

Crushable foam wrap mitigates subsea casing failures

A dual pressure/temperature trigger APB solution tackles extreme conditions in wells drilled in water depths greater than 1,600 ft.

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Annular pressure buildup (APB) has challenged the industry for many years. In some cases, thermal effects on trapped production fluids can cause such extreme pressurization in outer annuli that it leads to catastrophic failure of the production tubing.

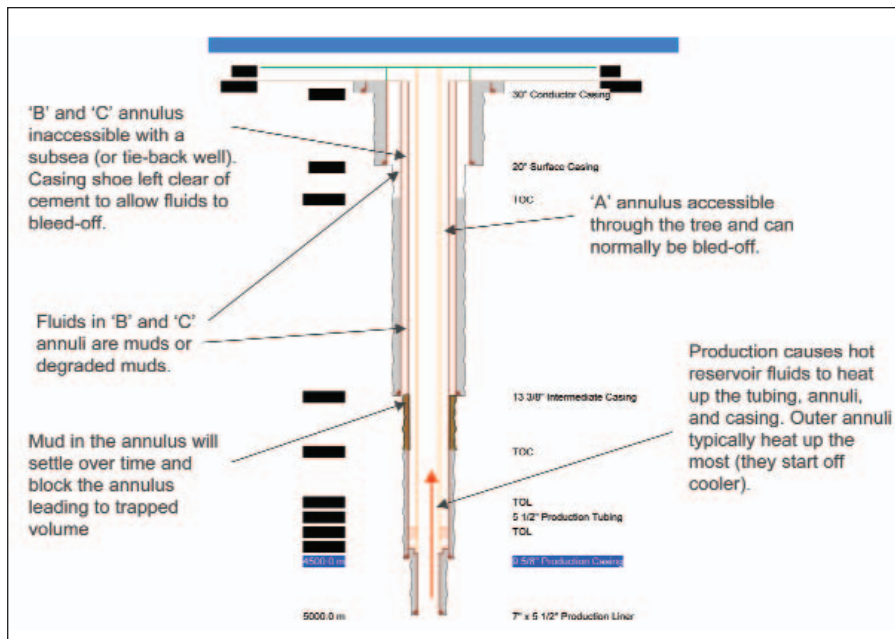
The increase in deepwater developments of greater than 1,600 ft (greater than 500 m), in which maximum flowing production temperatures can reach 350°F (176°C), has created the need for APB solutions that can be triggered by high temperatures and intense pressures of trapped production fluids.

Crushable foam wrap

Syntactic foam was originally developed by a Trelleborg company in the early 1960s to provide buoyancy in US Naval Submarine applications. Over the decades it has been further developed to become a key part of installations for the oil and gas industry where formulations are capable of withstanding beyond the extreme hydrostatic pressures found at 36,091 ft (11,000 m) of sea water (full ocean depth).

A request from Atkins Oil and Gas in 1991 spurred Trelleborg CRP to pioneer the development of crushable foam wrap (CFW) as an APB mitigation solution. Since 1994, CFW has been used in many subsea wells as a means of preventing APB buildup. It acts by reducing in volume by up to 33% at a pre-determined pressure or temperature and dissipates potentially hazardous increases in pressure. With an in-built thermal softening point safety feature, CFW acts as a mechanical fuse.

CFW is specially formulated syntactic



Production causes hot reservoir fluids to heat up the tubing, annuli, and casing, with outer annuli typically heating up the most, as they start off cooler. (Images courtesy Trelleborg CRP Ltd.)

foam comprising a rigid resin matrix infused with tiny glass microspheres. Typically installed within the “B” or “C” annulus of the well, CFW displaces the liquid that becomes trapped in the casing annulus when subsea wells are completed. Heat from drilling and production operations causes trapped fluids to expand. CFW is designed to collapse when sufficient pressure builds up or temperature rises above a specified point to allow expansion of the annulus fluids into the void created.

Trelleborg’s standard CFW APB solution has an operating range in excess of 4,000 psi at 140°F to 176°F (60°C to 80°C), which is sufficient to successfully meet the needs of many projects. But due to the demanding operating envelopes of an increasing number of deepwater developments, Trelleborg’s R&D labs turned their attention to producing an enhanced product to meet the more extreme conditions found in wells drilled in water depths greater than 1,600 ft and

with an operating range in excess of 220°F (104°C).

The result is CFW+, a high-temperature/high-pressure APB solution that is triggered by either temperature or pressure, rather than just pressure alone.

The operating range of CFW+ has been enhanced by modifying the resin system, which is also more resistant to water absorption, allowing improved downhole lifetime prior to use. CFW+ incorporates various grades of glass microspheres with high crush strength performance that, in combination with the improved resin, can operate at pressures greater than 20,000 psi.

Syntactic foam can be placed inside the previous casing shoe without significant operational challenges, or it can be bonded to casing prior to shipment to the rig and does not interfere with casing running or cementing operations. The foam can be formulated to collapse at a given pressure (and temperature) and is applicable to a wide range of wells and

conditions. In theory, there is also no current recognizable limit to the well depth in which CFW can be used.

System design

CFW is supplied in customizable quadrant cylinders typically 3.3 ft (1 m) long, which allows it to be handled and installed easily and located anywhere within the trapped annulus while still allowing the free flow of liquid. The quadrants are attached to the casing using a high performance acrylic adhesive.

The amount of CFW specified for a project is dictated by the “collapse volume” and “crush percentage” requirements within the annulus.

The collapse volume is the calculated volume increase of the annulus fluid brought about by thermal expansion between the installation temperature and the operating temperature. The crush percentage is the amount of compression the foam allows under isostatic load before catastrophic collapse.

The volume of foam required can be calculated from the collapse value and crush percentage. The amount of foam actually installed is typically increased by 20% of the calculated value to cover losses that can occur during installation or deployment and to provide a safety factor in the event that fluid expansion exceeds the calculated amount.

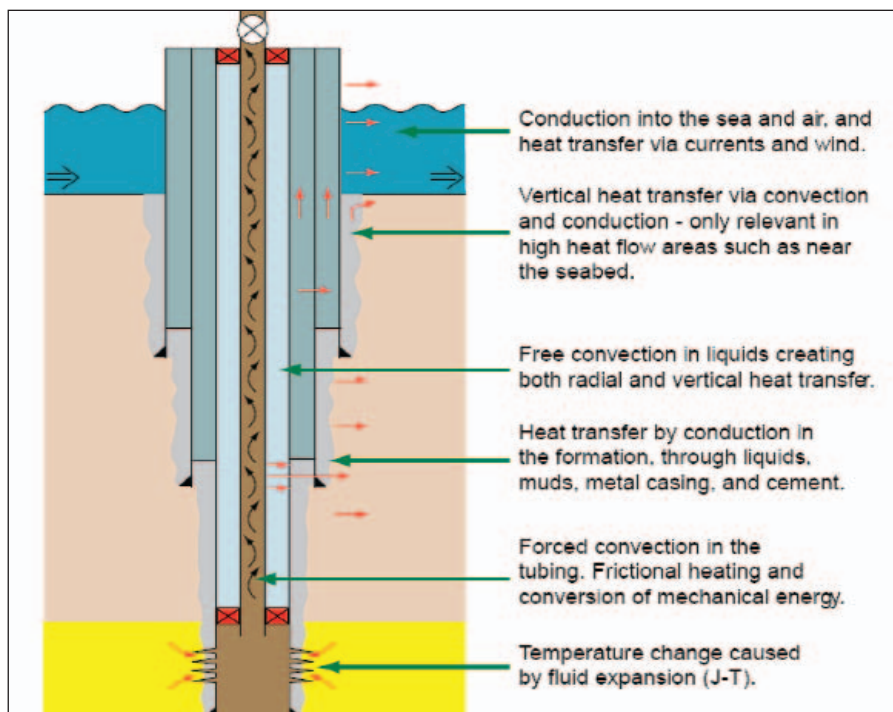
In the drilling start-up phase, the CFW remains *in situ*, with no significant volume change unless temperature increases beyond the collapse criteria.

As pressure and temperature in the well rise during operations, the voids within the CFW begin to collapse above the pre-defined temperature and pressure conditions relieving pressure in the narrow, confined space of the annulus.

The crush mechanism is progressive in nature over the pressure envelope, and complete failure is designed to occur well before the casing collapse pressure.

Measuring performance

TRACS International, a firm that delivers integrated studies and evaluations to the upstream petroleum industry, performed an independent assessment of the performance characteristics and projected use of CFW+ in “real case” scenarios to see if CFW could have prevented casing failure.



A 90°F (32°C) increase in temperature of trapped water can generate 11,500 psi increase in the annuli.

Using publicly available data (SPE 85113), TRACS was able to review a deepwater Gulf of Mexico well that suffered an APB-related failure of the intermediate and production casing and production tubing in 1999.

To replicate this scenario, TRACS calculated the following three conditions:

- Worst case “A” annulus pressure where “A,” “B,” and “C” annuli are all sealed, with hot, high-pressure production or hot shut-in;
- Worst case burst of uncemented production casing where the “A” annulus is sealed, with hot, high-pressure production or hot shut-in; and
- Worst case collapse of tubing with the “A,” “B,” and “C” annuli sealed with low pressure/hot production (approaching hot, evacuated case).

It was assumed that the “A” annulus pressure would be bled off through the tree, but that the “B” and “C” annuli would not have been bled off. It is also assumed that the shoes are blocked and that no mitigation equipment is installed.

Each annulus was considered in turn, with the aim of estimating the highest annulus pressure, the highest burst load on uncemented casing, and the highest collapse load.

TRACS used Wellcat (software for complex tubing and casing analysis) to perform the calculations based on a deep subsea well in 5,578 ft (1,700 m) of water with a 1.65°F (-16.8°C)/100-ft (31-m) temperature gradient — 296°F (147°C) reservoir temperature — and oil-based muds in the “B” and “C” annuli and brine in “A” annulus.

Analysis of the data predicted that annuli temperatures would rise to almost 300°F (149°C) during production and that 12 bbl of fluid needed to be removed from the ‘C’ annulus to lower pressure to acceptable levels. Calculations indicated that 40 bbl of CFW+ syntactic foam would have been needed to reduce the volume by 30% at a collapse pressure set at 2,500 psi and create a 12-bbl void. Adding the recommended 20% safety margin, TRACS concluded that the installation of 48 bbl of CFW+ in the “C” annulus would have prevented the APB-related collapse of the intermediate casing. CFW+ is an important tool in the drilling and completion engineers’ toolkit because it allows a formulation to be designed to match the specific collapse volume and pressure range for demanding deep and ultra-deep subsea APB mitigation needs. **ENR**