A Dual-Path Pulse-Echo Instrument for Speed of Sound of Liquids and Dense Gases and Measurements on Four Halogenated-Olefin Refrigerants

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We describe a new instrument for the measurement of liquid-phase speed of sound. It is based on the dual-path, pulse-echo technique and operates over a temperature range of –45 ˚C to 150 ˚C, with pressures to 90 MPa. A quartz crystal with a resonant frequency of 8 MHz sits in a sample volume 24 mm in diameter by 42 mm long; the path lengths are 12 mm and 30 mm. Several novel design features permit the entire transducer assembly (crystal, sample volume, and reflectors) to fit in a pressure vessel with internal dimensions of 29 mm diameter by 165 mm deep; the total volume of sample required is approximately 30 mL. An 8 MHz ultrasonic tone burst is generated with the crystal, which passes through the fluid to the short and long-path reflectors and returns to the crystal. The speed of sound is calculated from the time difference between the short-path and long-path echo signals, as recorded by a digital storage oscilloscope. The echo data, together with temperature and pressure data, are stored for off-line analysis of the speed of sound. The path lengths were calibrated with measurements on water and propane. Propane can be vapor, liquid, or supercritical over the temperature and pressure range of this instrument, allowing tests at lower densities and in the critical region where sound absorption and long crystal damping times make pulse-echo measurements challenging. The instrument is highly automated, allowing rapid measurements of sound speed along isochores. Sound speed data are reported on four halogentated-olefin refrigerants: R1234yf, R1234ze(E), R1233zd(E), and R1336mzz(Z). We are working towards absolute measurements that are not based on calibration with a fluid of “known” sound speed.