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Ultrasonic techniques for measuring physical properties of fluids in harsh environments

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Ultrasonic-based measurement techniques, either in the time domain or in the frequency domain, include a wide range of experimental methods for investigating physical properties of materials. This discussion is specifically focused on ultrasonic methods and instrumentation development for the determination of liquid properties at conditions typically found in subsurface environments (in the U.S., more than 80% of total energy needs are provided by subsurface energy sources). Such sensors require materials that can withstand harsh conditions of high pressure, high temperature and corrosiveness. These include the piezoelectric material, electrically conductive adhesives, sensor housings/enclosures, and the signal carrying cables, to name a few. A complete sensor package was developed for operation at high temperatures and pressures characteristic to geothermal/oil-industry reservoirs. This package is designed to provide real-time, simultaneous measurements of multiple physical parameters, such as temperature, pressure, salinity and sound speed. The basic principle for this sensor's operation is an ultrasonic frequency domain technique, combined with transducer resonance tracking. This multipurpose acoustic sensor can be used at depths of several thousand meters, temperatures up to 250 C, and in a very corrosive environment. In the context of high precision measurement of sound speed, the determination of acoustic nonlinearity of liquids will also be discussed, using two different approaches: (i) the thermodynamic method, in which precise and accurate frequency domain sound speed measurements are performed at high pressure and high temperature, and (ii) a modified finite amplitude method, requiring time domain measurements of the second harmonic at room temperature. Efforts toward the development of an acoustic source of collimated low-frequency (10-150 kHz) beam, with applications in imaging, will also be presented.