# SDC SOLENOID DESIGN NOTE #146

**TITLE:** Preliminary Investigation of an Isogrid Inner Vacuum Shell

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**INTRODUCTION:** This design note contains a calculation of the maximum collapse pressure $P_{cr}$ for an isogrid inner vacuum shell. It is assumed that the effective thickness of the isogrid shell is 1/4", and its overall thickness is 1/2". The calculation follows the "Isogrid Design Handbook"(1) (see calculation details in appendix). The maximum $P_{cr}$ is found to be a function of node spacing and skin thickness as shown in Figure 1. For the case of the skin thickness of 1/8", the maximum collapse pressure $P_{cr}$ is about 3.3 psi; it is about 3.45 psi for 1/12" and 1/16" of skin thickness for a proper node spacing. Compared with a solid plate design(2), which requires 3/8" thickness to give this Pcr, the radiation length for the isogrid inner vacuum shell is less by about 0.035 Xo.

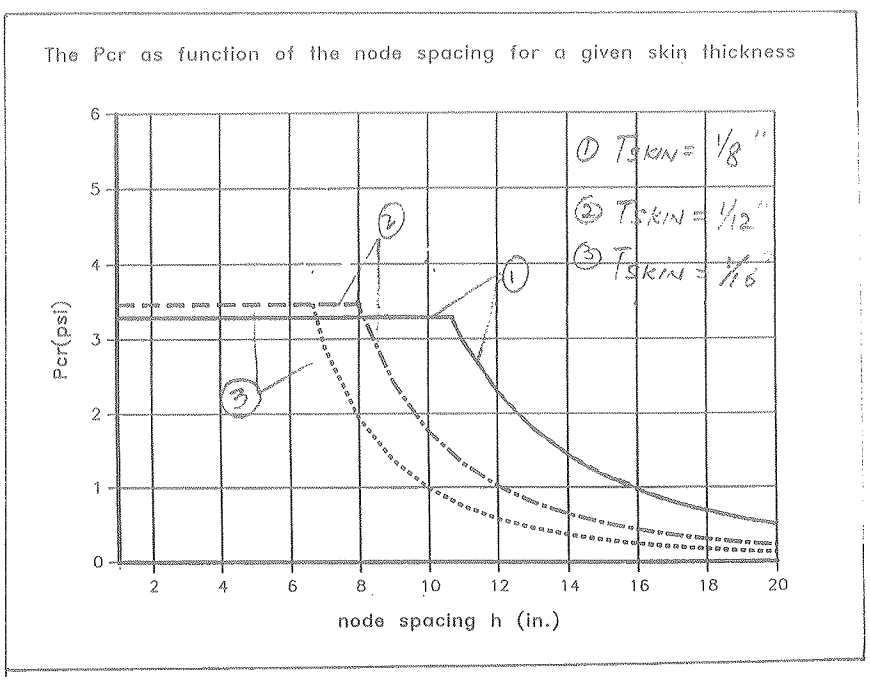


Fig 1 Pcr as a function of the node spacing for a set of skin thickness

## REFERENCES:

1. "Isogrid Design Handbook", General Dynamic,1973

2. R. W. Fast, "Design of Inner Vacuum Shell For SDC Solenoid Using Solid Plate", SSC Detector Solenoid Design Note 113, Fermilab, July 31,1990

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Appendix : Calculation Details For t(eff)=1/4" , t + d = 1/2" (isogrid inner vacuum shell with a straight side rib)

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ISO-GRID INNER VACUUM SHELL.

Assuming : $t_{effective} = 0.25''$

ID $= 134''$

L $= 360''$

Total overall Thickness : $0.5''$.

FIND : what is $P_{cr}$ (max)



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From "ISO-GRID Design Book" (Sec-2)

$$t^* = t\,(1+\alpha).$$

$$\alpha = \frac{b \cdot d}{t \cdot h}$$

$$\beta = \left[3\alpha\,(1+\delta)^2 + (1+\alpha)(1+\alpha\delta^2)\right]^{1/2}$$

$$\delta = \frac{d}{t}.$$

For stability: (Sec-4)

(1): $$N_{cr}^{(1)} = \frac{C_0 \cdot E \cdot R}{\left(\frac{R}{t}\right)^{5/2}\left(\frac{L}{R}\right)} \cdot \frac{\beta^{\frac{3}{2}}}{(1+\alpha)^{1/2}} = P_{cr} \cdot R.$$

(2). $$N_{cr}^{(2)} = C_1 \cdot E \cdot (1+\alpha)\,\frac{t^3}{h^2}.$$

(3) $$N_{cr}^{(3)} = C_2 \cdot E \cdot (1+\alpha) \cdot \frac{b^2}{d^2} \cdot t$$

$C_0 = 0.702$, $C_1 = 6.80$ $C_2 = 0.616$

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$$\because \quad t_{effective} = 0.25$$

$$\Rightarrow \quad t^* = t\,(1+\alpha) = 0.25$$

(4) $$\alpha = \frac{0.25}{t} - 1 = \alpha(t)$$

(5) $$\delta = \frac{d}{t} = \frac{0.5-t}{t} = \delta(t)$$

(6) $$\beta = \beta(\alpha, \delta) = \beta(t)$$

Sub: (4), (5), (6) INTO (1), (2), (3),

$$P_{cr}^{(1)} \cdot R = \frac{C_0 \cdot E \cdot R}{\left(\frac{R}{t}\right)^{\frac{5}{2}} \cdot \left(\frac{L}{R}\right)} \cdot \frac{\beta^{\frac{5}{2}}}{(1+\alpha)^{1/2}}$$

$$\therefore \quad P_{cr}^{(1)} = \frac{C_0 \cdot E \cdot}{\left(\frac{R}{t}\right)^{\frac{5}{2}} \left(\frac{L}{R}\right)} \cdot \frac{\beta(t)^{\frac{5}{2}}}{\left(\frac{0.25}{t}\right)^{0.5}}$$

(7) $$= P_{cr}(t)$$



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(8) $$P_{cr}^{(2)} = \left( C_1 \cdot E \ (1+\alpha) \frac{t^3}{h^2} \right) \frac{1}{R}$$

$$= C_1 \cdot E \cdot 0.25 \cdot \frac{t^2}{h^2} \cdot \frac{1}{R}$$

$$= P_{cr}^{(2)} (t, h)$$

(9) $$P_{cr}^{(3)} = C_2 \cdot E \cdot (1+\alpha) \left(\frac{b^2}{d^2}\right) \cdot t$$

$$= C_2 \cdot E \cdot 0.25 \left(\frac{b^2}{d^2}\right)$$

where $$\left(\frac{b^2}{d^2}\right) = \left[ \frac{(0.25 - t) \cdot h}{(0.5 - t)(0.5 - t)} \right]^2$$

$$\therefore \ P_{cr}^{(3)} = P_{cr}^{(3)} (t, h)$$



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Therefore, three stability equations become as

$$P_{cr}^{(1)} = \frac{C_0 \cdot E}{\left(\frac{R}{t}\right)^{5/2} \cdot \frac{L}{R}} \cdot \frac{\beta(t)}{\left(\frac{0.25}{t}\right)^{0.5}} = P_{cr}^{(1)}(t).$$

$$P_{cr}^{(2)} = 0.25\, E \cdot C_1 \frac{t^2}{h^2} \cdot \frac{1}{R} = P_{cr}^{(2)}(t, h).$$

$$P_{cr}^{(3)} = 0.25 \cdot E \cdot C_2 \cdot \left[\frac{(0.25-t)h}{(0.5-t)(0.5-t)}\right]^2 = P_{cr}^{(3)}(t, h)$$

For given $t = 1/8''$, $1/12''$ and $1/10''$, we plot $P_{cr}$ vs. $h$ as shown in Fig 1.

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