

AIRPORT PLANNING
AND ITS RELATION TO THE COMMUNITY

by

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ABSTRACT

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Submitted to the Department of Civil Engineering on May 1, 1954 in partial fulfillment of the requirements for the degree of Master of Science.

The problem of community encroachment on airports is a critical one which has been allowed to develop largely through the inadequate provision of appropriate planning measures. Airports which were originally sited in relatively open areas have become surrounded by residential and commercial developments. The simultaneous advancement in aeronautical technology and diffusion of the urban population have brought more people in contact with an increased influence from airport operation. The airport has acquired an unfavorable reputation, has been criticized as a nuisance, and the locations of new facilities have been opposed by citizens who reside in the vicinity of the proposed airport.

The primary complaints against airports are the nuisance from noise, hazard, and depreciation of property values. The hazard is more psychological than real, and existing data do not indicate that property values are lowered. However, the noise problem is serious and will become increasingly important with the anticipated conversion of civil aviation to jet operation.

The airport planning problem is twofold: First, the airport must be sited to provide the most economical construction, adequate approach protection, and integrated surface transportation to the urban region. Second, the airport location must be compatible with other community activities and through its operation must not unduly jeopardize the adjacent residents.

The most effective tool to secure an advantageous location is the integration of the airport plan into the comprehensive community or regional plan. The planning process must be supplemented by zoning legislation in the immediate vicinity of the airport and the purchase of property and avigation easements at the ends of runways.

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Dear Sir:

In partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering, I herewith submit this thesis entitled: "Airport Planning And Its Relation To The Community".

Respectfully yours,,

 James O. Putnam

The author wishes to
express his appreciation

- : to Professor Alexander J. Bone, thesis supervisor, for his co-operation and many helpful suggestions.

- : to Herbert E. Bell, First Lieutenant, USAF (MSC), who supplied much unpublished material on the subject of aircraft noise.

- : to his wife, Rosemary, who assisted in the preparation of the thesis and typed the final manuscript.

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CHAPTER I

STATEMENT OF THE PROBLEM

The past 20 years have witnessed a tremendous growth in the aviation industry and extensive development of the ground facilities required for aircraft operation. Every community regardless of size has its own airstrip or has access to an airport of some sort. Large metropolitan areas have an airport system comprising as many as 20 landing fields. In 1951 twenty-two million airline passengers flew a total of ten billion revenue passenger miles and scheduled airline services were available in 552 communities throughout the United States. The concepts of national defense have shifted from the ground to the air and many air bases have been constructed to serve the vast numbers of military aircraft. The influence of aviation has spread throughout the United States and with it the attendant problems of airport location, design, and operation.

THE PROBLEM

The early airports were located at some distance from urban centers where land was relatively cheap and runway approaches were unobstructed by natural features. There was no critical requirement for the airport to be located close to the urban center because passenger flights were few and

freight shipments were rare. The principal commercial service was the transport of air mail. The aircraft were small, required little space for landings and take-offs, and were operated within rather limited areas. The airport was a sign of a progressive community and was regarded with a spirit of community pride.

Technological advancements were embodied in new airplane designs and produced larger and faster models which required larger airport facilities and more air space in which to negotiate an approach to the runway. As the aviation industry grew other related activities were attracted to the airport site and commercial and residential construction followed. During the same period the living habits of the city population were undergoing a shift from an urban to a suburban society. The parallel development and wide use of the automobile precipitated a dispersion of population and the formation of a commuting public. The boundaries of metropolitan areas were expanded with the development of the new suburban districts.

The cities expanded until most airports which had previously been isolated were completely encircled by residential and commercial developments -- the airports had no place left in which to expand.

The size of aircraft was continually increased and the larger size was accompanied by higher noise levels and

greater disaster potentials. Flights became more frequent and traffic into the airports reached a point of saturation. Residents who lived adjacent to the airports began to protest the intrusion of aircraft nuisances and the public attitude towards airports underwent a complete reversal of sentiment. Communities which had previously been soliciting the location of airports near their boundaries vigorously protested the proposed location of airports near their commercial or residential districts.

The situation was climaxed by the three disastrous air crashes in Elizabeth, N.J. during the winter of 1952 and public sentiment was aptly reflected when the mayor of the city called the Newark Airport an "umbrella of death" over Elizabeth. The Newark disasters were followed by the appointment of a special airport commission by the President of the United States to study the problem of airport location near cities.

This then is the problem:

Airports are an essential factor in the transportation system and must be coordinated in the community scheme -- aviation must be utilized as a transportation medium without unduly jeopardizing the residents or facilities of the community which it serves.

An attempt will be made in this thesis to explore the objectionable features of airport operation and to present procedures whereby these features can be eliminated or reduced.

IMPORTANCE OF THE STUDY

In the investigations that followed the Newark Airport crashes it was reported that the accidents were a result of malfunctioning of the aircraft and that the proximity of the airport runway to residential districts was not a factor contributing to the accidents. It was further reported that 62 of the nation's airports have runways closer to residential districts than the runway at Newark. It was pointed out in Urban Land that this fact is not a justification of the soundness of the location of the Newark Airport but is rather an indictment of the locations of the other 62 airports.¹

Community encroachment on airport sites is not a factor which was incorporated in the original site selection but is a process which has been allowed to develop through the inadequate provision of appropriate planning measures. Community encroachment on airport sites is continuing to increase and will put many airports out of effective flying

¹ Plan-itorial in Urban Land, Vol.11, No.22, Feb. 1952, p.2.

business unless immediate corrective measures are taken to control the use of lands surrounding airports. The design and planning of new airports will be particularly sensitive and it will be incumbent upon the airport planner to insure that any proposed airport site will meet with public acceptance. A case in point is that of Warren Township, Michigan in which the protests of an aroused public were instrumental in the Michigan Aeronautics Commission ruling against the proposed location of an airport for the City of Detroit.²

It is economically unwise to plan and engineer an airport in which the location will be contested and perhaps enjoined by court action. Likewise, it is unsound economics to allow the public investment in airports to be jeopardized by the elimination of expansion possibilities or by lawsuits which cite the airport as a nuisance.

The anticipated conversion of civil aviation to jet aircraft will intensify an already critical problem. The jet aircraft will produce higher noise levels, require more space both for the airport and for the runway approaches, and will possibly cause a greater number of accidents. Past observations have indicated that new aircraft models usually

² Steven M. Spencer, "This Screaming World", The Saturday Evening Post, August 15, 1953, p. 89.

have a slightly higher accident rate until sufficient operational experience is obtained to disclose the inherent "bugs" in the new design.³ The de Haviland Comet has unfortunately undergone a series of such accidents and it is highly probable that American manufactured jet models will also suffer in the same respect.

The public has already developed a resistance to the idea of jet conversion and this sentiment has been reflected in the filing of three "anti-jet" bills in the legislature of the State of Massachusetts.⁴ These bills have been filed with the current legislature (1954) two of which seek to prohibit jet aircraft from Logan International Airport; one of these bills would also bar military jet aircraft. The third bill goes still farther and would bar commercial jet aircraft from any airport which is located within one mile of any city or town in the state having a population of 50,000 or more.

The encroachment of communities on airports has an adverse effect on the expansion possibility of the airport but presents a more serious problem to adjacent residential developments. It is a known fact that noise, hazard, and

³ William D. Perreault and Anthony Vandyk, "Did The Jet Age Come Too Soon?", Life, January 25, 1954, p.52-4.

⁴ House Bill No. 720, House Bill No. 1797, and Senate Bill No. 175 as reported by Arthur A. Riley, "Plane Talk", Boston Daily Globe, January 12, 1954, p.2.

vibration are some of the many causative agents in the formation of blighted areas. Persons who object to these nuisances leave the afflicted areas and the residences are occupied by persons of lesser financial means who do not provide the dwelling with the required degree of maintenance. Thus, land values tend to depreciate and a transition develops towards the formation of a blighted area. This sequence of events has occurred near railroad tracks, elevated railways and heavily traveled city streets. It remains to be seen if air traffic in the vicinity of airports will have the same effect.

Therefore it can be seen that the problem of airport planning and its relation to the community is a complex one. It is predicted that the volume of air traffic will more than double by 1970 and this increased traffic together with the anticipated conversion or partial conversion to jet operation will intensify the existing problem.

It is hoped that this thesis will provide a deeper insight into the problem and perhaps reveal a method of airport planning which is compatible with other community activities.

OTHER RESEARCH ON THE SUBJECT

The Department of the Air Force and the Civil Aeronautic Commission are vitally concerned with the problem and are conducting numerous individual projects on the various aspects of the problem. The National Advisory Committee on Aeronautics is keenly aware of the problem of aircraft noise and have conducted many research projects on this subject. There are many individual organizations which are interested in the various phases of aircraft safety and are conducting research in this field.

A significant contribution on the subject of the airport and the community is the report of the President's Airport Commission, The Airport and Its Neighbors, and is one of the few concerted efforts at a coordinated attack on the entire problem.

PRESENTATION OF THE SUBJECT

The problem will be discussed in this thesis in two phases. The first phase is an analysis of the factors which are responsible for the problem and the second phase is a discussion of the methods of control and the implementation of these controls.

CHAPTER II

AIRPORT DESIGN AS INFLUENCED BY AIRCRAFT DESIGN

During the past 30 years the design and development of the airport has paralleled or closely followed the development of the airplane. The operating characteristics of the aircraft have been the controlling factors in the design of the ground facilities for air transportation. However, aircraft characteristics have changed so rapidly that many airports were outmoded as soon as they were built. Many communities had the sad experience of constructing airports that became obsolete or relegated to secondary use long before the expiration of a reasonable amortization period.¹ A brief history of airport design as influenced by aircraft development will be presented below:

AIRPORT DESIGN TO WORLD WAR II

Prior to World War I the airplane was a novelty and a machine in the stage of experimental development. During World War I airplanes were used by belligerents on both sides and this use provided a tremendous stimulus to the

¹ Ralph H. Burke and Harry Otis Wright, Jr., "Directional Requirements For Airport Runways", Transactions, American Society of Civil Engineers, Vol. 117, p. 662.

improvement of the newly developed machine. The urgency of war created a demand for increased production of airplanes and the establishment of a training program to furnish pilots. After the war the surplus equipment was acquired by war-trained aviators who flew the craft, often obsolete and poorly maintained, in "barnstorming" services.²

The airplane was first presented to the public through "barnstorming" for use in sightseeing, hopping, advertising, industrial transportation, and air races. Many of the aviators who engaged in these services established enviable records in aviation; but many of the poorly trained and audacious pilots with inferior equipment contributed to accidents that initially gave aviation an unfavorable reputation with the public. An airport did not have to be designed to accommodate these early aircraft but was more often discovered by the pilot who arrived over a town and simply selected an open field in which to land.

Top-heavy, without brakes, and cluttered by struts and wires, these early aircraft required every possible

² G. Lloyd Wilson and Leslie A. Bryan, Air Transportation, p. 30.

advantage from any breeze which might have been blowing.³ The wind could be either an advantage or a disadvantage depending on the angle at which it met the aircraft; therefore, the wind became the dominating factor in the establishment of take-off and landing directions. The all-way airfield was the ideal solution and was often available since landing and take-off distances were short and pavement was not essential.

In the 1930's many improvements were introduced in aircraft design - higher power, cleaner design, brakes, and generally improved stability. The airplane became larger and heavier, and the airfield design concepts had to be improved accordingly. Turf areas could no longer support the heavier loads nor the increased traffic; therefore, paved areas had to be provided for landings and take-offs. It was impractical to pave an entire field, therefore the runway concept was introduced, that is, paved surfaces in the direction of the prevailing winds. The wind was the dominating factor in establishing the orientation of the runway. The aircraft could not accept a cross-wind component during landing or take-off so the runways had to be positioned in the direction of the winds.

³ Paul H. Stafford, "Runway Configurations - The One - Directional Airport", Proceedings, Conference on Ground Facilities For Air Transportation, Massachusetts Institute of Technology, September 12-14, 1950, p. 52.

The factor of wind necessitated the construction of numerous runways when one would have been sufficient to handle the traffic. The different runways usually intersected at some point; and since only one runway could be used at the time the airport was operationally a "one runway" airport in spite of the fact that there was physically more than one runway. The runway intersections also created problems in the design of the grades of separate runways and produced undesirable surface distortions at the points of intersection.

These early airport sites were selected at some distance from the city where land was cheap and where few buildings obstructed the natural approaches to the runway. There were few complaints of noise or nuisance because the noise was infrequent and not very loud. The airports were generally surrounded by open country and few people were exposed to the nuisances that existed. The aviation industry was growing and airport projects were strongly supported by community groups.

AIRPORT DESIGN DURING AND FOLLOWING WORLD WAR II

The advent of World War II precipitated a build-up of air power for the defense of the United States. The then existing civil airports and military airfields were not capable of providing ground facilities for the huge number

of airplanes which were required for the preparedness program; therefore, the U. S. Army embarked on an extensive program of airfield construction. The urgency of wartime conditions did not allow time for any comprehensive research into airport design concepts; accordingly, the new airfields were constructed using the existing principles of wind-directional runways. The limited airport research which was performed during this period was primarily on the subgrade and foundation aspects of runway construction.

The new heavy bombers required longer and stronger runways than were then in existence and many of the military airfields were constructed with runways up to a mile in length. The majority of these airfields were designed with many intersecting runways with lengths ranging from 3500 to 5000 feet. It was not uncommon to find training fields with as many as a dozen intersecting runways.

At the conclusion of the war some of these wartime airfields were retained by the Federal Government as permanent Air Force installations, but the majority were turned over to local governments for use as civil airports.

The progress made in aerodynamics during the war was applied to the development on new models of civil and military aircraft. These new innovations in aircraft design "leap-frogged" the capabilities of the nation's system of airports to handle the new models. Most communities found themselves

with an airport that could handle only the pre-war aircraft. Many of these communities, with financial assistance from the Federal government, began a program of airport re-development - some of the cross-wind runways were eliminated and the remaining ones were lengthened and strengthened to accommodate the post-war aircraft.

The lengthening of runways required an expansion of the airport's physical boundaries and many airports had no space available in which to expand. The nation-wide problem of community encroachment on airports came into sharp focus. Many airports had to either close down or curtail operations because there was no space available in which to construct runway extensions. The newer aircraft also required flatter glide angles and many airports were unable to meet new standards for runway approach clearances.

The CAA design standards⁴ of 1944 recommended a runway length of 4700 to 5700 feet for Class IV⁵ airports and a length of 5700 feet or over for Class V airports. The existing CAA standards specify a maximum runway length of 8400 feet for Intercontinental Express Airport⁶ and a policy

⁴ Airport Design, Civil Aeronautics Administration, April 1, 1944, p. 9.

⁵ Numerical designations to denote airport size have been superseded by descriptive designations, e.g., Express, Continental, Intercontinental, etc.

⁶ CAA Technical Standard Order N6a.

has been adopted by the CAA whereby the Federal Government will participate in financing only the first 8400 feet of a uni-directional runway. This policy of the CAA should produce an effect of limitation on the extent of ultimate airport expansion.

The large post-war airplanes were developed using a tricycle type landing gear and it was found that aircraft which utilized this type landing mechanism could land in moderate cross-winds without introducing undue stresses in the landing gear. This relatively new approach to landing gear design changed completely the airport design concepts. The practice of determination of runway orientation by wind direction was abandoned and the new concept of single direction runways was adopted.

THE ONE-DIRECTION AIRPORT

The entire problem of runway direction centers around the type of landing gear used on the aircraft. This gear is a detriment to the aircraft when it is in the air. Its only purposes are to permit acceleration of the aircraft during take-offs, deceleration during landings and maneuverability on the ground.⁷

⁷ Burke and Wright, op. cit., p. 663.

When the aircraft approaches the runway it is flying at some angle of crab depending upon the magnitude of the cross-wind component and the speed and direction of flight. If the resultant angle of crab is small no problem exists, for at the instant of contact the landing gear will track immediately and the wheels will roll freely. If, however, the angle of crab is large, the wheels of the landing gear must skid sideways causing severe overloads and possible failure of the landing gear.

New developments such as tricycle landing gear with steerable nosewheels in multi-engine planes, the ability to use more power on one side than on the other, and reversible pitch propellers have made it much easier to control the aircraft and it has been possible to accept higher velocities of cross-winds without decreasing safety.⁸ The perfection of a castering landing gear will further increase the ability of an aircraft to accept a higher cross-wind component.

The development of cross-wind landing gear and landing techniques has made possible the adoption of the "one-runway" design policy by both the U. S. Air Force and the Civil Aeronautics Administration. Wind direction is no longer the controlling factor in the determination of the direction of

⁸ Burke and Wright, loc. cit.

runway orientation and consequently more emphasis can be placed on the factors of runway obstructions, hazards to population, terrain conditions and air space requirements.

The present policy of the CAA provides for the construction of a single runway with cross-wind components up to 15 mph.⁹ This value has been established but there is evidence that the trend will be towards larger cross-wind tolerances. A successful version of a new tricycle landing gear is in existence on an Air Force C-54 and extensive tests indicate that landings in cross-winds up to 40 mph present no problem.¹⁰

ADVANTAGES OF ONE-DIRECTIONAL AIRPORT

The advantages of the one-directional airport over the "all way" field are numerous. A few of the more important advantages will be enumerated below.

Less space is required for actual airport construction and for runway approach control. A comparison between the acreage required for two parallel runways and that required by three wind directional runways is shown in Figure 1.¹¹

⁹ Airport Design, Civil Aeronautics Administration, 1949.

¹⁰ The Airport and Its Neighbors, The Report of the President's Airport Commission, May 16, 1952, p. 35.

¹¹ Ibid, p. 37.

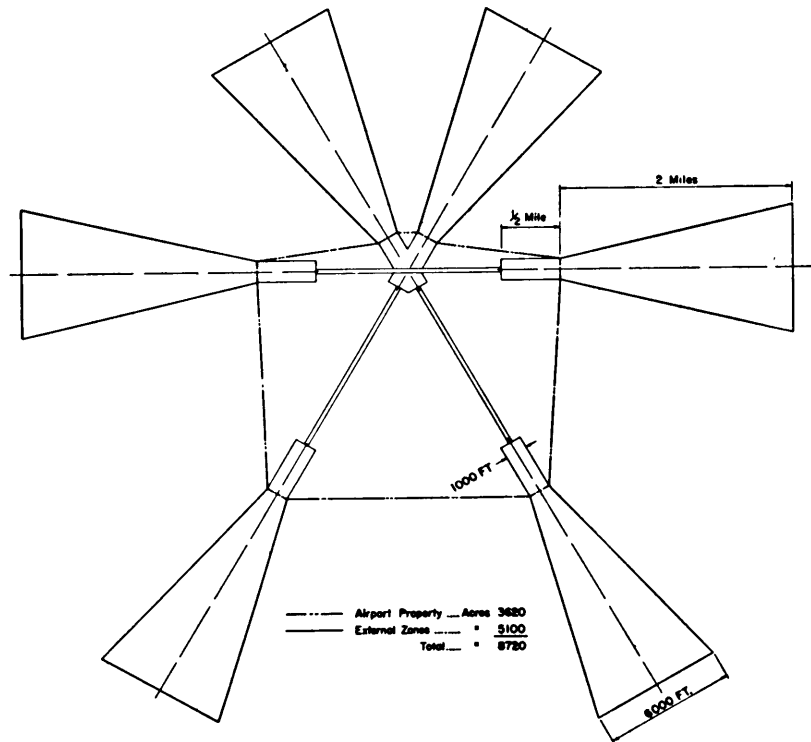
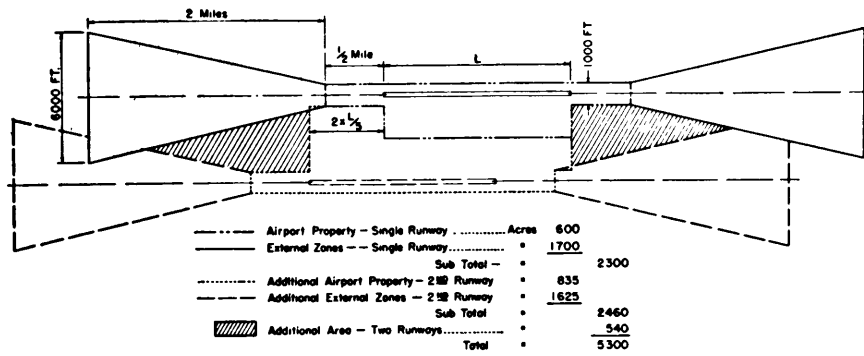


FIGURE 1

COMPARISON OF ACREAGE REQUIREMENTS
FOR PARALLEL AND INTERSECTING RUNWAY SYSTEMS

In addition to the savings in space the uni-directional runway system is capable of handling twice the traffic of the intersecting system. The saving in space requirements is a possible factor in support of close-in airport sites.

Instrument landing facilities are available for landings regardless of wind direction, thereby simplifying instrument approaches and increasing traffic capacity of runway system.

Reduced nuisance to nearby residents will be achieved by selection of runway orientation to reduce flights over congested areas.

Reduced first cost and maintenance of airport since fewer runways and taxiways are required.

Integration into a regional airport network is more easily accomplished when number and direction of runways are reduced.

Corridor technique of approach control is more easily adopted. Air corridors can be established which definitely limit the area covered by aircraft approaching or leaving the airport.

AIRPORT DESIGN AS RELATED TO FUTURE AIRCRAFT DESIGN

It has been observed that the design of airports has closely followed the development of aircraft and that each

new innovation in airplane performance has produced a consequent change in airport design. The airport design procedures have undergone a cycle in attempting to keep up with the changing characteristics of the aircraft. This cycle has been one of reconstruction to lengthen and strengthen runways, but has also been one of destruction through the abandonment of many obsolete cross-wind runways.

As this cycle of changing concepts is likely to continue it poses an interesting academic question. That is, should the airport be designed to reflect the changes in aircraft characteristics or should the aircraft be designed to operate from existing airports.

This cycle of "modernization to obsolescence" is not typical of other forms of transportation, but is peculiar to the aviation field alone. The railroad trackage and rolling stock are both owned and maintained by the same organization; therefore, an improvement in the rolling stock is carefully weighed with respect to the ability of the trackage to handle the improved product. The highway network is somewhat different in that the road system is owned by the public but the vehicles are owned by individuals or commercial organizations. The axle loads are established by the state legislatures and bridge clearances and other design features are established by the various highway departments.

These criteria might be exceeded by the vehicle manufacturer but the vehicle operator is forced to adhere to these design restrictions.

The problem of airport design and the airport's ability to accommodate existing as well as future aircraft is a vastly different problem. The airport problem must also be considered from two different aspects - that of the military air base and that of the civil airport.

The concepts of warfare and national defense have since World War II shifted from the ground to the air. The ability of a nation to defend itself is dependent upon the quality as well as the quantity of the aircraft that the nation can put into the air - and the quality of the aircraft is influenced by such operational factors as its speed, ceiling, range and maneuverability. The attainment of these essential combat characteristics cannot logically be compromised by inadequate ground facilities; therefore, any aeronautical advancement must be duplicated, if necessary, by parallel improvements to air base facilities. The design of ground facilities for military aircraft must keep pace with the aeronautical advancement of these aircraft.

The civil airport, on the other hand, presents a different problem. The civil airport is constructed and maintained by the public through governmental agencies, whereas the airlines are operated by private companies. Some

factions maintain that this governmental sponsorship of airports is a subsidy to the aviation industry. The merits of either side of this controversial subsidy question is not a point of discussion in this thesis and will be dismissed without further comment.

The important point is that the two activities are not controlled by the same organization, as with the railroads; therefore, there might exist a tendency on the part of aircraft manufacturers to partially disregard the limitations of airport facilities in the design of new aircraft. This procedure has been followed in the past and airport operators are apprehensive that the practice will continue.¹²

It is not intended that the progress of airplane evolution should be impeded but that more emphasis should be placed on the development of aircraft which can operate from existing facilities. John M. Kyle of the Port of New York Authority has recommended that the design standards of Technical Order No. N6a issued by the CAA be established as the absolute ultimate to which airport facilities will be expanded and that aircraft designers be advised that this is the maximum that they can anticipate in runway construction.¹³

¹² John M. Kyle, "Airport Standards", An address before the American Society of Civil Engineers, Chicago, Ill., September 5, 1952.

¹³ Loc. cit.

A partial step in the direction of designing the aircraft to fit the airport was taken in the design of the Convair B-36 in which a special landing gear was developed to allow the aircraft to operate from any air base capable of accommodating the B-29, then a standard aircraft.¹⁴ Another step in this direction was the design of the Avro-Jet-liner which was developed to successfully land and take-off from existing airfields without causing damage to existing pavements either from imposed load or angle of incidence of jet to runway surface.¹⁵

EFFECT OF JET TRANSPORTS

The conversion of civil aviation to jet type aircraft is no longer a question. The transition from piston planes to jet transports is within the realm of possibility and the question is not if there will be a conversion but when and to what extent the conversion will take place.

The British have introduced the de Havilland Comet into civil operation and indications are that other countries will follow the British by using later models of the Comet for overseas transportation. This aircraft has demonstrated such performances as the 6,724 mile trip from London to Johannesburg, South Africa to prove that the jet is

¹⁴ Robert McLarren, "Convair B-36", Aero Digest, January, 1954, p. 35.

¹⁵ Kyle, op. cit.

applicable to commercial aviation.

The American aircraft manufacturers have been concentrating on the production of jet aircraft for the military and are now turning to the development of jets for commercial service. Boeing has a jet transport under construction and expects to fly it during the Summer of 1954.¹⁶ Lockheed, Douglas, and Consolidated Vultee Aircraft have jet transports in the design stage. It has been predicted, therefore, that jet transports will be introduced into commercial service in the United States by 1957.

The Air Force has had about 8 years experience with jet aircraft and have solved and are studying many of the problems concerned with jet operation. Many problems continue to arise and will plague the operators of civil airports when jets are introduced into commercial service.

The most significant problems confronting them are those of:

1. Pavement damage by fuel spillage and jet blasts.
2. Increase in airport dimensions to accommodate jet aircraft.
3. Wider influence on surrounding property.

The pavement damage problem is one of pavement design and is not considered in this thesis. Much research has

¹⁶ "Faster Air Travel", New York Times, October 11, 1953, p. 26xx.

been conducted on this subject and has been discussed in the literature.^{17, 18}

The problem of wider influence on the surrounding property is discussed in Chapter IV of this thesis, An Evaluation of Aircraft Noise.

RUNWAY REQUIREMENTS FOR JET TRANSPORTS

The take-off characteristics of the jet transport are different from those of conventional aircraft primarily because the net thrust developed by the jet engine on take-off is considerably less than that developed by the reciprocating engine. In addition the jet depends on the intake of tremendous mass flows of air for the development of thrust and its output is more sensitive to increased temperature and altitude, both of which decrease air density.¹⁹

The runway gradient is also an important factor in

¹⁷ J. A. Bishop, "The Effect of Jet Aircraft on Air Force Pavements: Investigations Conducted by The Bureau of Yards and Docks", Proceedings, American Society of Civil Engineers, Vol. 79, Separate No. 317, October, 1953.

¹⁸ Gayle McFadden, "The Effect Of Jet Aircraft On Airport Pavements: Investigations Conducted By The Corps Of Engineers", Proceedings, American Society of Civil Engineers, Vol. 79, Separate No. 316, October, 1953.

¹⁹ J. G. Borger, "Jet Transport Economics - Influence On Airport And Airway", Proceedings, American Society of Civil Engineers, Vol. 79, Separate No. 241, August, 1953, p.8.

the determination of runway length for jet aircraft. The initial acceleration on take-off is slowly produced and steep adverse runway grades will retard the development of this acceleration. It is probable that future standards for jet runways will specify flatter grades than are now used for conventional runways.

A comparison of the actual maximum take-off and landing runway requirements for conventional and jet transports is given in Table I.²⁰

TABLE I
RUNWAY REQUIREMENTS FOR CONVENTIONAL AND JET AIRCRAFT

Plane	DC-6B	B377	Comet III	Adv. J/T Design
Gross Wt. lbs.	107,000	145,800	145,000	250,000
Take-off Runway:				
Sea level 59°F Ft.	6,340	7,075	6,030	7,900
Sea level 90°F Ft.	6,712	7,757	7,200	9,100
5,000 Ft. 80°F Ft.	7,584	8,478	10,725	11,500
Max. Landing Wt. lb	88,200	121,700	100,000	140,000 ?
Landing Runway:				
Sea level 59°F Ft.	5,150	6,420	6,600	6,100
Sea level 90°F Ft.	5,150	6,420	6,900	
5,000 Ft. 80°F Ft.	5,885	6,900	7,850	7,350

²⁰ Borger, op. cit., p. 9-10.

It can be observed from Table I that the take-off distance will be the final determinant in the establishment of a runway length and that this length should be greater than 9,100 feet for a sea level runway. It is interesting to note that a length of 10,000 feet is now a common minimum for Air Force runways and many runways have been engineered for lengths of 16,000 and 18,000 feet and at least two are in operation with lengths of 14,000 feet.²¹

Conversion to jet transports will require longer runways than are now in existence at the majority of civil airports. The lengths of existing runways at airports of major cities in the United States are given in Table II.²² These values were taken from the August, 1951 report of the Civil Aeronautics Administration and do not reflect any runway extensions which have been constructed since that date. It is interesting to observe, however, that only two airports in Table II would be capable of handling jet aircraft, Logan International at Boston, and Friendship International at Baltimore.

Another critical factor in the design of ground facilities for jet transports is the flatter glide angle required by these aircraft. The current CAA regulations

²¹ Lee B. Washbourne, "Effect Of Jet Conversion Program On Air Installations", The Military Engineer, Vol. XLV, No. 306, July-August, 1953, p. 257.

²² Airline Reports, Civil Aeronautics Administration, August 1, 1951,

TABLE II
 RUNWAY LENGTHS AT EXISTING AIRPORTS (1951)

Location	Airport	Longest Existing R/W Length in 100 Ft.	
		Actual	Corrected
Atlanta	Municipal	79	57
Baltimore	Friendship Intl.	95	83
Boston	Logan Intl.	100	93
Chicago	Midway	65	54
	O'Hare	58	48
Cleveland	Municipal	63	53
Denver	Stapleton	85	52
Detroit	Wayne Major	79	70
	Willow Run	73	63
Los Angeles	International	65	57
Miami	International	74	66
Milwaukee	General Mitchell	67	58
Minneapolis	Mpls.-St. Paul Intl.	65	54
Newark, N. J.	Municipal	60	54
New Orleans	Moisant Intl.	70	62
New York	International	82	75
	La Guardia	60	55
Philadelphia	International	54	50
Pittsburgh	Greater Pittsburgh	60	
San Diego	Lindbergh	87	82
San Francisco	Municipal	89	88
Seattle	Seattle-Tacoma Intl.	75	61
Washington, D.C.	National	67	61

specify a 1:40 glide angle (1:50 for instrument runways) for conventional aircraft. Air Force experience with jet aircraft has indicated that a glide angle as flat as 1:100 might be required for jet transports.²³ The glide angle requirement will perhaps be the more dominant one in deciding whether or not a particular airport can be used for jet operation. Airports which have the current 1:50 glide angle will probably encounter serious difficulties when attempts are made to secure a flatter glide angle and this factor will have a definite effect in limiting the number of airports that can be used for jet operation.

²³ Washbourne, op. cit., p. 257.

CHAPTER III

THE ELEMENT OF HAZARD

The attainment of a safe environment for the individual is an objective which has been pursued for years but which unfortunately has not been realized. Man does not exercise full control over his environment and consequently becomes exposed to numerous inherent hazards in the every day function of living. The occurrence of these hazards, or sources of potential accidents, has increased as our society has become more complex. Practically every technological advance has decreased some form of existing hazard but at the same time has introduced new sources of risk which had to be met and conquered.

The lantern which was upset by Mrs. O'Leary's cow and started the great Chicago fire of 1871 has been replaced by the electric light - yet, in 1949 one-thousand and forty-six people were killed by some form of electricity. Electric power has eliminated many sources of accidents, introduced unlimited benefits and provided the basis for many more technological advances; and at the same time it has introduced a new source of hazard - instant death through electrocution. The American people have accepted electricity as an absolute essential for living, have recognized its inherent hazards and, because of these hazards, have learned

to treat it with respect.

Likewise, the airplane is another technological advancement which has been accepted by the people as an absolute essential - an essential of communication through rapid transportation. The hazards of the airplane must be recognized - not exaggerated - and must be given the consideration which they deserve.

The benefits of aviation are beyond question, yet it presents a dangerous source of hazard, and, unfortunately for the aviation industry, a source of sensational hazard. It is a well known fact that the ordinary every day automobile accident which involves the death of one or two people receives little more than local publication. The air crash on the other hand is less frequent, more spectacular, involves more people and therefore receives national or international publication. Herein lie two dangerous psychological hazards which result from aircraft accidents:

First, practically every air crash is worthy of nation-wide newspaper headlines and the natural tendency of the individual is to interpret such accidents as being the rule rather than the exception.

Second, a local incident becomes a national problem. Witness the three air crashes in Elizabeth, N.J. which aroused local and national public opinion to the point where

the Newark Airport had to be closed until the construction of a new runway had been completed.

The above statements should not be interpreted to mean that there is no hazard in aircraft operation or that the Newark Airport was closed to appease an unjustified indignation of the public. The hazard is definitely a real one and presents a serious problem in the location and design of airport facilities.

There might exist a tendency to exaggerate the potential hazards of aircraft operation near an airport, but whether real or psychological, the danger is impressed on the person who resides in the runway approach zone. The mere possibility that an accident is likely to occur can give the airport neighbor the feeling that he is living under the "Sword of Damocles" and that "death from the sky" is eminent.

RELATIVE SAFETY OF AIR TRANSPORTATION

It has been pointed out that man cannot exercise full control over his environment; therefore, he cannot live in absolute safety. He can however reduce the number and the severity of the hazards to which he is exposed and thereby establish an environment in which he can live in relative safety. Man is constantly striving to reduce the margin between relative and absolute safety.

In spite of the increasing hazards of modern living, the trend of the accidental death rate per 1000 population in the United States is downward. The trend of accidental deaths is given in Figure 2¹ for the period 1900 to 1950. The data in Figure 2 indicate that the accidental death rate in 1950 is only 2/3 what it was in 1900. This remarkable progress in the prevention of accidental deaths is due in large part to the development of a safety conscious attitude on the part of the general public and to the work of organizations such as the National Safety Council. This progress is remarkable indeed when it is recalled that the automobile - the greatest killer of all - has come into prominence since 1925.

Safety has during the past 25 years become a by-word on the American scene. In industry, in households, on the highways - and in the airways - safety has become an important consideration in the environmental development of a mechanical age.

But the trend in accidents is not the sole yardstick for the determination of relative safety. A tabulation of the number of different types of fatal accidents is a more rational approach to the evaluation of the relative safety of a particular activity. The 1950 death certificate

¹ The Airport and Its Neighbors, op. cit., p. 48.

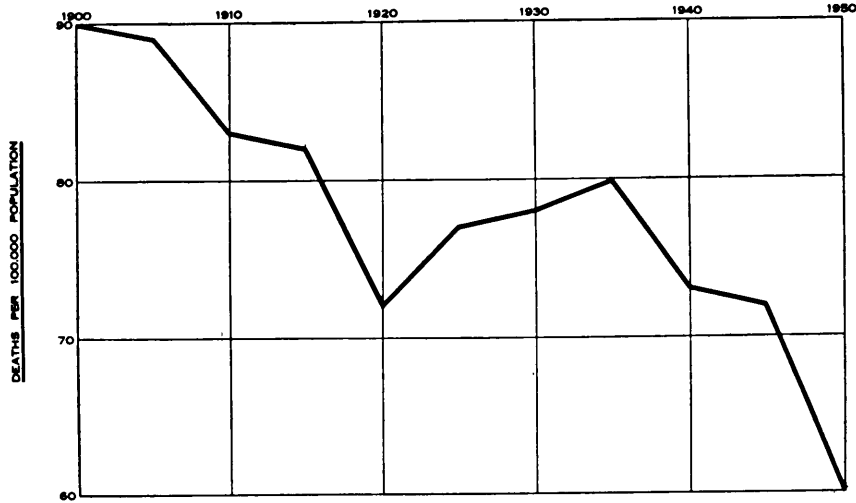


FIGURE 2

ACCIDENTAL DEATH RATE PER 1000 POPULATION

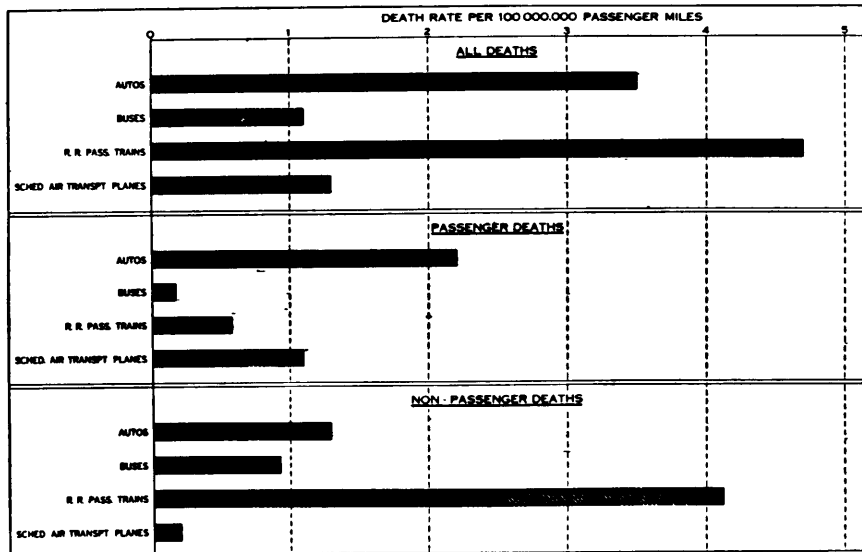


FIGURE 3

ACCIDENTAL DEATH RATES

FOR COMMON U.S. TRANSPORT VEHICLES FOR 1950

tabulation by the National Office of Vital Statistics establishes a list of accidental deaths by cause in the United States.² This list is shown in Table III and indicates that the death toll from aircraft accidents (civil and military) is a very small part of the national total - 1.6 percent to be exact. In 1950 there were 1,436 accidental deaths attributed to aircraft.

A means of measuring the relative safety of different modes of transportation is by use of the fatality rate per 100 million passenger miles. The fatality rates for the four methods of transportation, automobile, bus, railroad and airplane, are shown in Figure 3.³ The data in Figure 3 indicates that buses and scheduled air transportation have by far a better record per 100 million passenger miles than do the automobiles and railroads. The data in Figure 3 also indicate a rather obvious but important fact concerning the nature of aircraft fatalities. The greater number of aircraft fatalities do not occur to people on the ground but to the people on the aircraft. When this fact is taken into consideration the scheduled airlines have a better record than does any other form of transportation as far as non-passenger fatalities are concerned. This fact is

² Statistical Abstract of the United States 1953, p.76.

³ The Airport and Its Neighbors, op. cit., p. 52.

TABLE III
ACCIDENTAL DEATHS BY CAUSE—1950

Accident Type	Number	Percentage
Motor Vehicles	34,763	38.1
Falls	20,783	22.8
Fire, etc.	6,405	7.0
Drownings	4,785	5.2
Poisoning	2,353	2.6
Firearms	2,174	2.4
Railway	2,126	2.3
Machinery	1,771	1.9
Blows	1,613	1.8
Water Transport	1,502	1.7
Aircraft	1,436	1.6
Suffocation	1,350	1.5
Electricity	955	1.0
Others	<u>9,233</u>	<u>10.1</u>
Total	91,249	100.0

important since the airport site should be selected to provide maximum relative safety for the man on the ground as well as maximum safety from the standpoint of aircraft operation.

A rather astonishing fact concerning non-passenger fatalities was disclosed by the President's Airport Commission. Even bicycles kill more innocent bystanders than do airplanes.⁴ In 1949 seventeen persons were killed by bi-

⁴ Ibid, p. 53.

cycles as compared to fifteen (annual average 1946-1951) on the ground by aircraft.

The statistics presented above prove that the hazard to the man on the ground is not as serious as might be suspected. These statistics, however, fall short in one rather important respect. Aircraft accidents are in one way similar to a contagious disease. You can't contract the disease unless exposed to it, neither can you be killed or injured by an airplane unless exposed to the crash. Everyone on the ground is of course exposed to an air crash at some time. The person who lives in the runway approach zone, however, is subject to almost continuous exposure and is usually the "innocent bystander" who is killed or injured. Thus, the persons on the ground who are exposed to air crashes come from a rather small segment of the population and have a higher probability of being involved in an accident than might be indicated by statistics.

GROUND LOCATIONS OF GREATEST HAZARD

The probability that a distressed airplane will hit a given position on the ground is a function of the location of the position with respect to the runway and the class of airplane that is using the runway. The amount of damage which will be done will depend upon what it hits,

its kinetic energy upon contact, fuel load, size and maneuverability.

A technique has been developed for estimating the hazard to population in the vicinity of an airport.⁵ In this technique the probability that an airplane will crash in any given area is estimated and a hazard number is assigned to the area in accordance with the estimated probability. The hazard number is then combined with the population density of the area. A hazard index is thereby obtained, which gives the probability of a crash occurring and the possible extent of the resulting damage. The hazard number which is assigned to a particular area is not an absolute value but is a relative value as compared to other areas in the airport vicinity.

The assignment of hazard numbers cannot be approached on a completely scientific basis but is based mostly upon the experience and intuition of the engineers who developed the system. The shape and size of any hazard area is determined from consideration of the various unfortunate things that might happen to the aircraft, the glide angle and the amount of maneuvering that the pilot might be able to do under the circumstances. "Airport hazard number templates"

⁵ Airports And Their Use, A Report to the President's Airport Commission, Cornell Aeronautical Laboratory, Inc., pp. VI(a) 1-7.

have been developed which indicate the relative degree of danger to areas around an airport. Some of these templates are shown in Figure 4. The airport hazard areas are allocated on the following basis for twin engine aircraft.

Approach:

Area A: In case of complete power failure it is assumed that the pilot can make up to a 45° turn to select the most suitable spot to crash land the plane.

Area B: In case of partial power failure the pilot will attempt to make the runway. If this is impossible he will attempt a landing in the most suitable spot within areas A, B or C.

Area C: As the plane nears the field on its final approach it is going low and slow and probably has gear and flaps down. The consequences of partial power failure are worse than when further out and the danger of stalls is greater because of slow speed.

Take-off:

Area D: Engine failure before the aircraft reaches single-engine speed is certain to cause a crash if the aircraft cannot be stopped within the airport boundary. It is assumed that the pilot can make a turn up to 30° to select the best spot for crash landing.

Area E: If an engine fails after single engine speed

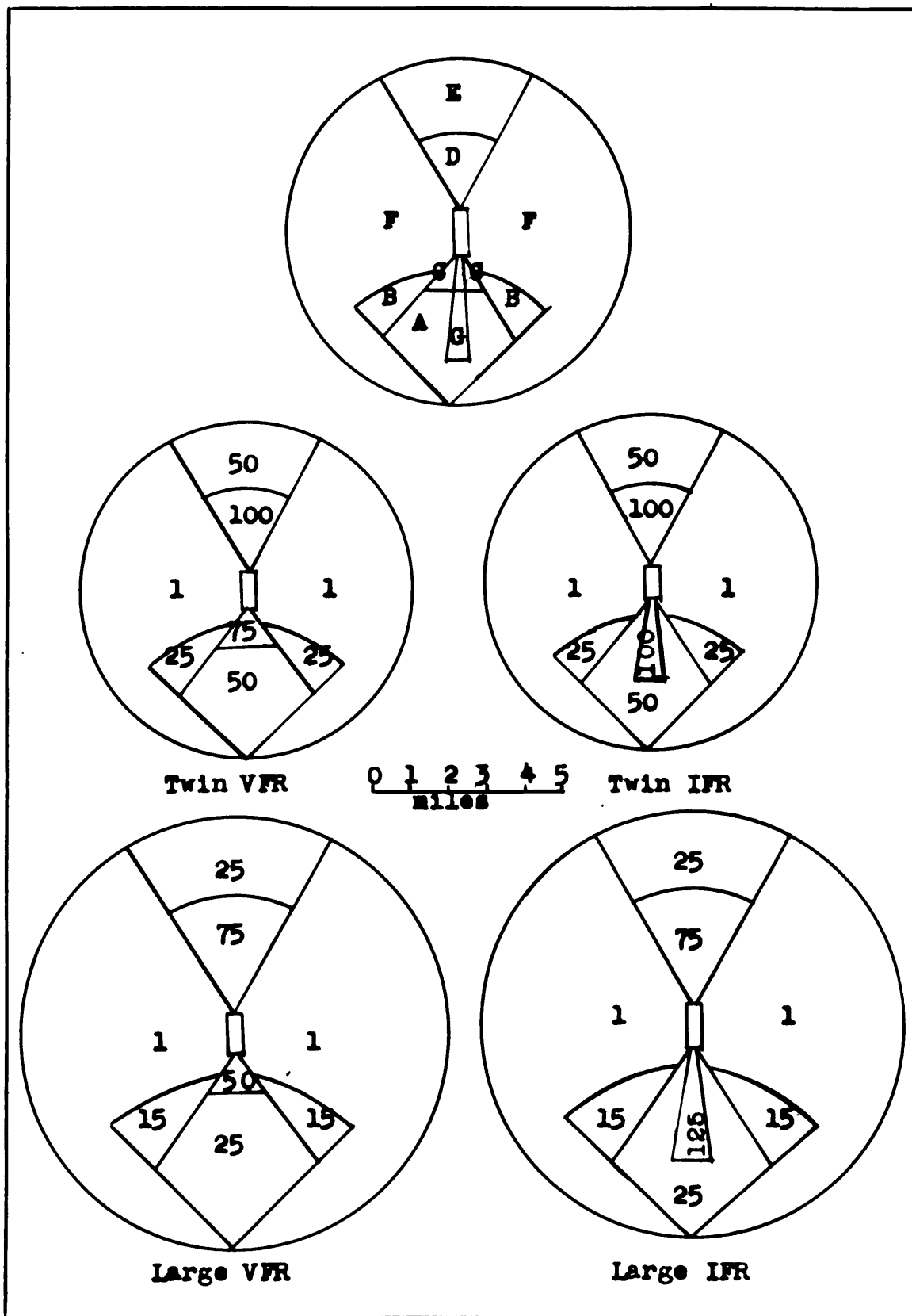


FIGURE 4
AIRPORT HAZARD NUMBER TEMPLATES

is reached, the airplane can presumably go around for a landing. However, the margin over single engine speed is small and there is still a possibility of a crash occurring.

Area F: This area covers all flying in the traffic pattern. The risk of an accident in this area is small but is still not negligible.

Instrument Approach:

Area G: This area is applicable for instrument approaches only. In this area the aircraft is most likely to hit objects on the ground because of poor visibility.

The assignment of hazard numbers for the different types of aircraft is worthy of note. The hazard numbers for VFR (visual flight rules) are larger for twin engine than for large (four or more engines) aircraft. The consequences of an engine failure is less serious in the large aircraft and is accordingly reflected in the hazard numbers. The hazard number for the instrument approach area under IFR (instrument flight rules) conditions is higher for large aircraft for two reasons. First, the accident would probably not be caused by an engine failure thereby eliminating the advantage held by large aircraft. Second, the large aircraft is heavier and carries more fuel and would therefore cause more extensive damage.

The technique of hazard numbers presents a rational approach for determining the areas in which accidents are

most likely to occur. It is interesting to compare the locations secured through the analysis with the actual locations of the crashes which have occurred in the past.

The majority of accidents which occur near airports can be classified in two general categories - those which occur on the final landing approach and those which occur either during or immediately after take-off. The approach accidents are caused by such factors as poor visibility, engine failure, stalls, malfunctioning of equipment, or errors in pilot judgment. The take-off accidents are caused by factors such as engine failure, malfunctioning of equipment, or errors in pilot judgment.

The relative locations of all commercial and military crashes near airports during the period 1946-52 which caused death or injury to persons on the ground are shown in Figure 5.⁶ The locations of these crashes are shown in relation to the runway. No distinction is made between those crashes which occurred during landings and those which occurred during take-offs.

Approximately 50 percent of the accidents shown in Figure 5 fall within half a mile of the end of the runway and along the runway centerline extended. Another 25 percent

⁶ The Airport and Its Neighbors, op. cit., p. 50.

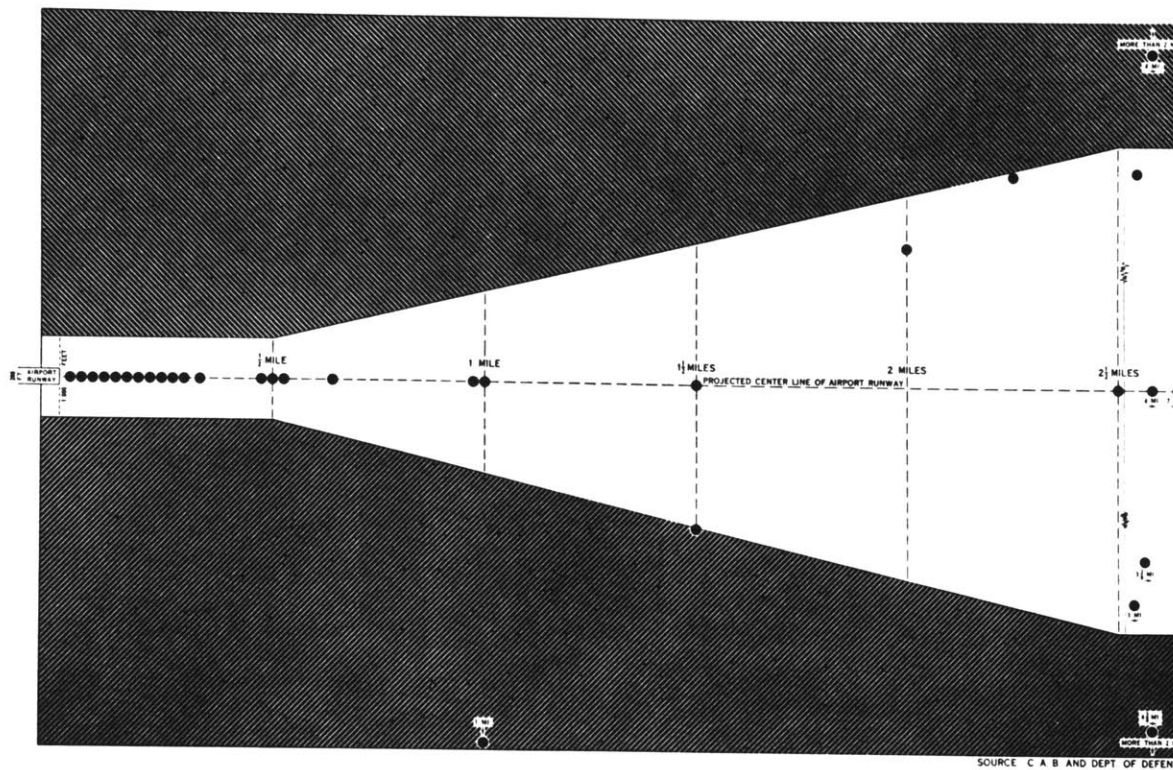


FIGURE 5

LOCATIONS OF CRASHES NEAR AIRPORTS

fall between one-half to two and one-half miles of the end of the runway but not all of these are along the runway centerline extended. These locations are in fairly close agreement with the hazard areas which were established through the hazard number technique.

METHODS OF DECREASING HAZARDS TO GROUND PERSONNEL

The convergence of aircraft within a limited area unquestionably subjects that area to an increased hazard. This hazard is statistically small but is one which the inhabitants of the area are loath to accept. The relative safety record of aircraft operation will probably continue to improve; however, the anticipated increase in air traffic will overshadow the improved safety record and yield a greater absolute number of accidents. The relative number of accidents per 100 million passenger miles or the accidents per 100,000 hours flown may decrease, but the absolute number of accidents will probably increase with the increase in traffic. There is even a possibility that the increased air traffic will cause a saturation of the airways and cause an increase in the relative as well as the absolute number of accidents.

The man on the ground is not concerned with relative safety - he wants and demands absolute safety. The predicted

increase in air traffic will increase the hazards to which he is exposed and will consequently increase his demands for safety.

Lederer⁷ has recommended three methods for decreasing the hazards around airports, which are:

1. Increase the safety of aircraft operations - thereby increasing the safety of ground personnel.
2. Airport planning and land use planning to minimize the danger from disabled aircraft.
3. Provide an adequate crash-rescue program to contain the damage once a crash has occurred.

The first and third methods will undoubtedly reduce the hazards to ground personnel but are beyond the scope of this thesis and will not be discussed further. The second method is the essence of an airport planning program and is discussed below.

AIRPORT PLANNING TO REDUCE HAZARDS

An airplane must have access from the runway to the navigable airspace and return access to the runway. The extent of the area required for this transition will vary with the operating characteristics of the individual aircraft.

⁷ Jerome Lederer, "Airport Safety", Paper presented before the Airport Operators Council, Los Angeles, Calif., March 20-23, 1952.

This transition or runway approach area must remain clear of obstructions to flight to insure a safe passage of the aircraft from the runway to the navigable airspace. The extent of the controlling airspace dimensions necessary to insure safe runway approaches have been established and will be discussed in Chapter VI.

The physical location and orientation of the airport runways will have the most significant effect on the hazards created by aircraft flight to and from the runway. The various aspects of runway design and orientation and their influence on the area surrounding the airport are discussed below.

Runway Length should be sufficient to allow take-off or landing operations and a reasonable allowance for variation in pilot technique, psychological effects, and unforeseen mechanical failures.

Runway Width is primarily related to aircraft operations under reduced visibility and to the control and stability of the aircraft in the final approach and landing. Large aircraft which are not very maneuverable will require wider runways than smaller aircraft. The present maximum width for civil airports is 200 feet and for Air Force Bases is 300 feet. (B 36 type aircraft)

Over-run Areas should be provided at the ends of runways. Air Force runways have 1000 feet over-run strips at each end. Most civil runways have no over-run strips at the present time; however, the President's Airport Commission has recommended that dominant runways of new airport projects should be protected by cleared extensions at each end at least one-half mile in length and 1000 feet wide.⁸

Runway Orientation should be selected to take traffic away from congested areas - and still be consistent with other runway design factors. The two methods to secure suitable orientation are:

1. Preferential Runways are used at airports which have several intersecting runways. The runway which creates the least hazard is used for the majority of aircraft operations.

2. Uni-directional Runways are the "new look" in airport design. All runways on the airport are oriented in the same direction thereby limiting the principal hazard to a single direction. Airport zoning regulations are more easily established and enforced.

Adequate Number of Runways is necessary to serve the anticipated traffic volume. The peak traffic that one runway

⁸ The Airport and Its Neighbors, op. cit., p. 17.

can handle is 40 movements per hour; however this optimum is rarely attained on existing runways.

Separation Between Runways must be a minimum of 3000 feet to permit simultaneous landings and take-offs. Shorter separations introduce the hazard of collisions between airborne planes.

Configuration of Traffic Pattern and Availability of Airspace will have a profound effect on the ability of an airport to handle a large traffic volume. Runways must be oriented to prevent interference between aircraft from different airports in the same region. Airspace must be available in which to develop a traffic pattern.

System of All-weather Navigational Aids is necessary to allow safe operation under all conditions of weather.

LAND USE PLANNING TO REDUCE HAZARDS

The ideal solution to the hazard problem is to provide an area around the airport 5 miles in radius which is entirely free of obstacles and inhabitants. This solution is of course in almost all cases impossible both from the economical and the efficient land use viewpoints. Airports are in existence to serve urban regions and of necessity are located close to these regions. The land surrounding the airport is required for other purposes and by virtue of its proximity

to the airport and the urban region is fairly expensive. The exceptions are marginal lands and water resources and where these geographical features exist they should be utilized as approach areas.

Since the land surrounding the airport cannot be maintained free from inhabitation it should be planned for land uses which will allow occupancy with a minimum of danger. This means dispersion of construction to take advantage of the laws of probability. Dispersion will also serve to reduce the conflagration hazard and will facilitate fire fighting and rescue.

The critical hazard areas are limited to the approach zone; therefore, land use controls should be applied most vigorously within these areas. The population density within the approach area should be maintained as low as is possible. A requirement for low population density automatically eliminates the development of extensive real estate projects such as multi-story apartments or congested housing districts. Likewise, the construction of schools, hospitals, theaters, churches, factories, and other places of public assembly should be prohibited within this area.

The approach lands should be utilized for purposes which will not encourage the erection of structures or the accumulation of population. Ideal usages are parks, forest

and game reservations, water reservoirs, and military reservations.⁹ It is desirable to have trees in the approach area to absorb the energy of impact from an air crash. The trees should not be large enough to offer resistance to the impact of the aircraft but should be a small species that will break and absorb only a partial amount of the impact. The most desirable trees for this purpose are sugar maple, red or black oak, birch, and black locust.¹⁰

It has been proposed by some that building construction within the approach area be of heavy reinforced concrete to withstand the impact of a crash. This method of protection can hardly be justified on an economical basis nor can it be approved as a life saving measure. Airplane passengers frequently survive crashes which should theoretically be catastrophic and non-survivable because the aircraft deflects from a structure and skids a considerable distance before stopping. The kinetic energy of the distressed aircraft is dissipated over a long distance and the passengers are not subjected to the instant deceleration which would result if the aircraft were to hit a solid structure. Rather than use a "pill-box" type construction,

⁹ Airport Planning (Civil Aeronautics Administration), July, 1952, p. 41.

¹⁰ Lederer, op. cit.

Lederer¹¹ has recommended that approach zone structures have flat roofs and possibly rounded corners to produce a deflecting effect. Also, the buildings should be constructed of non-inflammable materials to reduce the dangers of fire.

An analysis of an actual crash, which was theoretically non-survivable, will be presented below to demonstrate the effects of ground obstacles in the destruction of a crashing airplane and also the effects of the airplane on the structures which it hits. The analysis is a crash survival study of the National Airlines DC-6 accident at Elizabeth, N. J. on February 11, 1952.¹² The report was prepared by the Cornell University Medical College to determine the resistance of human beings in air crashes and the aircraft design features which are instrumental in preventing passenger fatalities. The report can be interpreted however to determine the destructive agents on the ground which either prevented or caused fatalities. This particular accident was climaxed by the closing of the Newark Airport on February 11, 1952.

11 Lederer, op. cit.

12 Crash Survival Study: National Airlines DC-6 Accident at Elizabeth, N. J. on February 11, 1952, Crash Injury Research, Cornell University Medical College, October, 1953.

ELIZABETH, N.J. ACCIDENT— FEBRUARY 11, 1952

The following description of the accident is quoted from the accident investigation report prepared by the Civil Aeronautics Board:

At approximately 0020E, February 11, 1952, a Douglas DC-6, N90891, owned and operated by National Airlines, Inc, as Flight 101, crashed and burned after striking an apartment house within the limits of the City of Elizabeth, New Jersey, shortly after take-off from the Newark Airport, New Jersey. There were 63 persons aboard the aircraft, including one infant and a crew of four. Of these, 26 passengers and three members of the crew lost their lives, together with four persons who were occupants of the apartment house into which the aircraft crashed. The other passengers and the stewardess received injuries varying from minor to serious.¹³

The scene of the accident is shown in Figure 6¹⁴ and an analysis of the progressive disintegration and kinematics of the aircraft are shown in Figure 7.¹⁵ The aircraft, in a partially controlled descent, first made light contact with the top of a tree and then "bellied" onto the roof of the apartment building. (Figure 7). Skidding across the roof the plane struck and leveled the low rear parapet of the building to the roof line. Simultaneously, the right outer wing panel was torn off and gasoline from the ruptured tanks cascaded onto the roof and ignited. Because the initial

¹³ Accident Investigation Report, Civil Aeronautics Board, SA-254, File No. 10015, Released: May 16, 1952, p. 1.

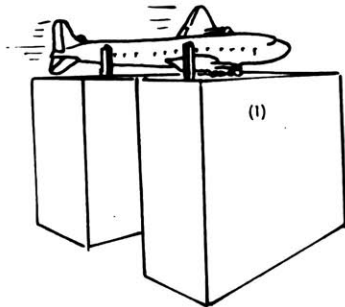
¹⁴ Crash Survival Study, op. cit.

¹⁵ Ibid.



FIGURE 6 SCENE OF ACCIDENT, ELIZABETH, N.J.

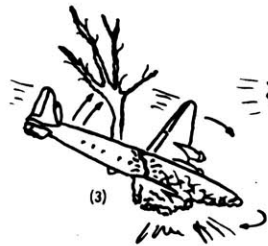
(1) AIRCRAFT BELTIES ONTO ROOF OF APARTMENT HOUSE. RIGHT OUTER WING PANEL TEARS OFF.



(3) REAR CABIN STARTS JACKKNIFING UPWARD AT REAR SPAR AS PLANE STRIKES GROUND.



(2) PLANE STARTS ROLLING TO RIGHT. NUMBER 4 ENGINE DROPS TO GROUND.



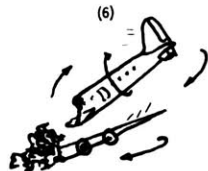
(5) REAR CABIN CONTINUES TO TEAR LOOSE DURING CARTWHEELING ACTION.



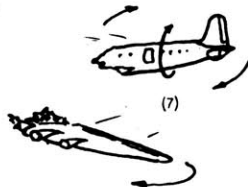
(4) JACKKNIFING CONTINUES AND CABIN BEGINS TO BREAK FREE AS THE FORWARD CABIN DISINTEGRATES AND THE CENTER SECTION STARTS CARTWHEELING.



(7) & (8) CENTER SECTION CONTINUES CARTWHEELING AS REAR CABIN ROLLS AND TURNS IN 'FLIGHT'.

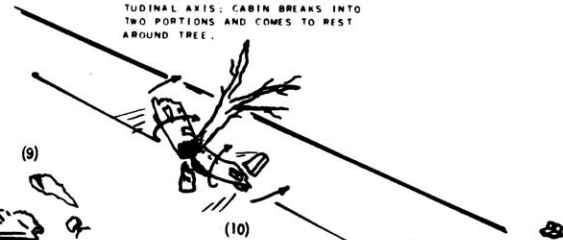


(6) REAR CABIN TEARS COMPLETELY LOOSE IN A "SNAP-THE-WHIP" ACTION AS IT STARTS ROLLING TO THE RIGHT AND TURNING ON ITS OWN AXES.



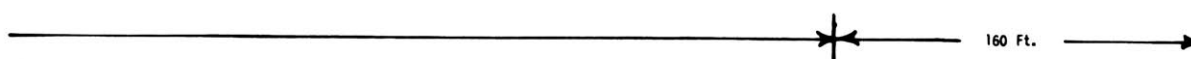
(9) CENTER SECTION COMES TO REST AND BURNS AFTER HAVING CARTWHEELED MORE THAN 180°.

(10) REAR CABIN, STILL IN 'FLIGHT', STRIKES TREE WHILE PARTIALLY INVERTED AND ROLLING ON ITS LONGITUDINAL AXIS; CABIN BREAKS INTO TWO PORTIONS AND COMES TO REST AROUND TREE.



SEAT THROWN FROM REAR CABIN DURING IMPACT WITH TREE.

280 Ft.



160 Ft.

FIGURE 7 ANALYSIS OF PROGRESSIVE DISINTEGRATION AND KINEMATICS OF AIRCRAFT

contact with the flat roof was at a low angle, no force of any consequence was transmitted to the passengers. The airplane then skidded off the building and a moment later struck the ground at about 140 mph.

The aircraft began to disintegrate upon contact with the ground. The center section, left wing, the demolished forward cabin structure (which struck the ground first), and the intact rear cabin cartwheeled towards a line of trees bordering a nearby street. During this cartwheeling, the rear cabin structure tore free from the center section and hurtled through the air. This "free flight" of the intact rear cabin ended abruptly when it struck a thick tree trunk. The section of the airplane jack-knifed around the tree and broke it off at the ground. The force of the impact crushed the two passengers who were seated at the point of contact.

It is astonishing that only 29 persons aboard the aircraft and only 4 persons in the apartment house were killed. This death toll would undoubtedly have been higher had the aircraft struck the school which was adjacent to the apartment house or had it struck any obstacle which would have caused an instantaneous deceleration. It is believed that the pilot of the DC-6 was attempting to make a crash landing in the open school yard (see Figure 6) which

probably accounts for the fact that the aircraft hit only one structure. This factor is another strong point in favor of dispersion of construction - that is, the pilot of a distressed aircraft will be able to find a spot in which to attempt a crash landing.

The four persons in the apartment house who were killed did not come in direct contact with the airplane but were killed in the fire which followed the crash. The fire was started when the aircraft hit the rear parapet and spilled gasoline over the roof; it is possible that the apartment house residents would have escaped injury had the roof been completely flat.

An analysis of this particular accident points up four important facts concerning land use in the runway approach zone:

1. Dispersion of construction is essential to reduce the probabilities and consequences of an airplane hitting a structure and to provide spots for crash landings of partially controlled aircraft.
2. Flat roofs are the best structural defense against air crashes.
3. Fire-proof construction is essential.
4. Trees should be of a small species so as to break under impact without offering a sizable resistance.

SUMMARY

The probability that an aircraft accident will occur near an airport is mathematically slight but disturbing to the airport neighbors. The point of greatest danger is in the half-mile strip at the end of the runway underlying the runway centerline extended. The best method for control of ground hazard is to design the airport to take the air traffic away from populated areas by locating runway approaches over water, marginal lands, forests or reservations. Where such runway orientation cannot be obtained the land use in the approach zone should be controlled to encourage the dispersion of structures and the use of fire-proof construction.

CHAPTER IV

AN EVALUATION OF AIRCRAFT NOISE

The problem of aircraft noise and its reduction has been of interest for many years but is now becoming a greater concern because of the higher noise levels which are being generated and the increasing number of persons who are being exposed to these noises.

Considerable progress has been made in the sound proofing of civilian passenger aircraft to protect the airline passenger from the harmful or irritating effects of engine noises; but little progress has been made in the reduction of the noise at its source, the aircraft power plant. Prior to World War II there was little attention given to the reduction of the actual engine or propeller noises since only the aircraft passenger was exposed to the noise and he could be adequately protected. Military aircraft on the other hand could not be operationally handicapped by the power loss which would accompany engine muffling or by the additional weight which would have been required for the reduction of propeller noises.

The development of larger and faster aircraft has been made possible by the parallel development of larger, and noisier, aircraft power plants. The operation of these noisier aircraft coupled with the tremendous increase in air

traffic has focused attention on the necessity for providing some sort of noise protection for the man on the ground.

Aircraft operating between airports usually fly at altitudes sufficiently high to eliminate the annoying effects of noise at ground level. It is only when the aircraft is near the ground, as in take-off or landing, that the noise is intense enough to become objectionable to persons on the ground. Unfortunately however, all aircraft which operate in any given vicinity must be funneled into the area airport or military air base and the continuous concentration of noise results in extreme annoyance or even pain to persons on the ground.

Some study has been made concerning the relationship between aircraft noises and airport neighbors and recommendations have been made regarding the possible selection of more feasible airport sites and improved operational procedures (for pilots) to minimize the effect of aircraft noise at ground level.¹ One obvious solution to the noise problem would be to site all airports in remote locations so that no one would be exposed to the aircraft noises. This solution however, would hardly be practical for the civilian airport. The remote location of airports would

¹ The Airport and Its Neighbors, op. cit., pp. 19-20.

partially nullify the advantage of fast air travel between cities since considerable time would be consumed by the increased amount of surface travel which would be required between airport and city. Military air bases on the other hand have no critical requirement for rapid surface transportation between air base and city; therefore, remote locations for air bases might be a practical solution to the military aircraft noise problem. However, the remote locations for air bases will afford no relief from noise for the five thousand to ten thousand permanent residents of the base who are likewise subjected to the high intensities of aircraft noises.

The effect of aircraft noise on ground personnel and the consideration of the noise problem in airport planning will be discussed in this thesis from the following aspects:

1. The effect of aircraft noise in relation to the residents who either live or work in the immediate vicinity of an airport, particularly those persons who are located in the runway approach zones.

2. The effect of aircraft noise in relation to the permanent residents of the air base or the employees of the civil airport.

3. The development of planning techniques to reduce or to control the sound levels which will reach human ears.

NOISE AND ITS EFFECT ON PEOPLE

The effect of noise on people and its consequent importance in airport planning will require an evaluation of the following items:²

1. Man and his receptor mechanisms through which the noise acts.

2. The composition of the noise field.

3. The reaction of the individual to the noise.

Man's reaction to noise will be used as a basis for determining the maximum allowable noise level to which a person can be safely exposed and the desirable maximum levels allowable to insure suitable working conditions.

SOUND AND THE MEASUREMENT OF SOUND INTENSITIES

Sound is a pressure variation in the air set up by a vibrating object. The vibrations cause alternating increases and decreases in the pressure of the air with which the object is in contact. The frequency of the sound wave is the number of complete cycles of pressure variation which occur in a unit time, usually a second. A series of pressure variations of the same frequency is a pure tone, and a mixture of pressure variations of different frequencies is noise.³

² Horace O. Parrack, "Aircraft Noise and Noise Suppression Facilities - An Evaluation", p. 1.

³ Ibid., p. 2.

When the hearing of a person is considered, noise may be defined simply as "unwanted sound".

The intensity of sound is measured by the decibel which is an expression of intensity as a ratio rather than as an absolute magnitude. The decibel is defined as 10 times the logarithm of the ratio of two energies; but it can also be applied to the ratio of two pressures, velocities, voltages, etc. which are related to energy by a square law. Therefore, the number of decibels in the ratio of two sound pressures is 20 times the logarithm of the ratio.

$$N = 10 \log \frac{E_1}{E_2} = 20 \log \frac{p_1}{p_2} \quad (1)$$

Where N is the number of decibels, E_1 and E_2 are the energies and p_1 and p_2 are the pressures.⁴

The decibel notation actually states the intensity of one sound as compared to the intensity of another sound; therefore, it has been necessary to establish a reference pressure level which can be used as a standard basis for comparison. The standard reference level has been defined by the American Standards Association as an intensity of 10^{-16} watts per square centimeter. This intensity

⁴ Hallowell Davis and Stanley S. Stevens, Hearing, Its Psychology And Physiology, p. 29.

corresponds to a root-mean-square pressure of 0.0002 dynes per square centimeter in a plane progressive sound wave.⁵ When a value of 0.0002 dynes per square centimeter is used as a reference pressure equation (1) becomes:

$$N = 20 \log \frac{p}{0.0002} \quad (2)$$

Where p is the pressure measured in dynes per square centimeter.

A decibel scale of sound intensities for various noises is illustrated in Figure 8.⁶ This scale of Figure 8 can be used as a basis for comparison of different types of noises.

The decibel scale is strictly a physical scale for the measurement of the intensity of a sound and does not reflect the effective sound intensity which is sensed by the ear. The ear has a tendency to reject sounds of low frequencies; therefore a sound of constant intensity which varies in frequency would not create the same sensation of "loudness" at the ear over the entire frequency range. This relationship between intensity and frequency is very important in the study of aircraft noises, since these noises contain sound frequencies over the entire audible range.

⁵ Albert London, Principles, Practice, And Progress Of Noise Reduction In Airplanes, NACA Technical Note No.748, p.5.

⁶ Ibid., Figure 1.

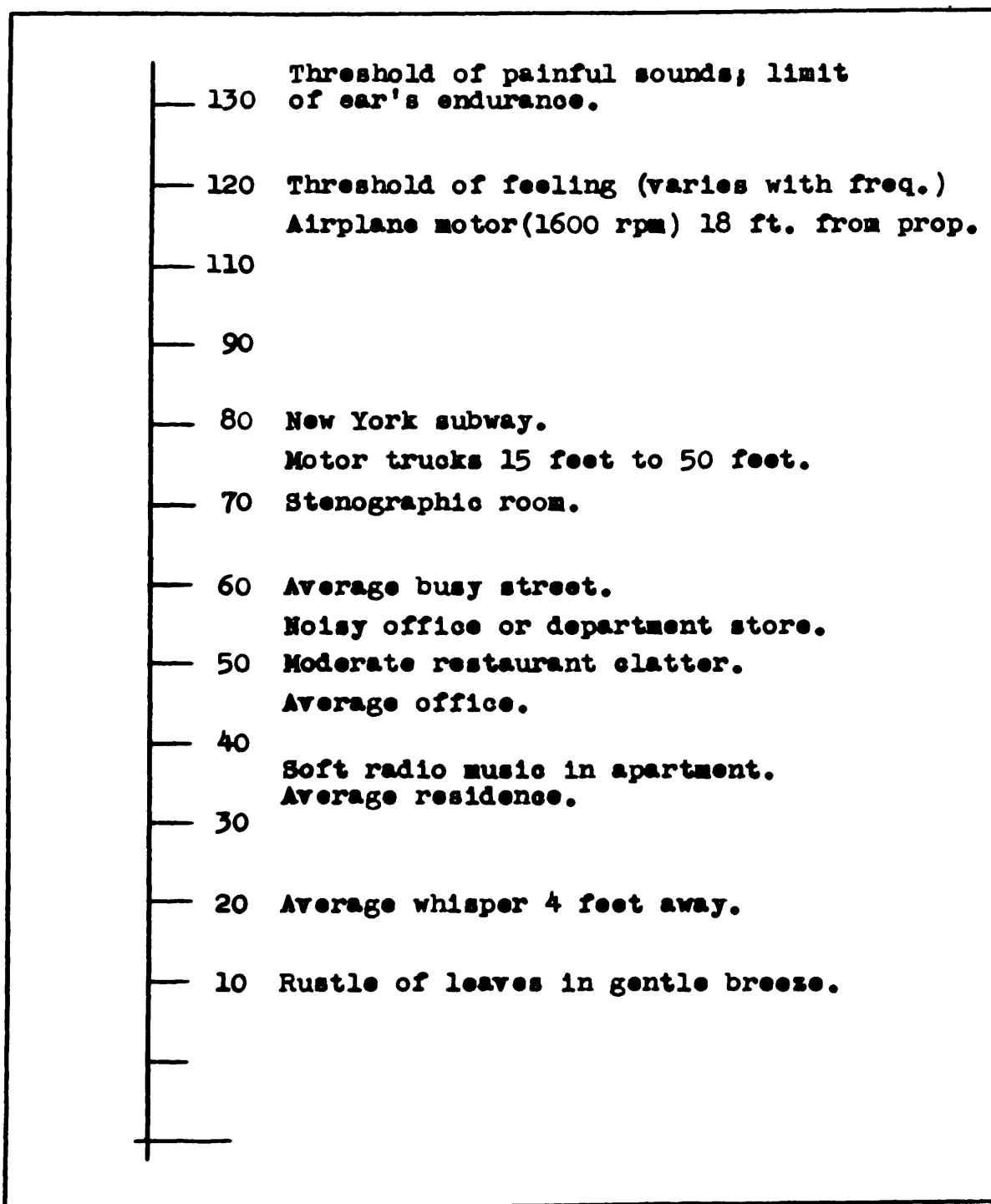


FIGURE 8
SOUND INTENSITY FOR VARIOUS NOISES

The sensation which is perceived by the ear as a result of sound vibrations is a function of both the frequency of the sound and the intensity of the sound. This physical sensation caused by the sound is of more importance than the actual intensity of the sound for a particular frequency. The term, "loudness", has been established to express the effective sound intensity which is perceived by the ear as a result of a sound stimulus.

The relationship between the frequency and the intensity of sound was investigated by Fletcher and Munson using a frequency of one thousand cycles as a reference tone. The results of this investigation were reported in the Journal of the Acoustical Society of America,⁷ and a graph which was developed as a result of this investigation is reproduced in Figure 9. Loudness contours are plotted on the graph using the frequency of the sound in cycles per second as the abscissa and the intensity level of the sound in decibels as the ordinate. The 120 decibel loudness level contour has been marked "Feeling". Data published on the threshold of feeling indicates that this contour is very close to the point where the ear can actually feel as well as hear the sound.

⁷ Harvey Fletcher and W. A. Munson, "Loudness, Its Definition, Measurement and Calculation", Journal of the Acoustical Society of America, Vol. 5, pp. 82-108.

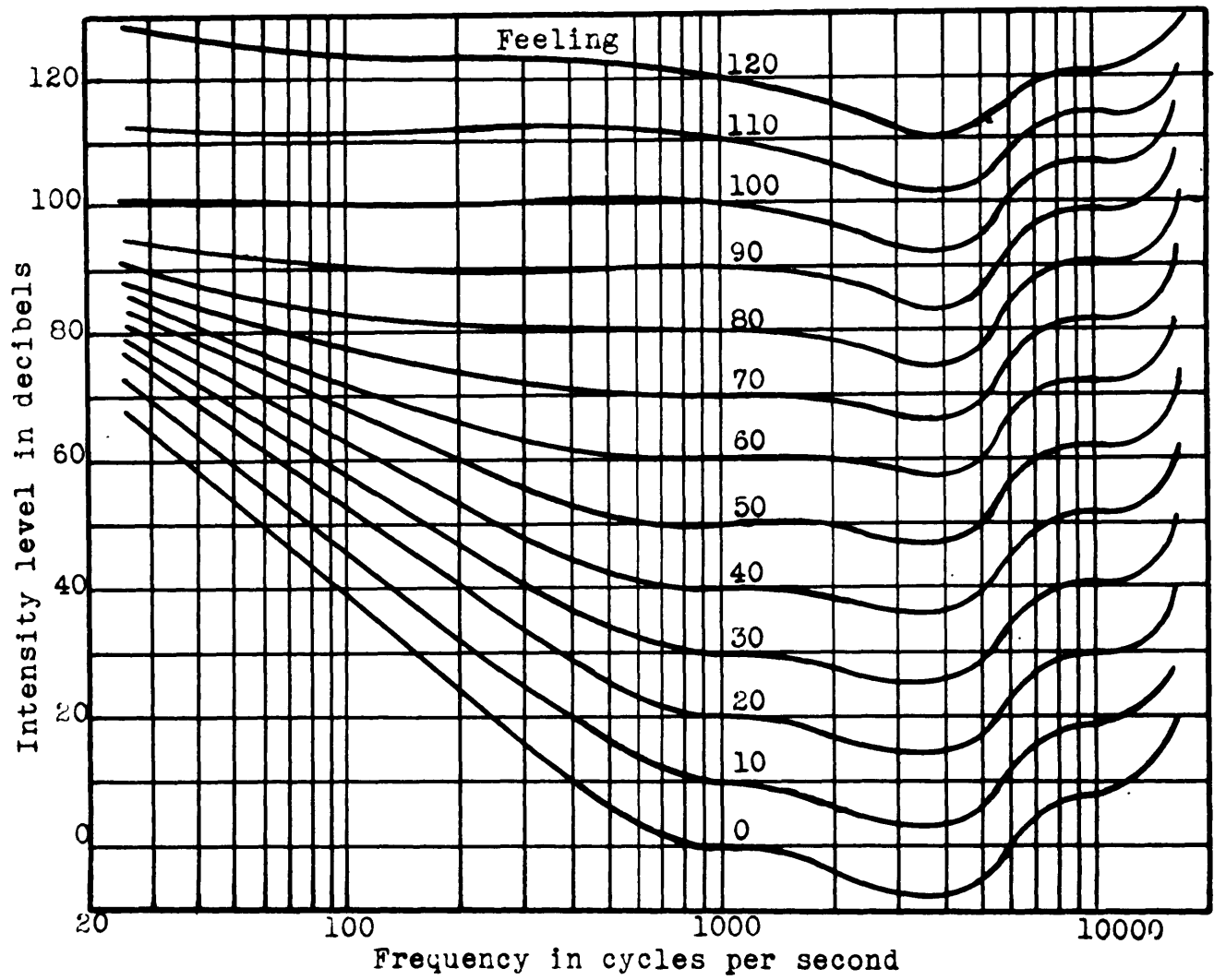


FIGURE 9

LOUDNESS-LEVEL CONTOURS

It can be noted from Figure 9 that the ear will experience the same sensation of loudness (30 decibels) for an 80 cycle sound at 60 decibels as for a one-thousand cycle sound at 30 decibels.

The loudness contours of Figure 9 represent loudness levels. The loudness level is usually expressed in phons. The term, sone, is used to express loudness and one sone is defined as the loudness of a one-thousand cycle tone with an intensity of 40 decibels above threshold. The threshold of feeling corresponds approximately to a loudness level of 120 decibels or to a loudness of 240 sones.⁸

IMPORTANT NOISE LEVELS TO BE CONSIDERED

There are several noise levels which must be considered before the full effect of aircraft noises on people can be analyzed. These levels are:

Conversational speech level. The overall pressure level of human speech varies considerably but the level of the five-hundred to one-thousand cycle band is just below 80 decibels when measured at a distance of 18 inches from the speaker's mouth. The speech level is 64 to 66 decibels at a distance of six feet from the speaker's mouth.⁹

⁸ Davis and Stevens, op. cit., p. 125.

⁹ Parrack, op. cit., p. 4.

Discomfort threshold. A sensation of discomfort is experienced by the ear at approximately 120 decibels.¹⁰ This level corresponds to the 120 decibel loudness contour of Figure 9.

Pain threshold. A sensation of pain is experienced by the ear when the sound level approaches 140 decibels. The pain threshold is located 140 decibels for all frequencies up to at least twelve thousand cycles per second in men with normal hearing.¹¹

Threshold of mechanical damage. The threshold of mechanical damage to the structure of the middle ear is at a sound level of approximately 160 decibels for all frequencies between 250 and ten thousand cycles per second.¹²

Body receptors other than the ear are stimulated by high noise levels. Certain frequencies at intensities of about 140 decibels produce a sensation of vibration of the skull, chest wall and abdominal wall. These vibrations have in some cases induced nausea and vomiting among individuals exposed to the high noise levels. Additional research has revealed that some persons who have suffered skull fractures or concussions will experience attacks of epilepsy when exposed to high noise levels.

10 Ibid., p. 5.

11 Loc. cit.

12 Loc. cit.

ESTABLISHMENT OF A MAXIMUM ALLOWABLE NOISE LEVEL

Continuous exposure to extremely high noise levels will eventually result in harmful effects upon the persons exposed. The noise levels which have previously been established for the thresholds of feeling, pain, and mechanical damage present the levels at which these harmful effects can be anticipated. A sound level of approximately 65 decibels has been established as the normal level for conversational speech and it can be further anticipated that noise levels much above this value will present a serious detriment to effective voice communication. This fact should be considered in establishing a maximum allowable noise level to be approached in airport design.

The design level which is established must be one which will allow voice communication between individuals and also one which will not physically affect persons who are exposed to this noise for a prolonged period of time.

Experiments to determine a maximum allowable noise level have been conducted at the research division of the Aero Medical Laboratory and some of the results of this investigation are reported below.

Specifications for the maximum noise levels in each octave that will not, in time, produce permanent damage to an ear, which is exposed daily and continuously for eight hours out of every twenty-four hours, is at this time impossible. Estimates of this maximum from different sources vary considerably. Perhaps the most liberal of these estimates would allow as much as 110 decibels for frequencies below 75 cycles per second, about 100 decibels for frequencies between 75 and 150 cycles per second and about 95 decibels for all higher octave bands. The authors consider the highest sound level which will allow direct speech communication with a loud voice between persons separated by a distance of 6 feet as a maximum for safety both for the ear and for the prevention of other accidents. Under these circumstances sound levels as high as 95 or 100 decibels may be allowed for the frequencies below 150 cycles per second, but the overall level for all other frequencies up to about 10,000 cycles per second must be no more than 85 decibels. Not a few otolaryngologists concerned with the problem of industrial noise feel that even this relatively low level is too high for safety.¹³

The United States Air Force has adopted a standard of 85 decibels as the highest sound level to which personnel should be continuously exposed without ear protection.¹⁴ This standard will be used in this thesis as a maximum allowable sound level for design and it will be assumed that only those persons whose duties are in the immediate vicinity of operating aircraft will require ear protection.

¹³ Horace O. Parrack and Donald H. Eldredge, "Noise Problems Associated with Aircraft Maintenance", The Journal of Aviation Medicine, Vol. 22, No. 6, pp. 470-1.

¹⁴ Air Force Regulation No. 160-3, "Precautionary Measures Against Noise Hazards", dated 31 August 1949.

The high noise levels generated by aircraft make it impossible to plan an air base so as to site all base activities beyond the 85 decibel noise level. However, an attempt will be made to analyze and to predict the locations of the maximum noise concentrations, to study the available means of noise attenuation, and to plan the physical arrangement of air base activities so as to utilize the quietest regions for specific purposes which require low noise levels.

METHODS OF NOISE ATTENUATION

There are three possible methods by which noise level can be reduced; namely attenuation at the source, attenuation by barriers and attenuation by distance.¹⁵ These three methods will be analyzed to determine the specific methods whereby the level of aircraft noises might be reduced before reaching airport personnel or nearby residents.

Attenuation at the Source will require the installation of mufflers on engine exhausts and the complete redesign of propellers to achieve any appreciable reduction in

¹⁵ Airports And Their Use, op. cit., p. VI(b)-4.

noise levels. Considerable research^{16,17} has been conducted to determine effective means of reducing noise levels at the source; however, all existing methods of engine noise reduction would be accompanied by additional weight penalties and loss of engine power. The operational effectiveness of military aircraft demands that weight be held at a minimum and power at a maximum to insure the highest combat efficiency of the aircraft. The penalties incurred by attenuation at the source cannot be accepted in military aircraft; therefore this method of noise reduction will not be considered as a means of reducing the aircraft noise levels. The levels which are generated by existing aircraft will be used in this thesis to develop airport planning techniques. Any significant future development in engine muffling or propeller quieting can then be applied against the anticipated higher noise levels of future aircraft.

Attenuation by Barriers is presently being utilized in the design of jet engine test cells and other fixed installations.¹⁸ These protective barriers are used primarily

16 Harvey H. Hubbard and Arthur A. Regier, "Status of Research on Propeller Noise and its Reduction", The Journal Of The Acoustical Society Of America, Vol. 25, No. 3, pp. 395-404.

17 Harvey H. Hubbard, A Survey Of The Aircraft Noise Problem With Special Reference To Its Physical Aspects, NACA Technical Note 2701, May, 1952.

18 Parrack, op. cit., p. 36.

in the testing of aircraft engines and serve to reduce the over-all sound level at ground level. It has been proposed that sound barriers or sound reflectors be constructed near the ends of runways to reduce the noises generated by aircraft which are performing pre-take-off engine checks. This type of barrier will provide some reduction in the over-all noise level, but the maximum noise levels are generated during the take-off and climb phase and such barriers would be of little benefit.

Another type of barrier against noise is the ear defender¹⁹ which is utilized by mechanics and maintenance personnel who are in very close contact with operating aircraft. This type of defense is ideally applicable to maintenance forces but can hardly be extended to other airport personnel or to residents outside the limits of the airport.

Attenuation by Distance represents the one possibility of reducing the noise level before it reaches human ears; namely by utilizing the natural attenuation of sound by distance. Sound which emanates from a concentrated source, and thus having a spherical wave front tends to diminish inversely as the square of the distance from the source. That is, whenever the distance is multiplied by ten the intensity of the sound is reduced by a factor of 100; or when

19 Parrack and Eldredge, op. cit., p. 474.

the distance is increased by a factor of 10, the intensity is reduced by 20 decibels.²⁰

This relationship between sound intensity and distance is plotted graphically in Figure 10,²¹ and demonstrates the effect of distance as a means of sound attenuation. The noise levels for three different aircraft, a "Cub" type, a heavy transport and a major type military aircraft are plotted in Figure 10 at assumed sound levels of 80, 110, and 140 decibels respectively, measured at a distance of 100 feet from the aircraft. No allowance was made in Figure 10 for the additional attenuation benefits associated with air damping and surface losses.

In addition to the attenuation achieved by the inverse square relationship there are two other advantages associated with the method of attenuation by distance. These advantages which will be discussed later are:

1. Absorption of sound energy by the atmosphere.
2. Absorption of sound energy by the terrain.

²⁰ Airports And Their Use, op. cit., p. VI(b)-5.

²¹ Ibid, p. VI(b)-7.

APPROXIMATE SOUND LEVEL vs DISTANCE
FOR THREE ASSUMED AIRCRAFT

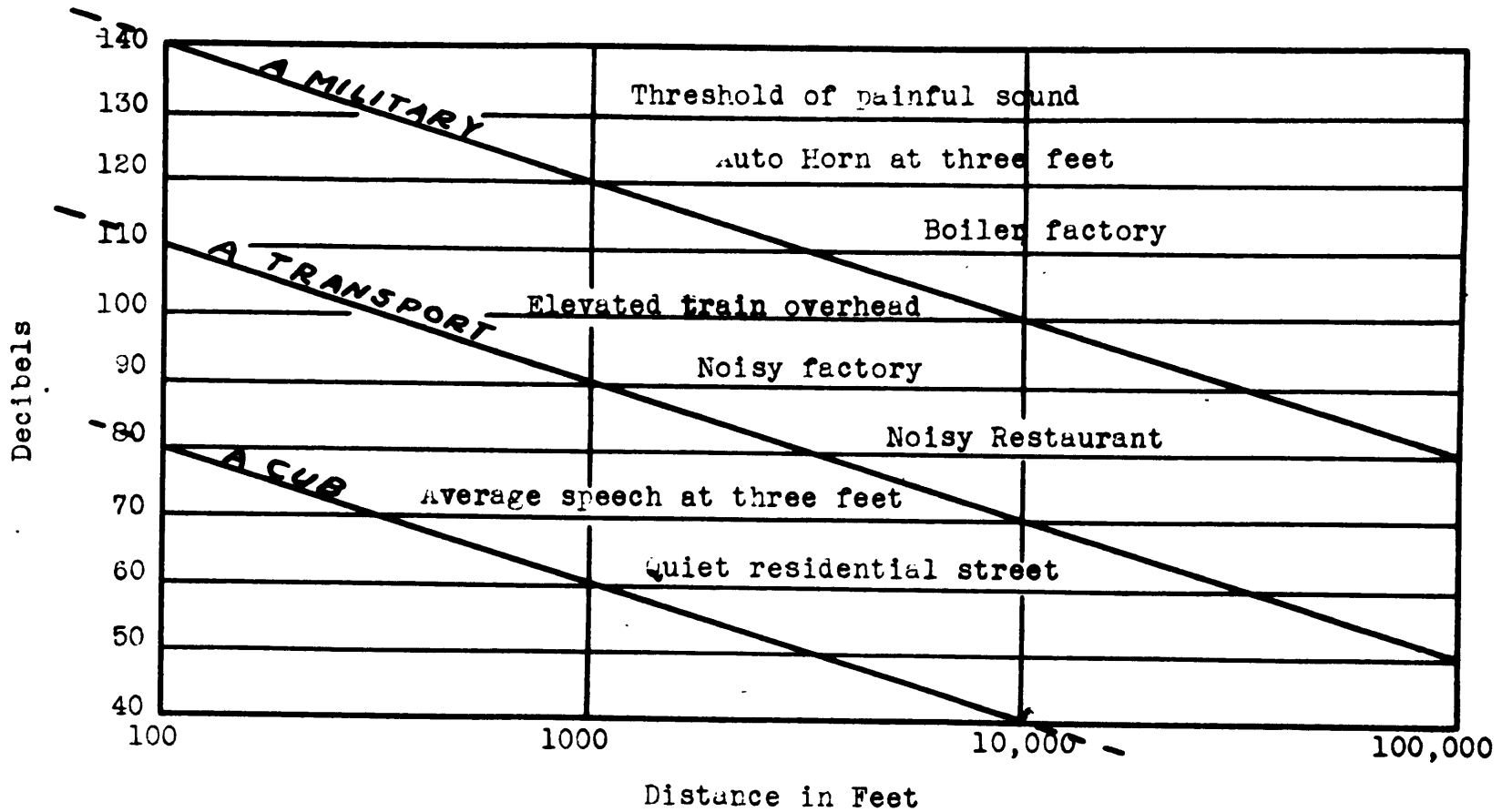


FIGURE 10

FACTORS GOVERNING THE ATTENUATION OF SOUND BY DISTANCE

The mathematical relationship²² for the attenuation of sound by distance can be expressed as,

$$I = -20 \log_{10} \frac{S_2}{S_1} - 4.34 m (S_2 - S_1) \quad (3)$$

where,

I = the difference in sound intensity level expressed in decibels.

S = the distance from the source.

m = the fraction of sound energy lost per unit distance.

Equation (3) indicates that the energy loss due to spreading of the sound wave varies as the logarithm of the distance ratios, whereas the losses due to absorption are proportional to the loss coefficient m and the distance between the two points under consideration.

The absorption of sound energy by the atmosphere is dependent upon several variable factors, which are:²³

1. The composition of the atmosphere.
2. Temperature gradients.
3. Wind gradients.

²² Arthur A. Regier, Effect Of Distance On Airplane Noise, NACA Technical Note No. 1353, June, 1947, p. 3.

²³ Uno Ingard, "A Review of the Influence of Meteorological Conditions on Sound Propagation", The Journal Of The Acoustical Society of America, Vol. 25, No. 3, p. 406.

4. Gustiness of the wind.
5. Terrain conditions.

The meteorological conditions (items 1-4) which influence the attenuation of sound vary over a wide range during the course of a year; therefore the attenuation effects of these factors will be essentially unpredictable. Experimental data indicate that maximum absorption of sound by the atmosphere occurs when the relative humidity is approximately 20 percent. Other data indicate that the atmosphere loses some of its absorbing qualities with increases in temperature. The calculated effect of the atmospheric absorption of sound energy is illustrated in Figure 11²⁴ for a temperature of 68°F and a relative humidity of 40 percent. The curve of no atmospheric losses is plotted as a straight line on the semi-logarithmic scale and represents the inverse square relationship of attenuation by distance. It is shown in Figure 11 that there is very little atmospheric absorption of the lower frequencies but there is a sizable absorption of the higher frequencies.

²⁴ Regier, op. cit., Figure 2.

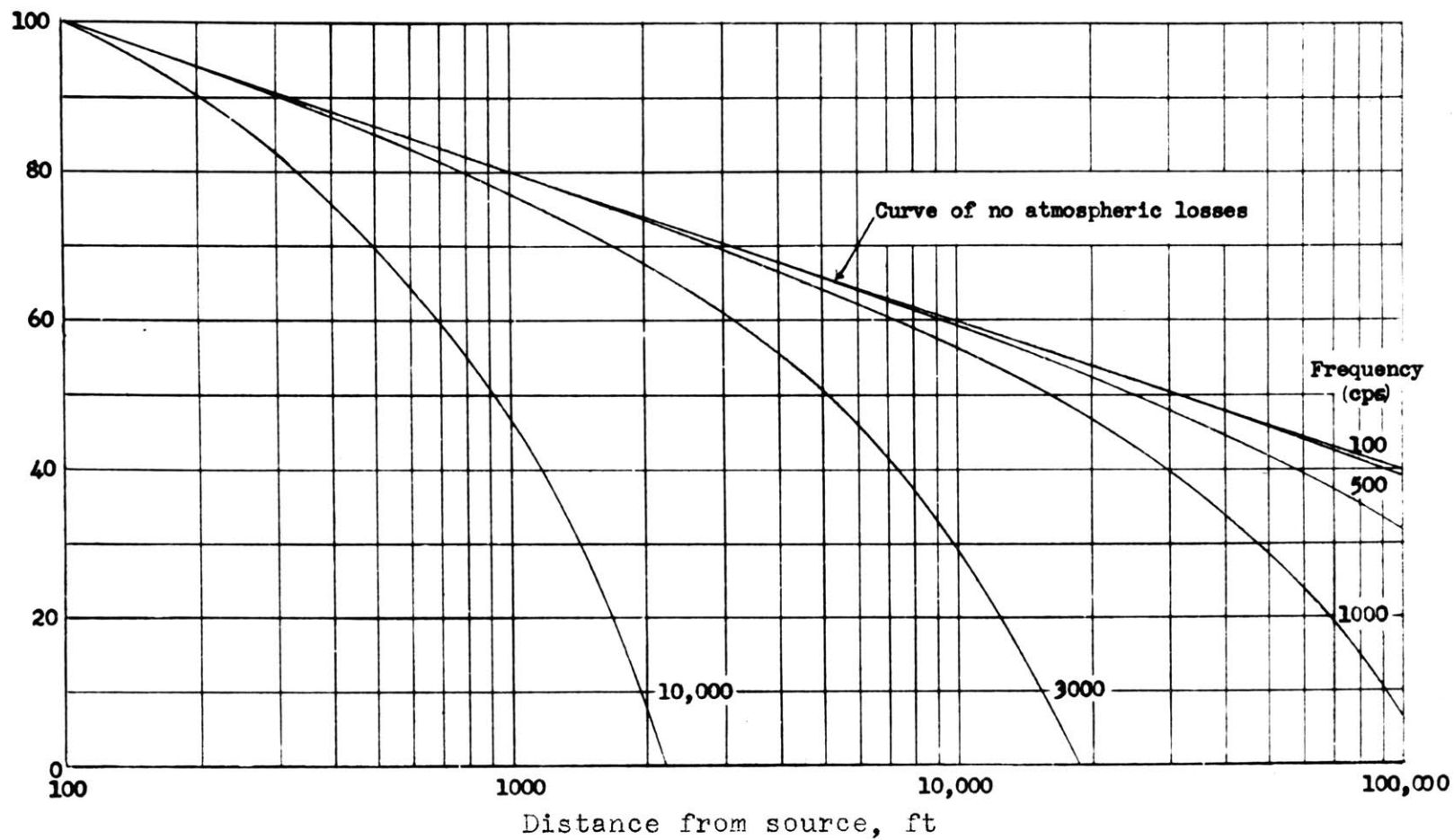


FIGURE 11

SOUND PRESSURE LEVEL AS A FUNCTION OF DISTANCE FROM SOURCE

ATTENUATION BY TERRAIN ABSORPTION

When a sound wave travels parallel to the surface of the earth a portion of the sound energy is dissipated at the edge of the wave as it travels across the ground. The extent of the energy dissipation will vary from a minimum value over a bare or paved surface to a maximum value over trees, high grass and dense underbrush. Experimental results indicate that the amount of this energy dissipation or frictional absorption due to high grass, shrubs and trees is probably large and will reflect a correspondingly large increase in the attenuation of sound level by distance.

The absorption of sound by trees, grass and shrubs is effective only when the sound waves travel parallel to the surface of the earth; therefore this absorption would be of little consequence when the noise source is directly overhead. The absorption by vegetation will be considerable when the noise source is on or near the ground and a significant distance separates the listener from the noise source. Aircraft generate maximum power, therefore maximum noise during the take-off and climb phase of operation when the aircraft leaves the runway and attains an altitude of 50 to 100 feet before it leaves the boundary of the airport. Herein lies the main advantage of absorption of sound energy by vegetation.

Heavy turf, tall grass, numerous shrubs and strategically located trees can be very effective in reducing the sound levels before the noise of the aircraft take-off reaches the residents of an air base or airport. Experiments have been conducted to determine the extent of sound propagation over various types of terrain. Some of the results of these experiments are presented in Table IV²⁵ and Table V.²⁶ The data in Table IV and Table V indicate that a significant reduction in sound levels can be achieved by placing grass or trees along the path of the sound wave. This reduction is particularly significant when the sound is in the higher frequency range.

The experiments of Eyring²⁷ reveal that the amount of sound which will be absorbed by a tree is dependent upon the amount of foliage of the tree, the more leaves there are on the tree the greater the sound absorption. This dependence upon foliage to accomplish the required sound absorption will influence the type of flora which is finally selected as a landscaping and sound absorbing medium for the airport. Deciduous trees will be very effective as sound absorbers during the summer months but will be less effective during

25 Regier, op. cit., p. 12.

26 Carl F. Eyring, "Jungle Acoustics", The Journal Of The Acoustical Society Of America, Vol. 18, No. 2, p. 264.

27 Ibid, pp. 257-270.

TABLE IV

TERRAIN AND ATMOSPHERIC ATTENUATION AS OBTAINED
FROM MEASUREMENTS OVER 2-INCH-HIGH GRASS

Sending frequency (cps)	Measured terrain and atmospheric attenuation (db per 1000 ft)	Calculated atmospheric attenuation, (db per 1000 ft)
100	0	0.0035
500	2	.085
1000	16	.34
5000	26	9.0

TABLE V

TERRAIN ABSORPTION COEFFICIENTS IN DECIBELS PER 1000 FEET

Frequencies (cps)	Thin grass 6 in. to 12 in. high	Thick grass 18 in. high	Average jungle 300 ft. visibility
100	2	2	20
500	10	30	20
1,000	--	30	40
5,000	--	30	63
10,000	--	60	70

the winter months after the leaves have fallen. Evergreen trees do not present the desired amount of foliage but do possess the advantage of having year-round leaves. The selection of the trees, shrubs and grasses for the airport will be dependent upon the sound absorbing qualities of the plant as well as upon the soil properties and geographical location of the airport.

APPLICATION OF ATTENUATION DISTANCE FACTOR

The distance which will be required to naturally attenuate the noise levels generated by aircraft will be dependent upon the intensity of the noise and the frequency spectrum of the noise generated. These factors are a characteristic of the particular aircraft which is being considered, consequently the noise problem of each individual airport must be analyzed by using the operating characteristics of the predominant type of aircraft stationed at the base. The noise field of the F-84 type aircraft will be used for purposes of illustration in this thesis but the procedure involved will be equally applicable to other types of aircraft.

The sound field created by a J-33 turbo-jet engine operated at take-off rpm is shown in Figure 12. This drawing shows the intensity of all frequencies between 1000 cps and 10,000 cps. Other sound measurements made on the

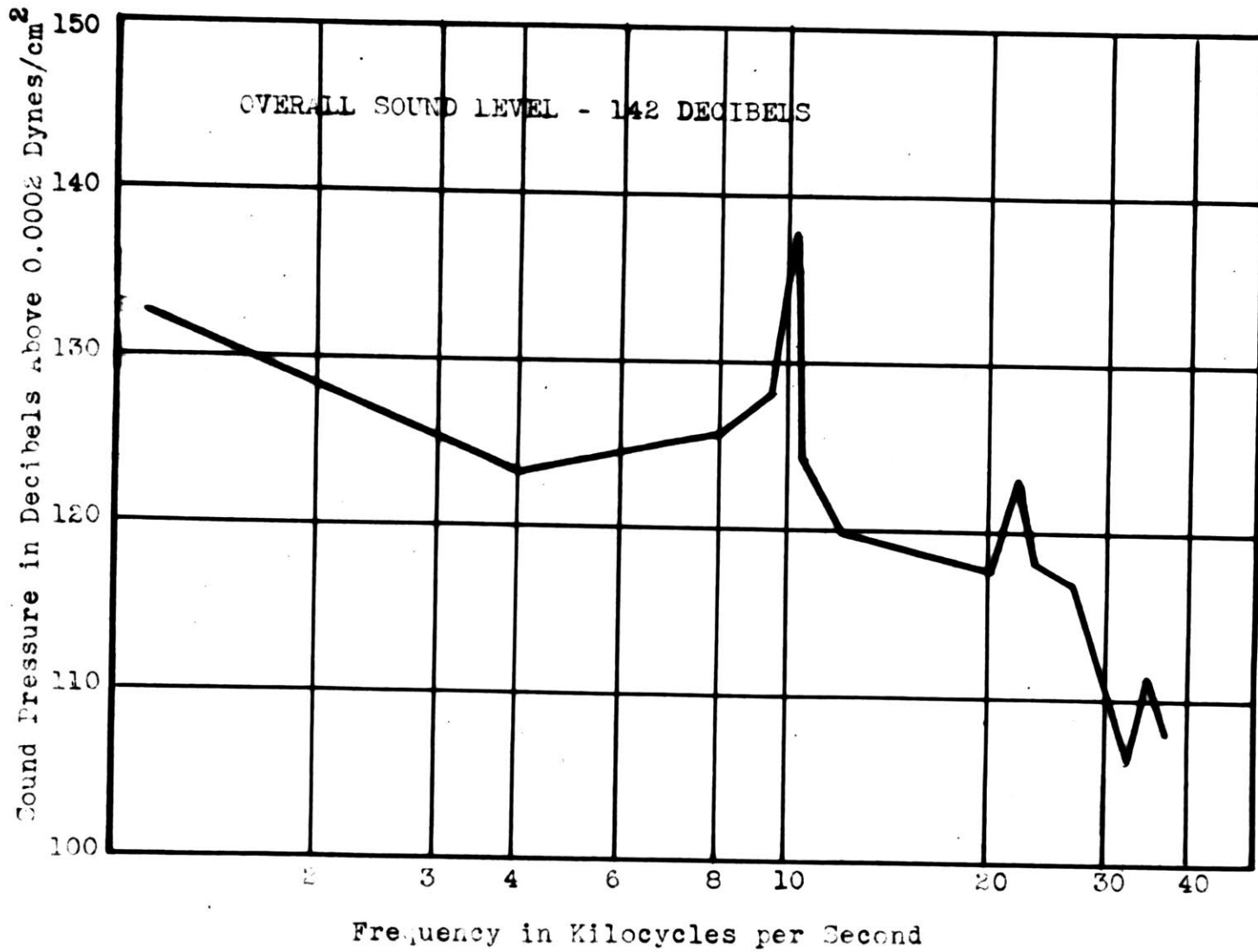


FIGURE 12

SOUND FIELD OF J-33 JET ENGINE

same engine disclosed that a level between 120 decibels and 130 decibels is maintained for all frequencies down to 100 cps and the sound level remained near 120 decibels down to a frequency of 25 cps.²⁸

The over-all sound levels around an F-84 type aircraft operated at idle rpm is shown in Figure 13,²⁹ and the over-all sound level around the same type aircraft operated at take-off rpm is shown in Figure 14.³⁰ It should be noted that the intensity of the sound is not the same in all directions but that the intensity is a maximum at an angle of 45° from the tail end of the aircraft. The sound levels which are indicated in Figures 13 and 14 were calculated from the measured data (80 ft levels) assuming free radiation of the sound energy. There was no reduction in noise level allowed for the atmospheric or terrain absorption. The 85 db level is reached at 170 feet when the aircraft is operated at idle rpm; however, the distance increases tremendously to 20,000 ft when the aircraft is operated at take-off rpm.

The extensive distance which is required to attenuate the noise of an F-84 to an acceptable level presents serious

28 Parrack, op. cit., pp. 9-10.

29 Parrack and Eldredge, op. cit., p. 471.

30 Ibid, p. 472.

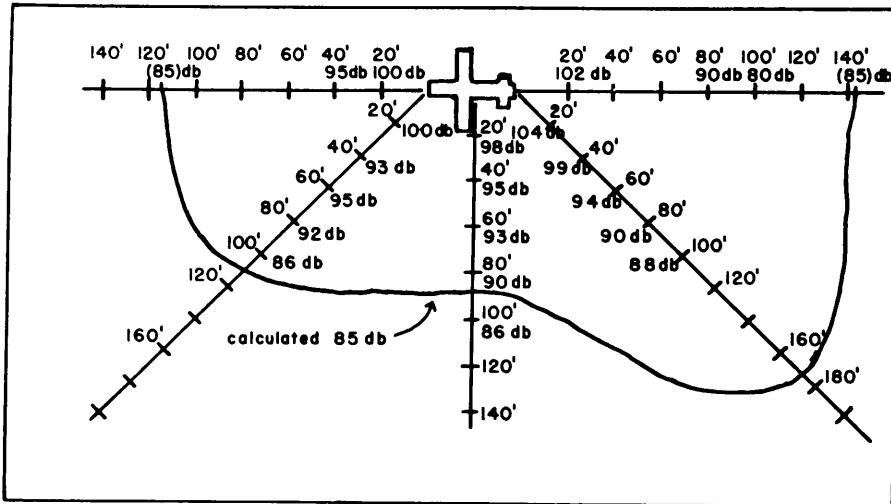


FIGURE 13

OVER-ALL SOUND LEVELS AROUND F-84 AIRCRAFT AT IDLE RPM

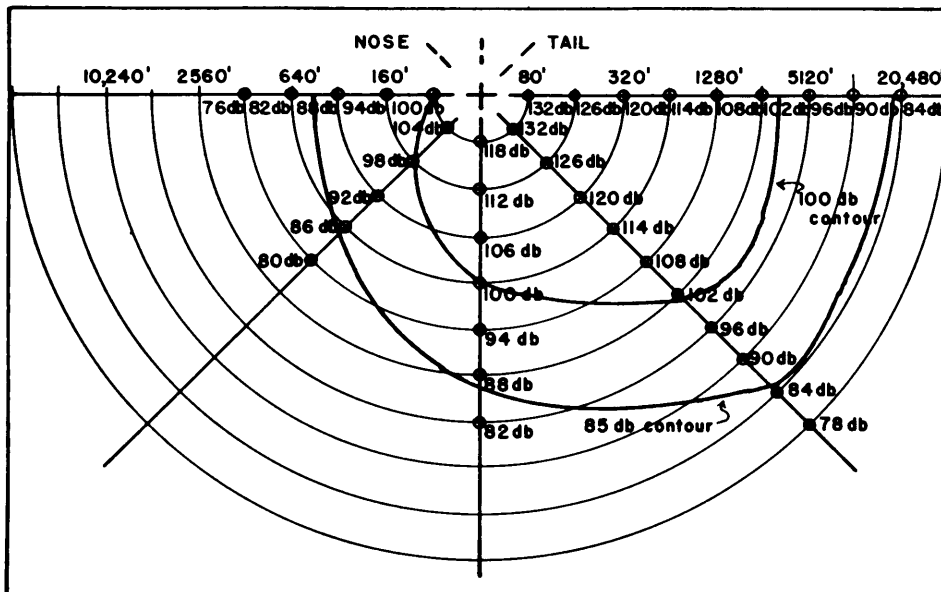


FIGURE 14

OVER-ALL SOUND LEVELS AROUND F-84 AIRCRAFT AT TAKE-OFF RPM

problems in airport planning. Theoretically, airport buildings would have to be located at least 4 miles from the runway and airborne aircraft would have to operate at altitudes greater than 20,000 ft in order to attenuate noise to a level of 85 db. Fortunately, jet aircraft operate most efficiently at altitudes of approximately 30,000 ft and when flying at this altitude produce no audible noise at ground level. High noise levels are produced at ground elevation only when the aircraft is taking off and until such time as the aircraft reaches its cruising altitude. The combined factor of reduced power and high altitude eliminate all noise at ground level once the aircraft has attained cruising altitude.

NOISE CONTROL OF GROUND OPERATIONS

It was shown in Figure 14 that the maximum noise level for the F-84 occurs at the tail end of the aircraft and at an angle of 45° with the axis of the aircraft. This particular direction of a sound propagation is a characteristic of the aircraft and is not typical of all types of aircraft. It can be assumed that aircraft of all types will be operated from any given runway; therefore the noise control practices should be designed by considering the direction of sound propagation for all aircraft concerned.

The line of maximum noise generated by the F-84 is projected at an angle of 45° with the axis of the aircraft and during take-off will be projected at an angle of 45° with the runway center line or centerline extension. Each area of the air base or airport will be successively exposed to the maximum noise level as the aircraft takes off; however, this maximum noise will be projected at an angle of 45° with the runway rather than perpendicular to the runway.

It is desirable to express the noise levels as occurring at some perpendicular distance from the runway centerline and this distance can be calculated by using the equation:

$$C = L \sin 45^\circ \quad (4)$$

where,

L = the distance from the runway centerline to the noise level in question, measured along the line of maximum noise intensity.

C = the perpendicular distance from the runway centerline to the noise level in question.

Equation (4) can be used to plot noise level contours in relation to the runway. There will also be noise projected at right angles to the runway (Figure 14), but these levels will be less than the value obtained by equation (4)

for the same location.

The aircraft take-off noises must travel across the safety zone between the runway and the aircraft parking apron before it reaches the airport buildings or the air base cantonment area. This safety zone is then the ideal area in which to initiate noise attenuation. Assuming a safety zone of 1000 ft. between runway centerline and the edge of the parking apron the noise must travel a distance equal to $\frac{1000}{\sin 45^\circ}$ or 1410 feet before reaching the apron. The noise attenuation at this distance will be:

$$N = -20 \log \frac{80}{1410-80} = -25 \text{db}$$

or the noise level will be:

$132 - 25 = 107 \text{db}$, assuming no atmospheric or terrain absorption.

The calculated natural attenuation which is achieved by divergence of the sound wave can be further increased by considering the absorption by the atmosphere and terrain. The amount of such absorption will increase as the frequency of the sound increases; therefore, it will be necessary to consider the absorption as a function of the frequency of the sound.

Sound frequencies above 3000 cps are effectively absorbed by the atmosphere and the rate of absorption increases with higher frequencies of sound. (Figure 11) This

type of absorption will be important in the consideration of jet aircraft as the major portion of these noises occur at frequencies higher than 1000 cps.

Terrain which is covered with a heavy grass is also effective in reducing the high frequencies. The data in Table IV indicate that considerable terrain absorption is obtained when sounds above 1000 cps are transmitted above grass two inches high. The quality of grass as a sound absorber increases with the height and thickness of the grass. It can be anticipated that large areas of grass will be very effective in attenuating the higher frequencies which predominate in jet aircraft noise, but will not be as effective in attenuating the lower frequencies of conventional type aircraft. However, trees and shrubs which provide a large area for sound absorption can be used to reduce the noises emanating from reciprocating engines and will also contribute a substantial absorption of the jet noises.

Unfortunately, trees and shrubs cannot be utilized close to the source of aircraft noises since established airport safety zones must be maintained. Grassed areas, therefore, represent the only available method of reducing aircraft take-off noise before this noise can reach the parking aprons and airport buildings which are sited on the apron.

Since the amount of sound absorption by grass increases with the height of the grass, a height should be established which is an allowable maximum or minimum consistent with good appearance, control of weeds, and elimination of potential grass fire hazards. The Air Force has established³¹ and the CAA recommended³² a maximum grass height of 8 inches and a minimum height of 3 inches on airfield grounds. These heights were established on the basis of appearance, weed control and elimination of fire hazard and probably do not reflect the important potential of tall grass as a source of noise reduction. Nevertheless, noise control should not be achieved at the expense of the other important determinants of grass height and a maximum height of 8 inches still appears to be the most logical choice. At any airport where a noise problem exists the minimum grass height can be increased to 4 or 5 inches; however, any increase in minimum height will reflect an increased cost of grounds maintenance.

Tree plantings around airports must be controlled to prevent the growth of trees which will encroach on the clearance zones. A Master Landscaping Plan to insure the

³¹ Air Force Regulation 90-1, Maintenance and Improvement of Grounds, dated 14 December 1950, para. 7a(1).

³² Airport Turfing, (Civil Aeronautics Administration) June, 1949, p. 28.

orderly placement of trees and the full utilization of shrubbery and trees for noise control as well as landscaping purposes should be prepared in conjunction with the General Airport Master Plan.

NOISE CONTROL IN THE APPROACH ZONES

The only possible method of exercising control over aircraft noise in the runway approach zones, other than by attenuation at the source, is by the application of the attenuation distance factor and the accompanying atmospheric absorption. There is no absorption by the terrain when the noise source is directly overhead as the sound waves are directed towards the earth and strike normal to the ground rather than traveling parallel to the ground.

An experiment³³ was conducted by the National Advisory Committee for Aeronautics to determine the effect of altitude on the sound pressure level of an airplane flying directly over the observer. The results of this experiment are reported in Table VI. The airplane used for this experiment was a single engine trainer of conventional design flying at an airspeed of 164 miles per hour, rotational speed 2000 rpm, and 400 horsepower.

³³ Arthur A. Regier, Effect of Distance on Airplane Noise, NACA Technical Note No. 1353, p. 9.

TABLE VI

MAXIMUM SOUND PRESSURE LEVEL FROM
AIRPLANE FLYING DIRECTLY OVER OBSERVER

Altitude of Aircraft ft.	Theoretical Sound Pressure level decibels	Measured Sound Pressure level decibels
300	90	88
600	84	82
2500	72	72
5000	65	65

The data in Table VI are in agreement with the inverse square relationship and indicate little or no atmospheric absorption. The predominant frequencies generated by the aircraft were in the range between 70 and 300 cycles per second which accounts for the absence of atmospheric absorption. These results are also in agreement with the data in Figure 11.

Although there is practically no absorption of the lower frequencies, the hearing mechanism of the ear comes to the rescue and tends to reject these low frequencies. The effective sound intensity which is perceived by the ear is less than the actual intensity of the sound, particularly for the frequencies below 500 cps. This relationship has been previously demonstrated in Figure 9 and is significant in the consideration of all noises generated by conventional aircraft.

At present there is no form of noise protection which can be offered to persons who reside in the aircraft approach zones. Conceivably these areas could be zoned for noise as well as for aircraft approach protection but the solution is hardly a practical one. The area of influence of aircraft noises is graphically shown in Figure 15,³⁴ and is compared the the area of influence of other forms of transportation. This high noise area is so extensive that it would be difficult if not impossible to limit the construction of buildings within the area.

The most practical solution for approach zone noise control lies in the proper selection of airport sites and the orientation of runways to minimize aircraft traffic over populated areas. An alternate solution in cases where the airport must be located close to an urban center is to select an orientation of runways which will coincide with existing high noise levels.

A procedure recommended by Cochran for finding a close-in airport site is as follows:³⁵

1. Recognize the noise of airplane operation and study the anticipated noise levels.

³⁴ H. C. Hardy, "Measuring Noise In Our Cities", Urban Land, Vol. 11, No. 10, November, 1952, pp. 3-5.

³⁵ M. W. Cochran, "Fear of Plane Noise Penalizes Many Communities", Air Transport, November, 1946, p. 27.

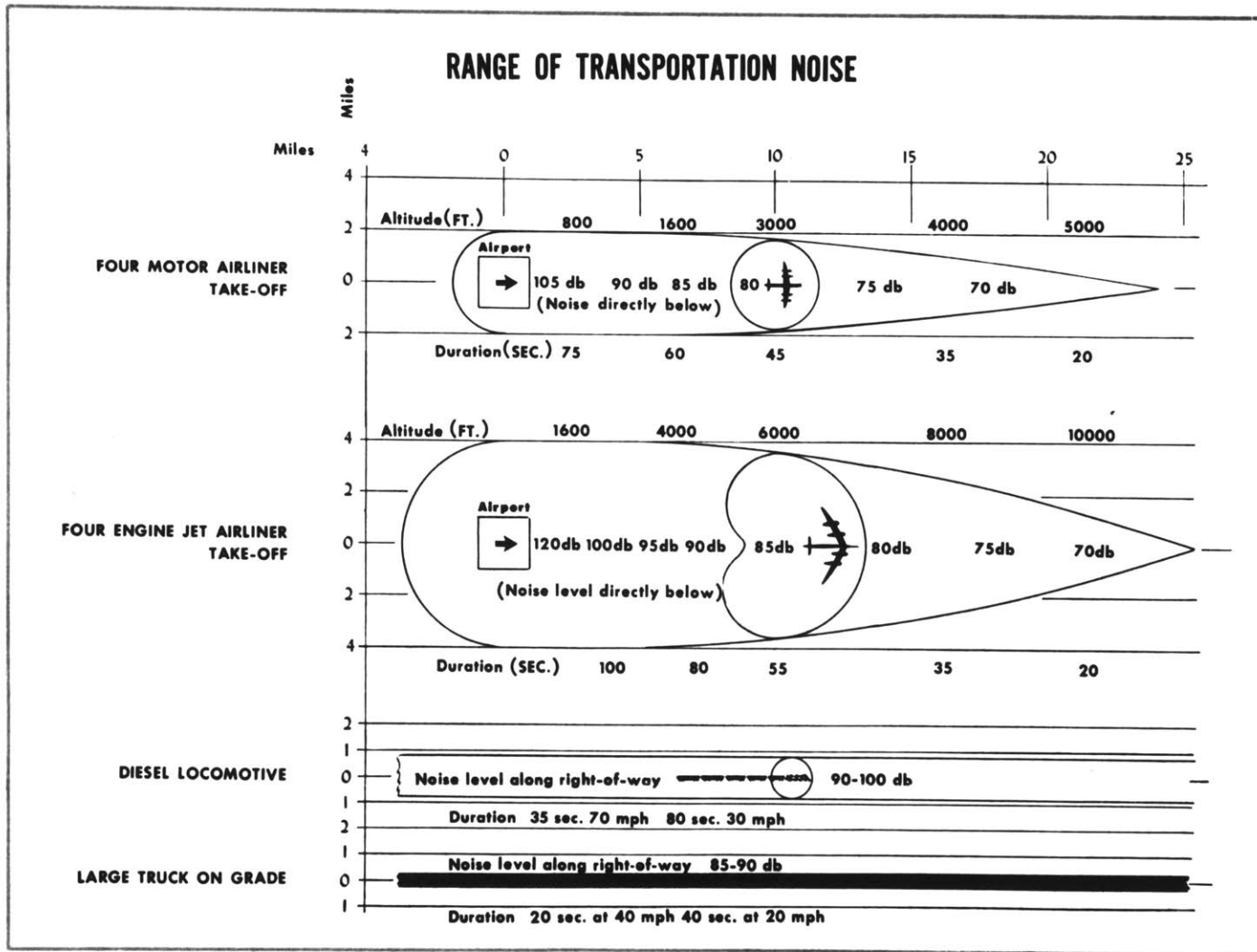


FIGURE 15

RANGE OF TRANSPORTATION NOISE

2. Measure the intensity of these noise levels with instruments at different heights and distances in the various atmospheric conditions of airplane operation.

3. Establish the noise levels which are now sustained and are therefore acceptable to the community.

When the above procedures are followed the airport can be designed to prevent operational noise levels which exceed the noise levels now accepted by the community. This procedure will be applicable where the proposed airport will be used for the operation of conventional aircraft generating noise levels below 120 decibels, but will have little merit where the airport is to be used for the operation of jet aircraft generating noise levels above 130 decibels.

CONTROL OF AIRCRAFT OPERATIONS TO MINIMIZE NOISE

It has been demonstrated that the noise levels generated during aircraft take-offs can be reduced by the attenuation-distance factor and the accompanying sound absorption, but that there is little defense against the noise generated by aircraft which are directly overhead. It is imperative therefore that aircraft operations at low altitudes be prohibited or definitely curtailed and that unnecessary flight operations in the airport vicinity be eliminated.

Recommendations advanced by the President's Airport Commission which will help to reduce operational noise levels are as follows:³⁶

1. Maintain positive air traffic control.
2. Raise circling and maneuvering minimums.
3. Accelerate ground noise reduction programs.
4. Instruct flight personnel concerning nuisance factors.
5. Arrange flight patterns to reduce ground noise.
6. Minimize training flights at congested airports.
7. Minimize test flights near metropolitan areas.
8. Avoid military training over congested areas.

Other specific recommendations³⁷ which have been advanced to curb operational noises are:

1. Aircraft operators should climb away from airports as quickly as possible, consistent with safety.
2. Operators should fly higher when approaching airports and then descend at a steeper angle.
3. Operators should study how to eliminate most of the engine run-ups before take-off.

³⁶ The Airport and Its Neighbors, *op. cit.*, pp. 18-20.

³⁷ Hall T. Hibbard, Aircraft Noise, Paper presented at the Airport Operators Council, March 20-22, 1952.

CHAPTER V

LEGAL ASPECTS OF AIRPORT OWNERSHIP AND OPERATION

Cases involving aircraft have been considered in the courts for approximately 40 years; but aeronautical law, as such, has been slow in developing. Laws which would specifically regulate aviation were non-existent during the early development of the industry; therefore when a case arose involving aircraft the courts resorted to common law and decided the case by analogy and general deduction. In general the legal conflicts regarding airports fell into three categories; the right of a governmental unit to own and operate an airport, the power of a governmental unit to acquire property for airport purposes by eminent domain, and the conflicting interests of the airport operator and the adjacent landowner.

These legal aspects of airport planning will be briefly discussed below. Admittedly the presentation lacks certain legal qualities; however, the subject matter is considered important as an integral part of the airport planning process.

AIRPORT ACQUISITION BY GOVERNMENTAL UNITS

All municipal corporations are given their powers by the state wherein they are located and these powers are

conferred by virtue of the state constitution or by specific statutes. Therefore, a municipal corporation can exercise only those powers which it is expressly granted or which are implied necessary to carry the granted powers into effect. This then means that the municipality has the powers which are essential to accomplish the declared objectives and purposes of the municipality. But if a particular activity is not authorized by specific legislation then that activity must be pursued under the implied powers of the municipality and it must be clearly in the public interest.

During the early development of the aviation industry the state statutes did not provide a specific authority for a community to acquire property for airport purposes or authority to construct and operate an airport. However, the airport was considered a "public utility" and the acquisition of property and construction of an airport was a legitimate public purpose under the implied powers of the community.

Individuals and groups of taxpayers sought to restrain the use of public funds for the acquisition of airports on the grounds that the airport was neither a "public utility" nor a "public purpose" but was a luxury for the select few who could afford to travel by air or to own airplanes. Typical of the resistance to community development

of airports is the viewpoint expressed by a citizen in the early City of St. Louis case.¹ The court quoted the rather picturesque language of a person who in 1928 was contesting the power of the city to issue bonds payable from tax funds, to develop certain lands as a city airport:

. . . It will offer a passenger station for the very few persons who are able to afford, and who desire to experience, the thrill of a novel and expensive mode of luxurious transportation.

In the very nature of things, the vast majority of the inhabitants of the city, a 99 percent majority, cannot now, and never can, reap any benefit from the existence of an airport.

True it may be permitted to the ordinary common garden variety of citizen to enter the airport free of charge, so that he can press his face against some restricting barrier, and sunburn his throat gazing at his fortunate compatriots as they sportingly navigate the empyream blue.

But beyond that, beyond the right to look hungrily on, the ordinary citizen gets no benefit from the taxes he is forced to pay.

In this case, the Missouri Supreme Court with unusual foresight for the time of the decision (1928) brushed aside the plaintiff's contentions and stated in part:

It is unquestionably true that the airplane is not in general use as a means of travel or transportation either in the City of St. Louis or elsewhere; and it never will be unless properly equipped landing fields are established.

1. Dysart v. City of St. Louis, 321 Mo. 514, 11 S.W. (2d) 1045 (1928) as reported by Charles S. Rhyne, Airports and the Courts, p. 21.

The Court concluded:

An airport with its beacons, landing fields, runways, and hangars, is analogous to a harbor with its lights, wharves, and docks; the one is the landing place and haven of ships that navigate the water, the other of those that navigate the air. With respect to the public use which each subserves they are essentially of the same character. If the ownership and maintenance of one falls within the scope of municipal government, it would seem that the other must necessarily do so. We accordingly hold that the acquisition and control of an airport is a city purpose within the purview of general constitutional law.

During the period 1926 through 1929, 27 states adopted legislation authorizing cities, counties or other public agencies to use public tax funds to acquire airports. And in 1944 every state and territory had legislation authorizing public bodies to acquire, maintain and operate public airports.² The first hurdle of community sponsorship of airports was passed and the next obstacle was the contest of the right of government to acquire the airport site through the power of eminent domain.

ACQUISITION OF PROPERTY FOR AIRPORT PURPOSES THROUGH EMINENT DOMAIN

Eminent domain is that power vested in a sovereignty to take or to authorize the taking of private property, without the owner's consent, where necessary for the public

² Charles S. Rhyne, Airports And The Courts, p. 20.

use.³ This power is held by both the Federal and State governments, however, the owner of the expropriated property must receive just compensation for the property taken. The Federal power of eminent domain is limited only by the Fifth Amendment of the Constitution which provides that: "No person shall be deprived of life, liberty, or property, without due process of law; nor shall private property be taken for public use without just compensation". The power of the States is similarly limited by the Fourteenth Amendment of the Federal Constitution.

The State may exercise its power of eminent domain or it may authorize another to exercise the power as, (1) a private corporation, i.e., a common carrier, or, (2) a political subdivision as a county or municipal corporation.⁴ The power of eminent domain cannot be used to secure property for the private use of an individual or organization; however, this purpose is to be distinguished from a case where the individual or organization is engaged in a public enterprise such as operating a railroad or other public activity. Any property obtained through the power of eminent domain must be used for a public purpose.

³ Gerald O. Dykstra and Lillian G. Dykstra, The Business Law of Aviation., p. 151.

⁴ Ibid, p. 52.

The nature of airport activity has required that the airport in many cases be located outside the boundaries of the sponsoring municipality. This feature has raised questions as to the legality of a community condemning property outside its boundaries by the power of eminent domain. In general it has been held that the municipality may not only condemn property within its limits but it may also condemn property within the confines of an adjoining municipality in the same state if that should be necessary and if the condemning municipality acts in good faith.⁵ A municipality of one state does not however have the power to condemn property located in an adjoining state since such condemnation would constitute a violation of the sovereignty of the adjoining state. It does however have the right to purchase and own property in an adjoining state.⁶

THEORIES OF AIR SPACE RIGHTS

There are three⁷ general theories regarding the ownership of the airspace above the land. These theories will be discussed below:

"Ad Coelum" Maxim. This theory stems from the common

⁵ Ibid, pp. 159-60.

⁶ Loc.Cit.

⁷ Rhyne lists 5 theories of air space rights which had been advanced in the court cases which were decided before 1944.

law and asserts that the surface owner has control of the air space above his land "even up to the heaven". This theory became part of the English common law more than two centuries before the advent of the airplane. It is now universally rejected as impractical since its literal application would make each flight of an airplane a trespass over all the lands along the route.

Zone Theory. This theory affirms that the ownership of the air space extends only so far as the surface owner can reasonably be expected to exercise effective possession over it.⁸ The difficulty with this theory is that there is a good deal of uncertainty regarding the landowners' rights. The ownership of the air space is related not only to the existing but also to the possible uses of the air space. The extent of the zone of "effective possession" will vary depending on the landowners' ideas of the possible uses of the land.

Nuisance Theory. This theory affirms that the landowner owns only the air space which he actually occupies and can only object to such uses of the air space over his property as does actual damage.⁹ This theory is based on

⁸ George L. Schmutz, "Valuation of Avigation Easements", The Appraisal Journal, Vol. 20, No. 4, p. 465.

⁹ Rhyne, op. cit., p. 161.

the idea that a landowner must actually occupy the air space which he claims to own but he can be protected against any use of the air space above his property which will constitute an actual interference with his possession or beneficial use of the land. If tangible property damage results from such an interference he can bring an action of trespass. If intangible annoyances result which actually interfere with his possession or use of the land he can bring an action of nuisance.

CONFLICTING INTERESTS OF PROPERTY OWNERS AND AIRPORT OPERATORS

The operation of airports has in many cases been contested by the adjoining property owners who maintain that the airport is a nuisance and should be closed. A summary of the cited effects of airport operation which contribute to its being labeled a nuisance is given below:¹⁰

1. Depreciation of adjacent property values.
2. Dust has been annoying and injurious to health.
3. Danger of falling aircraft has caused apprehension of injury and extreme fright.
4. Low flying has caused fright, dust, and excessive noise.

¹⁰ Ibid, p. 119.

5. Excessive noise from engine run-ups.
6. Crowds who were attracted to the airport have injured property and annoyed owners.

The problems involving disputes between landowners and airport operators have generally been resolved by the court based on the facts of each individual situation. In some cases, particularly earlier ones, the courts have gone so far as to close down some airports completely by enjoining them as a nuisance, but in more recent decisions the courts have taken a more sympathetic view towards airport operation.¹¹

Other suits have been initiated by the airport operator where property owners have erected structures which were a hazard to navigation. Where the obstruction was a legitimate one, such as a power line or a water tower, the courts have tended to rule in favor of the landowner; but where the obstruction was a "spite" construction such as tall poles of no value except to prevent low flying the courts have either required removal of the obstruction or have limited its height. In the Tucker Case¹² the landowner had planted fast growing trees expected to reach 35 feet or

¹¹ The Airport And Its Neighbors, op. cit., p. 69.

¹² City of Iowa City v Tucker, 1936, U. S. Av. R. 10 (Dist. Ct. Johnson Co. Iowa, 1935) as reported by Rhyne, op. cit., p. 87.

higher so as to make it dangerous to use the airport. The Court enjoined the landowner from erecting structures or growing trees over 25 feet high. After the injunctive limit of 25 feet was made the landowner erected a pole 24 feet 8 inches high topped by a red flag.

THE AIRPORT AS A NUISANCE

It is likely that any future court actions in regard to airport location and the operation of aircraft from same will be on the basis that the airport through its method of operation constitutes a nuisance. In this regard it is interesting to review the case of Warren Township School District No. 7 v City of Detroit.¹³

The City of Detroit maintained that the then existing city airport was inadequate and that it had become necessary for the city to acquire a site for a larger one. The plaintiffs claimed that the building and subsequent operation of such an airport in the immediate vicinity of their properties would destroy the use for which they were acquired and were being used. They showed that the airport, if used for larger airplanes, would cause such a nuisance because of the noise, light, vibration, and general disturbances

¹³ Warren Township School District v. City of Detroit
14 N.W. (2) 134,308 Mich. 460(1944) as reported by Dykstra
and Dykstra, op. cit., pp. 224-33.

incident to the operation of such an airport and airplanes in landing and taking off that they would be deprived of the peaceful use and quiet enjoyment of their respective properties without due process of law.

The Court refused to enjoin the City of Detroit from constructing the airport since the construction of the airport in itself would not constitute a nuisance, although its operation after construction might constitute a nuisance. The Court expressly warned the City by citing a recent decision in which it refused to enjoin construction of an incinerator by the city upon the city's representation that it would not be a nuisance and then its later decision enjoining the city from operating the incinerator because it, in actual operation, proved to be a nuisance. The Court said:

... It would be unfortunate indeed if the city, after spending a very large sum for an airport, should later be enjoined from using it for larger airplanes.

After this decision was rendered the city proceeded to condemn the site in question; however, it was later decided that the site in question was inadequate and the project was abandoned.

A famous case which serves to delineate the rights of landowners is the Causby case which was decided by the Supreme Court of the United States in May, 1946.¹⁴ The

¹⁴ Henry G. Hotchkiss, "Airports Before The Bench", Aero Digest, August, 1947, p. 37+.

findings in this case are very significant to the airport planner and operator and will therefore be reviewed below:

The plaintiffs (Causby) owned several acres of land on which was situated a dwelling house, barn, and chicken houses near an airport outside of Greensboro, N. C. The end of one runway is 2220 feet from the barn and 2275 feet from the house. The approach path of this runway passes directly over the property. The 30:1 glide angle, approved by the CAA, passes at 83 feet - which is 67 feet above the house and 18 feet above the highest tree.

Bomber, transport, and fighter aircraft belonging to the Armed Forces used this airport. The flights commenced in 1942 and were fairly frequent passing over the land and buildings in question. At times they came so close as to barely miss the tops of the trees.

The noise was reported to be startling and, at night, the glare from the planes brightly lit up the place. The plaintiffs had to give up their chicken business, having lost from 6 to 10 chickens in one day by their flying into the wall from fright - there were 150 casualties in all. Use of the property as a commercial chicken farm was destroyed.

The majority opinion of the court disclaimed the ancient doctrine (Ad Coelum), that ownership of the land carries with it ownership of the air space, by saying: "The

air is a public highway as Congress has declared. Were that not true, every transcontinental flight would subject the operator to countless trespass suits. Common sense revolts at the idea".

The Court proceeded to say that the general principle does not control the present (Causby) case. It holds—and the United States conceded—that, if the flights over the property rendered it uninhabitable, there would be a taking compensable under the Fifth Amendment—and found that there was, in fact, a partial taking.

The Court continues, saying that although the airspace is a public highway, "the landowner must have exclusive control of the immediate reaches of the enveloping atmosphere" and "owns as much of the air space above the ground as he can occupy or use in connection with the land".

Some airport operators have said that the decision of the Supreme Court in the Causby case will set aviation law back 50 years and result in a barrage of claims from landowners. This remains to be seen; however, the decision makes it essential that the airport planner take adequate steps to insure that the runway approaches are adequately protected from the standpoints of safe navigation and prevention of damage or nuisance to landowners. The methods of securing approach protection will be discussed in the following section, Chapter VI.

CHAPTER VI

AIRPORT APPROACH CONTROL

It has been demonstrated in the preceding chapters that the external problems associated with airport planning and operation, e.g., airport expansion, hazard to ground personnel, nuisance from noise, and legal actions to enjoin airport operation, have arisen in the area underlying the runway approaches. This area is then the critical location so far as the airport neighbor is concerned and is the location which will create the greatest detriment to airport operation unless adequate planning measures are taken to protect this area from encroachment.

The need for adequate planning measures is twofold. First, it is necessary to prevent the erection of physical obstructions to air navigation in the approaches to the runway, and second, to prevent the initiation of legal obstruction to airport operation by the adjacent property owners. The interests of the property owner are covered in the second reason since appropriate planning will largely eliminate the nuisances for which he might otherwise seek injunctive relief. This control might be exercised by three general methods: The outright purchase of the approach lands, the acquisition of air rights in the approach zone, or the enactment of a zoning ordinance to control land use and building heights. These methods will be covered in the discussion which follows.

COMPREHENSIVE ZONING

Zoning is a relatively recent development in the United States and has arisen through a process of evolution. The early forms of zoning were directed at the restriction of so-called nuisance activities such as the operation of laundries, livery stables, slaughter houses and brick yards. From this limited beginning it was extended to control building heights and land uses and then to encompass the comprehensive and systematic planning and control of all land uses within entire urban areas.

The constitutional validity of comprehensive zoning is based on the police power of the state. This is the power which permits the state to adopt regulations which are essential to the promotion and protection of the public health, safety, morals, comfort or general welfare. The police power, as a legal basis for zoning, is further supplemented by the common law principles of nuisance which require that a property owner must use his land in a manner that does not interfere with his neighbor's reasonable use of adjoining property.

A comprehensive zoning ordinance divides a city into specific use, height, and area zones. The desirable as well as undesirable land uses are regulated and the resulting benefits accrue to the entire community. This control of land use provides a better environment for home and community by

segregating residential, business, and industrial buildings. It further tends to stabilize property values in the respective areas.

AIRPORT ZONING AS A FACTOR IN COMPREHENSIVE ZONING

Airport zoning also involves the imposition of restrictions upon land use and in its operation does not materially differ from that of comprehensive zoning. Unfortunately, there exists a tendency to regard the two types of zoning as separate identities whereas the two should be inter-related to insure the most economical and efficient use of the land adjoining airports. For example, when a site is selected for a proposed airport the land in close proximity to the site should not be zoned as an industrial district but for some other use. Industrial buildings are usually high structures and have tall stacks, tanks and towers which are potential hazards to flight. These structures might be located within the runway approaches and such a situation would possibly prohibit the use of the proposed site as an airport. And should the airport be constructed the required zoning regulations would substantially invalidate the further use of the land as an industrial district. Thus, it can be seen that the integrated use of comprehensive and airport zoning will be most effective in the

elimination of obstructions and will provide the most efficient use of available lands.

Airport zoning differs from comprehensive zoning in that it is directed towards effectively preserving the current use of certain lands as an airport, whereas comprehensive zoning involves the allocation of land uses in the entire community according to an over-all integrated program without specifically attempting to maintain the current use of any particular land. The existing land use is, of course, a consideration in the comprehensive zoning program; however, the preservation of such usage is not the primary objective of such zoning.

The ultimate aims of the two types of zoning are the same and airport zoning should be integrated into the comprehensive zoning program whenever possible. The Model State Airport Zoning Act¹ as proposed by the CAA and the National Institute of Municipal Law Officers recognizes the importance of integrated zoning and specifies:

Section 4. Relation to comprehensive zoning regulations.
(1) Incorporation. — In the event that a political subdivision has adopted, or hereafter adopts, a comprehensive zoning ordinance regulating, among other things, the height of buildings, any airport zoning regulations applicable to the same area or portion thereof, may be incorporated in and made a part of such comprehensive zoning regulations, and be administered and enforced in connection

¹ Model State Airport Zoning Act, November 7, 1944, Civil Aeronautics Administration, U.S. Department of Commerce, and National Institute of Municipal Law Officers.

therewith.

(2) Conflict. In the event of conflict between any airport zoning regulations adopted under this Act and any other regulations applicable to the same area, whether the conflict be with respect to the height of structures or trees, the use of land, or any other matter, and whether such other regulations were adopted by the political subdivision which adopted the airport zoning regulations or by some other political subdivision, the more stringent limitation or requirement shall govern and prevail.

OBSTRUCTIONS TO AIRPORT APPROACHES

The physical obstructions to the air space approaches to a runway and which might be regulated by zoning may be classified as follows:²

Structural Hazards are those which directly interfere with the passage of planes through the air space. These obstructions might be buildings, trees, towers, electric transmission lines, or any structure which projects into the line of flight. These obstructions are tangible and can be regulated by prescribed height limitations.

Visibility Hazards are those which interfere with the pilot's visibility of the airport and surrounding areas. In this group are activities which create gases, smoke, dust, and glare in the atmosphere encompassing the airport. Frequently these hazards affect a large area and might not be

² Nelson Young, Airport Zoning, Aeronautical Bulletin No. 4, University of Illinois, 1948, pp. 13-4.

caused by an activity immediately adjacent to the airport, therefore control is practically impossible. Prime examples are the "smaze" of New York and the "smog" of Los Angeles. The effects of glare are more tangible since it might be caused by the reflection of the sun from a particular building. In this regard it has been found that white buildings on airport grounds produce a significant amount of glare and some of these buildings have been painted a non-reflecting color to reduce the glare.

Communication Hazards are those activities adjacent to the airport which create electrical interference with radio communication between the aircraft and the control tower. These hazards are again intangible and difficult to isolate and control.

Traffic Hazards are created by the improper location of additional airports in the vicinity of existing facilities. Airport zoning regulations might be used to restrict the location of future airports which might cause traffic interference, particularly from private airports.

AIRPORT ZONING

The power to zone is now an undisputed exercise of the State police power but as far as a municipality or other public body is concerned it must receive specific authority

from state legislation in order to zone. This authority is generally furnished in the form of State "enabling" legislation and as of 1950 thirty-five states had a statute authorizing the adoption of local airport zoning ordinances. These State acts are similar to the Model State Airport Zoning Act which has previously been cited.

An airport zoning ordinance must be adopted by the local political subdivision of the State before the airport approaches can be protected by zoning. The National Institute of Municipal Law Officers has prepared a Model Airport Zoning Ordinance³ for use by municipalities. Likewise, the Department of the Air Force has prepared a Model Zoning Ordinance⁴ for use by the local governing bodies in the vicinity of Air Force installations. These two model ordinances are essentially the same and differ only in the extent to which the areas are zoned.

The police power of zoning can be used to regulate the height of structures and the use of land, but there is a question as to the point where airport zoning ceases to be a regulation and becomes a "taking" of property. Zoning, as with any other exercise of the police power, takes away some

³ Model Airport Zoning Ordinance, September, 1945, National Institute of Municipal Law Officers.

⁴ Air Force Regulation 86-3, dated 24 March 1949, Attachment 1.

rights incident to the property in the public interest. But it should not deprive the landowner of a substantial interest in his property nor should it cause a marked reduction in the value of the property. If any airport zoning ordinance were to prescribe too low a limit on height or attempt to compel the removal or lowering of an existing non-conforming structure or use, it would probably be held to be an unconstitutional taking of private property without just compensation.⁵

The model airport zoning ordinances recognize the existence of non-conforming usages and state:

The regulations prescribed in ... this ordinance shall not be construed to require the removal, lowering, or other change or alteration of any structure or tree not conforming to the regulations as of the effective date hereof, or otherwise interfere with the continuance of any nonconforming use. Nothing herein contained shall require any change in the construction, alteration, or intended use of any structure, the construction or alteration of which was begun prior to the effective date of this ordinance, and is diligently prosecuted and completed within two years thereof.⁶

The CAA standards for determining obstructions to air navigation are shown in Figure 16.⁷ It can be seen from Section B of Figure 16 that a glide path of 50.1 begins at

⁵ John W. Hunter Jr., Problems Of Airport Zoning., (Paper presented at the Annual Planning Conference of the American Society of Planning Officials, New York, N.Y., May 6, 1946.

⁶ Model Airport Zoning Ordinance, op. cit., Section 6.

⁷ Technical Standard Order, N18, CAA, April 26, 1950.

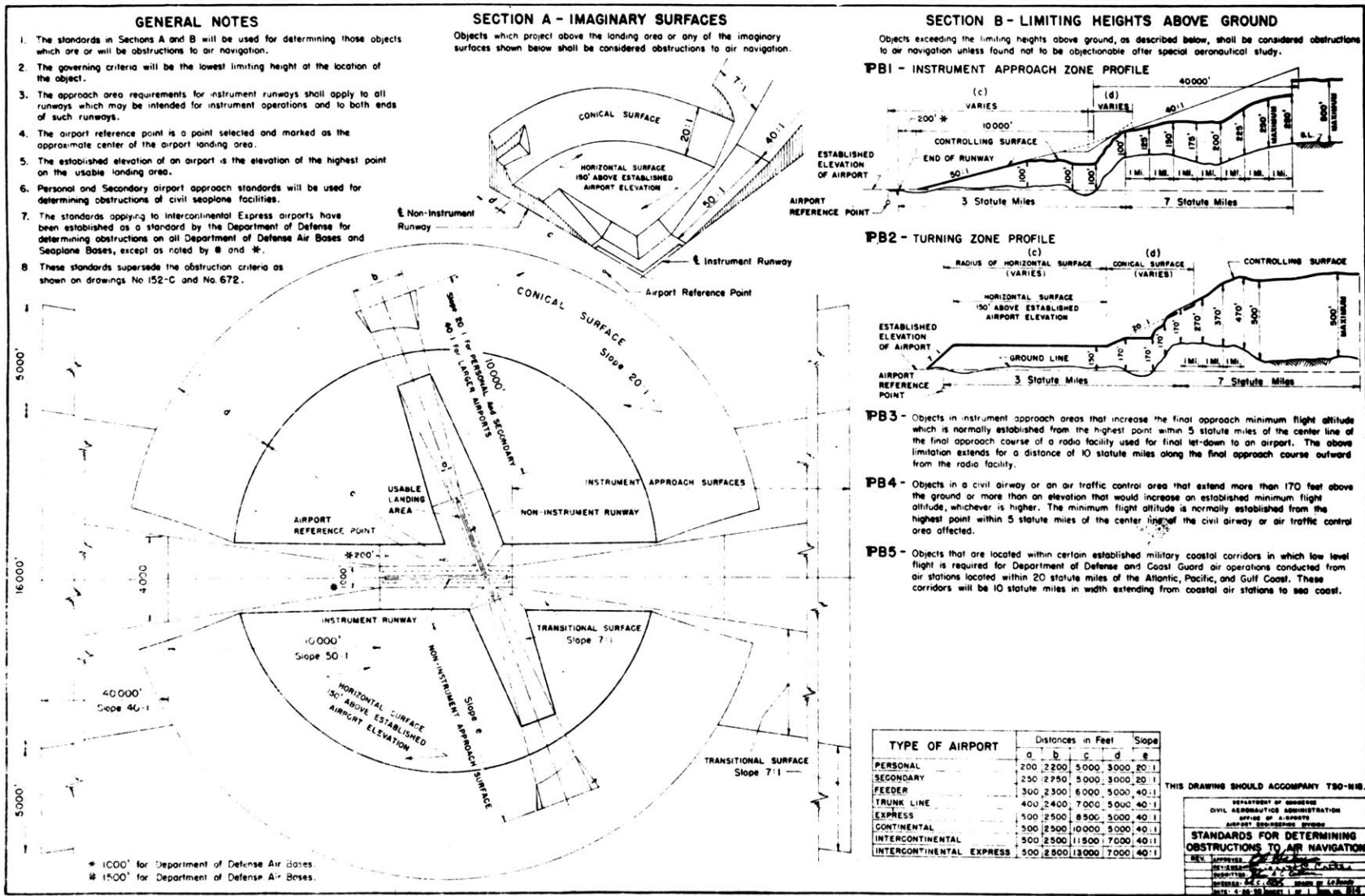


FIGURE 16
STANDARDS FOR DETERMINING OBSTRUCTIONS TO AIR NAVIGATION

200 feet (1000 ft. for air bases) from the end of the runway; therefore, a building which is 30 feet high cannot be constructed within 1700 ft. (2500 ft. for air bases) of the end of the runway.⁸

It is clear that a height limit as low as is necessary could not legally be imposed by the zoning method for some distance from the end of the runway since such a limit would constitute a "taking" of property. It is therefore recognized that airport zoning must be used in conjunction with or supplemented by the acquisition of property through either the outright purchase of the land or the purchase of the air space rights (avigation easements).

PURCHASE IN FEE SIMPLE

The land within the boundaries of the airport and upon which the runways, aprons and buildings are constructed must either be purchased outright or permanently leased from the owner. Likewise, any property which might be required for future expansion should be purchased at the time of construction. The proximity of the airport and the potential use of adjoining lands as a site for expansion increases the value of the adjacent property. Any development of the

⁸ It is assumed that the base of the building is at the same elevation as the runway.

adjacent land will further tend to increase its value and perhaps raise the price to a point where it could not be economically secured for expansion purposes.

The President's Airport Commission has recommended that a strip of land 1000 feet wide and at least one-half mile long at the end of dominant runways on new airport projects be acquired as an integral part of the airport. This area would be maintained completely free of housing and obstructions and would be extended at any time that the runways were extended. The acquisition of this land would insure positive approach protection close to the runway and the remainder of the approach zone could be protected by zoning.

It might also be necessary to secure title, through purchase or condemnation, of the sites which are occupied by non-conforming uses. It has been pointed out that a zoning ordinance should not be retroactive; therefore any obstruction which exists when the ordinance is adopted should be removed at no expense to the owner. This removal can be accomplished by purchasing the property and removing the obstruction or by purchasing an aviation easement where the obstruction can be modified to eliminate the hazard.

In cases where it is not legally possible to zone an area in the runway approach and where the purchase of the

property is too costly, the same objective might be realized by the purchase of the air rights to the property. The purchase of air rights is called an avigation easement and will be discussed below.

AVIGATION EASEMENTS

A practical method of preventing the erection of hazardous obstructions to runways, in the absence of zoning, is by the acquisition of avigation easements in the air space over the land upon which the erection of structures seems probable. The easements can also be acquired in those areas in which zoning would constitute a taking of property without just compensation. Generally this acquisition will involve less costs than outright purchase since little interference, if any, results in the use of the land by the owner.

The value of an avigation easement has been defined as the difference in the value of the entire bundle of rights, commonly called fee simple, and the value of the bundle after one of the rights has been taken away from the owner, e.g., the right of flight.⁹ The difficulty in the system arises in making a determination of the actual value of the easement. The value will depend on the potential as

⁹ Schmutz, op. cit., p. 465.

well as the present use of the land; and the potential use of property is a subject of considerable controversy. When the easement is to be purchased to supplement a zoning ordinance the potential use is more closely defined by the limitations of the zoning ordinance.

The loss of air rights is a definite limitation to the development potential of the property; industrial or residential land may be reduced to agricultural use, orchard land may be reduced to general crop use, or crop land may be reduced to pasture. Every case is different but in general the value of the easement will be a function of the location of the property with respect to the end of the runway, the distance from the runway centerline extended, and the height of the glide path above the property. Methods for appraising the value of an aviation easement have been developed and published in the literature.^{10,11}

FUTURE REQUIREMENTS

Design trends for future aircraft indicate that a flatter glide angle will be required for runway approaches and that the present glide path slope of 40:1 (50:1 for

¹⁰ Schmutz, *op. cit.*, pp. 465-472.

¹¹ Paul W. Fox, "Avigation Easement Appraisals", The Military Engineer, Vol. 43, No. 293, pp. 205-6.

instrument runways) will not meet that requirement. Approaches which are currently protected by zoning and aviation easements cannot be further expanded without encountering many additional obstructions which cannot be removed without a sizable financial investment. It is doubtful that existing zoning ordinances can be made more restrictive without creating numerous non-conforming uses and necessitating the purchase of more property and the acquisition of more aviation easements. These anticipated developments therefore place more emphasis upon the need for more initial planning and the integration of the airport planning into the regional and city plans.

The elimination of obstructions will satisfy the requirements for safe approaches but will not ease the public condemnation of the nuisances of airport operation. The noise and hazard of aircraft operation and their consequent effects on the airport neighbors cannot be controlled by airport zoning in its present form. The only solution to this problem is to either eliminate or reduce the extent of the nuisances and thereby decrease their influence on the airport neighbors.

The airport must exist at some location — it cannot be completely isolated from the community. Therefore techniques must be applied which will allow safe operation and

compatability with other community activities. This function is not entirely within the scope of airport planning, as such, but is more within the realm of comprehensive regional and city planning. The relationship between the airport and the community will be discussed in the following chapter.

CHAPTER VII

THE AIRPORT AS A FACTOR IN COMMUNITY PLANNING

It is a generally accepted fact that a city must have adequate transportation facilities if that city is to be a progressive force in the competitive race with other communities. Air transportation is becoming an increasingly important factor in the comprehensive transportation scheme; therefore, the progressive community must acquire an airport to maintain a high degree of transportation efficiency with respect to competitive communities and also to meet social responsibilities to its citizens.

Air transportation, like any other form of communication, has no value unless it can be used to communicate with other persons or places. Therefore, the more airports there are available for aircraft operations the more widespread and effective will be the communication through air transportation. The extent of travel by air is limited by the availability of airports.

A recent tabulation¹ indicated that of the 18000 urban communities in the United States 484 could be reached by domestic trunk airlines and 199 reached by feeder airlines.

¹ Wilfred Owen, "Our Earth-Bound Air Age", Air Force, Vol. 37, No. 2, February, 1954, p. 65.

An additional 5,966 destinations could be reached by combinations of air and surface transportation. These statistics can be compared with the 48,000 stations which are available on the railroad network to reveal that the air transportation system is confined to metropolitan centers and larger cities..

During the expansion period of the aviation industry there existed a tendency on the part of airport designers to regard air travel as being separate and distinct from other forms of transportation. Airports were often located from aeronautical considerations alone and little thought was given to the integration of the airport into a comprehensive transportation plan. This planning deficiency has created many problems in the form of surface bottlenecks and has detracted from the desirable features of air travel. The faster speeds of air travel and the increase in traffic demands have focused more attention on the need for the integration of airports into the surface transportation system. Little actual benefit is derived from faster air travel when the time which is saved by air is dissipated in the traffic tangles on the ground.

SURFACE TRANSPORTATION AS RELATED TO AIR TRAVEL

The superiority of air transportation over surface

transportation is based primarily on two factors — faster speeds and more flexibility of operation between terminals.

The higher speed of air travel as compared to surface travel is the outstanding competitive characteristic of aviation. The fastest surface travel is between 60 to 80 miles per hour whereas speeds five times that fast are achieved by air.

Flexibility of operation between terminals is easily attained since geographical features have no influence on the aerial route and the route is not necessarily confined by ground facilities. The aerial route is direct between origin and destination thereby introducing savings in both time and distance. In addition there is no requirement for the construction of roadway facilities such as the highway or railroad right-of-way. The aerial "highway" is defined by electronic aids to navigation and the cost is relatively small as compared to the cost of the fixed facilities of surface transportation.

But it is practically impossible to make an entire trip from origin to destination by air; it is necessary to employ surface transportation at both ends of the trip to communicate between airport and city. The air traveler is not concerned with how long he is actually in the air between origin and destination but how long it takes him to

make the entire "door to door" trip. Thus, surface transportation is playing an increasingly important role in the air transportation picture for as air time decreases the surface time becomes a larger percentage of the "door to door" time.

The distances and time requirements from airports to the downtown business districts for some of the principal cities of the United States are given in Table VII². These values are for highway transportation and the travel times are based on peak hour highway traffic conditions. The values in Table VII do not reflect any decreases which might be anticipated from proposed new highway construction.

The value of air transportation might be expressed as the convenience which is afforded through the faster speed of travel. This convenience can be measured by the time which is saved by air over surface transportation for any given trip. However, this savings cannot be expressed by a comparison of the terminal to terminal time for two transportation media but must be expressed by a comparison of the actual "door to door" time for the passenger or cargo in question. This basis of evaluation will naturally place more

² City to Airport Highways, Civil Aeronautics Administration, April, 1953, pp. 1-2.

TABLE VII

DISTANCE AND TRAVEL TIME REQUIRED
BETWEEN AIRPORTS AND DOWNTOWN BUSINESS CENTERS

City	Distance Miles	Time Minutes
Atlanta	8	30
Boston	3	35
Cleveland	8	40
Dayton	10	20
Detroit	32	60
Kansas City	1	10
Los Angeles	14	45
New Orleans	9	20
New York:		
Newark	13	38
International	17	42
La Guardia	9	25
Teterboro	12	37
Philadelphia	6	25
San Diego	1	6
San Francisco	12	30

emphasis on the integration of the airport into the urban transportation system since surface time might easily become the more dominant component of the total time.

An extreme example of the importance of the surface component is the air trip from Cleveland to Detroit. The air time is 46 minutes and the surface time (Table VII) is 100 minutes or 69% of the total travel time. The importance of the surface component in this example can be fully appreciated when it is considered that a large decrease in the air time would produce an insignificant decrease in the total time. The surface component will not be as large a percentage for longer trips, however, it will become more significant as faster aircraft trim the flying time between terminals. It can be said that the "air-age" is earth-bound and will become increasingly so unless steps are taken to coordinate airport locations with surface transportation networks.

As the size of airports increases and the nuisance factors of airport operation become more objectionable it becomes necessary to locate airports farther from the urban core. Thus, the interests of convenience and necessity conflict; as air time is decreased the surface distance is increased. The answer to this dilemma must be the provision of faster surface connections between airport and urban core.

This faster service might be secured through the helicopter taxi, connections to rapid transit systems, or by the limited-access highway. The limited-access highway presents the best solution since faster service would be distributed to all portions of the urban region and not necessarily to a particular location within the core.

AIRPORTS WITHIN A METROPOLITAN REGION

The influence of aircraft design on airport design has been discussed in Chapter II. It has been demonstrated that larger aircraft require more extensive airport facilities for their operation. Therefore, airports which are constructed for large aircraft should be reserved, as far as possible, for the exclusive use of such aircraft. When a small aircraft is using a runway it prohibits the use of that runway by a large aircraft until the small one has cleared the field, thereby introducing an inefficient utilization of airport facilities. It naturally follows then that there should be some classification of airports within a metropolitan region based on variations in the operating characteristics of the using aircraft. The airports within a metropolitan region can be classified as follows:³

³ The Airport and Its Neighbors, op. cit., pp. 87-8.

Community. The local airport which would be used for short range movements in light and small aircraft. These aircraft have small cross wind capabilities and it might be necessary to provide wind-directional runways; however, they do not have high noise levels and a site can therefore be more easily selected. These airports should be located close to the greatest number of users which will require a duplication of facilities to serve different areas and the acquisition of sites relatively close to populated districts.

Intermediate. The inter-metropolitan type is characterized by many of the existing airports with multi-runway designs. These airports should be retained by converting to the one runway design on the existing site. The value of the airport is delicately balanced on a time-distance relationship to the particular area which supports it.

Super-airport. This facility is to be used by the heaviest and fastest aircraft engaged in continental or inter-continental travel. Its future design requirements will permit and necessitate its location in an area remote from urban development. An area of approximately 8 square miles will be required for the ultimate development of the airport (see Figure 1) thereby eliminating sites close to the

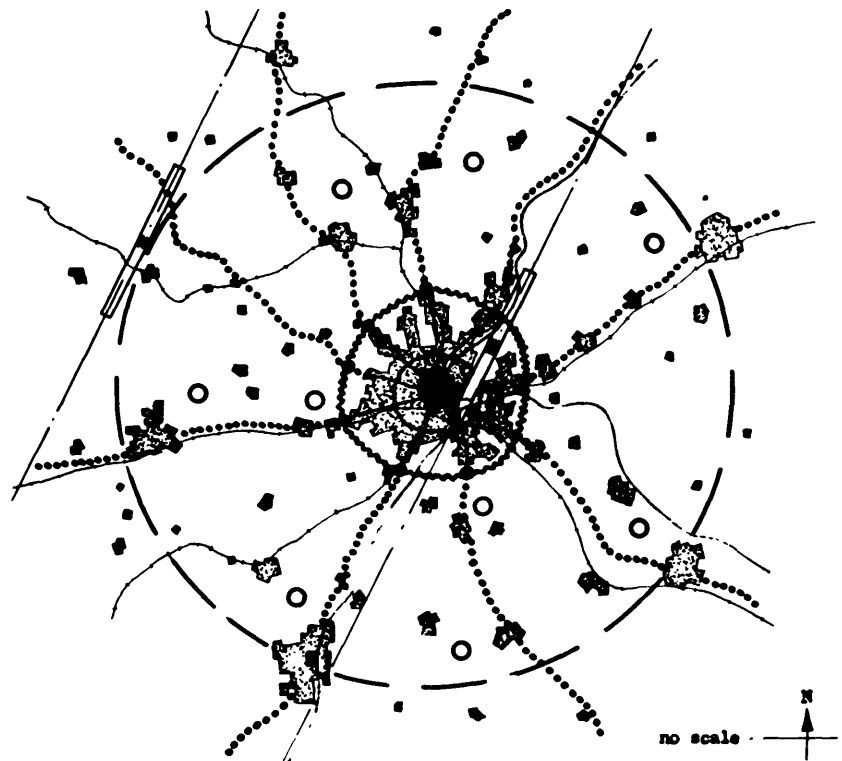
urban area. This airport will be particularly dependent upon fast surface transportation between the airport and urban core since it must be located from 30 to 40 miles from the downtown district of the city. It is doubtful if the airport in itself can generate sufficient vehicular traffic to justify the construction of a limited-access highway, therefore it will have to be located in conjunction with other regional facilities which will justify the highway construction.

The locations of these airport types with respect to the metropolitan region are shown in Figure 17.⁴ This locational pattern is an idealized arrangement showing how airports of the future should be geared into the regional master plan.

THE "JET-PORT"

The general classification system for airports considers only aircraft of conventional design. The airports in the "super" class can probably be used for the operation of jet aircraft; however, the operational characteristics of the jet aircraft will more dominantly influence the design of the airport. It is proposed therefore that the "Jet-port" be accepted as another classification of

⁴ Ibid, p. 84.



LEGEND





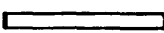






- | | | | |
|---|---|---|-----------------------|
|  | Urban Core |  | Community Airport |
|  | Highly Populated Areas |  | Major Highway Network |
|  | Air Approach Corridor |  | Peripheral Highways |
|  | Super-airport |  | Highway Interchange |
|  | Intermediate Airport |  | Major Railroads |
|  | Limit of Normal Commuting
(20 to 40 mile radius) | | |

FIGURE 17

AIRPORTS IN THE COMMUNITY MASTER PLAN

airport size or be considered as a particular type of "super" airport.

Jet transports will require longer runways and flatter glide angles and will produce higher noise levels than the existing types of conventional aircraft. The locational pattern of the super airport should however satisfy the requirements of the jet-port.

There have been some doubts as to the feasibility of integrating the two types of aircraft into the same flight pattern or operating the two from the same runway. Most of these doubts have been dispelled by the experience of the Air Force in operating the two types from Air Force runways. One outstanding characteristic of the jet is its large fuel consumption and fuel supply is a more critical consideration than with piston planes. The Air Force, because of this characteristic, has given operational preference to the jet, and in most cases the piston plane has followed the jet in both landings and take-offs.

The advantage of the jet over the conventional transport is its speed and passenger comfort in flight. It has been pointed out that further increases in aircraft speed will have little relative value for flights of short distances because of the surface component of the "door-to-door" time. The jets then will offer little advantage on short trips but

will be most efficient on trans-continental or inter-continental flights where distances are long. For the immediate future the jet-port will be feasible only in cities which have sufficient long range traffic to justify its construction. For the most part such cities will be confined to coastal locations. Jet-ports might be located in Boston, New York, Washington, Miami, Los Angeles, San Francisco and Seattle. Possibly the long range traffic of Chicago will also justify the construction of a jet-port.

It is anticipated that the jet transport will be introduced into commercial service in 1957 or shortly thereafter. Should the jet prove practical for civil operation there will be a period of transition in which the jets will gradually replace piston aircraft in certain long range operations and it will be 1962-1965 before there will be sufficient jet traffic to justify the construction of a jet-port. Any airport planning for the future should take into consideration the prospects of civil jet operation and the feasibility of constructing a jet-port for the predominant use of jet aircraft.

THE HELI-PORT

Some of those who view with despair the surface bottlenecks are expectantly awaiting the full scale introduction of

helicopter taxi service as the panacea for all airport to city transportation difficulties. Recent advancements in the design and usage of military helicopters have been encouraging in this respect. A recent study⁵ has indicated however that the helicopter will not be economically feasible for short range taxi service. The most efficient application of the helicopter will be for inter-city flights of a distance up to 250 miles. Therefore this newer type aircraft might be regarded as a replacement for some airplane operations rather than for surface operations.

This phase of helicopter usage will be beneficial for aviation in the long run because many short inter-city flights can be performed by helicopters operating from close-in locations, rather than by airplanes operating from peripheral locations. A good example of potential helicopter activity is as a substitute for the airplane in the Cleveland-Detroit trip which has previously been mentioned.

Regardless of the potential of the helicopter — as a feeder aircraft, inter-city bus, or airport to city taxi — the heli-port will have to be integrated into the urban surface transportation system. A downtown heli-port location, if such is available, will be beneficial to transients but of

⁵ Airports and Their Use, op. cit.

less benefit to residents of the city who must travel by surface means to their ultimate destination. The use of helicopter service will not then eliminate the surface component of time but will substantially decrease it. In any event, an efficient surface transportation network will be required to distribute airline passengers to their ultimate destination.

INFLUENCE OF AIRPORTS ON ADJACENT RESIDENTIAL PROPERTY

The opposition to airport location and operation is usually raised by the residents of the adjacent area. Their objections may range from a claims of nuisance such as noise, dust, glare, and hazard to economical factors such as a reduction of property values. The claim of reduction of property values is perhaps partially supported by the reluctance of the FHA and Veterans Administration to insure loans on houses located within two miles of an airport. The FHA in a July, 1951 analysis of residential areas near airports found that airports should be located at least two miles from houses, and said:

The resulting noise, vibration, and hazard-psychological as well as real—of low flying aircraft will have a depressing effect upon the desirability and marketability of land...⁶

⁶ As reported in "Near-Airport Land Values Unaffected by N.Y. Crashes as Homes Encircle Runways", Architectural Forum, Vol. 96, No. 4, April, 1952, p. 51.

Despite this reluctance on the part of the FHA and Veterans Administration, the CAA maintains that airports present desirable features which counterbalance the undesirable aspects and actually are conducive to increases in the value of lands adjacent to airports.⁷ This conviction is further validated by a recent report which indicates that airports do not adversely affect the real estate in the airport vicinity.⁸ The report was based on a comparison of the market behavior in the airport area with other similar areas in the same city and not in an airport environment. The survey was conducted at airports in Chicago, Los Angeles, Denver, Dallas, Newark, and New York and at all locations revealed that the airport does not have an unfavorable influence on the vicinage real estate. Some of the amenities of near-airport locations which were considered as being possible reasons for the favorable report are:

1. Better transportation developed on account of the airport..
2. Thousand of new employees at the airport strengthened the demand for housing.

⁷ Airport Planning, op. cit., p. 23.

⁸ Herman O. Walther, "The Impact of Municipal Airports on the Market Value of Real Estate in the Adjacent Areas", The Appraisal Journal, Vol. XXII, No. 1, January, 1954, pp. 15-25.

3. In many places new industry which built near the airport brings more job opportunities.

The data which have been collected to date indicate that airport proximity has little or no depressing effect on the value of adjacent real estate. However, it is felt by some that this condition of the market is a result of the relative shortage of housing in the metropolitan areas and that a detrimental influence will become apparent when the housing situation is eased.

A study has been completed on the appraisal damages that would probably result from the establishment of the proposed Northeast Airport in the Detroit Metropolitan Area.⁹ This study is unique in that it considers, among other factors, the effects of jet operation on the adjacent property values. The conclusions of the study relative to the probable damages to residential building sites in developed subdivisions varies from 0 to 75% depending on the distance of the site from the runway and the type of subdivision.

The attitude of a planning commission in regard to the compatibility of airports and residential districts is summed up in the following quotation from the regional plan for the Atlanta Metropolitan Area:

⁹ William J. Randall, "Appraisal of Damages Caused by Proximity to Jet Airport", The Appraisal Journal, Vol. XXII, No. 1, January 1954, pp. 39-42.

It is essential that areas adjacent to airport facilities be kept open or occupied by such uses as would not be blighted or endangered by air traffic. Residential districts definitely must not be allowed to build close to airports. This common-sense principle of land use is already violated in the Atlanta metropolitan area.¹⁰

Although the available data¹¹ indicate that airports do not have a detrimental effect on adjacent property values planners and real estate investors are justly apprehensive about developing residential districts near airports. The nuisance factors of noise, vibration, and hazard have been instrumental, along with other possibly more important factors, in the formation of blighted areas near factories, railroads, elevated railways, and heavily traveled streets. Therefore, it can be reasonably assumed that these factors might have somewhat the same effect on properties near airports. The higher noise levels of jet type aircraft might initiate or accelerate trends toward a decline in property values in the airport vicinity; accordingly, more emphasis should be placed on the need for sound land planning near airports.

COORDINATION OF AIRPORT AND COMMUNITY PLANNING

The requirement for an integrated urban transportation

¹⁰ Up Ahead, A Regional Land Use Plan For Metropolitan Atlanta, February, 1952, p. 79.

¹¹ This data does not apply to land at the immediate ends of runways but to approach lands and vicinage real estate.

network has been discussed. Another equally important planning factor is the coordination of other community planning with airport planning; specifically the location of other public works construction projects in relation to the airport location.

One of the important recommendations of the President's Airport Commission is that an area two miles long and ranging in width from 1000 to 6000 feet at the end of dominant runways should be kept clear of schools, hospitals, or other facilities wherein there might be a congregation of population. Governmental agencies which are aware of existing or proposed airport sites can appropriately plan their new construction activities to conform with this recommendation and possibly improve upon it.

An example of coordinated planning is that of a school which is to be constructed in the vicinity of the proposed Blue Ash Metropolitan Airport at Cincinnati, Ohio. Two sites were being considered as a location for the St. Xavier High School but before final selection was made an engineering firm was asked to report on the noise levels for the two sites under conditions of airport operation. The firm found that the noise level at one site, 2.8 miles south of the end of a major runway, would be so high as to approach the risk of deafness following sustained exposure. At the second site

conditions would be less severe but would still be noisy enough to require sound-proofing devices to reduce the interior noise levels.¹²

Contrasted to the Blue Ash co-ordination is the case at Los Angeles International Airport. The airport has had relatively clear runway approach zones; recently however, apparently without knowledge of the City of Los Angeles or the Board of Airport Commissioners, two schools were constructed in the County of Los Angeles directly in the approach areas to the airport.¹³ The divided jurisdiction over schools and airports as demonstrated in this case points up a need for comprehensive community and regional planning.

AIRPORT LOCATIONAL PLANNING FACTORS

There are numerous factors that enter into the final selection of a particular site for an airport. The most important of these factors are listed below:

1. Type and volume of air traffic to be accommodated.
2. Existing and proposed airport and air navigation facilities.

¹² "Airport Noise and Schools", Urban Land, January, 1954, p. 4.

¹³ R. G. Dinning, "Integration of Airport and Municipal Planning", Journal of the American Institute of Planners, Vol. XIX, No. 3, Summer, 1953, p. 127.

3. Existing and proposed transportation facilities.
4. Topography and meteorological conditions.
5. Existing and proposed community land use development.
6. Local laws.

Items 3, 5, and 6 have been discussed elsewhere in this thesis. Item 1 is a survey of the anticipated types and volumes of air traffic which must be accommodated and will directly influence the number and types of airports which will be required. This item will not be discussed further; but it is stressed that such a survey must be reasonably accurate and logically projected to some future date to provide a basis for a sound airport planning program.

Topography and Meteorological Conditions will limit the number of sites which can be adapted for airport purposes. This item is becoming a more restrictive one as larger and more level areas are required for airport construction. The heavier aircraft loadings require more substantial soils for runway construction thereby further limiting the sites which can be efficiently utilized. These factors are largely ones of airport design and will influence planning only in so far as they limit the number of sites which can be considered. In general, a high land site is preferable to a valley site because the latter are usually surrounded by terrain obstructions and are more susceptible to fog.

Existing and proposed airport facilities is becoming a more important locational consideration as additional airports are constructed. The airports should be separated by a sufficient distance so that maneuvering aircraft from neighboring airports will not interfere with each other and runways should be aligned so that approach corridors will neither intersect nor overlap. Large aircraft have a larger turning radius than small aircraft so the air space reservation will vary according to the size of the aircraft using the airport. The airspace reservations required for the various CAA class designations of airports operating under non-instrument conditions are given in Table VIII.¹⁴

TABLE VIII

AIR SPACE RESERVATIONS

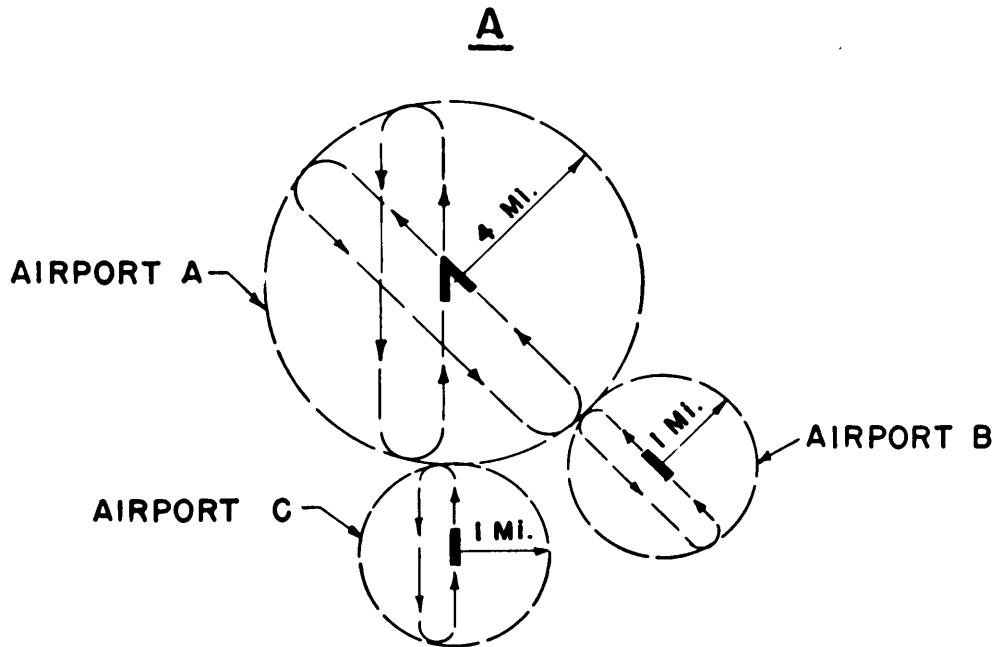
<u>Airport type</u>	<u>Radius of airspace miles</u>
Secondary	1
Feeder	2
Trunk line	3
Express	3
Continental	4
Intercontinental	4
Intercontinental express	4

¹⁴ Airport Planning, op. cit., p. 17.

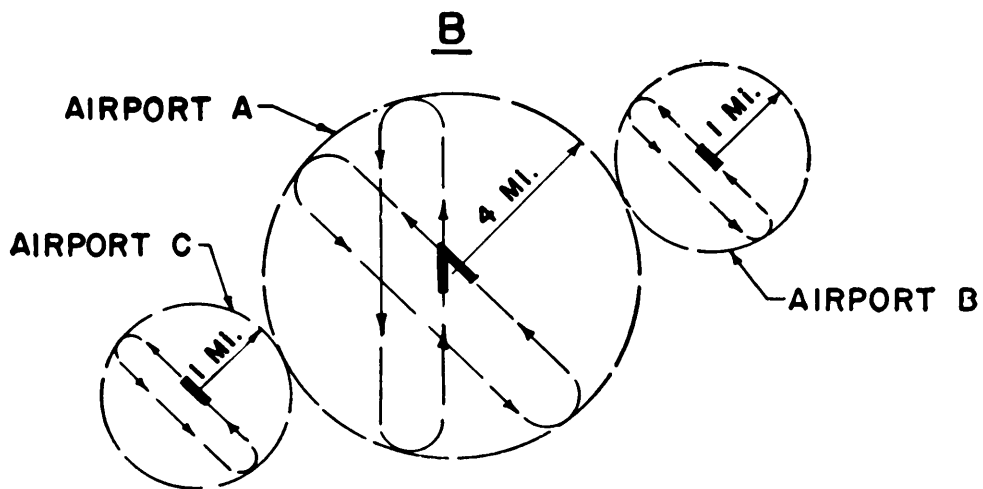
An example of the minimum spacing of airports and the desirable arrangement of parallel runways is shown in Figure 18.¹⁵ It can be seen that the parallel airport system provides more space for maneuvering at the ends of the runways and allows "straight-in" approaches. The parallel system must be used where the corridor technique of approach is employed and will also be required for approaches under instrument conditions. When the parallel arrangement is not used there is a loss of airport efficiency under instrument conditions.

The traffic hazards or loss of efficiency which might result from improper airport location again points up the need for integrating the airport plan into the comprehensive community or regional plan. The regional airport plan should be developed as an individual section of the comprehensive plan and the inter-relations or conflicts between airports studied to resolve the difficulties. The planning process can be supplemented and enforced by appropriate zoning legislation to insure the most efficient use of metropolitan air space.

¹⁵ Ibid, p. 18.



All runways in line



Better arrangement
(Runways parallel)

FIGURE 18

SPACING OF AIRPORTS

CHAPTER VIII

SUMMARY AND RECOMMENDATIONS

The problem of community encroachment on airports is the result of a number of factors working in combination. Airports which were originally located in relatively open spaces have become surrounded by an expanding urban periphery. The city population has undergone a transition from urban to suburban living and occupied the previously vacant land between the airport and city. This diffusion of population has also placed greater loads on the inadequate surface transportation connections between the airport and urban core.

Industries which are related to aviation have located adjacent to airports bringing additional residential developments and service industries, thereby placing a still higher premium on the potential airport expansion properties surrounding the airport. The advancement of aeronautical technology has produced larger aircraft which require more extensive airport facilities for their operation and existing facilities have had to be expanded. These parallel developments, the formation of a suburban population and the advancement in aircraft designs, have brought more people into contact with airports and the nuisances of airport operation.

The problem is twofold: First, some airports cannot meet the more stringent operational requirements of heavier aircraft and being unable to expand are forced to curtail operations; and, second, the airports which can be and are expanded and the new airports which are constructed subject the adjacent residents to an increasing influence from the nuisance of airport operation. The principal complaints of those persons who reside near airports are the depreciation of property values, nuisance from noise, and hazards of aircraft operation.

The existing data indicate that proximity to an airport does not have an adverse effect on property values. Some of the factors which favor near-airport locations are the improved transportation, possible influx of aviation related industries, and a strengthened demand for housing. However, the anticipated conversion of civil aviation to jet operation will produce higher noise levels and possibly greater hazards which might counterbalance the existing amenities of the near-airport location.

The danger or hazard from aircraft operations near airports is more psychological than real. The majority of accidents which do occur near airports and which involve people on the ground are located in a strip of land 1000 feet wide and one-half mile long at the end of the runway. The

hazard to ground personnel can be appreciably reduced by maintaining this strip of land as an integral part of the airport and excluding all construction within this area. It is desirable to maintain all lands in the runway approach area free from inhabitation, preferably by orienting runways to have approaches coincide with open water or areas of public ownership. Where this procedure is impossible the density of population within the approach area should be kept at a minimum and some protective features embodied in the building construction and area landscaping.

The influence of aircraft noise will become more widespread when civil aviation converts to jet operation. Noise levels above 120 db can cause deafness or injury to the ear, and noise levels above 85 db will interfere with normal voice communication. The desirable maximum noise level exposure is 60 db, however, intermittent exposures of 85 db can be accepted. There are three methods whereby noise levels can be attenuated — at the source, by distance, and by barriers. Attenuation by distance is the only method of protection from noises generated by airborne aircraft although barriers can be used to attenuate noise from ground facilities. Research is being conducted to decrease noise levels at the source; however little progress is being made.

The most dangerous areas within the runway approach

zone are shown graphically in Figure 19. The noise source was assumed as 132 db measured at 80 feet, the plane is airborne at 3000 feet from the end of the runway and has a take-off angle of 5 degrees. The noise level is assumed to be attenuated by distance alone and no allowance has been made for terrain or atmospheric absorption. The sound contours are therefore at a maximum distance from the runway centerline extended and appropriate absorption determinations will substantially decrease the range of influence for a given contour. It is interesting to note that noise levels above 120 db are confined within the airport boundaries. The hazard numbers of Figure 19 represent the most dangerous conditions for both take-offs and landings (see Chapter III).

The approaches to airports can be protected by airport zoning, outright purchase of lands in the approach area, or the acquisition of avigation easements. Generally, purchase in fee simple and the acquisition of avigation easements will be used to supplement zoning. The law of nuisance as related to airports has two sides: the airport can be a legal nuisance to the adjacent landowner, or the landowner can provide a legal nuisance to airport operation by erecting "spite" structures. It is particularly incumbent upon the airport planner to select a site at which the airport cannot be justifiably challenged as a legal nuisance.

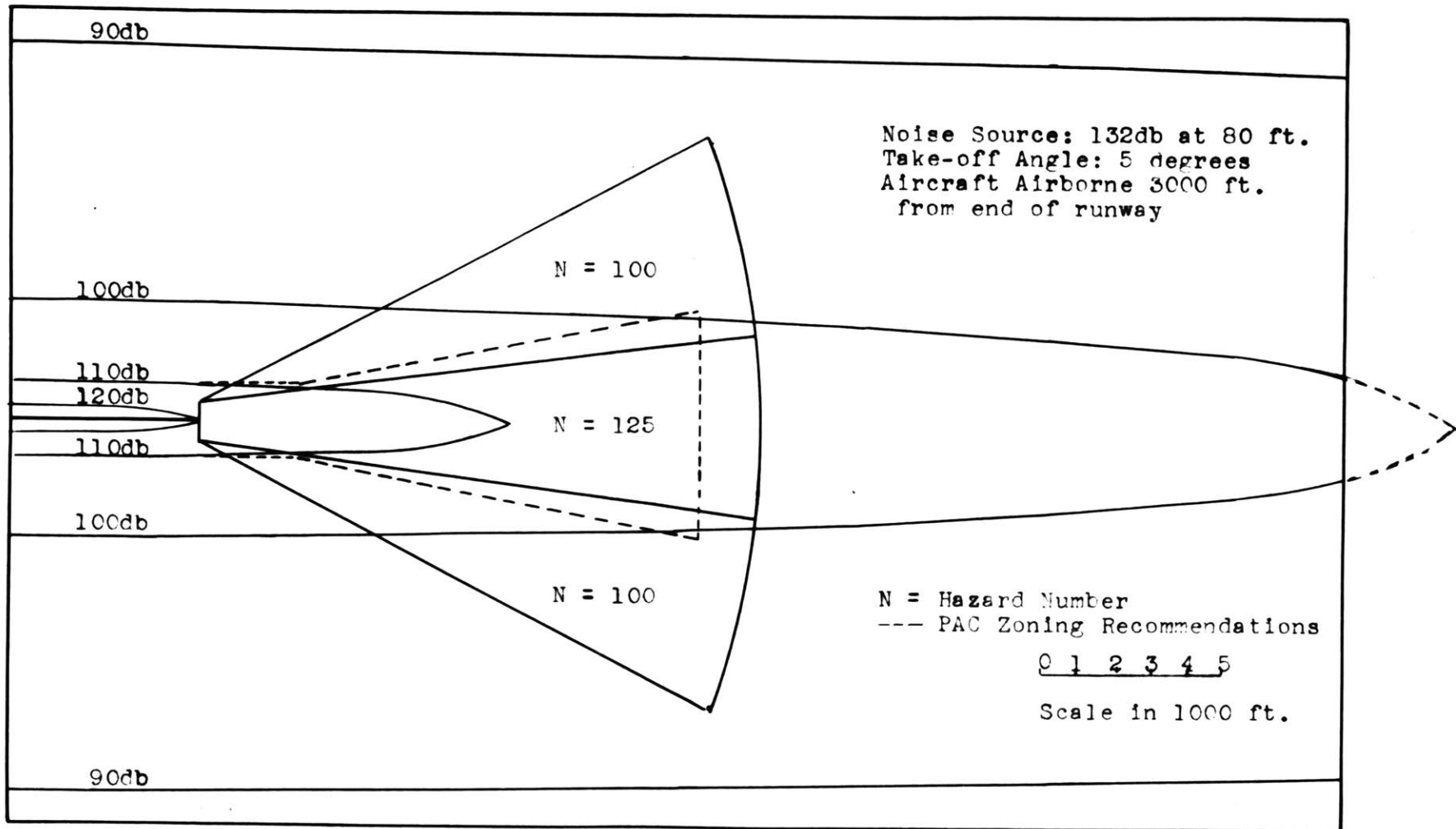


FIGURE 19

MAXIMUM NOISE AND HAZARD AT END OF RUNWAY

The airport plan should be integrated into a comprehensive plan for the community, metropolitan area, or region. Air transportation is becoming increasingly dependent upon the surface transportation network, therefore appropriate attention should be given to the surface transportation system in determining the final selection for an airport site.

RECOMMENDATIONS

The following recommendations are presented based on the material developed in this thesis:

1. Integrate community and airport planning. Airports should be developed as a part of the community master plan and urban transportation system. Particular attention should be given to the provision of a limited access highway between airport and urban core.

2. Incorporate cleared runway extension areas into runway. The dominant runways of new airport projects should be protected by cleared extension at each end of at least one-half mile in length and 1000 feet in width. This area should be maintained free from housing or any other form of obstruction. (PAC Recommendation shown in Figure 19).

3. Establish effective zoning laws. A fan-shaped zone, beyond the extension of Recommendation 2, at least two

miles long and 6000 feet wide at its outer limits should be established at new airports. In this area the height of buildings and use of land should be controlled to prohibit the erection of places of public assembly and to restrict residences to more distant locations within the zone. (PAC Recommendation shown in Figure 19).

4. Control land use around airports. The use of land in approach zones should be controlled to encourage agriculture or other low density activities. Preferably approach areas should coincide with areas of public ownership such as forests, reservoirs, and parks.

5. Proposed airports should be protected by zoning and land use planning. Whenever a site is selected for an airport immediate action should be taken to protect the site from encroachment or real estate speculation.

6. Analyze community potential to generate jet traffic. The air traffic of the community or region should be analyzed to determine if it will support civil jet operations. Increased airport facilities should be planned accordingly and existing facilities surveyed to ascertain their capabilities of supporting jet operations.

7. Promote airport public relations. It is becoming increasingly difficult to find suitable airport site, particularly in metropolitan areas. When a site is finally

selected the decision will likely be met by considerable opposition from private citizens who live in the vicinity of the proposed site. A sound public relations program should be used to present the aircraft hazard problem in its proper perspective and to regain public acceptance of airports.

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