for stainless steel, leading to a more sensitive measurement. In addition, more echoes are obtained with quartz because its ultrasonic attenuation is quite small. Calculations indicate that an uncertainty in the density measurement of 0.05% may be possible with the quartz design. In another design the shear wave transducer **31** is directly mounted on the stainless steel pipeline or spool piece and the 45-degree triangular wedge (preferably in a single stainless steel unit) is in contact with the liquid or slurry. In yet another design, the 45-degree wedge consists of two pieces, in which a part of the stainless steel pipeline wall is connected to a 45-degree trapezoid fastened to the wall, such as shown in FIG. **2**.

Comparison of the reflection for perpendicular longitudinal waves and the reflection for 45° shear waves show that the sensitivity for the 450 shear waves is 1.5 times that for the perpendicular longitudinal waves. The calculations also show that the 45° angle of incidence is optimum and about 90% of the ultrasound is reflected at the SS-liquid interface. Therefore, even though stainless steel is more attenuative than quartz, a sufficient number of echoes can be observed using a frequency of 2.25 MHz or 1 MHz.

Multiple reflections can be observed for both transducers **30** and **31** and so the self-calibrating feature applies to both transducers. In an alternative embodiment the shear wave inducing transmitter **31** is connected to an angle block **33** that is fastened directly to the wall member **40**. While in this embodiment the material for the wedge is the same as the wall, there will undoubtedly be reflections at the interface between the two pieces, but those reflections will not travel to transducer **31**. However, due to the multiple reflections and self-calibrating feature, these undesirable reflections will not affect the reflection coefficient measurement at 45°, but the number of echoes may well be reduced and that can affect the accuracy of the density measurement.

However, in either design, the velocity of sound can be determined without passage of ultrasound through a very attenuative medium or through a large vessel.

Preferably, the transducers that are useful for forming and receiving the ultrasound pulse echo series in practicing the present invention can operate in the range of about 0.5 to 20 MHz, more preferably between about 1 and 10 MHz, and most preferably about 5 MHz. However, due to the longer path for incidence at 45°, a smaller frequency such as 1 MHz may be advantageous. In certain applications of the invention, the thickness T of member **40** will be predetermined, and depending on the wavelength of ultrasound in the member **40**, the ratio of thickness T to wavelength could be significant, for example greater than about 0.05. As one example, it is contemplated that member **40** would be the existing wall of a stainless steel pipe or container about 0.15 inches thick. For at least some selected ultrasonic frequencies, the wavelength of ultrasound will be significant relative to the wall thickness.

In another form of the invention, because of materials desired for solid member **40** and fluid **25**, the acoustic impedance ratio Zsolid/Zliquid will be significant, for example, greater than about [5] five or [10] ten. The multiple reflections serve to amplify the effect of small changes in properties of fluid **25**. This amplification occurs because the amplitude of the pulse is diminished in accordance with the reflection coefficient (RCliquid) with each successive reflection with surface **44**. Also, because the higher echoes undergo more reflections with surface **44** and because the reflection coefficient (R.Cliquid) is a function of fluid properties, the effect of Thanges in these fluid properties are more pronounced in the higher echo numbers. Consequently, in one form of the invention, it is preferred that at least some of the higher number echoes are used in computing the decay rate.

In further forms of the invention, where reduction of the adverse effects of divergence and/or attenuation is of concern, selection of transducers **30**, **31**, member **40** dimensions, angle block **33** materials and their associated properties can be of particular interest. For example, the near field can be considered the region immediately in front of an ultrasonic transducer where the sound beam does not diverge and signal loss is at a minimum. The near field length (NO for an ultrasonic transducer can be approximated by Eq. (24)

$$Nf=0.25D^2/\text{lambda} \tag{24}$$

where lambda is the wavelength of the ultrasound in the medium (equal to local speed of sound divided by the frequency) and D is the largest dimension of the transducer face **32** associated with the member **40**. For circular transducers, D will be the diameter of the face **32** whereas for rectangular transducers D will be the larger length dimension of the rectangle. In one form of the invention, the near field of the transducer **30** is selected to encompass one or more of the reflections used to calculate the decay rate. In a preferred form a plurality of the echoes used to calculate the decay rate are within the near field length estimated by Eq. (24). in a further preferred form, the majority of the echoes used to calculate the decay rate are within this length.

From an examination of equation (24) one possibility for increasing the near field length is to increase the frequency of the ultrasound. However, there is a practical limit to the effectiveness of this approach, at least because losses due to attenuation of the ultrasound generally increase with increasing frequency. The near field length is therefore preferably maintained at a desired relative length by adjusting the ratio of the size of transducer size D to thickness T. Increasing the transducer size D increases the near field length whereas decreasing T decreases the pathlength of the echoes, allowing more echoes to be detected inside a given near field length, it is to be understood that the pathlength for each echo is the distance the pulse travels for each reflection (2T) times the echo number (the first echo has a pathlength of 2T, the second 4T, the third 6T, etc.). While any ratio can be utilized as would occur to those of skill in the art, in one form of the invention the ratio of D/T is preferably greater than about one. In other forms, the ratio Dif is about two [2] or above.

An advantage is realized by using the decay rate of the echo amplitudes in determining fluid properties. It has been found that, unlike the absolute magnitude of individual echo amplitudes, the slope of echo amplitude versus echo number is substantially independent of characteristics of the ultrasound pulse used to create the echoes. Thus, the self-calibrating feature of the multiple echoes is realized. For example, if the pulser voltage changes by, say, 1%, then each echo changes by the same amount and the Slope of the line, previously described, remains unchanged.

Exemplary materials for solid member **40** and angle block **33** include aluminum, stainless steel, fused quartz, and plastics. Preferably member **40** is non-porous is does not absorb fluid **25**. In particular applications, such as food processing and the transport of toxic material, stainless steel or other non-corrosive materials are preferred materials for these pieces.

In a further variation, data transmission between computer **80** and transducers **30**, **31** can be achieved wirelessly by provision of appropriate wireless communication devices.

Another application is the design of the unit for placement inside a tank for measurement of the density and velocity of sound. In such a design, the side of the 45° angular wedge could be made watertight so that ultrasound could still reflect from air on one side of the triangle. In another design, a