Welcome Everyone

CIBSE accredited Presentation by Gordon Pringle HASL – UK & Ireland Risycor Sole Distributors

become one of them and get #Risycord

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Est. 1982 also Tier 1 Technical Distributors for....

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BOA Group

BOA Group

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swep
CIBSE accredited Presentation by Gordon Pringle HASL – UK & Ireland Distributors Jan 2018

Preventing Corrosion by Continuous Monitoring
Water monitoring should not be considered simply as a retrofit once a system has gone awry, but properly included as part of the initial design. © Tim Dwyer, 2018.
Learning Objective

• This CPD module explains why, despite sound standards and guidelines many heating and cooling systems still suffer the often disastrous and costly effects of corrosion.

• The course explains what causes corrosion in closed systems and how it can be avoided.

• It goes on to show that continuous monitoring of system corrosion rates and other key factors can prevent the high costs associated with corrosion damage.
Contents

• Why do heating and cooling systems corrode
• The cost of corrosion
• What is corrosion and what causes it
• The role of oxygen and how it enters the system
• Methods for monitoring
• Why monitor for corrosion and pressure*
• Summary
• (Real life examples how monitoring can save systems)
Why do heating systems corrode?

- Sealed systems are designed to prevent corrosion
- In addition most systems in the UK are treated with corrosion inhibitors.
- There are many UK standards and guidelines all aimed at minimising corrosion.
  - ICOM Commercial Htg Systems Guide
  - Other European Standards are relevant i.e. VDI2035
  - CIBSE Heat Networks: Code of Practice for the UK (CP1)
  - CIBSE Heat Pump Installation for Large Non Domestic Building_AM17_2022*
Despite these old standards EVERYONE in the business has come across this
Ensuring Heat Network performance

- Heat networks are a crucial aspect of the path towards decarbonising heat.
- 17000 Heat Networks in the UK
- 90% of all connections are Residential
- Currently 2% of UK Heat Demand
- Cost Effectively 14-20% by 2030 & 43% by 2050
- In 2015 CCC est. 18% needs to be met for UK CRP
- Ambient Temp Loops inc. Heat Pump also driving forward development of these networks
- Greaves$^4$ illustrated that 15% of the 185 UK heat networks studied had suffered failures as a result of issues around water quality.
- Potentially 2573 Systems at risk now!
...and this
...or indeed this..
The real problem often remains invisible from the outside until it is far too late.
If systems are so well protected from corrosion, why has a whole industry developed around Power flushing and system cleaning?

41,600,000 hits on Google Search for the term Power flushing
Sales and variety of filters / magnetic dirt separators have exploded.
Which of the following may be contributing to corrosion problems?

- System design?
- Choice of materials?
- Modern high efficiency components?
- Cost cutting?
- Poor training?
- Poor maintenance?
- Incorrect / Poor chemical treatment regime?
- **Implication of Mixed Metals?**

All of these can lead to corrosion problems
There are many types of corrosion

- Uniform Corrosion
- Galvanic Corrosion
- Crevice Corrosion
- Pitting Corrosion
- Under Deposit Corrosion
- Microbiological Induced Corrosion (MIC)
- Intergranular Corrosion
- Erosion Corrosion
- Stress Corrosion
What is corrosion?

Without one of these components (uniform) corrosion cannot take place.
Corrosion is an electro-chemical process

- Iron Oxide (red rust) $\text{Fe}_2\text{O}_3$
- Magnetite (black sludge) $\text{Fe}_3\text{O}_4$
- Corrosion is not just limited to steel. It also effects, aluminium, stainless steel, brass and copper i.e. electropotential of metal and pH

In nearly all cases of excessive corrosion high levels of oxygen are to blame.
Eliminating one component (eliminates corrosion)

- Do not use water. E.g. Thermal oil
- Caution: Do not use st/steel or other metals e.g. plastics thinking issue is resolved!
- Eliminate oxygen from the system and keep it out
Implication of Mixed Metals

The ideal pH for passivity of metals in heating systems:

- Stainless Steel: pH 1 - 14
- Aluminium: pH 4 - 9
- Copper: pH 7 - 11
- Iron: pH 9 - 12.5

The formation of layers on metals and their stability is called passivation of metals. The metal itself becomes passive to corrosion. Below are the ranges for different metals.

www.heating-water.co.uk

pH-range According to VDI 2035
Eliminating oxygen is key - Initial fill

- Oxygen is held in solution in the water. How much can be dissolved depends on temperature and pressure. (Henry’s Law)

Drinking water contains approximately 10mg/l of O2.
- Initial fill cont.

• When the system is filled under high pressure dissolved oxygen levels will also be higher.
• Trapped air pockets after filling get absorbed
• Repeated draining and filling during pre-commission cleaning and commissioning adds more oxygen = more corrosion.

Danger! After pressure testing and / or cleaning a system must never be left empty!
O₂ is consumed shortly after filling in an untreated system.
How much Magnetite is created?

<table>
<thead>
<tr>
<th>Reason for oxygen ingress</th>
<th>Magnetite Once</th>
<th>Magnetite annually</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Restair 10%</td>
<td>91 g</td>
<td></td>
</tr>
<tr>
<td>2. First fill</td>
<td>36 g</td>
<td></td>
</tr>
<tr>
<td>3. Topping up</td>
<td></td>
<td>4g</td>
</tr>
<tr>
<td>4. Negative pressure</td>
<td>3658 g</td>
<td></td>
</tr>
<tr>
<td>5.1 Plastic pipe EVOH 500 m</td>
<td></td>
<td>130 g</td>
</tr>
<tr>
<td>5.3 Diffusion Butyl rubber hoses braided (50m)</td>
<td></td>
<td>5971 g</td>
</tr>
<tr>
<td>6.1 Diffusion expansion vessel</td>
<td>375 g</td>
<td></td>
</tr>
</tbody>
</table>

Source: NL ISSO 13*
How does $O_2$ enter the system?

- **Poor pressure control accounts** for 90% of all corrosion problems. Lack of understanding of EN12828.
  - Expansion Vessel **too small**
  - Pre-charge pressure too high
  - Pre-charge pressure too low
  - Loss of pre-charge pressure and lack of **maintenance**.
  - Incorrect Pump position (**neutral point**)
  - Defective bag or membrane (pump or compressor pressurisation*)

- **Leaks**
  - Automatic topping up with fresh water.
  - Compensation for water loss through Safety Valve. Usually due to incorrect pressure control!

- **Diffusion**
  - Rubber fan coil hoses (EPDM is highly permeable)
  - Non-barrier plastic pipes. Is the barrier **100% barrier**?
Position Matters

RISYCOR Corrosion Monitor positioned to monitor system corrosion rate at point of water make-up / refill to the system.

2 x 20mm branch connections at least 500mm apart. 20mm branch connections should be on the side of the main pipe, NOT top or bottom.

Shunt Pump, return to Boiler/Chiller.

Expansion pipe size =

*Required when using combined Vacuum Degasser & Pressurisation Unit
Size Matters
Permeation Matters on EV

- Loss of Pre-Charge & lack of maintenance

**Permeation Rate:** xxxx found their butyl material has a permeation rate of 0.2% per 14 days, and their EPDM material has a permeation rate of 1% per 14 day period. See below charts for annual air loss rates due to permeation.

![SEFA - Butyl Bladder Permeation](chart1)
![SEFA - EPDM Bladder Permeation](chart2)

**Conclusion:** These figures are relevant as they show the air loss rates of the Italian and Turkey bladder tanks and present further evidence that bladder tanks are leaking air at high rates through permeation alone. When coupled with air loss at the flange, the total precharge air loss is much higher and thus requires the customer to check and maintain the air precharge at regular intervals.
Methods of corrosion monitoring

• Traditional
  – Water sample testing
  – Corrosion Coupons
  – Removeable pipe sections
Methods of corrosion monitoring

• Advanced
  – Linear Polarisation Resistance (LPR method)
  – Sensors (PH, conductivity, O², etc.)
  – Corrosion Monitor (Electronic coupon method (ECM))
Continuous monitoring & recording with the ‘Electronic coupon’ method

- Direct corrosion measurement through loss of material mass. Not water chemistry
- Continuous measurement and recording
- Recording corrosion rate in microns (um/year)
- Lifetime analysis of corrosion activity is possible
- Instant VFC warning when corrosion rates rise to damaging levels
- Temperature recording and can validate TMon & improved seasonal Cx.
- Graphic output to assist with cause finding
Why monitor system corrosion?

• Although the corrosion process is fast it takes time before the damage becomes disruptive
• An early warning that the corrosion rate in the system has increased allows timely preventative intervention
• Water sampling is not very reliable and will not always reveal that there is a problem. For cost saving reasons it is often done too infrequently or not at all.
• Corrosion coupons are a sound method but only indicate a corrosion rate over a longer period of time (3 months) and do not give a VFC warning.
• The LPR (Linear Polarisation Resistance) is accurate but expensive
• Sensors that detect water quality can be useful but need expert interpretation, maintenance and recalibration.
• The newest method is the electronic coupon method. It combines the accuracy of coupons with the ease of reading and recording of a permanent sensor.
• BG29/2020, BG50/2021 Guidance and now CIBSE CP1 (2020) advises as best practice.

To be able to act in time it is essential to have some form of early warning or alarm system
Recording corrosion history

Detailed logging of **every change** in corrosion rate(s) and temperature since commissioning
Field Experience

• Some examples how monitoring can detect problems that could have led to severe corrosion damage and also maintain system efficiency.
  – Expansion vessel bladder ruptured (DE)
  – District Heating Gateshead (UK)
  – Resi biomass system without inhibitors (DE)
  – Perth Crematorium Refurbishment (UK)
  – Newbyres Care Home in East Lothian (UK)
  – Kells & Carlow School SC5 (NI)
  – Harvesters Way DH Edinburgh (UK)
  – Waterfront DH Edinburgh (UK)
Example 3- Apartment building with biomass boiler

- 1969 4 apartment building energy efficient refurbishment 2016/2017
- 31kw Biomass boiler
- 2.5 km UFH pipe, 1300 Ltrs
- Materials:
  - Pipe - Copper, barrier plastic
  - Boiler heat exchanger, towel rads and 1000l buffer vessel - steel
  - Heat stations with copper plate heat exchanger, brass fittings
Apartment building

- A Risycor corrosion monitor was fitted in the buffer vessel before first fill
- System filled with softened water (1500 l)
- No chemical inhibitors were added
- Deaerator and dirt separator fitted
- 200 l ‘Oversized’ expansion vessel fitted
## Output CXI Analysis

### Rob's Place CXI

#### Yearly Corrosion Rate

<table>
<thead>
<tr>
<th>Date</th>
<th>CXI</th>
<th>Status</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jun 15</td>
<td>19.57</td>
<td>Observe</td>
<td>1 Month, New System commissioned 5/12/2016</td>
</tr>
<tr>
<td>Jun 16</td>
<td>13.8</td>
<td>Healthy</td>
<td>Expansion vessel check 100l</td>
</tr>
<tr>
<td>Jun 17</td>
<td>7.45</td>
<td>Healthy</td>
<td></td>
</tr>
<tr>
<td>Jun 18</td>
<td>9.32</td>
<td>Healthy</td>
<td>System water demineralised in side stream (mixed bed) Exp. Vessel check 100l</td>
</tr>
<tr>
<td>Jun 19</td>
<td>12.3</td>
<td>Healthy</td>
<td>Immersion heater installation. Partial drain down and refill with demin water</td>
</tr>
<tr>
<td>Jun 20</td>
<td>11.2</td>
<td>Healthy</td>
<td>Solar thermal panels installed with partial loss of water. Refill with 280 L</td>
</tr>
<tr>
<td>Jun 21</td>
<td>2.72</td>
<td>Healthy</td>
<td>Readings taken 28.06.2022</td>
</tr>
</tbody>
</table>

### HOVAL Biotlty Biomass Heating System

<table>
<thead>
<tr>
<th>Year</th>
<th>CBU</th>
<th>CXI</th>
<th>System Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>19.57</td>
<td>Observe</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>13.8</td>
<td>Healthy</td>
<td>Expansion vessel check 100l</td>
</tr>
<tr>
<td>2018</td>
<td>7.45</td>
<td>Healthy</td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td>9.32</td>
<td>Healthy</td>
<td>System water demineralised in side stream (mixed bed) Exp. Vessel check 100l</td>
</tr>
<tr>
<td>2020</td>
<td>12.3</td>
<td>Healthy</td>
<td>Immersion heater installation. Partial drain down and refill with demin water</td>
</tr>
<tr>
<td>2021</td>
<td>11.2</td>
<td>Healthy</td>
<td>Solar thermal panels installed with partial loss of water. Refill with 280 L</td>
</tr>
<tr>
<td>2022</td>
<td>2.72</td>
<td>Healthy</td>
<td>Readings taken 28.06.2022</td>
</tr>
<tr>
<td>2023</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### System Volume 1400 l

<table>
<thead>
<tr>
<th>Water Make Up (l)</th>
<th>Water Make Up (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>7%</td>
</tr>
<tr>
<td>440</td>
<td>31%</td>
</tr>
<tr>
<td>280</td>
<td>20%</td>
</tr>
<tr>
<td>935</td>
<td>67%</td>
</tr>
</tbody>
</table>
Current situation after 5 years

- Very low levels of corrosion < 2 micron/year
- Low conductivity 40 micro Siemens
- Stable PH 8.6 - 10
- Water condition values are in line with VDI 2035

Water is totally clear
Example 4 Perth Crematorium
Example 4 Crematorium

80/60C F&R Htg & DHWS
400kW refurb Oct 2017
Expansion Vessel Line
PH1 2PE
Example 4 Crematorium

Perth Crematorium
LPHW Main Shunt Return Pipework

Report date: 09/08/2019

Corrosion rate

Temperature

(c) 2013 Resus nv

18/01/2023
Example 4 Crematorium cont..

LTHW Expansion Vessel Line / Make Up
Perth Crematorium

- Power on
- Alarm ignored
- X2_1524000062_p152400104_20200204
- Other faults

Corrosion rate

Temperature

Report date: 06/02/2020
Example 6 Kells & Carlow SC5

80/60C F&R Htg & DHWS
400kW New Build c 2019
119 Students & Staff
Ireland R93 X0FX
Example 6 Kells & Carlow SC5
Example 7 Harvesters Way EH14

70/40C F&R Htg & DHWS
400kW Peak New Build c 2016
183 Maisonettes, Flats & Town Houses
Edinburgh EH14
Steps

2. Install Resus PC Dashboard.
3. Open Resus PC Dashboard.
4. Disconnect power supply from the data logger and connect the mini-USB connector with a PC using a USB/mini-USB data cable.
5. Data will be downloaded automatically, wait until it is completed.
   (When it's not started automatically click on 'Analyse measurements')
6. You can zoom in on the graphs to get a more detailed view.
7. You can add installation name and location of the monitor if wanted.
8. You can save the measurements on your PC, you do this by clicking on 'Save sensor measurements to file'. A .csv file will be created.
9. You can save the graph image on your PC, you do this by clicking on 'Save image of graph'. A .png will be created.
**Method Statements used**

<table>
<thead>
<tr>
<th>System Details used</th>
<th>MS4</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Location</td>
<td></td>
</tr>
<tr>
<td>System Type</td>
<td>LTHW</td>
</tr>
<tr>
<td>Sample Point Location</td>
<td></td>
</tr>
<tr>
<td>Dosing Equipment</td>
<td></td>
</tr>
<tr>
<td>How is Chemical Dosed</td>
<td></td>
</tr>
<tr>
<td>Condition of Dosing Equipment</td>
<td></td>
</tr>
<tr>
<td>Biocide in Use - Type</td>
<td></td>
</tr>
</tbody>
</table>

**On-Site Analysis (where applicable)**

<table>
<thead>
<tr>
<th>Test</th>
<th>Control Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductivity μScm⁻¹</td>
<td>Reference 121</td>
</tr>
<tr>
<td>TDS</td>
<td>93</td>
</tr>
<tr>
<td>pH</td>
<td>&gt;8.0 &lt;10.5</td>
</tr>
<tr>
<td>Dissolved Iron mg/l Fe</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Total Iron mg/l Fe</td>
<td>&lt;15</td>
</tr>
<tr>
<td>Molybdate</td>
<td>300 - 500</td>
</tr>
<tr>
<td>Nitrite mg/l N</td>
<td>800 -1200</td>
</tr>
<tr>
<td>Hardness mg/l CaCO₃</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Tannin</td>
<td>100 - 150</td>
</tr>
<tr>
<td>Alkalinity mg/l CaCO₃</td>
<td>=mains</td>
</tr>
<tr>
<td>Chloride mg/l Cl</td>
<td>&lt;mains</td>
</tr>
<tr>
<td>Sulphate mg/l SO₄</td>
<td>=mains</td>
</tr>
<tr>
<td>Biocide</td>
<td>No</td>
</tr>
<tr>
<td>Micro Sample Taken</td>
<td>No</td>
</tr>
</tbody>
</table>

**Glycol % Solution**

<table>
<thead>
<tr>
<th>% Glycol</th>
<th>°C</th>
<th>Not Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>-3</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>-8</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>-14</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>-22</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>-34</td>
<td></td>
</tr>
</tbody>
</table>

**Comments**

Sample was clear and particulate free.
System should be dosed with a suitable scale/corrosion inhibitor.
### Harvesters Way EH14

#### Harvester Way

<table>
<thead>
<tr>
<th>Period</th>
<th>X2</th>
<th>System Status</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up To</td>
<td>AYCR (µm/y)</td>
<td></td>
<td>(Average Yearly Corrosion Rate)</td>
</tr>
<tr>
<td>11/10/2017</td>
<td>0.4</td>
<td>Healthy</td>
<td>New Installation</td>
</tr>
<tr>
<td>22/02/2019</td>
<td>1.46</td>
<td>Healthy</td>
<td></td>
</tr>
<tr>
<td>30/05/2019</td>
<td>1.51</td>
<td>Healthy</td>
<td></td>
</tr>
<tr>
<td>18/10/2019</td>
<td>0.63</td>
<td>Healthy</td>
<td></td>
</tr>
<tr>
<td>13/11/2020</td>
<td>3.11</td>
<td>Healthy</td>
<td>2 Corrosion peaks up to 50 µm/y due to expansion vessel maintenance</td>
</tr>
<tr>
<td>22/02/2021</td>
<td>2.19</td>
<td>Healthy</td>
<td></td>
</tr>
<tr>
<td>08/06/2021</td>
<td>4.47</td>
<td>Healthy</td>
<td></td>
</tr>
<tr>
<td>29/09/2021</td>
<td>2.04</td>
<td>Healthy</td>
<td></td>
</tr>
<tr>
<td>25/10/2022</td>
<td>3.08</td>
<td>Healthy</td>
<td>2 minor Corrosion peaks up to 30 µm/y due to maintenance</td>
</tr>
<tr>
<td>Total</td>
<td>2.3</td>
<td>Healthy</td>
<td>Low corrosion rate over total system life span</td>
</tr>
</tbody>
</table>

#### Temperature

![Temperature Graph](image)

(c) 2013 Resus nv
Example 8 Waterfront EH5 1HS

70/40C F&R Htg & DHWS
140kW Peak New Build c 2018
136 Flats & Town Houses
Edinburgh EH5
Waterfront EH5 1HS
What do standards and guidelines say?

As also explained in the Risycor Application Guideline, occasional spikes in corrosion rate (YCR) are usually not a problem. As far as we know, very little research has been done on corrosion rates in closed heating systems. This is possibly due to the fact that until now there has never been a practical, economical and accurate measuring method. Based on the extensive experience gained with thousands of Risycors in real installations, RESUS currently use:

<table>
<thead>
<tr>
<th>Average Yearly Corrosion Rate (AYCR)</th>
<th>Risk of Corrosion Damage</th>
<th>Result in the long term</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 7 μm/yr</td>
<td>Low</td>
<td>little chance of corrosion damage</td>
</tr>
<tr>
<td>7 - 21 μm/yr</td>
<td>Medium</td>
<td>corrosion damage probable</td>
</tr>
<tr>
<td>&gt; 21 μm/yr</td>
<td>High</td>
<td>serious chance of corrosion failure</td>
</tr>
</tbody>
</table>
Optimum Corrosion Monitoring

- Monitor circuits that reach to the top of the system and/or furthest extremities i.e. Index legs.

- Monitor close to cold feed (topping up) i.e. Shunt return*

- Monitor circuits containing plastic pipes or EPDM hoses which are not diffusion tight
CPLS2020 Digitisation

Construction is under-digitised

Productivity growth 2005-’14 CAGR, %
IoT – Smart Buildings

• “Smart Buildings deliver a solid foundation to enhance a building’s attractiveness, sustainability and efficiency”
  Robert Thorogood Hurley Palmer Flatt

• “Smart technology will actually make FMIs more valuable, as they can provide strategic guidance on all this data”
  Harry Badham MRICS, Axa Real Estate

• “The future of FM is more about predictability and less of a helpdesk” Phil Ratcliffe, Drees & Sommer

• RICS Modus FM in a post-pandemic world  Author: Helen Parton 3rd Sept 2020
Summary

- Despite many good standards and guidelines corrosion is still a problem. Not just PCS!
- Modern system components are much more susceptible to corrosion sludge. Therefore the problem will get worse not better.
- Corrosion inhibitors are not a universal miracle cure in isolation.
- By reducing O₂ levels it is possible to achieve very low levels of corrosion even without inhibitors.
- Corrosion caused by the first fill is minimal and not detrimental. Frequent refill is to be avoided.
- Correct pressure control/monitoring and minimising topping up is vital for enhanced corrosion control. Vacuum degassing make up water can only be advantageous if affordable.
- Monitoring corrosion should be mandatory to warn for sudden changes in the system. BG29/2020 has recently introduced Real Time Monitoring & Data Retrieval as has CP1 2020 Heat Networks. We commend BSRIA for this adoption to provide transparency. BG50/2013 Already had p76 6.6.4!
- Smart sensors such as the Risycor corrosion sensor sends alarms upon increased corrosion and records the entire corrosion history of the system.
- Greater consideration should be given to Northern European Standards DE VDI 2035 & pending* 2021-03 VDI 6044, Austrian ONORM H5195-1, ISSO NL Publication 13 and the Swiss SWKI for Hot & Cold Water plus Cooling Circuits, BE WTCB.
- Heard of the Golden Thread! Why it Matters…. Transparency is required as Condition based maintenance will improve TMon and Cx in delivering predictive maintenance.
NBS Source Collaboration
#RisyCord Come & Join Us
Thank you

Any Questions?

On behalf of HASL/RESUS we would like to thank you for attending this CIBSE HCSE Accredited CPD’s.

Gordon Pringle gpringle@hasl.co.uk

Feel free to connect with me on LinkedIn or follow me on Twitter @jugtastic67

Technical Due Diligence is coming more into focus!

(c) 2013 Resus nv
Get #Risycord – Where do they go?
Get #Risycord – Where do they go?
Interoperability

• BMS Volt Free Contact on all units
• Excel .csv file availed via PC dashboard & Risycom.
• Optional Cloud data (via router by others) which can be mapped back to 3rd Party software via API.
• Our Interval Temperature on all units will demonstrate good hydraulic control and energy efficiency of the circuit. Likewise short circuiting will present as an error code.