

The Royal Academy
of Engineering

Research Chairs

Fluid Property Sensors for Oilfield Applications

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Professor J P Martin Trusler

Department of Chemical Engineering, Imperial College
London, London SW7 2AZ



Reservoir Fluid Properties: Sampling and Sensing in the Field

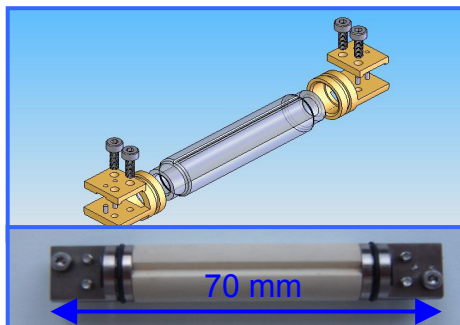
Objectives and Motivation

This project is concerned with the development and validation of sensors and sensor systems for the measurement *in situ* of key thermophysical properties of reservoir fluids (oil and gas). The effective economic evaluation and exploitation of hydrocarbon-bearing formations depend in part on knowledge of such properties, especially the bubble pressure, viscosity and density of the oil phase.

During exploration, the present approach is to collect bottom-hole fluid samples and return them to the surface in pressurised containers by means of a wire-line sampling tool. The samples are then transported to a PVT laboratory for analysis. This process is slow, costly and unreliable. The aim of this project is to permit some of the key properties to be measured *in situ* during both exploration and production.

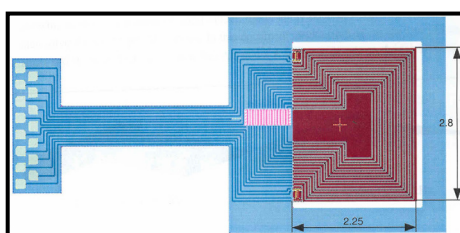
The environment in which property sensors must work is challenging in terms of the temperature (up to $\sim 175^\circ\text{C}$), pressure (up to ~ 1400 bar) and the nature of the fluids (corrosive, abrasive). Accordingly, the demands upon sensors are stringent.

Viscosity and Density Sensors Investigated



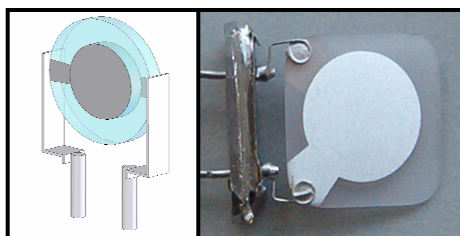
The Vibrating-Wire Sensor

- Based on forced-mode transverse oscillation of a tensioned wire.
- Sensitive to viscosity and density.
- Electromagnetic drive and detection of wire motion at 1 kHz approx.
- Robust design capable of operation in wide ranges of temperature and pressure.
- Viscosity measurements for fluids of known density accurate to $\pm 2\%$.



Micro-Electro-Mechanical-Systems (MEMS) Sensor

- Based on forced mode oscillation of a thin cantilever plate.
- Sensitive to density and viscosity.
- Electromagnetic drive and detection at 1-10 kHz.
- Potential for low unit-cost production.
- Density measurements for fluids of known viscosity accurate to $\pm 1\%$.



Piezoelectric Shear-Mode Sensor

- Based on forced mode oscillation of a 10 MHz shear-mode quartz plate.
- Sensitive to the product of density and viscosity.
- Simple and robust design.
- Can operate over very wide ranges of temperature and pressure.

Conclusions

The vibrating-wire and MEMS devices together comprise a powerful sensor system capable of determining both density and viscosity with useful accuracy. We have tested these devices successfully up to 175°C and 1400 bar. We are also working on sensors for sound speed and refractive index for monitoring the properties of fluids in subsea pipelines and risers. One application is monitoring the potential for gas hydrate formation.

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