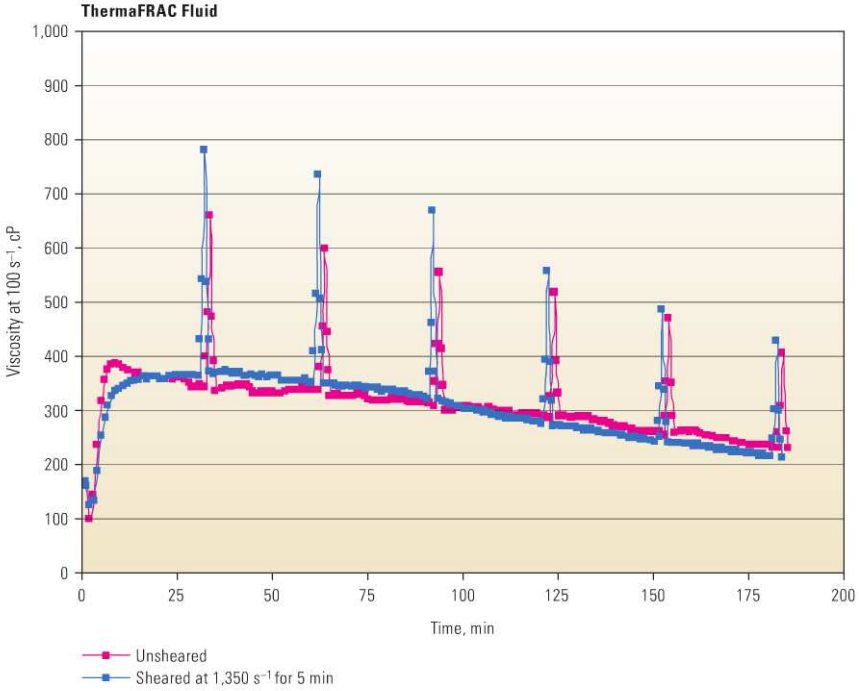
The operator approved a ThermaFRAC treatment that addressed the anticipated difficulties. The pad volume was unusually large—65% of the total job—and the CMHPG concentration was high—45 lbm/1,000 galUS [5.4 kg/L]—to compensate for the high leakoff rate.[34] To minimize friction pressure, the maximum pump rate was 12 bbl/min [1,908 L/min]. The proppant slurry placed 62,000 lbm [28,120 kg] of 20/40-mesh resin-coated bauxite at concentrations up to 8 lbm/galUS [961 kg/m^3] of fracturing fluid. Following the success of this treatment, the operator applied dual-crosslinker fluids in additional slimhole applications, including one in which 295,000 lbm [133,810 kg] of 20/40-mesh ceramic and resin-coated ceramic proppant were placed into a 74-ft [22.6-m] interval through 11,600 ft [3,536 m] of 2⅞-in. tubing. At this writing, more than 60 ThermaFRAC treatments involving 11 operators have been successfully performed in south Texas, at bottomhole temperatures between 121° and 191°C [250° and 375°F].

The new fracturing fluid has also been used to stimulate a gas-bearing HPHT sandstone reservoir in northern Germany. The average formation depth is 4,550 m [14,930 ft] TVD, and the BHT is approximately 150°C. BHPs vary from 25 to 30 MPa [3,630 to 4,350 psi], and the formation-permeability range is 0.1 to 5 mD. In this area, engineers usually perform fracturing treatments through a dedicated tubing string with the rig in place. To save money, the operator wanted to begin stimulating wells without the rig, pumping the treatment through the final well-completion string.

Fracturing fluids are usually prepared with ambient-temperature mix water. However, pumping a cool fluid through a finished completion would cause sufficient tubular contraction to exert excessive stress on packers and jeopardize zonal isolation. Therefore, to minimize thermal effects, it would be necessary to preheat the mix water to 50°C [122°F]. Zirconate crosslinking is temperature-dependent, and it was unlikely that reliable rheological control would be possible with a traditional single-crosslinker system.

To develop a solution, engineers conducted fluid-design experiments at the Schlumberger Client Support Laboratory in Aberdeen, Scotland. This facility has testing equipment that can simulate both the thermal environment and the shear environment anticipated in the German well. Test results showed that the dual-crosslinker fluid would allow sufficient leeway to design a treatment compatible with the operator's cost-saving goal.



^ Shear-history behavior of ThermaFRAC fluid at 135°C [275°F]. After prolonged exposure to a high shear rate in the shear-history simulator, the viscosity of ThermaFRAC fluid does not change significantly.

Engineers performed the ThermaFRAC treatment in a well with a 30-m [98-ft] producing zone, pumping 184 m^3 [48,600 galUS] of fluid with a CMHPG loading of 4.8 kg/m^3 [40 lbm/1,000 galUS], and placing 32 metric tons [70,500 lbm] of 20/40 resin-coated high-strength proppant in the fracture. The resulting fracture conductivity in this well was 250% higher than those of offset wells treated with conventional single-crosslinker fluids, and the production rate was 30% higher than the operator's prediction. Consequently, the operator has chosen this fluid to stimulate seven more wells in this region.

Certain types of HPHT reservoirs would not benefit significantly from matrix-acidizing or hydraulic-fracturing treatments. Perhaps the best examples are heavy-oil deposits, in which the preferred stimulation method involves oil-viscosity reduction by steam injection. Steam generation comprises approximately 75% of the SAGD operating expenses. Reducing the steam/oil ratio (SOR) and maintaining an optimal production rate are keys to improving profitability. Reducing steam input saves energy costs, decreases produced-water volume and treatment expenses, and curtails associated CO_2 emissions. A 10 to 25% SOR reduction may be achieved by using electric submersible pump (ESP) systems.

ESPs allow reservoirs to be produced at pressures that are independent of wellhead or separator pressures, thereby increasing steam-injection efficiency and decreasing the production cost by at least US $1.00 per barrel of produced oil. Numerous Canadian operators, including Encana, Suncor, ConocoPhillips, Nexen, TOTAL, Husky and

32. Guar gum, a powder consisting of the ground endosperm of guar beans, is used extensively as a food thickener. Guar-gum derivatives are purified and functionalized products with good thermal stability. Common derivatives for hydraulic-fracturing applications include hydroxypropyl guar (HPG) and carboxymethyl-hydroxypropyl guar (CMHPG).
33. Friction-pressure loss is the pressure decrease arising from frictional losses that occur as a fluid passes through pipe. The pressure decrease is mainly a function of pipe diameter, pipe length, fluid rheological properties and flow rate. High friction reduces the available fluid pressure at the pipe outlet.
34. Fracturing treatments consist of two fluid stages. The first stage, the pad, initiates and propagates the fracture. The second stage, the proppant slurry, transports proppant down the tubulars, through the perforations and into the fracture.