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The Premier Advanced Recording Technology Forum

THIC Inc.

The Mechanical Challenge of Ultra-High Track Densities: How Far Can Tape Guide Rollers Go?

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Presented at the THIC Meeting at the National Center for Atmospheric Research, 1850 Table Mesa Drive, Boulder CO 80305-5602

June 29-30, 2004

This talk will be about guiding tape smoothly over the head

- I’m going to size the problem with a picture
- I’m going to talk about the history of the problem
- I’m going review current guiding methods and pitfalls
- I’m going to suggest ways out

For those that go to sleep, a similar presentation can be found in an article I wrote for *Computer Technology Review’s* March 2004 issue.

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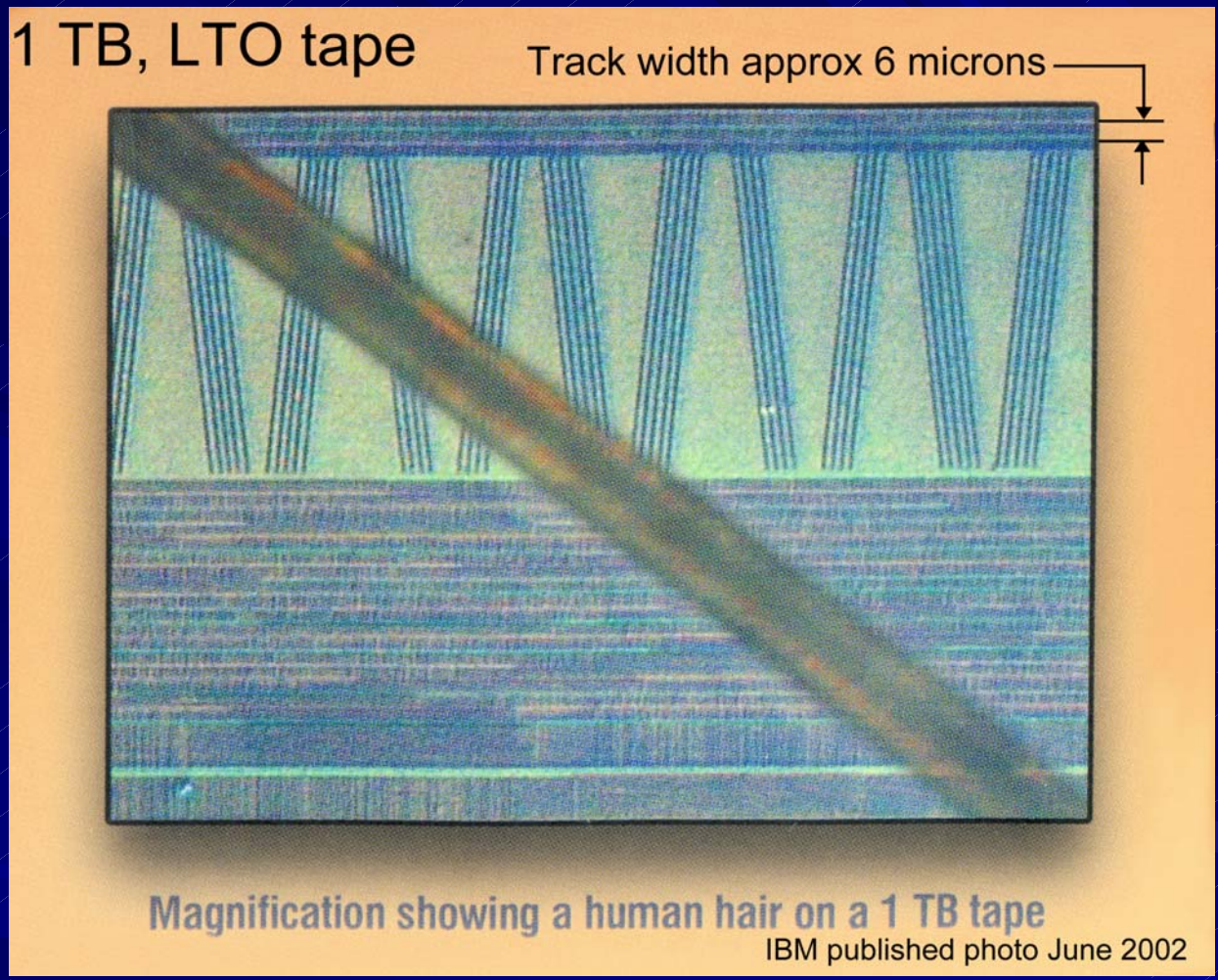
The challenge



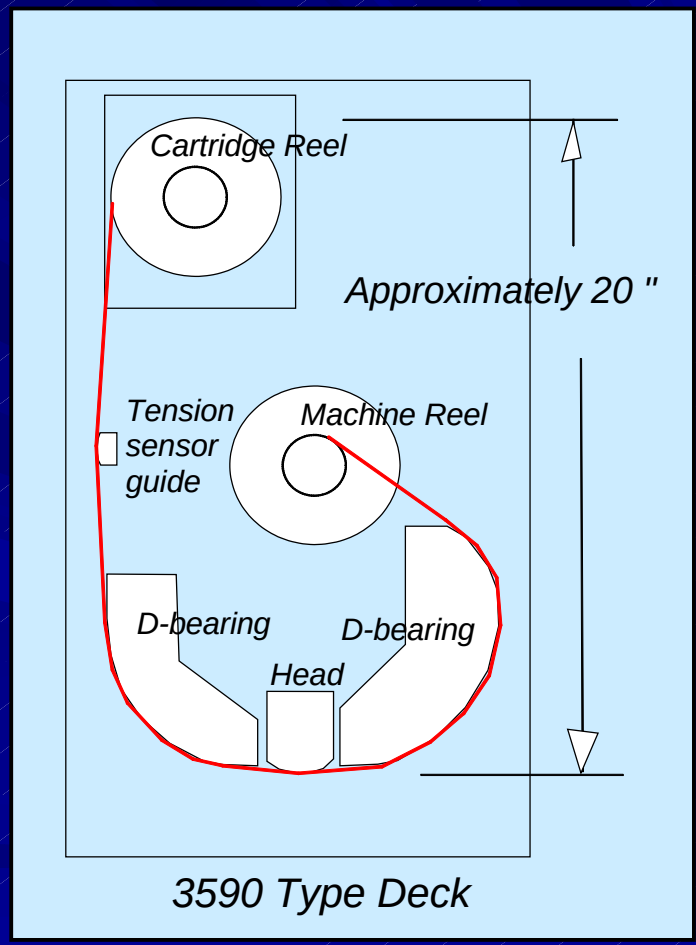
What tape guiding system will allow us to get this density and beyond?

Why must we depend so much on improved tape guiding?

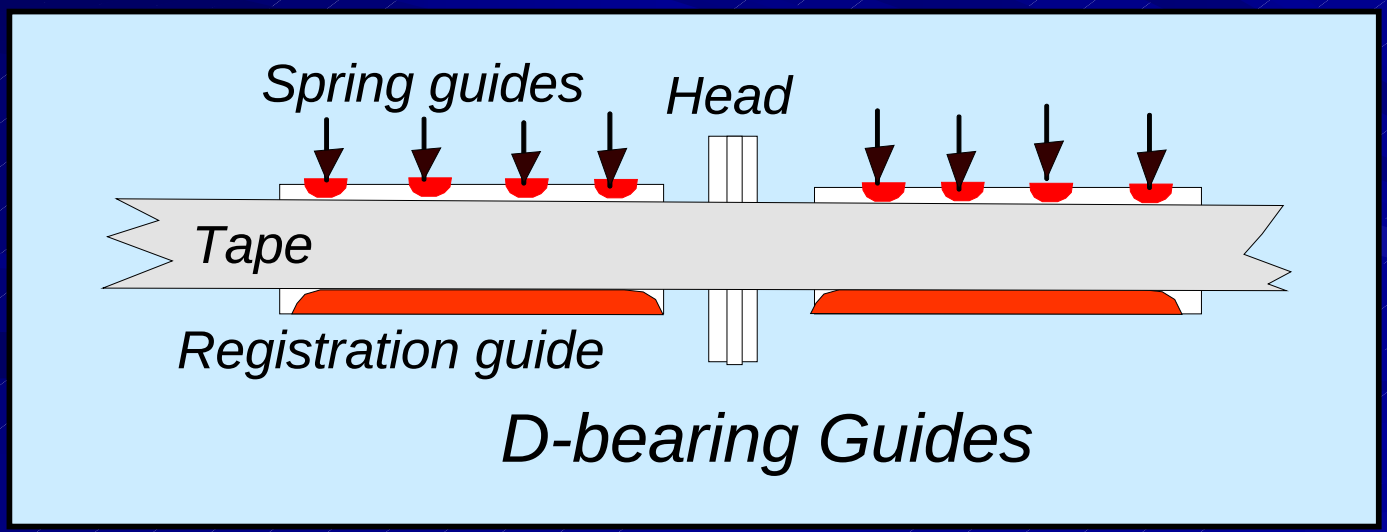
- Because traveling tape has jitter – known as Lateral Tape Motion or LTM.
- Because present guiding results in about 25 microns of LTM at the head – way too much for future track densities.
- Because wide-band servos cannot follow all of it -they have their limitations

How did we get this problem?

- In the 3590 era we had large tape decks
- Long tape paths allowed unevenly stacked tape at the reel to smooth out at the head
- Guiding was done by D-bearings – OK for 36 track tape



- D-bearings guided tape on a film of supplied air
- Spring fingers pressed down on top
- This worked fine for tracks of 250 u wide.
- This worked poorly for tracks of 25 u wide.



The problem with D-bearings

- Lateral vibrations are induced by the spring fingers
- Some vibrations are in the 500-800 Hz range which tracking servos could not follow.
- This lead to significant position error signal, or PES. Example.

D-bearings abandoned

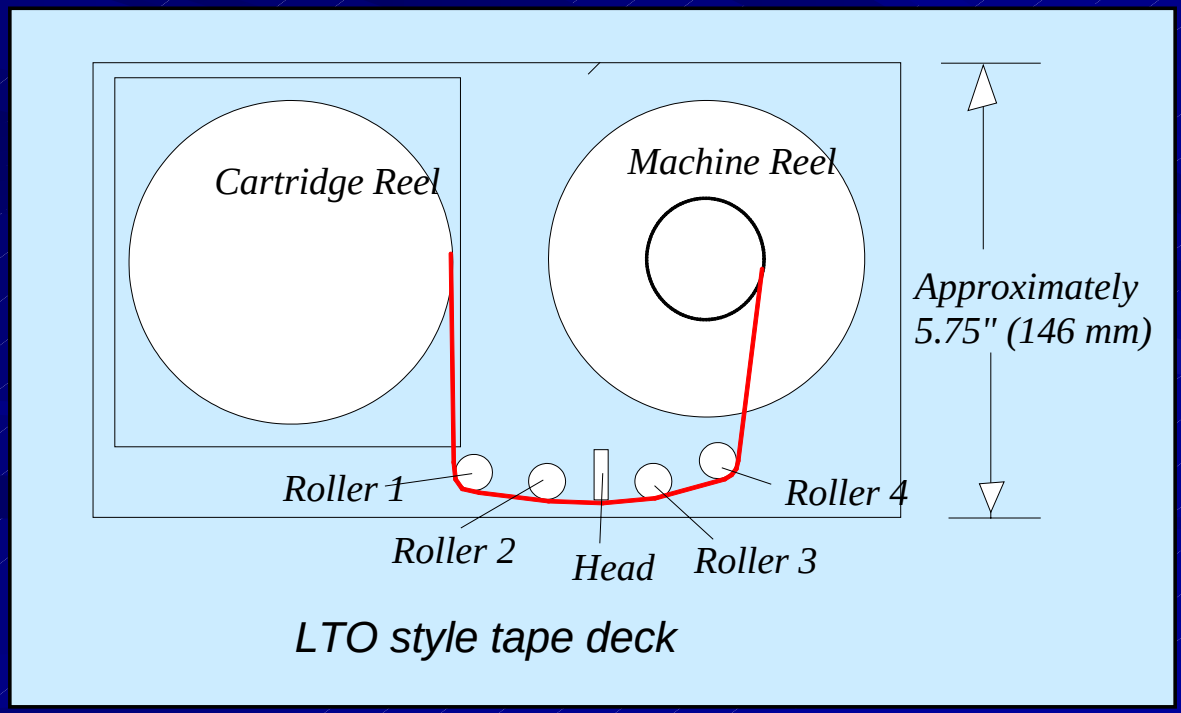
- Smaller drives prompted abandonment of *hydrostatic* bearings – with air pump
- *Hydrodynamic* bearings were substituted, where an air film is induced.
- Vibration problems persisted.
- This resulted in rollers being embraced

Guide rollers have long history

- Rollers used in many transports, especially video
- Because tape moved slowly, 3 to 4 ips, severe edge wear did not develop.
- Rollers were thought safe.

Short paths now

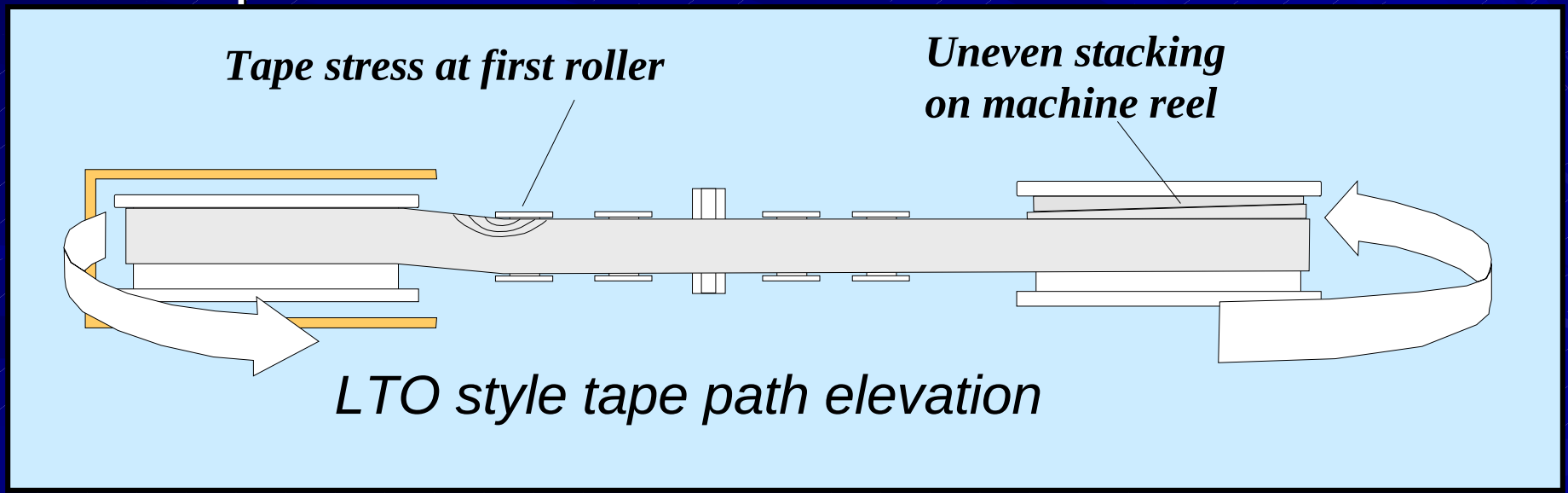
- Paths shortened and tape speeded up - 2 m/s, then 4 m/s, then 6 m/s
- This was a deadly combination



Rollers work hard

With shorter paths, rollers were expected to do more:

- Guide tape at high speed
- Quickly correct for stagger-wrap from the reel
- Damp out vibrations at the head



LTO style tape path elevation

But rollers can’t do it all!

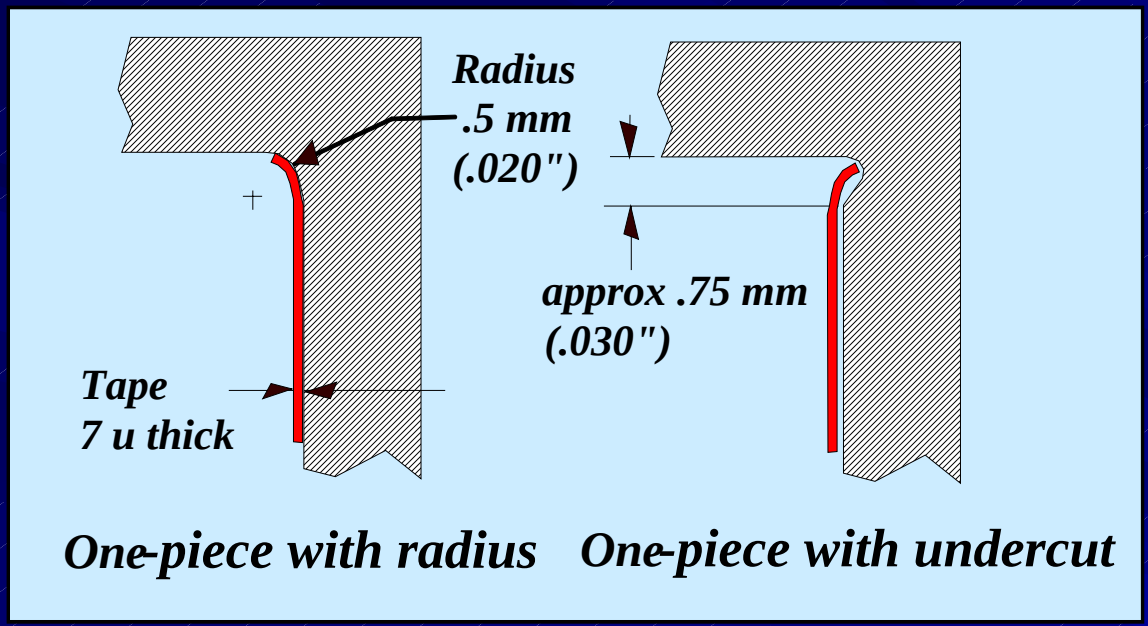
- Rollers 1 and 4 have different jobs than 2 and 3.
- Outer ones handle stagger-wrap; inner ones guide and damp
- Outer ones have smooth finish; inner have grooves.
- Tape flies over outer; adheres to inner.

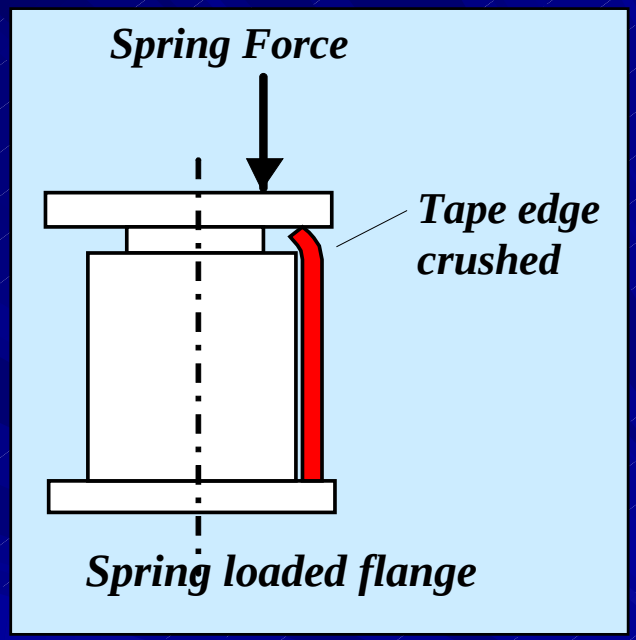
What kind of rollers, then, should be used?

Designers have chosen 3 types, none of which is easy on the tape

- A one-piece with a small corner radius
- A one-piece with a corner undercut
- A 3-piece with a spring loaded flange.

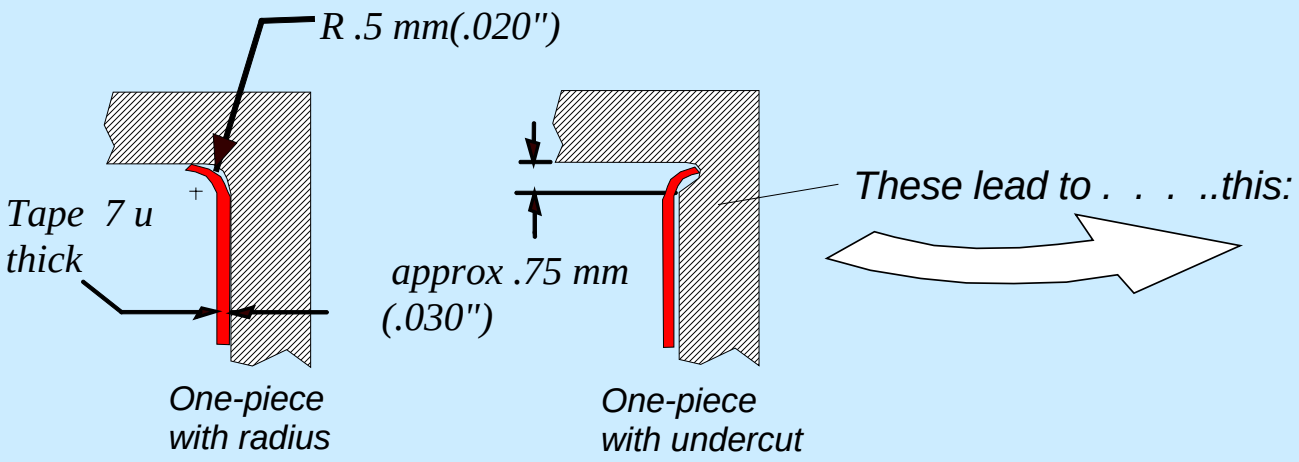
Current roller types





- All damage the tape edges

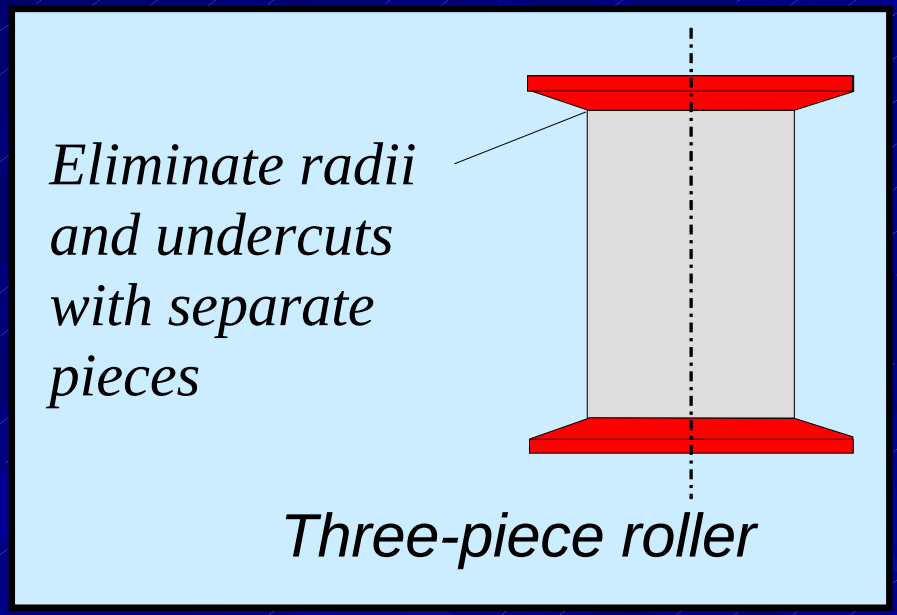
Damaged tape



How one-piece rollers scallop tape edges

My recommendation: a three-piece roller

- It eliminates undercuts and radii
- Eliminates abrasive flanges and possible “bowstringing” of tape edge
- Presents smooth guiding surface and firm corner for tape to bear against



How far, then, can rollers go?

- If care is taken with the type of rollers
- If the machine reel is refined to reduce stagger-wrap
- If careful but current machining practices are used
- Then I believe rollers can take us into 1 TB territory.

What about beyond that?

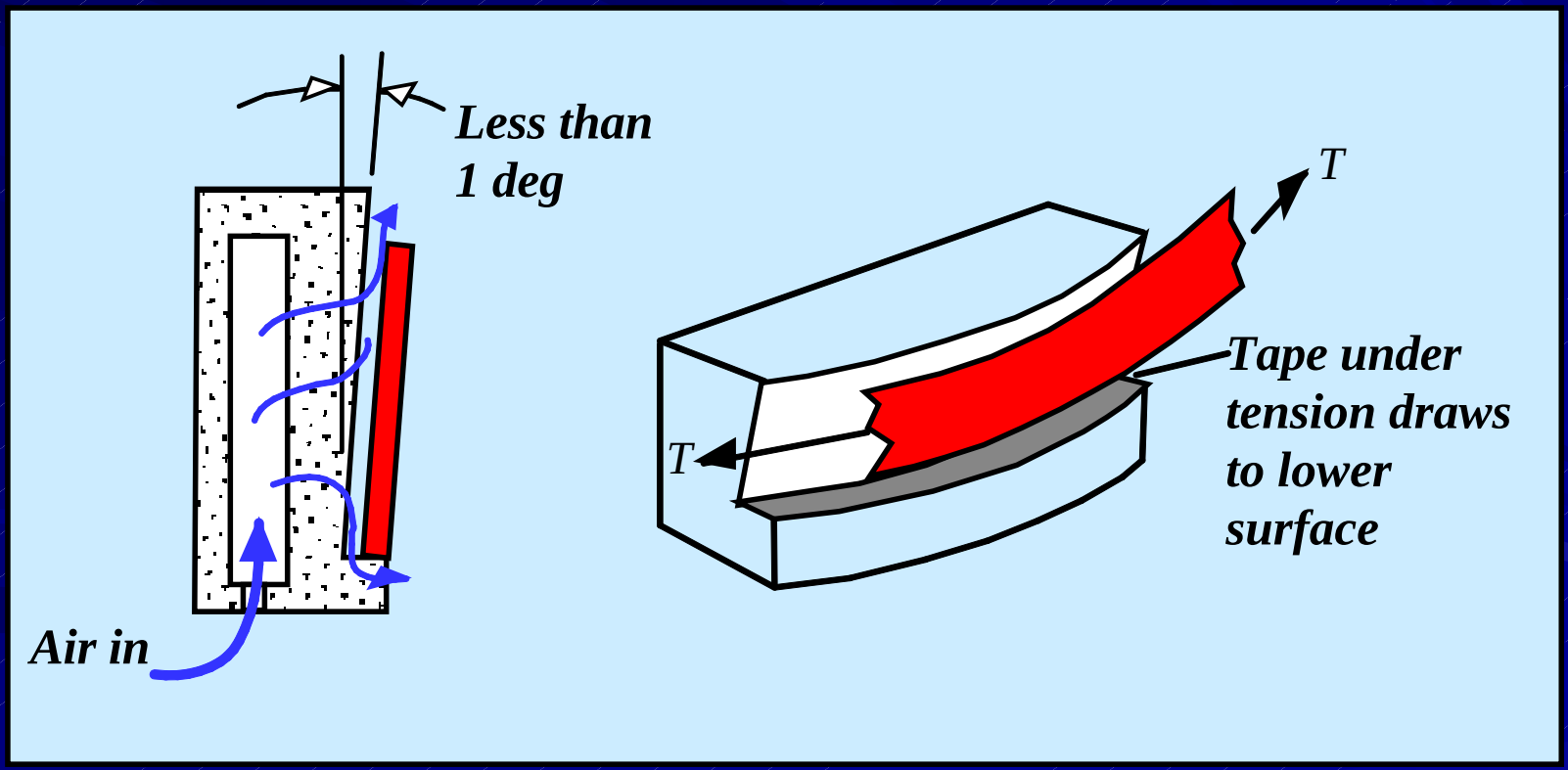
- The 1 TB half-inch tape drive is only several years away
- What about doubling or 10X capacity after that?
- What will designers do to get to a 1 micron track width?

The return of an old idea

- Designers may have to return to air fed D-bearings.
- They would have to be without pressure fingers – no vibrations induced
- Recently developed porous ceramic air-fed bearings show promise

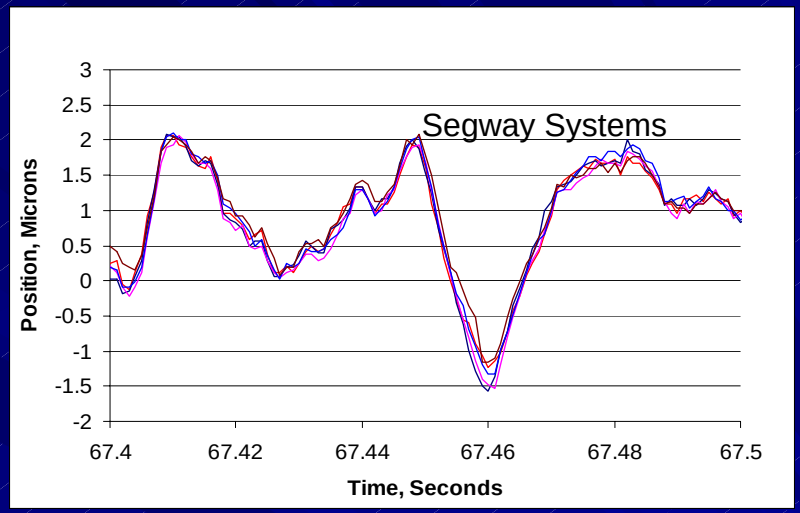
Porous D-bearings

- Register tape against the lower support by tilting outward less than 1 degree.

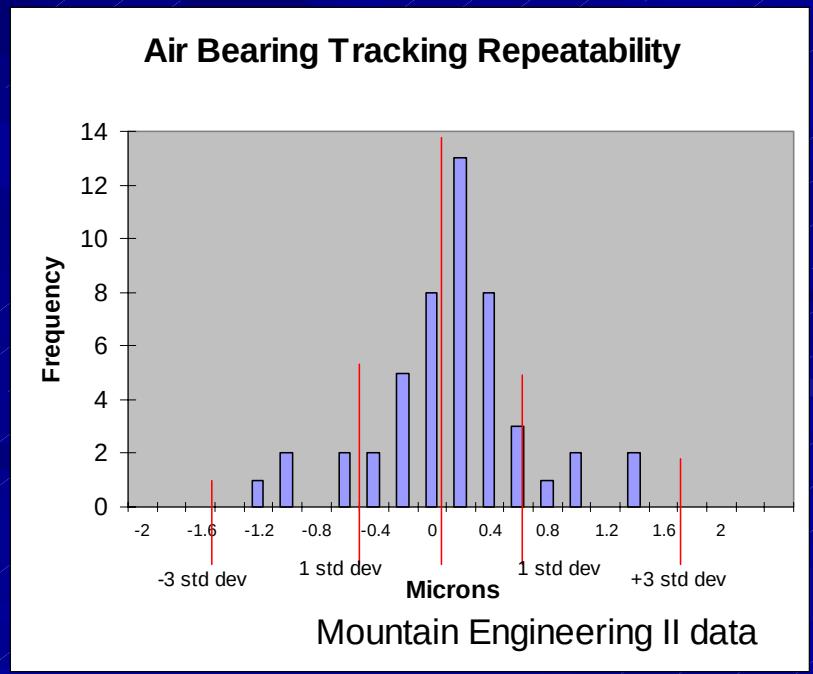


D-bearing tracking repeatability

- Tests show the edge-following repeatability for multiple passes



- 68% of LTM is within 1 micron
- 99% within 3 microns



Track following improvements

- PES increases as tape speed increases
- If speed doubles, a lateral frequency that was 500 Hz now approaches 1000 Hz
- Servo bandwidths must keep up
- This is not easy, and brute force with more coil current is not a good answer.

Head actuator improvements

- Present rail-and-roller method has friction hysteresis – won't work for 1u movements
- Present flexure method has resonances that must be avoided
- An air bearing actuator has possibilities
- A piezo actuator has possibilities

Summary and Conclusion

- Increasing track density strains the ability of guiding elements
- Present D-bearings vibrate tape
- Present Rollers damage tape
- With elements that include proper rollers, 1 TB can be recorded on an LTO format

Summary and Conclusion

- For the 10 TB range, tilted, air-fed D bearings show promise.
- For capacity comparison and perspective, 1.2 TB was StorageTek's first practical library capacity in 1985.
- It contained 6000 cartridges of 3480 style containing 200 MB each.

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