Fermilab

TS-SSC 90-59

9/10/90

To: R. Bossert, J. Carson, S. Delchamps, J.E. Haggard, N. Hassan, J. Kerby, W. Koska, P. Mantsch, E.G. Pewitt, R. Sims, M. Wake, M. Winters

From: Jim Strait

Subject: Evaluation of yoking tooling design

Using the results of finite element calculations[1] done by Eric Haggard I have calculated the expected final skin tension as a function of azimuth under several assumptions of yoke and skin dimensions and friction coefficients. Under all reasonable assumptions the resultant skin tension appears to be adequate.

The yoking tooling insert is shown in Figure 1 (taken from drawing 0102-ME-293169). The inner surface has a nominal radius equal to the sum of the maximum yoke radius and maximum skin thickness allowed by their respective tolerances. The nominal tooling radius is the minimum allowed by its tolerance. The center of curvature is at two different locations for the regions 0 to 60 degrees and 60 to 90 degrees from the weld. The center in the former region is shifted 7 mils the the ''left'' and 4 mils ''down'' relative to the latter region. In the region far from the weld the tooling is very rigid, while closer the the weld the tooling consists of a tapered ''finger'' which serves to limit the radial pressure applied to the skin while ensuring that the skin conforms to the yoke before welding. Because of yoke-skin and skin-tooling friction, the skin azimuthal tension is reduced by the radial pressure of the tooling and therefore this pressure should be minimized[2].

The combined tolerance bands on the yoke radius (±0.0005 in.), the skin thickness (±0.0025 in.) and the tooling (+.001/-0.000 in.) corresponds to a range of 7 mils. The interference and clearance between the skin and tooling are plotted in Figures 2a and 2b for the maximum and minimum interference conditions. It is assumed that the yoke+skin and the tooling are tangent at the point 90 degrees from the weld. The skin radial pressures calculated by Eric are shown in Figures 3a and 3b for the maximum and minimum material conditions respectively. (Compressive stress is defined here to be negative.) For the minimum material condition, Eric provided me with runs with two different ''spring rates'' for the skin-tooling gap elements; both are plotted in Figure 3b. (I do not claim to understand what these spring rates are. I show them only to indicate that the results do not depend terribly much on the assumptions in the ANSYS calculation. I do not know what spring rate was assumed in the maximum material condition run.)

In both the minimum and maximum material cases (but mostly in the minimum material case) positive or extensive stresses exist. This presumably results from some arcane behavior of gap elements, but clearly is non-physical. In the analysis discussed below I have used the radial stress as given (including positive values) and with the positive values truncated to zero. The total vertical component of the radial pressure should be 4500 lbs/in[3] to ensure that the yoke gap is closed when the skin is welded. In my analysis I have renormalized Eric's calculated pressures to give the correct total vertical load.

I have written a FORTRAN program which numerically integrates the differential equation[2] relating skin stress and tooling-skin pressure. In the following, the sign convention for the skin-tooling pressure has been changed so that here a radially inward pressure on the skin is positive. Figure 4 shows the computed skin pressure in and out of the press assuming a) the minimum material condition, b) gap spring rate = 10^7, c) friction coefficients = 0.5, d) skin stress at the weld = 40 kpsi after the weld has cooled and before the press has been opened, and e) negative pressures are set to zero. Figure 5 shows the results with the negative pressures included. Since the negative pressures are mostly near the weld, the skin stress in the press goes up in this region and the final stress also goes up. In all further analysis I have taken the more conservative approach and truncated negative pressures to zero. Figure 6 shows the results under the same assumptions as in Figure 4, except that the pressure from the spring rate = 10^5 calculation has been used. The resultant skin tension is almost indistinguishable from that with the larger gap spring rate. Figure 7 shows the result for the maximum material condition. The skin tension is only a little lower than in the minimum material case. Table I summarizes the results for various assumed friction coefficients for the maximum and minimum (10^7 spring rate) interference conditions. In all cases, even with the unreasonably[2] large friction coefficient of 1.0, the skin tension exceeds the 24 kpsi required to guarantee closure of the yoke-yoke gap at room temperature. (The requirement on the room temperature stress at the weld to keep the gap closed at 4.35 K and 7.5 T is considerably less stringent[3].)

Table I

Computed skin tension at the weld σ_0 and average skin tension $\langle\sigma\rangle$ for minimum and maximum interference between the yoke+skin and the tooling and for several values of friction coefficients.

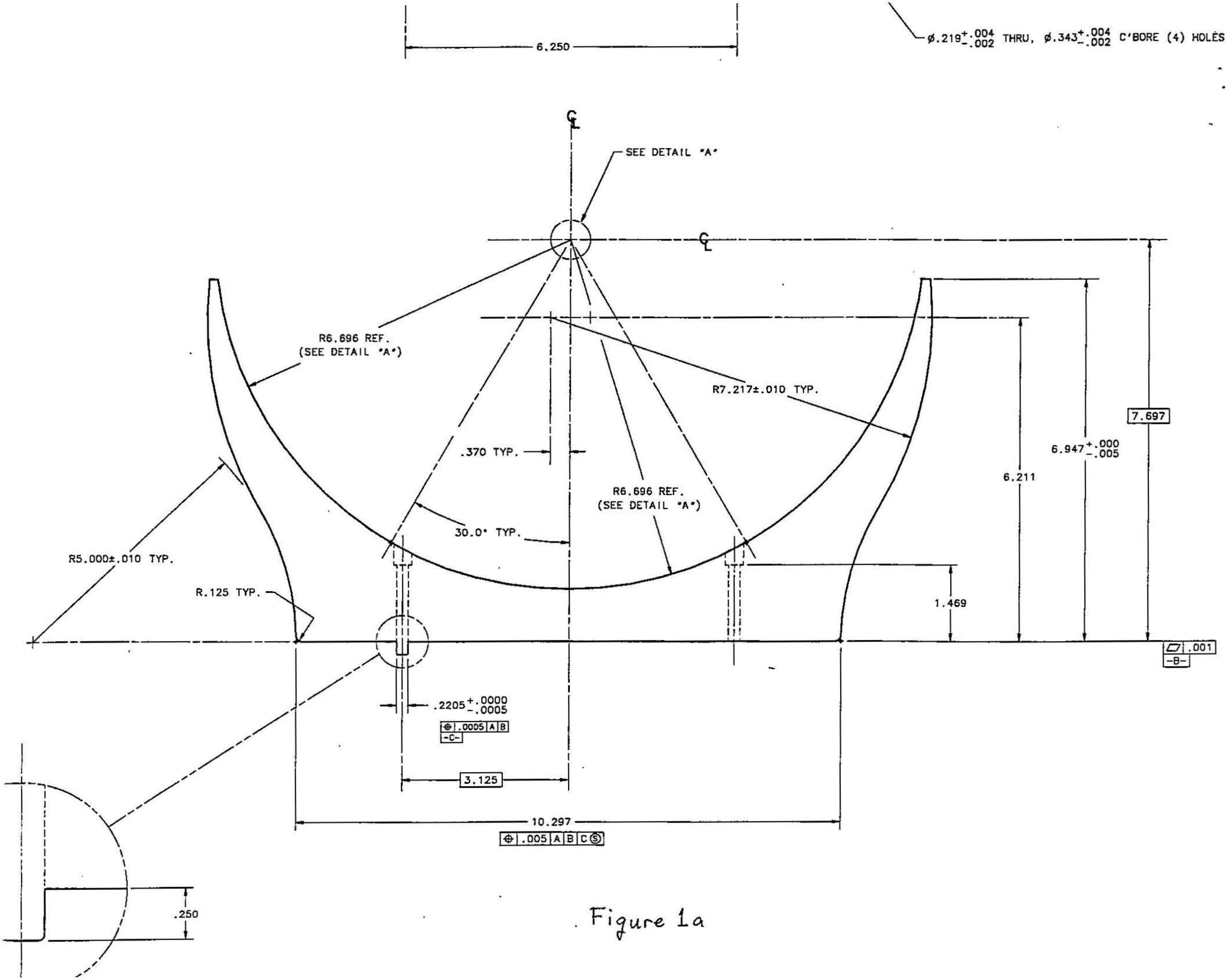
	Friction			
Interference	yoke-skin	skin-tooling	σ_0(kpsi)	$\langle\sigma\rangle$ (kpsi)
Minimum	0.25	0.25	37.3	30.8
	0.50	0.50	34.1	23.6
	0.75	0.75	30.8	18.1
	1.00	1.00	27.3	13.8
	0.75	0	35.2	20.7
	0.75	0.25	33.7	19.8
	0.75	0.50	32.3	19.0
	0.75	0.75	30.8	18.1
	0.75	1.00	29.4	17.6
Minimum	0.25	0.25	36.3	30.0
	0.50	0.50	31.8	22.0
	0.75	0.75	29.0	17.0
	1.00	1.00	27.3	13.8
	0.75	0	33.2	19.4
	0.75	0.25	31.6	18.5
	0.75	0.50	30.2	17.7
	0.75	0.75	29.0	17.0
	0.75	1.00	28.0	16.4

References

[1] Eric Haggard, private communication.

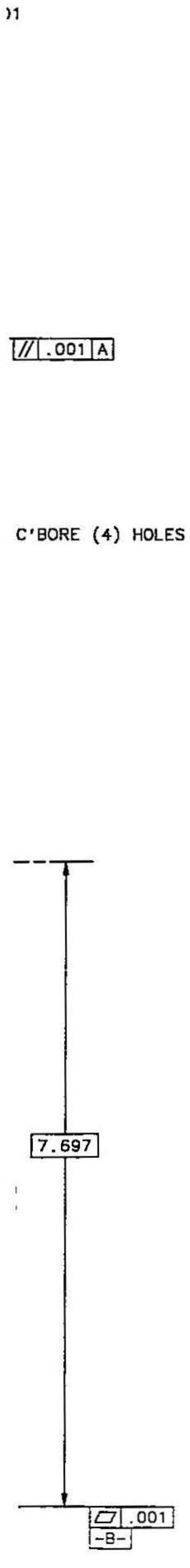
[2] J. Strait, Analysis of Yoke-Skin Interaction, TS-SSC 90-040, 6/28/90.

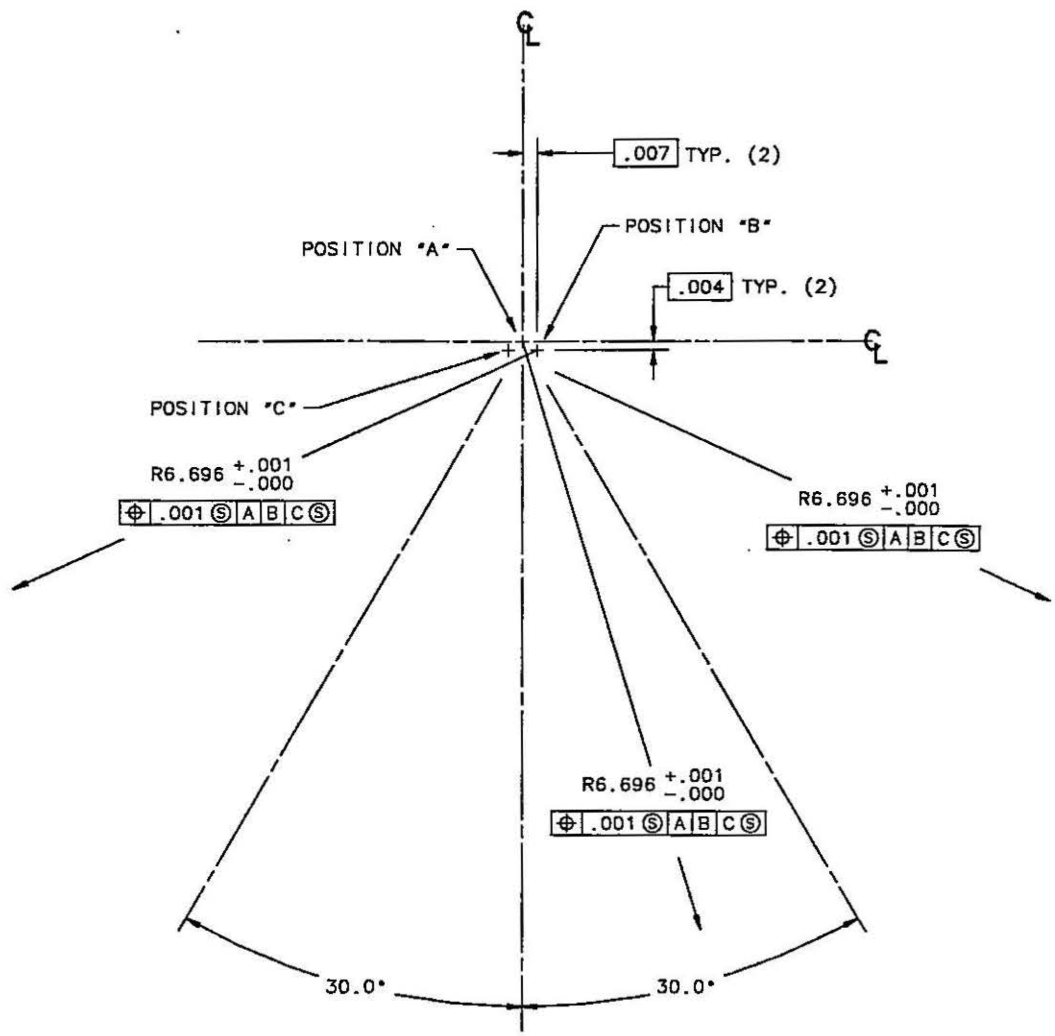
[3] J. Strait, Design of a Vertically Split Yoke and Associated Collar for the 50 mm SSC Collider Dipole: Yoke-Collar Interface, TS-SSC 90-033, 6/25/90.



6.250
Ø.219 +.004 -.002 THRU, Ø.343 +.004 -.002 C'BORE (4) HOLES
SEE DETAIL "A"
R6.696 REF.
(SEE DETAIL "A")
R7.217±.010 TYP.
7.697
.370 TYP.
6.947 +.000 -.005
6.211
R6.696 REF.
(SEE DETAIL "A")
30.0° TYP.
R5.000±.010 TYP.
R.125 TYP.
1.469
.001
-B-
.2205 +.0000 -.0005
.0005 A B
-C-
3.125
10.297
.005 A B C S
.250

Figure 1a





DETAIL "A" 20X SCALE

NOTES:

POSITION "A" RADIUS TO BE SWUNG 30° EITHER SIDE OF VERTICAL CENTER AS SHOWN.

POSITION "B" RADIUS TO BE SWUNG FROM 30° LEFT OF VERTICAL CENTER CLOCKWISE.

POSITION "C" RADIUS TO BE SWUNG FROM 30° RIGHT OF VERTICAL CENTER COUNTERCLOCKWISE.

Figure 1b

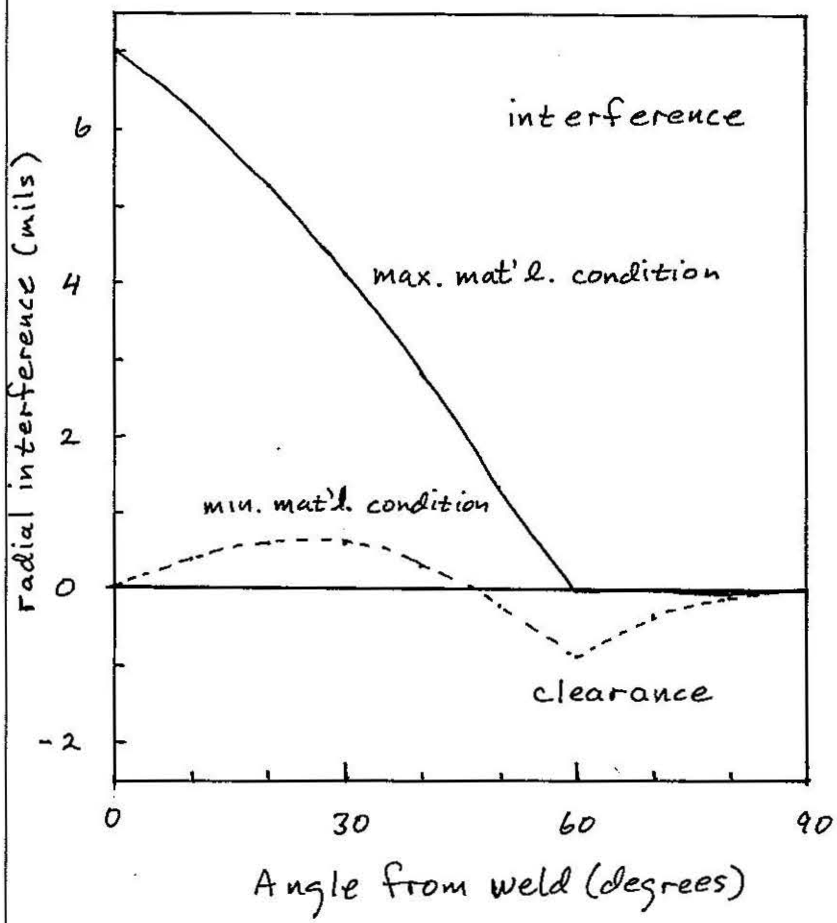

interference
max. mat'l. condition
min. mat'l. condition
clearance
radial interference (mils)
6
4
2
0
-2
0
30
60
90
Angle from weld (degrees)

Figure 2

Tooling-Skin Radial Pressure

Max Interference Condition

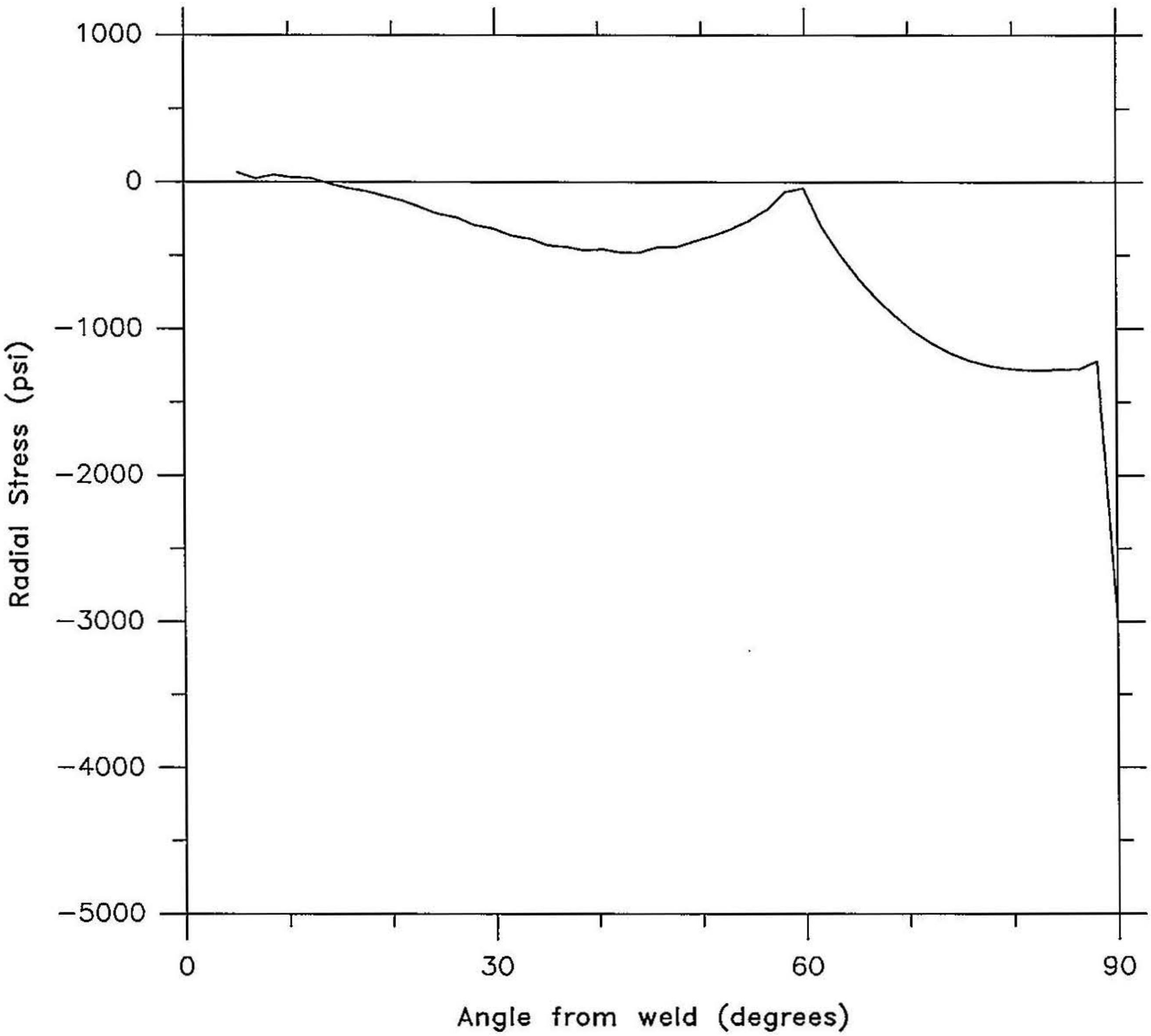


Figure 3a

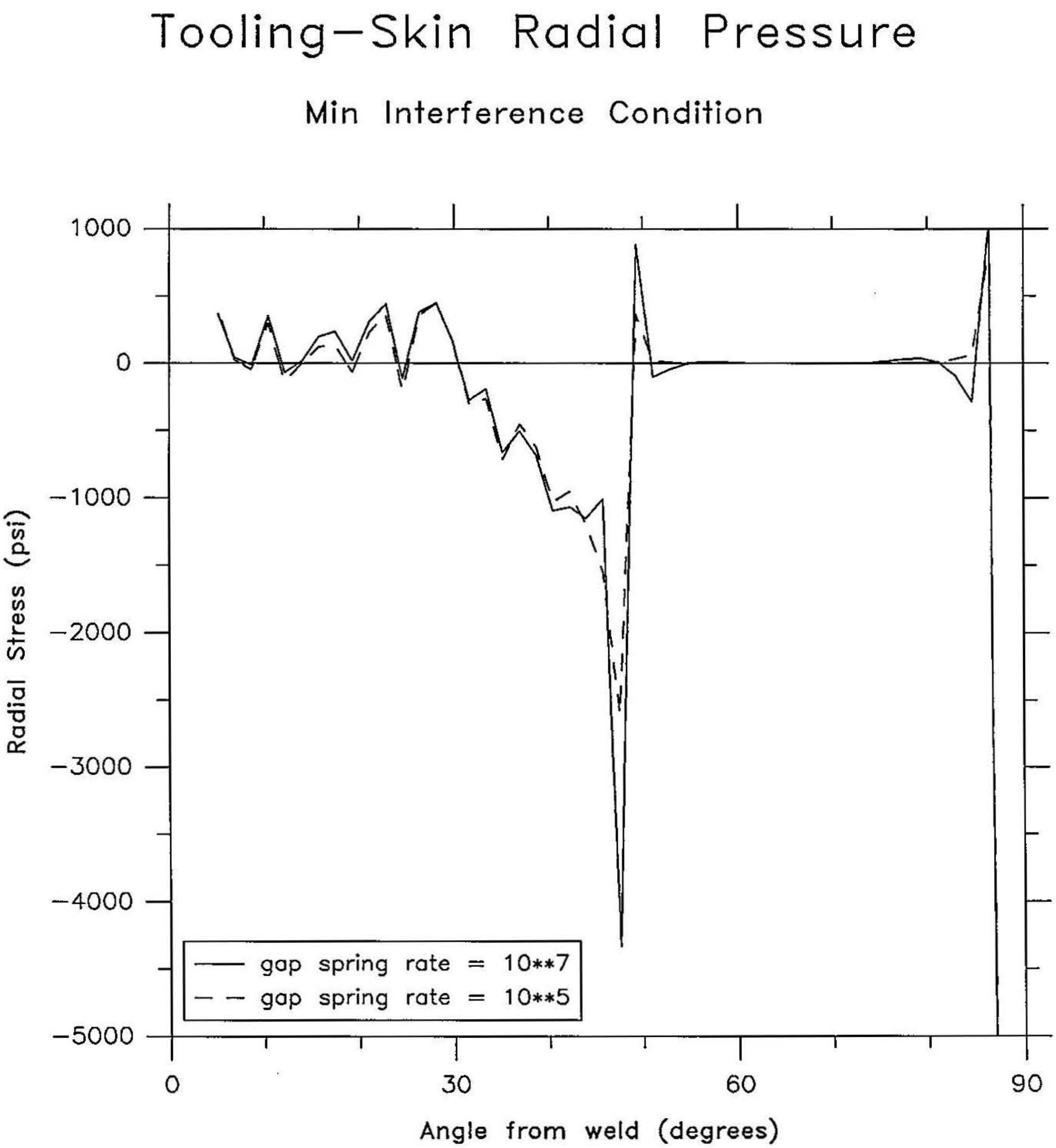

Tooling–Skin Radial Pressure
Min Interference Condition
1000
0
−1000
−2000
−3000
−4000
−5000
Radial Stress (psi)
0
30
60
90
Angle from weld (degrees)
gap spring rate = 10**7
gap spring rate = 10**5

Figure 3b

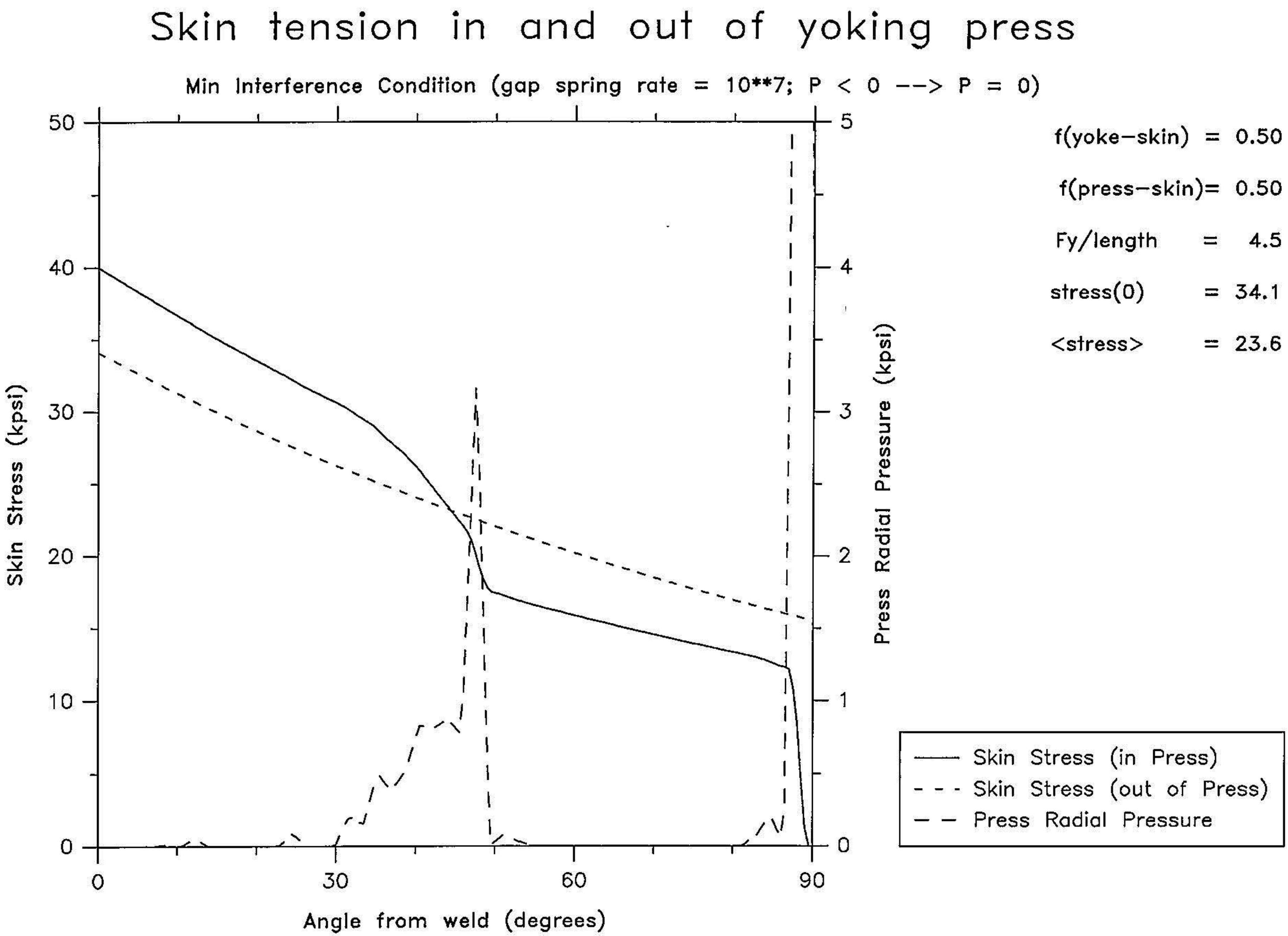
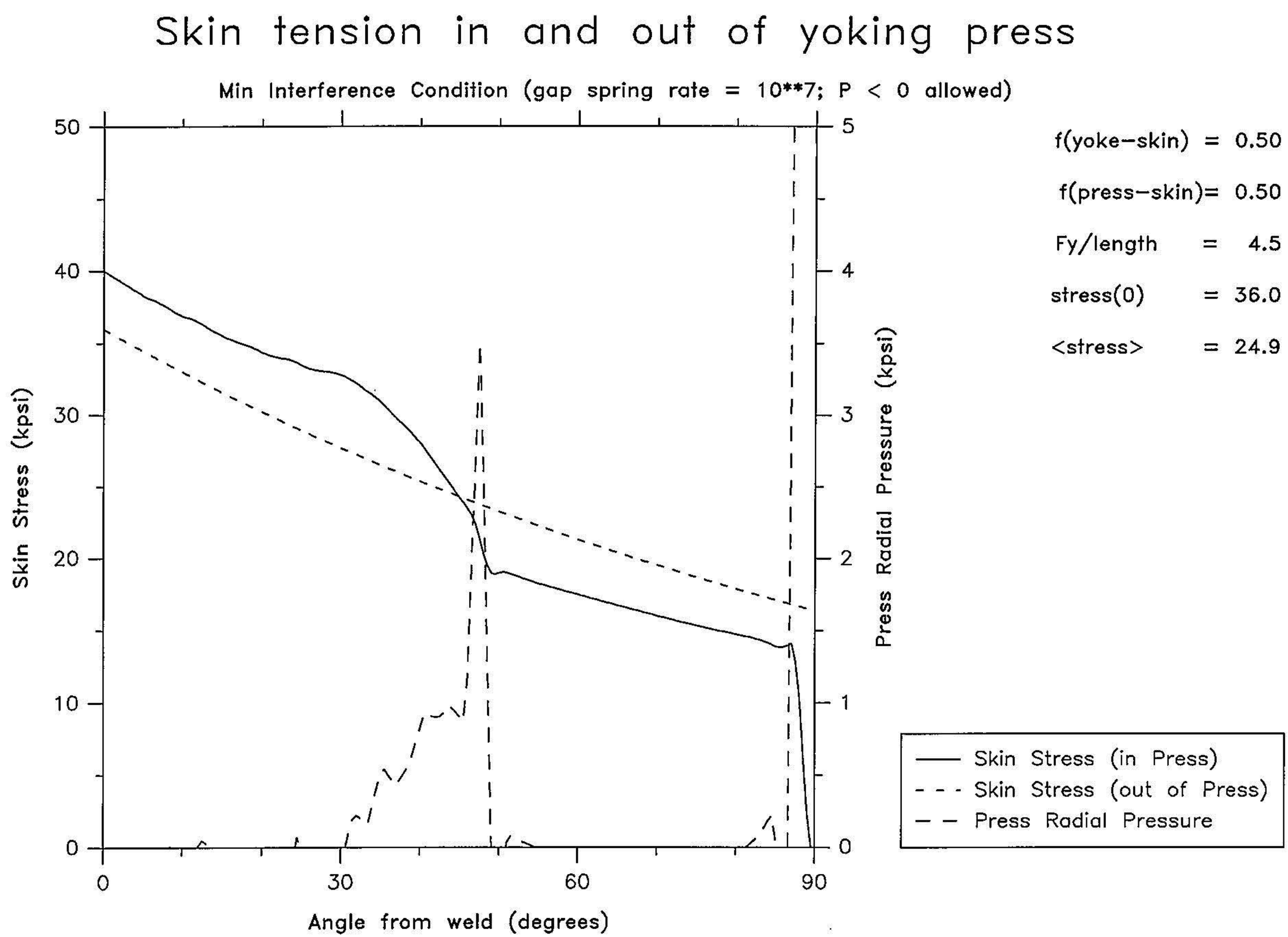

Skin tension in and out of yoking press
Min Interference Condition (gap spring rate = 10**7; P < 0 --> P = 0)
f(yoke−skin) = 0.50
f(press−skin)= 0.50
Fy/length = 4.5
stress(0) = 34.1
<stress> = 23.6
Skin Stress (kpsi)
Press Radial Pressure (kpsi)
Angle from weld (degrees)
0
30
60
90
10
20
40
50
1
2
3
4
5
Skin Stress (in Press)
Skin Stress (out of Press)
Press Radial Pressure

Figure 4



Skin tension in and out of yoking press
Min Interference Condition (gap spring rate = 10**7; P < 0 allowed)
Skin Stress (kpsi)
Press Radial Pressure (kpsi)
Angle from weld (degrees)
0
10
20
30
40
50
0
1
2
3
4
5
0
30
60
90
f(yoke-skin) = 0.50
f(press-skin)= 0.50
Fy/length = 4.5
stress(0) = 36.0
<stress> = 24.9
Skin Stress (in Press)
Skin Stress (out of Press)
Press Radial Pressure

Figure 5

Skin tension in and out of yoking press

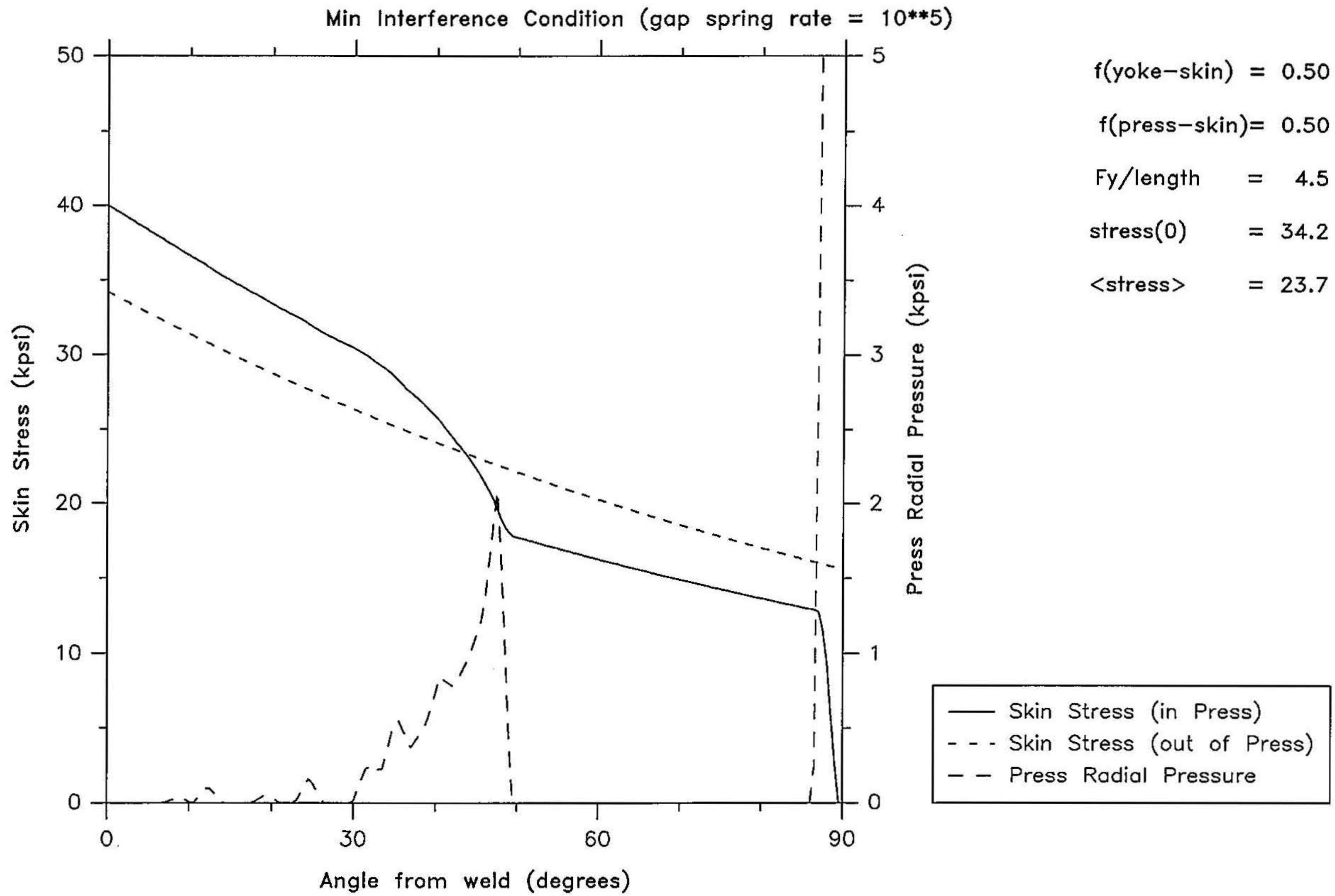


Figure 6

Skin tension in and out of yoking press

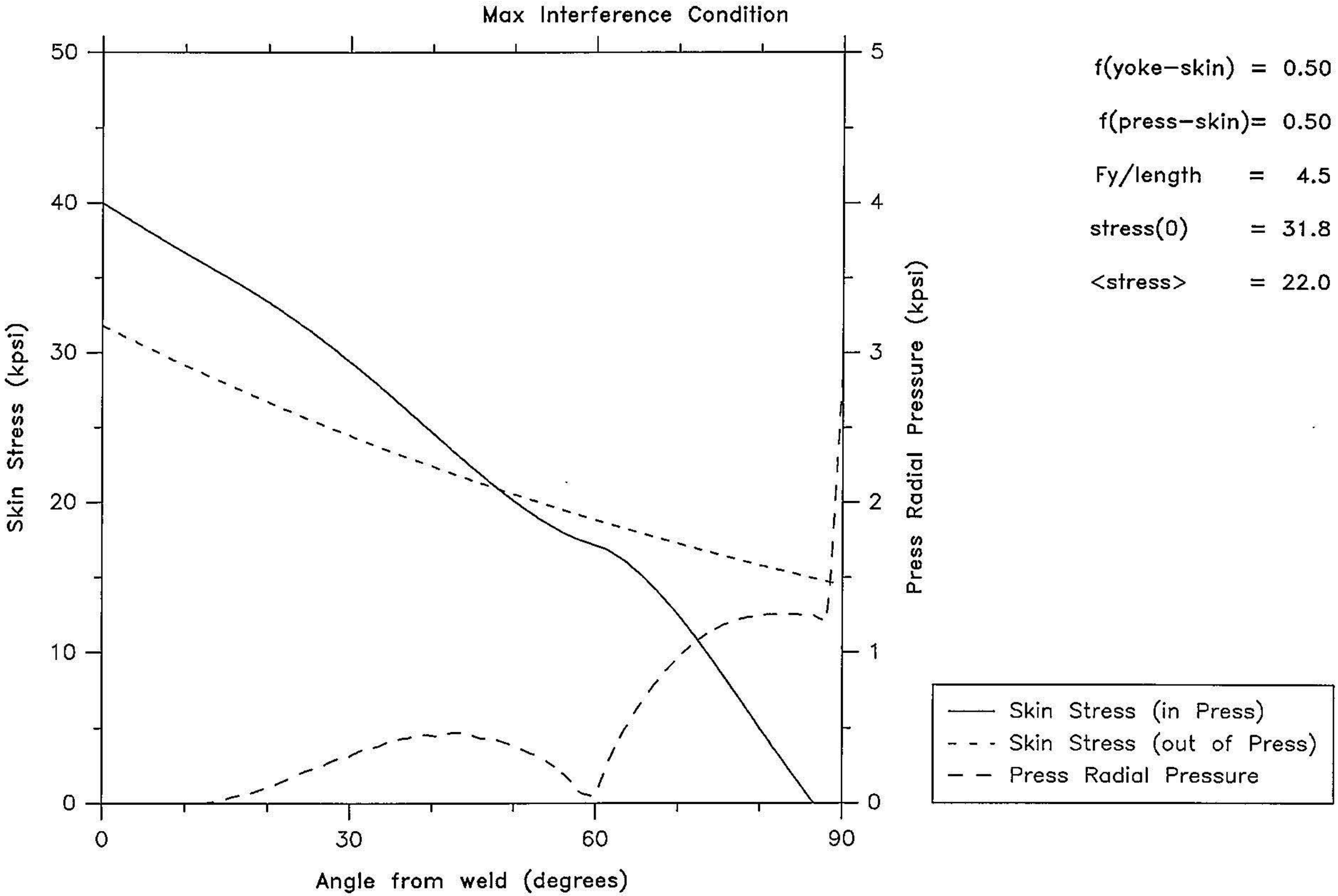


Figure 7

Fermilab

October 1, 1990

MEMO TO: Distribution

FROM: S. Delchamps

SUBJECT: Revised Technical Support Memo

This is to inform you that the Technical Support memo TS-SSC 90-060, **Report on Thermal Contraction of Some Materials Including Stycast 2850FT** has been revised and updated somewhat. Plots are now included showing the thermal contraction of G10 in the plane of the fibers and of "green putty." Acknowledgements and several explanatory notes have been added to the text. The figures have been slightly revised as well.

Distribution:
- R. Bossert
- J. Carson
- N. Hassan
- J. Hoffman
- W. Koska
- F. Markley
- D. Sims
- J. Strait
- M. Winters

Fermilab

September 12, 1990

MEMO TO: R. Bossert, J. Carson, N. Hassan, J. Kerby, W. Koska, P. Mantsch, G. Pewitt, R. Sims, J. Strait, M. Wake, M. Winters

FROM: S. Delchamps

SUBJECT: Report on Thermal Contraction of Materials

This memo presents some recent results on thermal contraction of materials including Stycast 2850, the material from which model end insulators for DS0311 has been fabricated.

Attachment