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AEROSPACE RECOMMENDED PRACTICE

ARP 836A

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DESIGN AND SAFETY CRITERIA FOR PASSENGER BOARDING STAIRWAYS

1. PURPOSE - It is the purpose of this recommended practice to provide certain criteria for the design and selection of stairways, for the boarding of passengers aboard an aircraft. The criteria presented are limited to those factors which affect the safety of the passengers and are coordinated, where applicable, with the practices of the architectural profession, with respect to the design of stairways.

   The practices suggested are applicable to both portable, variable-elevation-type stairways and fixed-elevation stairways of the type built into an aircraft fuselage.

2. SCOPE - The scope of this recommended practice can be broken into the following categories:

   a. Glossary of terms (para. 3)
   b. Description of basic types (para. 4)
   c. Basic stair design dimensions (para. 5)
   d. Recommended stair design dimensions for aircraft boarding (para. 6)
      1. Fixed-riser-type stairs
      2. Variable-riser-type stairs
   e. Design safety considerations (para. 7)
      1. Loading and safety factors
      2. Other safety considerations
   f. Recommended usage of ARP (para. 8)

3. GLOSSARY OF TERMS

   ø a. (1) Tread Depth T_1 - Theoretical dimension from one stair nosing to the adjacent stair nosing.

   ø a. (2) Effective Tread Depth T_2 - Effective dimension from one stair nosing to the adjacent stair vertical riser.

   b. Riser - R (height) - The distance between the surface of the tread of one step and the surface of the tread of a step above or below when measured perpendicularly between the tread surfaces.

   c. Riser to Tread Ratio - R/T - An arithmetical ratio of the height of one of the risers to the geometrical length of the tread, which ratio is equal to the tangent of the angle of inclination of the stairway.

   d. Step Width - W_1 - The width of the step surface as measured along the nose of the step.

   e. Handrail Height - H - The distance to the center of the handrail as measured at the nose of the step and perpendicular to the tread surface.

   f. Fixed-Riser Stairway - A stairway wherein the riser to tread ratio (R/T) is a constant which will result in a fixed angle of inclination.

   g. Variable-Riser Stairway - A stairway designed to allow variation of the riser to tread ratio and therefore variation of the angle of inclination to suit varying elevations.

   h. Stair Length - The distance measured horizontally and parallel to the tread surfaces between the face of the nose of the lowermost tread to the face of the nose of the uppermost tread. This is a geometric dimension only and does not include allowance for approach at the lower end, intermediate platforms in excess of the normal tread length, or lengths of the upper platforms.

   ø i. Step Width - W Dimensional distance from one side of a step to the other side.

4. DESCRIPTION OF BASIC TYPES - In general, two (2) types of stairways are employed for the boarding of passengers aboard transport-type aircraft, one employing a fixed-riser-to-tread ratio, the other employing a variable-riser-to-tread ratio. The built-in stairway incorporated into the fuselage of many aircraft is always of the fixed-riser-to-tread type.

4.1 Adjustable Fixed-Riser Stair - The adjustable fixed-riser-type stairway usually consists of a stationary lower section of fixed stairs and a movable upper section of stairs. The movable upper section is arranged to slide or roll behind and parallel with the lower fixed section. The lower stair section is topped with an intermediate platform which provides a point at which the lower and upper sections intersect when any tread of the upper section is at the same elevation as the intermediate platform.

The prime advantage of the fixed-riser-type stair is the fact that it can conform to recommended design criteria at any of its elevations of adjustment. But this prime advantage creates its major disadvantage, in that elevation adjustment to accommodate varying aircraft floor elevations is limited to increments of the stairs' riser. Certain stairways of this type have provisions for minor adjustment of the frame of the stair to attempt to reduce the increment. This provision is limited in its effectiveness by the angle to which the stair treads can be taken out of true horizontal before becoming a safety hazard. Secondly, while debatable as to whether it constitutes a disadvantage, the adjustable fixed-riser stair requires an intermediate platform where the fixed position lower section and the adjustable upper section intersect.

4.2 Variable-Riser Stair - Variable-riser stairs are usually constructed employing a parallelogram principle wherein the stair treads and the upper platform remain parallel at any angle of adjustment. The resulting stair is one of different riser and effective tread for every angle of adjustment.

The prime advantage of the variable riser stair is that it provides a continuous range of elevation adjustments to satisfy varying aircraft floor elevations within its adjustment limits. Again, this stair's prime advantage creates its major disadvantage in that the range of elevation adjustments wherein the stair will remain within the recommended limits of Table I is relatively narrow. A second apparent advantage is that the variable-riser stair is a continuous staircase without the need for an intermediate platform.

5. BASIC STAIR DESIGN DIMENSIONS

5.1 Minima and Maxima - Table I lists the limits of basic stair proportions generally accepted by the architectural profession for stair design.

TABLE I

	MIN.	MAX.	PREFERRED
Angle of Incline (deg)	20*	50*	30 - 35
Tread Length (T in.)	11:0	15:0	(See 5.2)
Riser Height (R in.)	6:0	7:75	(See 5.2)
Ramp (Platform) Angle of Incline (deg)	0	17	0 to 10

* Critical

5.2 A properly designed stairway requires the proportioning of certain basic dimensions, i.e., for every selected tread length (T) between the maximum and the minimum there is a best riser height (R) for best proportion. The proper proportion for best riser-to-tread ratio for any selected riser can be determined from the formula:

$$\frac{R}{T} = \text{Tan (R-3) 8 deg}$$

A tabulation of risers and treads within the limits of Table I are given in Table II:

TABLE II

Riser (R in.)	Tread (T in.)	Tan θ	Angle θ (deg)
5.50	15.1	.364	20
5.75	14.2	.405	22
6.00	13.5	.444	24
6.25	12.8	.488	26
6.50	12.2	.532	28
6.75	11.7	.577	30
7.00	11.2	.625	32
7.25	10.7	.677	34
7.50	10.3	.728	36
7.75	9.9	.783	38
8.00	9.4	.852	40

5.3 For any given elevation difference within the limits of Figure 1, Figure 1 may be employed to determine quickly the characteristics of an acceptable stair. As an example: assume a stair of proper proportion is desired for elevation differences of 11.0 in. Enter chart at Elevation 11 ft-0 in. and follow the 11 ft-0 in. elevation to its intersection with horizontal lines of "No. of Risers." Note that the 11 ft-0 in. elevation difference curve intersects all horization "No. of Risers" lines beginning at a maximum number of 24 down to a minimum number of 17. Note that these two limits represent the maxima and minima that would define a stair within the limits of TABLE II with 24 risers of 5.5 in. down to 17 risers of 7.75 in., respectively.

Projecting horizontally from the point of intersection of the 11 ft-0 in. elevation difference curve with the selected number of risers, the number of treads in the stair becomes immediately evident, i.e. 23 treads for 24 risers and 16 treads for 17 risers for the two limits cited above.

Table II lists the preferred tread (T) for given riser heights. The preferred tread length for a 5.5 in. riser is 15.1 in. The preferred tread length for 7.75 in. is 9.9 in. Figure 1 will allow the determination of these preferred relationships directly by reference to the tie lines labeled "TABLE II PROPORTIONS."

Using these preferred tread lengths (T) for the risers, the length of the stair for these limits is readily determined. The tread length (T) for the properly proportioned stair of 24 risers of 5.5 in. height is 15.1 in. Enter Figure 1 on the "TREAD LENGTH (T)" scale at 15.1 in. and project vertically to the intersection with the diagonal line extending from the point of 23 on the "NO. OF TREADS" vertical line. Project horizontally and read the stair length on the "LENGTH OF STAIR" scale at 28.75 in. By the same procedure a 9.9 in. tread length (T) for 16 treads at a riser height of 7.75 in. results in a stair length of approximately 13.3 in. These lengths meet the definition of paragraph 3 (h). It becomes evident that a stairway for 11 ft-0 in. elevation difference has maximum and minimum limits with respect to riser and tread length and corresponding stair lengths. It further becomes evident that the limiting factor on the design of the ideal stair at 30 to 35 deg angle of inclination becomes the length or space allowable for use of the stair.

As a second example, consider the characteristics of a stairway for this elevation difference as close as possible to the tread and riser limits recommended for this recommended practice as shown in Table III. Projecting vertically from the RISER HEIGHT (R) base line and 7.75 in. riser intersects the 11 ft-0 in. difference curve at 17 risers; a 7.00 in. riser intersects at 19 risers. The corresponding number of treads is therefore 16 and 18, respectively. The proper tread lengths are 9.9 and 11.2 in. respectively. The stair lengths are approximately 13.25 and 16.75 ft, respectively. A stairway conforming to this recommended practice should have characteristics within these limits. In analyzing elevation differences for which curves are not shown on FIGURE 1, interpolation must be employed.

5.4 Associated design dimensional data such as step width, handrail height (H), etc., require no dimensional analysis, and are shown as recommended limits below.

6. RECOMMENDED DIMENSIONS FOR DESIGN - Tables III and IV are tabulations of basic design data recommended to be followed in the design of new passenger boarding stairways or the selection of those already available for purchase.

Tolerances where noted are considered critical on a given stairway to maintain the design dimensions within limits such that the lack of dimensional control could not create additional hazards to the safe usage of the stairway. Where tolerances are not noted, commercial tolerances compatible to the type of equipment are considered acceptable.

Since the aircraft built-in type stairway and the fixed riser type stairway are identical in type and differ only in usage, data for these types is combined into a single tabulation.

TABLE III

Fixed-Riser Type

	ADJ. ELEVATION		TOLERANCES	BUILT-IN		REMARKS
STEP:	Max.	Min.	±	Max.	Min.	
Riser (R in.)	7.75	7.00	1/16	7.75	7.00	Note 1
Tread (T in.)	11.20	9.90	1/8	11.20	9.90	Note 1
STAIR:						
Angle θ (deg)	38	32		38	32	
Width (W_1 in.)	Note 2	42		Note 2	24	
Handrail Height (H in.)	36	30		32	30	Vertically at nose
Inside Handrails	W_1 + 4 in.	W_1		W_1 + 4 in.	W_1	
Handrail Dia. (in.)	2.50	1.5		2.50	1.5	
MID-PLATFORM:						
Width (W_2 in.)	Note 2	W_1		Note 3	Note 3	
Length	T+n3T	T+3T		Note 3	Note 3	n=whole digits
Handrail Height (H in.)	36	34		Note 3	Note 3	
Inside Handrails	W_2 + 4 in.	W_2		Note 3	Note 3	

(continued on following page)

TABLE III (Cont'd.)

Fixed-Riser Type

	ADJ. ELEVATION		TOLER-ANCES	BUILT-IN		REMARKS
TOP PLATFORM:	Max.	Min.	±	Max.	Min.	
Width (W_3)	Note 2	W_1 + 6 in.		Note 2	W_1	
Length	Note 2	48 in.		n3T	3T	n = whole digits
Handrail Height (H in.)	38	34		38	34	
Inside Handrails	W_3 + 4 in.	W_3		W_3 + 4 in.	W_3	

TABLE IV

Variable-Riser Type

	Max.	Min.	±	Max.	Min.	
STEP:						
Riser (R in.)	8.00	5.75	1/16			
Tread (T in.)	14.2	9.4	1/8			See Note 4
Ratio - R/T	.852	.405				
STAIR:						
Angle (deg)	40	22				
Width (W_1 in.)	Note 2	42				
Handrail Height (H in.)	36	30				
Inside Handrails	W_1 + 4 in.	W_1				
Handrail Dia. (in.)	2.50	1.50				
TOP PLATFORM:						
Width (W_2 in.)	Note 2	W_1				
Length	Note 2	48 in.				
Handrail Height (in.)	38	34				
Inside Handrails	W_2 + 4 in.	W_2				

NOTES:

1. Proportion per Table II.
2. May vary to suit specific requirements.
3. Not applicable.
4. Tabulation indicates geometric tread (T in.). Actual tread must be increased by minimum 1.5 in. at point of lowest design ratio (R/T) due to fact that parallelogram design uses open riser.

7. DESIGN SAFETY CONSIDERATIONS

7.1 Loading and Safety Factors - Table V is a tabulation of design loads and safety factors recommended for use in the design of new passenger boarding stairways or the selection for purchase of those already available. With respect to design loads and safety factors all variable elevation stairways are classed as portable and built-in stairways are so classed.

TABLE V

Design Factors

	RECOMMENDED MINIMA PORTABLE	BUILT-IN
Design load per step	500 lb	250 lb
Safety factor for live load *	3:1	3:1
Design load for intermediate platform	1500 lb	N.A.
Safety factor for live load *	3:1	N.A.
Design load for upper platform	2000 lb	500 lb
Safety factor for live load*	3:1	3:1
Design wind load - Fully lowered	80 mph wind	N.A.
- Fully elevated	50 mph wind	N.A.
Side rail deflection to horizontal lead at upper rail	400 lb	400 lb
Safety factor	3:1	3:1
Max. allowable deflection at max. load	.25 in. per ft of handrail height	.25 in. per ft of handrail height

* Safety factor based on yield strength.
Note: Recommended loads for design do not include safety factors.

7.2 Other Safety Considerations - Paragraphs 7.2.1 thru 7.2.4 set forth additional points of design over and above those of dimensions and weight-loading which are recommended to be considered in the design of new passenger boarding stairways or the selection for purchase of those already available.

7.2.1 Tread Material - In the selection of material to cover the horizontal step surfaces consideration must be given to the following:

a. Overall non-skid characteristics
b. Resistance to collection and ease of removal of water or snow
c. Non-skid characteristics when wet
d. Resistant to the catching of women's heels

When the step is separately nosed the joint between the nose material and the tread material must be flat within 1/16 in.

7.2.2 Elevation Safety - With respect to adjustable elevation stairways the reliance on the adjusting mechanism to provide fail-safe operation should not be considered acceptable. A minimum of one (1), and preferably two (2) separate and distinct safety locks should be incorporated in the stand to insure that the adjusted elevation is maintained.

The suitability of such safety devices should be proven with the stairway loaded to its maximum design load prior to acceptance of the stairway for usage.