Specialist Engineering Company Yeovil Site: Adiabatic Cooling System

Development Report May 2021 to September 2022

Prepared by Brian Smeeton, Hydro~Flo Environmental Ltd

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Hydro Flo Environmental

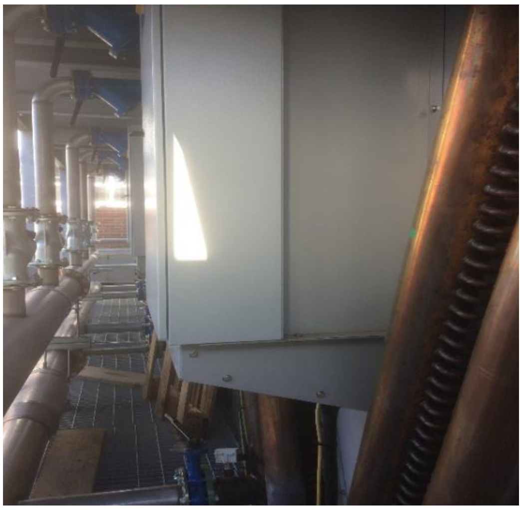
b.smeeton@hydroflowater.com
01884 861 747

1. System summary

This new adiabatic cooling system was installed in 2018 and it replaced the previous adiabatic system which had suffered extensive and irreparable damage - mostly in the form of leaks due to corrosion. This is an expensive one-off system and could be classed as a single point of failure (SPOF) in that if it fails, the systems and processes which it serves will come to a halt.

This report details what has been done to date to avoid another costly cooling system replacement and what further steps are required to help ensure that this system remains protected in the future.

The new system was built on a raised platform to help increase airflow across the coils. The system supplies cooled heat transfer fluid (HTF) to critical manufacturing and process machinery (some of which are over 50 years old) and is approximately 32,000 litres in volume. The new cooling system (and the equipment it serves) is of mixed metal construction. Some of the system construction is shown in the photographs below.



After cooling, the HTF fluid returns to a lidded retention tank situated at ground level. From there, it is pumped to the production equipment in the factory. Being located on the ground, the retention tank tends to act as a gathering point for existing corrosion particles and historical rust debris. This can be clearly seen where it collects on the tank floor.

The new system was flushed before adding the HTF and this action loosened additional existing debris which was removed. Due to the system age, these historical abrasive particles are seen as an inevitable but undesirable part of the system and need on-going management. This debris can be manually removed from time-to-time, and this will help control the potential damage from erosion corrosion.

The system was then filled with pre-mixed inhibited Heat Transfer Fluid.

2. Historical difficulties

The old system had suffered historical damage over the years, mostly due to corrosion.

However, on another part of the system (the essential cooling water spray bars) there was some patchy carbonate-based scale deposits noted on a few of the nozzles. This development could be seen on the nozzles themselves, the netting, and, in places, the cooling bundles. This scale was due to hard water (uninhibited town mains) being used for supplementary evaporative cooling during the summer months. Due to the potential for this to lower the heat exchange capacity, it was deemed necessary to have an anti-scale program in place for the spray bars.

This adiabatic cooling system can experience high end temperatures of up to 135°C but also low-end temperatures that would require freeze protection down to around -10°C. We also noted that the HTF level reduces very gradually over time because of the higher temperature levels experienced on some of the equipment.
On some occasions, large dilutions of the HTF reserve were noted. This was because site staff added town mains water in emergencies to make up for losses due to mechanical failures. This approach is understandable in an urgent situation, and it was carried out to keep production going, thus avoiding the associated losses due to shut down of the cooling system. However, the HTF in use, contains built-in corrosion and scale inhibitors which are designed to protect the system and any dilution with fresh water will lower the inhibitor reserve. This will potentially expose the system to corrosive attack, scaling, and of course, freezing in the winter months. It is therefore imperative that the minimum HTF reserve (20% v/v) is kept at all times to avoid scale and corrosion problems.

To always achieve the reserve, it was considered essential to install a system that could monitor the HTF level, display results at the point of monitoring and send alerts to operators informing them that the HTF reserve is low. This would help to highlight critical issues quickly, enable corrective action to be taken and avoid HTF dilutions. Furthermore, an auto-dose facility was required to make good any losses by dosing concentrated HTF (instead of water) and this action could be used to make up for the drop in protective levels of HTF. Gathering key data and sending alerts of impending problems to operators would also increase system management and control greatly.

3. A plan for controlling the historical difficulties

Connecting a new cooling system to production processes with historical damage can be problematic. Certain measures were therefore necessary to overcome (as much as possible) the compromised recirculating fluid conditions. The simple aim was to provide, or increase, the level of control in this vital system. It was decided to achieve this improved control in a planned manner by addressing the following areas:

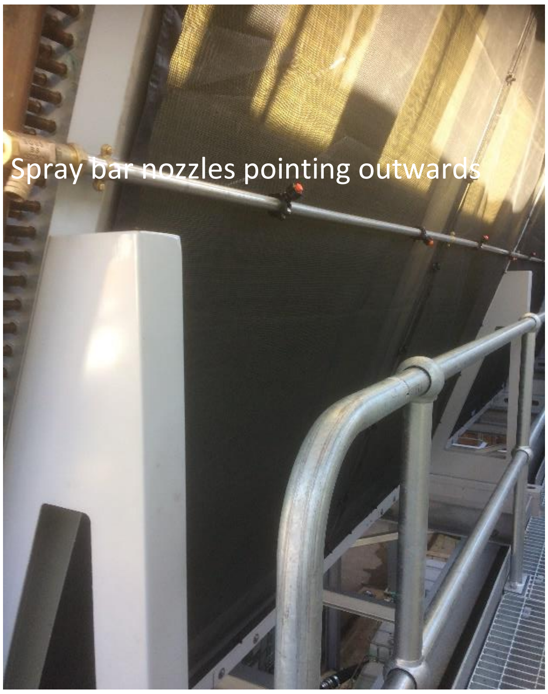
1) Ensure that the side-stream filter was working and regularly serviced✓
2) Add a further side stream filter - specifically aimed at removing abrasive corrosion debris from the retention tank floor✓
3) Ensure the spray nozzles and bundles were protected from hard scale formation by installing a proportional dose system for anti-scale, triggered by an impulse water meter in the make-up water line. The anti-scale agent would then be dosed to the spray-bar water supply line✓
4) Make-up for any leaks in the cooling system by dosing HTF concentrate and not fresh water✓
5) Install a corrosion rack on a by-pass line complete with corrosion coupons (6 different metals) to physically check and monitor the recirculating HTF protection performance✓
6) Track the HTF level in the system using a Cool Gauge RT-100, as, by keeping the HTF reserve above the minimum level, the built-in corrosion and scale protection is maintained. This is to be achieved by auto dosing HTF concentrate – this will also provide freeze and boiling point protection too✓

Installation of the above would follow the basic schematic guide shown on page 8.


Additional filters

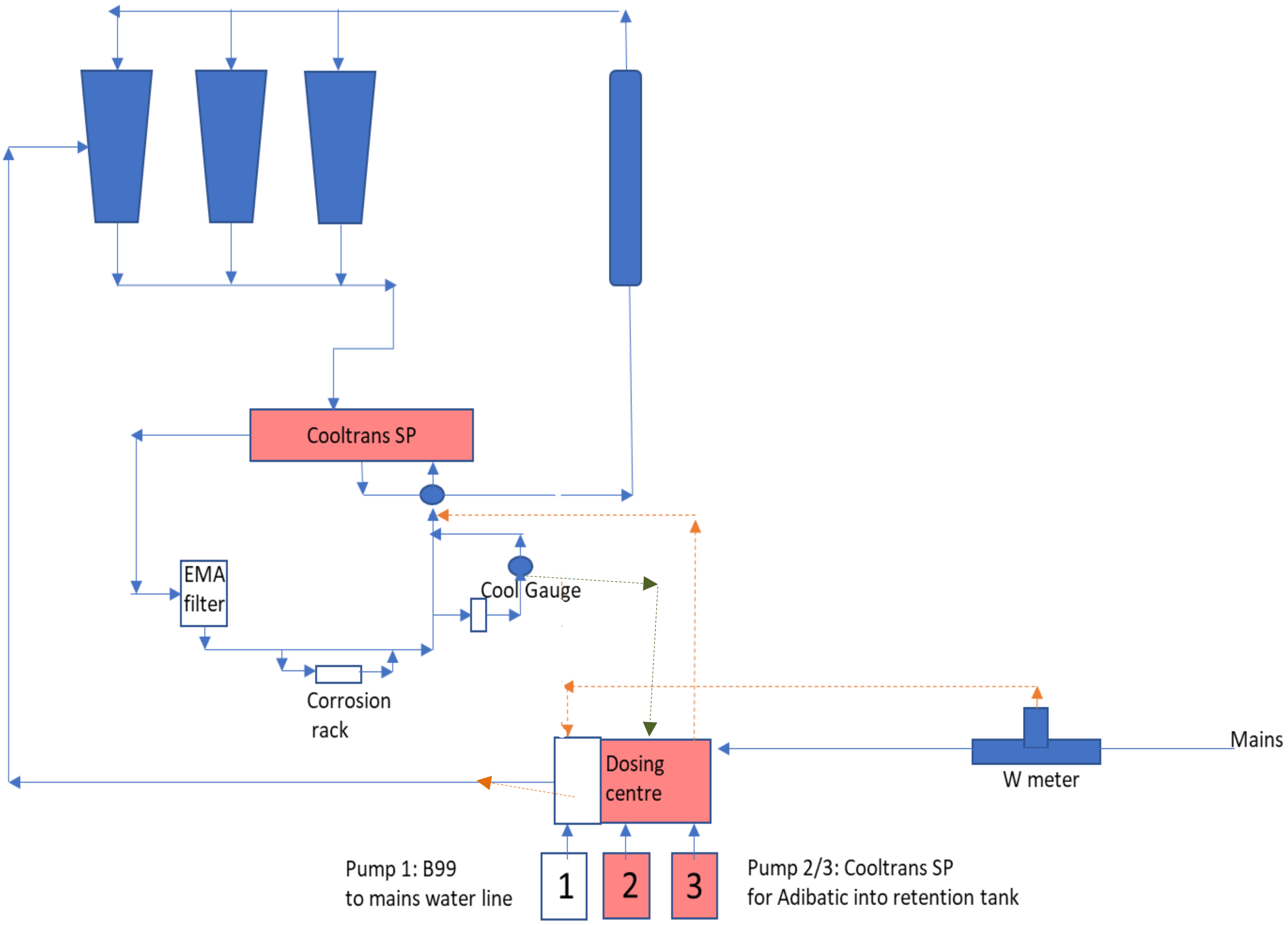

Historical debris


Anti-scale for spray bars


Spray bar nozzles pointing outwards


The corrosion rack assembly

Installation of the spray bar anti-scale system & the Cool Gauge RT-100



4. RT-100 - a summary of site requirements

It was decided to install and use the Cool Gauge RT-100 glycol sensor to help achieve the points summarized in the maintenance and control plan (as outlined on page 6). The reasoning behind the choice for the RT-100 was due to its technical capabilities and also the site's wish to recycle some older monitoring equipment for economy. To start to regain control the main points considered by the maintenance engineers are listed here:

- Re-use some old equipment and connect that equipment to the RT-100.
- The HTF in use is based on MPG and monitoring of this anti-freeze fluid is programmed into the RT-100.
- The push-button screen interface provides HTF choice if a different HTF is used in the future. Built-in temperature dependent equations are already programmed into the RT-100 and this allows monitoring all common anti-freeze formulations (%MPG, %MEG, %ALV, %ALV+ %BRIX, R.I, & %GEO).
- 4-20 mA output is available for auto-dosage.
- An RS-485 Modbus data output facility is available for remote viewing.
- The Cool Gauge system has a Bluetooth adapter, smartphone and APP capability for historical data gathering and the built-In data logger provides up to 56 Days of data all downloadable as a CSV file.
- Due to the outdoor placement the unit needed to be sturdy, and as the RT-100 device is made from 316L stainless-steel it is capable of withstanding harsh environments.
- The RT-100 is easily connected and removed via its stainless-steel Tri-Clamp flow cell assembly – this provides easy cleaning and maintenance.
- Full support and technical assistance are provided for the unit.

5. Enhanced system monitoring & management via Cool Gauge

There was a clearly identified need for greater control and management of the adiabatic cooling system. There is no back up for this critical cooling system, so concise system control and protection is vital if production is to be safeguarded. One of the key parameters to be kept under strict control is the HTF level as, by keeping the correct HTF reserve the system will receive the necessary all-round protection from the built-in corrosion and scale inhibitors. To do this, it was considered necessary to gather exact and meaningful HTF operating data from the system, and then react to that data to provide the required control of the recirculating fluid conditions. This monitoring supplies both point-of-use data and remote alerts which are sent to operators via text or email. This facility warns them of any impending problems such as drops in HTF levels due to leaks.

A Cool Gauge RT-100 was therefore installed to help provide the correct data to enable both remote monitoring facilities and an auto dose capability. The HTF is programmed to dose against set-points in the controller. The Cool Gauge RT-100 sensor is normally linked to its own dedicated controller (known as the UC-100G), but in this case, the RT-100 was linked to an Advantage Megatron controller. This controller was left over from the temporary Open Evaporative cooling tower which was used to supply cooling to the process water during the change-over from the old adiabatic system to the new adiabatic system. The controller assembly is built into a protective box which also holds the dosage pumps. These items were left over from the temporary open cooling tower, so they were also utilized to dose the HTF formulation and the spray bar anti-scale. The spray bar anti-scale agent is dosed proportionally to the mains water flow via an impulse water meter on a 4-20 mA signal. The water meter is installed on the incoming mains water make-up line and the anti-scale is dosed into the line supplying the spray bars.

6. Performance of the Cool Gauge RT-100

From May 2021 to date (July 2022) the Cool-Gauge RT-100 in-line monitoring system has provided a significant increase in the level of system examination with a corresponding advance in the level of control - details of which are described below. The RT-100 is the in-line sensor which is at the heart of the Cool gauge monitoring system. It monitors the refractive index of the HTF used by the site. The HTF used is based on MPG - but the RT-100 can also monitor other HTFs by simply selecting the required HTF from the OLED screen. The device is installed on a by-pass line (as shown on the schematic on page 8) and it constantly measures the refractive index of the HTF and converts this reading into the concentration of the selected HTF. The device provides an exceptional level of accuracy.

Traditional hand-held refractometer readings (measuring concentration, freeze point and R.I.) are used occasionally, and for the purposes of this study, to act as a double-check on the readings of the RT-100, (those shown on the RT-100 and controller screens) and the RT-100 has shown a remarkable degree of precision and proved exceptionally reliable. Of course, the manual tests are limited in scope and are only carried out monthly whereas the RT-100 monitors the system conditions on a full-time 24/7 basis and reacts to information gathered

Function - The RT-100 utilizes its built-in temperature dependent freeze curve equations to convert the measured sample temperature and corresponding refractive index into the percentage concentration of the HTF selected. The desired HTF is easily chosen from the OLED screen display using the up and down arrows as seen below. Typical operating temperatures for the RT-100 are -20 to +70 °C (-4 to 158 °F).

Cleaning - The RT-100 was placed in a by-pass line from the main recirculating loop and has a pre-filter installed to help remove any recirculating fluid debris thus keeping the sensor 'eye' as clean as possible. Recently, a sonic cleaner has been developed which can be retrofitted to the array to provide automatic cleaning on a time-selected automatic basis – installation of this unit may help to reduce any manual cleaning and ensure better recirculating fluid conditions.

Stand-alone - The Cool Gauge RT-100 can serve as a stand-alone device allowing operators to monitor the device manually, but in this case remote data viewing and auto-dose of HTF against set-points were required to help control critical recirculating fluid parameters and effectively manage any corrosion and scale issues. The RT-100 has 4-20mA and RS485 output capabilities and a data gathering function recording up to 56 days of data (or 80,000 data points) with readings taken every 5 minutes. Historical data can then be downloaded to a smart device as a CSV file via the Bluetooth adaptor and the APP – this can then be used to plot historical trends and show operating conditions.

Linking to the controller - The UC-100G is the usual controller for the RT-100 but in this case, an Advantage Megatron controller was used. When the RT-100 was linked to the Megatron controller the system became capable of auto-dosing corrective HTF fluids against controller set-points, and, if low or high-level settings are breached, the system can warn operators (in remote locations) by email or SMS. Viewing parameters remotely, via the Cool Gauge cloud-based website, became a major feature of the system as recirculating fluid details are viewed and monitored remotely by logging into the associated Cloud account from anywhere and at any time.

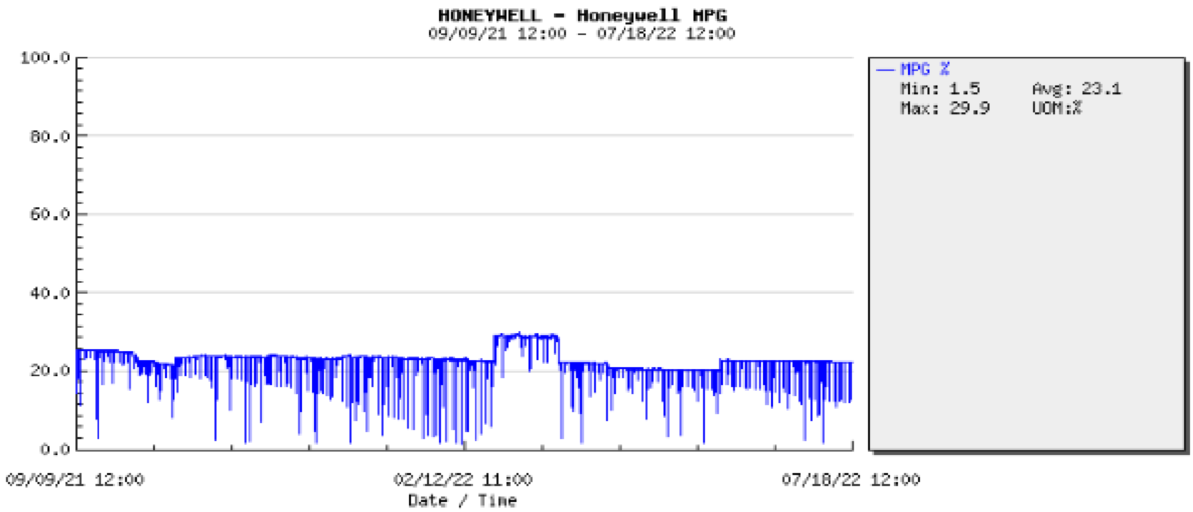
Additional warnings - Flashing warning lights were installed to warn against low chemical drum levels – this is a useful additional feature to attract attention to the low-level issue.

Connections - The RT-100 performs its functions via 4-20mA and RS485 Modbus capabilities and the system conditions can be seen and monitored (or altered) physically from the tabs on the controller screen itself or shown remotely in real-time via the Cool Gauge cloud-based website. These features help operators to achieve vastly superior levels of system control.

The site requirement was to be able to view the cooling system details remotely but, if required, the Cool Gauge system can be integrated with any microprocessor-based controller, display, PLC, DCS or BMS network.

Remote viewing - the system can be monitored, and real-time data can be seen via the cloud-based site. Below is a snapshot of how that control data appears:

10-month view



2 week view

Single day view

7. HTF drops, dips, rises and averages

Interpreting the site graphs - From the graphs on page 13 we can see some examples of the changes in the HTF level over set time periods. By logging into the Cool Gauge Cloud based website, operators can view the following:

- If required, you can view the actual HTF level on a real-time basis by accessing your Cool Gauge Cloud based website.
- The time scale you wish to view is specified in the menu – alter as required. Selected readings can also be 'zoomed' to show individual HTF readings at specific times or a specific point.
- If larger shot doses of HTF have been made to the system, the effects of that dosage increase can be seen as the reserve rises, hits a peak, and then forms a plateau. This happens as the HTF recirculates and mixes - the Cool Gauge system then adjusts to the new average.
- Steady or rapid drops in HTF reserves can be tracked over time – this may lead to the question 'is there a small leak?'
- Rapid drops in HTF reserve, i.e., those that breach the low-level controller set-point, indicate a more serious problem – an email or SMS will be sent to the operators and emergency action can be instigated.
- Once the low set point is breached, the auto-dose system will start. HTF will be pumped into the system to make up for the detected drop in HTF reserve. Dosage will stop as and when the upper set point is achieved. However, the most important thing is that the operator is made aware of the potential problem and can then investigate or initiate rapid remedial action.
- The straight horizontal line provides an instant guide of the averaged HTF levels. This is also reported numerically in the information boxes to the right of the graph.
- From the graphs, regular drops from the 'averaged' horizontal line, followed by a swift rise back can be seen. This indicates an air bubble may have temporarily attached to the sensor 'eye' – this is common and can indicate a foaming issue in the system and allows the operator to take remedial action, e.g., add anti-foam. Foaming can be operationally problematic so an indication that it is present is seen as a benefit.

The longer-term graphical view, shows clearly that the Cool Gauge RT-100 and controller held a steady reserve of HTF, demonstrating vastly improved control of the system – this is also reflected in the results of the corrosion coupons.

8. Physical demonstration of good HTF control

Corrosion Coupons – it was decided to install a corrosion rack with 6 metal coupons placed in the rack which represent the metals in the system. The metals are mild steel, copper, aluminium, stainless steel (304 and 316L) and admiralty brass. This would provide site with an actual demonstration of the effectiveness of the HTF dosing program, and the performance of the built-in inhibitors. The results below cover the period from May 2021 to November 2021 and the second set of reading are due in July 2022. See details below:

Analysis Results May 2021 to 25/11/21

Coupon Weight Loss

Test	Coupon Serial No.	ASTM D8039 Specification / mpy	SFD_2020_06 / mpy
Aluminium (AL 1200)	127	2.52	0.5626
Brass (CDA 443)	F5231	0.951	0.0017
Copper (CW 024A)	449	0.836	-0.0012
Mild Steel (1020)	1107	0.951	0.0005
Stainless Steel (316L)	12	0.951	0.0009
Stainless Steel (304)	08	0.951	-0.0028

** Negative number indicates weight gain.*

Analysis Results (below) – a further 8 months run in the system to 28/7/2022

Coupon Weight Loss

Test	Coupon Serial No.	ASTM D8039 Specification / mpy	SFD_2020_06 / mpy
Aluminium (AL 1200)	128	2.52	0.4507
Brass (CDA 443)	F5234	0.951	-0.0030
Copper (CW 024A)	601	0.836	0.0000
Mild Steel (1020)	1265	0.951	-0.0046
Stainless Steel (316L)	13	0.951	0.0010
Stainless Steel (304)	09	0.951	0.0006

** negative number indicates weight gain.*

It can be seen from the above that the recirculating HTF fluid containing the built-in inhibitors is providing very good corrosion control. Results are far below the limits set by ASTM D8039.

This is due to:

- Improved monitoring control through Cool Gauge (auto-dose) which also serves to focus attention on this system and its importance to production.
- Quicker response times (through remote monitoring) if larger HTF drops are noticed (system leak etc).
- The addition of occasional shot-doses of add-pack inhibitor if a steady decline in the monitored HTF is noticed (as shown in the Cool Gauge charts on page 13) which is carried out as a precautionary measure.

It should be noted that the above shows significant control of the recirculating fluid itself. However, corrosion debris (shown as iron particles) is only removed by filtration, bleed from low-points and occasional cleaning of the retention tank (to clear debris from gathering points) and this is an on-going task. A separate management strategy is underway to help combat and avoid the problems associated to erosion corrosion.

9. Proposed next steps

Conclusions so far - The above report demonstrates that the treated recirculating fluid conditions in the new adiabatic system have corrosion under control. Provided the conditions continue to be monitored and actions are taken from the data gathered it is likely to stay that way. Vital HTF fluid levels to protect against freezing have been constantly maintained.

Issues of concern – The most important issue of concern now is the level of iron particles being constantly released into the system from the old pipework and old equipment and the potential for this to cause erosion corrosion. Erosion corrosion is a combined effect and occurs when a rapid flow and particles are present - the rate of erosion increases in turbulent conditions and can result in leakages in tubes and pipes.

Erosion corrosion can be prevented or reduced through any of the following generalised methods:

- Reducing the turbulence of the fluid in the pipe.
- Control the velocity of the fluid to reduce high-flow velocities.
- Use corrosion-resistant materials.
- Use corrosion inhibitors and cathodic protection.
- Reduce the amount of oxygen dissolved in the fluid.
- Adjust the pH value of the fluid.
- Install an inline filter.

Many of the above cannot now be rectified or carried out. We can, however, address the following to help reduce any destructive conditions:

- Increase the level of filtration to remove particles from the retention tank on a more regular basis (the mobile filter rig)
- Drain and clean the retention tank at least twice yearly
- Shot dose inhibitors to maintain and repair any filming provided by the inhibitors on the metal surfaces
- Install an in-line combined (air) deaerator dirt separator such as the 1pass system (details already provided).

The Cool Gauge system continues to operate reliably and has helped the site to keep constant and on-going control to a level not previously seen. Being able to remote monitor this critical system has proven to be invaluable.

More details regarding Cool Gauge can be provided through the UK distributor as per the details below:

Dave Richards
UK Head of Sales
Tel. 0117 980 2520
Mob. 07866 540883
IDS Refrigeration Ltd (Climalife), 22 Apex Court, Woodlands, Bradley Stoke, Bristol, BS32 4JT

climalife®
www.climalife.co.uk
www.climalife.dehon.com