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Dump Me, Two: Beam stop design for the 2 GeV/c beamline

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Dump Me, Two*
Beam Stop Design for the 2 GeV/c Beamline

The design criteria and methods of calculation for a beam stop for the 2 GeV/c beam line are presented.

Operating Parameters

The 2 GeV/c beam line is expected to operate with intensities up to 10^7 particles/spill with a maximum momentum of 2 GeV/c. The beam stop is designed to provide 1 mrem/hr on contact while the beam is in normal operating conditions. For abnormal operating conditions such as mistuned beam, the stop is designed to provide for less than 10 mrem/hr on contact.

Hadron Cascade

The Monte Carlo program CASIM [1,2,3] was used to evaluate the required stop dimensions and materials. The star density per incident particle needed to satisfy the shielding criteria is given by

$$\rho_S = L/(I^*C)$$

where ρ_S is the stars/(cm^3-inc particle), I is the beam intensity in particle/hour, L is

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* Again, not intended as advice regarding continued employment!

the desired equivalent dose rate at contact in mrem/hr, and C is a conversion factor depending on the material. For iron and heavy concrete, C has values of 2.1×10^{-3} mrem/(star/cm^3) and 4.9×10^{-3} mrem/(star/cm^3) respectively.[4] The required star density is 4.8×10^{-8} stars/cm^3 for iron and 2.0×10^{-8} stars/cm^3 for heavy concrete.

The geometry of the dump used in the simulation is depicted in Figure 1. The main part of the beam stop starts at Z = 200 cm with a radius of 200 cm and a depth of 500 cm. A re-entrant cavity is placed in front to evaluate the health physics aspects of shine off the face of the stop. It is also expected that the experiment will desire a re-entrant cavity to reduce backgrounds in their detector.

The results for heavy concrete are shown in Figures 2, 3 and 4. In Fig. 2, it can be seen that 290 cm (9.5 ft) of heavy concrete is sufficient on the beam axis (r = 0). At a radius of 80 cm (2.6 ft), a thickness of 230 cm (7.7 ft) is needed. From Figure 3, the maximum radius of the stop required is 100 cm (3.3 ft) at a depth of roughly 150 cm from the front face of the stop. The star density shown in Figure 4 for the re-entrant cavity demonstrates that at a radial distance of 30 cm (1 ft) from the beam, the levels are below 1 mr/hr. It is concluded that a heavy concrete beam stop with radius 100 cm (3.3 ft) and depth 290 cm (9.5 ft) is sufficient to meet the design criteria.

Results for the iron beam stop are given in Figures 5, 6, and 7. It is concluded that an iron beam stop with a depth of 190 cm (6.3 ft) and radius 70 cm (2.3 ft) meets the design goals.

Muons

The muons will range out in the beam stop because of the dimensions required to contain the hadron cascade. At this energy and beam intensity the muons do not establish any critical dimensions provided the hadrons are properly shielded.

Additional Considerations

The beam stop must provide protection for operating conditions that are not considered normal. The primary cause of abnormal conditions would be mistuned beam which displaces the beam position on the stop or which causes exceptionally large losses in the experimental area.

The maximum angle the beam can be deflected in the horizontal and clear the inside gap of the spectrometer magnet is approximately 7°. This deflection can cause a 90 cm displacement on the beam stop face. With a current comparator on the last dipole, D3, demanding a tolerance of 15%, the maximum deviation angle would be less than 3°. However, the last quadrupole has sufficient strength to provide large deflections if the beam is sufficiently low in energy and off axis in the horizontal and the current comparator could fail. Therefore, it is prudent to add an appropriate width (~ 90 cm) to the beam stop to protect against these abnormal conditions.

Two main loss points might be anticipated in the experimental area. The first is the quadrupole provided it has a fixed aperture collimater inside. The second would be either horizontal mistuning the beam into the 48D48 magnet pole face or overpowering the spectrometer magnet and vertically pitching the beam into the coils or field clamps. To estimate the requirements for these abnormal running conditions, CASIM was run for a beam interacting in a thin/thick target in a 1-meter thick iron sphere, 3-meters in diameter. The results for the thin and thick (30 cm radius) targets are shown in Figures 8 and 9 respectively. Based on these results, it is concluded that a 100% loss in the quadrupole produces levels on the side the 48D48 which should be less than 10 mr/hr. The loss of beam on the downstream edge of the spectrometer magnet can cause levels to 10 mr/hr at 180 cm (6 ft) off normal beam axis in the horizontal.

A beam stop with horizontal dimensions of 360 cm (12 ft) and depth 290 cm (9.5 ft), should be sufficient to meet the design goals. The vertical height will be determined by the level of interlocks on the spectrometer magnet.

References

1. A. Van Ginneken and M. Awschalom, "High Energy Interactions in Large Targets," Fermilab, Batavia, IL (1975).

2. A. Van Ginneken, "CASIM. Program to Simulate Hadronic Cascades in Bulk Matter," Fermilab FN-272 (1975).

3. A.J. Stevens, "CASIM on VAX," AGS/ADD Technical Note 287 (1987).

4. G.R. Stevenson, "Dose Equivalent per Star in Hadron Cascade Calculation," CERN Divisional Report TIS-RP/173 (1986).

Figure Captions

1. Geometry of beam stop used in simulations. The stop has cylindrical symmetries about the beam axis. The maximum radius is 200 cm and depth of stop is 500 cm from the front face.

2. The log of the star densities given by CASIM for selected radii as a function of depth (cm). The material is heavy concrete.

3. The log of the star densities given by CASIM for selected depths as a function of radius (cm). The shielding material is heavy concrete.

4. Contours of star density given by CASIM for a stop made of heavy concrete.

5. Same as 2 but for iron.

6. Same as 3 but for iron.

7. Same as 4 but for iron.

8. Contours of star density for a thin target (1 cm radius) located in iron spherical of shell thickness 1-meter and radius 3-meters. The beam interactions in the target located at $Z = 300$ cm and $r = 0$.

9. Same as 8 but the target has radius of 30 cm.

CROSS SECTI[illegible] OF GEOMETRY FOR CONSTANT Y= 0.00 CM
ROM X= -[illegible] TO X= 200.00 CM (VERTICAL) AND
ROM Z= [illegible] O Z= 700.00 CM (HORIZONTAL)

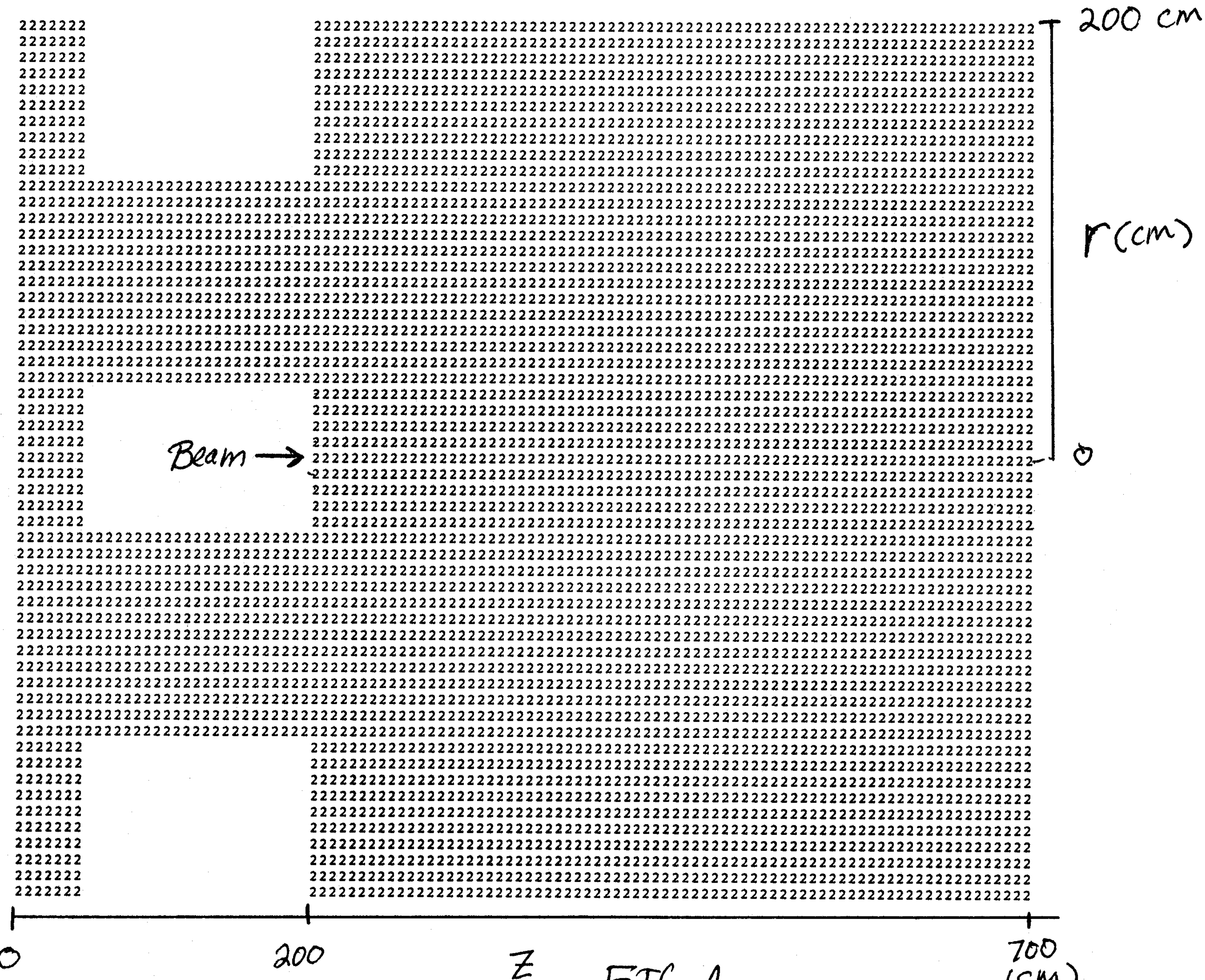
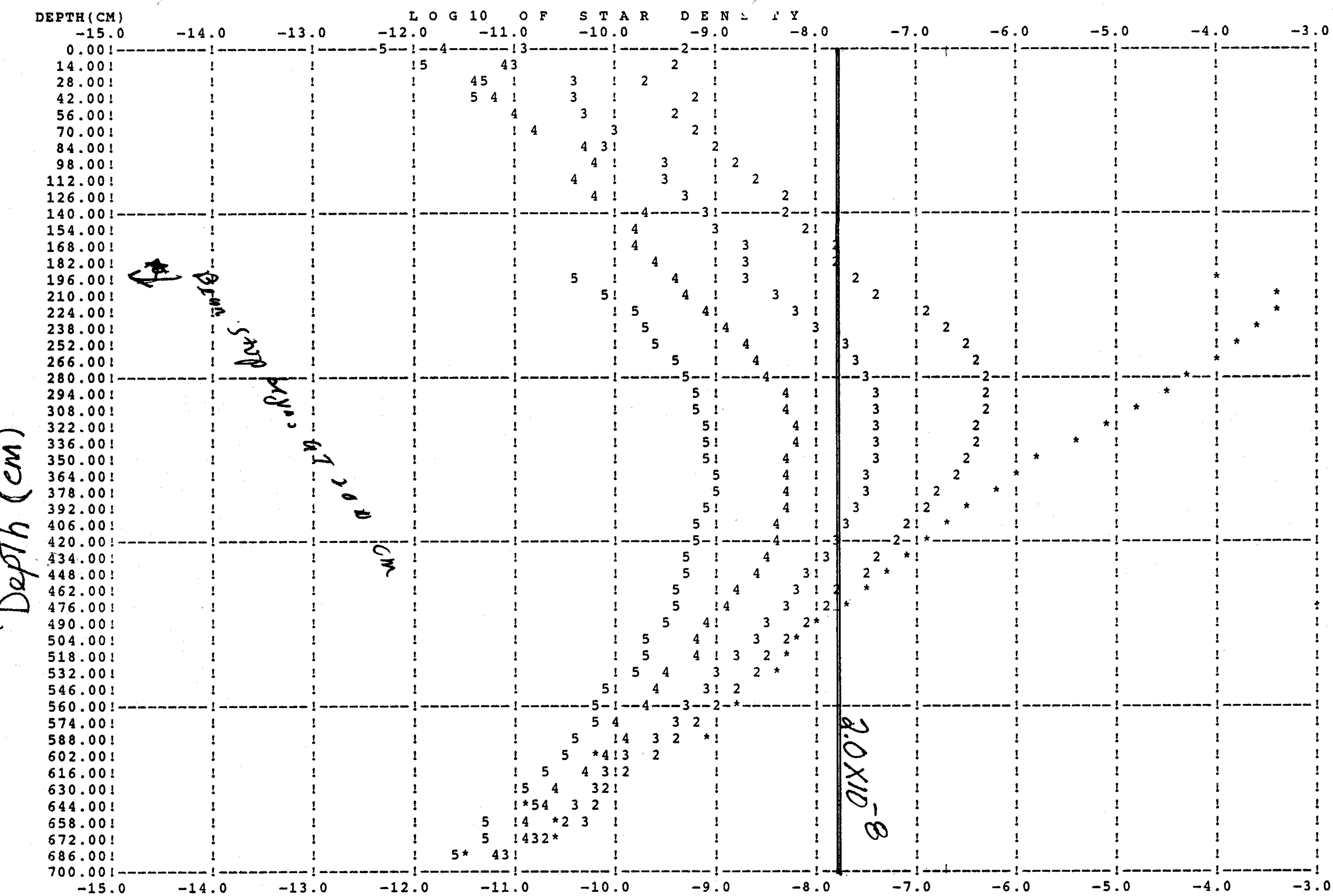


FIG. 1

PLOT OF LOG STAR DENSITY(STARS/CM3*INC.PTCLE)

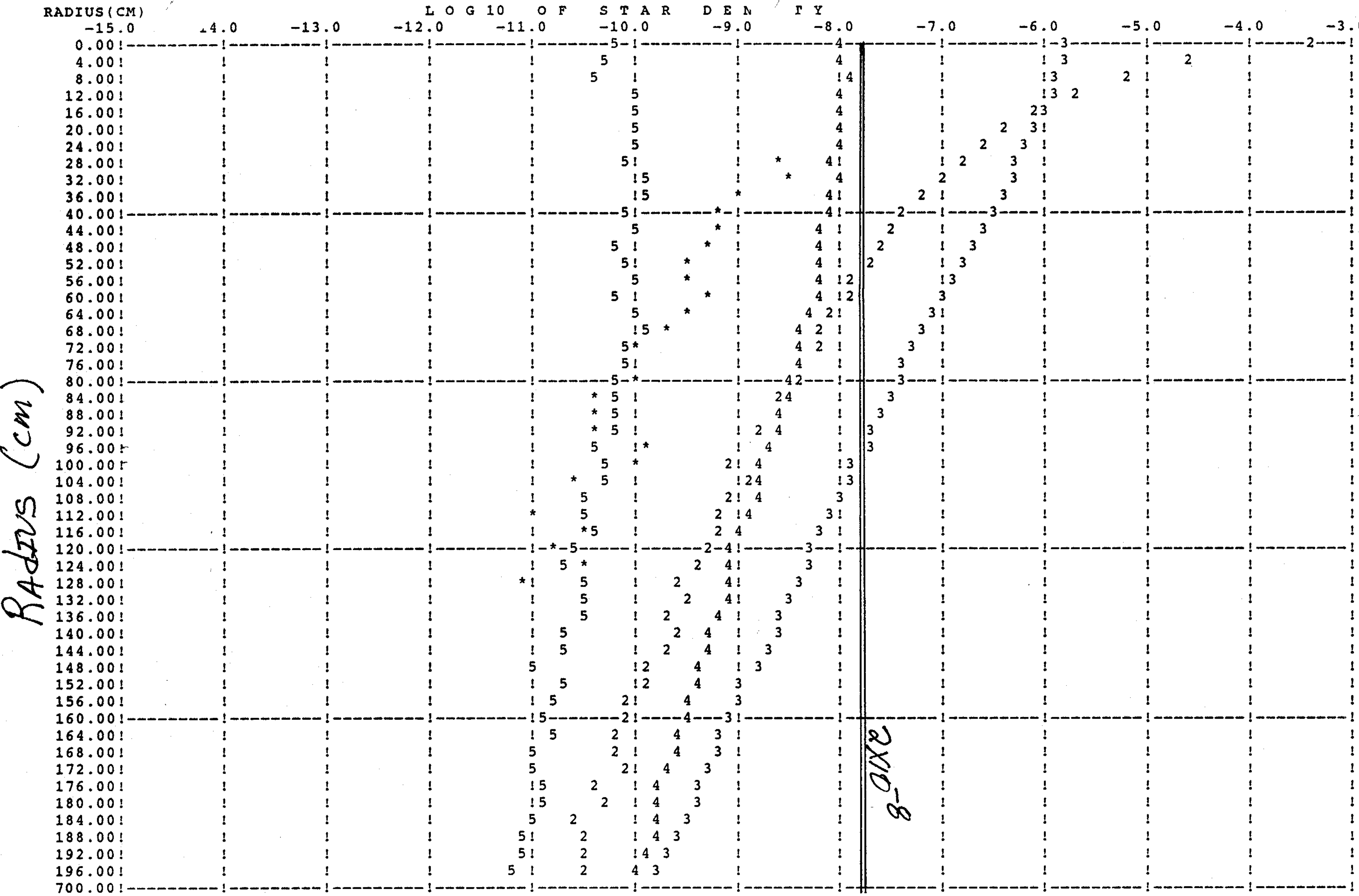


CURVES: *,2,3,4,5 ARE: R= 0.00 40.00 80.00 120.00 160.00 CM.
ALL GIVEN VALUES OF R AND Z ARE FOR THE SMALLER VALUES OF THE CORRESPONDING BINS.

LOG(Star Density)

FIG. 2

PLOT OF LOG STAR DENSITY(STARS/CM3*INC.PTCLE)

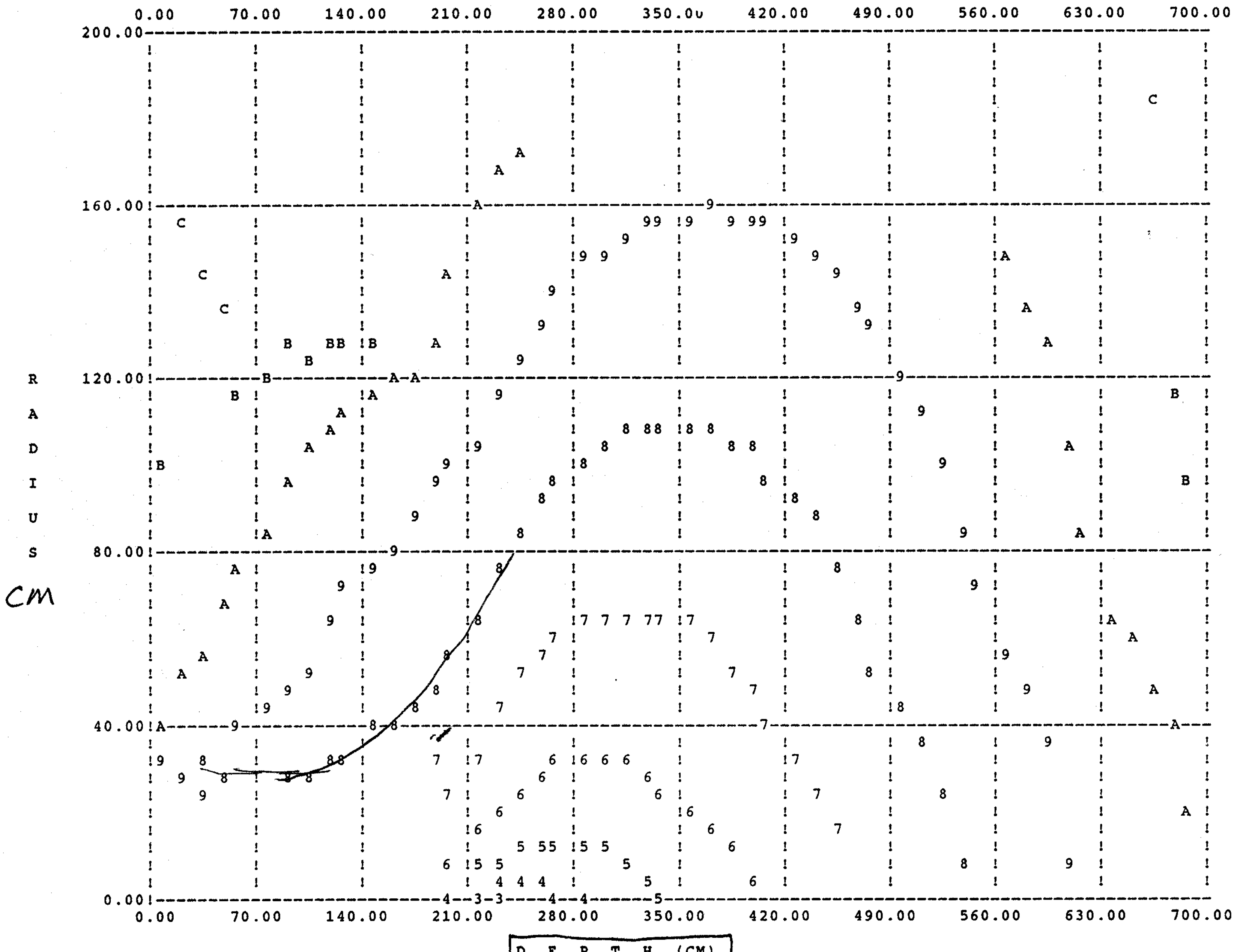


CURVES: *,2,3,4,5 ARE: Z= 70.00 210.00 350.00 490.00 630.00 CM.
ALL GIVEN VALUES OF R AND Z ARE FOR THE SMALLER VALUES OF THE CORRESPONDING BINS.

Log (Star Density)

FIG. 3

CONTOURS OF [E]QUAL STAR DENSITY (STARS/CM3*INC.PTCLE)
CONTOURS AR[E SHOW]N FOR INTEGRAL POWERS OF 10



R-LABELS REFER TO SMALLER VALUES OF CORRESPONDING BINS
LEGEND : NUMERICAL SYMBOLS REFER TO THE NEGATIVE POWER OF 10 OF THE STAR(ENERGY) DENSITY E.G., 5 REFERS TO THE 10**-5 CONTOUR
OTHER POWERS OF 10(SYMBOLS) :-10(A),-11(B),-12(C),-13(D),-14(E),-15(F),-16(G),-17(H),-18(I),-19(J)
1(Z),2(Y),3(X),4(W),5(V),6(U),7(T),8(S),9(R),10(Q)

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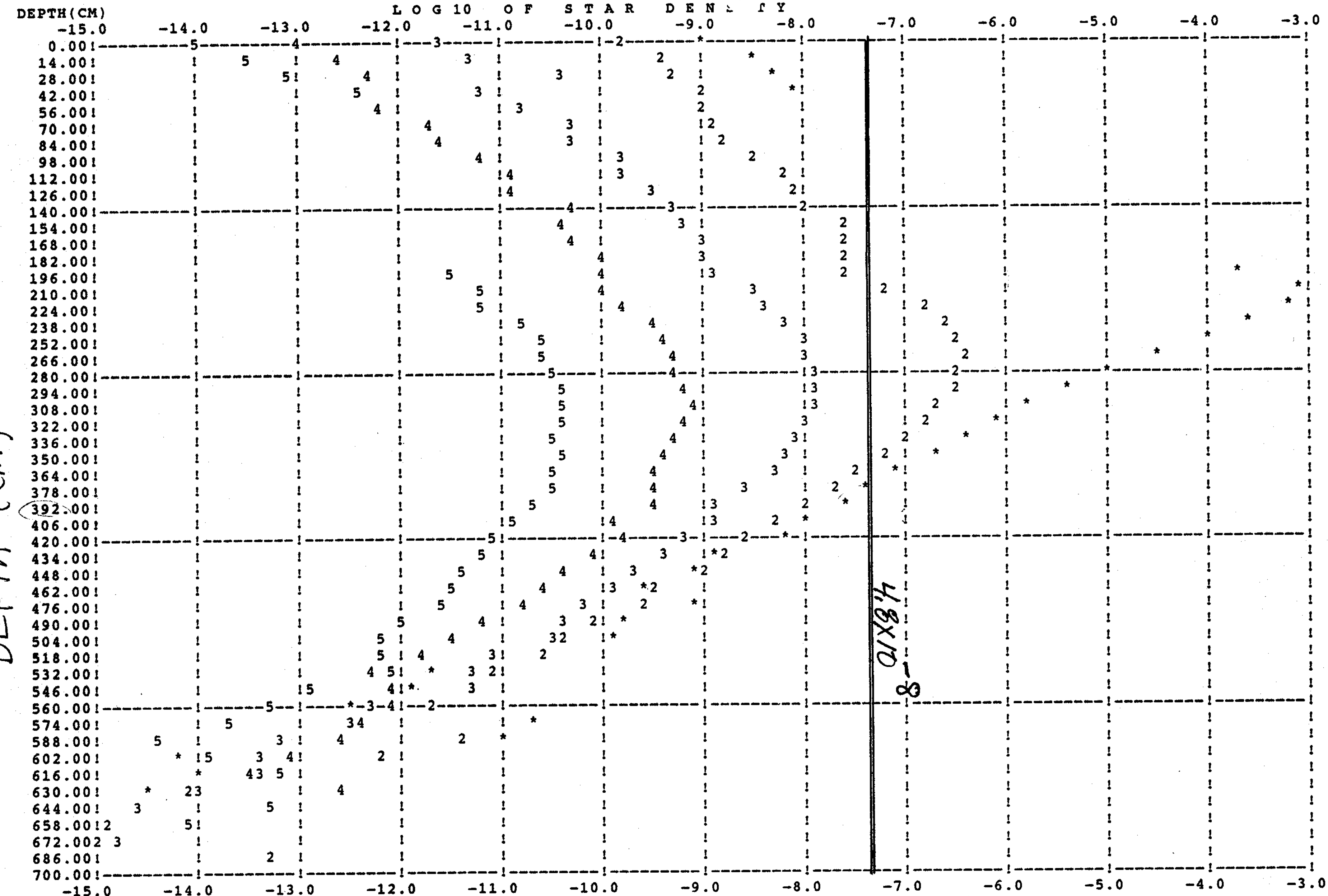
FIG. 4

Accounting information:

PLOT OF LOG DENSITY(STARS/CM3*INC.PTCLE)



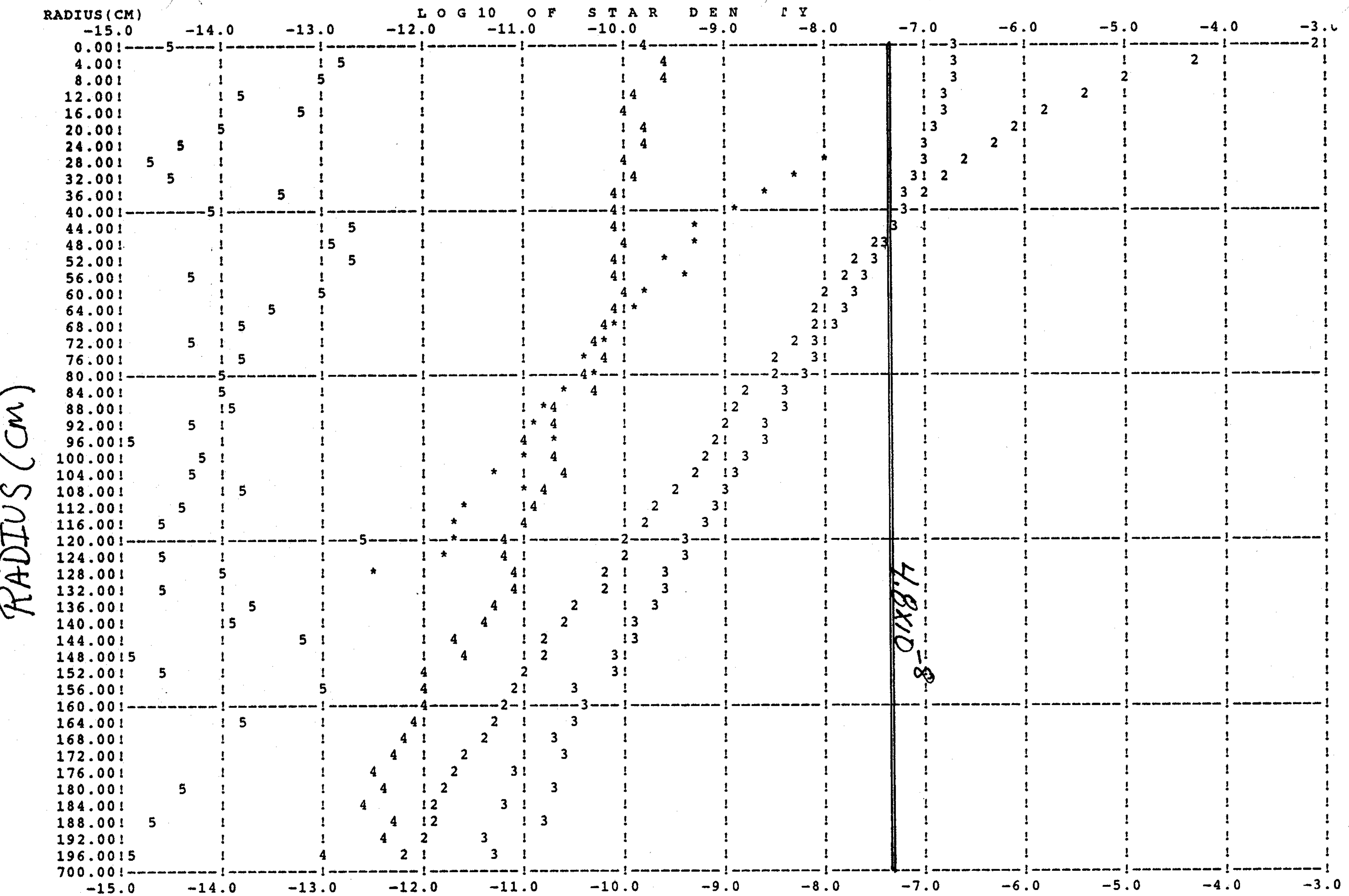
CURVES: *,2,3,4,5 ARE: R= 0.00 40.00 80.00 120.00 160.00 CM.

ALL GIVEN VALUES OF R AND Z ARE FOR THE SMALLER VALUES OF THE CORRESPONDING BINS.

Log(Star density)

FIG. 5

PLOT OF LOG TAR DENSITY(STARS/CM3*INC.PTCLE)

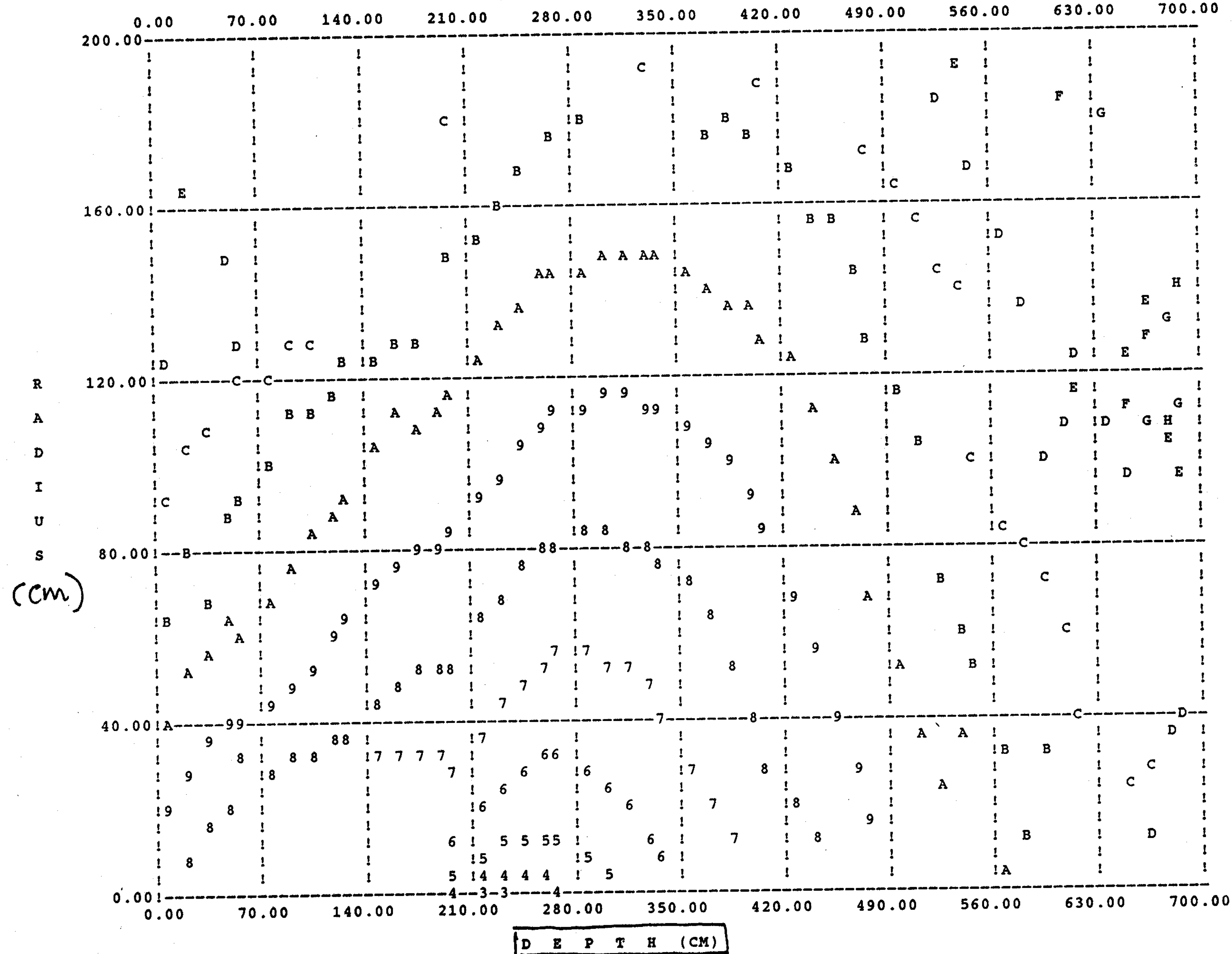


CURVES: *,2,3,4,5 ARE: Z= 70.00 210.00 350.00 490.00 630.00 CM.
ALL GIVEN VALUES OF R AND Z ARE FOR THE SMALLER VALUES OF THE CORRESPONDING BINS.

Log (star density)

Fig. 6

CONTOURS OF IAL STAR DENSITY (STARS/CM3*INC.PTCLE)
CONTOURS ARE N FOR INTEGRAL POWERS OF 10



R-LABELS REFER TO SMALLER VALUES OF CORRESPONDING BINS
LEGEND : NUMERICAL SYMBOLS REFER TO THE NEGATIVE POWER OF 10 OF THE STAR(ENERGY) DENSITY E.G., 5 REFERS TO THE 10**-5 CONTOUR
OTHER POWERS OF 10(SYMBOLS) :-10(A),-11(B),-12(C),-13(D),-14(E),-15(F),-16(G),-17(H),-18(I),-19(J)
1(Z),2(Y),3(X),4(W),5(V),6(U),7(T),8(S),9(R),10(Q)

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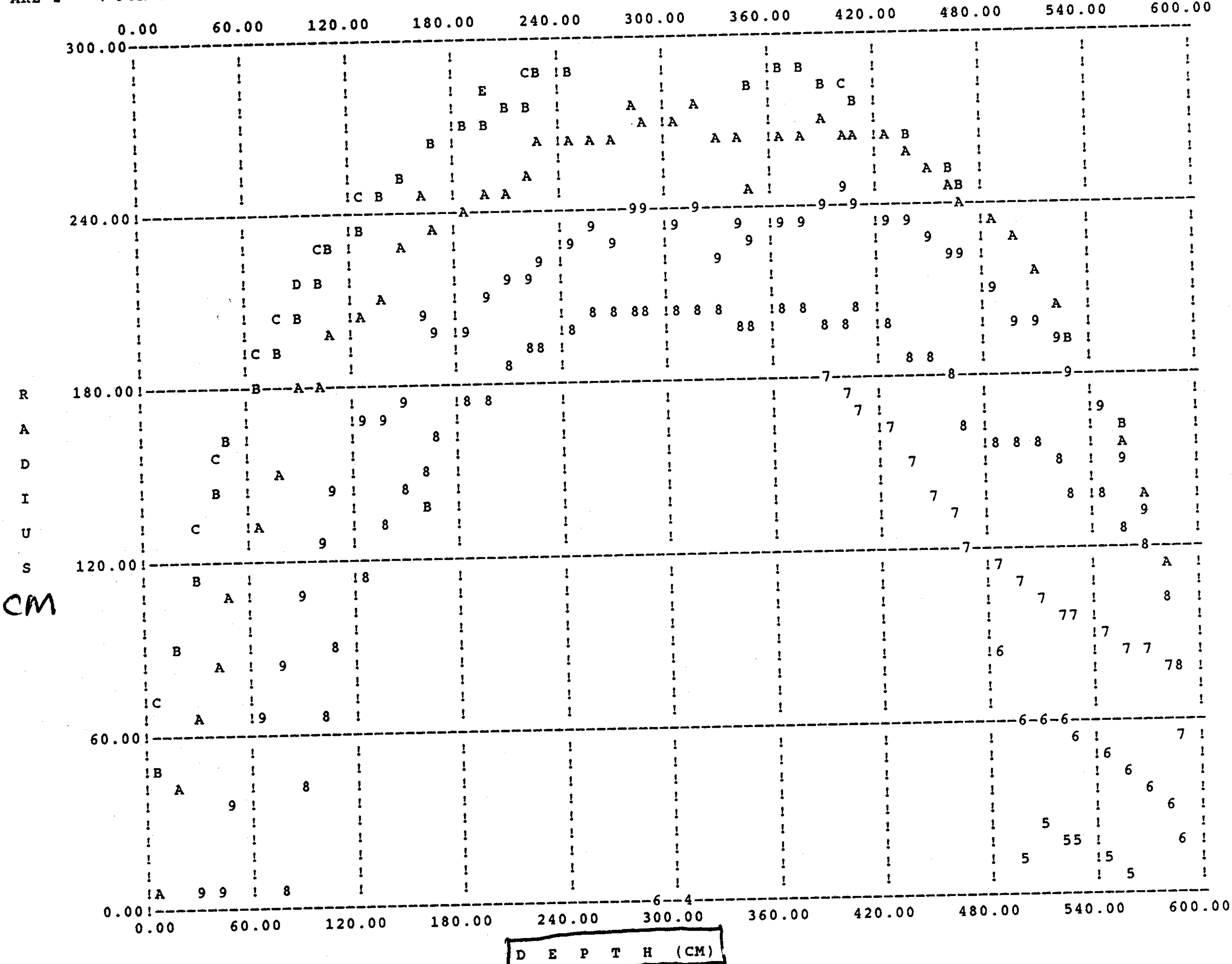
FIG. 7

Accounting information:

CONTOURS OF ... STAR DENSITY (STARS/CM3*INC.PTCLE)
CONTOURS ARE ... FOR INTEGRAL POWERS OF 10



R-LABELS REFER TO SMALLER VALUES OF CORRESPONDING BINS
LEGEND : NUMERICAL SYMBOLS REFER TO THE NEGATIVE POWER OF 10 OF THE STAR(ENERGY) DENSITY E.G., 5 REFERS TO THE 10**-5 CONTOUR
OTHER POWERS OF 10(SYMBOLS) :-10(A),-11(B),-12(C),-13(D),-14(E),-15(F),-16(G),-17(H),-18(I),-19(J)
1(Z),2(Y),3(X),4(W),5(V),6(U),7(T),8(S),9(R),10(Q)

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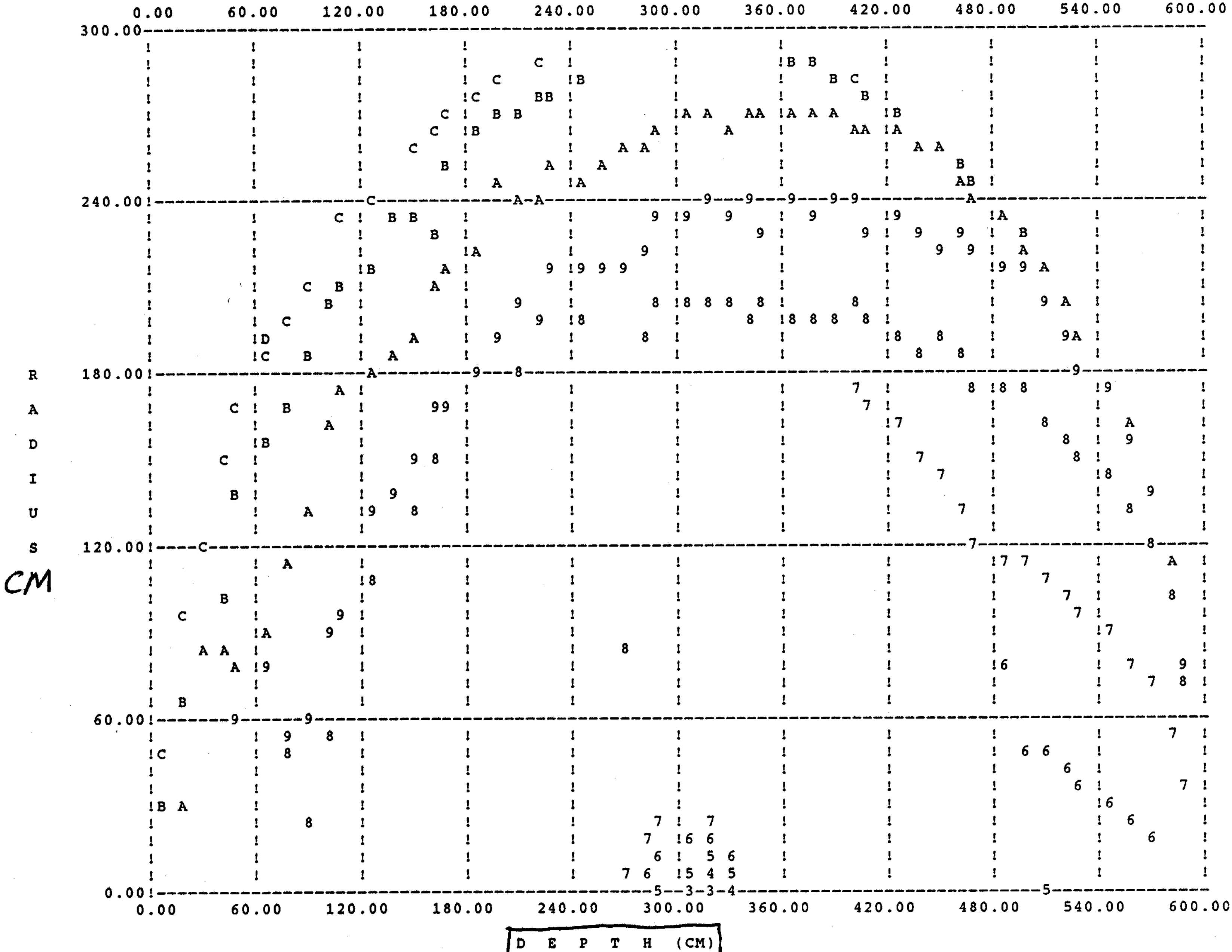
FIG. 8

Accounting information:

CONTOURS OF ... STAR DENSITY (STARS/CM3*INC.PTCLE)
CONTOURS ARE ... FOR INTEGRAL POWERS OF 10



R-LABELS REFER TO SMALLER VALUES OF CORRESPONDING BINS
LEGEND : NUMERICAL SYMBOLS REFER TO THE NEGATIVE POWER OF 10 OF THE STAR(ENERGY) DENSITY E.G., 5 REFERS TO THE 10**-5 CONTOUR
OTHER POWERS OF 10(SYMBOLS) :-10(A),-11(B),-12(C),-13(D),-14(E),-15(F),-16(G),-17(H),-18(I),-19(J)
1(Z),2(Y),3(X),4(W),5(V),6(U),7(T),8(S),9(R),10(Q)

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FIG. 9

Accounting information: