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Design and Safety Criteria for Passenger Boarding Stairways

RATIONALE

This document would be better identified as an Aerospace Information Report (AIR). The purpose of this revision is to convert the document from an ARP to an AIR. There will be no change to the title and there will be several minor additions to the new AIR. This document is currently under a 5 year review.

CANCELLATION NOTICE

This document has been declared "CANCELLED" as of March 2012 and has been superseded by AIR6133. By this action, this document will remain listed in the Numerical Section of the Aerospace Standards Index noting that it is superseded by AIR6133.

Cancelled specifications are available from SAE.

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1. SCOPE AND PURPOSE OF THIS DOCUMENT:

This SAE Aerospace Recommended Practice (ARP) is broken into various categories for convenience and ease of identification.

It is the purpose of this document to provide certain criteria for the design and selection of stairways, for the boarding of passengers onto 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 recommended practices are applicable to both mobile variable-elevation type stairways and to fixed-elevation stairways of the type built into an aircraft fuselage.

2. APPLICABLE DOCUMENTS:

2.1 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 2047-75

3. GLOSSARY OF TERMS:

TREAD DEPTH - T_1: Theoretical horizontal dimension from one stair nosing to the adjacent stair nosing.

EFFECTIVE TREAD DEPTH - T_2: Effective horizontal dimension from one stair nosing to the adjacent stair riser, $T_2 > T_1$.

RISER HEIGHT - R: The vertical 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.

RISER TO TREAD RATIO - R/T_1: An arithmetical ratio of the height of one of the risers to the depth of the tread, which ratio is equal to the tangent of the angle of inclination of the stairway.

ANGLE OF INCLINATION - A: The angle formed by a line joining the stair nosings of one flight of stairs and the horizontal. $A = \tan^{-1} R/T_1$.

STEP WIDTH - W: The width of the step surface as measured along the nosing of the step.

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.

FIXED RISER STAIRWAY: A stairway wherein the riser to tread ratio (R/T_1) is a constant which will result in a fixed angle of inclination.

3. (Continued):

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.

STAIR LENGTH: The distance measured horizontally and parallel to the tread surfaces between the nosing of the lowermost tread to the nosing of the uppermost tread. This is a geometric dimension only and does not include allowance for approach at the lower and intermediate platforms in excess of the normal tread length, or lengths of the upper platforms.

4. DESCRIPTION OF BASIC TYPES OF STAIRWAYS:

In general, two types of stairways are employed for the boarding of crew and 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 generally 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 an extendible upper section of stairs. The extendible 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.

4.2 (Continued):

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 adjustable 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 1 is relatively narrow. Also, 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 1 lists the limits of basic stair proportions generally accepted by the architectural profession for stair design.

TABLE 1

Attribute	Min	Max	Preferred
Angle of Inclination A (°)	20	40	30-35
Tread Depth T_1 (cm, [in])	28 [11]	38 [15]	See 5.2
Riser Height R (cm, [in])	14 [5.5]	20 [8]	See 5.2
Platform and Tread Slope (%)	0	5.2	0-3.5

5.2 Basic Stair Proportioning:

A properly designed stairway requires the proportioning of certain basic dimensions, i.e., for every selected tread depth (T_1) between the maximum and the minimum, there is a best riser height (R) for best proportion. The proper proportion for any selected riser can be determined from the formula:

$$R/T_1 = \text{Tan}\,[(R-3)(8)]^\circ \qquad \text{(Eq. 1)}$$

A tabulation of risers and treads within the limits of Table 1 is given on Table 2.

TABLE 2

Riser R (cm, [in])	Tread T_1 (cm, [in])	Angle A (°)	Tan A (or Tan R/T_1)
14 [5.5]	38.5 [15.1]	20	.364
14.5 [5.75]	36 [14.2]	22	.405
15 [6.0]	34 [13.5]	24	.444
16 [6.25]	32.5 [12.8]	26	.488
16.5 [6.5]	31 [12.2]	28	.533
17 [6.75]	30 [11.7]	30	.577
18 [7.0]	28.5 [11.2]	32	.625
18.5 [7.25]	27 [10.7]	34	.678
19 [7.5]	26 [10.3]	36	.728
19.5 [7.75]	25 [9.9]	38	.783
20.3 [8.0]	24 [9.5]	40	.842

5.3 Elevation Limits:

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 an elevation of 3.35 m (11.0 ft). Enter graph at Elevation 3.35 m (11 ft), and follow that line to its intersection with horizontal lines of "NO. OF RISERS". Note that the 3.35 m (11 ft) elevation line intersects the "No. of Risers" from a maximum of 24 to a minimum of 17. These define stairs within the limits of Table 1, with a maximum of 24 risers of 14 cm (5.5 in) to a minimum of 17 risers of 20 cm (7-3/4 in) respectively.

Projecting horizontally from the point of intersection of the 3.35 m (11 ft) elevation curve with the selected number of risers indicates the number of treads in the stair, i.e., 23 treads for 24 risers, and 16 treads for 17 risers, for limits cited.

Table 2 lists preferred tread depth (T_1) for any riser height (R). The preferred tread depth for a 14 cm (5.5 in) riser is 38 cm (15.1 in). Preferred tread for 19.5 cm (7.75 in) riser is 25 cm (9.9 in). Figure 1 indicates these preferred relationships directly by reference to the tie lines.

Using these preferred tread depths for the corresponding risers, stair lengths for these limits is readily determined. The tread depth for the properly proportioned stair of 24 risers of 14 cm (5.5 in) height is 38 cm (15 in). Enter Figure 1 on the "TREAD DEPTH (T_1)" scale at 38 cm (15 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 8.84 m (29 ft). Similarly, a 25.5 cm (10 in) tread depth (T_1) for 16 treads at a riser height of 20 cm (7-3/4 in) results in a stair length of about 4 m (13.3 ft).

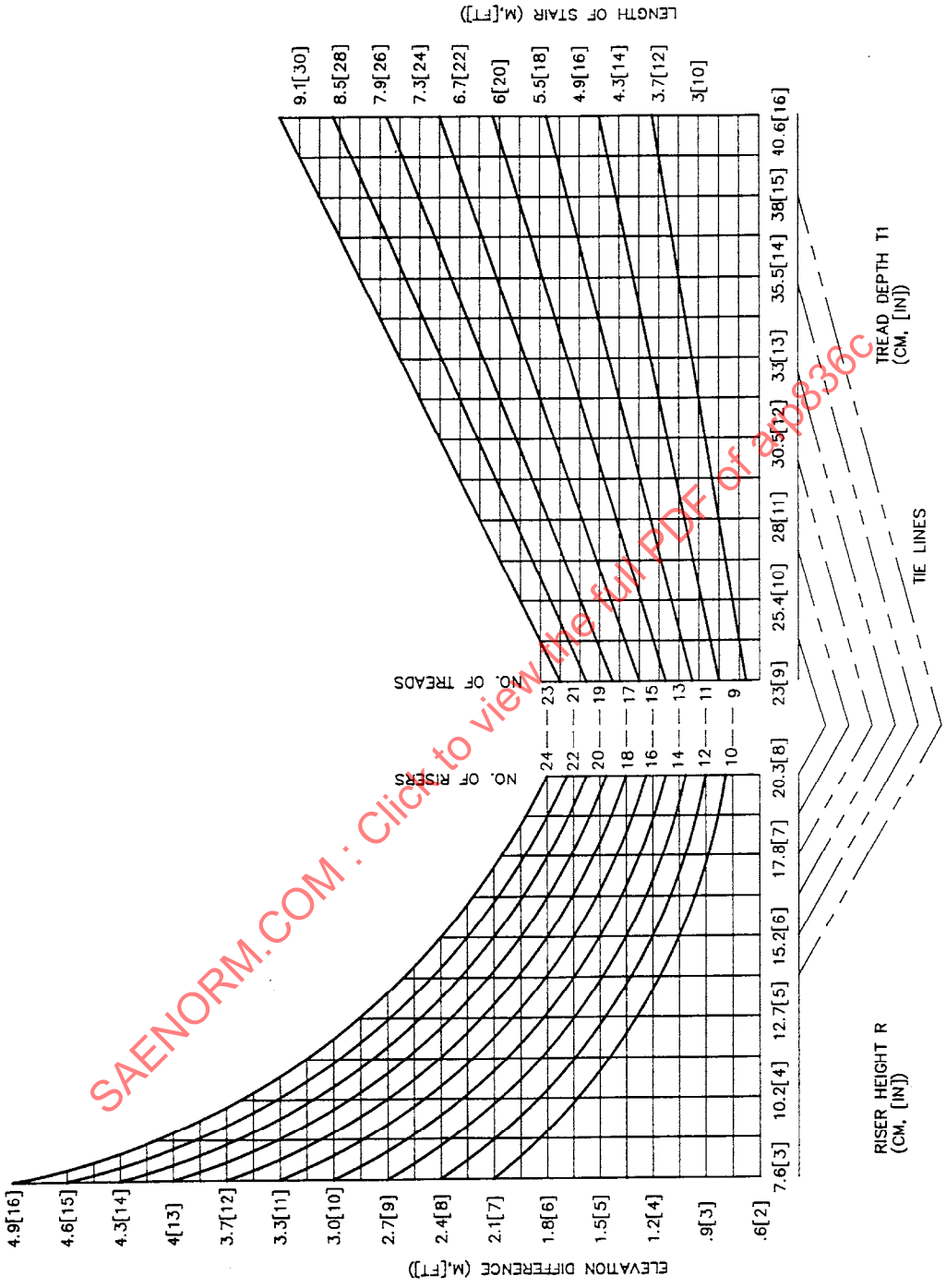

FIGURE 1 - Stair Design Data Chart

5.3 (Continued):

It is evident that the limiting factor on design of the ideal stair is available space. Stairways conforming to recommended practice will have characteristics within limits iterated in Table 1. Use of the graph of Figure 1 assists in establishing optimum configuration, recognizing that the range of inclination angle (A) between 30 and 35 degrees is preferred. For this study, interpolation may be employed. Realize that scale of the graph is too small for exact results, for which the use of Equation 1 is employed.

6. RECOMMENDED DIMENSIONS FOR DESIGN:

Tables 3 and 4 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. Proportions and dimensions recommended for those parameters not covered in Section 5, do not require analysis, but result from experience in the industry.

TABLE 3 - Fixed Riser Type

Attribute	Mobile Max	Mobile Min	Built-In Max	Built-In Min
STEP:				
Riser R (cm, [in])	20 [7.75]	18 [7.0]	20 [7.75]	18 [7.0]
Tread T_1 (cm, [in])	28.5 [11.2]	25 [9.9]	28.5 [11.2]	25 [9.9]
STAIR:				
Angle A (°)	38	32	38	32
Width W (cm, [in])	Note 1	107 [42]	Note 1	61 [24]
Handrail Ht H (cm, [in])	86 [34]	76 [30]	81 [32]	76 [30]
Inside Handrails	W + 10 [W + 4]	W	W + 10 [W + 4]	W
MID-PLATFORM:				
Width W (cm, [in])	Note 1	W	Inapplicable	Inapplicable
Length	Note 1	3T1	Inapplicable	Inapplicable
Handrail Ht H (cm, [in])	106.5 [42]	91 [36]	Inapplicable	Inapplicable
Inside Handrails	W + 10 [W + 4]	W	Inapplicable	Inapplicable
PLATFORM:				
Width W (cm, [in])	Note 1	W + 15 [W + 6]	Note 1	W
Length L (cm, [in])	Note 1	122 [48]	Note 1	$3T_1$
Handrail Ht H (cm, [in])	106.5 [42]	91 [36]	96.5 [38]	86 [34]
Inside Handrails	W + 10 [W + 4]	W	W + 10 [W + 4]	W

NOTE 1: May vary to suit requirements.

TABLE 4 - Variable Riser Type

Attribute	Max	Min
STEP:		
Riser R (cm, [in])	20 [8]	14 [5.5]
Tread T_1 (cm, [in])	38 [15.1]	24 [9.5]
Ratio R/T_1	0.842	0.364
STAIR:		
Angle A (°)	40	20
Width W (cm, [in])	Note 1	107 [42]
Handrail Ht H (cm, [in])	86 [34]	76 [30]
Inside Handrails	W + 10 [W + 4]	W
Handrail Dia. (cm, [in])	5.0 [2.0]	2.5 [1.0]
PLATFORM:	Note 2	Note 2

NOTE 1: May vary to suit requirements.
NOTE 2: Platform specifications for fixed riser type (Table 3) apply.

6. (Continued):

Within the accepted range of tread depths and riser heights, consistency must be maintained within a given stair, to avoid creation of additional hazards. Overall tread depths should not vary more than 3 mm (1/8 in), riser heights not more than 1.5 mm (1/16 in).

Since aircraft built-in stairways and fixed riser stairways are considered the same type, data for these are combined into a single tabulation in Table 3.

Analysis of the tread to riser relationship for variable riser type stairways must address the geometric conditions resulting from the use of a parallelogram mechanism that varies the height by changing the position of each step to the next.

This stairway makes use of open risers, and to avoid a horizontal opening between adjacent treads at minimum height, an additional minimum of 4 cm (1.5 in) must be added to the depth of each tread. This increases T2 only, and is not involved in the elevation analysis, as the extra material lies under the next higher tread at higher elevations.