Fermilab

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DOUBLER DIPOLE COIL COLLAR FATIGUE MEASUREMENTS

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In order to limit the reaction of the superconducting coils to the radial component of the Lorentz force present when the coils are energized, the coils are encased in a rigid coil clamp collar system. This system consists mainly of alternating "U" shaped .060 inch stainless steel type 4 collar laminations. (Fig. 1) They are bonded in the overlapping leg region on either side of the coils with three welds followed by a surface coat of low viscosity epoxy. A small spacer lamination (also shown in Fig. 1) is inserted top and bottom in the space between collar laminations. A 100 ton/ft hydraulic press forces the collar to the required dimension prior to welding.

To measure the long term effects of the cyclically stressed epoxy and steel at cryogenic temperature, a fatigue tester was constructed. The device consists of a hydraulic cylinder whose pressure can be modulated at a rate of 3 cycles per second, thereby greatly reducing the time required to achieve 10^7 cycles, the anticipated life of the Doubler. The force of the hydraulic cylinder is transmitted to a 1" section of collar system under test in Liquid Nitrogen via a rigid steel shaft. The contact points for this force on the system section are shown in Fig. 2. A stress analysis performed by Warren Young, Madison, indicated that this geometry results in collar stresses that are a good approximation of stresses present in the magnet collar during peak field. The results of fatigue tests performed on different collar materials and types are summarized in Fig. 3. It is evident that our present type 4 collar system design with Nitronic 33 or 316 stainless steel material will fail after 7.5×10^5 cycles. Using aluminum instead of stainless steel would reduce the failure point to 10^5 cycles. The failure mode in these two cases was metal fatigue at the sharp corner of the inner coil azimuthal boundary. Stress relieving of this corner with a .060" radius raised the failure point to 1.6×10^6 cycles.

The keylock collar system (Fig. 4) differs from the standard type 4 collar system in that the spacer lamination is enlarged, doubling the strength of the collar system in the key areas. Tests performed on this collar system constructed of Nitronic 33 stainless steel indicated a failure point of 8×10^6 cycles, marginally acceptable. The failure mode for this collar type was metal fatigue at the sharp corner (.060" radius) of the outer coil azimuthal boundary.

The strongest collar system tested was a type 4 collar with a spacer lamination completely filling the space between collars. This is called the "solid" system and is made of Nitronic 33. This system failed after 8×10^7 cycles at the upper to lower lamination butt joints.

It should be noted that at no time did the epoxy or the welds joining the laminations fail. In every case, the failure was metal fatigue in the stamped laminations. The adoption of either the keylock or solid system design in stainless steel or a solid aluminum collar system should result in coils that survive the required 10^7 cycles.

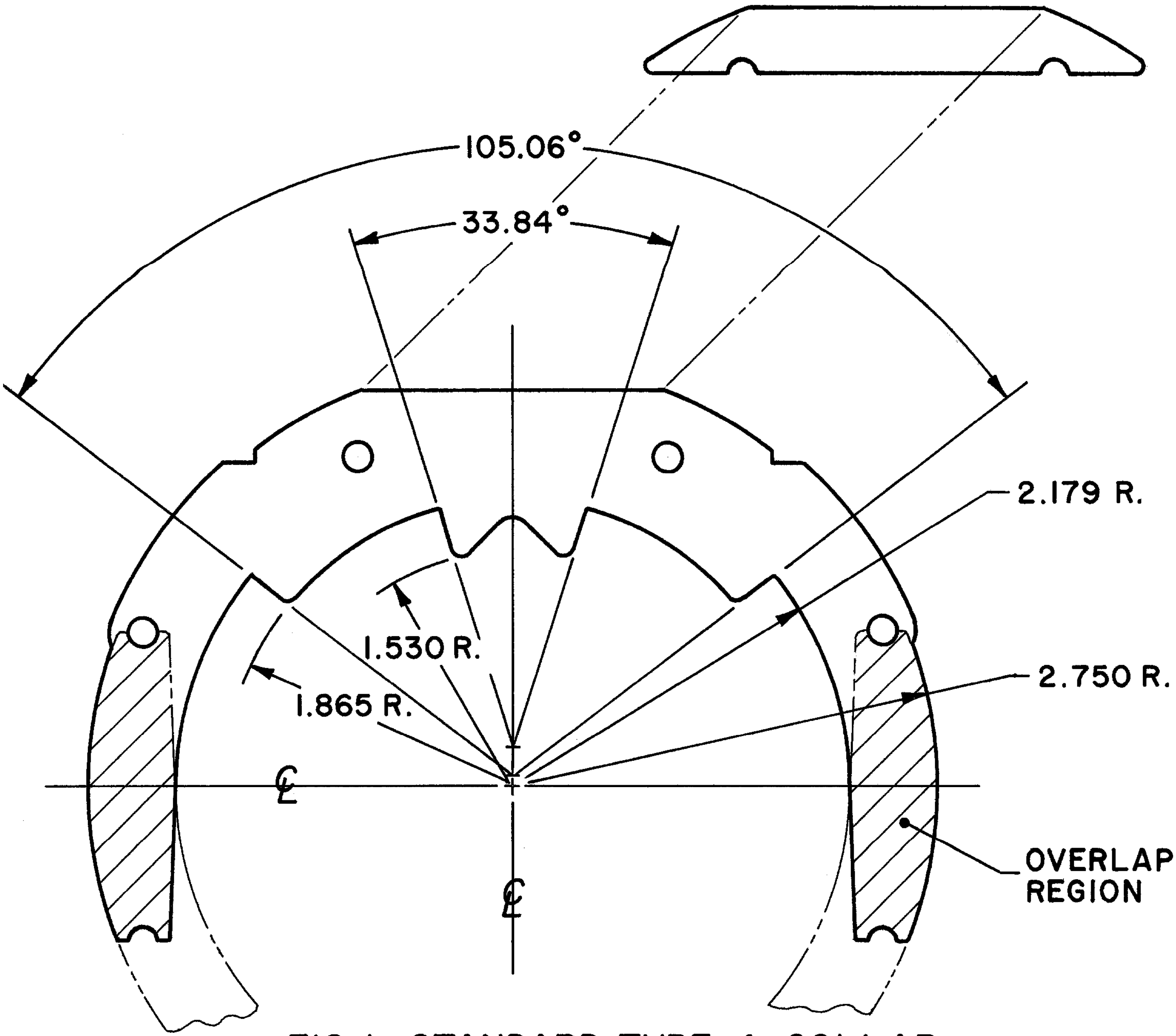


FIG. 1 STANDARD TYPE 4 COLLAR LAMINATION AND SPACER

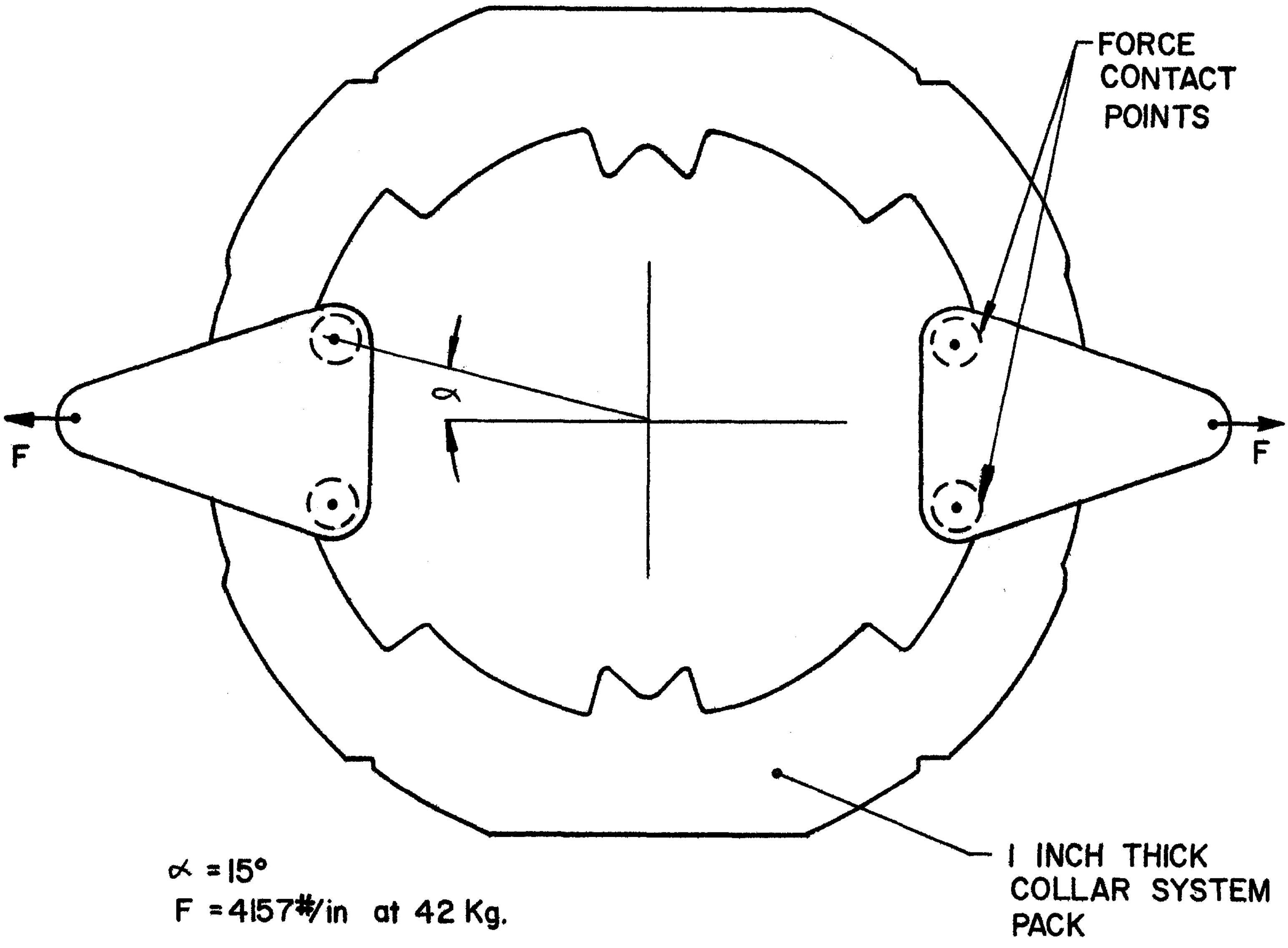
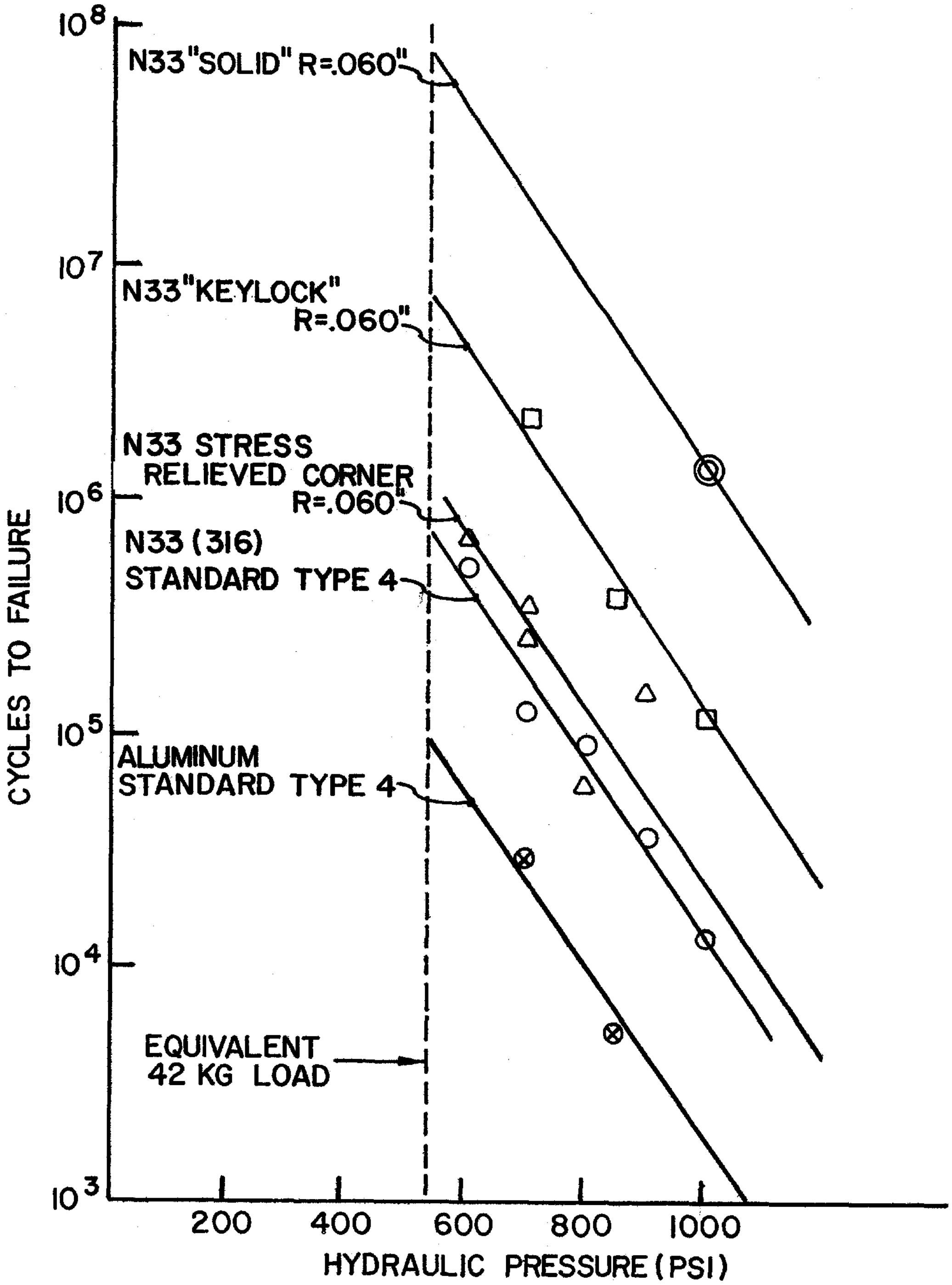


Fig. 2 Force contact that approximates stress distribution in magnet collar at a field of 42 Kg.



CYCLES TO FAILURE
10^8
10^7
10^6
10^5
10^4
10^3
N33"SOLID" R=.060"
N33"KEYLOCK" R=.060"
N33 STRESS RELIEVED CORNER R=.060"
N33 (316) STANDARD TYPE 4
ALUMINUM STANDARD TYPE 4
EQUIVALENT 42 KG LOAD
200
400
600
800
1000
HYDRAULIC PRESSURE (PSI)

Fig. 3

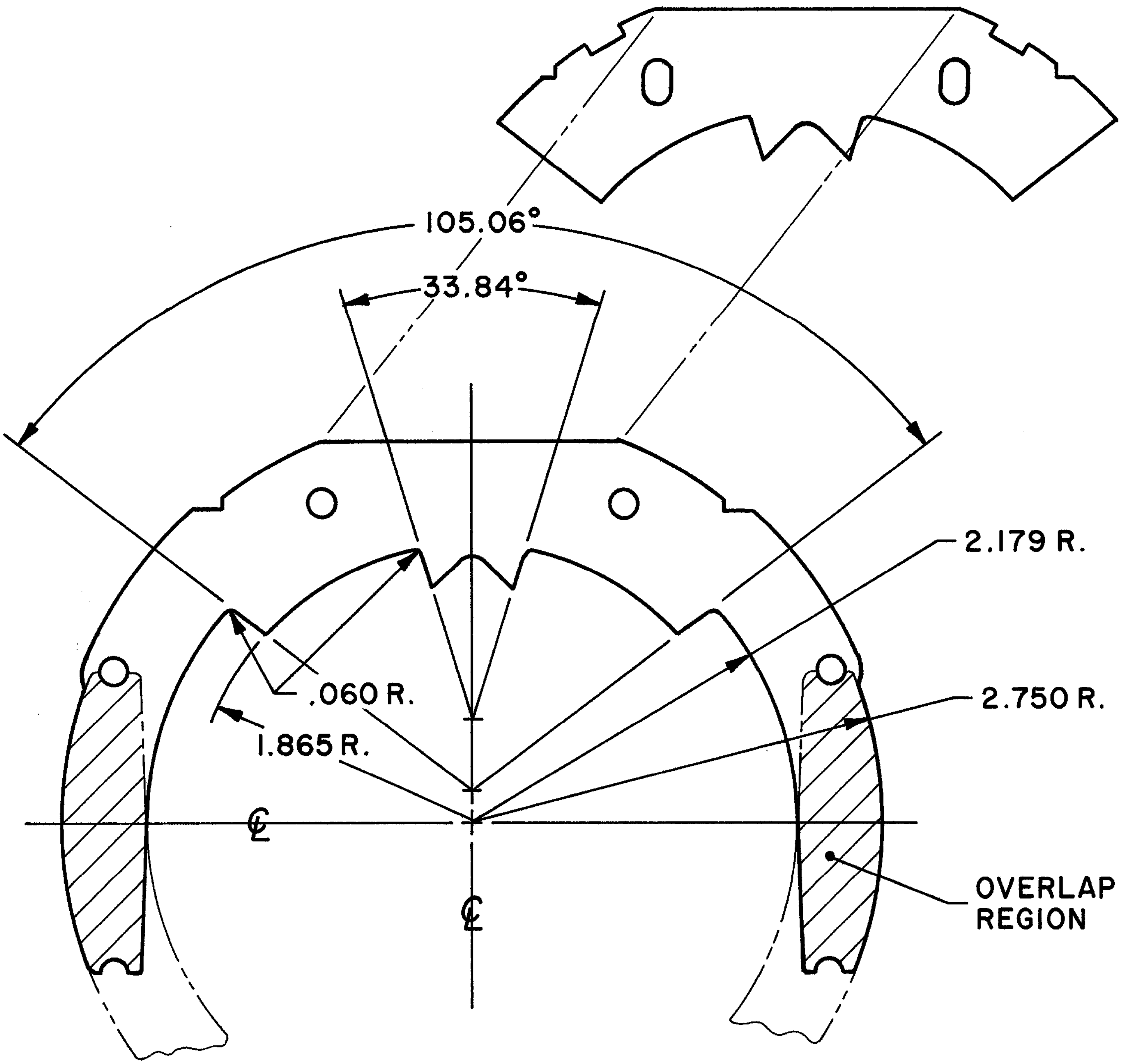


FIG. 4 KEYLOCK COLLAR LAMINATION AND SPACER