TS-SSC 90-033

# Design of a Vertically Split Yoke and Associated Collar for the 50 mm SSC Collider Dipole: Yoke-Collar Interface

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In a recent note[1] I described the design of the yoke and collar for a vertically split yoke configuration for the 40 mm SSD dipole. I describe here the configuration of the outer surface of the collar for the 50 mm dipole and the interaction among the collar, yoke and skin. In a companion note[11] I describe the specification of the inner surface of the collar and in a future note will give more details of the yoke-skin interaction.

The design criteria and calculation methods are the same as used for the design of the 40 mm dipole[1]. A simple spring model was used to model the interaction among the collar, yoke, and skin and to check the sensitivity of the system to uncertainties in the parameters of the calculation and part tolerances. Most of the parameters were derived from finite element calculations.[2] The precise collar dimensions used in the finite element analysis differed by a small amount from the final dimension chosen here.

The calculation models the collars as coupled vertical and horizontal springs with effective spring constants and vertical-horizontal couplings for forces applied by coil prestress and skin tension. Because the collars are designed so that they always clear the yoke in the vertical direction, the model is insensitive to parameters relevant to the vertical radius. The finite stiffness of the yoke is not explicitly included, but since the effective spring constants come from finite element calculations that include yoke elastic properties, these effects are implicitly included. The parameters of the calculation are shown in Table Ia and the source of their values are given below.

<u>rv and rh</u> The vertical and horizontal collar radii relative to the yoke at room temperature are chosen to give the desired yoke collar interaction and varied to check the effect of parts tolerances.

<u>Skin Stress</u> The azimuthal skin stress at 300 K and 4 K is based on measurements made at Fermilab on model magnets F3[3] and DSS012[4] and at LBL on the first QC cross section 40 mm quadrupole[5]. The skin stress near the yoke parting plane determines the clamping force and this was measured to be 25-30 kpsi at room temperature and 45-50 kpsi at 4 K. The low end of the range was used in both cases. In fact, the model calculates the skin tension required to close the mid-plane gap at both temperatures, so the effect of varying the skin tension can be easily seen.

Thermal Contraction The integrated thermal contraction of the collar and the yoke material are taken from measurements done at BNL[6].

Nominal Radius This is the yoke inner radius for the magnetic design of the W6733 cross section.

drv/drh The ratio of vertical to horizontal radius change for a horizontal force applied by the yoke was copied from the 40 mm model. Because of the similarity of the 40 mm and 50 mm designs, the value of drv/drh should be similar. Variations of ±10% about the central value were tried.

drv/dpr and drh/dpr The rate of change of collar vertical and horizontal radius with prestress (average of inner and outer coils) was taken from finite element calculations[2,7] and measurements of 40 mm magnets.[8] The finite element results depend on whether or not the wedges are allowed to slide relative to the adjacent conductors:

| | drv/dpr | drh/dpr |
|---|---|---|
| slip[2] | 0.38 | -0.05 mils/kpsi |
| no slip[7] | 0.45 | -0.02 mils/kpsi |

Measured[8] vertical deflections of 40 mm collars, 0.54 mils/kpsi, are somewhat larger than predicted by finite element calculations,[9] 0.44 mils/kpsi. Values of drv/dpr from 0.35 to 0.50 mils/kpsi and of drh/dpr from 0 to -0.10 mils/kpsi were tried. Because there is no vertical yoke-collar interaction and the values of drh/dpr are small, the results are not very sensitive to these variations.

Prestress The target collared coil room temperature prestress is approximately 10 kpsi. A range of ±3 kpsi, somewhat larger than is expected, was tried.

Cooldown Prestress Loss To simplify the calculation of the effects of cooldown, the model separately cools the collared coil and the yoke, and then assembles them cold. The prestress loss with cooldown used in the model is that for a free collared coil. This has been measured in 40 mm magnets[10] to be approximately 2.5 and 2.0 kpsi for the inner and outer coils respectively. Values of 2.25 and 3.25 kpsi (average of inner and outer coils) were tried. Since this affects mainly the collared coil vertical radius it is not a very important parameter.

drh/d(skin stress) The rate of change of collared coil vertical radius with skin tension has two values depending on whether the collars are free to expand vertically or not. Because the collars always clear the yoke, only the first (larger) value is important. Its value, -0.28 mils/kpsi, is taken from finite element calculations[2] and is varied between -0.25 and -0.32 mils/kpsi.

The results of the calculations are shown in Tables Ib-c. The three tables correspond to three values of collar horizontal radius representing the estimated range of 5.5 ± 1.1 mils of horizontal yoke collar interference (see below). In each table the first line represents the "central values" of the parameters, which are then varied, as indicated by comments in the tables, in subsequent lines. For each set of parameters the vertical and horizontal radii of the free collared coil relative to the yoke are computed at both room temperature and 4 K. The helium temperature yoke-collar interference in the horizontal direction is 2.4 ± 1.1 ± 0.5 mils, where the first error bar is from parts tolerances and the second is from uncertainties in the calculation parameters. The room temperature vertical clearances before and after assembly are 13.5 and 10.8 ± 2.0 ± 1.3 ± 0.6 mils, where the error bars are parts tolerances, prestress variation, and parameter uncertainties respectively. The vertical clearance at 4 K is 4-5 mils larger than at 300 K.

The skin tension required to make the collar horizontal radius equal the yoke radius, that is too close the yoke mid-plane gap, is 18 ± 4 ± 2 kpsi at room temperature and 9 ± 4 ± 2 kpsi at 4 K. With the assumed skin stress of 25 kpsi at room temperature the yoke gap is just closed under the least favorable conditions but closed with a 30% margin for the central values of the parameters. At 4 K the skin stress is assumed to be 45 kpsi; of this 36 ± 4 ± 2 kpsi is balanced by the pressure at the yoke mating surface and is therefore available to balance the Lorentz force. Assuming a 3/16" thick skin, this is a force of 6800 ± 800 ± 400 lb/in. This is larger than the Lorentz force of 5000 lbs/in at full field, so the yoke gap should stay closed even if the entire Lorentz force is transferred to the yoke and skin. Finite element calculations[2] indicate that the collars are sufficiently stiff that only about 45% of the force is transferred to the yoke, so this design has more than a 100% margin against yoke gap opening.

The collar is given different horizontal and vertical radii by offsetting the center of curvature away from the center line of the assembled collar pair. In the neighborhood of the horizontal mid-plane the collar is flattened for the benefit of the keys. (See Figure 1, from a preliminary version of drawing 102-ME-292059.) The yoke (see Figure 2, from a preliminary version of drawing 102-ME-292123) is also flattened in this region but the collar and yoke are designed so that they contact first just above the keys. After assembly there is 5 ± 3 mils of clearance in the key region. The first point on the circular cross section of the collars is just above the keys at an distance of 0.401-0.421 inches from the mid-plane, the range of values depending on the radius on the upper corner of the key slot. The values of collar radius and offset are chosen to give the desired 5.5 mils of collar-yoke interference just above the keys and approximately 18 mils of clearance at the pole. The radial collar-yoke clearance and interference as a function of azimuth are plotted in Figure 3. (For theta $< 20$ degrees the radial and horizontal interferences are equal within 0.1 mils and for theta $> 80$ degrees the radial and vertical clearances are equal within 0.2 mils.) The tolerance on the collar outer radius is ±0.5 mil, the tolerance on the displacement of the center of curvature from the center line is ±1 mil (Fig. 1) and the tolerance on the yoke inner diameter is ±1 mil (Fig. 2). The resultant tolerance band of ±1.1 mils on the collar-yoke interference is shown by the cross-hatched region in Fig. 3.

The flats on the side of the collar and the yoke at the base of the collar-yoke alignment tab are, in the undeflected parts, at the identical distance from the vertical center-line. However, because of the 5.5 mils of interference just above the flats, after assembly the collars are deflected so that there is 5 ± 3 mils of clearance between the yoke and collars at the base of the alignment tab. The lower bound of the tolerance band on the tab width of the yoke is equal to the upper bound of the collar. However, because the collar is displaced 5.5 mils radially inwards in the assembly, there is a minimum of 0.8 mils of clearance on either side of the alignment tab.

References


1. J. Strait, Design of a Vertically-Split Yoke and Associated Collar for the 40 mm Dipole, TS-SSC-90-029, 6/11/90.

2. J. Kerby, 50 mm Vertical Split FE Conclusions, Presented to the 5 cm Task Force, 5/23/90, TS-SSC 90-32, and private communications.

3. J. Strait, FNAL Short Magnet Program, Minutes of MSIM, 11/9-10/88.

4. J. Strait, Status of FNAL Short Magnet Program, Minutes of MSIM, 4/13-14/89.

5. C. Taylor, LBL Quadrupole Program, Minutes of MSIM, 6/12/90.

6. C. Goodzeit, Structural Response of DSX201 Yoke and Shell (and Vertically Split Version) to Thermal and Lorentz Loads, 4/23/90.

7. J. R. Turner, Mechanical Analysis of the W6733H Cross Section, MD-TA-143.

8. J. Strait, Notes on Collared Coil Mechanics and Sextupole Moment, Minutes of MSIM, 10/10-11/89

9. J. Cortella, private communication. See Ref. 10.

10. J. Strait, Calculation of Desired Vertical Ovality of SSC Collars, Minutes of MSIM, 10/10-11/89.

11. J. Strait, Design of a Vertically Split Yoke and Associated Collar for the 50 mm Collider Dipole: Collar Interior Dimensions, TS-SSC 90-034, 6/25/90.

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Table Ia

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***********************************************************
********* Collared Coil In Vertically Split Yoke **********
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------------------ Input Parameters -----------------------
rv(Rv)           = collar(yoke) vertical   radius - nominal radius (mils)
rh(Rh)           = collar(yoke) horizontal radius - nominal radius (mils)
skin_stress      = azimuthal skin stress at 4 K (kpsi)
skin_stress_300K= azimuthal skin stress at 300 K (kpsi)
contract_collar = integrated thermal contraction to 4 K of collar material (mils/inch)
contract_yoke    = integrated thermal contraction to 4 K of yoke   material (mils/inch)
r_nominal        = nominal 300 K unstressed collar radius (inches)
drv/drh          = drv/drh for horizontal force
drv/dpr          = drv/d(prestress) (average of inner and outer) (mils/kpsi)
drh/dpr          = drh/d(prestress) (average of inner and outer) (mils/kpsi)
prestr           = free collared coil prestress at 300 K (average of inner and outer) (kpsi)
dcool            = free collared coil cooldown prestress change (average of inner and outer) (kpsi)
dh/ds1           = drh/d(skin stress) rv < Rv (mils/kpsi)
dh/ds2           = drh/d(skin stress) rv > Rv (mils/kpsi)

------------------ Output Parameters ----------------------
rv               = rv-Rv of free collared coil (mils)
rh               = rh-Rh of free collared coil (mils)
rh_rv0           = rh-Rh for rv = Rv (mils)
rv_rh0           = rv-Rv for rh = Rh (mils)
rh_sk            = rh-Rh for assumed skin stress (mils)
rv_sk            = rv-Rv for assumed skin stress (mils)
sk_rv0           = skin stress to make rv = Rv (kpsi)
sk_rh0           = skin stress to make rh = Rh (kpsi)

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Table Ib

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---------------------------------------
r_nominal          =   2.670 inches
rv                 = -18.000 mils
rh                 =   4.400 mils
skin_stress_300K   =  25.000 kpsi
skin_stress        =  45.000 kpsi
contract_collar    =  -2.900 mils/inch
contract_yoke      =  -2.100 mils/inch
---------------------------------------
```

| | | | | | | | ------- T = 300 K ------- | | | | ------------------- T = 4 K ------------------- | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| drv/drh | drv/dpr | drh/dpr | prestr | dcool | dh/ds1 | dh/ds2 | rh | rv | rv_rh0 | sk_rh0 | rh | rv | rh_rv0 | rv_rh0 | rh_sk | rv_sk | sk_rv0 | sk_rh0 |
| -0.55 | 0.45 | -0.05 | 10.00 | -2.25 | -0.28 | -0.03 | 3.9 | -13.5 | -11.4 | 14.1 | 1.9 | -16.6 | -28.4 | -15.6 | 0.0 | -15.6 | - | 6.8 |
| -0.55 | 0.35 | -0.05 | 13.00 | -2.25 | -0.28 | -0.03 | 3.8 | -13.5 | -11.4 | 13.6 | 1.7 | -16.4 | -28.0 | -15.4 | 0.0 | -15.4 | - | 6.3 |
| ----- Vary Coil Prestress and Cooldown Loss ----- | | | | | | | | | | | | | | | | | | |
| -0.55 | 0.45 | -0.05 | 13.00 | -2.25 | -0.28 | -0.03 | 3.8 | -12.2 | -10.1 | 13.6 | 1.7 | -15.3 | -26.1 | -14.3 | 0.0 | -14.3 | - | 6.3 |
| -0.55 | 0.45 | -0.05 | 7.00 | -2.25 | -0.28 | -0.03 | 4.1 | -14.9 | -12.6 | 14.7 | 2.0 | -18.0 | -30.7 | -16.9 | 0.0 | -16.9 | - | 7.3 |
| -0.55 | 0.45 | -0.05 | 10.00 | -3.25 | -0.28 | -0.03 | 3.9 | -13.5 | -11.4 | 14.1 | 1.9 | -17.1 | -29.2 | -16.0 | 0.0 | -16.0 | - | 7.0 |
| ----- Vary dr/d(prestress) ----- | | | | | | | | | | | | | | | | | | |
| -0.55 | 0.35 | -0.05 | 10.00 | -2.25 | -0.28 | -0.03 | 3.9 | -14.5 | -12.4 | 14.1 | 1.9 | -17.4 | -29.8 | -16.4 | 0.0 | -16.4 | - | 6.8 |
| -0.55 | 0.40 | -0.05 | 10.00 | -2.25 | -0.28 | -0.03 | 3.9 | -14.0 | -11.9 | 14.1 | 1.9 | -17.0 | -29.1 | -16.0 | 0.0 | -16.0 | - | 6.8 |
| -0.55 | 0.50 | -0.05 | 10.00 | -2.25 | -0.28 | -0.03 | 3.9 | -13.0 | -10.9 | 14.1 | 1.9 | -16.3 | -27.7 | -15.2 | 0.0 | -15.2 | - | 6.8 |
| ----- Choose values that give a small and a big collared coil (vertically) ----- | | | | | | | | | | | | | | | | | | |
| -0.55 | 0.35 | -0.05 | 7.00 | -3.25 | -0.28 | -0.03 | 4.1 | -15.6 | -13.3 | 14.7 | 2.1 | -18.8 | -32.1 | -17.7 | 0.0 | -17.7 | - | 7.5 |
| -0.55 | 0.50 | -0.05 | 13.00 | -2.25 | -0.28 | -0.03 | 3.8 | -11.5 | -9.4 | 13.6 | 1.7 | -14.8 | -25.1 | -13.8 | 0.0 | -13.8 | - | 6.3 |
| ----- Choose values that give a small and a big collared coil (horizontally) ----- | | | | | | | | | | | | | | | | | | |
| -0.55 | 0.45 | -0.10 | 13.00 | -2.25 | -0.28 | -0.03 | 3.1 | -12.2 | -10.4 | 11.2 | 1.2 | -15.3 | -26.6 | -14.6 | 0.0 | -14.6 | - | 4.3 |
| -0.55 | 0.45 | 0.00 | 10.00 | -2.25 | -0.28 | -0.03 | 4.4 | -13.5 | -11.1 | 15.9 | 2.3 | -16.6 | -28.0 | -15.4 | 0.0 | -15.4 | - | 8.2 |
| ----- Vary dr/d(skin stress) ----- | | | | | | | | | | | | | | | | | | |
| -0.55 | 0.45 | -0.05 | 10.00 | -2.25 | -0.25 | -0.03 | 3.9 | -13.5 | -11.4 | 15.8 | 1.9 | -16.6 | -28.4 | -15.6 | 0.0 | -15.6 | - | 7.6 |
| -0.55 | 0.45 | -0.05 | 10.00 | -2.25 | -0.28 | -0.03 | 3.9 | -13.5 | -11.4 | 14.1 | 1.9 | -16.6 | -28.4 | -15.6 | 0.0 | -15.6 | - | 6.8 |
| -0.55 | 0.45 | -0.05 | 10.00 | -2.25 | -0.32 | -0.04 | 3.9 | -13.5 | -11.4 | 12.2 | 1.9 | -16.6 | -28.4 | -15.6 | 0.0 | -15.6 | - | 5.9 |
| ----- Vary drv/drh ----- | | | | | | | | | | | | | | | | | | |
| -0.50 | 0.45 | -0.05 | 10.00 | -2.25 | -0.28 | -0.03 | 3.9 | -13.5 | -11.6 | 14.1 | 1.9 | -16.6 | -31.4 | -15.7 | 0.0 | -15.7 | - | 6.8 |
| -0.60 | 0.45 | -0.05 | 10.00 | -2.25 | -0.28 | -0.03 | 3.9 | -13.5 | -11.2 | 14.1 | 1.9 | -16.6 | -25.9 | -15.5 | 0.0 | -15.5 | - | 6.8 |

## Table Ic

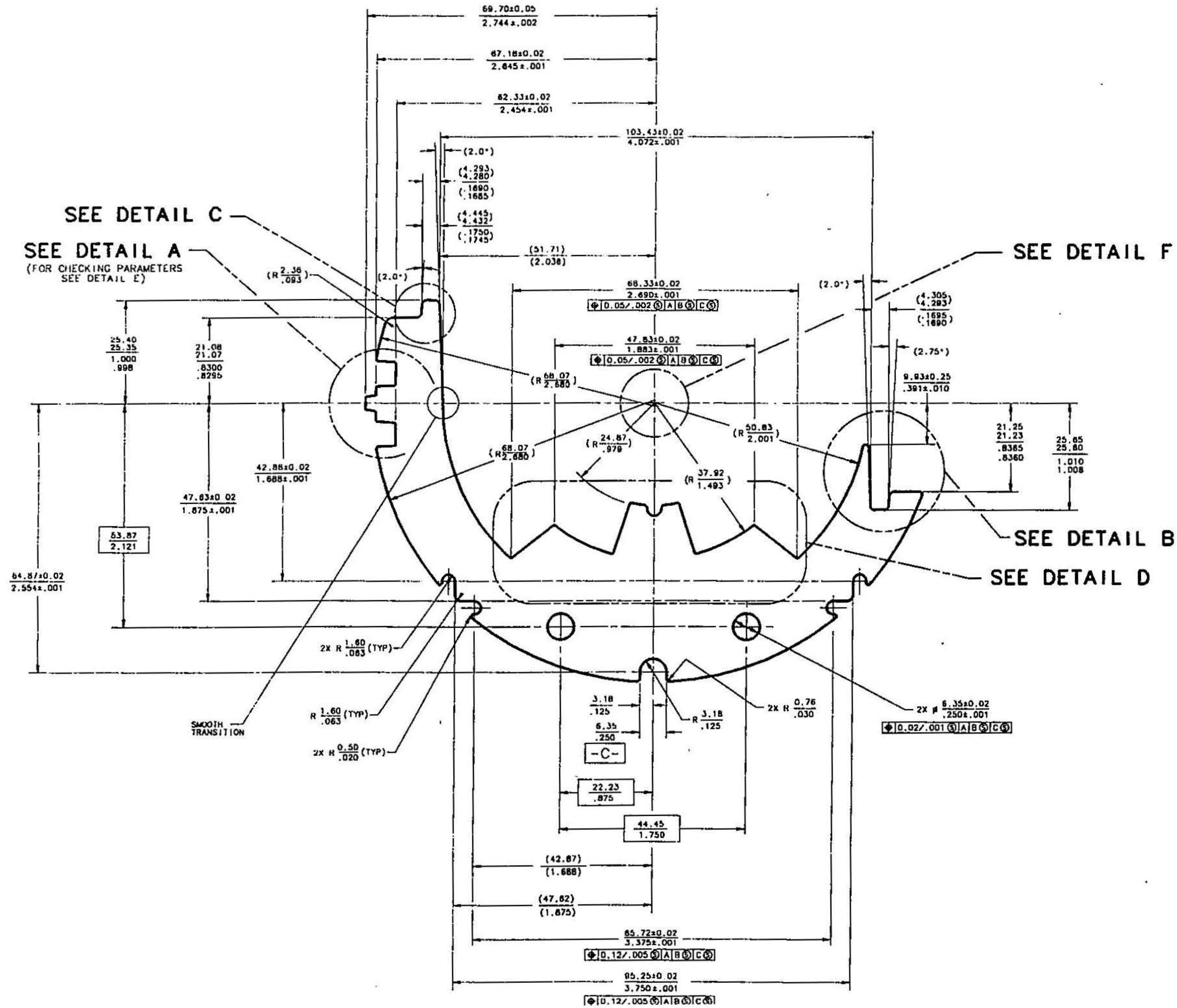
| | | |
|---|---|---|
| r_nominal | = | 2.670 inches |
| rv | = | -18.000 mils |
| rh | = | 5.500 mils |
| skin_stress_300K | = | 25.000 kpsi |
| skin_stress | = | 45.000 kpsi |
| contract_collar | = | -2.900 mils/inch |
| contract_yoke | = | -2.100 mils/inch |

| | | | | | | | T = 300 K | | | | T = 4 K | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| drv/drh | drv/dpr | drh/dpr | prestr | dcool | dh/ds1 | dh/ds2 | rh | rv | rv_rh0 | sk_rh0 | rh | rv | rh_rv0 | rv_rh0 | rh_sk | rv_sk | sk_rv0 | sk_rh0 |
| -0.55 | 0.45 | -0.05 | 10.00 | -2.25 | -0.28 | -0.03 | 5.0 | -13.5 | -10.8 | 18.1 | 3.0 | -16.6 | -27.3 | -15.0 | 0.0 | -15.0 | - | 10.8 |
| -0.55 | 0.35 | -0.05 | 13.00 | -2.25 | -0.28 | -0.03 | 4.8 | -13.5 | -10.8 | 17.6 | 2.8 | -16.4 | -26.9 | -14.8 | 0.0 | -14.8 | - | 10.2 |
| ----- Vary Coil Prestress and Cooldown Loss ----- | | | | | | | | | | | | | | | | | | |
| -0.55 | 0.45 | -0.05 | 13.00 | -2.25 | -0.28 | -0.03 | 4.8 | -12.2 | -9.5 | 17.6 | 2.8 | -15.3 | -25.0 | -13.7 | 0.0 | -13.7 | - | 10.2 |
| -0.55 | 0.45 | -0.05 | 7.00 | -2.25 | -0.28 | -0.03 | 5.2 | -14.9 | -12.0 | 18.7 | 3.1 | -18.0 | -29.6 | -16.3 | 0.0 | -16.3 | - | 11.3 |
| -0.55 | 0.45 | -0.05 | 10.00 | -3.25 | -0.28 | -0.03 | 5.0 | -13.5 | -10.8 | 18.1 | 3.0 | -17.1 | -28.1 | -15.4 | 0.0 | -15.4 | - | 11.0 |
| ----- Vary dr/d(prestress) ----- | | | | | | | | | | | | | | | | | | |
| -0.55 | 0.35 | -0.05 | 10.00 | -2.25 | -0.28 | -0.03 | 5.0 | -14.5 | -11.8 | 18.1 | 3.0 | -17.4 | -28.7 | -15.8 | 0.0 | -15.8 | - | 10.8 |
| -0.55 | 0.40 | -0.05 | 10.00 | -2.25 | -0.28 | -0.03 | 5.0 | -14.0 | -11.3 | 18.1 | 3.0 | -17.0 | -28.0 | -15.4 | 0.0 | -15.4 | - | 10.8 |
| -0.55 | 0.50 | -0.05 | 10.00 | -2.25 | -0.28 | -0.03 | 5.0 | -13.0 | -10.3 | 18.1 | 3.0 | -16.3 | -26.6 | -14.6 | 0.0 | -14.6 | - | 10.8 |
| ----- Choose values that give a small and a big collared coil (vertically) ----- | | | | | | | | | | | | | | | | | | |
| -0.55 | 0.35 | -0.05 | 7.00 | -3.25 | -0.28 | -0.03 | 5.2 | -15.6 | -12.7 | 18.7 | 3.2 | -18.8 | -31.0 | -17.1 | 0.0 | -17.1 | - | 11.5 |
| -0.55 | 0.50 | -0.05 | 13.00 | -2.25 | -0.28 | -0.03 | 4.8 | -11.5 | -8.8 | 17.6 | 2.8 | -14.8 | -24.0 | -13.2 | 0.0 | -13.2 | - | 10.2 |
| ----- Choose values that give a small and a big collared coil (horizontally) ----- | | | | | | | | | | | | | | | | | | |
| -0.55 | 0.45 | -0.10 | 13.00 | -2.25 | -0.28 | -0.03 | 4.2 | -12.2 | -9.8 | 15.2 | 2.3 | -15.3 | -25.5 | -14.0 | 0.0 | -14.0 | - | 8.3 |
| -0.55 | 0.45 | 0.00 | 10.00 | -2.25 | -0.28 | -0.03 | 5.5 | -13.5 | -10.5 | 19.9 | 3.4 | -16.6 | -26.9 | -14.8 | 0.0 | -14.8 | - | 12.2 |
| ----- Vary dr/d(skin stress) ----- | | | | | | | | | | | | | | | | | | |
| -0.55 | 0.45 | -0.05 | 10.00 | -2.25 | -0.25 | -0.03 | 5.0 | -13.5 | -10.8 | 20.2 | 3.0 | -16.6 | -27.3 | -15.0 | 0.0 | -15.0 | - | 12.1 |
| -0.55 | 0.45 | -0.05 | 10.00 | -2.25 | -0.28 | -0.03 | 5.0 | -13.5 | -10.8 | 18.1 | 3.0 | -16.6 | -27.3 | -15.0 | 0.0 | -15.0 | - | 10.8 |
| -0.55 | 0.45 | -0.05 | 10.00 | -2.25 | -0.32 | -0.04 | 5.0 | -13.5 | -10.8 | 15.6 | 3.0 | -16.6 | -27.3 | -15.0 | 0.0 | -15.0 | - | 9.3 |
| ----- Vary drv/drh ----- | | | | | | | | | | | | | | | | | | |
| -0.50 | 0.45 | -0.05 | 10.00 | -2.25 | -0.28 | -0.03 | 5.0 | -13.5 | -11.0 | 18.1 | 3.0 | -16.6 | -30.3 | -15.2 | 0.0 | -15.2 | - | 10.8 |
| -0.60 | 0.45 | -0.05 | 10.00 | -2.25 | -0.28 | -0.03 | 5.0 | -13.5 | -10.5 | 18.1 | 3.0 | -16.6 | -24.8 | -14.9 | 0.0 | -14.9 | - | 10.8 |

Table Id

| | | |
|---|---|---|
| r_nominal | = | 2.670 inches |
| rv | = | -18.000 mils |
| rh | = | 6.600 mils |
| skin_stress_300K | = | 25.000 kpsi |
| skin_stress | = | 45.000 kpsi |
| contract_collar | = | -2.900 mils/inch |
| contract_yoke | = | -2.100 mils/inch |

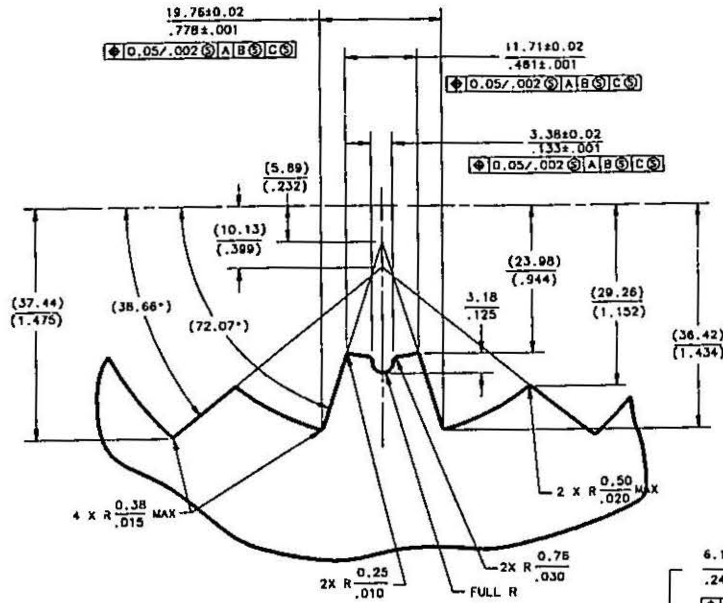
| | | | | | | | T = 300 K | | | | T = 4 K | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| drv/drh | drv/dpr | drh/dpr | prestr | dcool | dh/ds1 | dh/ds2 | rh | rv | rv_rh0 | sk_rh0 | rh | rv | rh_rv0 | rv_rh0 | rh_sk | rv_sk | sk_rv0 | sk_rh0 |
| -0.55 | 0.45 | -0.05 | 10.00 | -2.25 | -0.28 | -0.03 | 6.1 | -13.5 | -10.1 | 22.1 | 4.1 | -16.6 | -26.2 | -14.4 | 0.0 | -14.4 | - | 14.8 |
| -0.55 | 0.35 | -0.05 | 13.00 | -2.25 | -0.28 | -0.03 | 5.9 | -13.5 | -10.2 | 21.6 | 3.9 | -16.4 | -25.8 | -14.2 | 0.0 | -14.2 | - | 14.2 |
| ----- Vary Coil Prestress and Cooldown Loss ----- | | | | | | | | | | | | | | | | | | |
| -0.55 | 0.45 | -0.05 | 13.00 | -2.25 | -0.28 | -0.03 | 5.9 | -12.2 | -8.9 | 21.6 | 3.9 | -15.3 | -23.9 | -13.1 | 0.0 | -13.1 | - | 14.2 |
| -0.55 | 0.45 | -0.05 | 7.00 | -2.25 | -0.28 | -0.03 | 6.3 | -14.9 | -11.4 | 22.6 | 4.2 | -18.0 | -28.5 | -15.7 | 0.0 | -15.7 | - | 15.3 |
| -0.55 | 0.45 | -0.05 | 10.00 | -3.25 | -0.28 | -0.03 | 6.1 | -13.5 | -10.1 | 22.1 | 4.1 | -17.1 | -27.0 | -14.8 | 0.0 | -14.8 | - | 15.0 |
| ----- Vary dr/d(prestress) ----- | | | | | | | | | | | | | | | | | | |
| -0.55 | 0.35 | -0.05 | 10.00 | -2.25 | -0.28 | -0.03 | 6.1 | -14.5 | -11.1 | 22.1 | 4.1 | -17.4 | -27.6 | -15.2 | 0.0 | -15.2 | - | 14.8 |
| -0.55 | 0.40 | -0.05 | 10.00 | -2.25 | -0.28 | -0.03 | 6.1 | -14.0 | -10.6 | 22.1 | 4.1 | -17.0 | -26.9 | -14.8 | 0.0 | -14.8 | - | 14.8 |
| -0.55 | 0.50 | -0.05 | 10.00 | -2.25 | -0.28 | -0.03 | 6.1 | -13.0 | -9.6 | 22.1 | 4.1 | -16.3 | -25.5 | -14.0 | 0.0 | -14.0 | - | 14.8 |
| ----- Choose values that give a small and a big collared coil (vertically) ----- | | | | | | | | | | | | | | | | | | |
| -0.55 | 0.35 | -0.05 | 7.00 | -3.25 | -0.28 | -0.03 | 6.3 | -15.6 | -12.1 | 22.6 | 4.3 | -18.8 | -29.9 | -16.5 | 0.0 | -16.5 | - | 15.5 |
| -0.55 | 0.50 | -0.05 | 13.00 | -2.25 | -0.28 | -0.03 | 5.9 | -11.5 | -8.2 | 21.6 | 3.9 | -14.8 | -22.9 | -12.6 | 0.0 | -12.6 | - | 14.2 |
| ----- Choose values that give a small and a big collared coil (horizontally) ----- | | | | | | | | | | | | | | | | | | |
| -0.55 | 0.45 | -0.10 | 13.00 | -2.25 | -0.28 | -0.03 | 5.3 | -12.2 | -9.2 | 19.2 | 3.4 | -15.3 | -24.4 | -13.4 | 0.0 | -13.4 | - | 12.3 |
| -0.55 | 0.45 | 0.00 | 10.00 | -2.25 | -0.28 | -0.03 | 6.6 | -13.5 | -9.9 | 23.9 | 4.5 | -16.6 | -25.8 | -14.2 | 0.0 | -14.2 | - | 16.2 |
| ----- Vary dr/d(skin stress) ----- | | | | | | | | | | | | | | | | | | |
| -0.55 | 0.45 | -0.05 | 10.00 | -2.25 | -0.25 | -0.03 | 6.1 | -13.5 | -10.1 | 24.7 | 4.1 | -16.6 | -26.2 | -14.4 | 0.0 | -14.4 | - | 16.5 |
| -0.55 | 0.45 | -0.05 | 10.00 | -2.25 | -0.28 | -0.03 | 6.1 | -13.5 | -10.1 | 22.1 | 4.1 | -16.6 | -26.2 | -14.4 | 0.0 | -14.4 | - | 14.8 |
| -0.55 | 0.45 | -0.05 | 10.00 | -2.25 | -0.32 | -0.04 | 6.1 | -13.5 | -10.1 | 19.1 | 4.1 | -16.6 | -26.2 | -14.4 | 0.0 | -14.4 | - | 12.7 |
| ----- Vary drv/drh ----- | | | | | | | | | | | | | | | | | | |
| -0.50 | 0.45 | -0.05 | 10.00 | -2.25 | -0.28 | -0.03 | 6.1 | -13.5 | -10.4 | 22.1 | 4.1 | -16.6 | -29.2 | -14.6 | 0.0 | -14.6 | - | 14.8 |
| -0.60 | 0.45 | -0.05 | 10.00 | -2.25 | -0.28 | -0.03 | 6.1 | -13.5 | -9.8 | 22.1 | 4.1 | -16.6 | -23.7 | -14.2 | 0.0 | -14.2 | - | 14.8 |



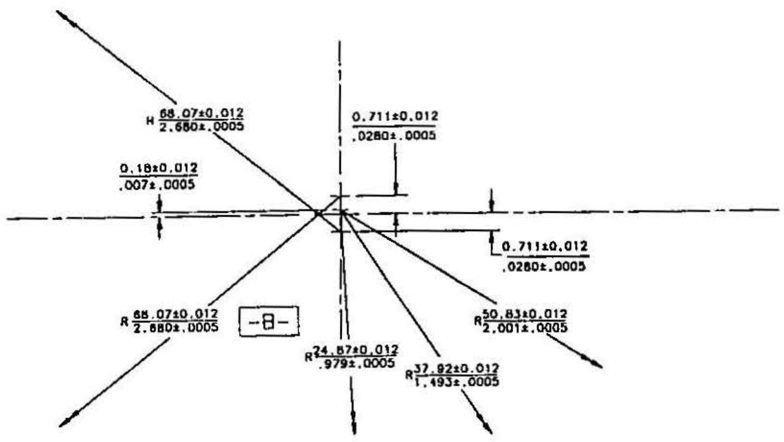
SEE DETAIL C
SEE DETAIL A
(FOR CHECKING PARAMETERS SEE DETAIL E)
SEE DETAIL F
SEE DETAIL B
SEE DETAIL D
69.70±0.05 / 2.744±.002
67.18±0.02 / 2.645±.001
62.33±0.02 / 2.454±.001
103.43±0.02 / 4.072±.001
(51.71) / (2.036)
68.33±0.02 / 2.690±.001
47.83±0.02 / 1.883±.001
9.93±0.25 / .391±.010
42.88±0.02 / 1.688±.001
47.63±0.02 / 1.875±.001
64.87±0.02 / 2.554±.001
53.87 / 2.121
SMOOTH TRANSITION
-C-
22.23 / .875
44.45 / 1.750
(42.87) / (1.688)
(47.62) / (1.875)
85.72±0.02 / 3.375±.001
95.25±0.02 / 3.750±.001


Figure 1a

Figure 1b

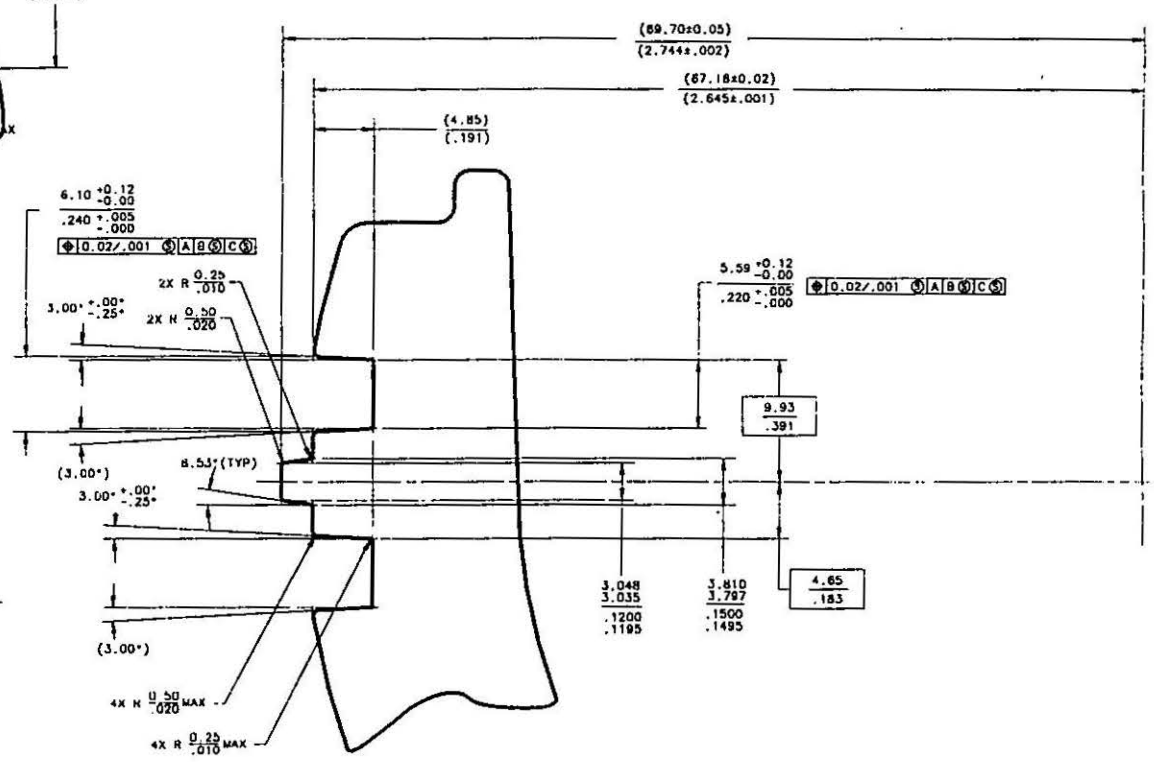



DETAIL D




DETAIL F

SCALE 4 : 1




DETAIL A

SCALE 4 : 1

DIMENSIONS ARE TO INTERSECTION AS SHOWN

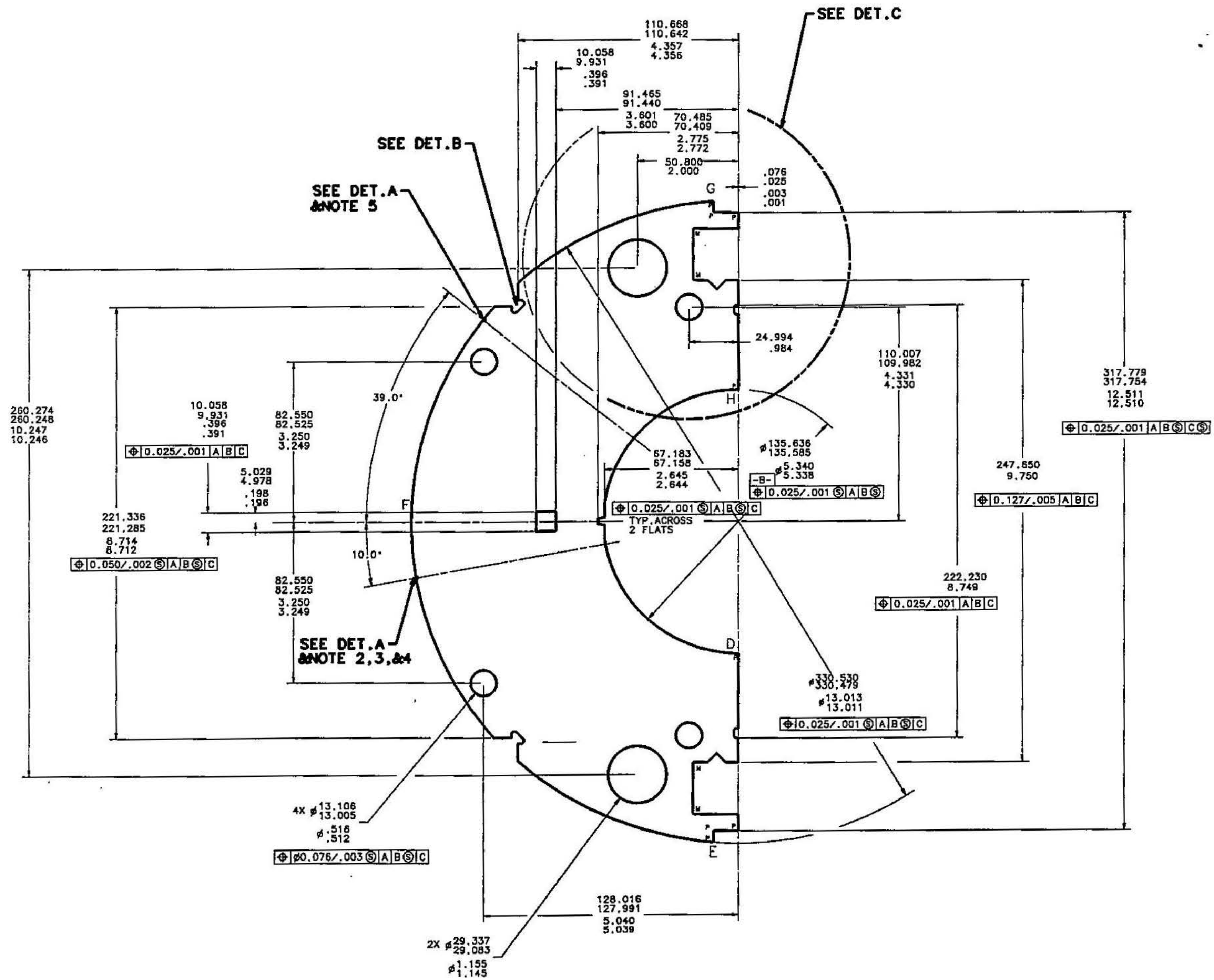
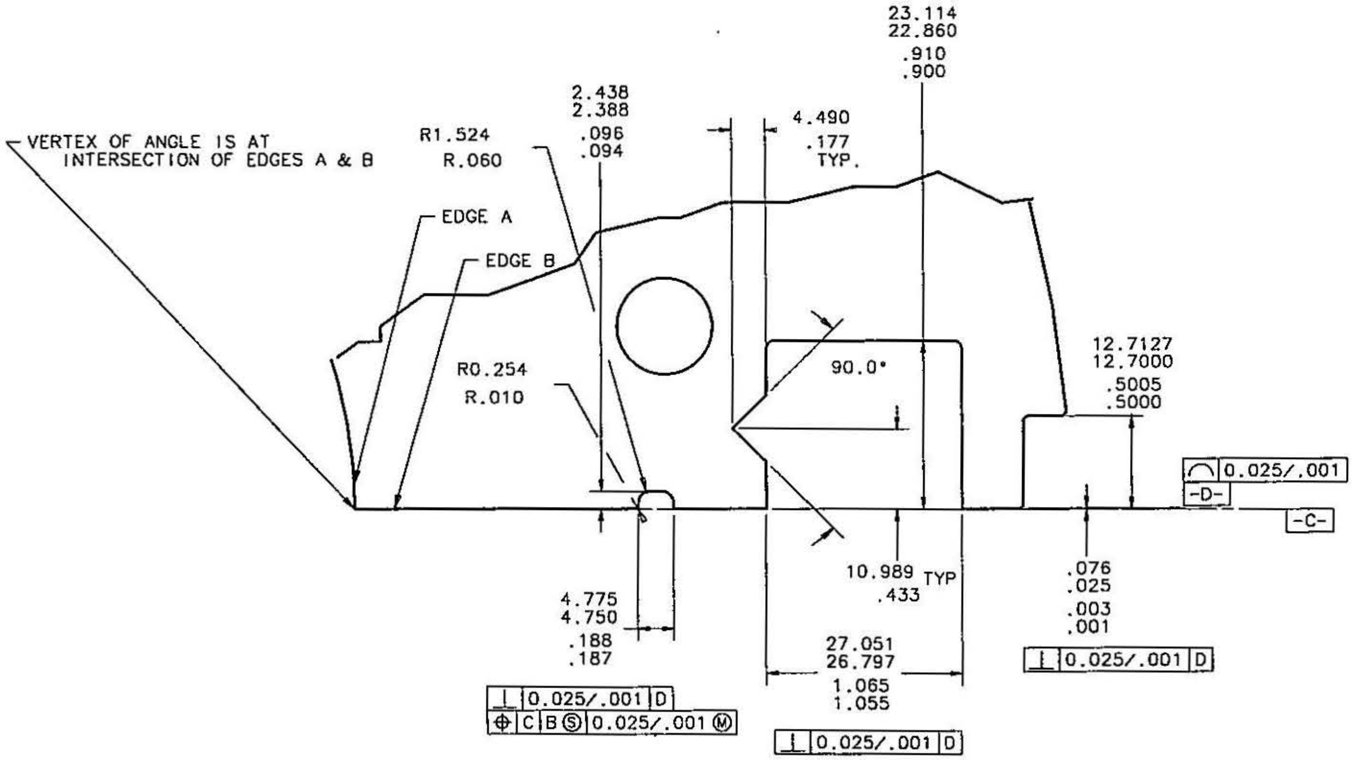
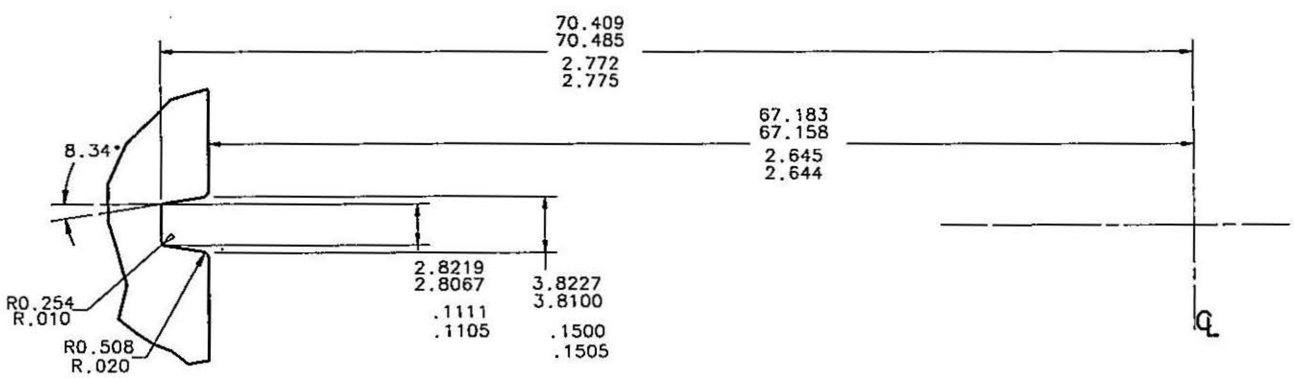

SEE DET.C
SEE DET.B
SEE DET.A
&NOTE 5
SEE DET.A
&NOTE 2,3,&4
110.668
110.642
4.357
4.356
10.058
9.931
.396
.391
91.465
91.440
3.601
3.600
70.485
70.409
2.775
2.772
50.800
2.000
.076
.025
.003
.001
G
24.994
.984
110.007
109.982
4.331
4.330
317.779
317.754
12.511
12.510
0.025/.001 A B S C S
H
39.0°
260.274
260.248
10.247
10.246
10.058
9.931
.396
.391
0.025/.001 A B C
82.550
82.525
3.250
3.249
5.029
4.978
.198
.196
67.183
67.158
2.645
2.644
ø135.636
135.585
-B-
ø5.340
5.338
0.025/.001 S A B S
247.650
9.750
0.127/.005 A B C
F
0.025/.001 S A B S C
TYP.ACROSS
2 FLATS
221.336
221.285
8.714
8.712
0.050/.002 S A B S C
10.0°
82.550
82.525
3.250
3.249
222.230
8.749
0.025/.001 A B C
D
ø330.530
330.479
ø13.013
13.011
0.025/.001 S A B S C
4X ø13.106
13.005
ø.516
.512
ø0.076/.003 S A B S C
E
128.016
127.991
5.040
5.039
2X ø29.337
29.083
ø1.155
1.145

Figure 2a



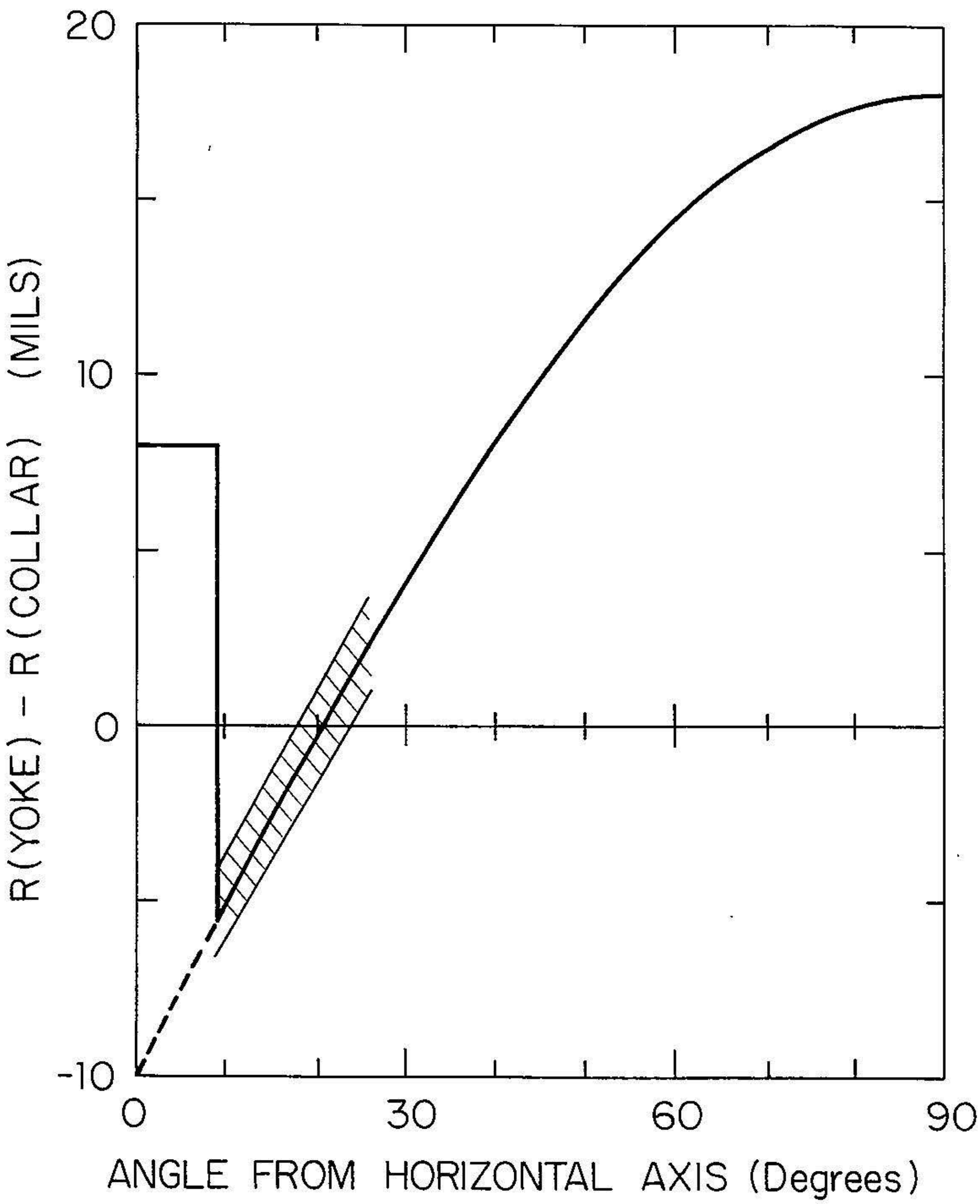

DET C 2XSIZE
SHOWN OUT OF POSITION




DIMENSIONS ARE TO INTERSECTIONS
OR TO SHARP CORNERS

DET.D 4XSIZE

Figure 2b



20
10
0
-10
0
30
60
90
R(YOKE) - R(COLLAR) (MILS)
ANGLE FROM HORIZONTAL AXIS (Degrees)


Figure 3