

Thermally Insulating Packer Fluids

By Weyman Dunaway

Deepwater Interest

One deepwater project manager recently stated that, "Flow assurance and thermal management are the principle drivers of ultra-deepwater riser design." Thermally insulating packer fluids are aimed directly at flow assurance and thermal management issues, because they provide insulating benefit in addition to their traditional role of providing hydrostatic head. Several operators and engineering firms have expressed strong interest in thermally insulating packer fluids as evidenced by the large number of technical presentations at the 2002 Offshore Technology Conference.

Several supply and service companies have responded to this technical need and customer interest by developing thermally insulating packer fluid products. TETRA Technologies, Inc. is now marketing its new ThermaFix™ insulating packer fluid—an advanced, second-generation insulating product. This article discusses the technical requirements for thermally insulating packer fluids and TETRA® chemists' development efforts to meet those requirements.

Temperature Retention versus Heat Transfer Coefficient

Common sense suggests that adding insulation is more cost effective than buying a bigger heater. The same is true for insulating pipes; you may still need a heater, but the heater can be smaller and less complex if you insulate first. Therefore, a primary consideration for insulating packer fluids is their insulation value.

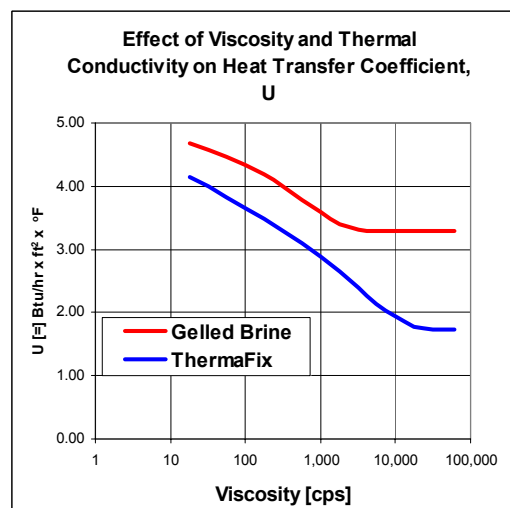
Some vendors have expressed the insulating value of their products in terms of temperature retention. Because it ignores surface area, time, and energy flux, temperature retention is an inadequate method of quantifying insulation value. A more useful method of quantifying insulating value is the overall heat transfer coefficient, U , and U has the dimensions of:

$$U [=] \text{Btu/ft}^2 \times \text{°F} \times \text{hr}$$

Convection versus Thermal Conductivity

The three modes of heat transfer are conduction, convection and radiation. Radiation is rarely a factor in oil wells. Calculation of a riser's heat transfer coefficient with conduction and convection effects involves a complex set of equations that are best performed on a computer simulation program such as OLGA.

The following graph shows the relative effects of convection and thermal conductivity on the overall heat transfer coefficient for a hypothetical deepwater riser using different packer fluids:



In this scenario, adding viscosifier to conventional brine eliminates convection losses at about 1,200 cps and reduces the overall heat transfer coefficient by about 30%. Reducing the thermal conductivity by 70% reduced the heat transfer coefficient by another 30%. Therefore, convection and conduction effects are equally important for an insulating packer fluid.

Measuring Thermal Properties

One approach to developing a better insulating packer fluid is to measure properties such as thermal conductivity and specific heat. However, TETRA has found that commercial Thermal Conductivity Laboratories can report results that differ from published values by as much as 50%. Therefore, care must be taken to select a lab that gets results similar to published values for known materials in the range of interest.

The onset of convection is a very low shear phenomenon. Most of the insulating packer fluids are non-Newtonian gels, so it is important to measure the viscosity at very low shear rates. TETRA measures very low shear viscosity of insulating packer fluids at 0.09 sec^{-1} (0.05 rpm); that is one revolution every 20 minutes.

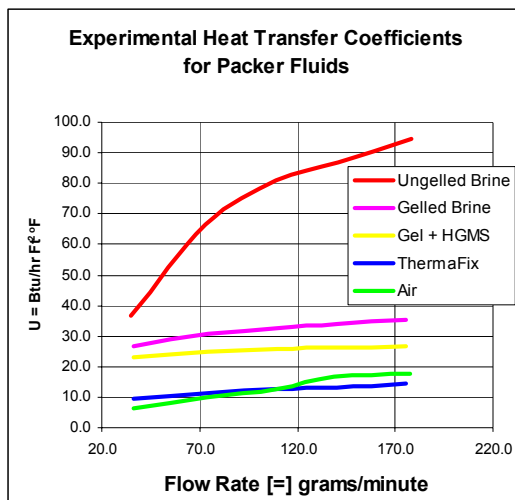
TETRA recognizes that computer models and property measurements can be instructive; however, they are no substitute for also measuring heat transfer coefficients in a realistic geometry. Therefore, TETRA has designed and

constructed a 20 foot thermal flow loop to measure the heat transfer coefficients of packer fluids in an offshore riser configuration:



TETRA's Thermal Flow Loop

TETRA's thermal flow loop consists of a production string surrounded by a casing string filled with packer fluid. The riser assembly is surrounded by a jacket containing chilled water. Hot fluid is circulated through the production string. Temperature measurements and flow rates allow the calculation of the measured heat transfer coefficient. The following plot shows typical results from the 20 foot thermal flow loop:



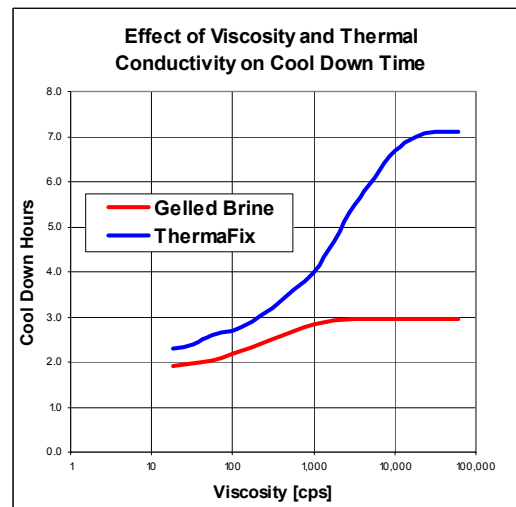
The very non-linear results for ungelled brine are characteristic of a material that demonstrates both conductive and convective

heat transfer. Gelling the brine makes the heat transfer coefficient both lower and more linear.

The Gel + HGMS curve is particularly interesting because it represents a mixture of gelled brine and hollow glass microspheres (HGMS). The HGMS were tested as a means of lowering the thermal conductivity of the gelled brine. These results show that HGMS is beneficial at lowering the heat transfer coefficient. However, HGMS is thermally inferior to ThermaFix.

Cool Down Time

Another key attribute of insulating packer fluids is Cool Down Time (CDT)—the time required for the riser to cool down to the hydrate formation temperature after production has been interrupted. CDTs depend on the composition of the produced fluid, the riser geometry, and the thermal characteristics of the packer fluid. So, OLGA simulations are also used to estimate CDT. The following plot shows the effect of viscosity and thermal conductivity on CDT for the same hypothetical offshore riser used in the heat transfer coefficient study:

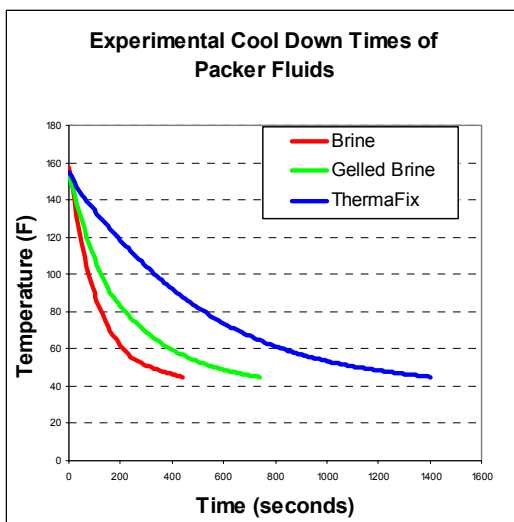


Gelling the brine increased CDT by about 50%. Reducing the thermal conductivity by 70% and viscosifying increased CDT by more than 270%.

Again, being mindful of the need to actually test CDTs, TETRA has designed and constructed a cool down tester as shown in the next photograph:



TETRA's cool down tester consists of a jacketed glass column fitted with temperature sensors on each end. The inside of the column is filled with hot packing fluid. Then, chilled water is circulated through the jacket. A computer logs the temperatures inside the packer fluid and averages the two RTDs. Typical results are shown in the following plot:



The time required to cool these fluids from 150°F to 60°F was:

Experimental Cool Down Times (150°F to 60°F)			
Fluid	Seconds	% Increase	Computer Simulation
Brine	210	Basis	Basis
Gelled Brine	397	89%	50%
ThermaFix	807	280%	270%

These experimental results show remarkably good agreement with the computer simulated data.

Conclusions

- The key attributes for an effective insulating packer fluid are heat transfer coefficient and cool down time.
- Gelling the packer fluid alone has benefits; but gelling plus lowering the thermal conductivity provides even greater benefits.
- ThermaFix exceeds the thermal performance of gelled brines and gels filled with a proven insulator such as hollow glass microspheres.



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