X-ray based core scanners for reservoir modelling

High stability, High imaging contrast, High Resolution X-ray Technology with tomographical imaging option.

Objectives:

Reservoir modelling is a key task on the assessment of the economic potential of oil exploration. Advanced computer models are supported by real, small scale, core flow measurements of oil, gas, and water. The simple models involves a one-dimensional approach where a reservoir rock core is injected with oil, water, gas, and mixtures hereof, at reservoir T-P conditions. The core is contained in a CFRP-aluminum core holder, and may be rotated during the measurements in order to avoid gravity effects on the measurements. X-rays are used to image (or measure) the core interior, the voids and the flow through the voids of the rock core. Quantification of the content of the different phases is done by either a time consuming scanning at 1, 2 or 5 mm intervals through a mm-sized aperture in front of (e.g.) a scintillation detector with a multiple channel analyser (MCA). This gives a line scan through the mid-axis, but the largest part of the core remains unassessed. Alternatively, a smarter technology using a multispectral imaging detector can be used. Or, the flow content can be dynamically imaged at a very high resolution at multiple stages, and through correlation to the MCA a quantitative assessment may be performed at pixel level.

Due to the limitation of the core scanners, reservoir studies may be based on reservoir rock plates of a large area and with a specific thickness. Flow measurement of these plates provides three dimensional data which are more realistic relative to the geological conditions. Multispectral imaging devices are especially relevant, due to a very time consuming scanning process when based on scintillation-MCA detectors.

Solutions:

InnospeXion has provided Systems, Parts & Utilities for accurate, fast & cost effective measurement of the migration of gas, oil and water in drill cores and rock slabs since year 2000. The basis of our systems is the use of **calibration**, of using **high stability** X-ray emission sources, **high stability** detectors and **precision** mechanics. To this, add our **expertise** in X-ray safety and **know-how** on X-ray technology, - this is the solution to **precise** laboratory tests and trials on **1-, 2–, and 3-D flow interpretation**.
We offer systems based on X-ray attenuation measurement and real-time high sensitivity imaging. Simple core scanners or 3-D rock slab imaging & measurement systems.

1D X-ray scanner: THE 1D-X-RAY CORE SCANNER is based on high stability X-ray source that emits a narrow beam of electromagnetic radiation, which is attenuated by a porous reservoir rock sample. Attenuation depends on the composition and porosity of the sample. The sample is placed in a special holder, which is made accurately to fit the core sample.

Three-dimensional X-ray imaging for reservoir studies
Our latest **3D-X-RAY CORE SCANNER** combines imaging with accurate measurement of the three-phase flow in rock slabs to obtain an improved interpretation for oil exploration. The **3-D X-RAY CORE SCANNER** is based on quantitative **attenuation** and **imaging** measurement of up to 1 by 1 m^2 rock slabs. The sample is placed in slide tray, which is made accurately to fit a 1000 x 1000 mm sample. The sample holder provides for an auxiliary system that enables a flow of a liquid through the sample, in a direction normal to the X-ray beam.
The entire system can be tilted at any angle from vertical to horizontal. Numerous calibration options, a large sample tray, large double door access, remote monitoring, multiple software configurations, and many other options to tailor the system capability, provides state-of-the-art cost efficiency.
THE **3D-X-RAY CORE SCANNER** incorporates two distinct measurement options: (a) the real-time imaging of the actual attenuation image using a linear array that is moved across the sample simultaneously with the X-

ray source, and (b) the measurement of attenuation by the rock sample using a NaI scintillation detector which is moved in steps simultaneously with the X-ray source. The first technique provides an image that may be correlated to an actual flow pattern and flow composition within the sample, whereas the second technique enables a more accurate assessment of the actual composition of the flow constituents across the sample.
The latest development involves the use of multiple energy linear array detectors for real-time pixel based derivation of the flow composition.

PRECISION & SCAN SPEED
THE **1-D** and **3D-X-RAY CORE SCANNERS** has been developed for quantitative studies of the migration of various fluid in the rock sample. The positional accuracy depends on scanning speed, and the statistical accuracy depends on the rock, the thickness and the integration time. At routine usage, the X-Y position accuracy is about 0.5—1 mm, and the counting accuracy is about 1-2 per cent for an average count rate of 20000 cps.
Better precision is possible at the expense of scan speed. A total scan at 5 mm resolution of a 1 x 1 m^2 rock in counting mode will take about 250^2 to 400^2 seconds, whereas the complete image scan takes about 1 to 30 minutes.
The new multiple energy detectors can achieve both imaging and quantitative derivation of the oil/gas/water flow at a precision of about 1-2 per cent with scanning speeds up to 30 m/minute.

Figures:

1. The 1-D X-ray core scanner in a high T-P version including an oven to 120 degrees C heating of the core. This version integrates a core rotation mechanism and enables CT slices to be made at a very high resolution (0.1 mm).
2. Tailored 1-D X-ray core scanner based on a very high flux X-ray source and a very high flux detector, to enable precision scanning better than 0.5% relative to oil-water flow in the pores of the core reservoir rock.