VLBA ACQUISITION MEMO #257

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To: VLBA Data Acquisition Group

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Subject: Dynamic Friction and Viscous Drag in the Vacuum Columns

With the thin tape it is especially important to ensure that the tape is not excessively strained as it passes through the transport. There is some concern that there may be a problem with the dynamic friction of tape against the wall of the vacuum column "E" casting. In the original Honeywell transport, these walls were covered with "scotchflex" material. This material provides a rough, but low friction surface. Calculations now confirm the presence of an "anti"-air-bearing at the trailing edge of the loop. The vacuum pull-down effect was recently observed by H.F. Hinteregger following a reduction in the opening angle needed to quench the "honking" sound in the vacuum columns. It was shown in Acquisition Memo #254 that the vacuum pressure in the wedge of opening angle ϕ is

$$P = \frac{2V\mu}{r\phi^2} \quad \textit{for small } \phi$$

or a total force of

$$F = \frac{2V\mu \ln(L/\lambda)W}{\phi^2}$$

where

V	=	velocity
μ	=	viscosity
W	=	width of tape
L/λ	=	length of opening in mean free paths
ϕ	=	angle of opening

This force will control the distance S over which the tape remains in close contact with the wall (see Figure 1 for the geometry) due to the negative pressure developed on the trailing edge. Equating the vacuum force with the component of tension perpendicular to the wall (valid for very thin tape).

$$T\phi = 2V\mu\ ln(L/\lambda)W/\phi^2$$

$$\phi = (2V\mu\ ln(L/\lambda)W/T)^{\frac{1}{3}}$$

Also from the geometry of the vacuum column

$$\phi = (a - bx)/(L-s)$$

where

α	=	perpendicular distance of idler circumference ~ 0.15"
b	=	vacuum wall slope = 0.05 (3°)
L	=	distance from idler to turn-around contact ~4"
x	=	distance from outer edge of tape

from which

$$S(x) = L + (bx-a)(2V\mu ln(L/\lambda)W/T)^{-\frac{1}{3}} \quad for\ S > 0$$
$$= 0\ otherwise$$

A triangular shaped contact patch will start to form at V > 135 IPS and grow to a length of about 1" at 320 IPS for T = 0.5 lbs. This theory is confirmed by observations of the pull-down region using a plexiglass front vacuum door. Since there is reduced pressure on the leading edge of the turn-around loop , the pressure in the contact area will equal this pressure - unless there is significant air flow from the leading edge. If we assume the contact area is under the vacuum pressure then the drag force at 320 IPS is approximately

$$STu/(2D) + \mu VSW/(4\lambda) \sim 0.08 + 0.12 lbs$$

where

u	=	coefficient of friction (~0.4 for Aluminum, ~0.1 for scotchflex)
D	=	vacuum column width ~2.5"
λ	=	mean free path (0.07 μm)
S	=	maximum pull-down distance, i.e., area ~ SW/4 (see Figure 1)

The drag is significant and might stretch a tape run at high speed with low vacuum unless the coefficient of friction is low and geometry designed to reduce the viscous drag. Tests run on a transport with very smooth walls (made by sticking some magnetic tape with oxide exposed to the walls) show that on occasion a very high drag results from momentary adhesion of the surface. My conclusion is that the low friction rough surface formed by the scotchflex is needed and should be installed. In addition to the problem of tape damage by excessive drag, the drag produces an asymmetry in the forward/reverse tension. For heads in the upper positions the tape tension is higher in forward than it is in reverse and vice-versa for the heads in the lower position. Measurements of the forward/reverse tension by observing force on dummy head post tangential to the tape gave the following:

Speed	Vacuum	FOR-REV Tension % (in upper head locations)
135	6"	5 ± 5%
270	6"	15 ± 5%

This observed forward/reverse tension didn't change much when I convered the aluminum column wall with scotchflex. However, when I reduced the length of the scotchflex so that the pull-down region was reduced from about 1" long to under 0.5" long, the forward/reverse tension decreased dramatically to 5 ± 5%. The scotchflex is thick enough (150 µm) to provide a step transition on the trailing edge and thereby limit the pull-down region. This is consistent with one of the E-casting configurations tested by H.F. Hinteregger in which material was removed to form a step. Owing to the log dependence of (L/λ) - a very small step will suffice in order to eliminate the low pressure beyond the region of contact.

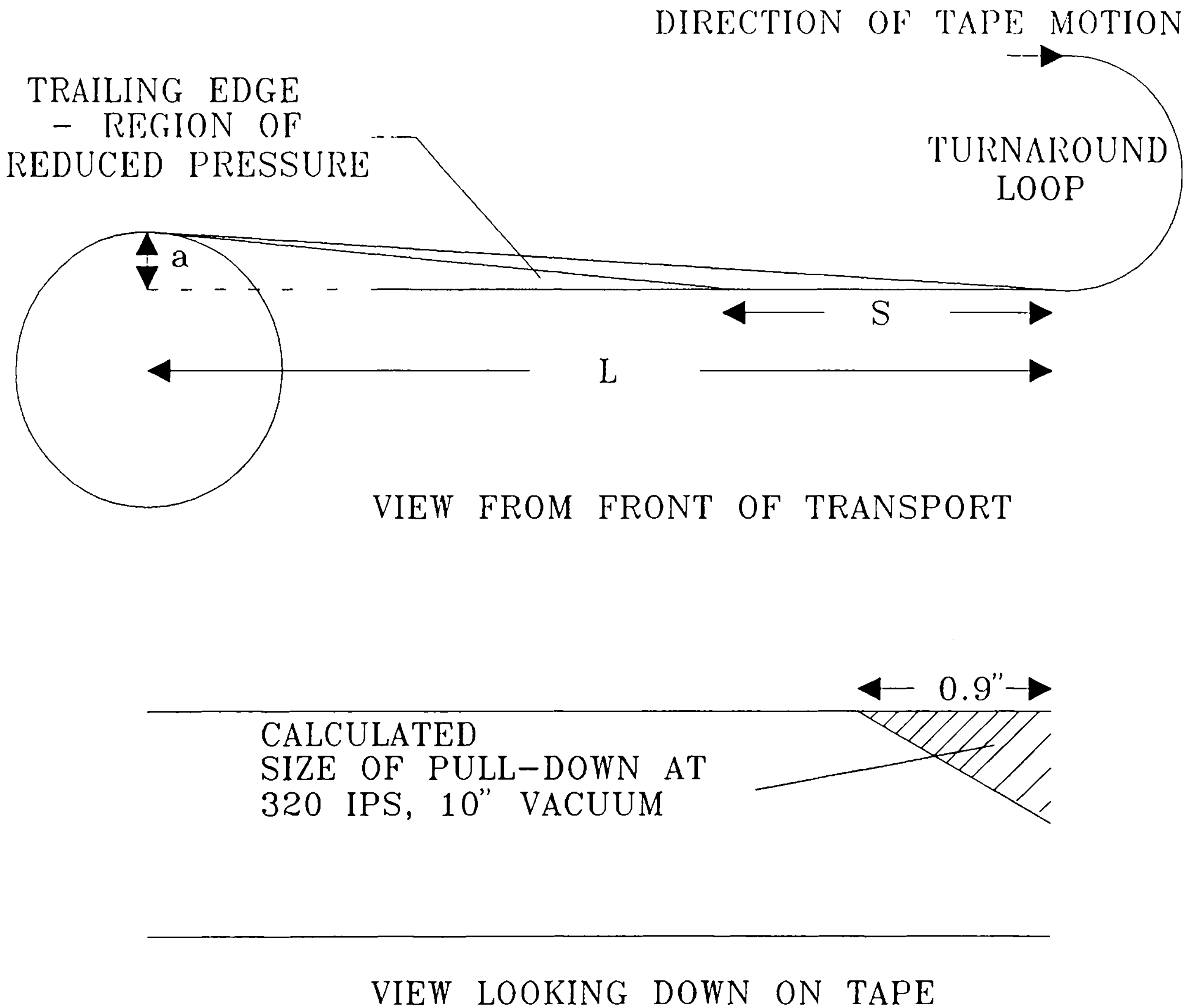

FIGURE 1. VACUUM "PULL-DOWN" OF TAPE AT HIGH SPEEDS