The Premier Advanced Recording Technology Forum

THIC Inc.

Bi-Directional Magnetic Read/Write Recording Head Surface Contour with Plurality of Bernoulli Pocket Cavities for Generating Very Low Media-to-Head Separations

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Presented at the THIC Meeting at the National Center for Atmospheric Research

Boulder CO 80305-5602

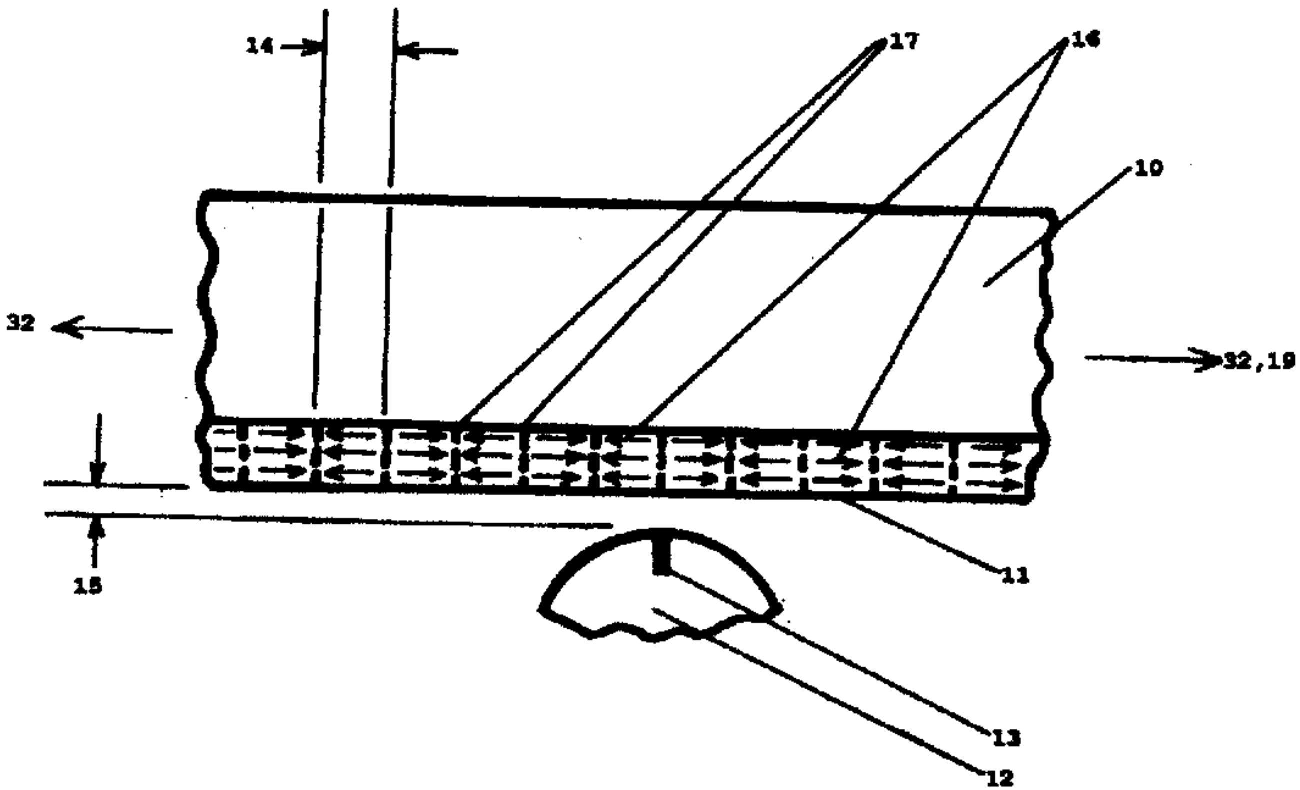
June 11-12, 2002

Decrease of Media – Head Separation

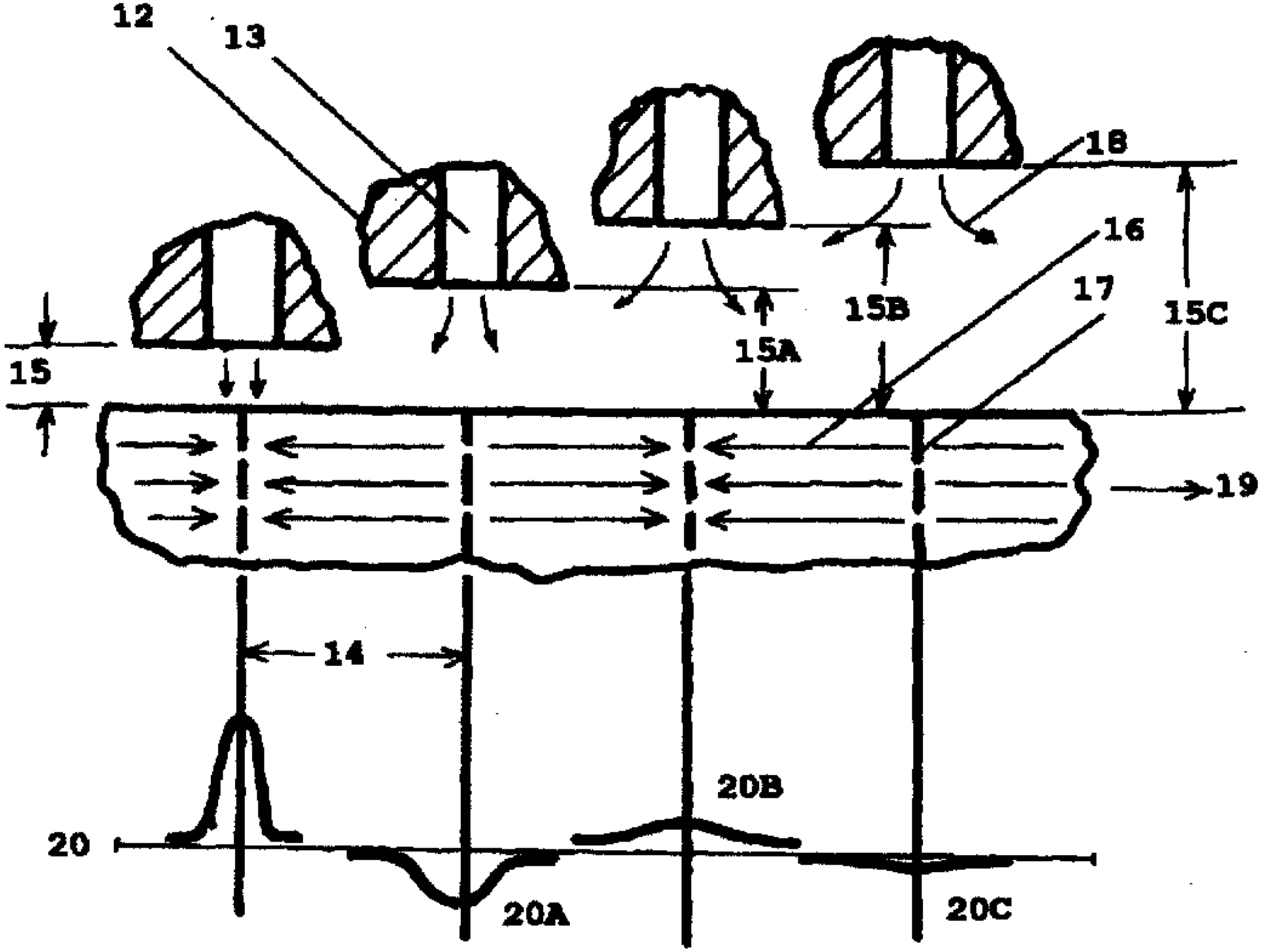
- Higher Data Cartridge Capacities
  - Higher track density
  - Higher Linear density
- Increase of Linear Density
  - Lower media to head separation
    - Increase of RAW bit error rate
      - More ECC overhead
    - Impact of Channel design
    - Detection problems

Impact of Density Increase on Detection

- Media with bit cells defined and head in close proximity

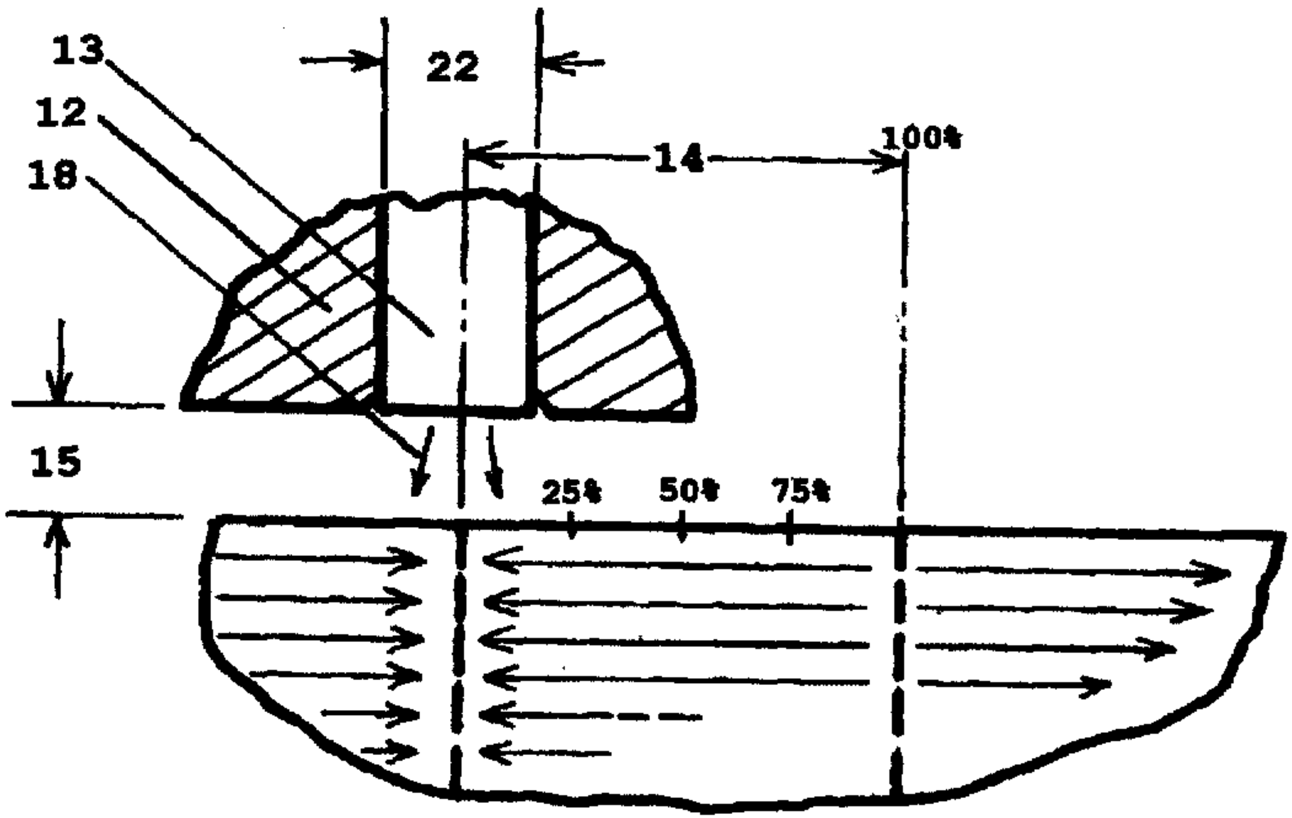


Result of increased Separation



Maximum Flying Height

- 25% of bit cell length (Bob Cope)



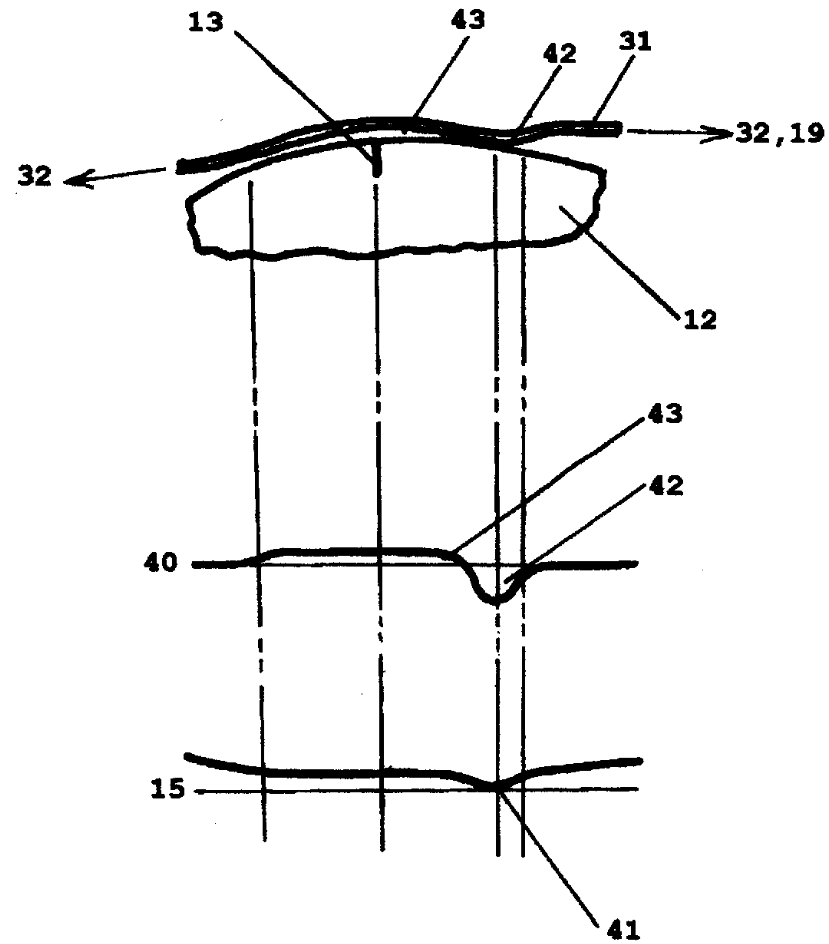
Requirements of the "25%" rule

- Benchmark DLT1
  - 3,940 FR/mm (100,000 FR/in) (1999)
  - Bit cell length = 0.254 μm (0.000010 in)
  - Flying height according to 25% rule

    0.066 μm (0.000002 in)
- Sub-micron flying height demands extraordinary head contour design

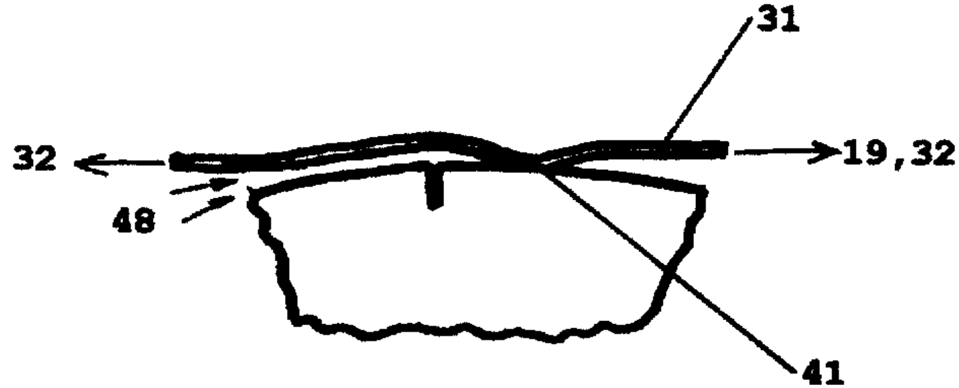
Media to Head Separation

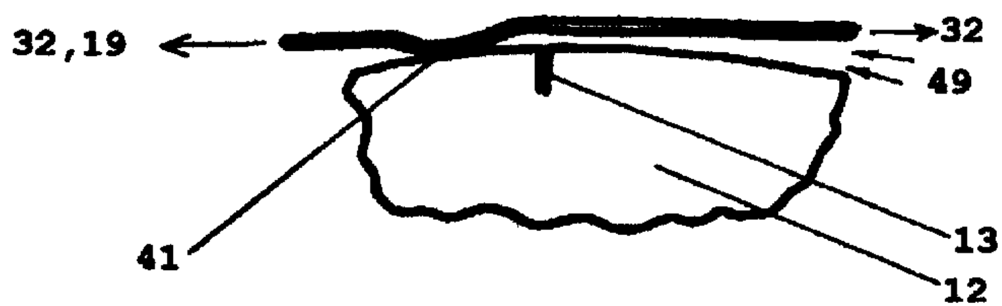
- Air pressure develops as media moves over head surface



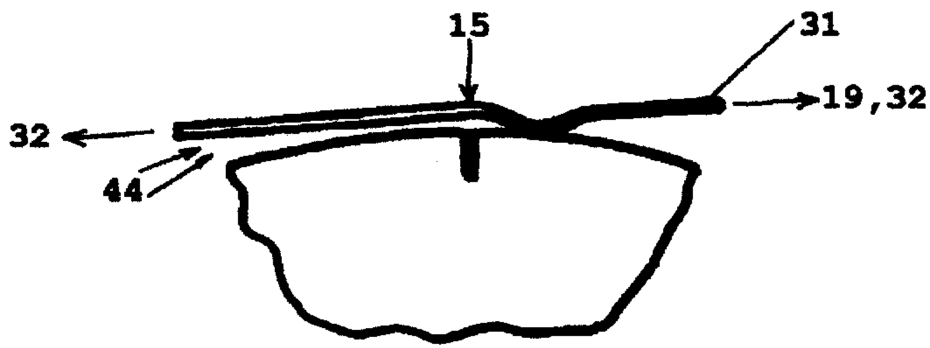
Media to Head Separation

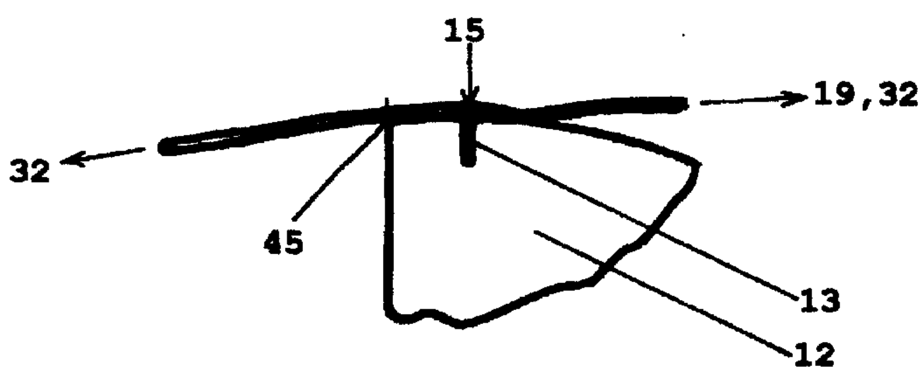
- Reversal of direction





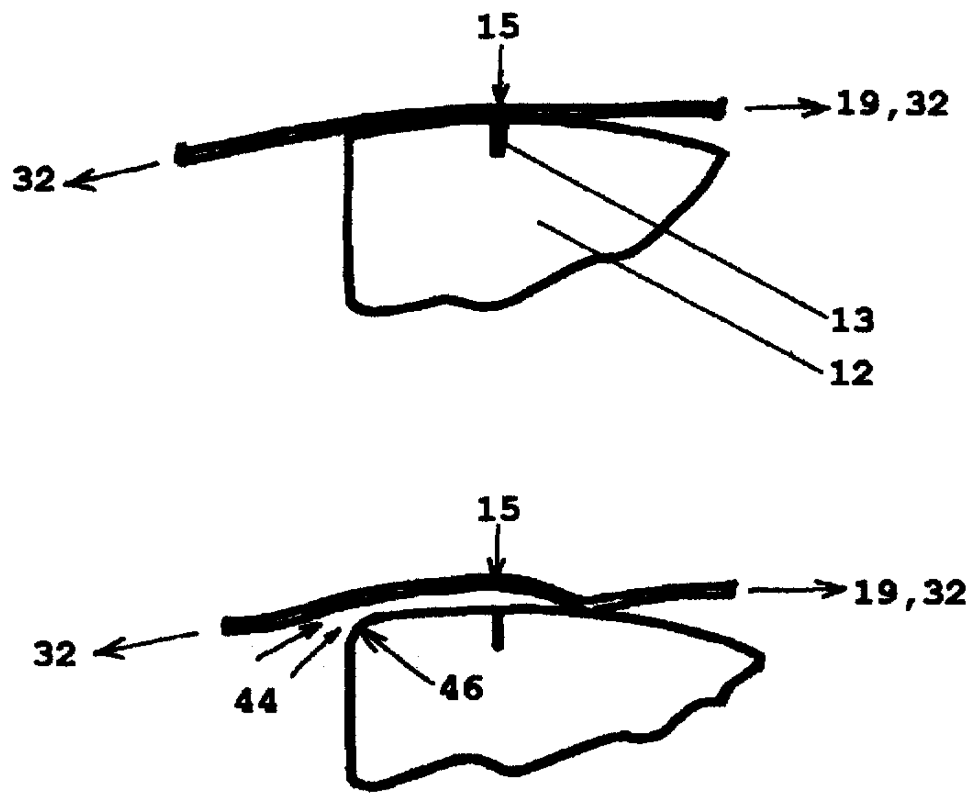
Common Design Approach to Lower Flying Height



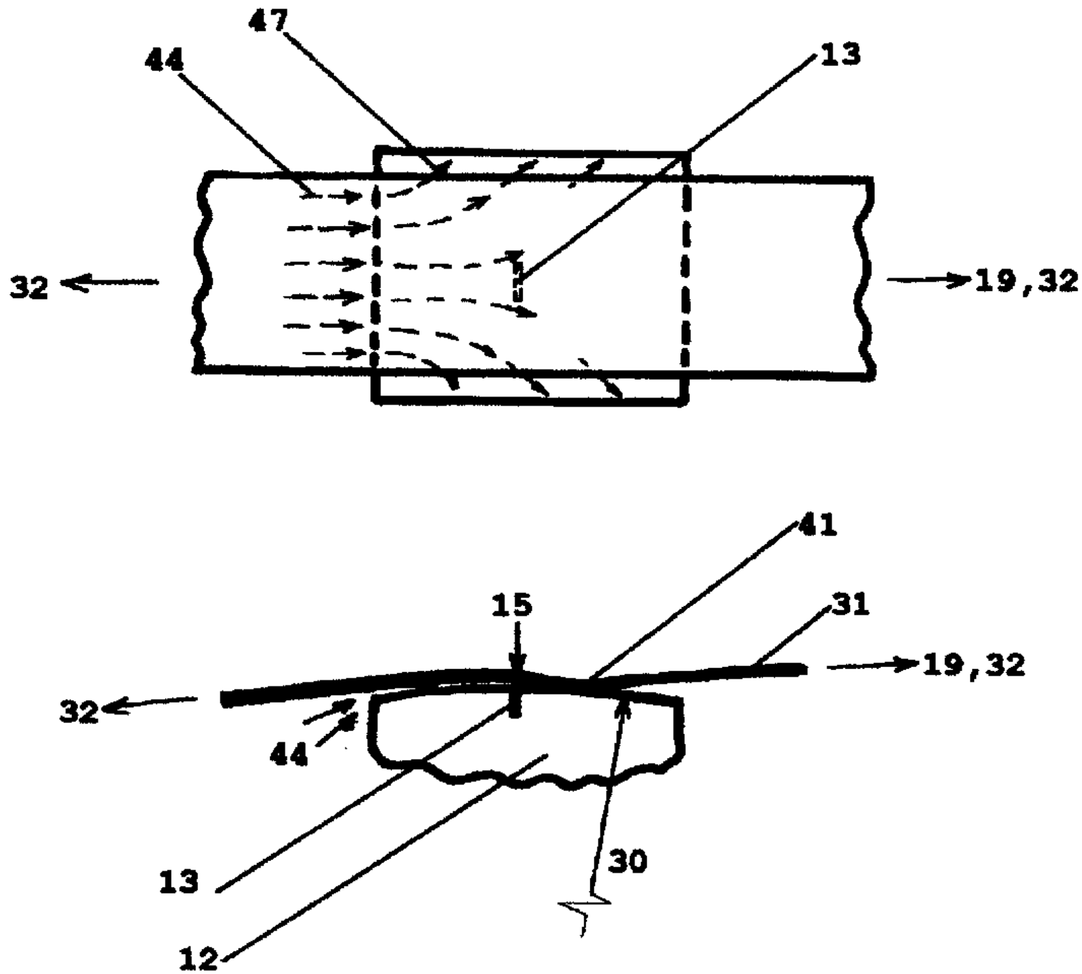


Common Design Approach to Lower Flying Height

- Wear of leading edge impacts separation



Media Width vs. Edge Flying Height



Design Considerations for Head Contour

- Media is under tension (T)
- Media has Modulus of Elasticity (E)
- Media has a Poisson's ratio attribute (v)
- Media under tension has bending stiffness property (D)
- Media is positioned in a path with curved surfaces (R)
- Media is positioned with wrap angles (w)
- Media has the Thickness (t)

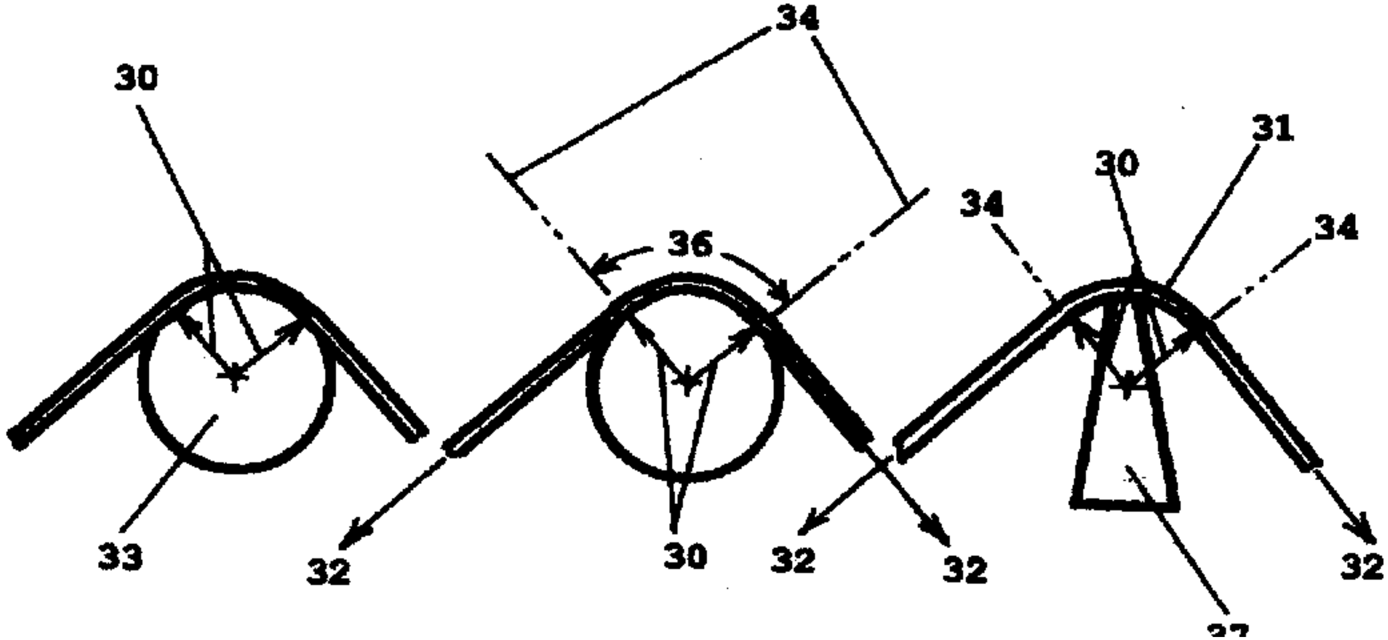
Design Considerations for Head Contour

- The most important attribute is:

Critical Radius R_c

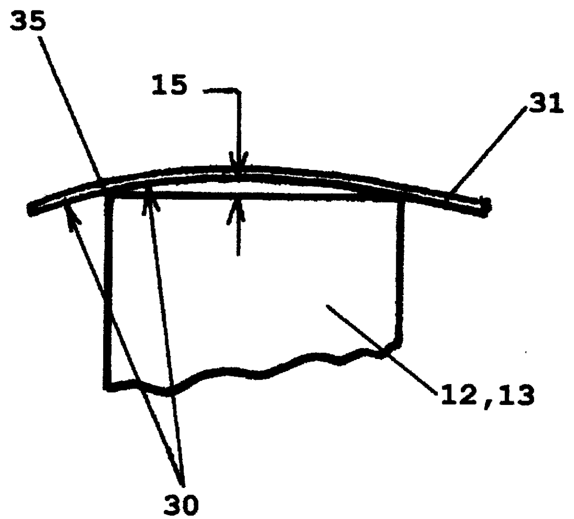
Impact of critical radius

- Match of Guide/Roller radius and Critical Radius
  - Knife blade can be substituted



Impact of critical radius

- Features sharper than critical radius
  - High stress contact areas
  - Requirement to place R/W gaps under contact areas



Teeter-Totter Effect

Source: <u>A Simple Wrap Around a Guide: Some Complexities</u>, by S.P.Clurman, IEEE Transactions On Magnetics, Vol MAG-17, No. 6, Nov 1981

Calculation of Critical Radius

- Calculate bending stiffness of media

$$D = E * t^3 * \frac{1-v^2}{12}$$

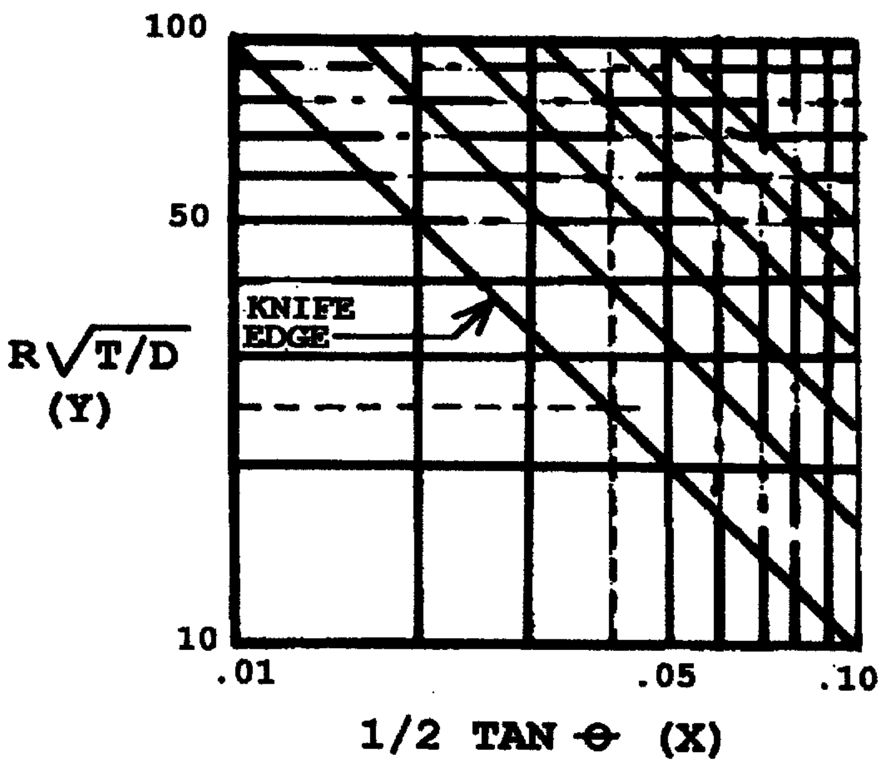
- Determine parameter X from the wrap angle(s) of the tape path

$$X = \frac{1}{2}\tan(\text{wrap angle})$$

Source: EFFECTS OF BENDING STIFFNESS IN MAGNETIC TAPE, By R.E. Norwood, IBM Journal of Research and Development, Volume 13-2, Pages 205-208 (1969)

Calculation of Critical Radius

- From the chart below locate the calculated value for X



Calculation of Critical Radius

- Project up to the ‘knife edge’ line, and then over to the Y value:

$$Y = R_C * \sqrt{\frac{T}{D}}$$

- Critical radius: $R_C = \frac{Y}{\sqrt{\frac{T}{D}}}$

Critical Radius Conclusions

- All edges in contact with media must be greater than R_C
- All basic radii on the head contour must be greater than R_C
- Otherwise placement of R/W gaps under the low points will be difficult

Critical Radius Conclusions

- Problems
  - Flying height maybe too high
  - Large radius contour will lift the media
  - Channel error rate will be adversely impacted

Flying Height Function

- The flying height (h) is defined as:

$$h = 0.643 * R * \left(6 * u * \frac{U}{T} \right)^{\frac{2}{3}}$$

  - U = relative velocity
  - u = viscosity of air
  - T = foil tension
  - R = radius
- Increase of radius R increases flying height

SOURCE: <u>FLUID FILM LUBRICATION</u> BY GROSS, MATSCH, CASTELLI, ESHEL, VOHR , WILDERMANN and MARION

Between a rock and a hard place

- Radii must be greater than R_C
- Flying height increases with increased radii

- Solution: Bernoulli pockets on either or on both sides of the gaps

Bernoulli Effects

- Constant air flow conditions
- Change in velocity
- Change in local pressure
- Forces exerted on specific area

14-4] *APPLICATIONS OF BERNOULLI'S EQUATION* 253

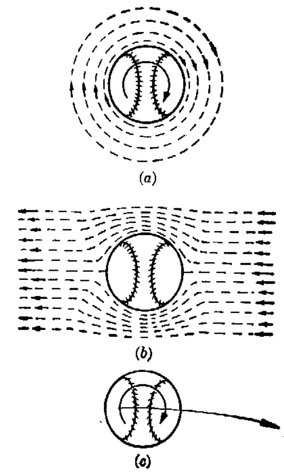


Fig. 14-8. Curved flight of a spinning ball.

(5) *The curved flight of a spinning ball.* Fig. 14-8(a) represents a top view of a ball spinning about a vertical axis. Because of friction between the ball and the surrounding air, a thin layer of air is dragged around by the spinning ball.

Fig. 14-8(b) represents a stationary ball in a blast of air moving from right to left. The motion of the air stream around and past the ball is the same as though the ball were moving through still air from left to right. If the ball is moving from left to right and spinning at the same time, the actual velocity of the air at any point is the resultant of the velocities at the same point in (a) and (b). At the top of the diagram the two velocities are in opposite directions, while the reverse is true at the bottom of the diagram. The top is a region of low velocity and high pressure, while the bottom is a region of high velocity and low pressure. There is therefore an excess pressure forcing the ball down in the diagram, so that if moving from left to right and spinning at the same time, it deviates from a straight line as shown in the top view in Fig. 14-8(c).

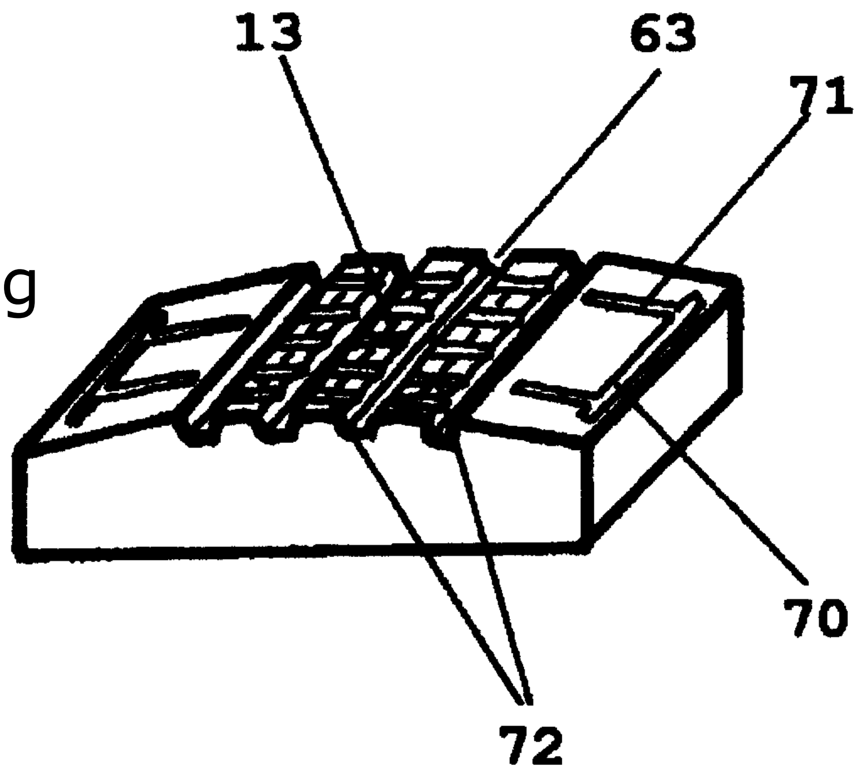
(6) *Lift on an airplane wing.* Fig. 14-9 is a photograph of streamline flow around a section in the shape of an airplane wing or an airfoil, at three different angles of attack. The apparatus consists of two parallel glass plates spaced about 1 mm apart. The wing section, whose thickness equals the separation of the plates, is inserted between them and alternate streams of clear water and ink flow by gravity between the plates and past the section. The photographs have been turned through 90° to give the effect of horizontal air flow past an airplane wing. Because the fluid is water flowing relatively slowly, the nature of the flow pattern is not identical with that of air moving at high speed past an actual wing.

Consider the first photograph, which corresponds to a plane in level flight. It will be seen that there is relatively little disturbance of the

SOURCE: COLLEGE PHYSICS by Sears and Zemanski, 1955, pp 253

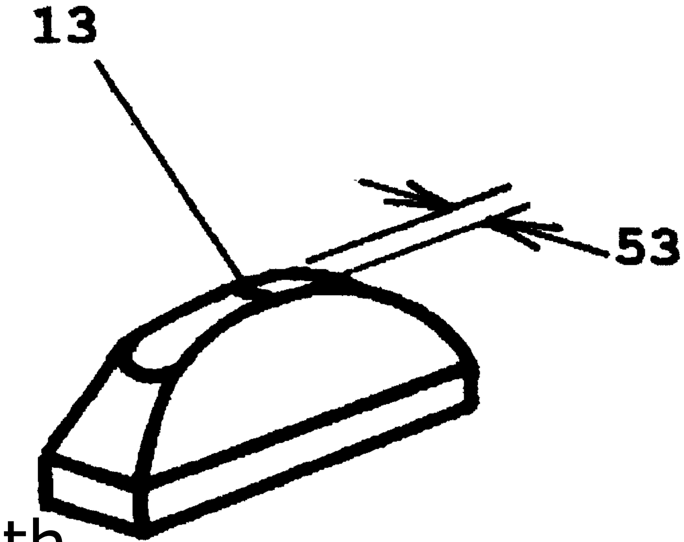
Bernoulli History

- Head in IBM 2400 vacuum 9-track tape drive
  - Cut-away for low flying height
  - No sealing of cavities



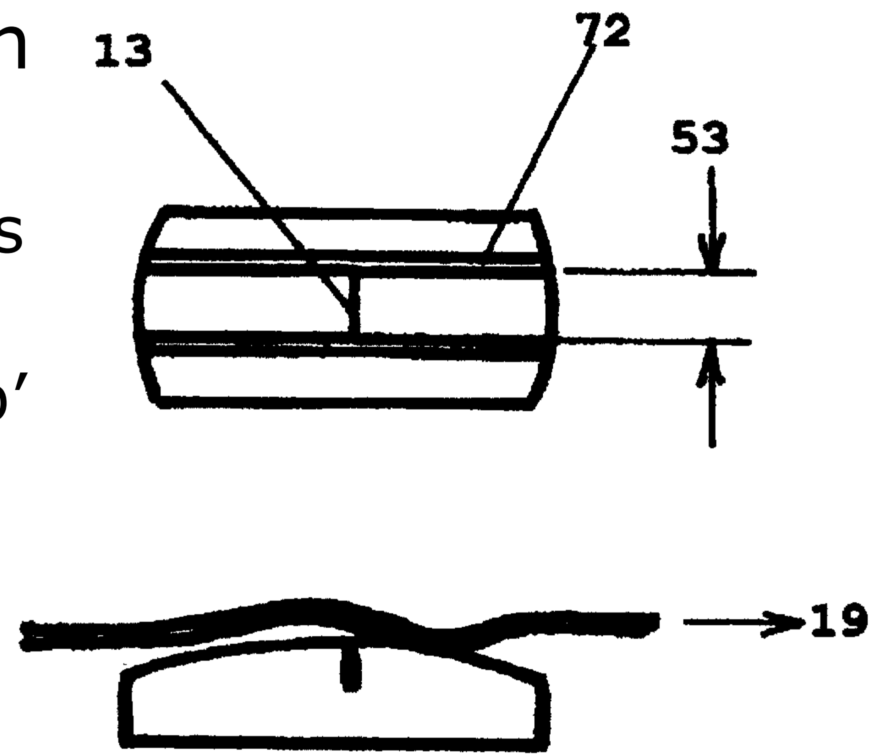
Bernoulli History

- IBM 3850 helical scan recorder
  - Original contour used (Freeman)
  - 25 MPS (1,000 IPS)
  - 68.6 mm (2.7 in) media width
  - Slots fixed separation problem
  - Single direction (BOT → EOT)



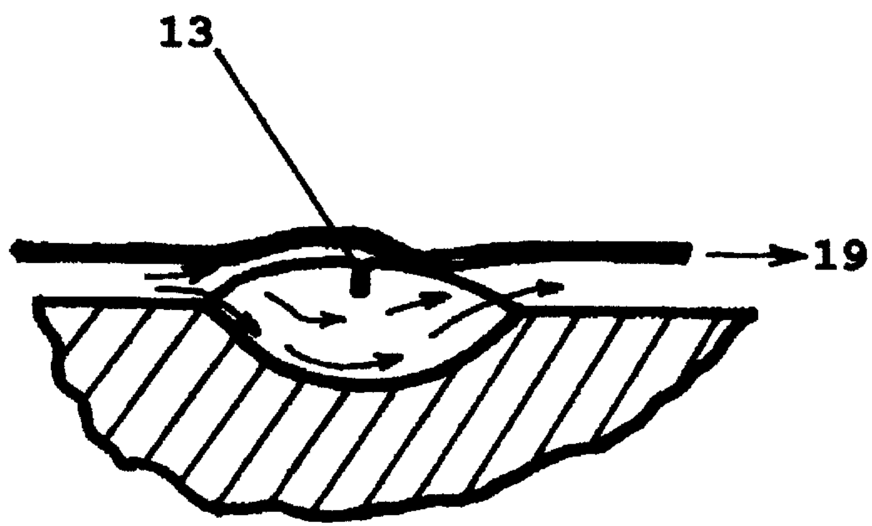
Bernoulli History

- Final contour used on 3850
  - Slots placed into glass walls
  - Gap placed under ‘dip’
  - Slots vented to atmosphere



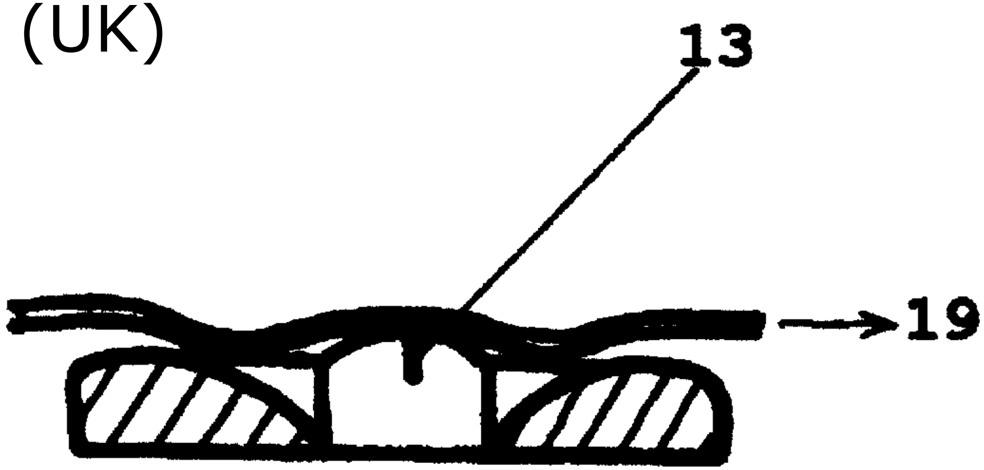
Bernoulli History

- Early drum recorder idea (Sano)
  - Multiple gap heads with spacers
  - Spacers provided cavities
  - Side cavities to leak air
  - Side voids are vented to atmosphere



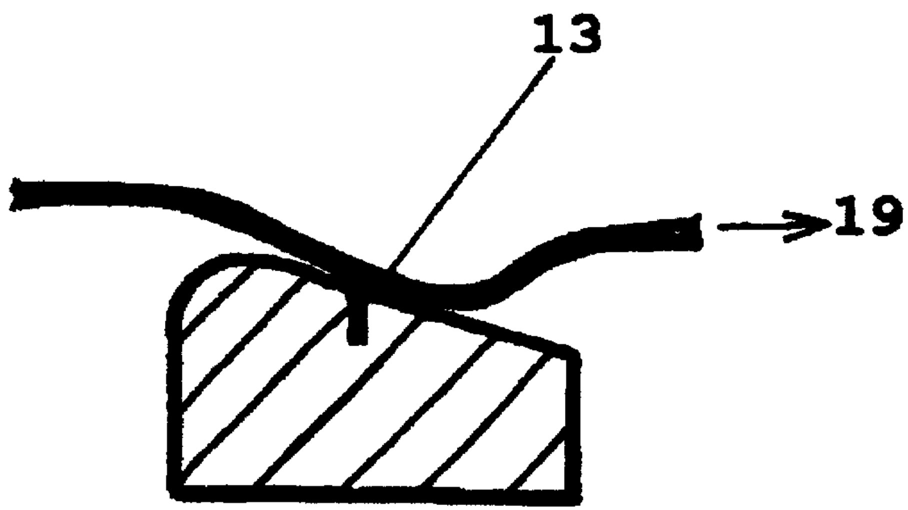
Bernoulli History

- Bernoulli head ring (Wright)
  - Separate piece provides vacuum
  - Cavity is closed to atmosphere
  - Bernoulli disk product originally developed at IBM (UK)



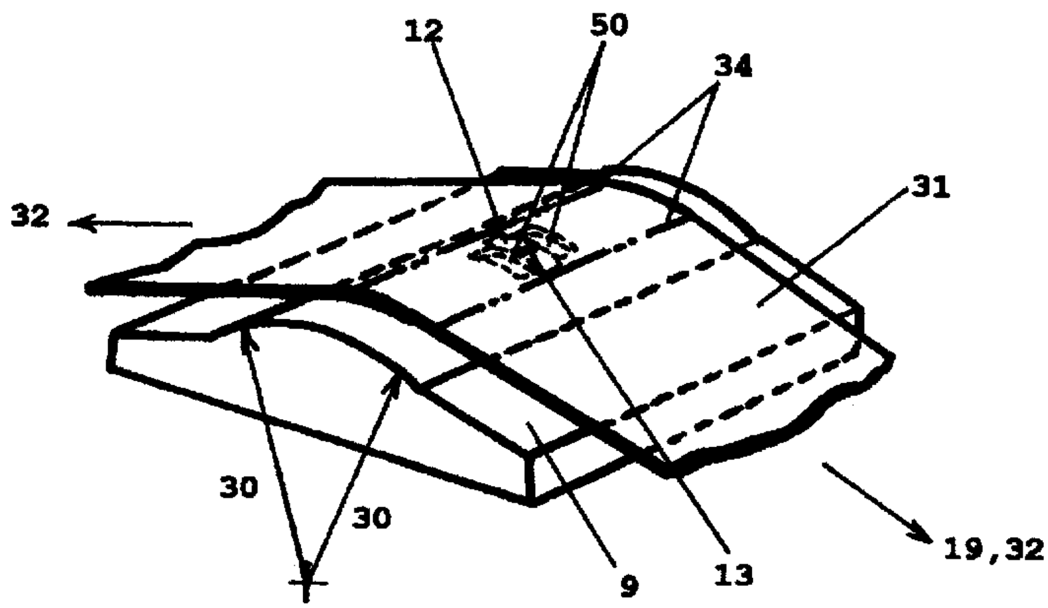
Bernoulli History

- Single direction product (Negishi)
- Exaggerated negative pressure slope
- Improved media stability



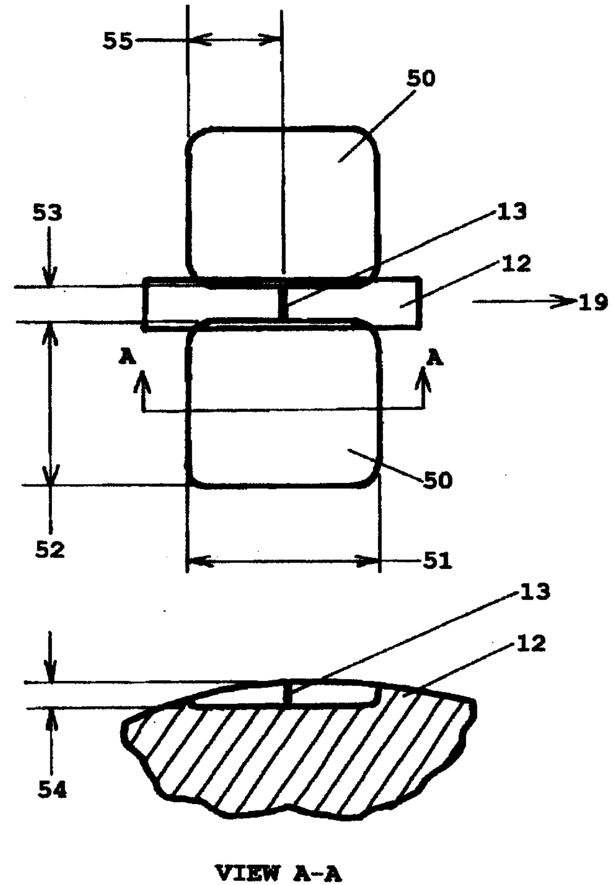
Best Design Approach

- Bernoulli pocket design
  - Localized area for Bernoulli effects
  - Placed immediately adjacent to gaps
  - Head radius meets or exceeds R_C
  - Sealed area outside of pocket



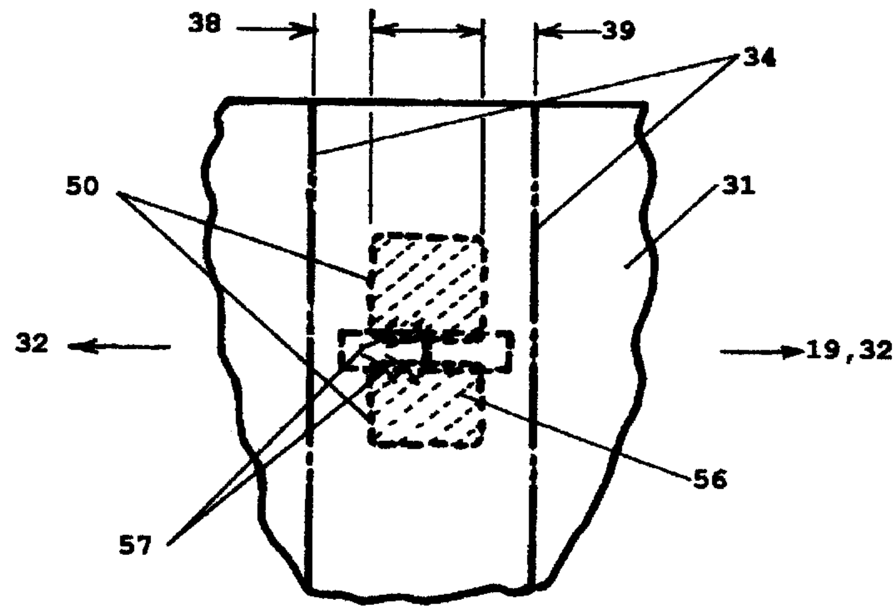
Best Design Approach

- Gap width defined by pockets
- Flat bottom pockets provide Bernoulli effects
- Side view shows effects of manufacturing tolerances



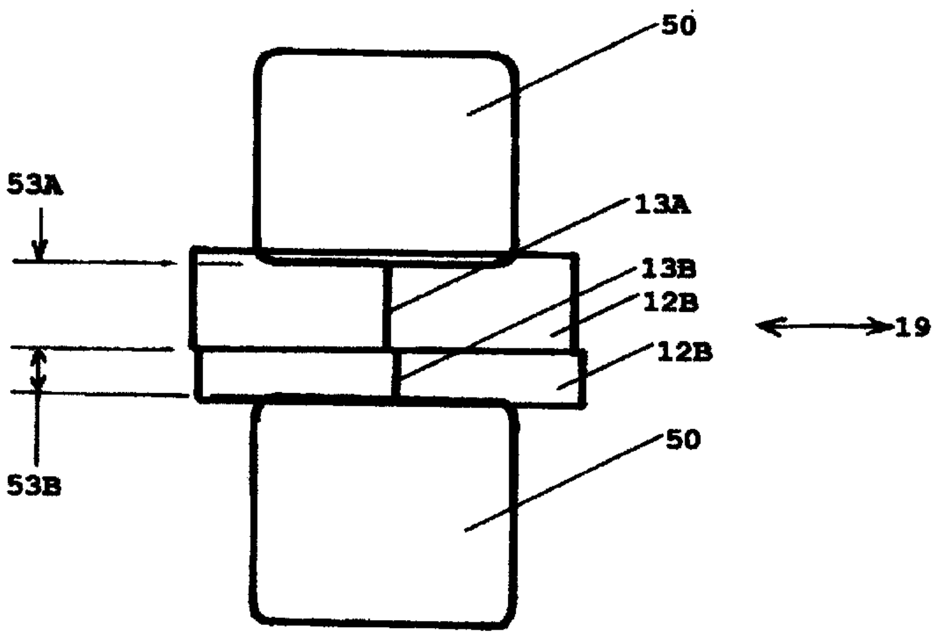
Best Design Approach

- Pockets have sealed boundaries
  - Provided by media under tension
- Wrap angle tangent lines important
- Movement of media causes aerodynamic effects inside pockets



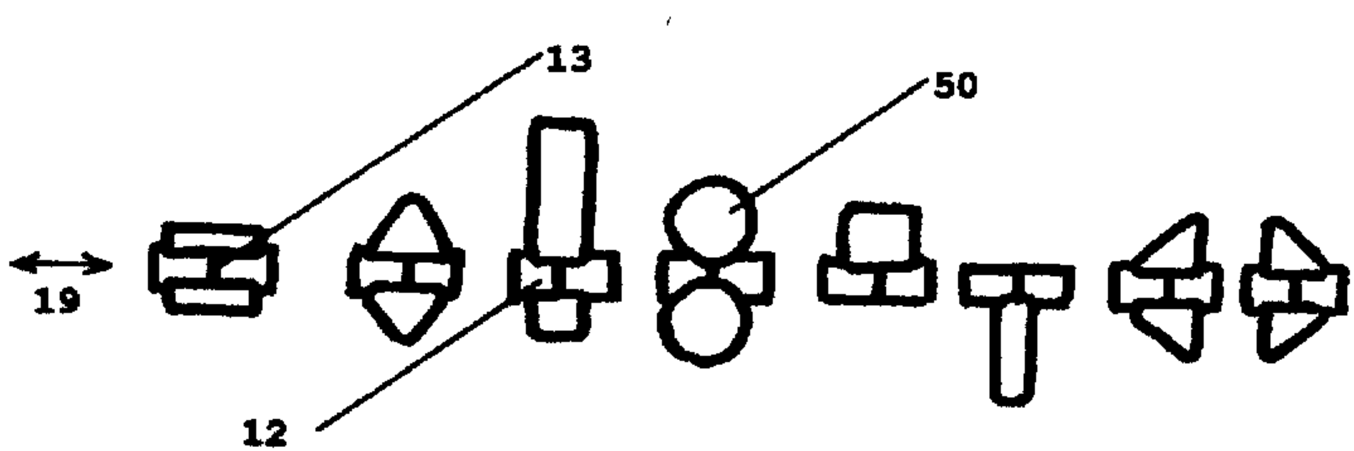
Best Design Approach

- Multiple gap design approach
- Write gap with narrow read gap



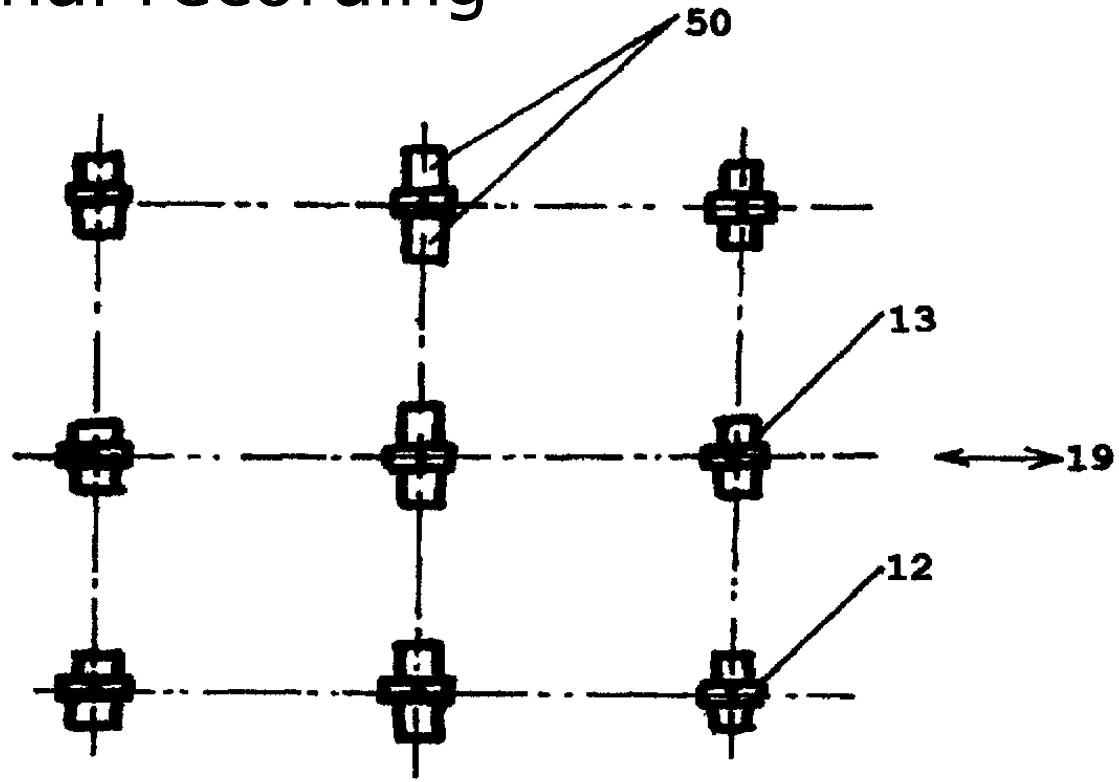
Best Design Approach

- Bernoulli pocket is not shape (top) dependent
- Seal from atmosphere is important



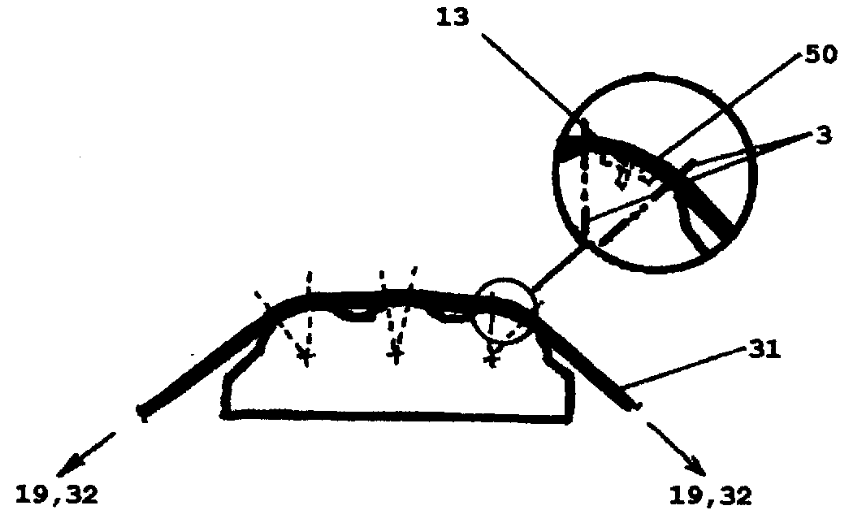
Best Design Approach

- Multiple gaps
- Bi-directional recording



Best Design Approach

- Example of a triple bank gap design for serpentine recording format
  - Each radius meets or exceeds R_C
  - Pockets placed onto each bank adjacent to gaps
  - Tangent lines seal pocket outline



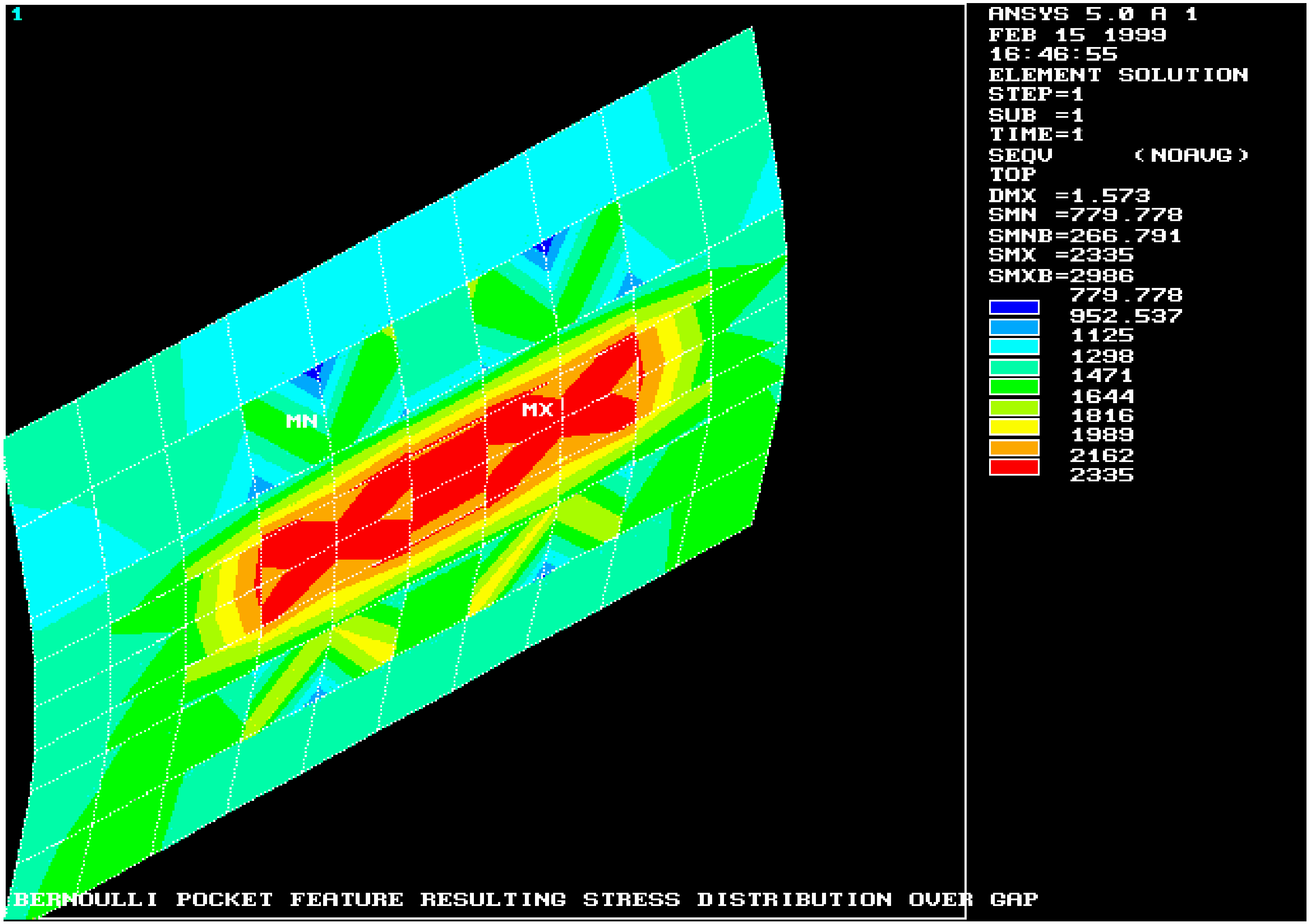
Pocket Design Issues

- Applicable to flexible media
- Applies to moving media/fixed head products
- Applies to moving head/fixed media products
- Placing pockets a small finite distance from gaps
  - Easier to manufacture
  - Not optimum design

Pocket Design Issues

- Additional benefit of the pocket design
  - Superior separation control
  - Gap region is under very uniform stress
  - Does not rely on Bernoulli effect

Finite Element Model Result



QUESTIONS ?