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SLOPE CRITERIA AFFECTING CONSTRUCTION AND OPERATION OF AIRPORTS AND HELIPORTS

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Airports and heliports must meet two sets of stringent slope requirements, one governing permissible grades on runways, shoulders, and taxiways, and the other concerned with unobstructed airspace to a considerable distance beyond and above the installation. Both sets of slope criteria derive from performance characteristics of aircraft and the need, for reasons of safety, for worldwide uniformity, so far as is possible, among heliports and airports. Other airport slope requirements differ in no way from those of other large commercial construction efforts. The large amount of land needed even for a small airport suggeststhat the potential for airport siting should be considered area-wide by planners and developers in a systematic way. These notes are designed to aid in this effort.

Though ground slope requirements can be met by cutting and grading, the large areas needed for runways, taxiways and hardstands, and the very flat grades that must be obtained usually result in choosing naturally flat terrain for an airport. Other factors than cost, such as position relative to cities and industries, is so important that some airports have been built where the natural terrain is irregular; examples are airports near Charleston, West Virginia, (Kanawha Airport), and Pittsburgh, Pennsylvania, (Greater Pittsburgh Airport). However, both airports were expensive to build, and both are situated where no large expanses of gentle terrain occur.

Airspace requirements are less amenable to cutting and grading. They are concerned with maintaining obstacle-free landing and takeoff areas around the airport. Hills and other natural projections and artificial objects such as buildings and antennae that stand high enough above the runway and near enough to the runway to be obstacles can make sites whose ground characteristics are favorable quite unusable for an airport. The heights of natural or manmade objects that would constitute obstructions and the distances away from the runway that obstruction standards obtain are described by a set of mathematical abstractions called "imaginary surfaces". The imaginary surfaces change systematically according to runway length, aircraft approach procedures, and function of the airport. Imaginary surfaces are mostly cones or arcs, close to ground level near the runway and rising away from the airport. The horizontal component of the area covered by airport-related imaginary surfaces can have a length longer than 20 miles. The diagram on the upper right shows these imaginary surfaces.

Areas wherein slope criteria are critical for siting or enlarging airports are very large. Once land that is favorable in terms of slope has been occupied for urban or suburban use or for a use that causes airspace obstructions, it is difficult and expensive to create an airport on it. In the absence of other available cheap sites, it may be necessary to use expensive land (in terms of purchase price) because air-passenger travel and shipment of goods is so important to modern economics and thought patterns. Equally, if a market and population center is situated far from level land, it may be economically feasible to use land that is expensive in terms of grading requirements and approach restrictions in order to obtain a conveniently situated airport. In many places, such airport features as high noise levels and high land consumption are causing communities to expand the areal search for sites that will discommode airport neighbors least.

A common and simple procedure used when making inventories of potential airport sites is to construct, to scale, a transparent template that includes the runway and clear zones (primary surface), transition surface, horizontal surface, conical surface, and approach surface applicable to the type and size of airport desired. To determine slope favorability or slope hazards, the template can be manipulated over a topographic map. Being transparent, the template overlies but does not obscure the existing terrain and culture. In addition to slope analysis, the template and maps can be used in appraising other suitability parameters as well, and areas can be accepted or rejected as potential airport sites according to criteria devised or accepted by the template manipulator. Possibly favorable sites can be outlined and subjected to a more searching appraisal concerning ultimate favorability. This simple procedure has the great advantage of delimiting the largest number of possible sites for early planning consideration. One can construct additional templates for other types of airports, and determine possible consequences if an airport built to certain specifications were later to be enlarged.

The U.S. Federal Aviation Administration commonly uses a classification of airport types based on kind of services performed by the facility. The International Civil Aviation Organization (ICAO) uses a system based on physical aspects of the facility - length of runway, corrected to sea-level pressure, 59°F, no wind, and no runway slope. The two systems are compatible where overlap occurs, and U.S. airports involved in air-carrier operations meet ICAO requirements. The two systems yield similar or identical results when their parameters are used in planning an airport facility. The definitions below define FAA airport categories, and the slope requirements listed in the tabulation that follows are in terms of FAA categories.

Heliport - an area, either at ground level or elevated on a structure, used for landing and takeoff of helicopters. Has the smallest ground-surface dimensions and can utilize the steepest approach-takeoff surface of any type of airport. Minimum diameter of a landing and take-off area is 1.5 times the length of the helicopter type expected to use the heliport. Few heliports have ILS* facilities.

Utility airport - an airport facility devoted to the part of civil aviation engaged in recreational, instructional, commercial and business flying. Aircraft within this category are mostly propeller aircraft of up to 12,500 pounds gross weight. Runways of utility airports are 3,000 or less feet long (corrected to sea-level pressure and 59° F). Many utility airports operate under IFR*, but few have ILS*; some are equipped only for VFR* operation.

Civil general transport airport - an airport facility accommodating business jets, air taxis, and general freight operations. Aircraft include both jets and propeller craft. Usually equipped for IFR*: many are equipped for ILS*.

Civil air-carrier airport - an airport serving regularly scheduled airlines. Runway lengths and airport dimensions based on types of aircraft served and length of flights that emanate from the airport; flight length categories include local (normally not exceeding 500 miles), trunk (normally not exceeding 1,000 miles), continental, and intercontinental. Runway lengths (corrected to standard temperature and pressure) are longer than 3,200 ft. and may exceed 10,000 ft. Most air-carrier airports are equipped for ILS* operations.

Military airport - dimensional criteria are based on performance characteristics of the particular aircraft for which the airport is designed. Ground and airspace criteria are usually more stringent than those for civil airports because of advanced design of military aircraft. Most military airports are equipped with ILS*.

*For safety and continuity of operations various types of navigational guidance systems to facilitate takeoffs and landings are parts of most large airports. Not all airports have all types of guidance systems, and the weather and light conditions under which landings and takeoffs occur differ accordingly. The most rigorous system--and the one which permits the best continuity of operations--is the Instrument Landing System (ILS). ILS airports also have the most rigorous and largest approach-surface slope requirements. Instrument Flying Rules (IFR) permit operations under moderately adverse conditions, and IFR airports have intermediate approach-surface slope requirements. The approach-surface slope requirements at airports operating under VFR (Visual Flight Rules) are least rigorous, and the guidance systems are simplest.

References

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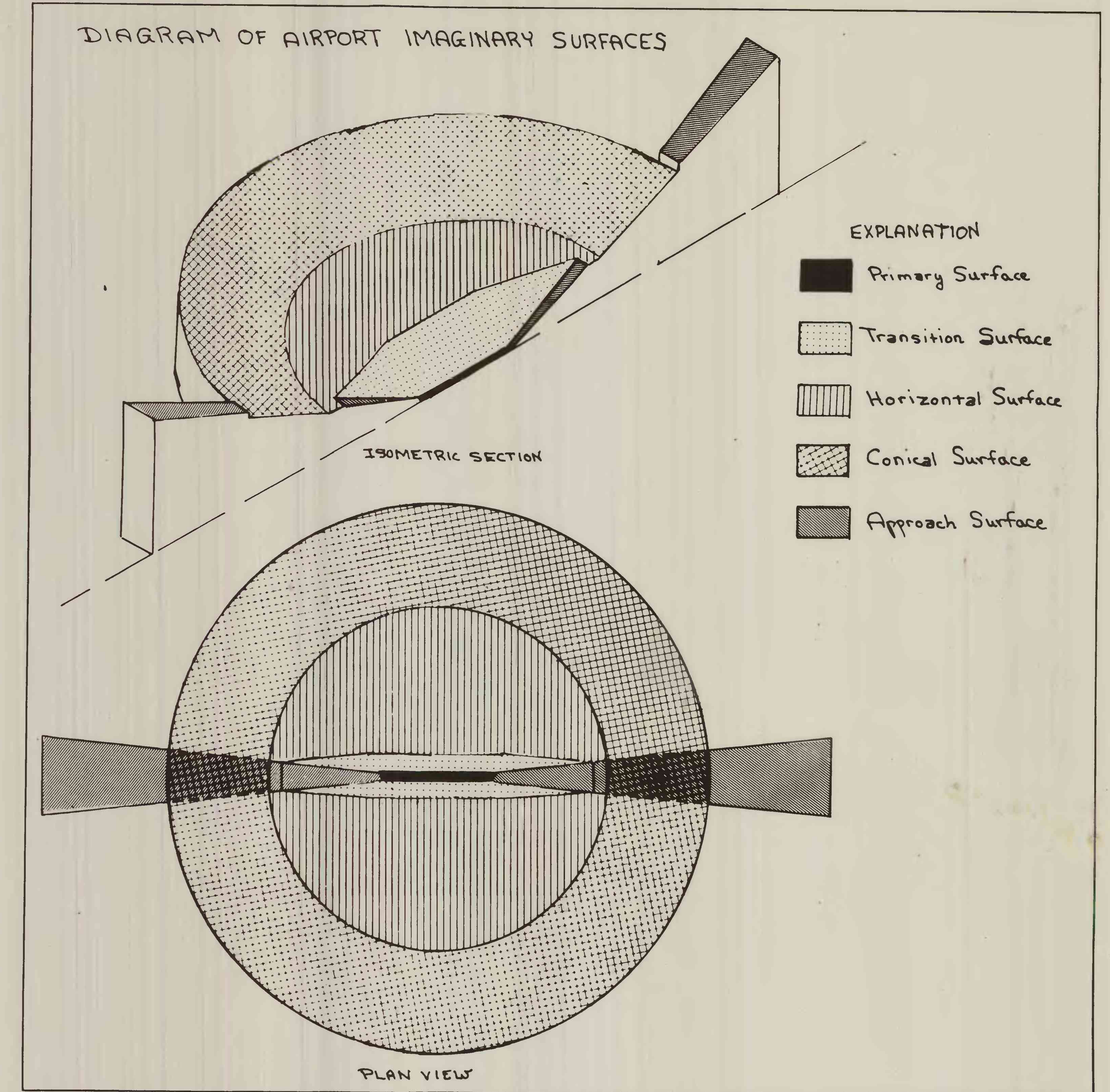

CRITICAL AIRPORT SLOPE QUANTITIES

GROUND-SPACE CONDITIONS

AIRPORT TYPE	Runway a): Longitudinal profile, Minimum	Longitudinal profile, Preferred	Longitudinal profile, Maximum	Transverse profile, Minimum	Transverse profile, Preferred	Transverse profile, Maximum	Shoulders: Transverse slope c)	Taxiways: Longitudinal profile	Taxiways: Transverse profile
Heliport	-	-	2.0%	-	-	2.0%	-5% for 10 ft.; then-3%; (preferred)c)	-	-
Utility airport	0.0%	-	2.0%b)	1.0%	1.5%	1.5%	-3% to -5% for 10 ft.; then -0.5% to -3%	0.0 to 2.0% b)	1.0 to 1.5%
General transport airport	0.0%	-	1.5%b,d)	0.5%	-	1.5%	-5% for 10 ft.; then -1.5 to -3%	2% (maximum) b)	1.5% (maximum)
Aircarrier airport	0.0%	0.5%	1.5%b,d)	0.5%	-	1.5%	-5% for 10 ft.; then -1.5% to -2%	1.5% (maximum)b)	1.5% (maximum)
Military airport	0.0%	0.5%b)	1.0%b)	0.5%	0.5%	1.5%	-5% for 10 ft.; then -1% to -4%	1.5% maximum (Air Force)b) 3% maximum (Navy)b)	0.5% to 1.5% maximum

AIR-SPACE RESTRICTIONS
If a natural or manmade object, fixed or mobile, were to project above these "imaginary surfaces", it would be an obstruction to aircraft operations

AIRPORT TYPE	Primary Surface (Longitudinally centered on runway at ground elevation)	Transition Surface (Between primary surface or approach surface and the horizontal surface)	Horizontal Surface (A circular plane 150 ft. above the established airport elevation)	Approach Surface: ILS (Precision approach under Instrument Flight Rules)	Approach Surface: Non-ILS (Both IFR and VFR)	Conical Surface (Extends up and out from periphery of horizontal surface)
Heliport	Equal to landing-takeoff area	+ 2:1c) (50%) for 200 ft. horizontally (VFR) + 4:1 (25%) for 200 to 300 ft. (precision IFR)	Not applicable	+15:1 (6.7%) for 10,000 ft. horizontally; width widens upward from 300 to 3,400 ft.	+ 8:1 (12.5%) for 4,000 ft. horizontally (VFR); width flares evenly from 300 to 500 ft. e)	Not applicable
Utility airport	Slope same as slope of longitudinal runway profile length is runway length, plus 100 ft. at each end for VFR runways or 200 ft. at each end for all other runways width is: -200 ft. for runways shorter than 3,200 ft. -400 ft. for non-ILS runways 3,200 to 4,200 ft. -500 ft. for non-ILS runways longer than 4,200 ft. -1000 ft. for ILS runways	+7:1 (14.3%) between primary or approach surface and conical surface of all runways except VFR runways ∞(vertical surface) at VFR runways	0.0%, radius 5,000 ft.	Not applicable	+ 20:1 (5%) from each end of primary surface for 10,000 ft. horizontally; width flares from 200 to 2,250 ft.	+ 20:1 (5%) -- for a horizontal distance of 3,000 ft. and height of 300 ft. at utility airports, VFR airports, and airports with runways less than 3,200 ft. long + 20:1 (5%) -- for a horizontal distance of 5,000 ft. and height of 400 ft. where runway is between 3,200 and 6,000 ft. + 20:1 (5%) -- for a horizontal distance of 7,000 ft. and height of 500 ft. where longest runway is more than 6,000 ft. long
General transport airport			0.0%, radius 5,000 ft. at runway of VFR airport and any runway less than 3,200 ft. long -radius 7,000 ft. at runway between 3,200 and 6,000 ft. -radius 11,000 ft. at runway between 6,000 and 7,500 ft. -radius 13,000 ft. where runway is longer than 7,500 ft.	+ 50:1 (2%) for 10,000 ft. horizontally from each end of primary surface; then + 40:1 (2.5%) for 40,000 ft. horizontally. Width flares from 1,000 to 16,000 ft.	VFR: + 20:1 (5%) from each end of primary surface for 3,000 ft. horizontally; width flares from 200 to 500 ft. IFR: for runways 3,200 ft. or less long: + 20:1 (5%) from each end of primary surface for 10,000 ft. horizontally; width flares from 200 to 2,250 ft. -for runways between 3,200 and 4,200 ft. long: + 40:1 (2.5%) from primary surface for 10,000 ft. horizontally; width flares from 400 to 2,400 ft. -for runways longer than 4,200 ft.: + 40:1 (2.5%) for 10,000 ft. horizontally width flares from 500 to 2,500 ft.	
Aircarrier airport						
Military airport	Slope is same as slope of longitudinal runway profile; length same as runway; width 2,000 ft. for runways longer than 5,000 ft.		0.0% for inner horizontal surface; arc with radius of 7,500 ft. about runway center line f)	+ 50:1 (2%) from 200 ft. beyond each end of the primary surface to elevation of 500 ft., then horizontal for nearly 50,000 ft. Width increases from width of primary surface to 16,000 ft.g)		

a) The "runway" space at a heliport is called the "landing and takeoff area". It is commonly square, rectangular, or circular.

b) With additional restrictions concerned with line-of-sight and amplitude of vertical curves. Maximum grade change that does not require a vertical curve is 0.4% ; maximum permissible grade change, 2%.

c) The minus quantity indicates downslope direction from the runway; a plus quantity indicates upslope direction from the runway.

d) Maximum permissible effective gradient of runways of airports serving aircarrier operations is 1%. "Effective gradient" is the difference between the highest and lowest profile elevation divided by the entire runway length.

e) For helicopter operations, approach-departure clearance surfaces may be curved.

f) At military airports an outer horizontal surface extends out from the conical surface at a height of 500 ft. above the established airport elevation for a horizontal distance of 30,000 ft.

g) At military airports called the approach-clearance surface

Metric Conversion Table

1 ft. (foot) = 0.3048 m (metres)
1 mi. (mile) = 1.609 km (kilometres)
1 lb. (pound) = 0.454 kg (kilogrammes)
59°F (Fahrenheit) = 15° k (Kelvin)