MINIMIZING THE MAX COIL CURRENT DENSITY

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- GLOBAL + LOCAL APPROACHES taken by coil group
  - GLOBAL: Minimize the J_{max} of the current sheet.
  - LOCAL: Minimize J_{max} at the stage of cutting coils from the sheet.
- Analysis presented here is relevant to the local approach. In particular,
  - Examine the problematic region where the coils are near their minimum separation.
  - Making some simplifying assumptions, it is possible to derive expressions for the optimum coil aspect ratio which, for a fixed coil current, minimizes the J_{max}. The expressions show explicitly the dependence of J_{max} on coil separation, ligament thickness, and normal curvature.

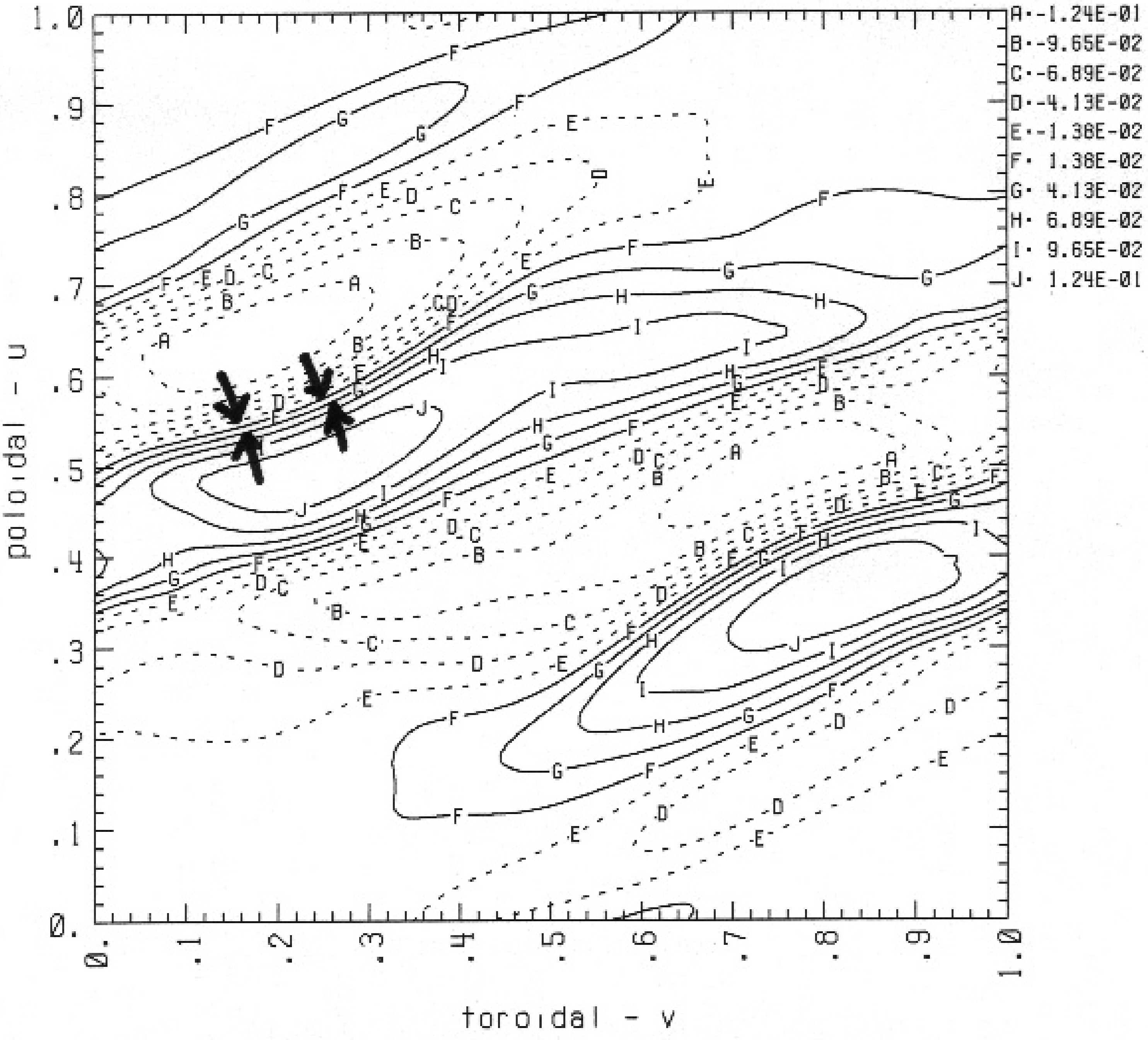
PROBLEMATIC REGION IS LOCAL

eg SEE THIS U-V PROJECTION

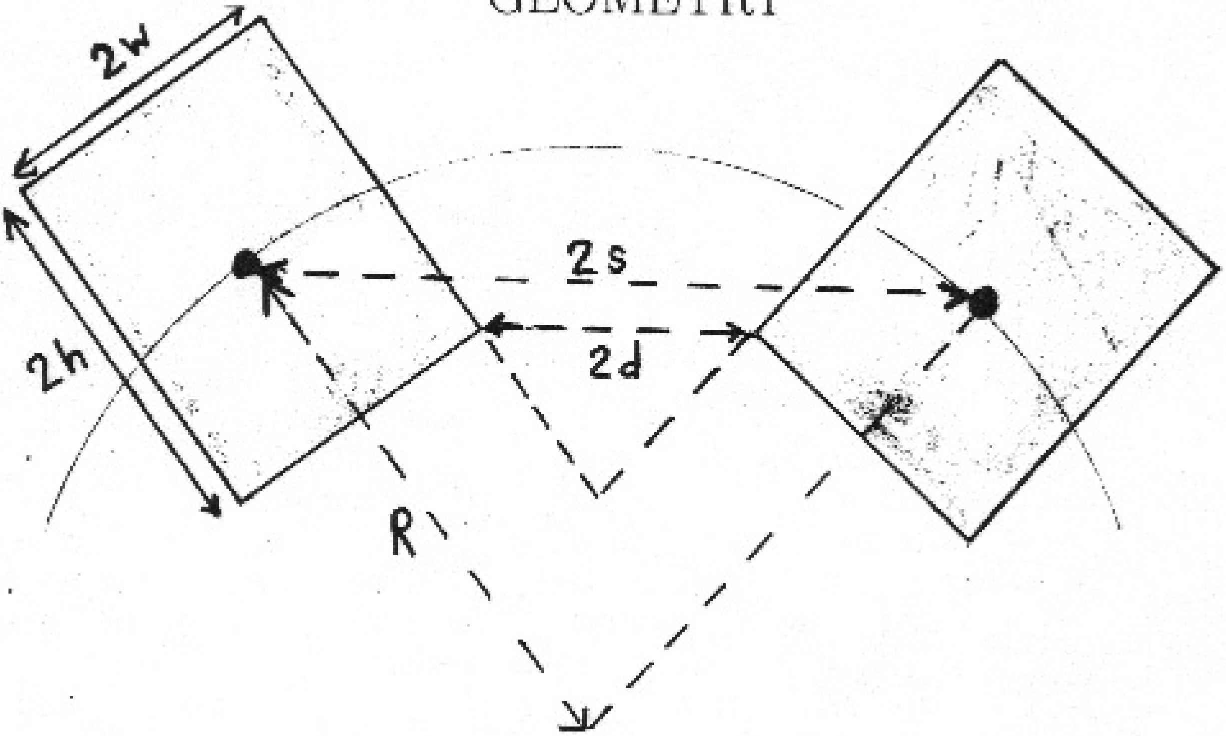
Current Potential pc_3_c10a.sad185noef

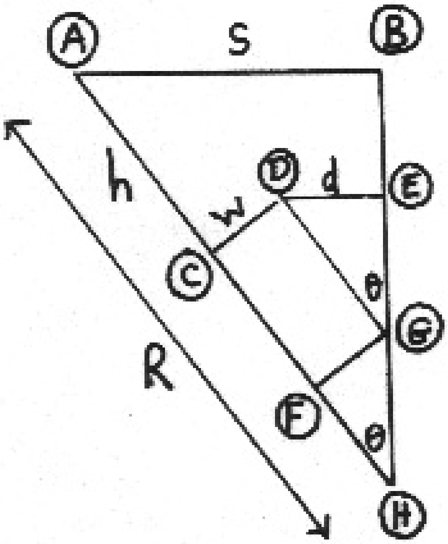
1.53% Max Err. 0.11% Mean Err. 1.80E-06 Var

Max Value = 1.52E-01 Min Value = -1.52E-01 Contours = 2.76E-02



GEOMETRY





R = Radius of Curvature (of current centroid)

w = 1/2 width of coil winding pack

h = 1/2 height of winding pack

s = separation distance between coil centroids

d = minimum allowed separation between adjacent coil winding packs (ligament thickness)

$$R = h + d/\sin\theta + w\cot\theta$$

$\Rightarrow$

$$R = h + ds/R + w\sqrt{(R/s)^2 - 1}$$

Consider coil aspect ratio h/w) as independent variable. Solve for w as a function of (h/w) for fixed d, s and R:

$$w = R(1 - d/s)/[(h/w) + \sqrt{(R/s)^2 - 1}] \qquad (1)$$

For fixed coil current, I, (assumed equal in the two adjacent coils) the current density is

$$J = I/A$$

(assumes unit packing fraction). We can write the area in terms of (h/w) as $A = 4w^2(h/w)$. Using Eq.1 for w leads to an equation for the area as a function of (h/w) and known parameters.

An optimal (h/w) maximizes A, which minimizes the current density for a given I, s, d and R. We obtain

$$(h/w)_* = \sqrt{(R/s)^2 - 1}$$

$$\Rightarrow J_{max} = \frac{I\sqrt{(R/s)^2 - 1}}{(R/s)^2(s - d)^2}$$

Taking numbers from Wayne's 3/31 presentation (for c10), we have

$h = 35.0\text{mm}$, $w = 8.85\text{mm} \Rightarrow (h/w) = 3.96$

$R = 104\text{mm}$, $s = 11.35\text{mm}$, $d = 2.5\text{mm}$

$\Rightarrow (h/w)_* = 9.11$

The reason for the apparent discrepancy is that radial build requirements imply a minimum separation (14.5cm) between the bottom of the winding pack and the plasma surface. Since we have assumed an 18cm distance between the coil centroids and the plasma, the requirement places an upper bound on the acceptable coil height, h. This bound was achieved well short of the "optimum" value of h for the given d, raising the question whether we can improve the current density by moving the coil surface FURTHER from the plasma (in the problematic regions).

Note $R \gg s \gg d$ is the relevant limit $\Rightarrow$

$$J_{max} \sim \frac{I}{Rs}$$