final report

Project code: P.PIP.0545

Prepared by: All Energy Pty Ltd

Date published: July 2017

PUBLISHED BY
Meat and Livestock Australia Limited
Locked Bag 1961
NORTH SYDNEY NSW 2059

DAF Float Processing and Hydrocyclone Trial

This is an MLA Donor Company funded project.

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government and contributions from the Australian Meat Processor Corporation to support the research and development detailed in this publication.

Abstract

Wastewater streams from red meat processing (RMP) plants can contain high levels of fats, suspended solids, biological oxygen demand (BOD) and other elements that are unacceptably high for industrial outfalls to local water authorities and/or are difficult to process in on-site waste water treatment plants. Dissolved Air Floatation (DAF) provides a solution for removing particles down to 25 µm (or towards 10 µm with chemical dosing) compared to a Saveall which removes particles in the 100µm+ range. However, DAF sludge tends to be generated at around 2 to 8% solids (depending upon the inlet and operations of the DAF, hence there is motivation to consider firstly removing fat to create a tallow product before processing through a DAF and to also consider concentrating the DAF sludge to reduce waste management costs. Hydrocyclone technology (where liquid is pumped into a cone arrangement that applies high centrifugal forces) can separate fat particles towards 15 µm hence providing an opportunity to create a tallow product from a RMP red stream and could also concentrate DAF to a higher solids concentration. Removal of fats from the red stream showed strong technical viability with an estimated 1.2-year payback.

Executive Summary

Red meat processing (RMP) plants are experiencing higher waste management costs hence there exists the opportunity to consider options for removing water from waste streams trucked away from site and also whether products can be created from waste streams (e.g. a low grade tallow from the red waste water stream. Further, more stringent water outfall conditions are being placed on RMPs. Due to its ease of use, low operating costs, small footprint and minimal rotating parts, hydrocyclone technology offers a solution to de-water existing waste streams, such as sludges, and/or remove fat from waste water streams such as the red stream.

The results for processing a screened red stream through a hydrocyclone resulted in fat recovery of around 78.7% to 89.2%, 15% COD recovery and 21% total solids recovery. The hydrocyclone that was trialled showed better fat capture rates than the existing non-chemical dosed DAF system. The hydrocyclone produces a "clean tallow" whereas Salsnes Screens and DAF systems creates a homogenous protein/fat/fibre mix. Further, there is evidence that separating fats before the DAF system reduces the creation of free fatty acids due which can reduce the value of a tallow product. For the DAF float, the fat capture rates were 80.2% (Run 1) and 72.6% (Run 3) with COD capture at 53.1% and 51.9% whilst TS capture was at 83.4%.

Chemical flocculation is considered economically viable to dewater sludge out of the heavy outlet stream from a hydrocyclone.

It may be possible to employ a single Ultraspin unit for two purposes: to process the red stream for approximately 20 hours per day and to dewater DAF float for a period of approximately 10 to 20 minutes per day. Where the cost-benefit analysis (CBA) assumes that the heavy stream created can be sent to the belt press with an associated flocculation to create a liquid stream suitable for treatment in the aerated wastewater treatment plant, and the fat from the red stream can be sold as a B-grade tallow, a payback period of 7 months could be achieved. This CBA does not include advantages of:

- Lower solids, BOD/COD, N and fats through the DAF by removing ~80% fats entering the DAF hence improving the performance of the DAF.
- Potential funding for this system via ARENA.
- Where decanted water from tops is sent straight to WWTP, the volumetric load on the DAF could be further reduced by about 6.9% (no desander) to 19.4% (with desander where decanted water is sent straight to WWTP and desander settled sludge is sent to the belt filter).
- More concentrated feedstock for future AD plant.
- Slightly lower solids, BOD/COD, N, and fats through the WWTP.

As a second scenario, where the aim is to send materials to an anaerobic digester, the fats are first recovered via the use of a hydrocyclone, the red stream is further treated by the DAF to remove the remaining fat, then a combined post-DAF red stream and screened green stream could be processed through a Salsnes screen to create an 18% solids sludge. This arrangement provides an advantage of having tighter control over the amount of fat entering an anaerobic digester, as high fat levels can result in the creation of free fatty acids and an acidic pH in the digester, which reduces the production of biogas. This arrangement is estimated to recover 49.4 to 59.1% of solids from the screened red stream and 42% of solids from the screened green stream.

Noise modelling predicts that a hydrocyclone will readily comply with licenced and council noise limits.

Table of Contents

1 Project objectives

The overall objective of the project is to conduct a pilot trial on a hydrocyclone to process DAF float, red stream, and green stream waste.

Specific objectives are:

- Development of detailed scope, trial design, and work schedule
- Conduction of a pilot trial evaluation on DAF float processing and hydrocyclone
- Detailed cost benefit analysis and business case
- Contribute to specific knowledge of the suitability and viability of hydrocyclone processing to lighten load on WWTP at Australian RMPFs

2 Background

2.1 Hydrocyclone Technology

Hydrocyclones are typically cono-cylindrical in shape, with a tangential feed inlet into the cylindrical section, an outlet at the cylindrical section called the vortex finder and an outlet at the conical end called the spigot[1]. Larger particles and higher density materials (e.g. water) move through the fluid to the outside of the cyclone in a spiral motion, and exit through the spigot whilst lighter materials (e.g. fats and oils) exit through the top.

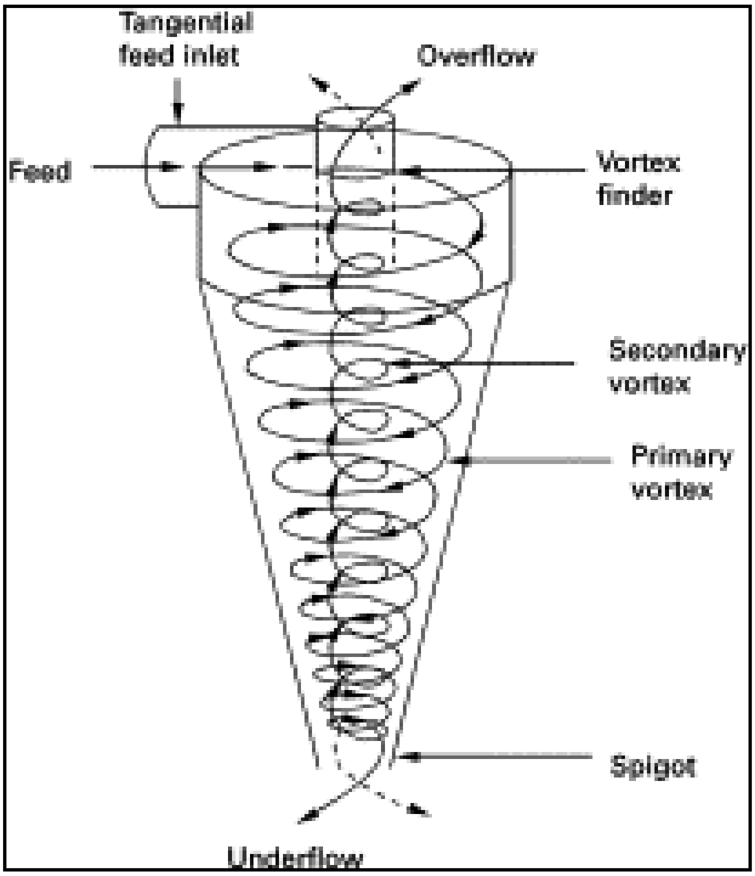

Figure 1:Principal features of a hydrocyclone[1].

[1] Cilliers J., “PARTICLE SIZE SEPARATION - Hydrocyclones for Particle Size Separation”, Encyclopedia of Separation Science, 2000.

2.2 Business Case for Hydrocyclone Technology and Potential Arrangement Within a Red Meat Processing facility

The following section outlines the commercial and business case motivations for processing liquid waste streams via a hydrocyclone.

Assumptions:

- Post-equilibration tank red flow of 44 m3/h, 20 hours per day - based on DAF plant DCS data during week of hydrocyclone trial.
- 250 operational days per annum.
- Mass balance as per section 4.2

In practice, the tops would be sent to a settling / skimming tank where the fat is removed for sale and the heavier water sent to the WWTP. This water contains a COD of 1500 mg/L which is below the target of 4,533 mg/L. Hence, processing the red stream through a hydrocyclone will have the advantage of reducing the fat load on the DAF by 78.7%. Figure 5 below shows a hydrocyclone configuration for maximizing the concentration of fat in the tops stream.

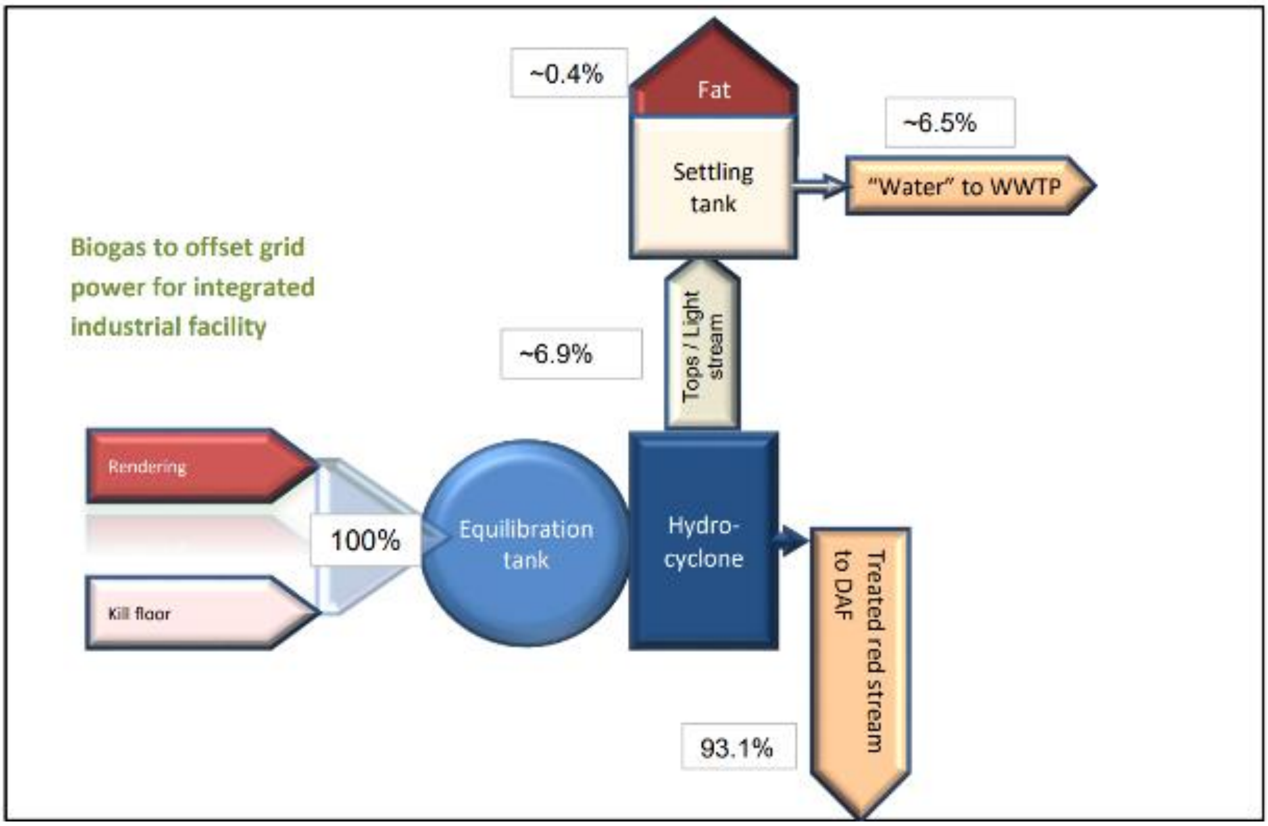

Figure 2: Hydrocyclone arrangement for obtaining a high concentration of fat in the top outlet stream from the hydrocyclone.

Desanders are used on the heavy stream from a hydrocyclone to remove solids. Desanders creates backpressure on the hydrocyclone, increasing the percentage flow exiting in the light stream and decreasing the percentage flow in the heavy stream. Utilizing mass balance data for runs where the desander was utilized, up to 17% of solids in the heavy hydrocyclone stream may be recovered via the desander, which for the red stream is around 0.74 tonnes per day solids recovered of which around 0.5 – 0.6 tonnes per day is estimated to be volatiles, contained within 39.5 m^3/day of liquid. At scale, this desander stream would be sent to a tank for decanting into a sludge (creating approximately 9 – 11% solids; volume of up to 8.3 m^3/day) which can then be sent to the filter press. Overall, the tops plus desander streams combined could reduce the volume load on the DAF by up to 19% and reduce the solids load by up to 39% (fats + desanded stream) assuming that the water from the tops stream is sent to the WWTP and the desanded heavy stream is sent to the DAF. Figure 6 below outlines an option "at scale" for producing a stream with the majority of the fat and a stream with concentrated solids.

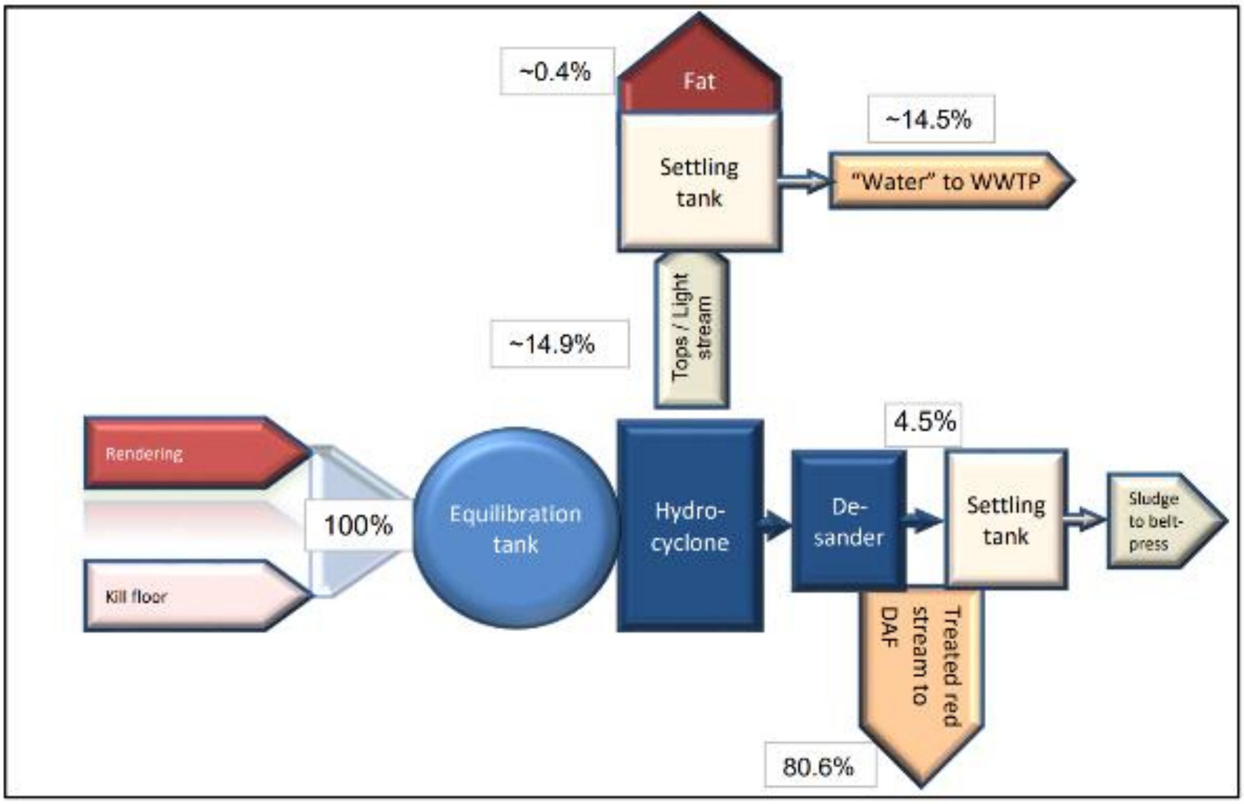

Figure 3: Hydrocyclone arrangement for obtaining a tops stream containing the majority of the fats and a "desanded" stream containing solids.

Assuming the above data, 619 tonnes per annum of fats can be recovered. Taking power load, RECs and thermal heat that can be created into account; the simple payback is estimated at 1.2 years.

This payback analysis does not include the following advantages:

- Lower solids, BOD/COD, N and fats loads on the DAF and aerated WWTP.
- Potential funding for this system via ARENA.
- Where decanted water from tops is sent straight to WWTP, the volumetric load on the DAF could be reduced by about 6.9% (no desander) to 19.4% (with desander where decanted water is sent straight to WWTP and desander settled sludge is sent to the belt filter).
- Slightly lower volumetric load through the aerated WWTP.

3 Methodology

3.1 Project Methodology

The following stages make up the overall project methodology.

Stage 1: Project contracts, equipment set-up and trial by Ultraspin staff in the first week, with associated training, then be left onsite for a further month.

Stage 2: DAF float, chemically dosed DAF float, red stream and green stream trials. Associated sampling and testing. The preliminary trial will require a 3m x 4m area for the skid plus areas for tanks / ICBs. Power requirement for 3.5 to 7 m^3/hr is 3 phase, 1.5 kW, 5 A (or compressed air at 500 kPa / 5 bar at 20 scfpm). Control included with the hydrocyclone system includes alarms on each motor, flow rate, and pressure.

Where achievable, the DAF system operation will also be considered in order to achieve optimised operation (i.e. towards 75% or greater solids removal; towards 90% FOGs removal) by varying, for example, the compressed air injection and red feed pumping rate. Ultraspin staff will be onsite in week 1 for commissioning and running of trials.

The following table 1 outlines the trials and associated inlets and outlets as well as the compositional analyses of interest.

Table 1: Pilot Trial Schedule

<table>
<tr><th>Trial #</th><th>Inlet</th><th>Outlets</th><th colspan="2">Composition</th></tr>
<tr><td>1</td><td>Screened Red trial</td><td rowspan="3">FOGs: X%
Solids: Y%
Water: Z%</td><td rowspan="3">All:
O&G
TS
VS
COD
TKN
Ammonia
COD Filtered

Not green:
Testing of FOGs suitability for tallow: FFA, MIU, FAC, R&B, Titre.

Testing of Solids suitability for meat and bone meal: Digestibility, Ash, Fat, Protein, Moisture.</td><td>Red:
[1] Maximize % of fats and solids recovered.
[2] Achieve a purity of FOGs and solids which provides opportunity to be used as a "value added" product (i.e. for meat and bone meal and/or low grade tallow).</td></tr>
<tr><td>2</td><td>Screened Green trial</td><td>Green:
Maximize % removal of volatile solids / COD to reduce loading on WWTP whilst concentrating to a solids level "acceptable" for anaerobic digestion (i.e. >10% solids).</td></tr>
<tr><td>3</td><td>DAF Float trial</td><td>DAF Float:
[1] Maximize % of water removed whilst ensuring "acceptable" composition for WWTP.
[2] Achieve a purity of FOGs and solids which provides opportunity to be used as a "value added" product.</td></tr>
</table>

“Acceptable” water quality could be that the water is approximately the same as the post-DAF red stream: TS 0.23% (2330 mg/L) [WWTP aim: 45 mg/L]

VS/TS 87.02% (VS = 2028 mg/L)
FOGs 0.03%
COD **4,533 mg/L** [WWTP BOD aim: 40 mg/L]
Dissolved COD 1,450 mg/L
TKN 325 mg/L
Ammonia 50 mg/L

Stage 3: Cost-benefit analysis to determine economic drivers for hydrocyclone and DAF chemical dosing. The items to be quantified include:

- Whether using a hydrocyclone can remove the need for chemical dosing in the DAF
- That by removing most FOGs in a hydrocyclone, having no chemicals and low FFA in the recovered fat increases its reuse value; hence consider options for direct sale or sending back to rendering.
- Consider direct sale or reuse in meat and bone meal production for the solids that are generated.
- Using red stream hot in the hydrocyclone provides opportunity to reduce temperature further and/or reduce power requirements for P403 / P404 pumping
- Rental versus outright purchase
- Ultraspin claims removal of fat particles down to 15 µm (compared to saveall's which remove particles in 100µm+ range, DAF at 25 µm and DAF with chemical dosing at 10 µm).

A final report will be produced summarising findings from Stages 1-3. A company specific report will be provided by All Energy to RMP partner and MLA.

3.2 Milestone 1 Methodology

The job hazard analyses (JHAs) and safe work method statements were completed by All Energy Pty Ltd (AEPL) and employees of Ultraspin in partnership with the RMP trial site. Vendor experience was used as the framework as it was judged that this party would have intimate knowledge of their product, with further experience and knowledge of good engineering practice and safety from AEPL and the RMP trial site.

4 Results and Discussion

4.1 Trial Plant

Figures 1 (front) and 2 (reverse angle) below shows the trial skid suitable for processing approximately 7 m3/h of liquid feed.

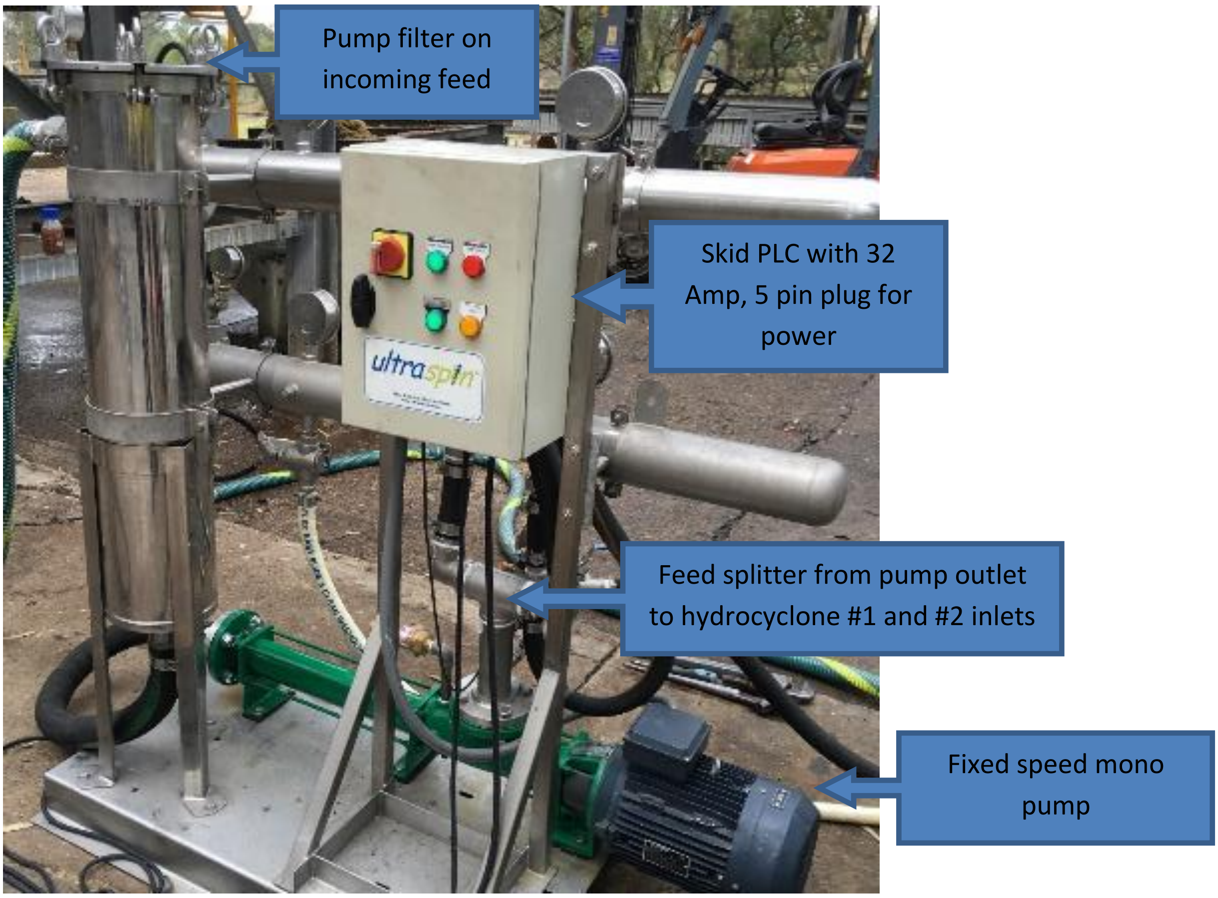

Figure 4: Hydrocyclone Pilot Plant Front Angle.

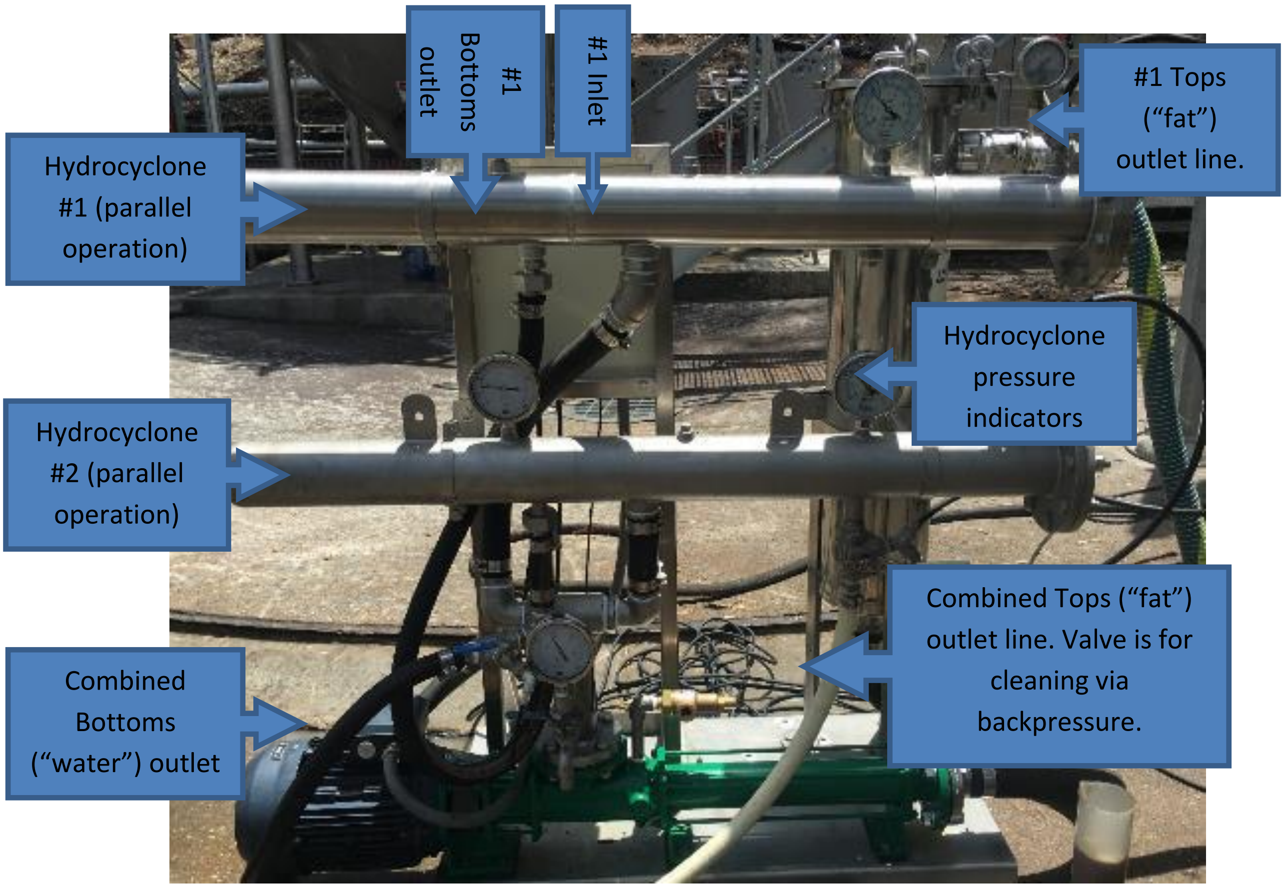

Figure 5: Hydrocyclone Pilot Plant Reverse Angle.

Figure 6: Hydrocyclone internals.

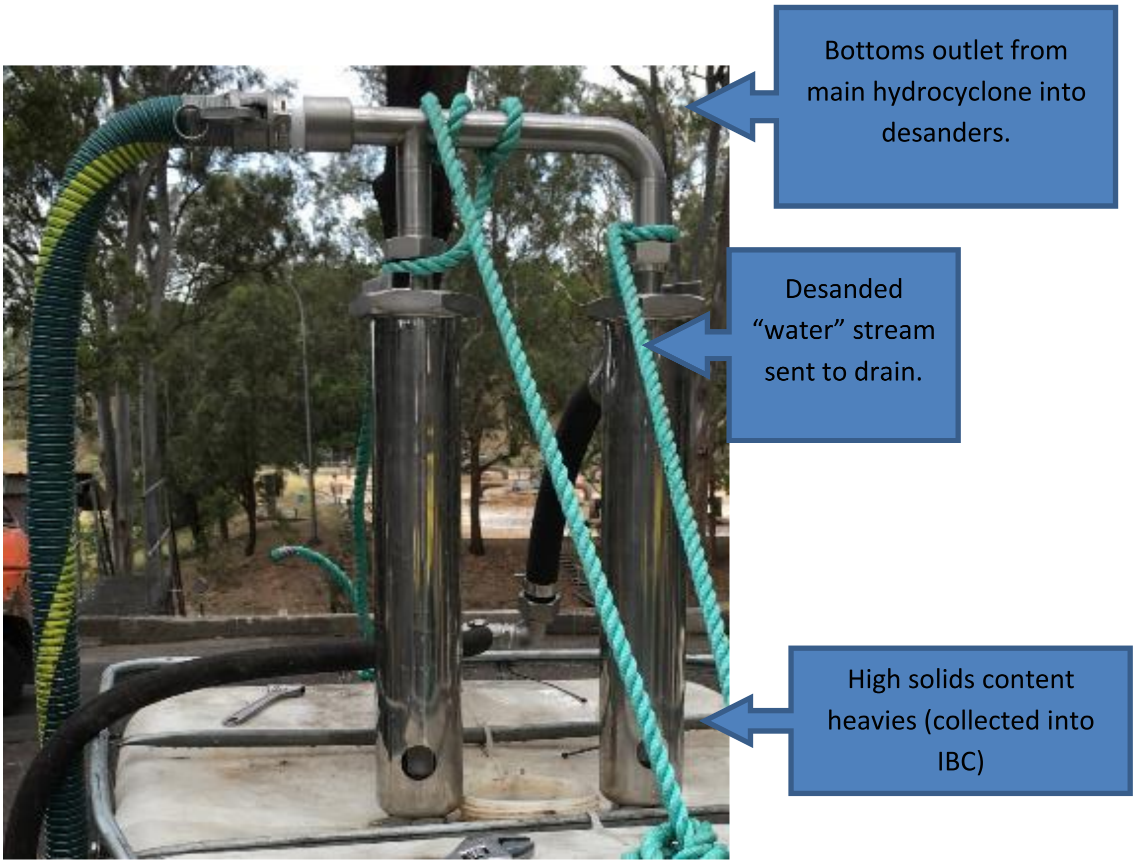

Figure 7: Desander arrangement with two columns operating in parallel.

Incoming feed was first strained and sent to the primary horizontal hydrocyclone (two systems operating in parallel; Figures 1-3) where lights / tops/ fats were discharged as overflow due to its ratio of density to fluid resistance, and water and suspended solids were discharged as underflow. A secondary vertical hydrocyclone (desander; Figure 4) repeated this process, where solids were ejected to an IBC. In a commercial installation, gravity settling is then used to remove fat from water and solids from water. The clarified water can then be sent to drain.

4.2 Results – Red Stream

4.2.1 Trial Data for Red stream

A "water" from the first run was allowed to settle under gravity and a sample of the clarified water was taken at approximately 4 hours. This resulted in a water stream containing a COD level of 3600 mg/L, which was 49% that of the original red stream and below the target COD of 4,533 mg/L. The filtered COD level for this clarified "water" stream was exactly the same as the filtered COD level for the unclarified water, which confirms that 4 hours of gravity settling is able to remove non-soluble solids.

Table 2: Red stream hydrocyclone results.

Red	**Units**	**Red stream inlet**	**Heavy stream / Bottoms**	**Light stream / Tops**	**"Water" decanted from light stream**
Trial Results					
Total Solids %	%	1.16%	0.31%	1.30%	0.22%
VS	mg/L	3500	3100	13000	1800
O&G – lab results %w/v	%	0.40%	0.082%	4.1%	0.052%
O&G – via decant	%			4.7%	
COD	mg/L	7300	5300	13000	**1500**
TKN	mg/L	220	260	220	160
Ammonia	mg/L	39	52		41
COD filtered	mg/L	1500	1800	2200	1500
Trial Volumetric Flow (n = 3)	m^3/h	6.90	6.42	0.47	0.45
TS % of total	%	100%	79%	21%	
VS % of totals	%	100%	76%	24%	3.1%
Fat % of totals	%	100%	21.3%	78.7%	0.9%
COD % of totals	%	100%	85%	15%	1.7%
Extrapolation to Full Red Stream Flow	**m^3/day**	**880.0**	**819.6**	**60.41**	**57.59**
Volumetric Flow	%	100%	93.1%	6.9%	6.5%
Fat tonnes per day - Full red stream	tpd	3.15	0.67	2.48	0.03
Volatiles tonnes per day - Full red stream	tpd	3.08	2.54	0.79	0.10
Solids tonnes per day - Full red stream	tpd	10.24	2.54	0.79	0.13
COD tonnage	tpd	5.13	4.3	0.79	0.09
Options			Sent to DAF	Fat decanted and sold	Sent to WWTP

The Ultraspin analysis of O&G utilized a solvent extraction method which increases the accuracy at higher O&G levels. Using a mass balance approach for the Ultraspin results, the fat recovery equated to 89.9% recovery of fat into the top (light) stream. Hence, in the analysis the more conservative 78.7% recovery was assumed.

Figure 8: Visual results for hydrocyclone trial. From the left: red stream inlet (some fat collecting at the top), “water” out of the bottoms and the tops (or “reject”) with a clearly defined fat phase representing approximately 4.7% of the total tops volume.

4.3 Results – Green Stream

The ultimate aim of the green stream run was to determine if volatile solids could be concentrated into the a stream suitable for anaerobic digestion. As shown in the results below show, about 14.7% of the volatile solids can be recovered into the "desanded" stream which represents 4.5% of the total green stream volume. Extrapolated to full scale, this represents 0.4 tonnes per day of volatiles in a flow of 78 m^3/day. Decanting this stream is expected to reduce this volume down to around 8.6 m^3/day.

Table 3: Green stream hydrocyclone results.

Green	Units	Green stream inlet	Water from desander	Light stream / Tops	Desanded solids
Trial Results					
Total Solids %	%	0.21%	0.18%	0.17%	0.79%
VS	mg/L	860	1400	640	4700
O&G	mg/L	170	120	240	170
COD	mg/L	2800	2500	2400	9300

The payback on a hydrocyclone to recover solids for an anaerobic digester is estimated to have a simple payback period of 14 years. This payback analysis does not include the following advantages:

- Lower solids, BOD/COD and ammonia loads on the aerated WWTP.
- Lower volumetric load through the aerated system WWTP.
- Funding for this system via ARENA.

4.4 Results – DAF Stream

Three runs were completed on the DAF stream with the inlet processed through the hydrocyclone and desanders:

[1] Float tank contents processed through hydrocyclone. One quarter shut valve position on water from desanders (i.e. allowing for a moderate level water flow).

[2] “Water” generated in run [1] was reprocessed through the hydrocyclone and desanders. Three quarter shut valve position on “water” from desanders and backpressure plugs installed on “water” lines i.e. to constrict “water” flow to increase percentage of fat sent to tops and percentage of solids sent to desander.

[3] A repeat of [1] but with backpressure on “water” stream: Float tank contents processed through hydrocyclone. Three quarter shut valve position on “water” from desanders and backpressure plugs installed on “water” lines i.e. to constrict “water” flow to increase percentage of fat sent to tops and percentage of solids sent to desander.

[4] Chemical dosing of “water” from [1].

4.4.1 Run 1: DAF float

Figure 9: DAF float hydrocyclone visual results shows, from left: DAF float inlet, tops containing a defined fat layer, the desander bottoms showing a clear liquid at the top and solids at the bottom, and the “water” outlet.

Table 4: DAF stream hydrocyclone results.

[1] DAF Float	**Units**	**DAF float inlet**	**Desander**	**Light stream / Tops**	**“Water”**
Trial Results					
Total Solids % w/v	%	7.6%	14.3%	17.3%	2.1%
VS	mg/L	31,000	27,000	140,000	19,000
O&G – lab results %w/v	%	2.9%	0.4%	11.0%	0.89%
O&G – via decant	%			4.7%	
COD	mg/L	100,000	91,000	240,000	71,000
TKN	mg/L	1600	1800	950	1800
Ammonia	mg/L	69	110	20	90
COD filtered	mg/L			11,000	**4400**
Trial Volumetric Flow	m^3/h	6.83	1.11	1.60	4.12
VS % of total tonnage	%	100%	9.0%	67.5%	23.5%
Fat % of total tonnage	%	100%	2.2%	80.2%	16.7%
COD % of total tonnage	%	100%	30.3%	53.1%	16.6%
TS of total tonnage	%	100%	9.4%	65.4%	25.2%
Volumetric Flow	%	100%	16.2%	23.5%	60.3%
Extrapolation to DAF Stream Flow	**m^3/day**	**20**	**3.24**	**4.69**	**12.06**
Fat tonnes per day	tpd	0.64	0.01	0.52	0.11
Volatiles tonnes per day	tpd	0.97	0.09	0.66	0.23
Solids tonnes per day	tpd	1.01	0.09	0.66	0.23
COD tonnage	tpd	2.28	0.30	1.13	0.86
Options			Heavy layer sent to DAF float tank.	Decanted fat for sale. Heavy layer sent to DAF float tank.	Flocculate and filter out sludge via belt press

Whilst the COD level is above the red stream post-DAF, processing the DAF float through a hydrocyclone can reduce the volume of the DAF float by 60.3% whilst retaining 83.3% of the COD in the tops and desander streams. By further processing the “water” through a filtration system (e.g. chemically dosed belt filter) the COD could be reduced to as low as 4,400 mg/L which is below the target COD. At 12.06 m^3/day, this would represent ~2.2% of the current volumetric flow of the WAS from the bottom of the clarifier being processed through the belt press.

4.4.2 Run 2: reprocessed DAF float Run 1 water

Reprocessing of “water” reduces COD by 41%, with the aim being to reduce the COD in the “water” for sending directly to the WWTP. The first pass already removes the majority (83.3%) of the COD with the remaining COD expected to be stable colloids of <15 microns which would require chemical dosing or another technology to remove to obtain a COD <4566 ppm.

Table 5: Results of processing “water” or heavy stream through hydrocyclone a second time.

[2] DAF Float Run 1 Water	Units	Run 1 Water inlet	Desander	Light stream / Tops	“Water”
Trial Results					
Total Solids % w/v	%				2.1%
VS	mg/L	13000	35000	13000	9600
O&G – lab results %w/v	%	0.98%	0.42%	1.30%	0.52%
COD	mg/L	52,000	48,000	130,000	42,000
Trial Volumetric Flow	m^3/h	4.89	1.11	1.15	2.63
VS % of total tonnage	%	100%	49.1%	19.0%	31.9%
Fat % of total tonnage	%	100%	14.0%	45.0%	41.1%
COD % of total tonnages	%	100%	17.0%	47.8%	35.2%
Volumetric Flow	%	100%	22.7%	23.6%	53.8

4.4.3 Run 3: DAF float with higher backpressure on "water" outlet

Presented in Table 6 below is a summary of the composition analysis on the DAF run 3 sample taken on 17th Nov with analysis completed by 6 Dec 2016. On a dry weight basis, the desanded material and water contained 25.9% and 34.3% respectively with minimal protein loss in the tops. The lab analysis showed that the FFA in the fat increases from 15.99% pre-DAF to 87.4% post-DAF (often attributable to the large increase in dissolved oxygen caused by the DAF compressed air injection process).

Table 6: Results of processing DAF float with a higher backpressure on the water outlet to increase fat recovery into the top stream.

[3] DAF Float	Units	DAF float inlet	Desander	Light stream / Tops	"Water"
Trial Results					
VS	mg/L	32,000	6,900	130,000	43,000
O&G – lab results %w/v	%	2.9%	1.1%	9.3%	1.70%
COD	mg/L	160,000	130,000	280,000	110,000
TKN	mg/L	4,700	4,300	2,400	2,100
Ammonia	mg/L	65	120	20	92
COD filtered	mg/L				**4,800**
Trial Volumetric Flow	m^3/h	4.70	0.80	1.44	2.46
VS % of total tonnages	%	100%	1.8%	62.8%	35.4%
Fat % of total tonnages	%	100%	4.8%	72.6%	22.6%
COD % of total tonnages	%	100%	13.4%	51.9%	34.7%
Volumetric Flow	%	100%	17.0%	30.7%	52.3%
Extrapolation to DAF Stream Flow	**m^3/day**	**20**	**3.41**	**6.14**	**10.45**
Fat tonnes per day	tpd	0.64	0.01	0.52	0.11
Volatiles tonnes per day	tpd	0.97	0.09	0.66	0.23
Solids tonnes per day	tpd	1.01	0.09	0.66	0.23
COD tonnage	tpd	2.28	0.30	1.13	0.86

Analysis	Unit	BA012706.001 DAF FAT #1 DECANTED	BA012706.002 DAF DESANDER #1	BA012706.003 DAF WATER #1
Protein	%	4.9	25.9	34.3
Crude Fibre	%	1.2	34.5	8.6
Ash	%	1.4	11.0	13.4
NFE	%	9.2	16.5	15.1
ME - Ruminant	MJ/kg	27.8	10.9	15.5
Free Fatty Acid - As Oleic Acid	%	87.4	22.8	35.9

Results are on a 'dry matter' basis.
Protein is N x 6.25
Analysis subcontracted to accredited facility; Agrifood Technology, 260 Princess Highway, Werribee VIC 3030, NATA Accreditation: 2726, report 177539

Analysed Between 17/11/2016 - 06/12/2016

4.4.5 Challenges in Processing DAF Float

Clogging of the pump strainer / filter occurred after approximately 30 mins. One simple solution is to select an appropriate pump (e.g. diaphram pump suitable for slurries using compressed air) which would overcome the need for a pump strainer and/or larger pore diameter for the strainer. The updated design would utilize a strainer at a 5 mm aperture (as opposed to 3 mm aperture).

Further, if fat is left in the lines for any length of time at low temperatures (e.g. overnight) the fat conjeals which results in lione blockages and difficulties / time delays in re-commisioning the plant.

Figure 10: DAF float clogging the pump filter during trial.

4.4.6 Flocculant

Clinton Barnes, Senior Account Manager, SNF (Australia) Pty Ltd completed jar tests on the red stream (detailed analysis provided in the Appendix). Acceptable flocculation was achieved for the existing flocculant at approximately 20 ppm of the power flocculant currently used on-site (FO4698SH). Further, a jar test was performed on the DAF float "water" produced by the hydrocyclone trial using 20 ppm of FO4698SH. Analysis was then performed on these samples as per the table below.

Table 7: Results of utilizing flocculant in the hydrocyclone.

[1] DAF Float	**Units**	**DAF float inlet**	**"Water"**	**"Water" decanted from floc jar test** (clear water)	**"Water" from floc jar test filtered through filter paper** ~11 microns
COD	mg/L	160,000	110,000	53,000	**<1250**
COD filtered	mg/L		**4,800**	**4,300**	**36**
VS	mg/L	32,000	43,000	16,000	Not tested
O&G – lab results %w/v	%	2.9%	1.70%	0.92%	Not tested
TKN	mg/L	4,700	2,100	4,300	100
Ammonia	mg/L	65	92	93	45
TS		7.6%	2.1%	1.9%	Not tested

There exists two options for the use of polymer flocculant:
[1] Option 1: dosing at 20ppm into red stream.

[2] Option 2: dosing at 20ppm into hydrocyclone "water" from DAF float processing that is sent to belt press.

4.4.7 DAF Float Processing CBA

Assuming:

- That the pump screen clogging issues can be overcome.
- that the DAF float "water" can be sent to the belt press and flocculated to achieve an acceptable COD level of approximately <4500 ppm, as evidenced by the sample jar testing and filtered COD results
- "water" is generated / recovered from the DAF float after flowing through the belt press at 12.06 m^3 per day, 250 days per annum.
- a sludge is created at a rate of 2.28 tonnes of sludge assuming a 90% solids recovery, 10% solids content of the slurry.

An Ultraspin system sized for processing the DAF float has an estimated simple payback of approximately 2 months (supply only). Assuming additional pipework costs to covey "water" to the belt press, desander optimization and other set-up works to recycle "tops" and "desander" back into the DAF float tank, a payback of 5-7 months is estimated.

4.5 Results – Noise Modelling

ASK Consulting Engineers Pty Ltd (ASK) was commissioned to provide noise consultancy services for the proposed red and green stream hydrocyclones under consideration. A report addressed the potential noise emissions from two hydrocyclones associated with the new facility in relation to the nearest sensitive receivers (residential dwellings located approximately 335m to the south).

Using noise modelling software PEN3D, noise predictions at the residences to south and west were undertaken. The model assumed a worst case scenario noise level (flat earth shielding with no shielding between noise sources and receptors) at the residences from the hydro-cyclone units.

The results of the predictions are that the two units will readily comply with the Licence Noise Limits. The noise levels from the two hydro-cyclone units are also predicted to comply with the relevant noise criteria within the Brisbane City Council Industry Code (refer below).

Table 4.3 Hydro-cyclone Noise at Residences

Receptor	Predicted Noise Levels (Provided Data) dBA	Predicted Noise Levels (Adjusted Data) dBA
South Residences	7	24
West Residences	3	19

Table 5.3 Relevant Noise Criteria For Industry Code (Partial Copy of Code Table 9.3.12.3.E)

Criteria location	Intrusive noise criteria	Acoustic amenity criteria		
	Day, evening and night $L_{Aeq,adj,T}$ are not greater than the RBL plus the value in this column for the relevant criteria location, where T equals: day – 11hr evening – 4hr night – 9hr	Day, evening and night $L_{Aeq,adj,T}$ are not greater than the values in the columns below for the relevant criteria location, where T equals: day – 11hr evening – 4hr night – 9hr		
		Day	Evening	Night
Low medium density residential zone boundary	3dBA	55dBA	45dBA	40dBA
At a sensitive use in the District centre zone	5dBA	60dBA	55dBA	50dBA

Figure 11: Summary of findings from noise model of hydrocyclones.

5 Conclusions / recommendations

The red stream results are in keeping with ranges reported in the literature[2]: 78.7% fat recovery from the red stream (40-90% from literature), 15% COD (10-30% from literature), and 21% total solids (15 – 60% from literature). Ultraspin solvent extraction data (rather than lab dilution data) suggested capture as high as 89.2%. Recycling of the "bottoms" back into the red equilibration tank will further enhance fat capture rates.

These results can be compared to results of fine screens completed by a 3rd party[3] on "beef slaughterhouse" waste using Salsnes screens[4]: "When the screen operated downstream of the existing screens using a 350 µm belt, the COD removal across the Salsnes averaged 15% (7), BOD5 removal was 42% (1), and TSS removal was also 42% (1)." For the second plant using raw waste: "When the screen was equipped with a 500 µm belt, the average BOD5 removal was 26% (5), whereas the TSS removal was 49% (5)." The cake was found to have an average of ~18% solids (ranged from 12 to 26% solids).

Where the total mass per day of fat in the red stream is 3.1 5 t/day (based on measured O&G levels and flow meter data), it would appear that during the trial week the DAF was capturing around 0.64 – 0.79 t/day (based on measured O&G levels and a DAF float rate of 20 m^3/day) hence a capture rate of 20.3% to 25.0%. Earlier sampling suggested an O&G capture level within the DAF of 56.8%. Hence, the hydrocyclone that was trialled showed better fat capture rates than the existing DAF system. In particular, the hydrocyclone produces a "clean tallow" whereas the Salsnes Screen and DAF creates a homogenous protein/fat mix.

For the DAF float, the fat capture rates were 80.2% (Run 1) and 72.6% (Run 3) with COD capture at 53.1% and 51.9% whilst TS capture into the tops and desander streams was at 83.4%. The trial system used was found to not be suitable to the high solids levels of the DAF float and hence the at scale system would require modifications such as a larger pump screen size and consideration of rheological properties.

A DAF system that does not utilize chemical dosing would be expected to remove particles down to 25 microns, whilst systems with chemical dosing can achieve particle separation down to 10 microns[5]. Separation of FOGs and solids in a DAF depends upon a number of factors, including the adherence of the bubbles to the particles, interaction of the particles and gas, the size of the floc and the amount of gas in the floc. Ultraspin claims removal of fat particles down to 15 µm (compared to a saveall which removes particles in 100µm+ range). The Ultraspin creates forces over 1000 times higher than gravity, which results in coalescence of the fat particles thereby resulting in a better fat recovery compared to the DAF. This improved fat recovery is evidence by the trial works completed. A Salsnes screen can come with a cut off pore size of 20 microns, however the creation of a filter cake, as would be created with paunch material, may be able to capture even smaller particles.

Chemical flocculation was evidenced at around 10 ppm, with the CBA assuming 20 ppm required.

One scenario is to employ a single Ultraspin unit for two purposes:

[1] To process the red stream for approximately 20 hours per day,

---

[2] "Assessment of Hydrocyclones for Fat Removal from Meat Processing Wastewater Streams", PRENV.022 Prepared by: GHD Pty Limited on behalf of Meat and Livestock Australia, October 2003.

[3] http://www.waterworld.com/articles/iww/print/volume-11/issue-6/feature-editorial/demonstration-trials-screen-system-at-beef-slaughterhouse.html, accessed 5 July 2017.

[4] http://www.salsnes-filter.com/, accessed 5 July 2017.

[5] Kilner, M.J., "ADVANCED ON-LINE INSTRUMENTATION HELPS DAF SYSTEMS LOWER COSTS", Hach Company, 2013.

[2] Processing the DAF float for a period of approximately 10 to 20 minutes very early or very late in the day (when the DAF float tank is full). Assuming that the "water" created can be sent to the belt press with an associated flocculation to create a liquid stream suitable for the WWTP a simple payback period of 7 months is estimated. This CBA does not include advantages of:

- Lower solids, BOD/COD, N and fats through the DAF by removing ~80% fats entering the DAF hence improving the performance of the DAF.
- Potential funding for this system via ARENA.
- Where decanted water from tops is sent straight to WWTP, the volumetric load on the DAF could be further reduced by about 6.9% (no desander) to 19.4% (with desander where decanted water is sent straight to WWTP and desander settled sludge is sent to the belt filter).
- More concentrated feedstock for future AD plant.
- Slightly lower solids, BOD/COD, N, and fats through the WWTP.
- As a second scenario for consideration, where the aim is to send materials to a waste to energy system, the fats are first recovered via the use of a hydrocyclone, the red stream is further treated by the DAF to remove the remaining fat, then the combined red stream outfall and screen green stream is processed through a Salsnes screen.
- Under a 6400 head per week scenario, it is estimated that a Salsnes screen could generate around 5000 - 7000 tpa of 18% solids sludge (estimated at 5150 tpa).
- The results are generally within the range of expected results as previously reported in the literature as per keeping with can be compared to previous values in the literature as per Figure 11 below.
- Noise modelling predicts that a hydrocyclone will readily comply with licenced and council noise limits.

Summary of Single-stage Hydrocyclones versus Other O&G Removal Technologies

	Save-all	DAF (with no chemicals)	DAF	IAF	IC-Sep	H/cyclone
Treatment Efficiency						
COD/BOD	20 – 25%	30 – 40%	30 – 90%	~ 80%	~ 90%	10 – 30%
SS	50 – 60%	50 – 65%	50 – 90%	~ 90%	~ 98%	15 – 60%
O&G	50 – 80%	60 – 80%	80 – 95%	~ 95%	~ 99%	40 – 90%
Nitrogen	-	-	-	-	-	10 – 25%
Phosphorus	-	-	-	-	-	10 – 25%
Capital Costs						
$ / tonne COD removed / year	$870	$1,360	$970	$950	$1,390	$1,090
$ / tonne TSS removed / year	$850	$1,950	$2,260	$1,980	$3,070	$1,270
$ / tonne OG removed / year	$1,900	$4,760	$6,420	$5,610	$9,220	$2,540
Operating & Maintenance Costs						
$ / tonne COD removed / year	$8.40	$7.70	$7.10	$7.90	$6.80	$7.10
$ / tonne TSS removed / year	$8.20	$11.00	$16.60	$16.40	$15.00	$8.30
$ / tonne OG removed / year	$18.40	$26.90	$47.10	$46.70	$44.90	$16.60

Figure 12: Extract from "Assessment of Hydrocyclones for Fat Removal from Meat Processing Wastewater Streams", PRENV.022 Prepared by: GHD Pty Limited on behalf of Meat and Livestock Australia, October 2003. IAF: Induced air floatation, IC-Sep: Induced Cyclonic Separation (similar to DAF but dissolved air put into the entire wastewater stream rather than a side stream as per DAF.

6 Key Messages

Hydrocyclones provide a low capital cost and low operating cost option for removing fats from the red stream as a new product (low grade tallow) can be produced whilst reducing the fat content of waste sent to DAF systems and/or waste water treatment plants. A hydrocyclone could be well suited to a facility that wishes to remove fats from a red stream thereby avoiding investment in a DAF or other waste treatment facility and/or has a DAF or other system that is at capacity or overloaded with fat levels. The opportunities for green stream processing DAF float processing more limited due to the hydrocyclone effectively being designed for fat and oil removal of liquid streams rather than BOD, COD and solids removal from high solids concentration streams which tends to lead to clogging.

Other competing technologies for water removal from sludges and/or contaminant removal from waste water include mechanical screws / presses, Salsnes screens, save-alls, and DAFs. However, none of these technologies are considered suitable for created of a low-grade tallow.

7 Bibliography

Cilliers J., “PARTICLE SIZE SEPARATION - Hydrocyclones for Particle Size Separation”, Encyclopedia of Separation Science, 2000.

GHD Pty Ltd, “Assessment of Hydrocyclones for Fat Removal from Meat Processing Wastewater Streams”, PRENV.022 Prepared by: GHD Pty Limited on behalf of Meat and Livestock Australia, October 2003.

http://www.salsnes-filter.com/, accessed 5 July 2017.

http://www.waterworld.com/articles/iww/print/volume-11/issue-6/feature-editorial/demonstration-trials-screen-system-at-beef-slaughterhouse.html, accessed 5 July 2017.

Kilner, M.J., “ADVANCED ON-LINE INSTRUMENTATION HELPS DAF SYSTEMS LOWER COSTS”, Hach Company, 2013.