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Using engineered composite materials in sealless magnetic drive pumps to eliminate eddy currents and improve reliability

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Authors Biographies



- Ian Guthrie, is a business development manager with Sundyne, specializing in sealless technology. He has been working in the industry for over 18 years in engineering, manufacturing, sales and business development roles with 11 years at Sundyne.



- Samuel Stutz, is a Scientist with Greene Tweed & Co. He obtained a Masters degree and a PhD in materials science at the Swiss Federal Institute of Technology (EPFL)

Background – Pump application

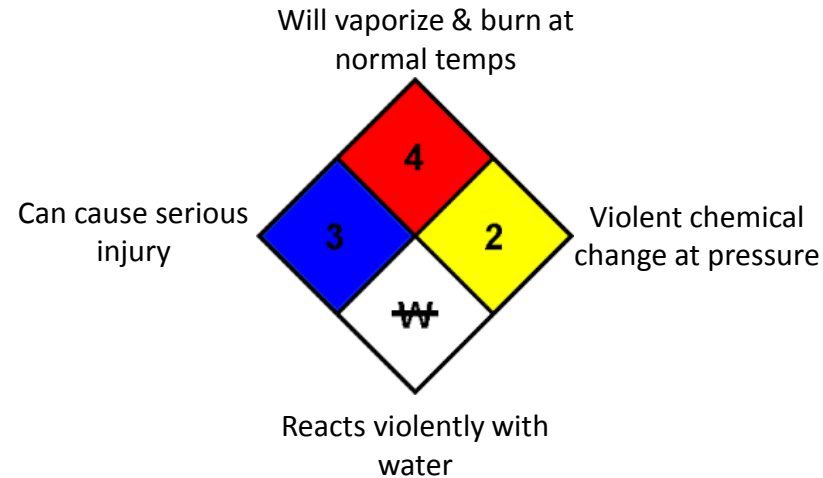
This case study is based on an application supplied into a Polysilicon production facility. The purpose of the application is to pump Trichlorosilane (TCS) liquid into the production process which allows the Polysilicon crystals to grow within a reactor.

The pumps were API 685 2nd edition compliant (parallel standard to API 610) and supplied with a secondary containment system per API 685 para 4.6.2.2

The pumps duty conditions were 217.5m³/Hr @ 120.5m (955 uspgm @ 395 Feet) and operating at rotational speed of 3500rpm with a 185kW (250 Hp)

Background – liquid characteristics

Trichlorosilane (TCS) is a challenging liquid to pump in terms of its liquid characteristics.



Problem statement

Pumps were installed and commissioned without issue

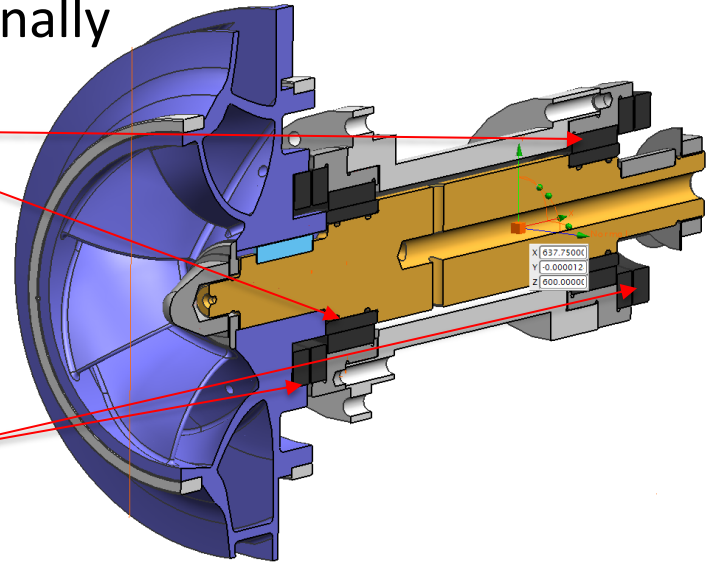
They then experienced premature failures on start up of process fluid. All three pumps in the system failed in the same way

Loss of the internal flow regime – DRY RUNNING

SiC bearing & thrust assembly failure seen internally

SiC bearing locations

SiC thrust assembly



Root cause analysis – Dry Running

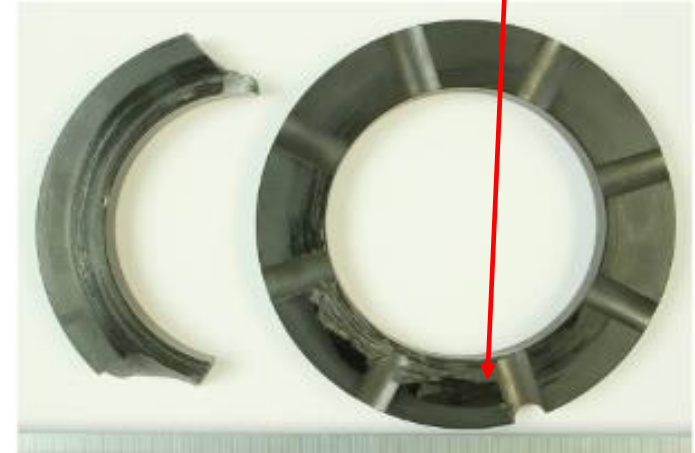
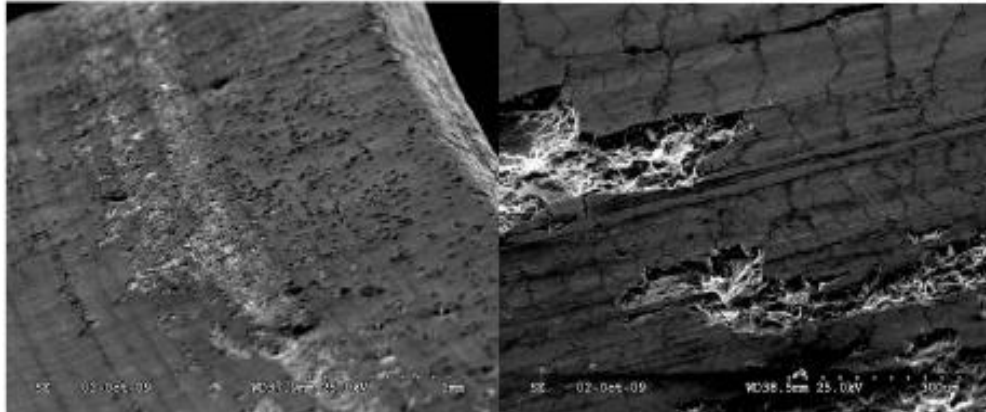
Thrust bearings exhibit face to face contact. further analysis validated the liquid was “flashing off” on the faces

- Hydraulic wedge is lost
- SiC has a high coefficient of friction
- Does not tolerate the loss of liquid and fails

Scanning electron microscope image

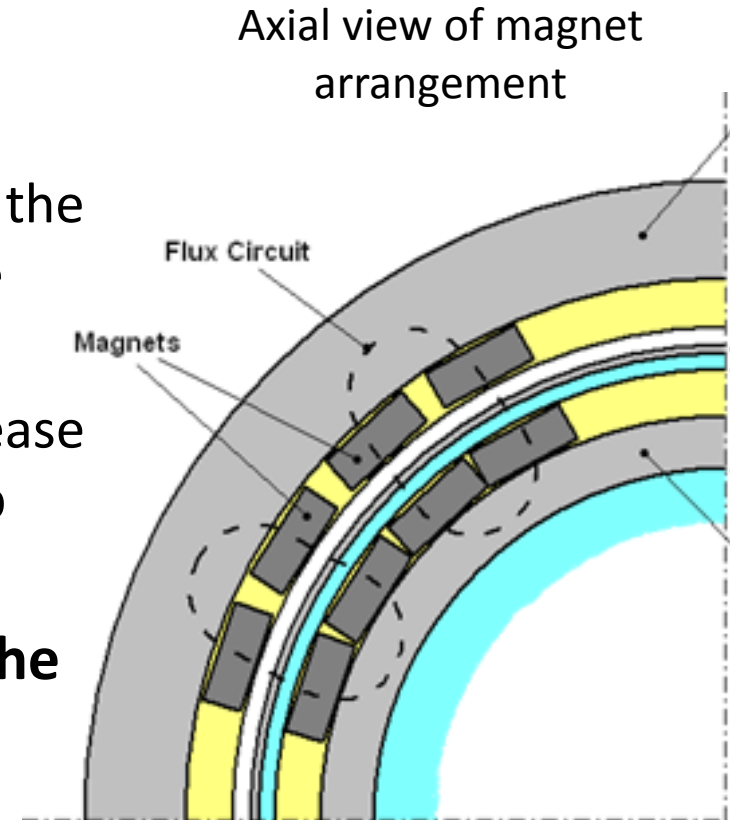
Magnification Factor x30

Magnification Factor x100



Root cause analysis – heat input

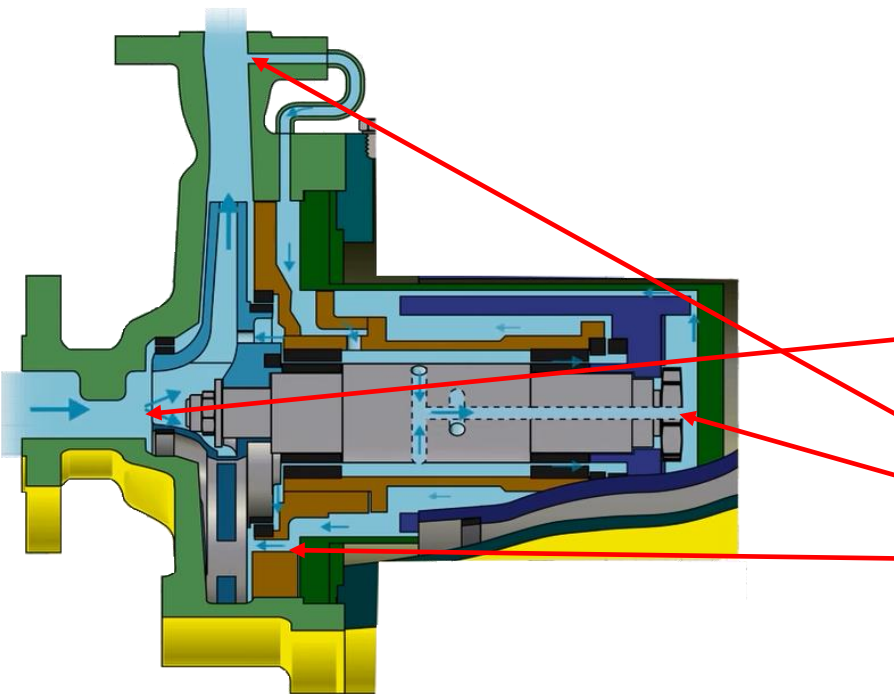
- One of the known “tradeoffs” of using magnetic drive sealless pumps is their lower levels of efficiency.
- The efficiency loss is due to Eddy Currents in the conductive containment shell induced by the rotating magnets.
- The Eddy Currents generate heat which increase the temperature of the fluid inside the pump (TCS)
- **Process liquid is used to cool/lubricate the pump**



Root cause analysis – heat balance

Validation of internal feed system

Takes Vapour Pressure, Specific Heat, SG into account ensures product vaporization does not occur in the internal flow regime.



A - Suction Pressure

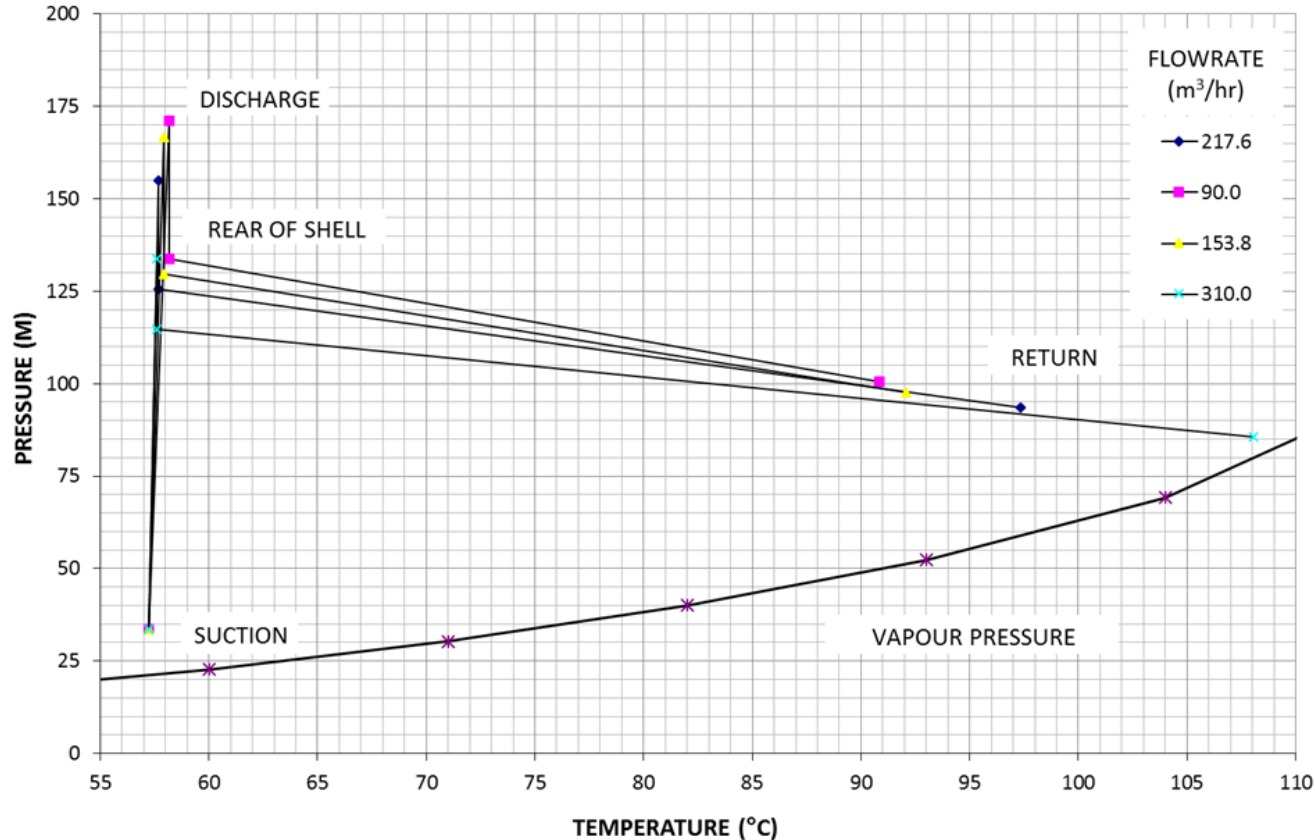
B – Discharge Pressure

C – Pressure at rear of Containment Shell

D – Pressure at return feed point

Route cause analysis – heat balance

PRESSURE TEMPERATURE PROFILE

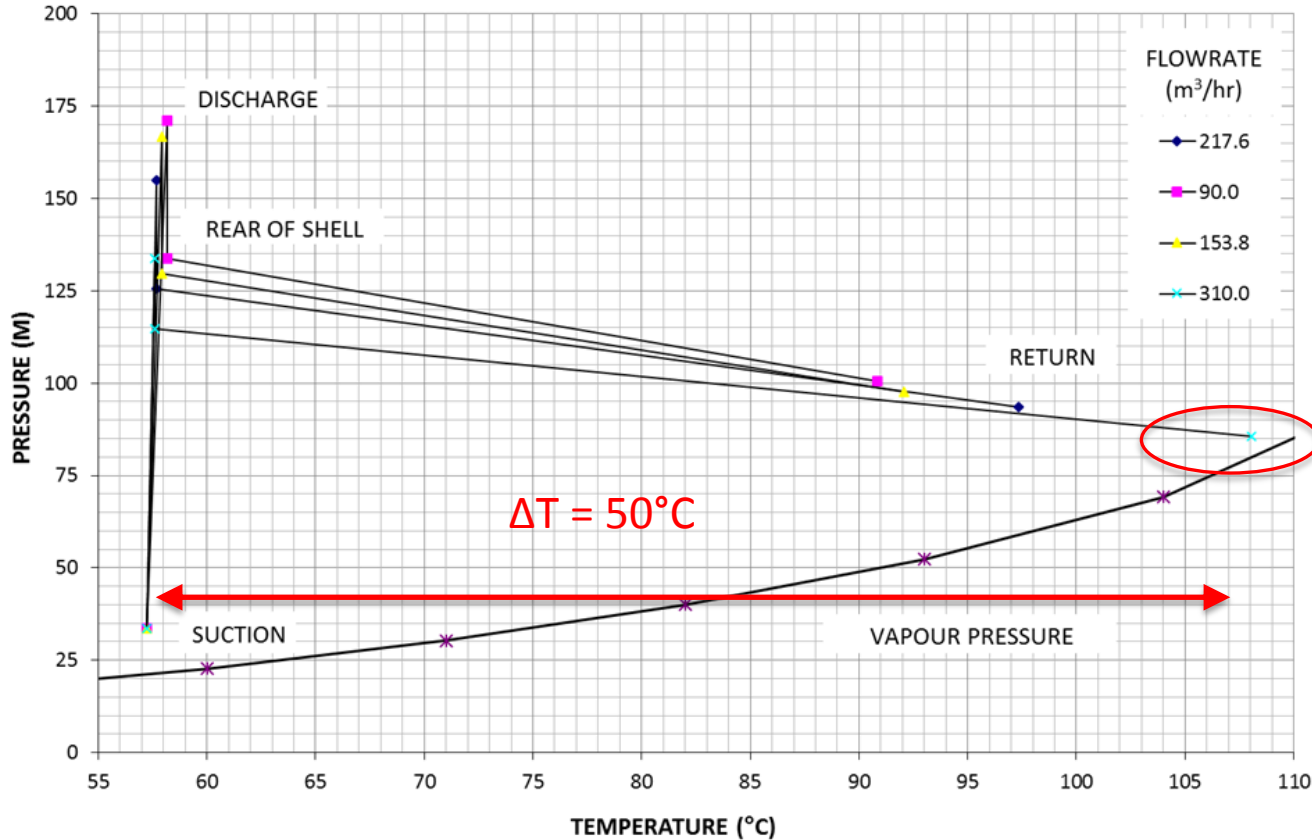


A thermodynamic calculation and the input of known variables such as Magnetic Coupling Losses

The other key inputs are liquid properties:
Specific Heat
Specific Gravity
Suction Pressure
Vapour Pressure

Route cause analysis – heat balance

PRESSURE TEMPERATURE PROFILE




In some conditions (possibly caused by system instability), it is likely the liquid will flash, and change state to Vapour.

This will have the impact of Vapour forming in the rear of the shell, eventually causing the internal bearings to dry run.

Solution – Reduce Heat Input

- The pumps operating conditions were fixed, as was the process system design
- So which parameters could we change/control?

Material	Electric resistivity [$\mu\Omega \times m$]
Hastelloy C276	1.3
Titanium (Ti 6 Al4V)	1.78
Zirconia (ZrO_2)	$>10^{16}$
Polymer/carbon fiber composite	150-200

$$P_{heating} = k \frac{\pi \hat{B}^2 \Omega^2 r^3 L e}{\rho}$$


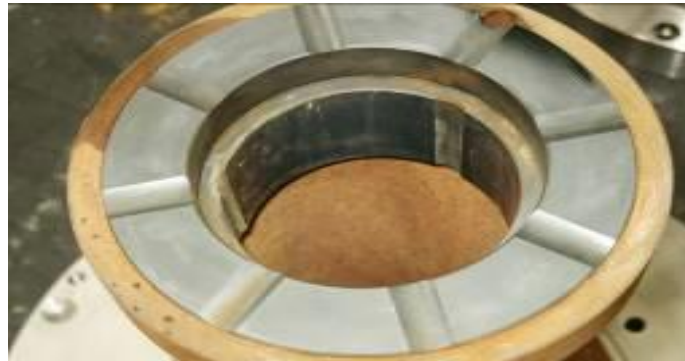
Replacing a Hastelloy containment shell by a composite containment shell reduces the heating power by 99%!

Solution – Composite Material

- The composite containment shell needs to support the same mechanical, chemical, and thermal load as the metallic version
- The composite containment shell has to function with only minimal changes on the geometry in order to allow for a retrofit
- Use 60% Carbon fiber reinforced PEEK advanced composite to make a shell
- API 685 compliant (40Bar) 580 psi

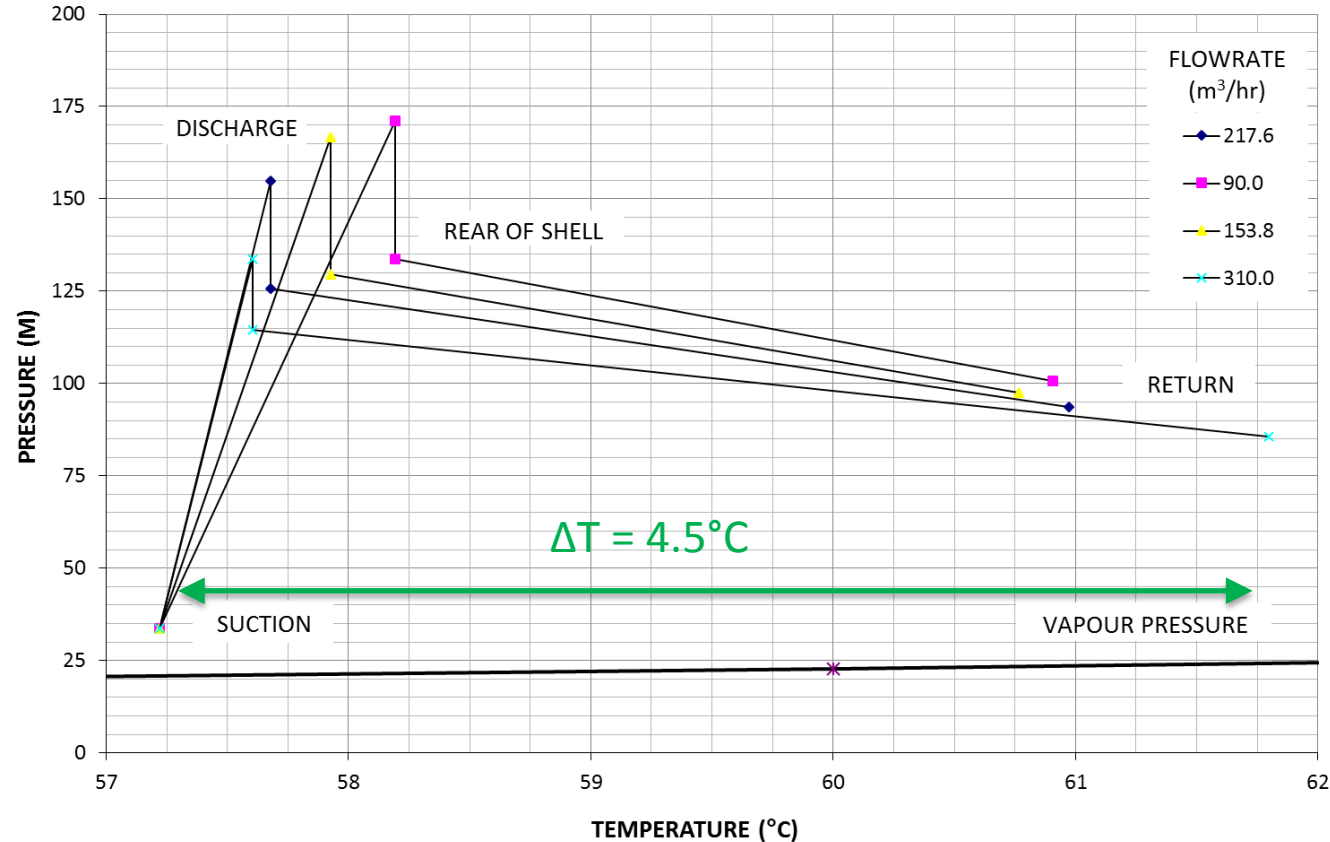


Solution – test stand validation of closed valve test



Solution – heat balance with composite shell

PRESSURE TEMPERATURE PROFILE



Significant reduction in heating into the TCS.

4.5C vs 50C.

- improves the margin to flash value
- pump does not experience Vapour issues
- More tolerance to upset conditions

conclusions

1. TCS is a very challenging liquid to pump and should be recognized as such
2. Applying an advanced composite containment shell affords a greater margin to flash making the pump more robust and more tolerant to partial dry-run conditions:
 - A reduction in differential temperature rise within the internal flow regime of 45°C
 - An increase in operational envelope
 - Significant increase in margin of safety between the Vapour Pressure and the Internal Feed Pressure
3. Applying an advanced composite also significantly reduces absorbed power
 - A reduction in absorbed power (From 153.5kW to 121.4kW)
4. Conditions on site may not always reflect those in the enquiries