VLBA ACQUISITION MEMO #179

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To: VLBA Data Acquisition Group

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Subject: Head to tape contact pressure

A] The short wavelength response of a magnetic tape is dependent on the pressure with which the tape contacts the gap. This pressure dependence is the result of surface roughness which prevents all the magnetic particles along the gap line from being in perfect contact with the gap. If the surface roughness has a gaussian distribution of surface height with r.m.s of σ the loss at wavelength λ is approximately

$$55\ K\ \sigma/\lambda \quad \text{dB}$$

where K is a constant which depends on the pressure and elasticity of the surface. If the surface is not deformed $K \approx 4$ since the cumulative normal distribution function becomes vanishingly small at $K \geq 4\ \sigma$. That is, without deformation the tape rides on the peaks of the gaussian distribution. If an average pressure ρ is applied, the pressure on the gaussian peak is $\rho/\Phi\ (K)$ where $\Phi\ (K)$ is the cumulative normal distribution function

$$\Phi(K) = 1/(2\pi)^{1/2} \int_K^\infty e^{-x^2/2}\, dx$$

The surface deforms and K is approximately given by the solution of the following equation

$$K \approx 4 - \rho\, S/(Y\, \Phi\, (K)\, \sigma)$$

where

Y	=	Young's modulus in thickness direction ($\approx 7 \times 10^4$ lbs/sq")
ρ	=	average pressure (7 lbs/sq" nominal)
S	=	characteristic scale length of surface deviations (probably ≈50 microns - see memo on optical measurement of surface roughness)

For σ = 0.1 microns and using the values of Y, ρ, L, above, the following solutions for K are obtained

ρ	K	Loss(at 1 μm)
50%	2.3	12.6 dB
100%	2	11.0 dB
200%	1.7	9.3 dB

The expected variation of loss with pressure of about 3 dB per factor of 2 change in pressure is not very sensitive to the scale length or Young's modulus and is almost directly proportional to σ.

B] Pressure dependence on vacuum

If the vacuum pressure on model 96 is changed, eventually the pressure at the gap will change in direct proportion to the vacuum. However, when a pressure change is made without allowing enough time for the head to reach a stable contour the pressure change at the gap follows the curves given in figure 1.

Figure 2 illustrates what happens when the tension is changed. When the tension is decreased, the tape no longer touches at the headstep and the contact distance M from the gap is given by

$$M = R\,\theta - \ell$$

where ℓ is the characteristic length (see Acquisition Memo #141). R is the radius of curvature of a stable ("worn") profile given by

$$R = \frac{(L + \ell)}{\theta}$$

where

L = distance from gap to headstep (0.006")

θ = tape half angle (5 deg)

The pressure ρ at the gap, due to tape tension T, is proportional to

$$T/M = T/(R\,\theta - \ell)$$

which has the interesting property that results in an enhanced value at low vacuum pressures as shown in Figure 1. However, the elastic deformation of the tape will modify the curves of Figure 1 so that for 1 mil tape a 2:1 pressure increase is about the most that can be achieved by dropping the vacuum to 5" and even less by raising the vacuum.

When the tension is increased, the tape pressure becomes singular at the headstep edge and there is a region of lost contact from beyond the contact distance M to the edge of the headstep. In this case, M is given by the solution of the equation

$$Z^2/R = (\theta - M/R)\, Z\, \ell\, (1 - e^{-z/\ell}) \,/\, (2\,Z + e^{-z/\ell}\,(Z + 2\,\ell))$$

where

$$Z = L - M$$

In order to calculate the pressure at the gap it is not necessary to find M since the force F at the headstep edge is

$$F = (\theta - M/R)\,T$$

and the force over the arc of length M is

$$T\,\theta - F = MT/R$$

so that the pressure is proportional to

$$T/R$$

and doesn't depend on M as long as contact is not lost completely (M = 0.). However, when the tape deformation in the thickness direction is taken into account, the contact arc length M is increased by

$$\approx (2\,R\,\rho\,t/Y)^{1/2}$$

Y = Young's modulus in the thickness direction

t = tape thickness

it becomes necessary to solve for M in order to calculate the pressure at the gap. The lower curves in Figure 1 include this approximation to the effect of deformation in the thickness direction.

C] Measurement of the pressure sensitivity of the short wavelength response of 3M5358 and D1K

The initial performance tests of 3M5358 (which is 1 mil thick) were performed by running on heads previously contoured by 0.5 mil tape. When the performance was again tested, this time on heads contoured with 1 mil tape the performance at 1 micron was degraded by 4 dB (see Acquisition Memo #175). If this loss is attributed to reduced head to tape pressure the decline is about 4 dB for a factor of 2 pressure reduction. This pressure dependence can be more quickly tested using the pressure change with vacuum given in Figure 1. Figure 2 shows the results of the test, which although noisy (due to modulation noise and variability down the tape), gives a value of about 5±1 dB per factor of 2 pressure change. Obviously the degree of signal improvement with increased pressure will eventually decline as the tape becomes perfectly smooth. The roughness is probably the primary reason for the loss of short wavelength response. Other short wavelength losses result from particle size and gap length. The particle size is given by one tape manufacturer (a Japanese visitor translated the information on a package of MAXELL tape) as 0.15 μm. If we assume that the particle size puts wiggles in the boundary of magnetic transition then at 1 μm wavelength 0.15 μm would be equivalent to 54 degrees of phase noise and a corresponding loss of 2 dB for a gaussian distribution. The gap loss at 1 micron for our heads is also about 2 dB. The total loss at 1 micron relative to 4 micron response for our D1K reference tape is 18 dB* so that there is about 14 dB "spacing" loss. If we assume that the average particle is 0.1 μm from the surface (half the particle size plus a small allowance for surface coating), then 6 dB of the spacing loss can be attributed to particle size and 8 dB to roughness.

The 1 μm wavelength response of D1K was found to increase by 0.5 ± 0.2 dB from 6 to 12 inches vacuum. The relatively small pressure sensitivity of D1K is an indication that it has a much smoother surface. However, if the roughness has a scale size much larger than the tape thickness the surface of 13 μm tape will be more easily smoothed than 25 μm tape. The scale of roughness and the effect of tape thickness, wrap angle and headstep size need further study.

*Measured by comparing the output of a 2 MHz recording made and played back at 270 IPS with a 2 MHz recording made and played back at 80 IPS. The use of the same frequency eliminates the uncertainties in the electronics bandpass.

MODULUS OF ELASTICITY 7E05 LBS/SQ" - ALONG TAPE
MODULUS OF ELASTICITY 7E04 LBS/SQ" - IN THICKNESS DIRECTION
TAPE HALF ANGLE 5 DEG HEADSTEP 0.006" FROM GAP
ASSUMES HEADS ARE CONTOURED AT 10 INCHES
WITH 10" VACUUM NOMINAL PRESSURE IS 7 LBS/SQ"

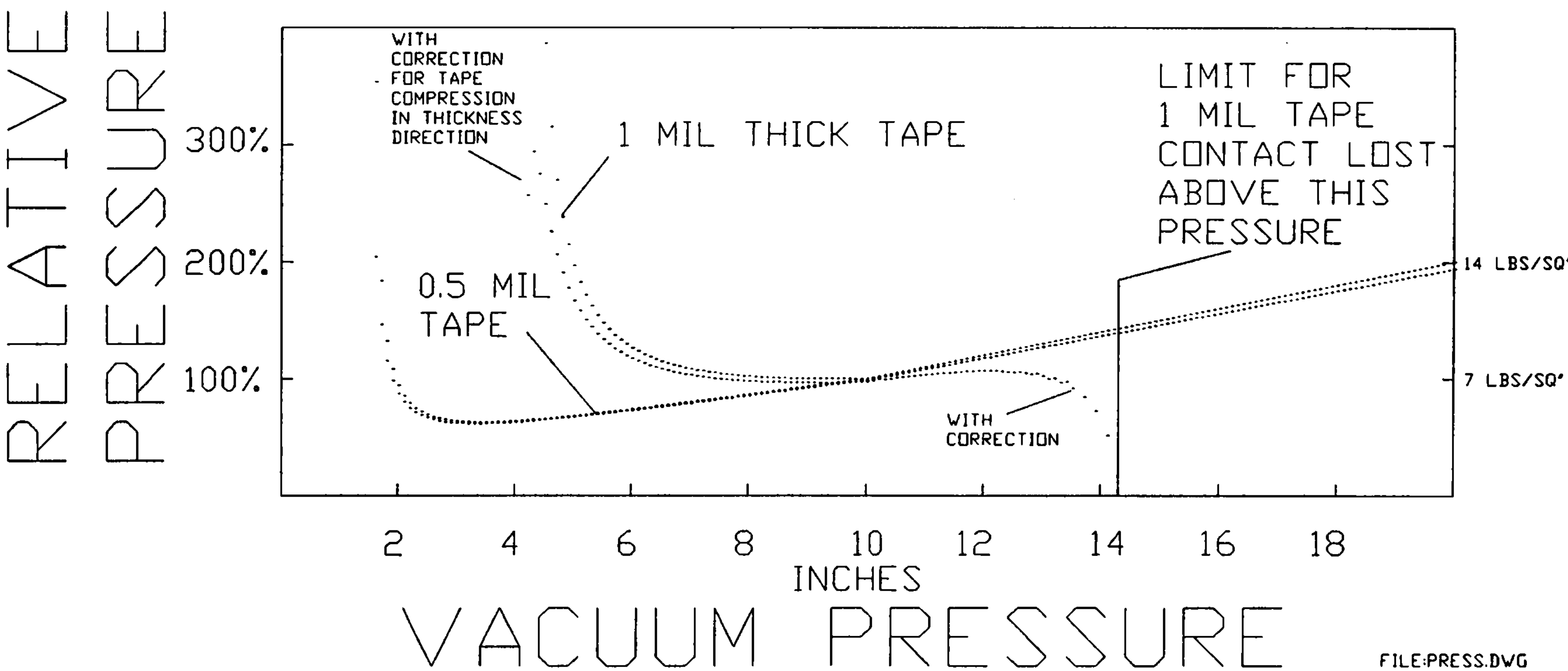

FIG 1 RELATIVE PRESSURE AT GAP VS VACUUM

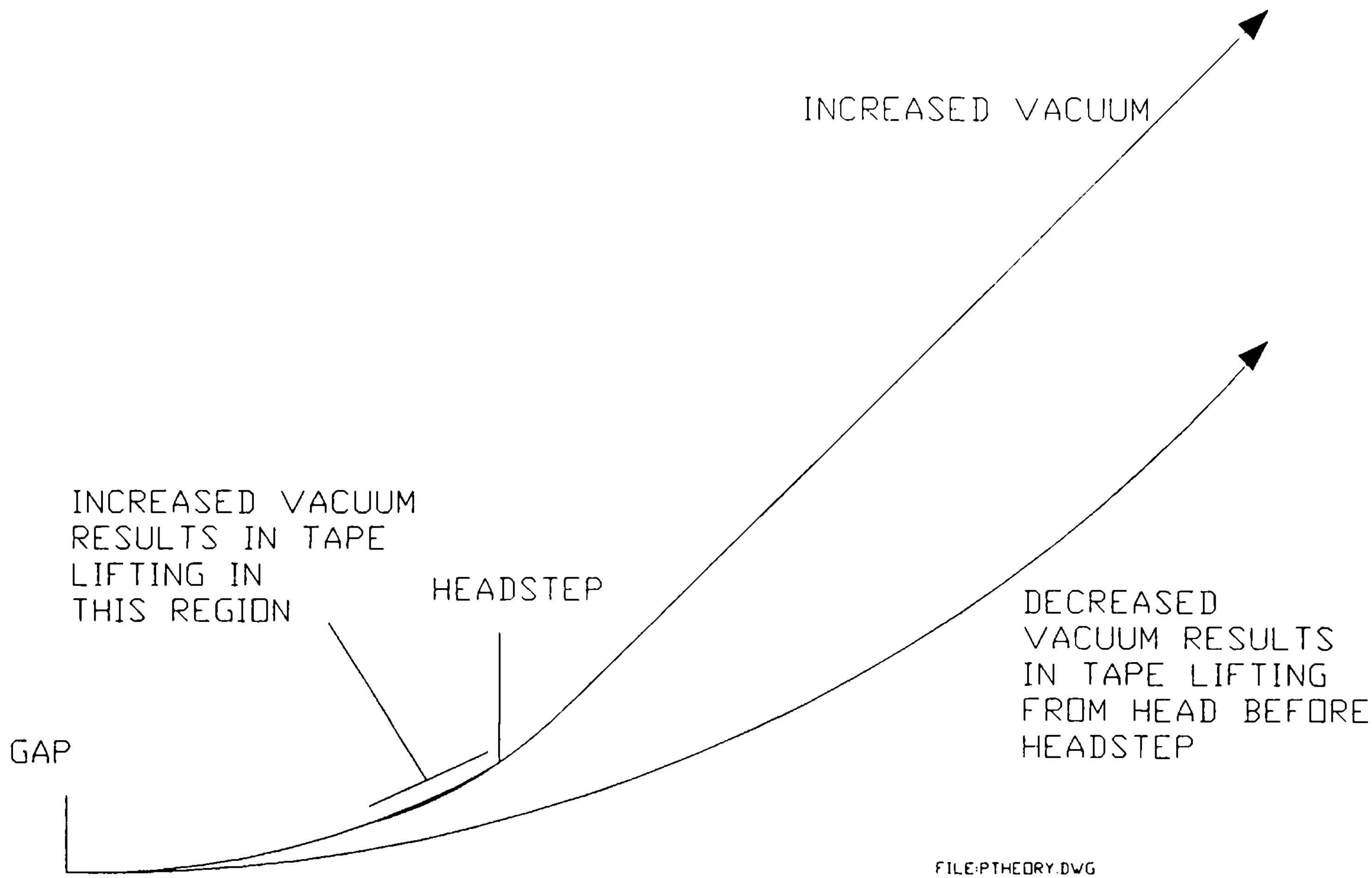

FIG.2 TAPE PROFILE FOR INCREASED AND DECREASED VACUUM

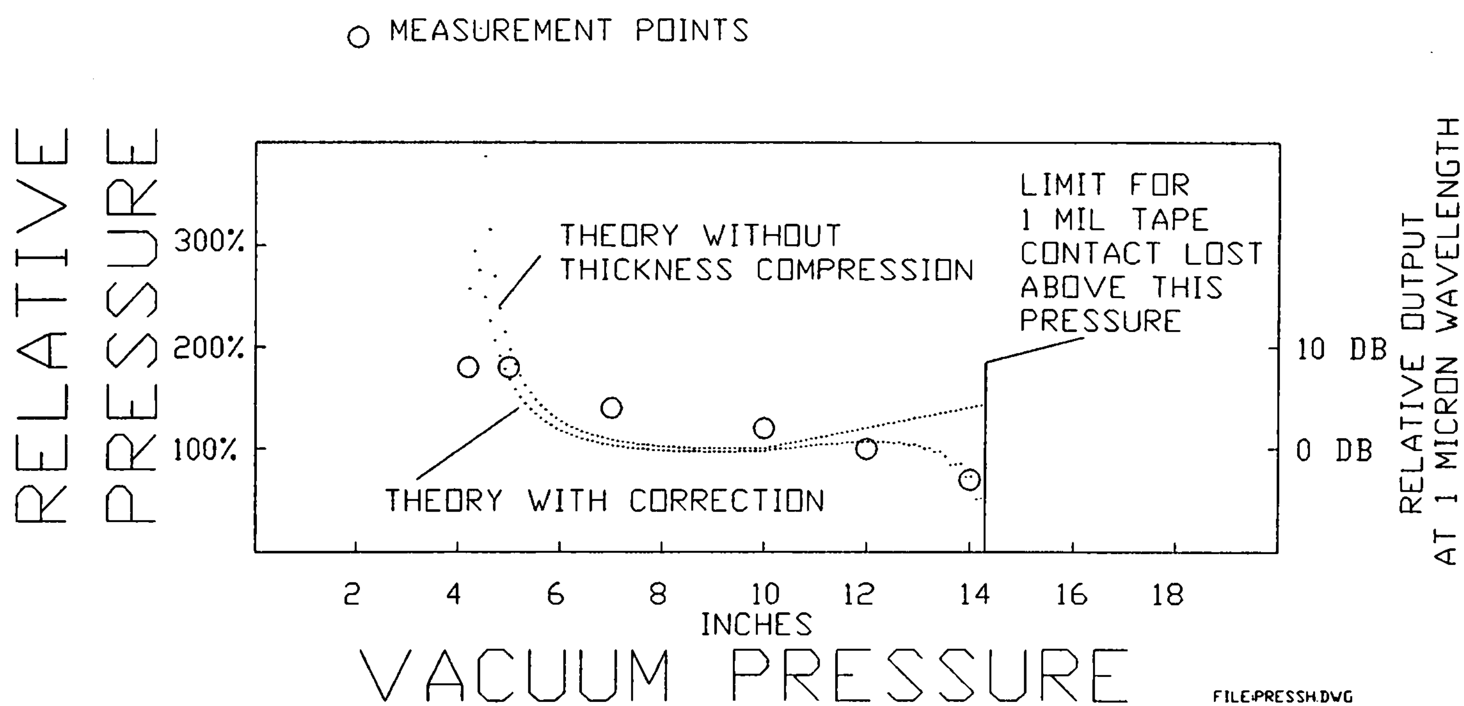

FIG 3 RELATIVE OUTPUT OF 3M5358 VS HEAD TO TAPE PRESSURE