogas pipe near the blower;
- Double block & bleed valves;
- Emergency vent;
- Take-off to the genset;
- Enclosed flare;
- A biogas mass flow meter was installed subsequently, but not as part of the original project.

Biogas quality-metering (oxygen and/or methane) was not installed.

Figure 4 Biogas blower pumping gas to the engines

3.4.1 Biogas Flare

The flare was manufactured and installed by Australian Burner Manufacturers (ABM). Due to the urban setting of the facility, it was a fully enclosed type with a height of 5 metres and 0.8 metres diameter with a stainless steel shroud.

The flare had a continuous pilot light which was originally fuelled with biogas. This was changed to bottled LPG due to various difficulties. The pilot consumed two 100 lb cylinders of LPG per week.

Air was introduced into the flare burner by a simple venturi which meant that the air rate was fixed. Under normal (300 m^3 biogas/hr) operation, the flare was not visible.

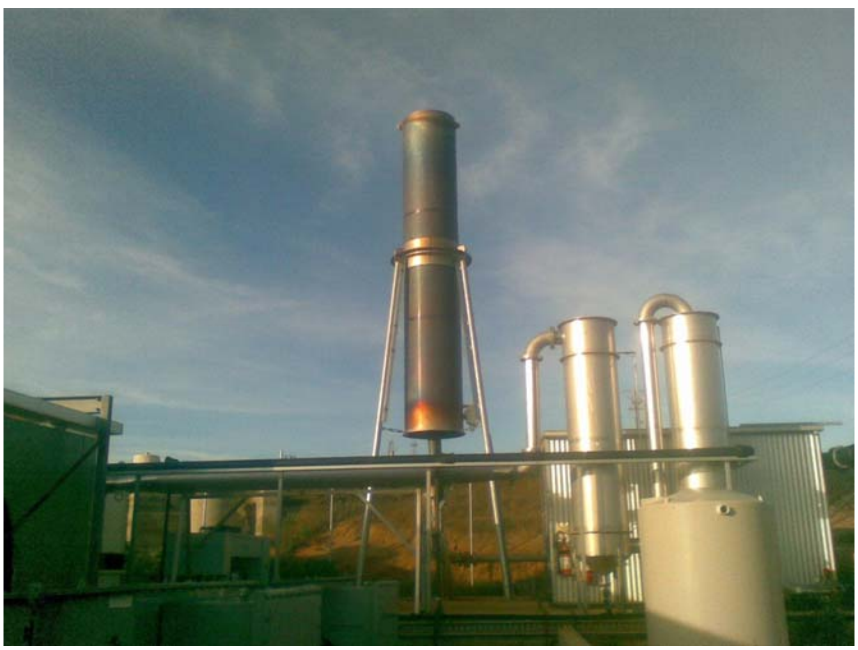

Figure 5 ABM enclosed flare with caustic desulphurisation scrubbers (right)

3.4.2 Operational Control.

A signal went to an on/off controller via closed loop control circuit, controlled by the biogas pressure under the cover (measured by the transducer in the gas main upstream of the blowers). If the pressure was out of specification (between 5 - 30 Pa), the two check valves downstream of the blower were triggered, biogas supply to the flare was stopped and instead vented to the atmosphere from an outlet between the two check valves.

The on/off controller also had a signal from a “fire eye” in the flare enclosure, which turned off the biogas blower if the flame went out. The gas flow to the flare was controlled to deliver a constant pressure of 5 kPa to the flare burner.

3.5 Gensets & Biogas Conditioning

3.5.1 Gas Conditioning.

Two 800 kW Perkins gensets (gas engines) were installed, on a one duty/one standby arrangement. Because the electricity generated could not be sold back into the grid, the cogen unit was sized to meet the minimum plant base load (2am Sunday morning).
The biogas needed conditioning prior to feeding to the gensets, especially due to quality issues that were experienced after installation. The single genset operation covered the facility base load.

Figure 6 Genset Step-up Transformers

The conditioning consisted of:

- A caustic scrubber to reduce H_2S levels in the biogas (Figure 7).
- Dual shell & tube heat exchangers to chill the biogas using a glycol circuit to reduce moisture;

  These treatments worked well.

Figure 7 Desulphurisation scrubbers

3.5.2 Heat Recovery.

Typical gas engine efficiency is of the order of 35 – 40% electrical. Additional efficiency can be obtained by recovering waste heat energy in the form of hot water. Although BMP operated a Low Temperature Rendering plant fitted with waste heat recovery it was unable to supply the total hot water required for the plants operation.

PLC-controlled hot water recovery was fitted by the plant engineer to capture this benefit (Figure 8). Hot water recovery of 200 kL/day was obtained by heating ambient water at 15^{o}C to around 60- 80^{o}C using the gas engine exhaust gas at approximately 460^{o}C. The exhaust can be cooled safely to about 120-200^{o}C . Cooling the exhaust to less than the dew point could result in water vapour getting back into the engine and causing problems.

The hot water recovery made the cogeneration unit economic to operate

Figure 8 Plate heat exchanger (centre) generating hot water from gas engine water jacket cooling

4 Gas Production and Quality

Pond cover supplier (Fabtech) estimated biogas production would be 300m^3/hr and this was proved correct for the maximum 940 tonne/week throughput, which generated about 1.2ML/day wastewater. The biogas volume was relatively constant during the week, with relatively little fall-off during the weekend (typically no more than 10%).

The typical methane content of the biogas produced at BMP was 62 - 63%v/v. The remainder was carbon dioxide (CO_2) and H_2S

Hydrogen sulphide (H_2S) levels were surprisingly high with levels reaching up to 8%v/v. These levels are very high by industry standards.

5 Major Capital Items

Table 1 presents approximate capital costs for major plant items associated with the covered anaerobic lagoon and the accompanying biogas handling system. The following points apply:

- The CAL cover does not include a pond liner, which is usually adopted in more recent ponds.
- The flare cost is only for the flare and does not include electricals, which were provided by the BMP engineering team.
- The genset capex was approximately $1,000 per kWe.
- The cost of the anaerobic pond, decrusting activities and approvals are not included.

Table 1. Capital cost of major items

Item	**Cost (A$) 2006 base**	**Comment**
CAL cover	$300,000	Fabtech. Approx $60/m^2 installed
Biogas flare	$150,000	ABM enclosed flare @ 300 m^3/h biogas
Sulphide scrubber	$ 30,000	Site-built
Gas engines, each	$750,000	Perkins (UK) including $150k for sulphide-resistant internals.

All costs ex GST.

6 Problems and suggestions for CAL design, installation and operation

6.1 High Hydrogen Sulphide Levels in Biogas

As previously stated, the 8%v/v H_2S composition of the gas was significantly higher than the design value of 2%. This level of H_2S is unusual for red meat CAL operations, where H_2S levels are usually less than 1%v/v.

Possible sources of H_2S include:

- Low temperature rendering of the blood, since blood contains high levels of sulphur.
- A lot of tallow in skins is extractable in low temp rendering. At this stage BMP were processing 2000 skins/day.
- Wool and hair hydrolysis stream (caustic hydrolysis). Wool hydrolysis effluent, although low in volume, contains very high sulphur levels since wool sulphur content can range from 3-4 % sulphur. The hydrolyser effluent went to the pond.

The scrubber units built on-site were effective in reducing the H_2S in the biogas from 8% to approximately 0.2%v/v, which after conditioning was suitable for the gensets. The idea of an iron filings filter was also considered, but the gas flow was too large for this concept.

6.2 Flare Ignition

The flare was supplied with a standard double block and bleed system with igniter. The igniter was fuelled by biogas, but proved troublesome. Subsequently, it was replaced with a continuous pilot flame supplied by LPG gas bottles. The disadvantage of this is the high LPG consumption.

Operation of the biogas flare was controlled by a pressure transducer originally installed in the biogas main upstream of, but near, the blower. The operators found they were unable to get a reliable and stable pressure reading from this configuration, even with maximum dampening in the control loop. The transducer was re-installed adjacent to the biogas take-off near the cover. This was somewhat more successful but still gave unstable readings resulting in unreliable flare operation.

As it was not possible to find a controller with any more dampening on the transducer signal, a water-type manometer with a fine orifice on to the transducer was installed, allowing substantial dampening. This allowed the system to operate adequately, however it was still very unreliable in windy conditions as the wind causing the pressure under the cover to fluctuate wildly.

6.3 Excessive Gas Flow

During the time the CAL was operational, production increases led to biogas flows as high as 420 m^3/hr. The enclosed-type flares struggle with this if they are not sized to cope, since the air available is limited by the design of the flare (unlike the simpler candlestick flares).

As a result, there were a number of undesirable outcomes including:

- Poor combustion of the excess biogas leading to odour issues;
- The flame was higher and rose above the shroud, exposing neighbours to light during the evening and being highly visible;
- Noise was also an issue.

Appropriate sizing of flares is therefore an important issue.

6.4 Supplying Electricity to the Grid

The original intention was to use the gensets to export electricity back to power grid. Unfortunately, negotiations with the electrical utility proved so difficult that this approach had to be abandoned. It is crucial that the electricity utility is engaged well in advance to ensure that contractual issues are not insurmountable.

6.5 Crust Accumulation

The risks of crust accumulating under the cover are well documented and a particular risk for the red meat processing industry. Crust accumulation was an ongoing issue for the BMP CAL and necessitated treatment with enzymes to reduce it to manageable levels.

The crust is a threat to the emergency cover spears and to the biogas collection main under the cover.

6.6 Operational Comments

- The operators recommend spending 6 months developing a proper maintenance program, primarily focusing on mechanical operation of the engine.
- If capturing biogas and running a cogeneration plant (gas engine), it is suggested that one person full time is required to monitor and manage it, as loss of a cogeneration can be expensive and time consuming to resolve. However operation when just flaring is not a problem and would not require a full time operator.
- Consideration needs to be given to plant shutdowns. An agreement can be reached with the gas provider to deal with start-up energy demand after a shutdown, but electricity providers are very inflexible and surcharges are applied.
- Installation of a manual emergency flare at the pond is not advisable as an operator might leave it on, or the flame might die out and the vent could become a hazard.
- A mass flow biogas meter could be an advantage.