Chapter 14

Design of Flexible Airport Pavements

AC 150/5320-6D

AIRCRAFT CONSIDERATIONS.

a. Load.

maximum anticipated takeoff weight of the aircraft. The design procedure assumes 95 percent of the gross weight is carried by the main landing gears and 5 percent is carried by the nose gear.

b. Landing Gear Type and Geometry.

(1)Single Gear Aircraft.
(2) Dual Gear Aircraft.
(3) Dual Tandem Gear Aircraft.
(4) Wide Body Aircraft.

C. Tire Pressure.

Tire pressure varies between 75 and 200 PSI (516 to 1 380 kPa) depending on gear configuration and gross weight.

d. Traffic Volume.

Forecasts of annual departures by aircraft type are needed for pavement design. Information on aircraft operations is available from Airport Master Plans, Terminal Area Forecasts,

DETERMINATION OF DESIGN AIRCRAFT.

- The forecast of annual departures by aircraft type will result in a list of a number of different aircraft.
- The design aircraft should be selected on the basis of the one requiring the greatest pavement thickness.
- Each aircraft type in the forecast should be checked to determine the pavement thickness required by using the appropriate design curve with the forecast number of annual departures for that aircraft.
- The aircraft type which produces the greatest pavement thickness is the design aircraft.
- The design aircraft is not necessarily the heaviest aircraft in the forecast.

DETERMINATION OF EQUIVALENT ANNUAL DEPARTURES BY THE DESIGN AIRCRAFT.

a. **Conversions.** Since the traffic forecast is a mixture of a variety of aircraft having different landing gear types and different weights, the effects of all traffic must be accounted for in terms of the design aircraft.

First,

all aircraft must be converted to the same landing gear type as the design aircraft.

To Convert From	To	Multiply Departures by
single wheel	dual wheel	0.8
single wheel	dual tandem	0.5
dual wheel	dual tandem	0.6
double dual tandem	dual tandem	1.0
dual tandem	single wheel	2.0
dual tandem	dual wheel	1.7
dual wheel	single wheel	1.3
double dual tandem	dual wheel	1.7

Secondly,

after the aircraft have been grouped into the same landing gear configuration, the conversion to equivalent annual departures of the design aircraft should be determined by the following formula:

$$\log R_1 = \log R_2 \times \left(\frac{W_2}{W_1}\right)^{\frac{1}{2}}$$

where:

R_1 = equivalent annual departures by the design aircraft

R_2 = annual departures expressed in design aircraft landing gear

W_1 = wheel load of the design aircraft

W_2 = wheel load of the aircraft in question

- **For this computation 95 percent of the gross weight of the aircraft is assumed to be carried by the main landing gears.**

- **Wide body aircraft require special attention in this calculation. Since wide body aircraft have significantly different landing gear assembly spacings more than other aircraft, special considerations are needed to maintain the relative effects. This is done by treating each wide body as a 300,000-pound (136 100 kg) dual tandem aircraft when computing equivalent annual departures. This should be done in every instance even when the design aircraft is a wide body.**

- **After the equivalent annual departures are determined, the design should proceed using the appropriate design curve for the design aircraft.**

- **For example if a wide body is the design aircraft, all equivalent departures should be calculated as described above; then the design curve for the wide body should be used with the calculated equivalent annual departures.**

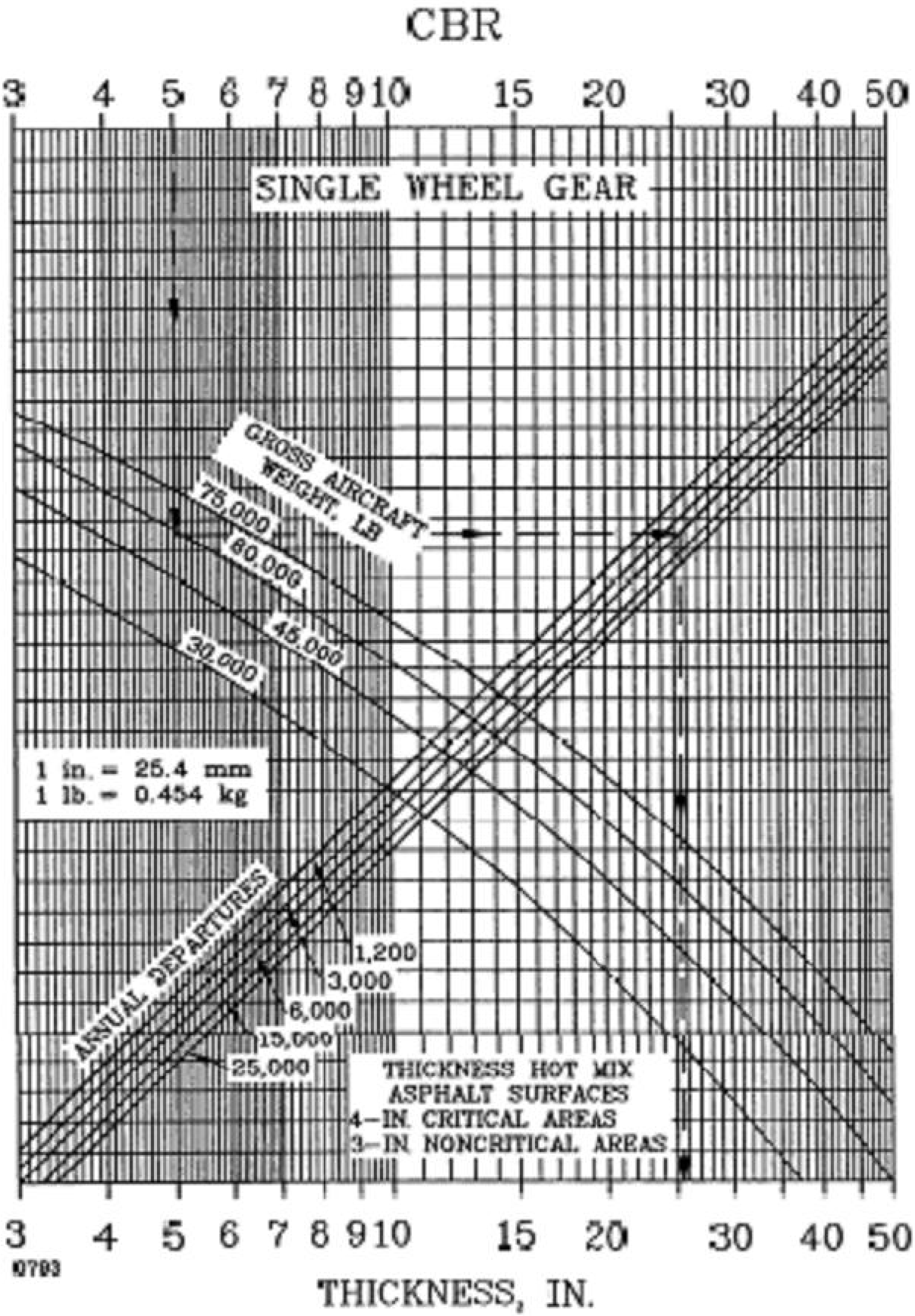


FIGURE 3-2 FLEXIBLE PAVEMENT DESIGN CURVES, SINGLE WHEEL GEAR

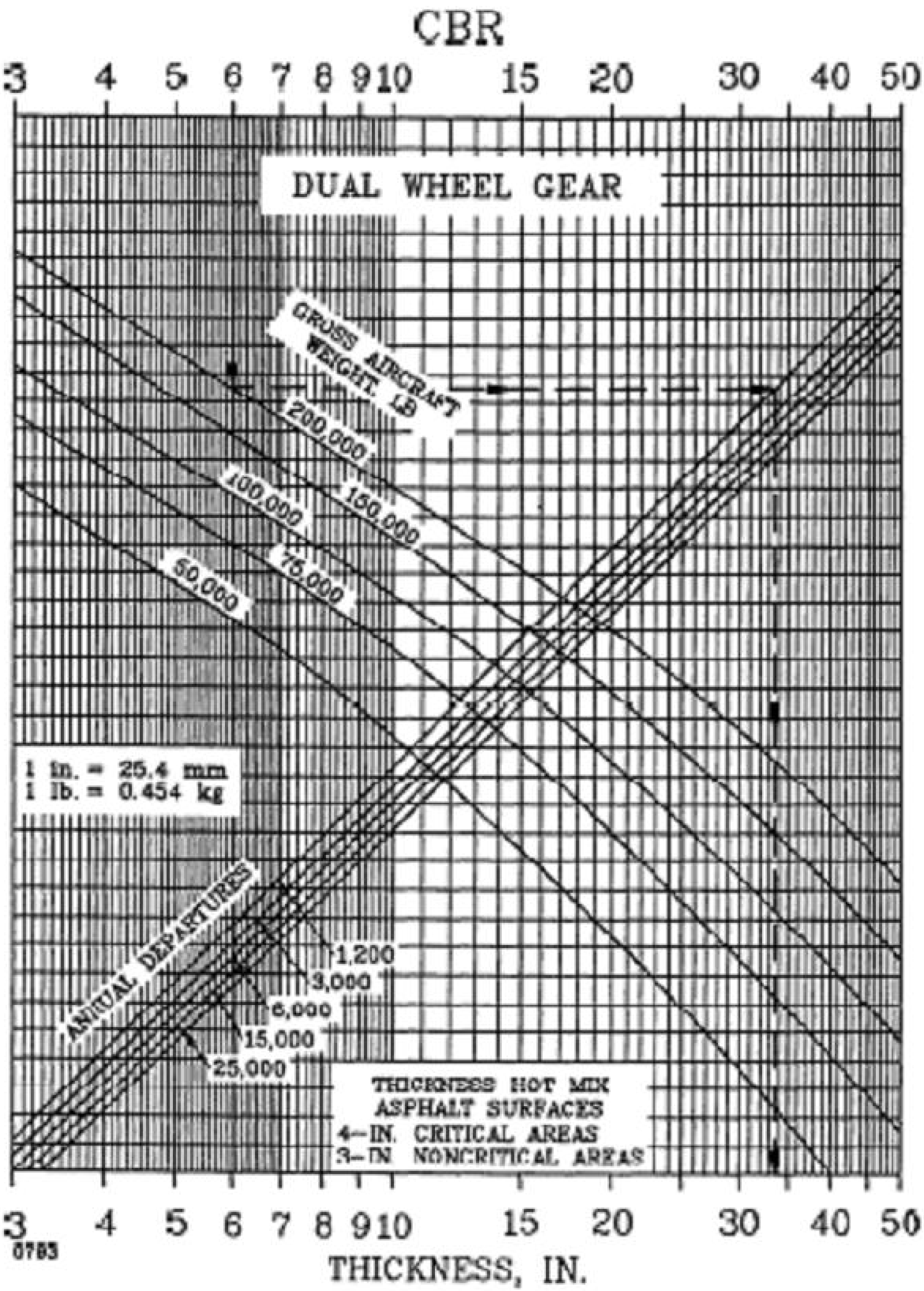


FIGURE 3-3 FLEXIBLE PAVEMENT DESIGN CURVES, DUAL WHEEL GEAR

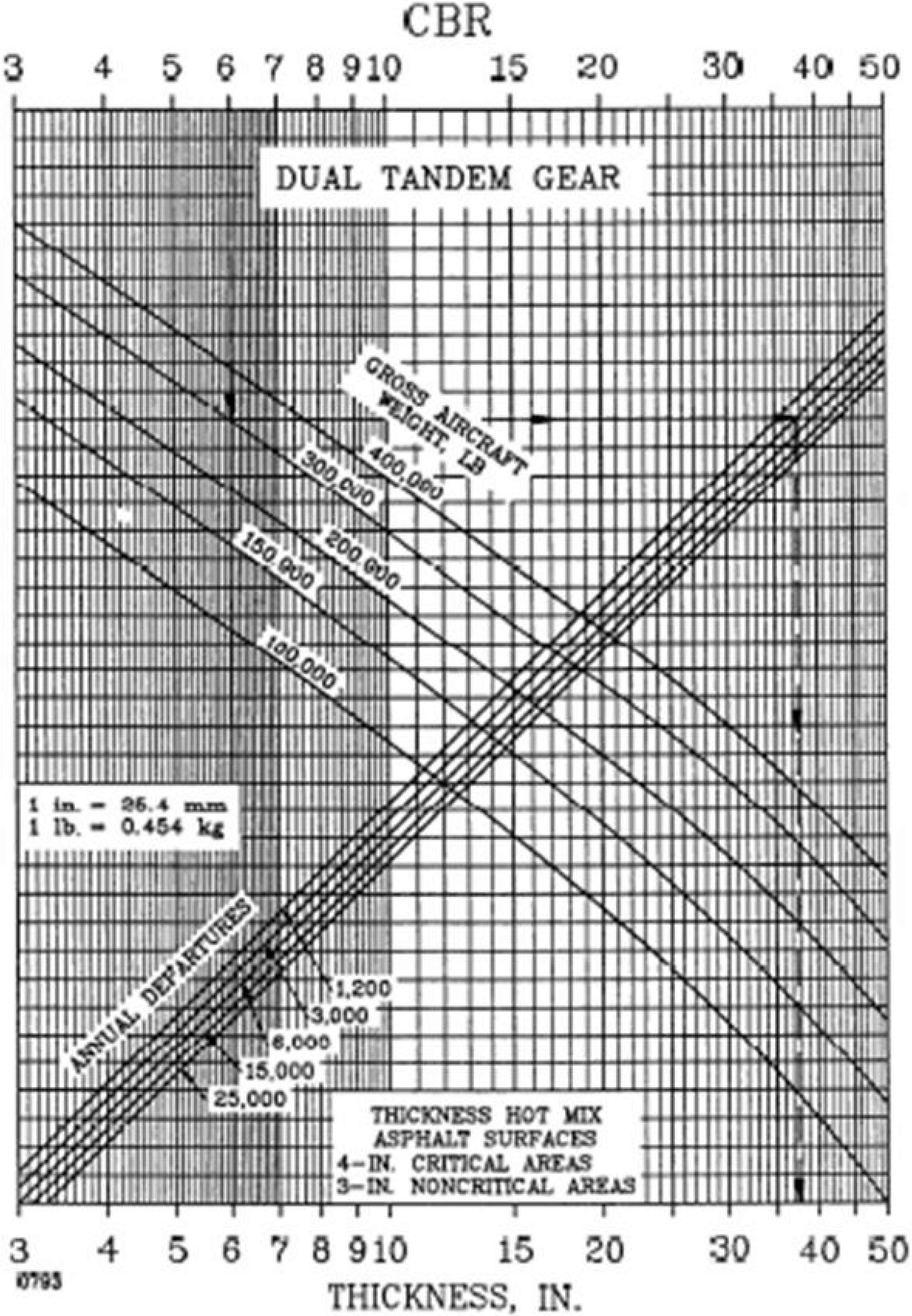


FIGURE 3-4 FLEXIBLE PAVEMENT DESIGN CURVES, DUAL TANDEM GEAR

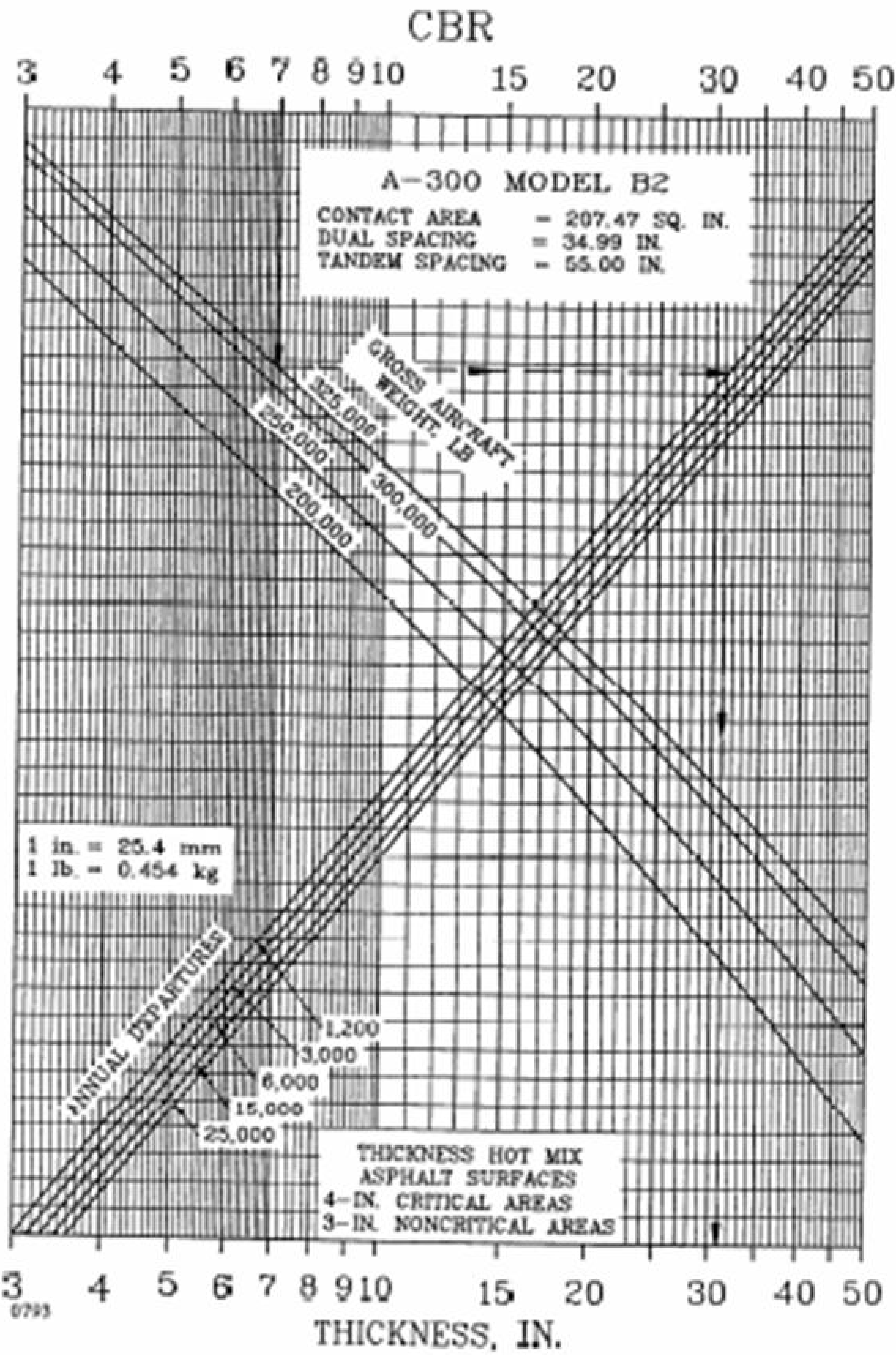


FIGURE 3-5 FLEXIBLE PAVEMENT DESIGN CURVES, A-300 MODEL B2

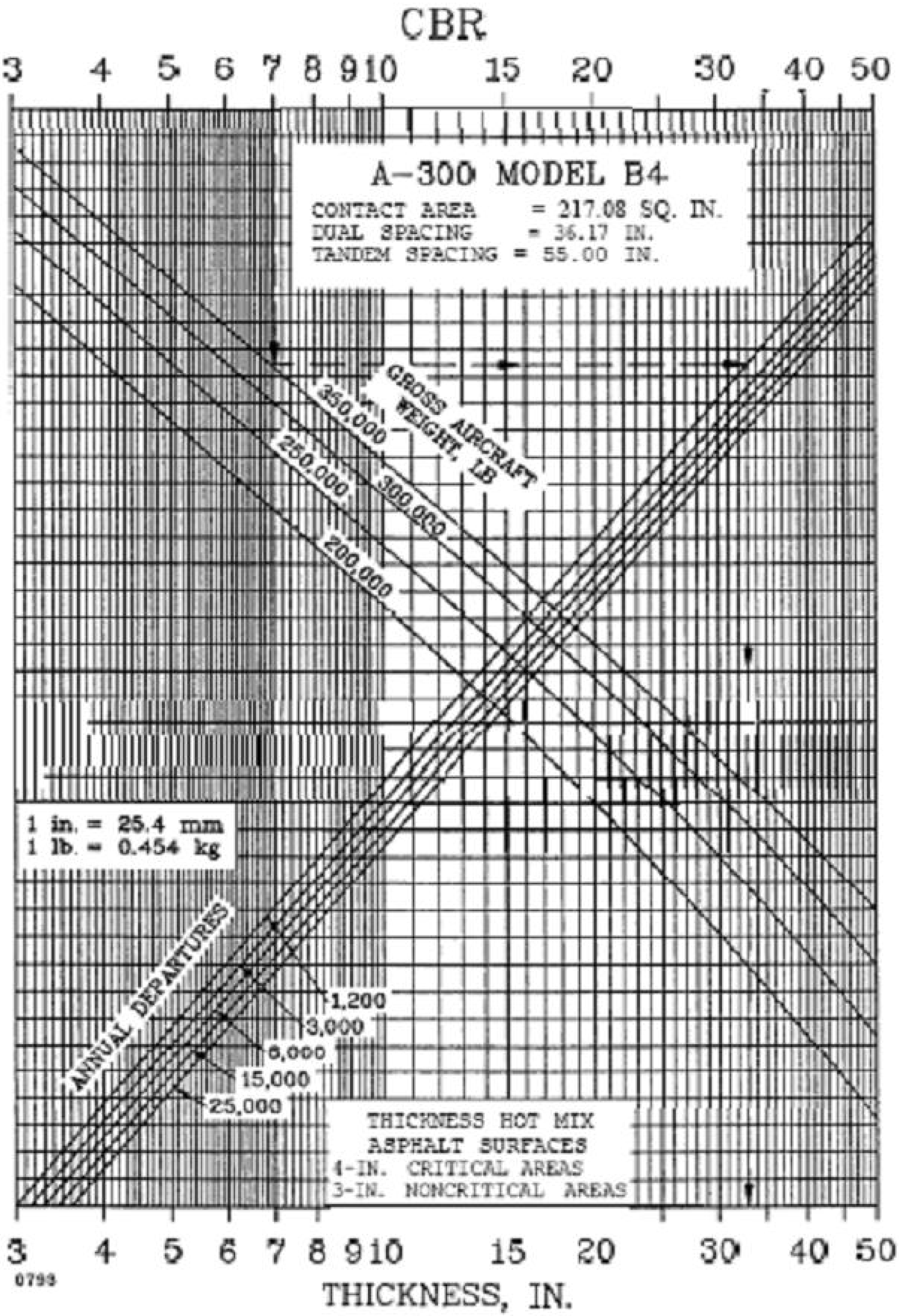


FIGURE 3-6 FLEXIBLE PAVEMENT DESIGN CURVES, A-300 MODEL B4

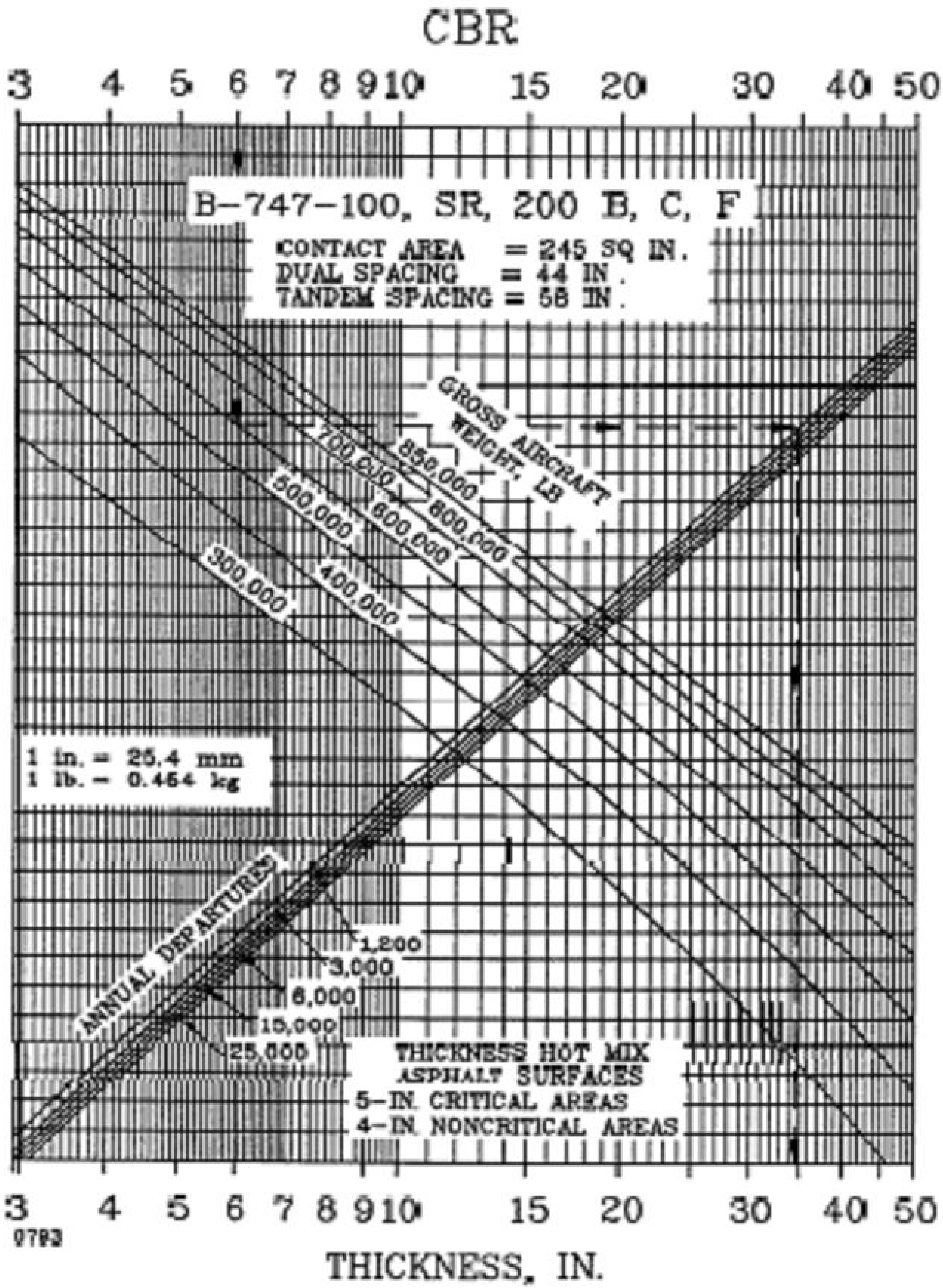


FIGURE 3-7 FLEXIBLE PAVEMENT DESIGN CURVES, B-747-100,SR, 200 B, C, F

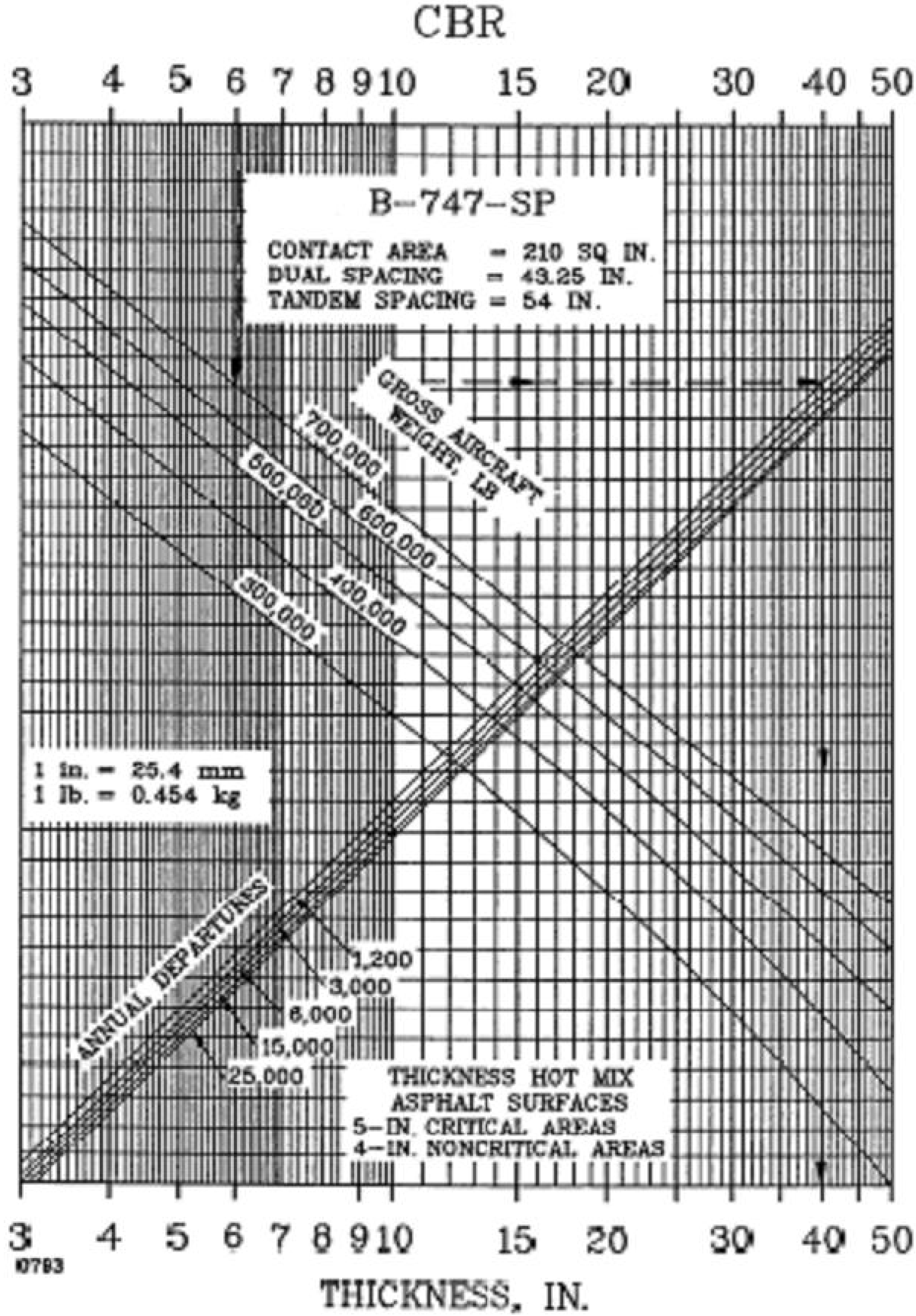


FIGURE 3-8 FLEXIBLE PAVEMENT DESIGN CURVES, B-747-SP

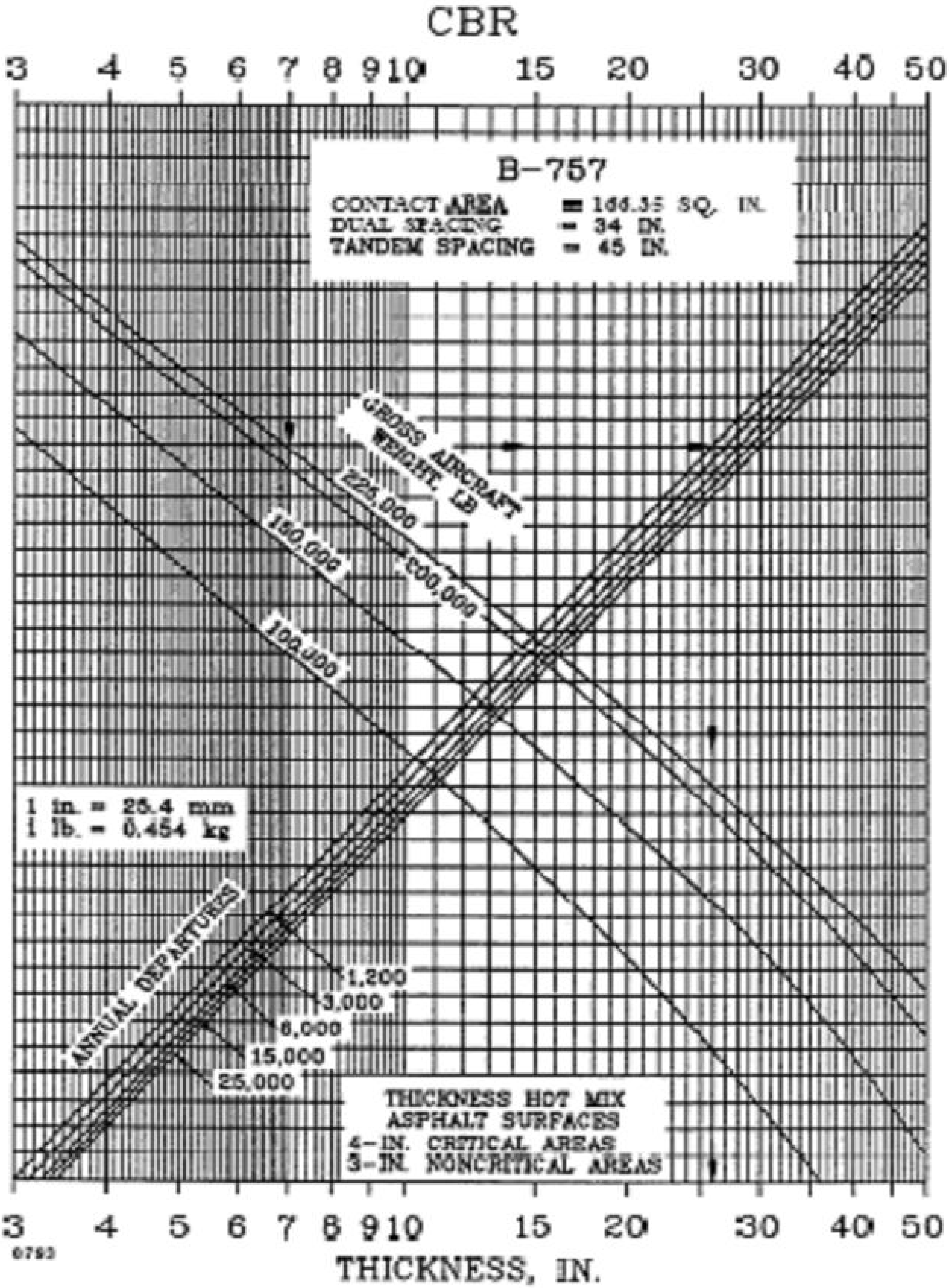


FIGURE 3-9 FLEXIBLE PAVEMENT DESIGN CURVES, B-757

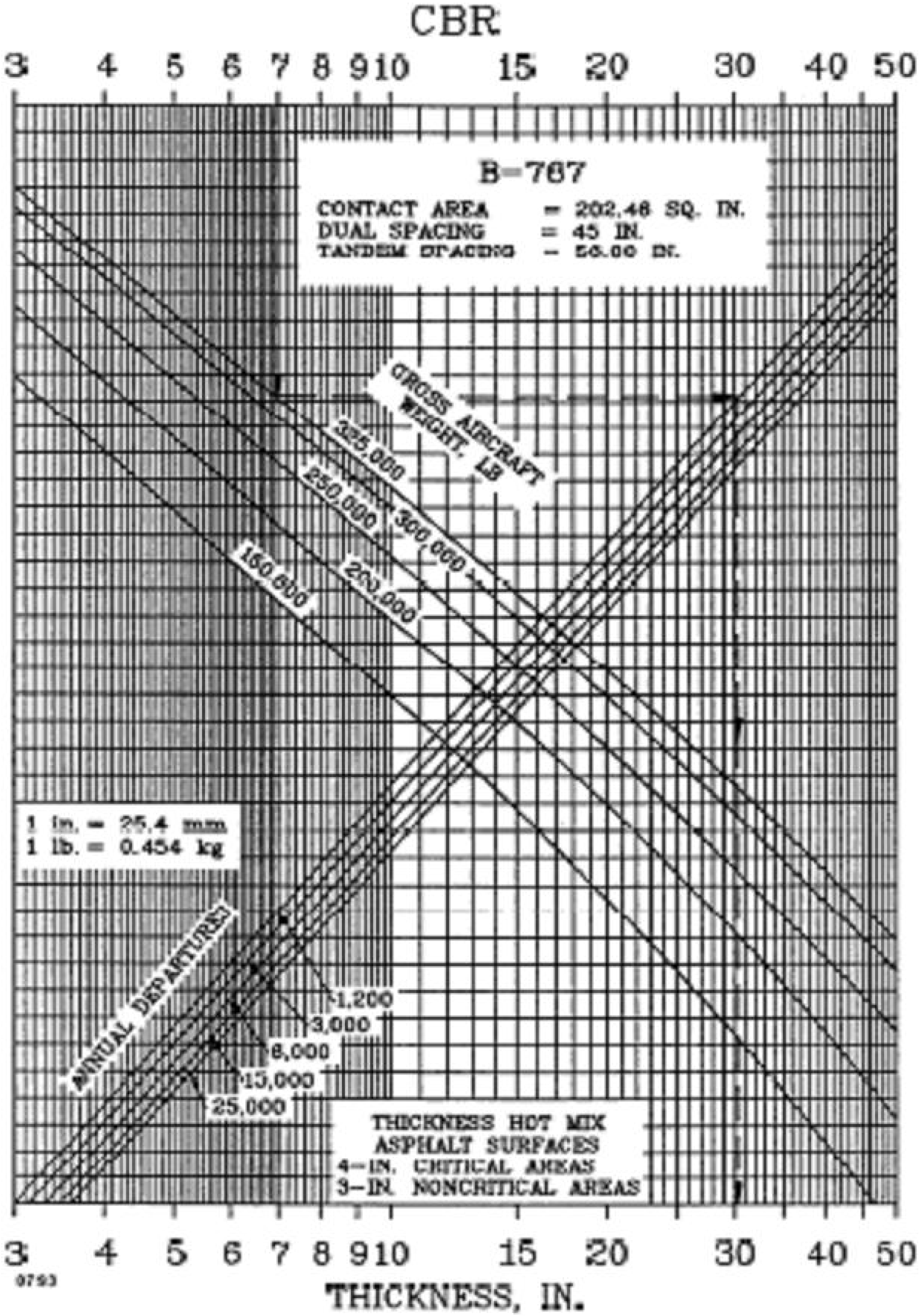


FIGURE 3-10 FLEXIBLE PAVEMENT DESIGN CURVES, B-767

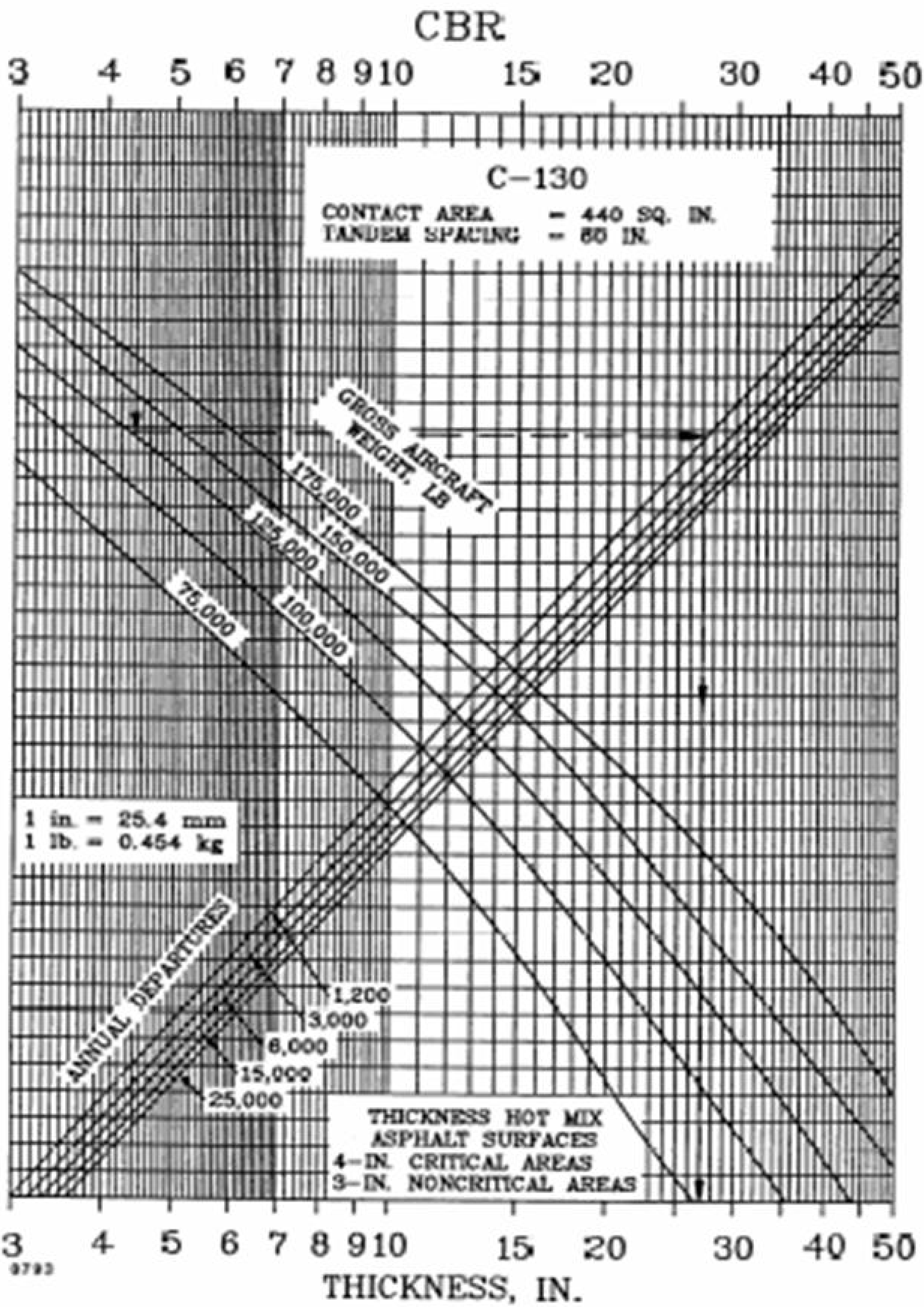


FIGURE 3-11 FLEXIBLE PAVEMENT DESIGN CURVES, C-130

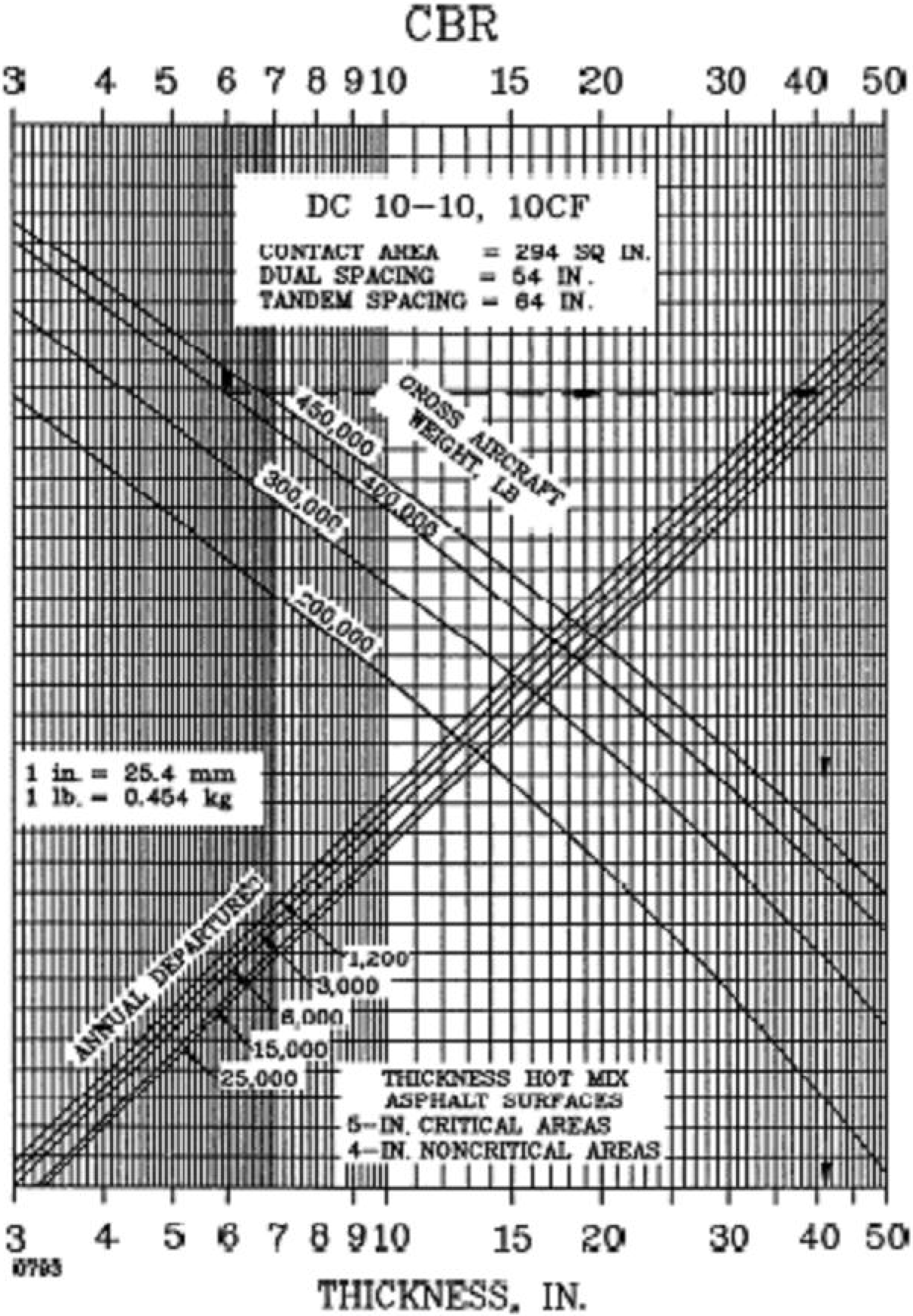


FIGURE 3-12 FLEXIBLE PAVEMENT DESIGN CURVES, DC 10-10, 10CF

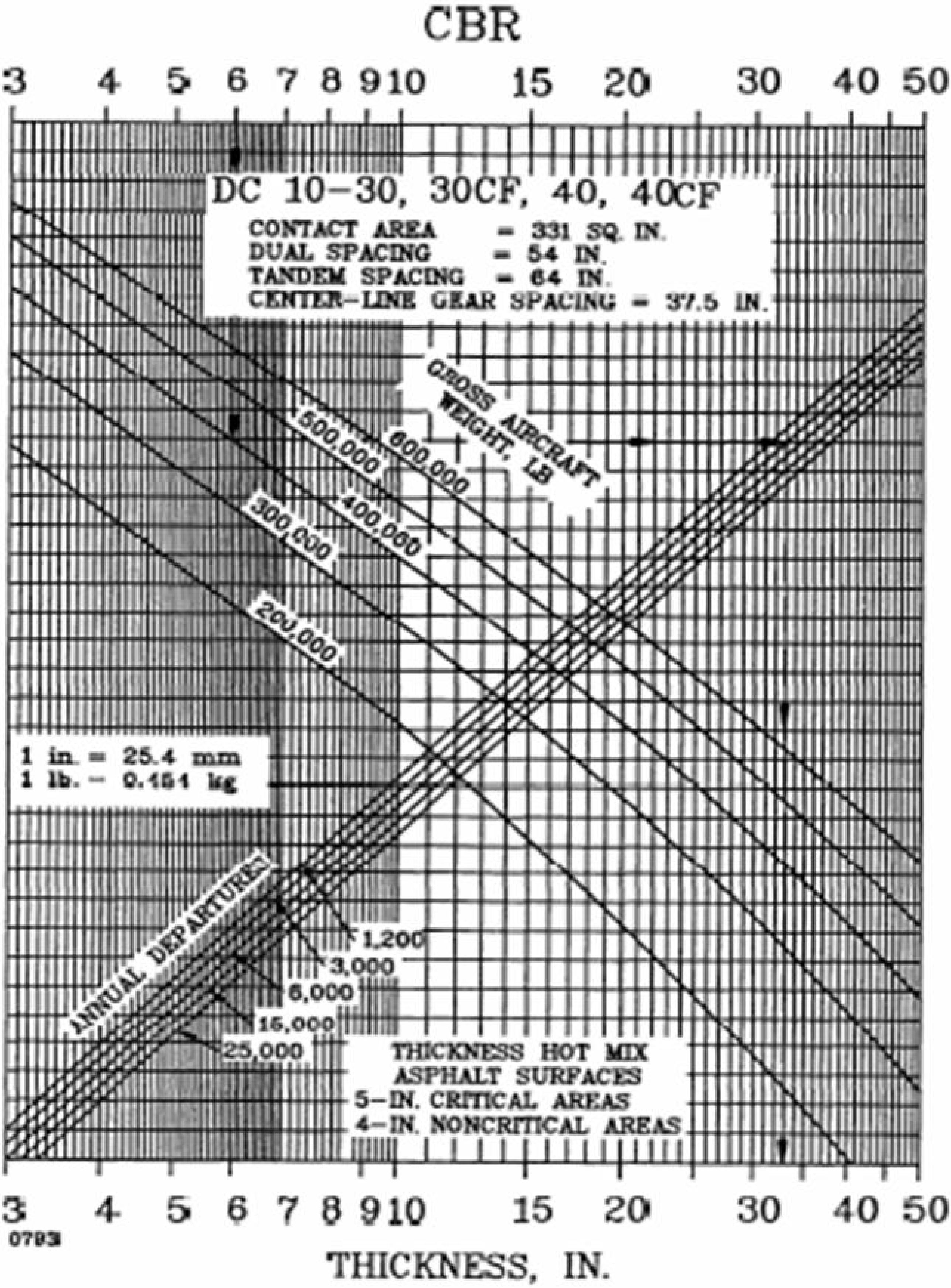


FIGURE 3-13 FLEXIBLE PAVEMENT DESIGN CURVES, DC 10-30, 30CF, 40, 40CF

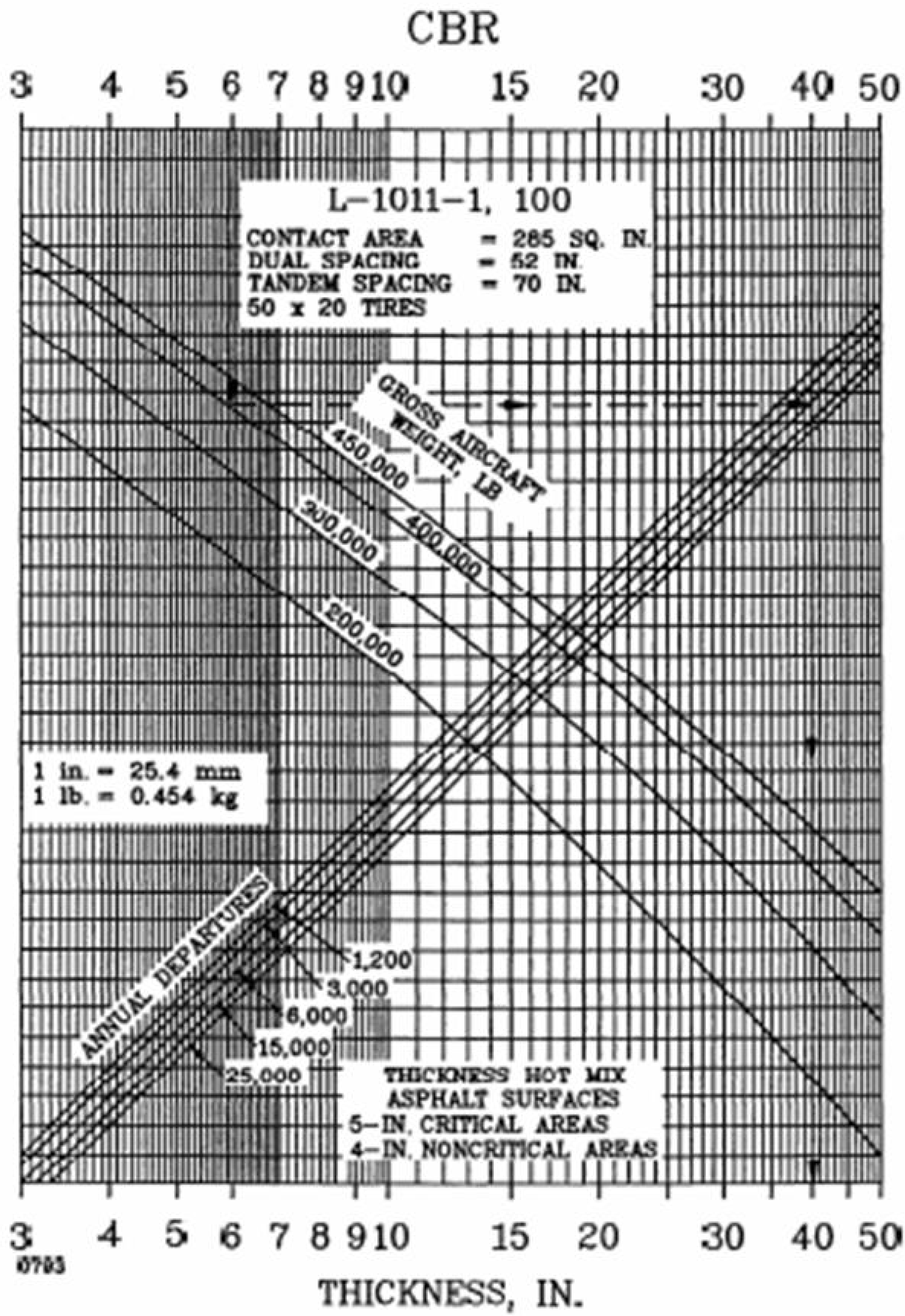


FIGURE 3-14 FLEXIBLE PAVEMENT DESIGN CURVES, L-1011-1,100

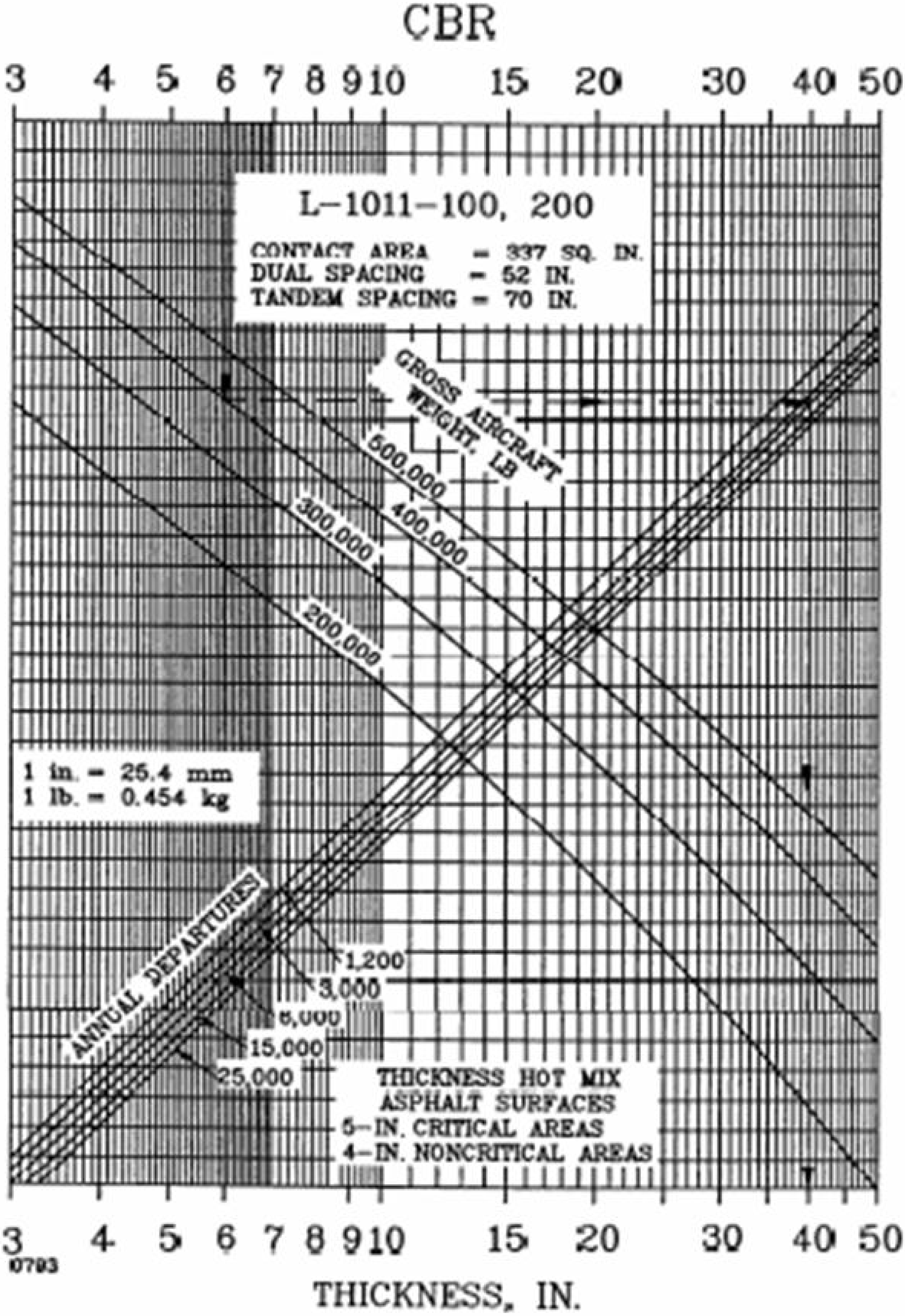


FIGURE 3-15 FLEXIBLE PAVEMENT DESIGN CURVES, L-1011, -100,200

Example

Aircraft	Gear Type	Average Annual Departures	Maximum Takeoff Weight lbs.	(kg)
727-100	dual	3,760	160,000	(72600)
727-200	dual	9,080	190,500	(86500)
707-320B	dual tandem	3,050	327,000	(148 500)
DC-g-30	dual	5,800	108,000	(49000)
cv-880	dual tandem	400	184,500	(83 948)
737-200	dual	2,650	115,500	(52 440)
L-101 1-100	dual tandem	1,710	450,000	(204 120)
747-100	double dual tandem	85	700,000	(3 17 800)

(1) **Determine Design Aircraft.** A pavement thickness is determined for each aircraft in the forecast using the appropriate design curves. The pavement input data, CBR, K value, flexural strength, etc., should be the same for all aircraft. Aircraft weights and departure levels must correspond to the particular aircraft in the forecast. In this example the 727-200 requires the greatest pavement thickness and is thus the design aircraft.

(2) **Group Forecast Traffic into Landing Gear of Design Aircraft.** In this example the design aircraft is equipped with a dual wheel landing gear so all traffic must be grouped into the dual wheel configuration.

(3) **Convert Aircraft to Equivalent Annual Departures of the Design Aircraft.** After the aircraft mixture has been grouped into a common landing gear configuration, the equivalent annual departures of the design aircraft can be calculated.

Aircraft	Equi. Dual Gear Departs.	Wheel Load lbs.	Wheel Load (kg)	Wheel Load of Design Aircraft lbs.	Wheel Load of Design Aircraft (kg)	Equi. Annual Departs Design Aircraft
727-100	3,760	38,000	(17 240)	45,240	(20 520)	1,891
727-200	9,080	45,240	(20 520)	45,240	(20 520)	9,080
707-320B	5,185	38,830	(17 610)	45,240	(20 520)	2,764
DC-g-30	5,800	25,650	(11 630)	45,240	(20 520)	682
cv-880	680	21,910	(9 940)	45,240	(20 520)	94
737-200	2,650	27,430	(12,440)	45,240	(20 520)	463
747	145	35,625'	(16 160)	45,240	(20520)	83
L-101 1	2,907	35,625'	(16 160)	45,240	(20,520)	1,184
						Total = 16,241

'Wheel loads for wide body aircraft will be taken as the wheel load for a 300,000-pound (136 100 kg) aircraft for equivalent annual departure calculations.

(4) **Final Result.** For this example the pavement would be designed for 16,000 annual departures of a dual wheel aircraft weighing 190,500 pounds (86 500 kg). The design should, however, provide for the heaviest aircraft in the traffic mixture, B747-100, when considering depth of compaction, thickness of asphalt surface, drainage structures, etc.

TABLE 3-5. PAVEMENT THICKNESS FOR HIGH DEPARTURE LEVELS

Annual Departure Level	Percent of 25,000 Departure Thickness
50,000	104
100,000	108
150,000	110
200,000	112

Note:

TABLE 3-4. MINIMUM BASE COURSE THICKNESS

Design Aircraft	Design Load Range		Minimum Base Course Thickness	
	lbs.	(kg)	in.	(mm)
Single Wheel	30,000 - 50,000	(13600 - 22 700)	4	(100)
	50,000 - 75,000	(22700 - 34 000)	6	(150)
Dual Wheel	50,000 - 100,000	(22700 - 45 000)	6	(150)
	100,000 - 200,000	(45 000 - 90 700)	8	(200)
Dual Tandem	100,000 - 250,000	(45 000 - 113 400)	6	(150)
	250,000 - 400,000	(113400 - 181 000)	8	(200)
757 767	200,000 - 400,000	(90700 - 181000)	6	(150)
DC-10 L1011	400,000 - 600,000	(181 000 - 272000)	8	(200)
B-747	400,000 - 600,000	(181 000 - 272000)	6	(150)
	600,000 - 850,000	(272 000 - 385 700)	8	(200)
c-130	75,000 - 125,000	(34 000 - 56 700)	4	(100)
	125,000 - 175,000	(56700 - 79 400)	6	(150)

Note: The calculated base course thicknesses should be compared with the minimum base course thicknesses listed above. The greater thickness, calculated or minimum, should be specified in the design section.

TABLE 3-6. RECOMMENDED EQUIVALENCY FACTOR RANGES FOR HIGH QUALITY GRANULAR SUBBASE

Material	Equivalency Factor Range
P-208, Aggregate Base Course	1.0 - 1.5
P-209, Crushed Aggregate Base Course	1.2 - 1.8
P-2 I1, Lime Rock Base Course	1.0 - 1.5

TABLE 3-8. RECOMMENDED EQUIVALENCY FACTOR RANGES FOR GRANULAR BASE

Material	Equivalency Factor Range
P-208, Aggregate Base Course	1.0'
P-21 1, Lime Rock Base Course	1.0

'Substitution of P-208 for P-209 is permissible only if the gross weight of the design aircraft is 60,000 lbs (27 000 kg) or less. In addition, if P-208 is substituted for P-209, the required thickness of hot mix asphalt surfacing shown on the design curves should be increased 1 inch (25 mm).

TABLE 3-9. RECOMMENDED EQUIVALENCY FACTOR RANGES FOR STABILIZED BASE

Material	Eauivalencv Factor Range
P-304, Cement Treated Base Course	1.2 - 1.6
P-306, Econocrete Subbase Course	1.2 - 1.6
P-401, Plant Mix Bituminous Pavements	1.2 - 1.6

Note: Reflection cracking may be encountered when P-304 or P-306 is used as base for a flexible pavement. The thickness of the hot mix asphalt surfacing course should be at least 4 inches (100 mm) to minimize reflection cracking in these instances.

TABLE 3-7. RECOMMENDED EQUWALENCY FACTOR RANGES FOR STABILIZED SUBBASE

Material	Equivalency Factor Range
P-301, Soil Cement Base Course	1.0 - 1.5
P-304, Cement Treated Base Course	1.6 - 2.3
P-306, Econocrete Subbase Course	1.6 - 2.3
P-401, Plant Mix Bituminous Pavements	1.7 - 2.3

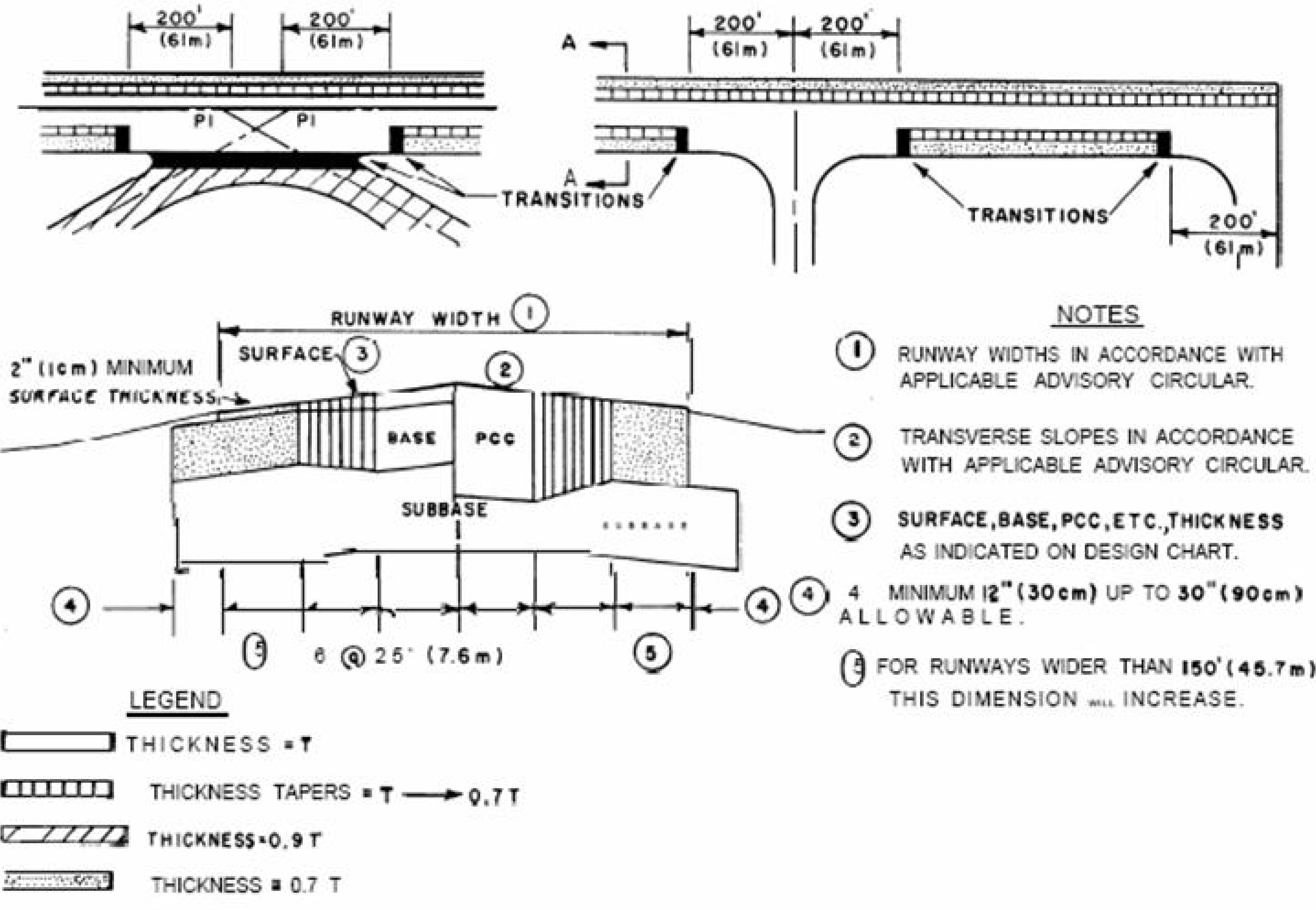
TYPICAL SECTIONS.

Airport pavements are generally constructed in uniform, full width sections.

Runways may be constructed with a transversely variable section, if practical. A variable section permits a reduction in the quantity of materials required for the upper paving layers of the runway. However, more complex construction operations are associated with variable sections and are usually more costly.

pavement thickness of 0.9T will be specified where traffic will be arrivals such as high speed turnoffs; and pavement thickness of 0.7T will **be** specified where pavement is required but traffic is unlikely such as along the extreme outer edges of the runway.

Note that the full-strength keel section is 50 feet (15 m) on the basis of the research study discussed in paragraph 306a.



319. DESIGN EXAMPLE. As an example of the use of the design curves, assume a flexible pavement is to be designed for a dual gear aircraft having a gross weight of 75,000 pounds (34 000 kg) and 6,000 annual equivalent departures of the design aircraft. Design CBR values for the subbase and subgrade are 20 and 6, respectively.

a. **Total Pavement Thickness.** The total pavement thickness required is determined from Figure 3-3. Enter the upper abscissa with the subgrade CBR value, 6. Project vertically downward to the gross weight of the design aircraft, 75,000 pounds (34 000 kg). At the point of intersection of the vertical projection and the aircraft gross weight, make a horizontal projection to the equivalent annual departures, 6000. From the point of intersection of the horizontal projection and the annual departure level, make a vertical projection down to the lower abscissa and read the total pavement thickness; in this example - 23 inches (584 mm).

b. **Thickness of Subbase Course.** The thickness of the subbase course is determined in a manner similar to the total pavement thickness. Using Figure 3-3, enter the upper abscissa with the design CBR value for the subbase, 20. The chart is used in the same manner as described in "a" above, i.e., vertical projection to aircraft gross weight, horizontal projection to annual departures, and vertical projection to lower abscissa. In this example the thickness obtained is 9.5 inches (241 mm). This means that the combined thickness of hot mix asphalt surface and base course needed over a 20 CBR subbase is 9.5 inches (241 mm), thus leaving a subbase thickness of 23 - 9.5 = 13.5 inches (343 mm).

c. **Thickness of Hot Mix Asphalt Surface.** As indicated by the note in Figure 3-3, the thickness of hot mix asphalt surface for critical areas is 4 inches (100 mm) and for noncritical, 3 inches (76 mm).

d. **Thickness of Base Course.** The thickness of base course can be computed by subtracting the thickness of hot mix asphalt surface from the combined thickness of surface and base determined in "b" above; in this example 9.5 - 4.0 = 5.5 (150 mm) of base course. The thickness of base course thus calculated should be compared with the minimum base course thickness required as shown in Table 3-4. Note that the minimum base course thickness is 6 inches (150 mm) from Table 3-4. Therefore the minimum base course thickness from Table 3-4, 6 inches (152 mm), would control. If the minimum base course thickness from Table 3-4 had been less than the calculated thickness, the calculated thickness would have controlled. Note also that use of Item P-208, Aggregate Base Course, as base course is not permissible since the weight of the design aircraft exceeds 60,000 lbs. (27 000 kg).

e. **Thickness of Noncritical Areas.** The total pavement thickness for noncritical areas is obtained by taking 0.9 of the critical pavement base and subbase thicknesses plus the required hot mix asphalt surface thickness given on the design charts. For the thinned edge portion of the critical and noncritical pavements, the 0.7T factor applies only to the base course because the subbase should allow for transverse drainage. The transition section and surface course requirements are as noted in Figure 3-1.

f. **Summary.** The thickness calculated in the above paragraphs should be rounded off to even increments as discussed in paragraph 3 18. If conditions for detrimental frost action exist, another analysis is required. The final design thicknesses for this example would be as follows:

THICKNESS REQUIREMENTS

	Critical in. (mm)	Non-Critical in. (mm)	Edge in. (mm)
Hot Mix Asphalt Surface (P-209 Base)	4 (100)	3 (75)	2 (50)
Base Course (P-209, or P-21 1)	6 (200)	5 (1'25)	4 (100)
Subbase Course (P-154)	14 (355)	13 (330)	10 (255)
Transverse Drainage Course (if needed)	0 (0)	3 (75)	8 (205)

BASE COURSE.

types of base courses for use on airports for aircraft design loads of 30,000 pounds (14 000 kg) or more are as follows:

(1) Item P-208 - Aggregate Base Course’
(2) Item P-209 - Crushed Aggregate Base Course
(3) Item P-21 1 - Lime Rock Base Course
(4) Item P-304 - Cement Treated Base Course
(5) Item P-306 - Econocrete Subbase Course
(6) Item P-401 - Plant Mix Bituminous Pavements

‘The use of Item P-208, Aggregate Base Course, as base course is limited to pavements designed for gross loads of 60,000 Ibs. (27 000 kg) or less When Item P-208 is used as base course the thickness of the hot mix asphalt surfacing should be increased 1 inch (25 mm) over that shown on the design curves.

TABLE 3-2. SUBGRADE COMPACTION REQUIREMENTS FOR FLEXIBLE PAVEMENTS

DESIGN AIRCRAFT	Gross Weight lbs.	NON-COHESIVE SOILS Depth of Compaction In.				COHESIVE SOILS Depth of Compaction In.			
		100%	95%	90%	85%	95%	90%	85%	80%
Single Wheel	30,000	8	8-18	18-32	32-44	6	6-9	9-12	12-17
	50,000	10	10-24	24-36	36-48	6	6-9	9-16	16-20
	75,000	12	12-30	30-40	40-52	6	6-12	12-19	19-25
Dual Wheel (incls. C-130)	50,000	12	12-28	28-38	38-50	6	6-10	10-17	17-22
	100,000	17	17-30	30-42	42-55	6	6-12	12-19	19-25
	150,000	19	19-32	32-46	46-60	7	7-14	14-21	21-28
	200,000	21	21-37	37-53	53-69	9	8-16	16-24	24-32
Dual Tand. (incls. 757, 767, A-300)	100,000	14	14-26	26-38	38-49	6	6-10	10-17	17-22
	200,000	17	17-30	30-43	43-56	6	6-12	12-18	18-26
	300,000	20	20-34	34-48	48-63	7	7-14	14-22	22-29
	400,000	23	23-4 1	41-59	59-76	9	9-18	18-27	27-36
DC-10	400,000	21	21-36	36-55	55-70	8	8-15	15-20	20-28
L1011	600,000	23	23-4 1	41-59	59-76	9	9-18	18-27	27-36
747	800,000	23	23-41	41-59	59-76	9	9-18	18-27	27-36

Notes: