calculations to determine properties of fluid **25** based upon the receipt of transducer output signals.

In operation, pulser **50** generates and delivers a short duration stimulus to transducers **30**, **31**. Transducer **30** responds to the stimulus by emitting a longitudinal. wave pulse of ultrasound into member **40**. This ultrasonic pulse reflects between surfaces **44** and **42** producing a series of pulse echoes at t ansducer **30**. This resulting echo series will be of successively diminishing echo amplitude because each successive echo will have reflected from the solid fluid interface at surface **44** one time more than the previous echo. in a similar fashion shear wave transducer **31** responds to the stimulus by emitting a shear wave pulse of ultrasound to the interface **23** between member **40** and the fluid **25**. This ultrasonic pulse reflects off of the interface **23** and in the preferred embodiment into the angle block **31**. The air on the opposing side of the angle block **31** then reflects preferably 100 percent of this ultrasonic pulse back toward the interface surface **23** and then back to the shear wave transducer **31** producing a series of pulse echoes at shear wave transducer **31**.

Transducers **30**, **31** respond to the echoes by producing an output signal proportional to the echo amplitude that is amplified by receiver **60**, digitized by digitizer **70** and passed to computer **80**. Computer **80** includes programming instructions encoded on fixed and/or removable memory devices **84**, **86**, respectively, to gather the select a peak echo amplitude for the series echoes and to determine the average decay rate of the peak echo amplitudes with increasing echo number in the echo series. Alternatively, computer **80** can be at least partially hard wired with dedicated memory devices and configured to execute logic according to the present invention. Computer **80** is operatively coupled to display **82** to output selected information about fluid **25** integrated with transducers **30**, **31**.

A shear wave transducer is used for transducer **31** rather than a longitudinal one because when a longitudinal wave strikes a solid-liquid interface at an angle (no matter the size of the angle), the following will always be produced: (1) a reflected longitudinal wave at the same angle as the incident one, (2) a mode-converted shear wave at about half the angle of the incident longitudinal (depending upon Snell's Law) and (3) a transmitted longitudinal wave in the liquid. Thus, if the reflected longitudinal waves are observed, there would be only a few reflections (particularly for stainless steel) because energy has been used to create the mode-converted shear waves.

When a shear wave transducer (SV mode of operation) is used at small incident angles with the vertical, a mode-converted reflected longitudinal wave is produced. That is, all three types of waves are produced as has just been discussed in the preceding paragraph. However, when the incident angle is 45°, a reflected shear wave is produced, but a reflected mode-converted longitudinal wave simply cannot be produced. The reason is that the reflected longitudinal wave always has a greater angle than the reflected shear wave, but at some incident angle (slightly less than 45°) the mode-converted longitudinal wave becomes 90°. Since 90° is the limit for the mode-converted reflected longitudinal wave, this wave is simply not produced at 45°. For a shear wave incident upon a solid-liquid interface at a 45°, two types of waves are produced: (1) reflected shear wave and (2) a transmitted longitudinal wave in the liquid. Therefore, when the reflected shear wave is observed, energy is available for many reflections. In summary, more reflections are observed using a SV shear wave transducer at an incident angle of 45° than would be obtained using a longitudinal transducer.

The transducers **30**, **31** can be applied to any solid unit, but there are two materials that have special significance for process control: (1) stainless steel and (2) fused quartz. Fused quartz is often used as windows in a pipeline and the pipeline is often constructed of stainless steel. Fused quartz has a very low attenuation of ultrasound and so is a very good choice for the material. Stainless steel may be preferred in some cases, but it can be quite attenuative. For this reason, the experiments were carried out to show that this method can be applicable even for stainless steel.

Preferably a number of echo amplitudes, for example [5] five or more, spanning a range of echo numbers are used in computing the decay rate both the longitudinal wave reflections emanating and being reflected through transducer **30**, as well as the shear wave reflections being sent from sent from shear wave transducer **31**. This feature referred to at times as "self-calibration" preferably occurs with the information received from each of the two transducers. Information from the longitudinal transducer **30** yields the reflection coefficient for ultrasound perpendicular to the solid-liquid interface, while that from the shear wave transducer **31** yields the reflection coefficient for ultrasound incident at 45°. In one preferred form, each reflection coefficient depends upon the density of the liquid or slurry that is being measured and the velocity of the sound in the liquid. By then solving these two equations for each of these two unknowns, the density and velocity of the sound in the liquid can be determined.

In one embodiment the computer **80** is programmed to first compute the fast Fourier transform (FFT) of the digitized signals, converting them from the time domain to the frequency domain and then determine the peak amplitude at a selected frequency, where the frequency is selected to be, for example, the center frequency of transducer **30** and transducer **31**.

The objective is to compare the experimental measurement of each reflection coefficient with a theoretical calculation and to extract the density of the material and the velocity of sound. The experimental measurement of the perpendicular coefficient and the coefficient at a 45° are both measured by looking at the multiple echo pattern. However, each set of multiple reflections has a different decay rate and hence, a different value for the reflection coefficient. The following description applies to both types of reflections.

The FFT amplitude at a given frequency is proportional to RC^N, where RC is the reflection coefficient and N is the echo number.

$$V \alpha RC^N \tag{1}$$

For example, if the RC is 0.8, then the amplitude of the 5^{th} echo is equal to 0.32768 C and that of the first echo, equal to 0.8 C, where C is a constant of proportionality. Thus, the amplitude of the 5^{th} echo is about 41% of that for the first echo.

This proportionality can be written for a liquid and for water. For the same experimental setup, the (unknown) constant of proportionality is the same for both. Thus, the constant of proportionality drops out when the two equations are divided.

$$V\text{liq}(N)/V\text{wtr}(N)=RC\text{liq}^N/RC\text{wtr}^N \tag{2}$$

Taking the natural logarithm of both sides yields the following:

$$\text{Ln}(V\text{liq}(N)/V\text{wtr}(N))=N\ln(RC\text{liq}/RC\text{wtr}) \tag{3}$$

Vliq is identified as the EFT amplitude for a liquid and similarly defined for Vwtr, When the left-hand quantity is plotted on the vertical axis (y) of a graph and the echo number