Technical Information
Surface Casing Vent Flow (SCVF) Remediation
Winterhawk’s technology

- Winterhawk has developed a technically superior and lower cost suite of SCVF remediation and well-abandonment tools:
  - **Casing Expanding Tool** (CET) uses a rubber element capable of permanently expanding casing diameter by 1.5” or more to shut off SCVF or place plugs or permanent liners in wellbore;
  - **Mechanical Diagnostic Tool** (MDT) that uses the same rubber element to sequentially *elastically* expand casing to locate sources of surface casing vent flow (SCVF);
  - **Polymer-Modified-Asphalt Abandonment Tool** (PMAT), a *cement-less* abandonment plug with a 700-year+ lifespan and SCVF shut-in casing expansion capability.
  - **Expandable Liner System** (ELS) stainless steel casing patch expanded into place.
• Wells have a three-component matrix: steel, cement and reservoir geology.
• Steel is elastically and plastically deformable.
• Cement shrinks with age.
• Geology is varied and dynamic.
• SCVF sources such as shallow gas formations or “storage zones” are difficult to locate.
Simple solution – reforming casing shuts off SCVF

- Cement flaws include micro-annular leak paths caused by cement shrinkage, axial and radial cracks, wormholes and “short” cement tops.
- Steel casing is plastically deformed to repair cement flaws (“dry cement squeeze”).
- Shop tests have shown that a multi-expansion “labyrinth seal” is effective in shutting off SCVF.
- The casing expansion tool can deliver multiple expansions to assure that SCVF can be eliminated on first run.
Test device – 7” J55 17 lb/ft casing in cement

- Test device was designed to mimic a downhole cement sheath with micro-annular leak paths and wormholes.
- Cement was cured for 28 days.
- Test device outer 9¾” casing was drilled for pressure supply and monitoring taps.
Test device pressure/flow test

- Shop air pressure at 825 kPa (120 psi) was delivered to the bottom of cement annulus of the 7” casing OD and almost immediately showed leakage at surface and wire “wormholes.”
- Pressure at the two taps above the supply point inflated tattle-tale balloons.
- The 7” casing expansion was planned at three points, with annular gas flow checks after each expansion.
Winterhawk has a 200,000 lb/f and a 400,000 lb/f hydraulic setting tool.

Hydraulic setting tools will run all of Winterhawk’s downhole devices/systems.

An electric/hydraulic power head is being built to enable running tools on electric wireline by Q3 2019.
Rubber expansion element

- Tests have shown that shorter elements deliver more efficient energy transfer to casing.
- The 70-durometer rubber elements have been reused multiple times.
Inside casing view of 3-expansion “labyrinth seal”

• SCVF flow ceased after first expansion done at bottom pressure tap; the second and third expansions were done to assess expansion placement accuracy.

• The test device was left under pressure for 24 hours and no further leakage occurred.

• Test demonstrated the setting tool will allow multiple expansions to assure that SCVF can be eliminated on first run.
Test device radial cross section

- The test device was cut through the maximum casing expansion region.
- There is no visible gap on either the inner or outer diameter of the cement sheath.
- The wire wormhole devices are tightly held and there are no visible porosities in the cement.
• The middle expansion of the test device was cut length wise and the cut released hoop stresses in both the inner and outer pipe causing them to “spring” open slightly. (The gap visible here is not present in the intact pipe.)

• The cement sheath is mechanically intact with no evidence of fracture, fragmentation or loss of integrity.

• The compressed cement is denser and has a higher compressive strength than the original cement.
P&A plug – stainless steel pleated rings

- 4140 stainless steel is corrosion resistant.
- The number, width, profile and thickness of rings is designed to suit the well.
- PMA coated rings are plastically deformed to expand casing and seal the well.
Polymer-modified asphalt (PMA)

- Polymer-modified asphalt (PMA) acts as a pseudo-hydraulic fluid, lubricant and sealant.
- Varying the percentage of polymer allows a range of properties from a “rubberized” asphalt to an “asphaltized” rubber.
- At room temperature, the PMA is a solid with sufficient plasticity to move in response to the compressing rings.

The viscosity of the PMA at room temperature is demonstrated with this coffee cup set on top of the material.
• The PMAT’s design uses four components: steel spacers, stainless-steel pleated rings on a locking mandrel and polymer modified asphalt.
• The OD is very near to casing drift to maximize expansion of casing.
• The mandrel will be solid not hollow as shown.
PMA coating applied

- The plug is dipped into 130°C PMA bath.
- The PMA floods the interstitial spaces, displaces air.
- The plug is then removed from bath, water bath cools and PMA solidifies.
- The tool is ready to be run into the test casing.
Cut-away with mandrel and PMA removed

- The PMA acts like hydraulic fluid and applies radial pressure when the tool is compressed.
- The stainless steel rings plastically deform and hold the casing expansion in place.
- The mandrel has been removed for clarity.
Expandable Liner System (ELS) shop test

- The L-80 liner pipe is ⅛” thick.
- The wall thickness was turned down to ⅛₁₆” at both ends and a thin coating of PMA was applied.
- The PMA shear strength can be modified by a change in the polymer percentage.
The proof-of-concept test was successful.

The $\frac{1}{16}$" liner wall split on expansion (3⁄₄" axial tear).

The seal leaked at 200 psi.

Stainless steel liner material is recommended for the next test.
Field and shop testing highlights

- Tests in the shop and field show that casing expansion can be precisely controlled by axial force applied.
- The MDT has effected a 60% reduction in SCVF gas volume in field trials by elastically reducing micro-annular leak paths by as little as 0.016”.
- Shop testing of the PMAT tool demonstrated the capability of plastically expanding 5.5” and 7” casing OD by 1.5”+.
- Field testing with Husky in July 2018 demonstrated multi-run capability of setting tool and elements.
- Casing-cement-casing shop tests validated “dry-cement squeeze” theories.