The force vectors CA and CB represent the tensional forces in Suspension Rope. The force vector CD represents the total compressive force, and hence displacement, which is applied to the Mass Transducer. Such an embodiment allows the displacement of the Flow Tube to be caused significantly by the density of the media inside, to a lesser extent by the weight of the Flow Tube itself, and to still lesser extent, by the relatively small mass of the Suspension Rope. Additionally, it has been shown that this arrangement has an inherent relatively low natural frequency and able to absorb much induced pink noise up to 200 Hz.

From Lami's Theorem in mechanical statics and reference to Figure 6.

$$\frac{A}{\sin \alpha} = \frac{B}{\sin \beta} = \frac{C}{\sin \lambda} \qquad (6)$$

By example, for an angle $\theta = 2°$, which is typical for the angle of the Suspension Rope to the longitudinal axis of the Flow Tube, angle $\lambda = 176°$ and angles β and $\alpha = 92°$ then:

$\sin \lambda = 0.0698$ and $\sin \alpha$ and $\beta = 0.9994$
and then:
Force C = (0.0698 / 0.9994) B = 0.0698 B (7)

Accordingly, the compressive force vector CD approximates to and typifies a mere 7% of the tensional force applied to the Suspension Rope. This allows a small change in media density to be resolved by the Mass Transducer, while the high tension in the Suspension Rope assures good repeatability.

The deflection of the Flow Tube is determined by simple variation in the length cubed and diameter D raised to the power 4 of the Suspension Rope. Accordingly, small changes Suspension Rope length and diameter have significant influence on the deflection applied on the Mass Transducer.

A Tension Spring Assembly provides for a series of tension springs to help support the weight of the Flow Tube, or raise its weight to remove the Mass Transducer. Alternatively, compression springs may be provided to overcome Flow Tube stiffness, dependent on Sciam Density Meter size or range of slurry specific gravity (sg). The sg ranges are normally increments of 0.500, normally from 1.000 (water) to 4.000. The Sciam Density Meter sizes normally range from 50mm to 1000mm (2 inches to 40 inches).

Life expectancy of the Flow Tube ranges typically from 5 years with highly abrasive slurries to as much as 20 years for with clay slurry. An internal flange at each end of the Rubber Flow Tube allows rotation of the entire Flow Tube to allow even erosion on its internal diameter, which increases service life.

Without preventative maintenance, when the service life of the Flow Tube is finally reached, it may burst. However, the Pressure Chamber is designed to contain the media under full working pressure. The Mass Transducer can provide a sudden electrical failure warning. Recommended spares are relatively low cost, comprising a spare Mass Transducer and Flow Tube. These can be simply replaced on job-site by unbolting the appropriate Pressure Chamber Flanges.

TEMPERATURE COMPENSATION

In its basic form, temperature compensation is achieved by the stainless steel Suspension Rope expanding with increase in ambient or media temperature to compensate for the lowering of the modulus of elasticity of the Rubber Flow Tube. As such, the Suspension Rope increases the upward supporting force on the Rubber Flow Tube to compensate for the apparent increased weight on the Mass Transducer due to lower stiffness. Conversely, with lowering of ambient or media temperature the Suspension Ropes reduces in length to compensate for the increase in modulus of elasticity of the Rubber Flow tube.

Correct compensation was empirically determined by the length of the Pressure Chamber, the diameter and length of the Suspension Rope, as well as its angle to the longitudinal axis to the Rubber Flow Tube. Accordingly, a temperature error coefficient of ± 0.0014% of span per °C (± 0.0008% per °F) was achieved.

VIBRATION COMPENSATION

Due to the low natural frequency of the Flow Tube and Suspension Rope, the SCIAM Density Meter absorbs a significant amount of energy from media noise and externally induced vibration. However, it is also necessary to compensate for these vibration forces in the remote transmitter electronics.

Figure 7 shows typical pink noise from the media and externally induced vibration superimposed on the true density signal. The remote transmitter contains an algorithm which interrogates the pink noise at 110 times per second and calculates the average values for pink noise periods both above and below the true density signal. It then averages these positive and negative values to provide the true density signal.

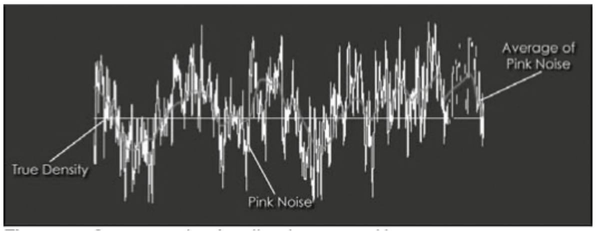

Figure 7. Compensation for vibration at 110 Hz.

SOURCES OF ERROR

Table 1 provides the major sources of error in the SCIAM Density Meter. The errors are based on a 2 σ standard deviation, with the resultant error is based on the square root of the sum of the squares of the component errors, resulting in a 95% confidence level.

COST SAVINGS

Figure 8 provides both typical initial cost and operating cost comparisons between a SCIAM Density Meter and a nuclear density meter.

Externally induced plant vibration and media noise	< ± 0.1%
Temperature Coefficient Error 0.0014% per °C over 30°C	< ± 0.04 %
Tilt in 2 planes over ± 20° to horizontal	< ± 0.2%
Mass transducer and remote transmitter accuracy	< ± 0.1%
Pressure error coefficient	< ± 0.1%
Velocity coefficient error from 0.03 – 10 m/s (1 – 30 fps)	Negligible
Typical Flow Tube erosion effect on calibrated volume	< + 0.1%
Root of sum of squares of component errors	< ± 0.285%