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## High Performance Water-Based Insulating Packer Fluids

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### Abstract

Deepwater production well design and equipment installation presents a host of challenges for operators. One of the major problems is the uncontrolled heat transfer to outer annuli and heat loss from the production tubing which can be detrimental to the integrity of outer annuli. This can reduce the well productivity in case deposition of paraffin and asphaltenes occurs, and could contribute to the formation of gas hydrates. Vacuum insulated tubing (VIT) has had limited success but has numerous drawbacks (e.g., cost, breakdown, "hot spots" at connection joints, etc.). To avoid these problems, high viscosity insulating packer fluids (IPFs) have been employed to thermally isolate production tubing from the exterior pipe and to provide the required hydrostatic pressure.

Numerous combinations of both water- and oil-based materials have been utilized in attempts to devise a cost effective solution. Successful fluids have a low inherent thermal conductivity, remain viscosified or gelled to eliminate convective heat transfer and are expected to have service lifetimes of up to 20 years. However, the current state of the art falls short of meeting these objectives. Oil-based IPFs often have low thermal conductivity, but cannot be weighted, suffer from toxicity and often come with HSE issues. Water based IPFs can be weighted, but generally have temperature stability limitations  $> 250^{\circ}\text{F}$  ( $121.1^{\circ}\text{C}$ ) as well as higher inherent thermal conductivity than oil-based IPF's.

Through extensive investigation of multidisciplinary technologies, a superior performing aqueous-based IPF was developed for elevated temperatures. The novel system delivers performance beyond conventional systems of comparable thermal conductivity ( $k$ ). The new system covers a density range of 8.5 - 14.6 lb/gal (1.02 – 1.75 sp.gr.) and displays heat transfer measurements between 0.12 - 0.17 BTU/hr ft<sup>2</sup>F. High-temperature static aging tests have demonstrated superior gel integrity with no phase separation or syneresis after exposure to 280°F (137.8°C) for three months. Parallel testing at 325°F (162.8°C) has shown similar

success. The new fluids are hydrate inhibitive, pass oil and grease testing, and can be made environmentally acceptable for the Gulf of Mexico. Laboratory data generated under deepwater simulated conditions will be presented and discussed in this paper.

### Introduction

In thermal physics, heat transfer is the passage of thermal energy from a hot to a cold body. When a physical object or fluid is at a different temperature than its surroundings or another object, and is put into "thermal contact", transfer of thermal energy occurs to the extent that the surroundings reach thermal equilibrium. Heat transfer constantly occurs from a hot entity to a cold one (described by the second law of thermodynamics). Classical transfer of thermal energy occurs through conduction, convection, radiation or any combination of these. Heat transfer associated with carriage of the heat of phase change by a substance (i.e., steam which carries the heat of boiling) is sometimes considered a type of convective heat transfer.<sup>1-2</sup>

Conduction is the transfer of thermal energy from a region of elevated temperature to a region of lower temperature through direct molecular communication within a medium or between media in direct physical contact without a flow of the material medium. The transfer of energy can proceed by elastic impact as in fluids, free electron diffusion as predominant in metals, or phonon vibration as predominant in insulators. In other words, heat is conveyed by conduction when adjacent atoms vibrate against one another, or as electrons move from atom to atom. Conduction is superior in solids, where atoms are in constant contact. In liquids (except liquid metals) and gases, the molecules are usually further separated, decreasing the chance of molecules colliding and passing on thermal energy. Conduction does not transpire in an ideal vacuum. Thermal conductivity (i.e., conductivity constant or conduction coefficient,  $k$ ) is employed to quantify the ease at which a substance conducts thermal energy.<sup>1</sup>

Convection is a combination of conduction and the transfer of thermal energy by fluid circulation of warm particles in bulk to cooler areas in a material medium. Unlike the case of pure conduction, *currents in fluids* are also involved in convection. This movement occurs into a fluid or within a fluid, and cannot happen in solids. In solids, molecules keep their relative position to such an extent that *bulk movement* or flow is prohibited, and therefore convection does not occur.

Convection occurs in two forms: natural and forced convection. In natural convection, fluid surrounding a heat source receives heat, thereby rising due to decreased density.