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Keith Airless Rendering Process
Executive summary

Airless rendering involves cooking and drying at atmospheric pressure, using super-heated steam instead of hot air. Keith Engineering validated to the potential advantages of the process and constructed and trialled a prototype unit based on the success of a gel-bone drier in commercial operation in New Zealand utilising the superheated steam concept.

During validation of the process it was determined that the proposed process had much to commend it, but some critical issues had not yet been adequately addressed. In some cases, definitive answers on the issues raised could only be answered by pilot plant trials.

By the end of the trials the prototype plant had been proven to work effectively on boning room materials. Tallow and crax quality had been shown to be at least as good as product made from the same material using a continuous dry rendering process.

The trials of the prototype plant determined that the Keith Airless Rendering process is a technically feasible alternative to other rendering processes that produces high quality products from boning room materials. Development of the process should be progressed with patenting of the process for rendering.

Further work to validate energy efficiencies would require the construction of a full production scale unit. Further work on the pilot plant would only be useful in investigating performance on other materials including mixed hard bone and soft offal materials.

On the success of the pilot trials on a range of materials, patenting of the process has been carried out. A patent has been granted in New Zealand with patents applied for in Australia and other countries.
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1 Background

As part of an ongoing program of research and development Keith Engineering Pty Ltd has reviewed the various benefits of high temperature rendering (HTR) and Low Temperature (wet) Rendering (LTR). As one outcome of this review, Keith Engineering developed the concept of airless rendering utilising superheated steam as the cooking, drying and sterilisation medium along with additional innovative equipment within the rendering process. Keith Engineering had at that time applied for patent protection of this process via Australian Patent Application No 527005. For internal use, the process became known as the Keith Airless Rendering Process (KARP).

Airless rendering involves cooking and drying at atmospheric pressure, using super-heated steam instead of hot air. At the initiation stage of this project, Keith Engineering have had a gel-bone drier in commercial operation in New Zealand utilising the superheated steam concept. In gel-bone drying only water evaporation is involved which differentiates it from the requirement for three phase separation required in rendering – water, tallow and solids.

The perceived advantages of the airless rendering system include:

- Almost total removal of oxygen from drying stream produces unique benefits.
- Increased energy efficient and improved environmental friendliness when compared to other traditional rendering techniques
- Cost effective solutions to a number of challenges facing the meat industry.

Keith Engineering’s principal activity is in the research, design, manufacture, installation and ongoing support to the Rendering Sector within Australasia and beyond. This has seen a dominant Keith Engineering presence for over 40 years.

Keith Engineering believes there is a clear signal from the industry that the issues of fluctuating product quality, lack of robust sterilisation data, poor energy consumption and at best, marginal environmental performance will not be acceptable into the future.
The successful commercialisation of the Keith Airless Drier at the Graeme Lowe Hawera site in New Zealand and in particular the realisation of direct benefits in; sterilisation, energy consumption and environmental friendliness, has resulted in the possibility of using the AIRLESS process across the entire rendering process.

Keith Engineering believes that an AIRLESS Rendering Process would combine the benefits of both high and low temperature conventional rendering whilst overcoming the disadvantages of each process.

The Keith Airless Rendering Process (KARP) would be the most significant development in the Rendering Industry over the past three decades. This project will enhance the commercial value of rendered by-products; reduce operating costs as well as relieving the pressure on environmental compliance.

To support this Keith Engineering has conducted a SWOT analysis and an analysis of market size, process aims, product capability, market placement, pricing & forecasting, product promotion and market competition. The outcomes of this are reported in Keith Engineering’s KARP Business Plan.

As a result of this analysis Keith Engineering believes that the KARP process has significant market potential.
2 Project objectives

This project aims to verify the technical potential of the process and construct a prototype unit to establish initial performance criteria for the process.

3 Milestone activities

3.1 Technical evaluation, including comparison with other systems

Greeneng's assessment was made on the basis of information provided by Keith Engineering on the airless drying concept and their learning from the gel-bone plant operating in New Zealand.
Claimed advantages for the process include:

- Airless heating and drying results in less odorous emissions
- There may be no need for antioxidants as the process takes place in an oxygen free environment
- There is no fire risk
- Good energy efficiency – 80.3 % in drier, 84 % in heat loop
- It is believed that meal lysine value and digestibility are improved
- No boiler is required to operate the system – excess steam is produced from the product. However, an external heat source is needed to start the process (not necessarily requiring a boiler).
- Some or all water is evaporated - the process may produce minimal contaminated stickwater
- Keith Engineering further believed that there will be no need for separate odour control for ancillaries – vibrating screen, centrifuge, surge bin, press. Keith Engineering aimed to direct all emission as combustion air to the combustion unit.

Keith Engineering has recognised that there may be problems with the following issues:

- The process does not meet current EU requirements for 20 min at 133°C at 3 bar (absolute)
- The design of the internal tallow screens had not been resolved and would be a critical issue
- Ideal steam temperature had not been established but up to 450°C was proposed
- The impact of live superheated steam in direct contact with tallow was unknown
- Tallow from the press may be low grade compared to tallow from the main process vessel.

Greeneng made the following summary comparison between various rendering systems and airless rendering in Table 1.
Table 1 – Rendering system comparison

<table>
<thead>
<tr>
<th>Process</th>
<th>Keith Engineering Airless Rendering</th>
<th>HT Rendering</th>
<th>LT Rendering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Material Sizing</td>
<td>Fine</td>
<td>Coarse</td>
<td>Fine</td>
</tr>
<tr>
<td>RM Heating</td>
<td>Direct product contact with SH steam at 450°C. Steam temperature drops along process vessel.</td>
<td>Indirect via steam. Typical steam temperature up to 150°C</td>
<td>Usually by direct steam injection with saturated steam.</td>
</tr>
</tbody>
</table>
| Source of steam          | From process – needs steam source to start up  
(\textit{Can also start up on hot air – therefore no boiler required}) | Boiler                                            | Boiler                                            |
<p>| Primary phase separation | Gravity separation of water and tallow from solids within process vessel. \textit{Some solids also discharged} | Water separated within process vessel by evaporation | Water/tallow separated from solids via screening/decanter/press following preheater |
| Secondary phase separation | Vibrating screen and separators produce refined tallow and stickwater. It is intended there will be much less S/W than typical LTR. | Tallow and solids separated via screening and press. Tallow refined in separator | Separators produce refined tallow and stickwater |
| Solids drying            | Via direct contact with SH steam in process vessel. Solids from vibrating screen may need drying. \textit{Later proven not to be required} | Not required – water removed in process vessel | Requires separate drier – eg steam heated disc drier, direct fired drier. |</p>
<table>
<thead>
<tr>
<th>Heat recovery or condensing of excess water vapour</th>
<th>Excess steam produced in process vessel removed in condenser.</th>
<th>Vapour from process vessel removed in condenser</th>
<th>Vapour from indirect heated drier removed in condenser. No heat recovery with direct fired drier.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Effluent (stickwater)</strong></td>
<td>Two streams:</td>
<td>Condensate high in ammonia and pH but otherwise a minimal environmental problem. Needs care to avoid odour problem.</td>
<td>Two streams:</td>
</tr>
<tr>
<td></td>
<td>#Condensate from excess steam – likely to be similar to HTR</td>
<td></td>
<td>#Condensate from indirect drier - likely to be similar to HTR</td>
</tr>
<tr>
<td></td>
<td>#Stickwater from tallow refining. If minimal, this will be a plus C/F LTR</td>
<td></td>
<td>#Stickwater from tallow refining. This is a major environmental problem – may contain +/- 10 % of tallow and meat meal if there is no recovery system.</td>
</tr>
<tr>
<td></td>
<td><em>(Elimination is preferred. Stickwater properties likely to be similar to LTR)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Meat meal lysine value (typ)</strong></td>
<td>Not known</td>
<td>Early pressure – 74 %</td>
<td>Up to 97 %</td>
</tr>
<tr>
<td><em>(Batterham, 1991(4)) (Data is for pigs)</em></td>
<td></td>
<td>Late pressure – 46 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>125°C, 4 hrs – 84 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>150°C, 4 hrs – 38 %</td>
<td></td>
</tr>
<tr>
<td><strong>Tallow quality (comparable RM)</strong></td>
<td>Not known. <em>Keith Engineering suggest two grades of tallow may be produced: #Prime grade ex the internal vessel screen #Second grade ex the meal press</em></td>
<td>Darker</td>
<td>Lighter. More tolerant of ingesta in RM</td>
</tr>
</tbody>
</table>

Greeneng made comments on the claimed advantages of the proposed process in Table 2 and on the identified key issues in Table 3.
### Table 2 Claimed Advantages

<table>
<thead>
<tr>
<th>Claim</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>With the SHS system there are minimal odours to treat – Biofilter or afterburner might be eliminated, or at least reduced in size, as capture of odour sources could be the combustion air source for the combustion unit.</td>
<td>In all rendering plants the process vessel is the source of low volumes of high concentration odorous vapours. Sources of high volumes of lower odour concentration must also be treated – crax and cake conveyors, presses, vibrating screens, decanters, polishers. A biofilter will most likely be required for these sources.</td>
</tr>
<tr>
<td>Oxidation – “if we could exclude oxygen from rendered material, we could all but eliminate or prevent oxidation”.</td>
<td>No comment</td>
</tr>
<tr>
<td>Reduced energy costs</td>
<td>Will be substantially less than conventional HTR systems.</td>
</tr>
<tr>
<td>Higher quality tallow and meat meal</td>
<td>No comment</td>
</tr>
<tr>
<td>Reduced greenhouse gases</td>
<td>In line with energy requirements</td>
</tr>
<tr>
<td>No fires</td>
<td>Fires are rare in rendering systems but likely to be lower than, say, direct fired drier systems.</td>
</tr>
<tr>
<td>Faster response to inconsistent raw materials</td>
<td>Inconsistent raw materials may well cause problems in ancillary equipment rather than in the process vessel. Eg, bones only usually cause operating problems with presses in HTR systems – this is controlled by mixing of fats/soft offal with bones. Otherwise, no comment.</td>
</tr>
</tbody>
</table>
### Table 3 Summary Comments on the Key Issues

<table>
<thead>
<tr>
<th>Issue</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Tallow Screen</td>
<td>No information has been submitted indicating how this will work. This is a critical design issue.</td>
</tr>
<tr>
<td>Stickwater</td>
<td>The objective should be no stickwater. Elimination of stickwater would solve a potential problem with downstream processing of solids from the vibrating screen. If these solids are wet can they be mixed with dried solids from the process vessel?</td>
</tr>
<tr>
<td>Impact of Superheated Steam on Tallow Quality</td>
<td>Not known – if adverse, it may mean that press tallow cannot be mixed with screened tallow. Operators would dislike the need for two tallow systems. Use of low grade tallow as fuel unlikely to be attractive.</td>
</tr>
<tr>
<td>Steam Generation</td>
<td>No boiler required. System can startup on hot air – the air has to be removed to a biofilter as water vapour builds up.</td>
</tr>
<tr>
<td>Equipment Sealing</td>
<td>Keith Engineering will need to carefully consider differential positive and negative pressures in ducting and the process vessel to ensure there are no leaks to atmosphere</td>
</tr>
<tr>
<td>Infeed Particle Size</td>
<td>Particle size will influence preheating, position of screen and quantity of solids removed at vibrating screen.</td>
</tr>
<tr>
<td>Metallurgical Issues</td>
<td>With expected steam temperatures up to 450°C, advice from a metallurgist in regard to material selection and manufacture is recommended.</td>
</tr>
<tr>
<td>Combustion Unit and Heat Exchanger</td>
<td>May be subject to fouling from particulate matter, non condensable vapours and tallow vapour in the vapour discharged and recycled from the process vessel.</td>
</tr>
<tr>
<td>Non condensable gases</td>
<td>To be continuously removed from the recycled vapour and directed to a biofilter</td>
</tr>
</tbody>
</table>
### Odour Emissions

Claim by Keith Engineering that there may be no need for separate odour treatment as all can be utilised in the combustion unit is unrealistic. A biofilter will be needed. In a recent design project for a HTR plant carried out by Greeneng, estimated non condensable vapours total 10 m$^3$/hr, all other sources to be treated totalled an estimated 350 m$^3$/hr.

### EU Compliance

Not considered a significant issue. Most plants rely on post sterilisation.
Greeneng concluded that:

- The proposed airless rendering system is an entirely new process whereby superheated steam is proposed as a medium for heating, drying and sterilising waste materials from abattoirs and the like. Further, the superheated steam is in direct contact with the materials being processed at all stages of the heating and drying process. Only in LTR systems with direct fired driers is there extended direct contact between the heating/drying medium and the rendered products.

- In principle, the proposed process has much to commend it, but some critical issues had not been adequately addressed at this stage. In some cases, definitive answers on the issues raised could only be answered by pilot plant trials. These issues must be considered in pilot plant design and where possible, facilities and/or time allowed for measurement of relevant parameters.

- It should remembered that the HTR process in both continuous and batch form still remains popular with industry despite the fact that, in general, they are less energy efficient, and produce meals and tallow/solids of lower quality than newer LTR systems. Factors that are considered to make HTR systems retain popularity include a combination of the issues shown in Table 4.

### Table 4 HTR popularity issues

<table>
<thead>
<tr>
<th>Issue</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost</td>
<td>HTR is generally lower. In LTR systems, costs are reduced by utilising direct fired driers.</td>
</tr>
<tr>
<td>Process simplicity and control</td>
<td>Considered comparable</td>
</tr>
</tbody>
</table>
| Process Wastewater           | Stickwater is a major environmental problem with LTR. Greeneng believes LTR stickwater should be evaporated with all tallow/solids returned to the meal system. This is expensive.  
                                | By comparison HTR condensate is benign.                                                                                                  |
| Odour Emissions              | Strong odour emissions are produced by HTR systems but are effectively controlled through capture and treatment in a biofilter.            |
|                              | The discharge from direct fired LTR driers is more difficult to treat effectively in a biofilter than most other rendering process emissions. |
3.2 Pilot Plant design by Keith Engineering

As a result of the successful desk analysis a “Go” decision to progress to conceptual and detail design was made with agreement by Keith Engineering, Meat NZ, and MLA. Keith Engineering prepared a series of engineering drawings showing the overall conceptual design of a pilot scale airless rendering plant and the necessary detailed drawings to construct the pilot scale prototype.

3.3 Assessment of Conceptual Design – Greeneng Pty Ltd

Keith Engineering provided drawings for a review of the design. These drawings included sufficient information on the design and details of construction of the pilot plant for an assessment to be completed by Greeneng. Greeneng recommended that the project proceed to manufacture and testing of a pilot plant constructed to the drawings provided. This recommendation did not imply that all issues raised in Milestone 1 had been resolved. However, Greeneng was confident that the design of the pilot plant would be suitable for testing the concept of airless rendering. It would also enable key issues of tallow screening within the rotating drum and stickwater to be adequately investigated, as well as issues of the impact of superheated steam on tallow and protein meal properties.

3.4 Purchase of capital equipment

An allocation was made in the project budget for the purchase of capital items required to construct the pilot scale prototype airless rendering plant. Capital purchases are itemised below.

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fans</td>
<td>$16,000</td>
</tr>
<tr>
<td>Heat exchanger</td>
<td>$22,000</td>
</tr>
<tr>
<td>Computer hardware</td>
<td>$18,000</td>
</tr>
<tr>
<td>Instrumentation</td>
<td>$21,000</td>
</tr>
<tr>
<td>Flue recovery</td>
<td>$8,000</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>$ 85,000</strong></td>
</tr>
</tbody>
</table>

This capital expenditure represented approximately 30% of the pilot plant construction cost.
3.5 Manufacture and commissioning of Prototype

3.5.1 Design & construction

Based on an evaluation of the concept design requirements the pilot plant sizing was decided as follows:

- **Evaporation Rate**: 125 kg/hr
- **Heat Source**: Electric 90 Kw
- **Foot Print**: 5000 x 2400 x 2400 Ht to suit normal transport
- **Self-contained**: Easily Relocatable
- **Variable**: Sectioned Drying Drum
  - 2 Banks of Electric Heating Elements
  - All motors fitted with Variable Speed Drives (VSD)

The KARP Pilot Plant was fitted to a fabricated steel frame, which is easily lifted by forklift or crane onto a standard flatbed truck. All components were designed for road transport and the complete unit could be placed in a 20’ shipping container.

The main single pass drum was designed in 4 sections. This allows for the drum to be lengthened or shortened if required.

The drainer section designed for tallow extraction could be reversed or exchanged with the third drum section, therefore giving variability to the tallow extraction, if required. The extraction screens were changeable and reversible. The design allowed for perforated screens, however, wedge wire or other types of screens could be fitted if required. The plant is supplied with a standard section, which does not include screen sections. All sections were designed to be reversible and interchangeable.

The electrical heat exchange was fitted with 2 banks of 45Kw heating elements. The Pilot Plant could operate with either bank of elements, therefore designing into the plant versatility and redundancy.

The unit was fitted with sight glasses at appropriate points and a light to illuminate inside the drum. Instrumentation was provided to relevant points throughout the process loop and additional fittings were in place for further instrumentation if it was required.

3.5.1.1 Material Handling

Inlet and Outlet Screw Conveyors were designed to allow for easy change of screw flight types and flight pitch if this was required.
3.5.1.2 Drum Flight

The single pass drum was fitted with lifting and feeding flights mounted on an independent cage to allow for modification and changeability to the internal flights. This was a completely bolted design and therefore very variable to suit possible changing conditions.

3.5.1.3 Drive

The drum drive was a robust sprocket assembly to allow for substantial variation in speed range for changing cooking and drying conditions. The drum was supported on two tyres and rotated with idler wheels and positioned by a tracking bearing assembly.

3.5.1.4 Material Selection

The process loop was constructed of a suitable austenitic stainless steel to adequately protect against corrosion and heat conditions expected throughout the trials.

Consideration was given to changing conditions during trials, which may have come from product changes or variations in water quality.

3.5.1.5 Computerisation

All drives and controls were designed and implemented with variability to allow changes in product and conditions. A computer with touch screen was installed and the pilot plant was controlled via Citec programming. A graphic display of the Drier allowed ease of human interface. Automatic control allowed the computer to keep the Drier within certain temperature ranges.

3.5.1.6 Ancillary Equipment

A heat exchanger was installed to keep the evaporated moisture from entering the atmosphere. A product transfer conveyor was added to allow the drier to be fed from a larger source of product.

A selection of photographs of the pilot plant prototype is included as Appendix 1.
3.5.2 Commissioning trial

A preliminary trial was conducted at Keith Engineering’s manufacturing site with 120kg of beef raw material sourced from the nearest rendering plant. This trial identified that the plant was capable of producing a crax tallow mixture that would be possible to press. This trial also identified that some improvements were needed including changes to the raw material screw feed system and the internal draining screen before the plant could be more extensively trialed at a rendering site.

As a result a shaftless feed screw was fitted and the internal draining screen removed. For remaining trials an external draining screen would be used.

3.6 Manufacture and commissioning of Prototype

A series of trials were conducted at AJ Bush’s rendering site at Rouse Hill in Sydney’s western suburbs. These trials allowed the pilot plant to be modified slightly to optimise performance and prove that capability of the pilot plant to render animal raw material to produce high quality crax and tallow.
4 Conclusions and recommendations from the final trial

By the end of the trials the KARP pilot plant had been proven to work effectively on boning room materials. Tallow and crax quality had been shown to be at least as good as product made from the same material using a continuous dry rendering process.

4.1 Conclusions

- The KARP process appeared to be able to effectively cook boning room raw material to a consistency where fat was released and the solids were dried sufficiently to be able to be pressed. Free run tallow was easily released and contained minimal water.

- Free run tallow should easily be able to be recovered using the internal perforated plate originally fitted but was removed after difficulties with poultry raw material.

- Steady state conditions were easy to establish and maintain during operation. High temperatures during operation should be avoided, as they will cause problems with tallow colour.

- Outlet product temperatures around 140 - 150°C will give good quality tallow, at least as good as standard product made from this material by AJ Bush’s continuous dry rendering process. Low temperatures around 110 - 115°C will also give good quality tallow but leave residual moisture in the crax.

- Preliminary evidence of the energy efficiency of the system indicated that the KARP was not as efficient as conventional continuous dry rendering process. (Conventional dry rendering 3.92 MJ/Kg of water evaporated versus KARP 5.4 MJ/Kg of evaporation). This is important, as the main support for the technology would be in the possible increased energy efficiency of
the system. It should be noted though that the energy and mass balances contained a number of losses that resulted from the small trial size and that would not occur in full production.

- There was no concern regarding stickwater as moisture content of crax or tallow can be controlled through maintenance of steady state conditions and feed-rate control.

- Some fatty solids were retained in the drum at the end of a run. However these solids should be commercially sterile so should only present a problem when the plant is not in operation for an extended period. There should be no greater problem with the KARP equipment than with current continuous cookers over night or over weekend breaks in production.

4.2 Recommendations

- The Keith Airless Rendering process is a technically feasible alternative to other rendering processes that produces high quality products from boning room materials.

- Development of the process should be progressed with patenting of the process for rendering and investigation of a partner to fund a full production scale unit.

- Further work to validate energy efficiencies will require the construction of a full production scale unit.

- Further work on the pilot plant would only be useful in investigating performance on other materials including mixed hard bone and soft offal materials.

Note: A video clip is available of the final trial showing the products being recovered from the process.
5 Patents

On the success of the pilot trials on a range of materials, patenting of the process has been carried out. At the time of this report, a patent has been granted in New Zealand with patents applied for in:

- Australia
- South Africa Application Number 2007/01579
- USA
- European Community (including UK)
- Canada
6 Appendices

Photographs of pilot plant prototype

General view of pilot plant  Discharge end view of pilot plant

Feed end view of pilot plant  Internal view of cooker drum
Control panel of pilot plant

Interactive screen of pilot plant

Cooker drum seal