

PRELIMINARY INFORMATION

7.0 PAVEMENT DATA

7.1 General Information

7.2 Landing Gear Footprint

7.3 Maximum Pavement Loads

7.4 Landing Gear Loading on Pavement

7.5 Flexible Pavement Requirements - U.S. Army Corps of Engineers Method S-77-1

7.6 Flexible Pavement Requirements - LCN Conversion

7.7 Rigid Pavement Requirements - Portland Cement Association Design Method

7.8 Rigid Pavement Requirements - LCN Conversion

7.9 Rigid Pavement Requirements - FAA Method

7.10 ACN/PCN Reporting System - Flexible and Rigid Pavements

PRELIMINARY INFORMATION

7.0 PAVEMENT DATA

7.1 General Information

A brief description of the pavement charts that follow will help in their use for airport planning. Each airplane configuration is depicted with a minimum range of six loads imposed on the main landing gear to aid in interpolation between the discrete values shown. All curves for any single chart represent data based on rated loads and tire pressures considered normal and acceptable by current aircraft tire manufacturer's standards. Tire pressures, where specifically designated on tables and charts, are at values obtained under loaded conditions as certificated for commercial use.

Section 7.2 presents basic data on the landing gear footprint configuration, maximum design taxi loads, and tire sizes and pressures.

Maximum pavement loads for certain critical conditions at the tire-to-ground interface are shown in Section 7.3, with the tires having equal loads on the struts.

Pavement requirements for commercial airplanes are customarily derived from the static analysis of loads imposed on the main landing gear struts. The chart in Section 7.4 is provided in order to determine these loads throughout the stability limits of the airplane at rest on the pavement. These main landing gear loads are used as the point of entry to the pavement design charts, interpolating load values where necessary.

The flexible pavement design curves (Section 7.5) are based on procedures set forth in Instruction Report No. S-77-1, "Procedures for Development of CBR Design Curves," dated June 1977, and as modified according to the methods described in ICAO Aerodrome Design Manual, Part 3, Pavements, 2nd Edition, 1983, Section 1.1 (The ACN-PCN Method), and utilizing the alpha factors approved by ICAO in October 2007. Instruction Report No. S-77-1 was prepared by the U.S. Army Corps of Engineers Waterways Experiment Station, Soils and Pavements Laboratory, Vicksburg, Mississippi. The line showing 10,000 coverages is used to calculate Aircraft Classification Number (ACN).

The following procedure is used to develop the curves, such as shown in Section 7.5:

1. Having established the scale for pavement depth at the bottom and the scale for CBR at the top, an arbitrary line is drawn representing 6,000 annual departures.
2. Values of the aircraft gross weight are then plotted.

PRELIMINARY INFORMATION

3. Additional annual departure lines are drawn based on the load lines of the aircraft gross weights already established.
4. An additional line representing 10,000 coverages (used to calculate the flexible pavement Aircraft Classification Number) is also placed.

All Load Classification Number (LCN) curves (Sections 7.6 and 7.8) have been developed from a computer program based on data provided in International Civil Aviation Organization (ICAO) document 9157-AN/901, Aerodrome Design Manual, Part 3, "Pavements", First Edition, 1977. LCN values are shown directly for parameters of weight on main landing gear, tire pressure, and radius of relative stiffness (t) for rigid pavement or pavement thickness or depth factor (h) for flexible pavement.

Rigid pavement design curves (Section 7.7) have been prepared with the Westergaard equation in general accordance with the procedures outlined in the Design of Concrete Airport Pavement (1955 edition) by Robert G. Packard, published by the American Concrete Pavement Association, 3800 North Wilke Road, Arlington Heights, Illinois 60004-1268. These curves are modified to the format described in the Portland Cement Association publication XP6705-2, Computer Program for Airport Pavement Design (Program PDILB), 1968, by Robert G. Packard.

The following procedure is used to develop the rigid pavement design curves shown in Section 7.7:

1. Having established the scale for pavement thickness to the left and the scale for allowable working stress to the right, an arbitrary load line is drawn representing the main landing gear maximum weight to be shown.
2. Values of the subgrade modulus (k) are then plotted.
3. Additional load lines for the incremental values of weight on the main landing gear are drawn on the basis of the curve for $k = 300$, already established.

The rigid pavement design curves (Section 7.9) have been developed based on methods used in the FAA Advisory Circular AC 150/5320-6D July 7, 1995. The following procedure is used to develop the curves, such as shown in Section 7.9:

1. Having established the scale for pavement flexure strength on the left and temporary scale for pavement thickness on the right, an arbitrary load line is drawn representing the main landing gear maximum weight to be shown at 5,000 coverages.

PRELIMINARY INFORMATION

2. Values of the subgrade modulus (k) are then plotted.
3. Additional load lines for the incremental values of weight are then drawn on the basis of the subgrade modulus curves already established.
4. The permanent scale for the rigid-pavement thickness is then placed. Lines for other than 5,000 coverages are established based on the aircraft pass-to-coverage ratio.

The ACN/PCN system (Section 7.10) as referenced in ICAO Annex 14, “Aerodromes, Fourth Edition, July 2004, provides a standardized international airplane/pavement rating system replacing the various S, T, TT, LCN, AUW, ISWL, etc., rating systems used throughout the world. ACN is the Aircraft Classification Number and PCN is the Pavement Classification Number. An aircraft having an ACN equal to or less than the PCN can operate on the pavement subject to any limitation on the tire pressure. Numerically, the ACN is two times the derived single-wheel load expressed in thousands of kilograms, where the derived single wheel load is defined as the load on a single tire inflated to 181 psi (1.25 MPa) that would have the same pavement requirements as the aircraft. Computationally, the ACN/PCN system uses the PCA program PDILB for rigid pavements and S-77-1 for flexible pavements to calculate ACN values. The method of pavement evaluation is left up to the airport with the results of their evaluation presented as follows:

PCN	PAVEMENT TYPE	SUBGRADE CATEGORY	TIRE PRESSURE CATEGORY	EVALUATION METHOD
	R = Rigid F = Flexible	A = High B = Medium C = Low D = Ultra Low	W = No Limit X = To 217 psi (1.5 MPa) Y = To 145 psi (1.0 MPa) Z = To 73 psi (0.5 MPa)	T = Technical U = Using Aircraft

Section 7.10.1 shows the aircraft ACN values for flexible pavements. The four subgrade categories are:

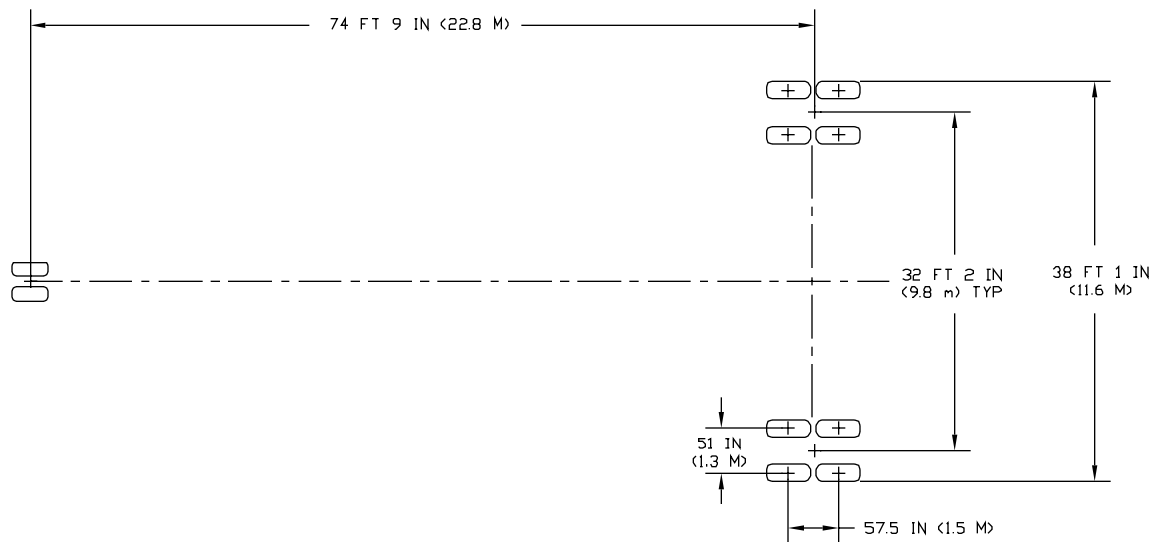
- Code A - High Strength - CBR 15
- Code B - Medium Strength - CBR 10
- Code C - Low Strength - CBR 6
- Code D - Ultra Low Strength - CBR 3

Section 7.10.2 shows the aircraft ACN values for rigid pavements. The four subgrade categories are:

- Code A - High Strength, $k = 550 \text{ pci (150 MN/m}^3\text{)}$
- Code B - Medium Strength, $k = 300 \text{ pci (80 MN/m}^3\text{)}$
- Code C - Low Strength, $k = 150 \text{ pci (40 MN/m}^3\text{)}$
- Code D - Ultra Low Strength, $k = 75 \text{ pci (20 MN/m}^3\text{)}$

D6-58333

PRELIMINARY INFORMATION



	UNITS	787-8
MAXIMUM DESIGN	LB	486,000
TAXI WEIGHT	KG	220,445
PERCENT OF WEIGHT ON MAIN GEAR		SEE SECTION 7.4
NOSE GEAR TIRE SIZE	IN.	40 x 16.0 R16 26PR
NOSE GEAR TIRE PRESSURE	PSI	187
	KG/CM ²	13.15
MAIN GEAR TIRE SIZE	IN.	50 x 20.0 R22 34 PR
MAIN GEAR TIRE PRESSURE	PSI	221
	KG/CM ²	15.47

7.2 LANDING GEAR FOOTPRINT

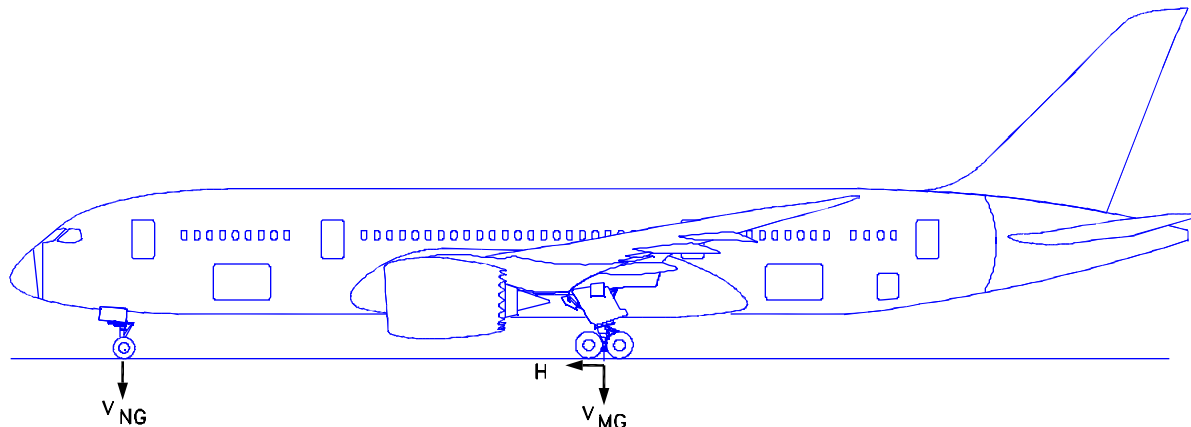
MODEL 787-8

PRELIMINARY INFORMATION

$V_{(NG)}$ = MAXIMUM VERTICAL NOSE GEAR GROUND LOAD AT MOST FORWARD CENTER OF GRAVITY

$V_{(MG)}$ = MAXIMUM VERTICAL MAIN GEAR GROUND LOAD AT MOST AFT CENTER OF GRAVITY

H = MAXIMUM HORIZONTAL GROUND LOAD FROM BRAKING



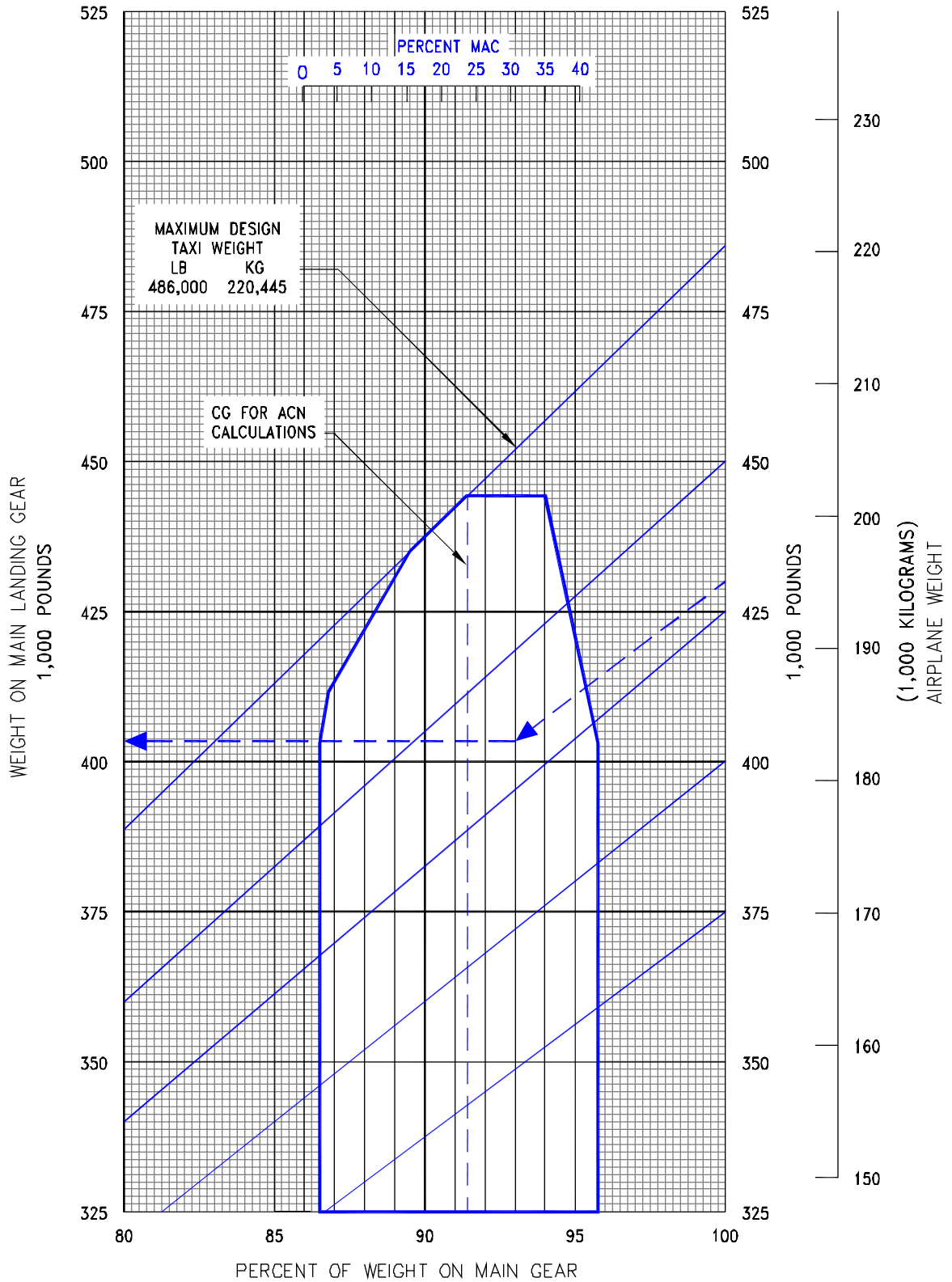
NOTE: ALL LOADS CALCULATED USING AIRPLANE MAXIMUM DESIGN TAXI WEIGHT

MODEL	UNIT	MAXIMUM DESIGN TAXI WEIGHT	$V_{(NG)}$		$V_{(MG)}$ PER STRUT	H PER STRUT	
			STATIC AT MOST FWD C.G.	STATIC + BRAKING 10 FT/SEC ² DECEL	MAX LOAD AT STATIC AFT C.G.	STEADY BRAKING 10 FT/SEC ² DECEL	AT INSTANTANEOUS BRAKING ($\mu=0.8$)
787-8	LB	486,000	51,208	80,524	222,012	75,476	177,609
	KG	220,445	23,228	36,525	100,703	34,235	80,562

7.3 MAXIMUM PAVEMENT LOADS

MODEL 787-8

PRELIMINARY INFORMATION



7.4 LANDING GEAR LOADING ON PAVEMENT

MODEL 787-8

D6-58333

PRELIMINARY INFORMATION

7.5 Flexible Pavement Requirements - U.S. Army Corps of Engineers Method (S-77-1)

The following flexible-pavement design chart presents the data of five incremental main-gear loads at the minimum tire pressure required at the maximum design taxi weight.

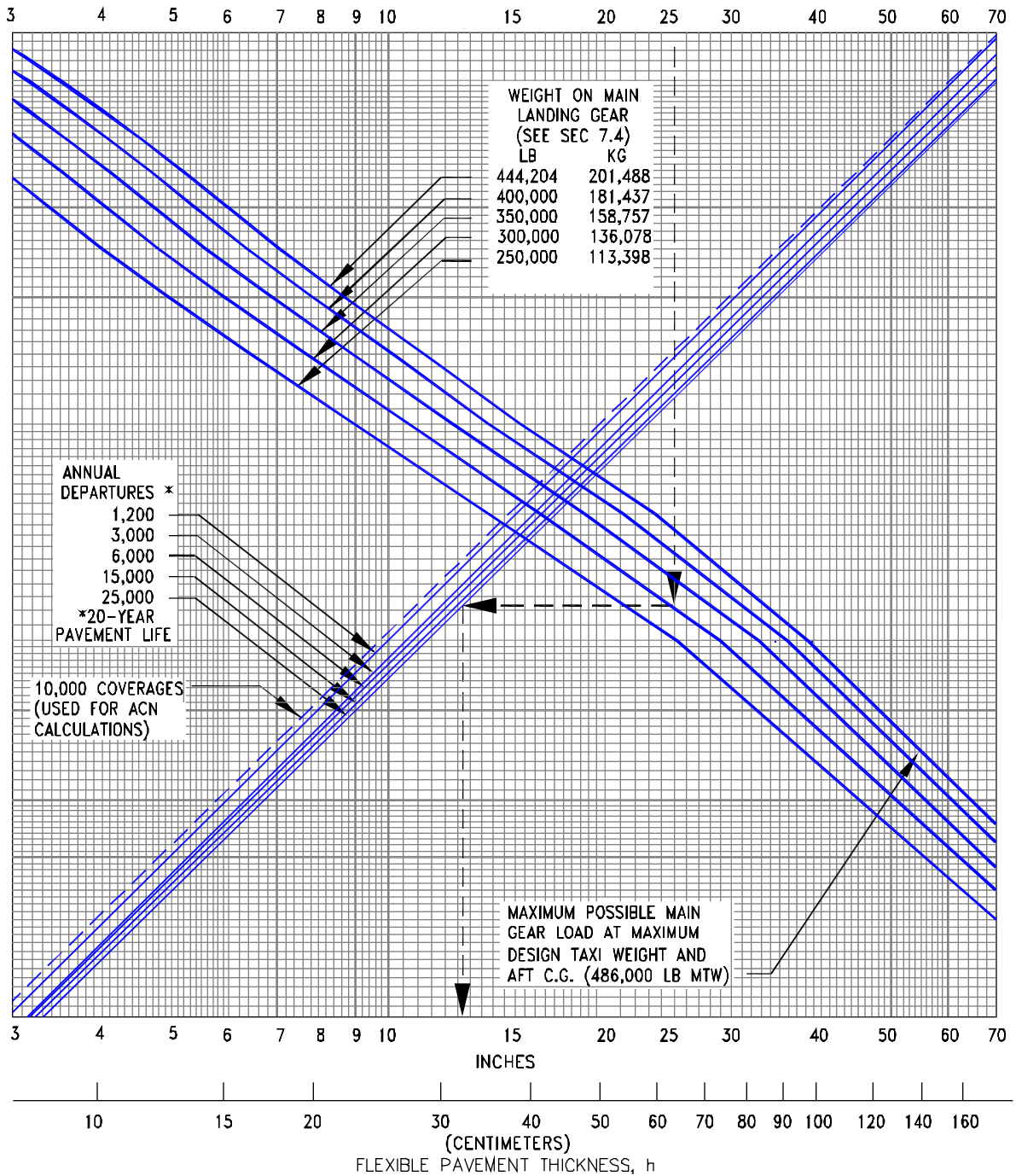
In the example shown, for a CBR of 25 and an annual departure level of 25,000, the required flexible pavement thickness for an airplane with a main gear loading of 300,000 pounds is 12.6 inches.

The line showing 10,000 coverages is used for ACN calculations (see Section 7.10).

The FAA design method uses a similar procedure using total airplane weight instead of weight on the main landing gears. The equivalent main gear loads for a given airplane weight could be calculated from Section 7.4.

PRELIMINARY INFORMATION

NOTE: TIRES - 50 x 20 R22 34 PR AT 221 PSI (15.47 KG/CM SQ)
CALIFORNIA BEARING RATIO, CBR



7.5.1 FLEXIBLE PAVEMENT REQUIREMENTS - U.S. ARMY CORPS OF ENGINEERS DESIGN METHOD (S-77-1)

MODEL 787-8

PRELIMINARY INFORMATION

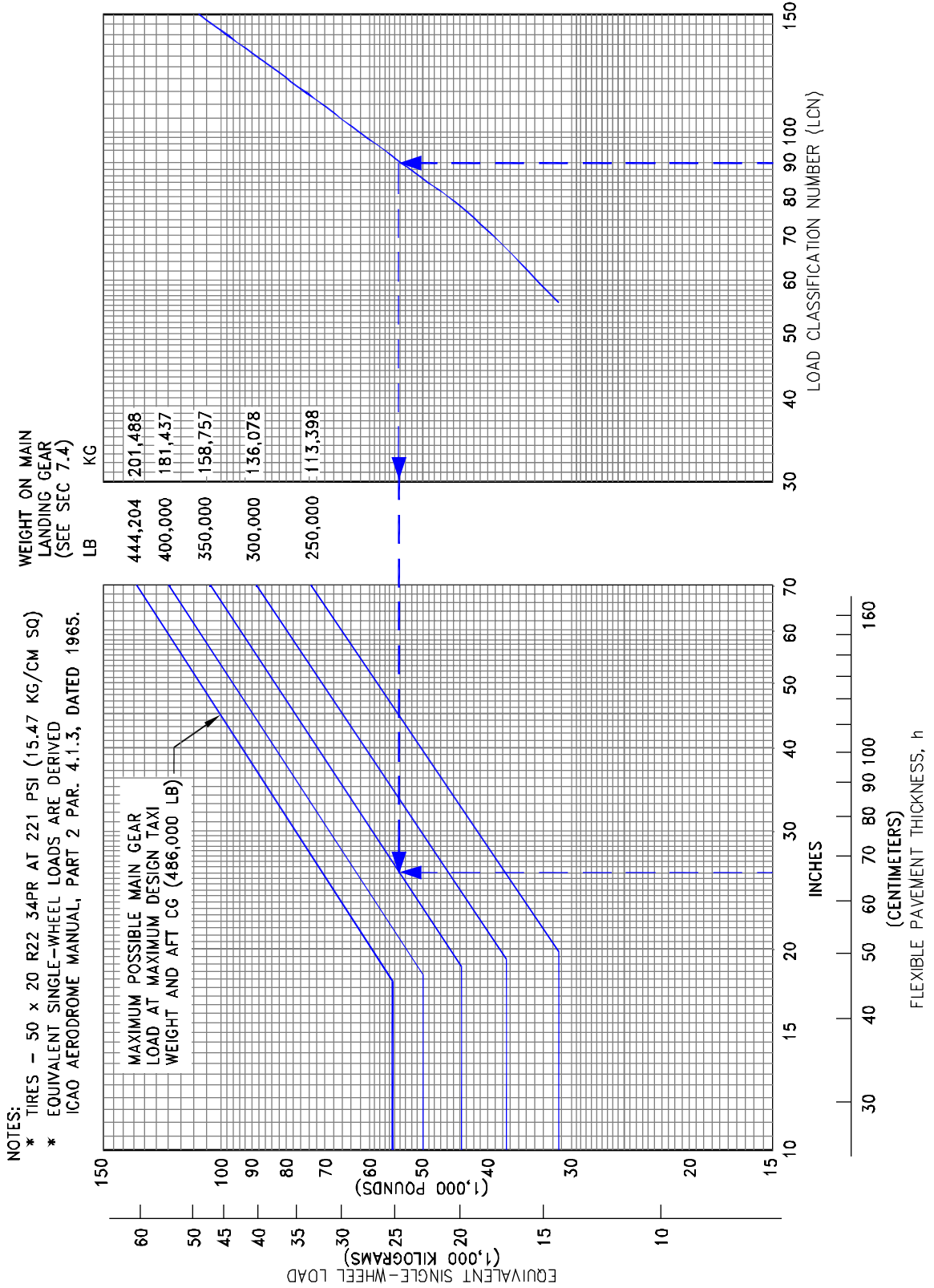
7.6 Flexible Pavement Requirements - LCN Method

To determine the airplane weight that can be accommodated on a particular flexible pavement, both the Load Classification Number (LCN) of the pavement and the thickness must be known.

In the example shown, flexible pavement thickness is shown at 28 in. with an LCN of 90. For these conditions, the apparent maximum allowable weight permissible on the main landing gear is 350,000 lb for an airplane with 221-psi main gear tires.

Note: If the resultant aircraft LCN is not more than 10% above the published pavement LCN, the bearing strength of the pavement can be considered sufficient for unlimited use by the airplane. The figure 10% has been chosen as representing the lowest degree of variation in LCN that is significant (reference: ICAO Aerodrome Manual, Part 2, "Aerodrome Physical Characteristics," Chapter 4, Paragraph 4.1.5.7v, 2nd Edition dated 1965).

PRELIMINARY INFORMATION



7.6.1 FLEXIBLE PAVEMENT REQUIREMENTS - LCN METHOD MODEL 787-8

PRELIMINARY INFORMATION

7.7 Rigid Pavement Requirements - Portland Cement Association Design Method

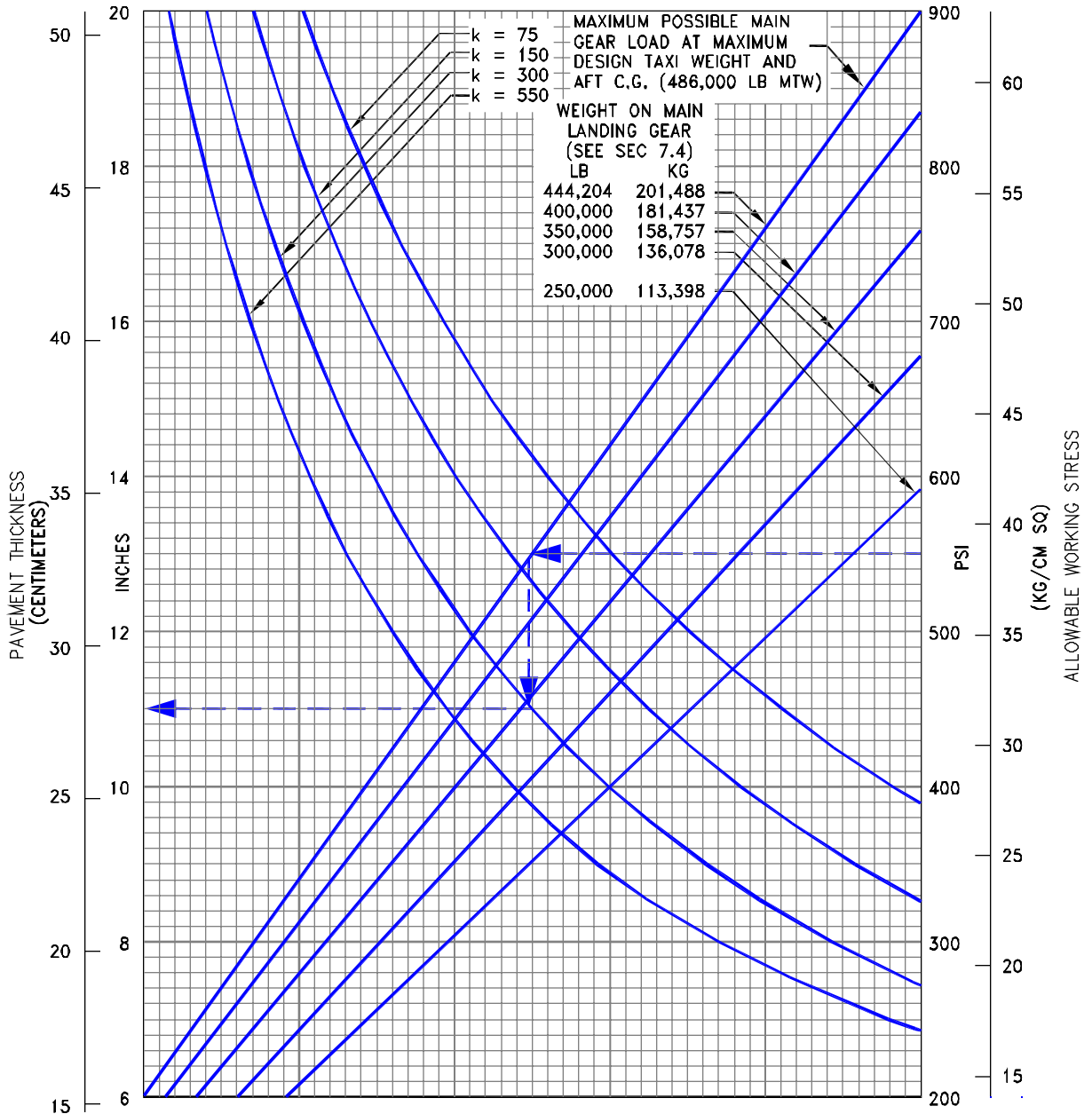
The Portland Cement Association method of calculating rigid pavement requirements is based on the computerized version of "Design of Concrete Airport Pavement" (Portland Cement Association, 1955) as described in XP6705-2, "Computer Program for Airport Pavement Design" by Robert G. Packard, Portland Cement Association, 1968.

The following rigid pavement design chart presents the data for five incremental main gear loads at the minimum tire pressure required at the maximum design taxi weight.

In the example shown, for an allowable working stress of 550 psi, a main gear load of 444,204 lb, and a subgrade strength (k) of 300, the required rigid pavement thickness is 11.0 in.

PRELIMINARY INFORMATION

NOTE: TIRES - 50 x 20 R22 34 PR AT 221 PSI (15.47 KG/CM SQ)



NOTE:
 THE VALUES OBTAINED BY USING THE
 MAXIMUM LOAD REFERENCE LINE AND
 ANY VALUE OF k ARE EXACT.
 FOR LOADS LESS THAN MAXIMUM, THE CURVES
 ARE EXACT FOR k = 300 BUT DEVIATE
 SLIGHTLY FOR OTHER VALUES OF k.

REFERENCES:
 "DESIGN OF CONCRETE AIRPORT
 PAVEMENT" AND "COMPUTER
 PROGRAM FOR AIRPORT PAVEMENT
 DESIGN - PROGRAM PDILB"
 PORTLAND CEMENT ASSOCIATION.

7.7.1 RIGID PAVEMENT REQUIREMENTS - PORTLAND CEMENT ASSOCIATION DESIGN METHOD MODEL 787-8

PRELIMINARY INFORMATION

7.8 Rigid Pavement Requirements - LCN Conversion

To determine the airplane weight that can be accommodated on a particular rigid pavement, both the LCN of the pavement and the radius of relative stiffness (l) of the pavement must be known.

In the example shown in 7.8.2, for a rigid pavement with a radius of relative stiffness of 39 with an LCN of 88, the apparent maximum allowable weight permissible on the main landing gear is 350,000 lb for an airplane with 221-psi main tires.

Note: If the resultant aircraft LCN is not more than 10% above the published pavement LCN, the bearing strength of the pavement can be considered sufficient for unlimited use by the airplane. The figure 10% has been chosen as representing the lowest degree of variation in LCN that is significant (reference: ICAO Aerodrome Manual, Part 2, "Aerodrome Physical Characteristics," Chapter 4, Paragraph 4.1.5.7v, 2nd Edition dated 1965).

PRELIMINARY INFORMATION

RADIUS OF RELATIVE STIFFNESS (ℓ)
VALUES IN INCHES

$$\ell = \sqrt[4]{\frac{Ed^3}{12(1-\mu^2)k}} = 24.1652 \sqrt[4]{\frac{d^3}{k}}$$

WHERE: E = YOUNG'S MODULUS OF ELASTICITY = 4×10^6 psi

k = SUBGRADE MODULUS, LB PER CU IN

d = RIGID PAVEMENT THICKNESS, IN

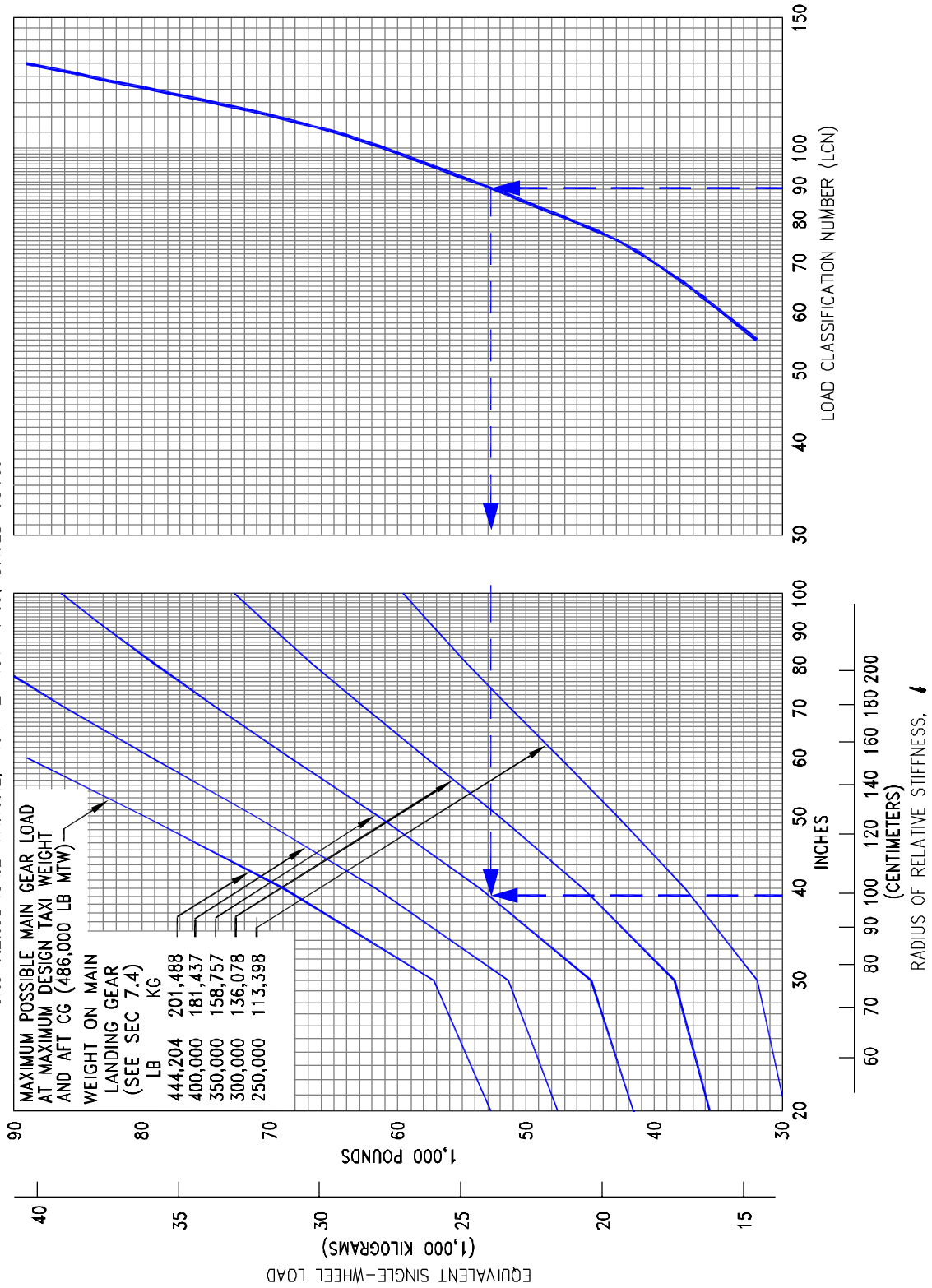
μ = POISSON'S RATIO = 0.15

d	k = 75	k = 100	k = 150	k = 200	k = 250	k = 300	k = 350	k = 400	k = 500	k = 550
6.0	31.48	29.29	26.47	24.63	23.30	22.26	21.42	20.71	19.59	19.13
6.5	33.42	31.10	28.11	26.16	24.74	23.63	22.74	21.99	20.80	20.31
7.0	35.33	32.88	29.71	27.65	26.15	24.99	24.04	23.25	21.99	21.47
7.5	37.21	34.63	31.29	29.12	27.54	26.31	25.32	24.49	23.16	22.61
8.0	39.06	36.35	32.84	30.56	28.91	27.62	26.57	25.70	24.31	23.73
8.5	40.87	38.04	34.37	31.99	30.25	28.90	27.81	26.90	25.44	24.84
9.0	42.66	39.70	35.88	33.39	31.57	30.17	29.03	28.07	26.55	25.93
9.5	44.43	41.35	37.36	34.77	32.88	31.42	30.23	29.24	27.65	27.00
10.0	46.17	42.97	38.83	36.13	34.17	32.65	31.41	30.38	28.73	28.06
10.5	47.89	44.57	40.27	37.48	35.44	33.87	32.58	31.52	29.81	29.10
11.0	49.59	46.15	41.70	38.81	36.70	35.07	33.74	32.63	30.86	30.14
11.5	51.27	47.72	43.12	40.12	37.95	36.26	34.89	33.74	31.91	31.16
12.0	52.94	49.26	44.51	41.43	39.18	37.43	36.02	34.83	32.94	32.17
12.5	54.58	50.80	45.90	42.71	40.40	38.60	37.14	35.92	33.97	33.17
13.0	56.21	52.31	47.27	43.99	41.60	39.75	38.25	36.99	34.98	34.16
13.5	57.83	53.81	48.63	45.25	42.80	40.89	39.34	38.05	35.99	35.14
14.0	59.43	55.30	49.97	46.50	43.98	42.02	40.43	39.10	36.98	36.11
14.5	61.01	56.78	51.30	47.74	45.15	43.14	41.51	40.15	37.97	37.07
15.0	62.58	58.24	52.62	48.97	46.32	44.25	42.58	41.18	38.95	38.03
15.5	64.14	59.69	53.93	50.19	47.47	45.35	43.64	42.21	39.92	38.98
16.0	65.69	61.13	55.23	51.40	48.61	46.45	44.69	43.22	40.88	39.92
16.5	67.22	62.55	56.52	52.60	49.75	47.53	45.73	44.23	41.83	40.85
17.0	68.74	63.97	57.80	53.79	50.87	48.61	46.77	45.23	42.78	41.77
17.5	70.25	65.38	59.07	54.97	51.99	49.68	47.80	46.23	43.72	42.69
18.0	71.75	66.77	60.34	56.15	53.10	50.74	48.82	47.22	44.65	43.60
19.0	74.72	69.54	62.83	58.47	55.30	52.84	50.84	49.17	46.50	45.41
20.0	77.65	72.26	65.30	60.77	57.47	54.91	52.83	51.10	48.33	47.19
21.0	80.55	74.96	67.73	63.03	59.61	56.95	54.80	53.00	50.13	48.95
22.0	83.41	77.62	70.14	65.27	61.73	58.98	56.75	54.88	51.91	50.68
23.0	86.23	80.25	72.51	67.48	63.82	60.98	58.67	56.74	53.67	52.40
24.0	89.03	82.85	74.86	69.67	65.89	62.95	60.57	58.58	55.41	54.10
25.0	91.80	85.43	77.19	71.84	67.94	64.91	62.46	60.41	57.13	55.78

7.8.1 RADIUS OF RELATIVE STIFFNESS (REFERENCE: PORTLAND CEMENT ASSOCIATION)

PRELIMINARY INFORMATION

NOTES: * TIRES - 50 x 20 R22 34PR AT 221 PSI (15.47 KG/CM SQ)
 * EQUIVALENT SINGLE-WHEEL LOADS ARE DERIVED FROM ICAO AERODROME MANUAL, PART 2 PAR 4.1.3, DATED 1965.



7.8.2 RIGID PAVEMENT REQUIREMENTS - LCN CONVERSION

MODEL 787-8

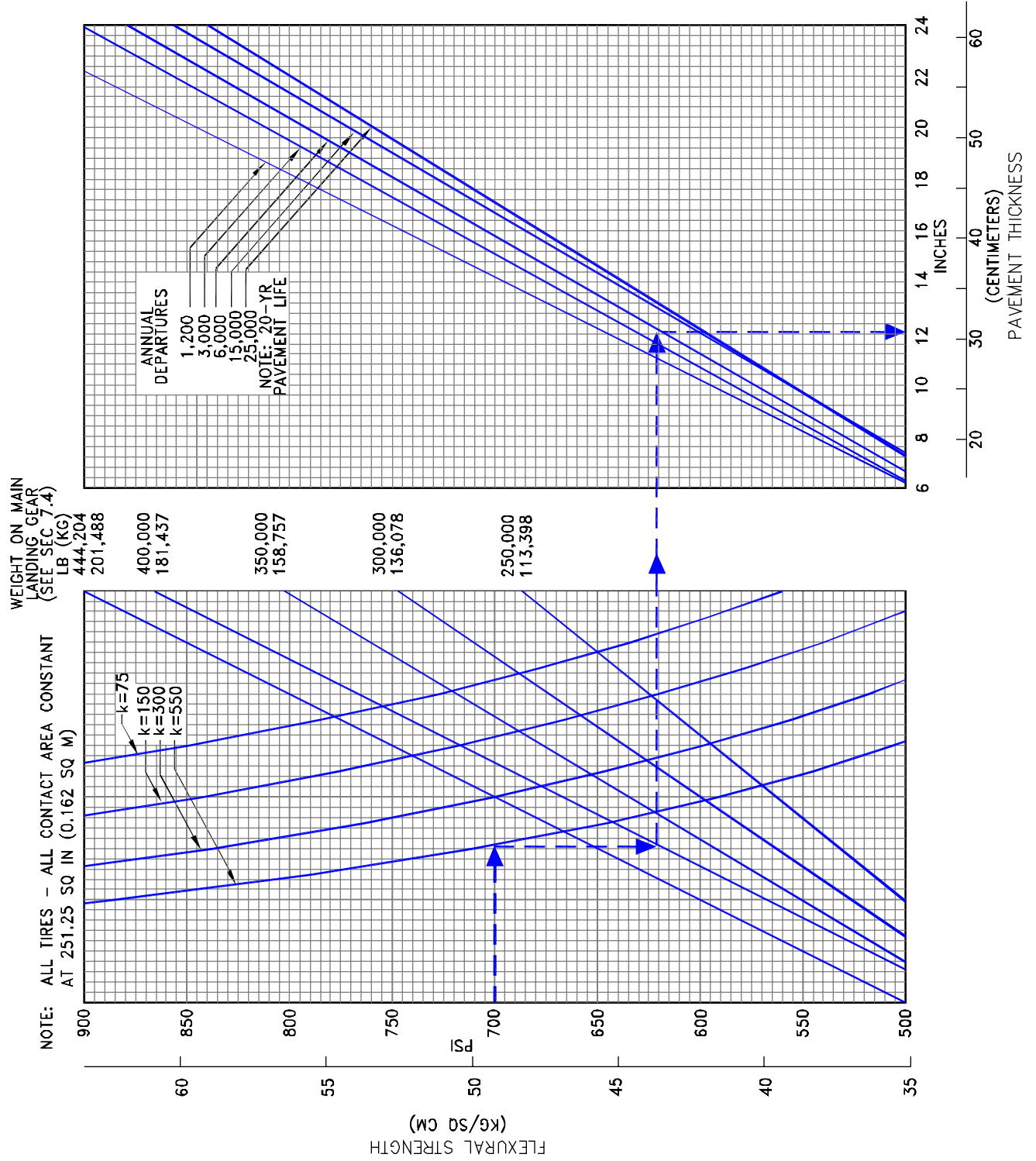
PRELIMINARY INFORMATION

7.9 Rigid Pavement Requirements - FAA Design Method

The following rigid-pavement design chart presents data on five incremental main gear loads at the minimum tire pressure required at the maximum design taxi weight.

In the example shown, the pavement flexural strength is shown at 700 psi, the subgrade strength is shown at $k = 550$, and the annual departure level is 6,000. For these conditions, the required rigid pavement thickness for an airplane with a main gear loading of 400,000 pounds is 12.0 inches.

PRELIMINARY INFORMATION



7.9.1 RIGID PAVEMENT REQUIREMENTS - FAA METHOD MODEL 787-8

PRELIMINARY INFORMATION

7.10 ACN/PCN Reporting System - Flexible and Rigid Pavements

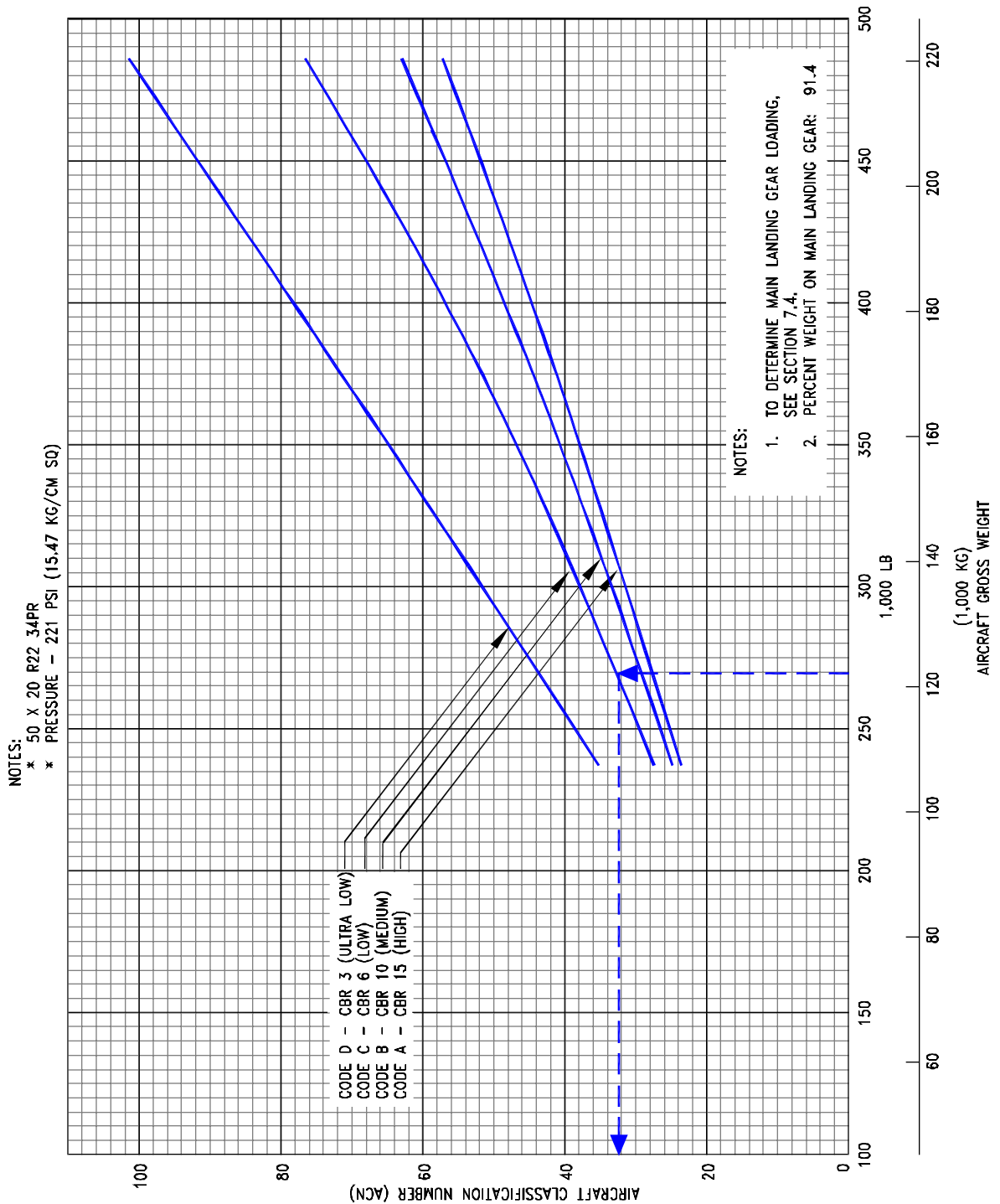
To determine the ACN of an aircraft on flexible or rigid pavement, both the aircraft gross weight and the subgrade strength category must be known. In the chart in 7.10.1, for an aircraft with gross weight of 270,000 lb on a low subgrade strength (Code C), the flexible pavement ACN is 32. Referring to 7.10.2, the same aircraft on a low subgrade rigid pavement has an ACN of 36.

The following table provides ACN data in tabular format similar to the one used by ICAO in the “Aerodrome Design Manual Part 3, Pavements.” If the ACN for an intermediate weight between taxi weight and empty fuel weight of the aircraft is required, Figures 7.10.1 through 7.10.2 should be consulted.

AIRCRAFT TYPE	MAXIMUM TAXI WEIGHT/ MINIMUM WT (1) LB (KG)	LOAD ON ONE MAIN GEAR LEG (%)	TIRE PRESSURE PSI (MPa)	ACN FOR RIGID PAVEMENT SUBGRADES – MN/m ²				ACN FOR FLEXIBLE PAVEMENT SUBGRADES – CBR			
				HIGH 150	MEDIUM 80	LOW 40	ULTRA LOW 20	HIGH 15	MEDIUM 10	LOW 6	ULTRA LOW 3
787-8	486,000(220,445)	45.70	221 (1.52)	57	67	79	91	57	63	77	101
	237,400(107,683)			28	31	36	42	24	25	28	36

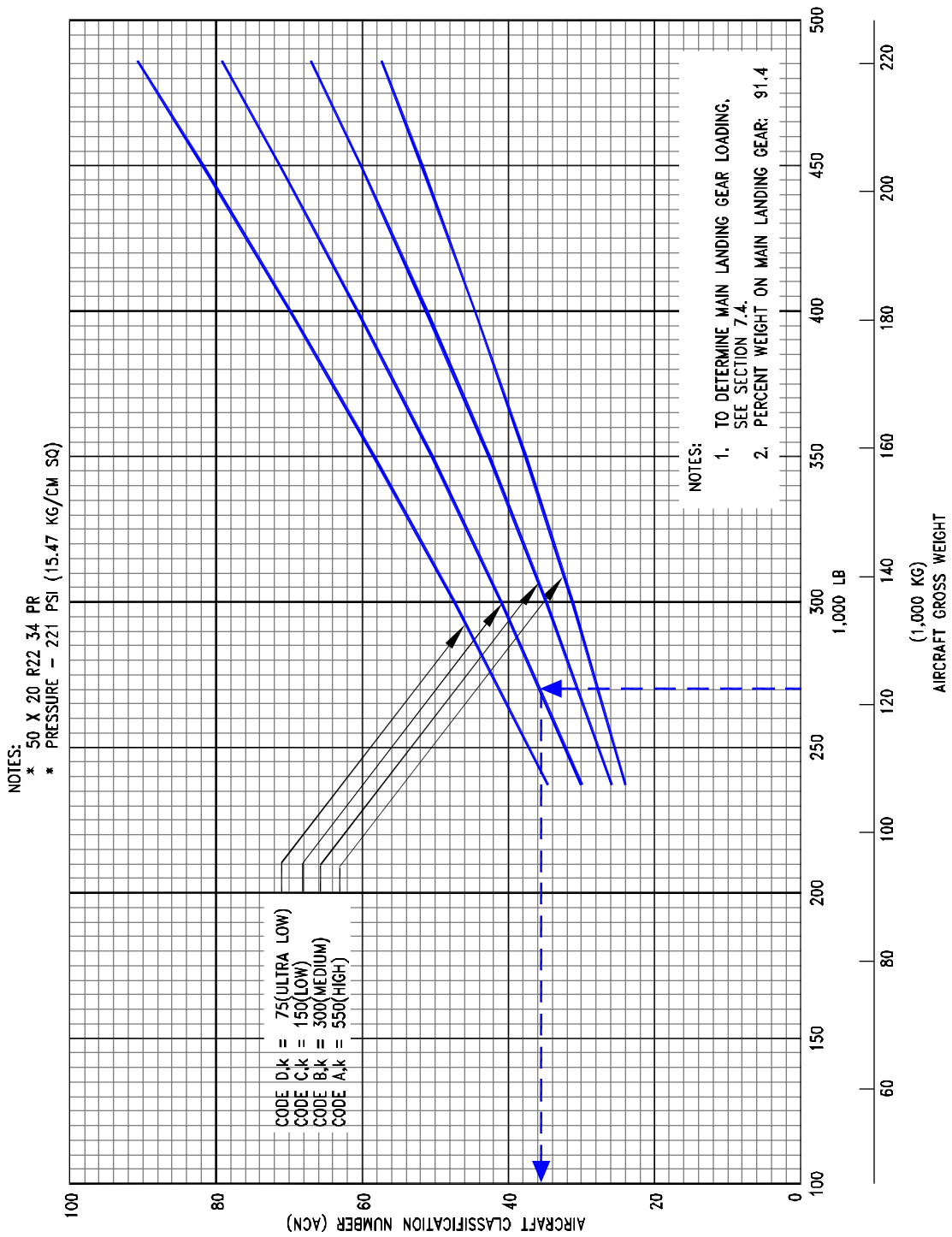
(1) Minimum weight used solely as a baseline for ACN curve generation.

PRELIMINARY INFORMATION



7.10.1 AIRCRAFT CLASSIFICATION NUMBER - FLEXIBLE PAVEMENT MODEL 787-8

PRELIMINARY INFORMATION



7.10.2 AIRCRAFT CLASSIFICATION NUMBER - RIGID PAVEMENT MODEL 787-8

PRELIMINARY INFORMATION

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