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To: VLBA Data Acquisition Group

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Subject: Tape Packing at Low Tensions

Introduction

In order to determine if the VLBA recorder can be operated at lower vacuum (lower tension), we have first studied the tape pack tightness as a function of tape tension. At very low vacuum the tape pack can become loose enough that pulling on the end of the tape causes the pack to tighten as the layers slip against each other. To provide a more quantitative measure of the tape pack, we have measured the elastic modulus of the tape pack with an apparatus that allows an in place measurement. Since a tape pack has the property that the effective modulus is a function of the interlayer pressure, it is possible to infer the interlayer pressure from the modulus measurements.

Modulus Measurements

The elastic modulus in the radial direction of the tape pack was measured using the apparatus shown in Figure 1. The deflection at point B in response to the force applied by the weight is measured with the dial indicator. The elastic modulus is derived using the theory of rollers in compression by Timoshenko (Strength of Materials, Vol.II, Pg.342) from which the following relation can be derived,

$$\lambda = 1.5^2 F / (2 EW)$$

where

λ = displacement
F = force on tape (50.5 lb)
W = tape width (1 inch)
E = Young's Modulus

While the above relation is dimensionally correct, there is some question of the value of the constants.

Measurements were made for tapes wound at 240 ips over a range of vacuums. The results are plotted in Figure 2 and 3. Temperature cycling data was obtained from tape packs wound at 5" of water.

Temperature Cycling

The elastic modulus appeared to decline following a cooling cycle to 0^{o} F; however the value obtained in a Sony tape varied at different points of the tape pack. The 3M tape modulus was found to decrease by 18%

Heating cycle to 130^{o} F resulted in some discrepancy. Heating the tapes for 4-5 hours showed a decline of the modulus; however, heating them overnight for 14 hours resulted in an increase of the modulus. The Sony tape modulus increased by 39% while the 3M tape modulus(77%) almost doubled that amount. Also, the heating cycle loosens the tapes dramatically.

Interlayer Pressure

Measurements of the modulus reported in VLBA Acquisition Memo #325 and those made by Willet and Poesch (Journal of Applied Mechanics, Vol.55, Pg.365, June 1988) show that the interlayer pressure goes to zero at a modulus of about 7-10 x 10^4 kPa. If 10^5 kPa is taken as the value for interlayer pressure then the minimum tension needed to provide some interlayer pressure is about 5" (see Figure 2 and 3). This is roughly consistent with the observation that at tensions less than 5" the pack is loose enough that it can be tightened by pulling on the end.

Variations With Tape Speed

The tape pack modulus can be increased by winding at lower speed, especially at the low tensions. The modulus increase at 120 ips is about 6-10% at 5" on the Sony tape. At lower speed there is less air entrapment (see VLBA Acquisition Memo #263).

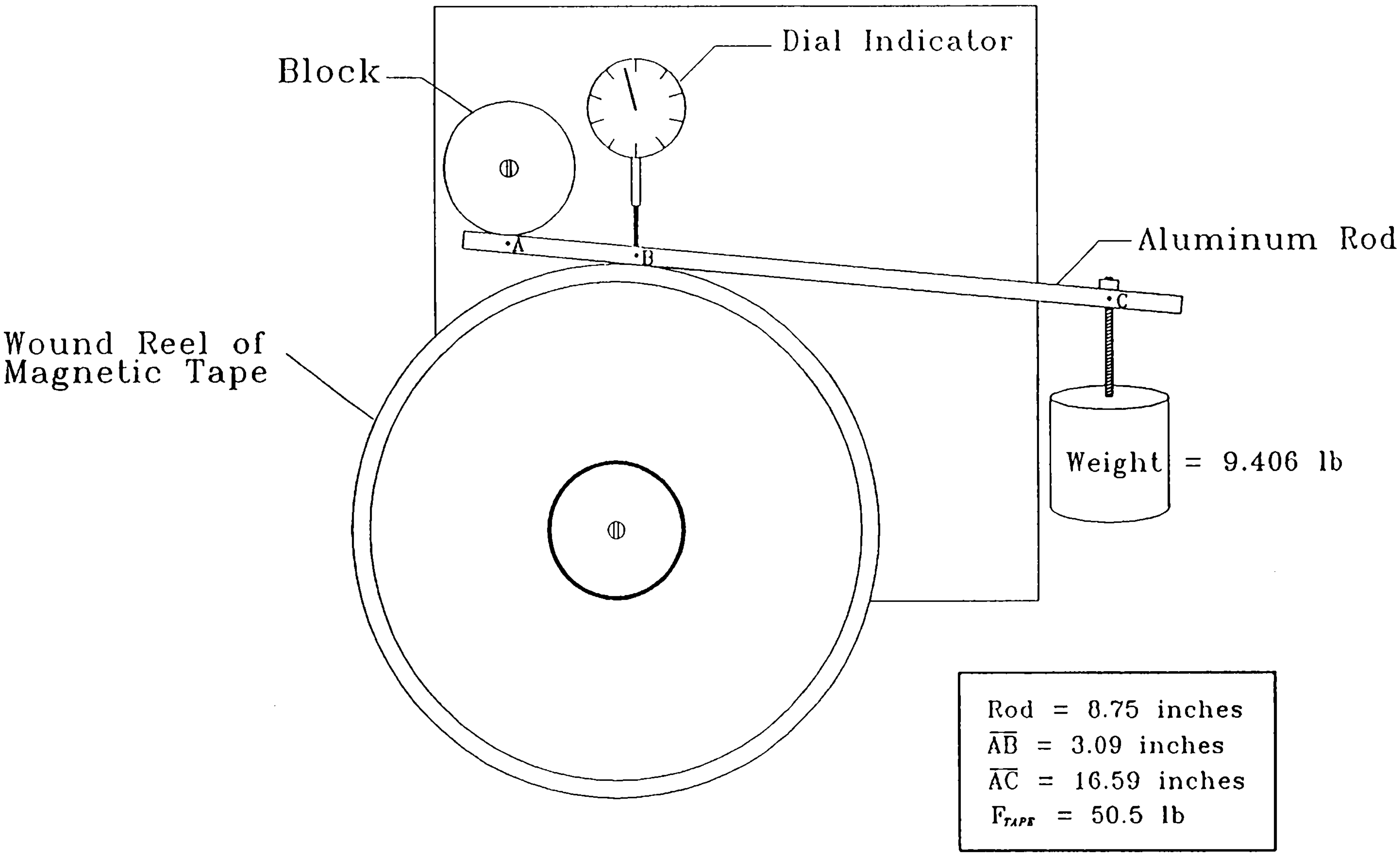
Differences Between the Sony and 3M Tape

The 3M tape has a more linear modulus change with tape tension presumably owing to the greater roughness of the 3M backcoat. The Sony tape has a smoother backcoat and therefore the layers slip against each other more readily.

Conclusion

A tension of at least 5" (1.1 Newtons) is needed to provide sufficient interlayer pressure in the tape pack to prevent slippage between layers. Heating the tapes to a temperature of 130^{o} F appears to affect the modulus more extremely than cooling them.

Figure 1: Apparatus to Determine the Lowest Tension



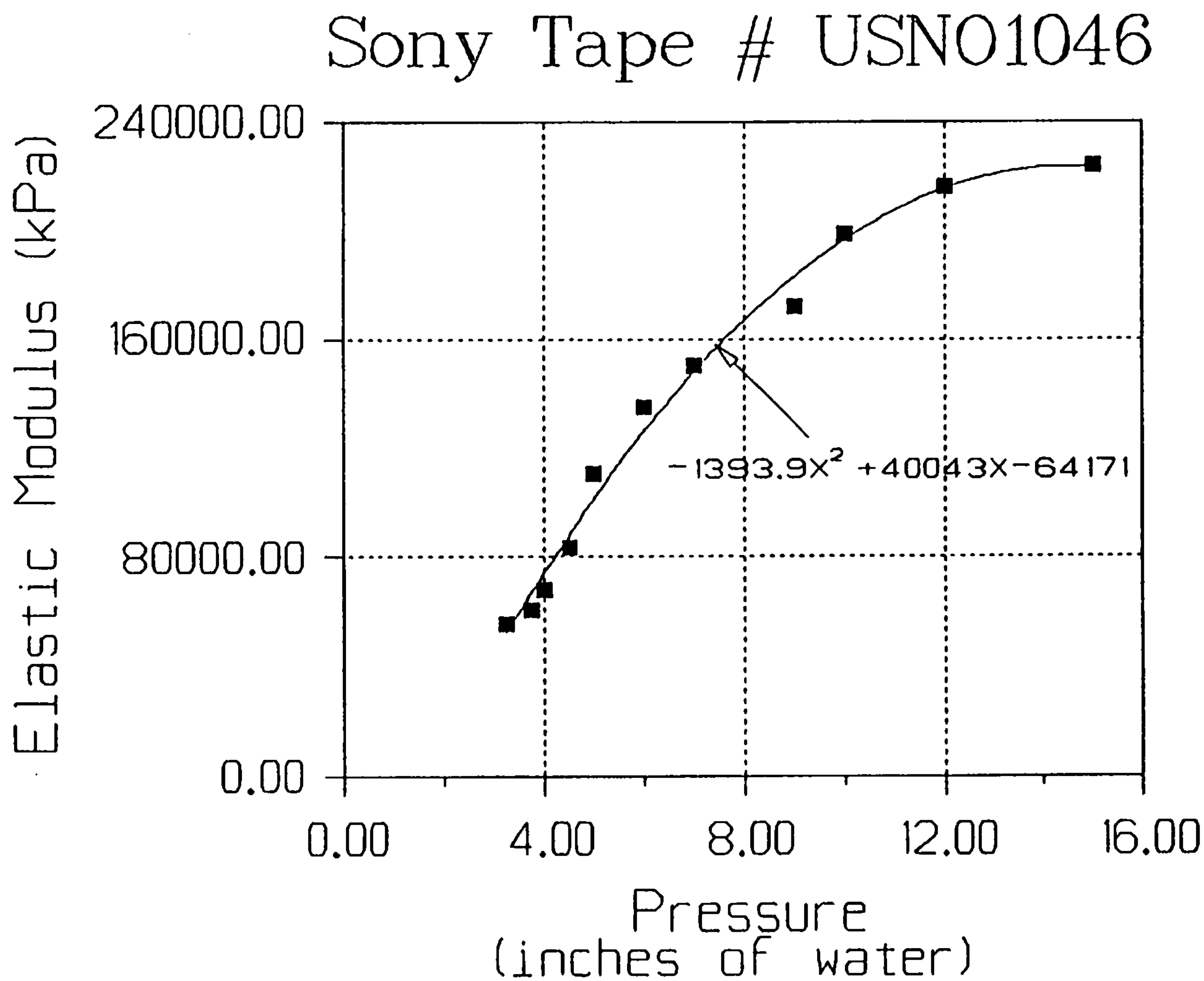


Figure 2: Sony Tape Plot at 240 ips

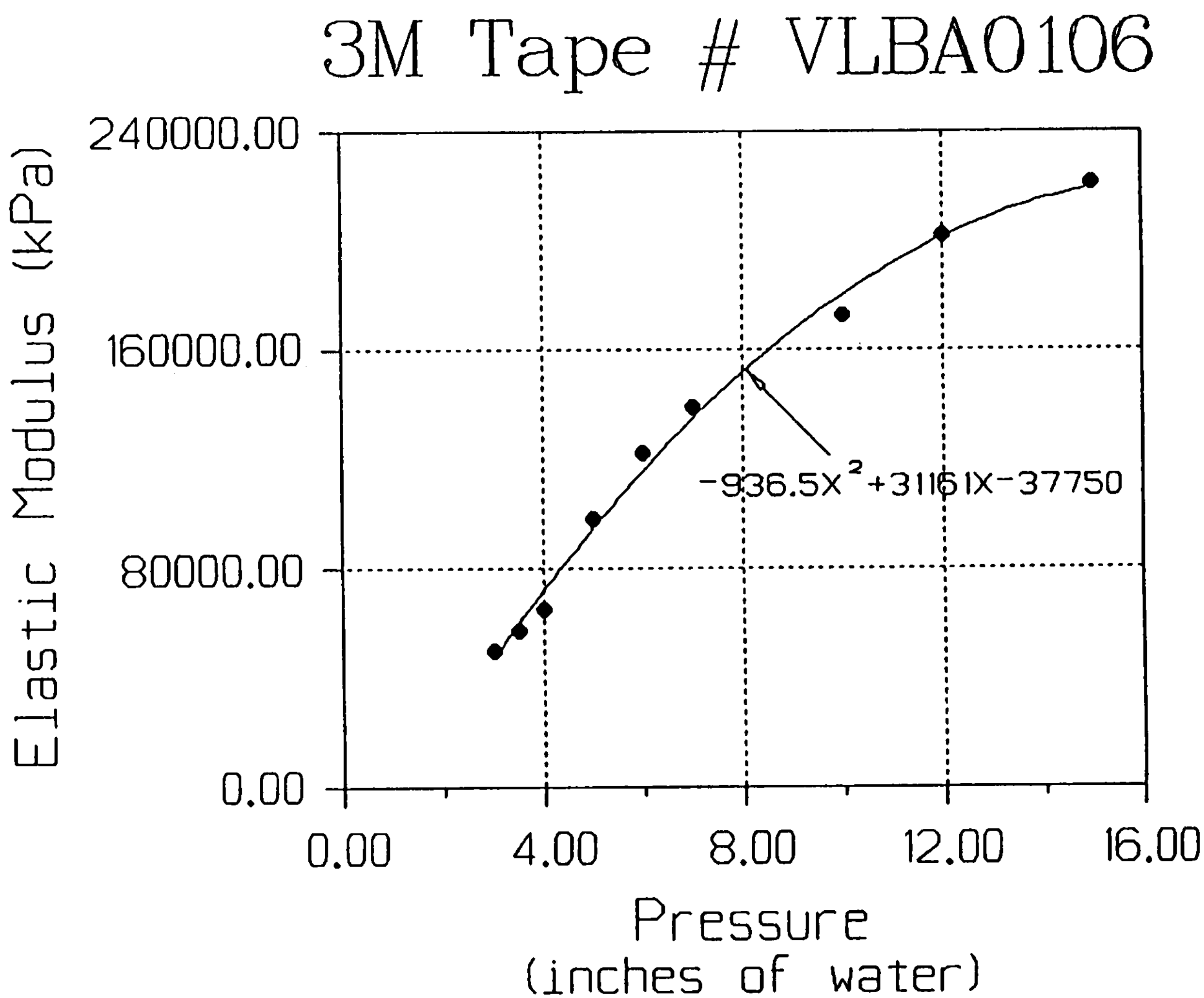


Figure 3: 3M Tape Plot at 240 ips