ANALYSIS OF AIRLINE OPERATING COSTS AND REVENUES

by

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I. INTRODUCTION

The economic factors in airplane operation are of fundamental importance to all airlines. Inasmuch as no two airlines, with similar routes, have the same significant or direct operating expenses and the same overhead or indirect operating expenses, this limits analysis to each particularly-defined situation.

The purpose of this investigation is to show that given such a postulate situation, the use of variant cost equations, plotted into curves, can determine the specific operating costs of an individual air route. A hypothetical case will be considered to illustrate the use of such cost curves.

The basis for cost determination is calculated in units of cost per mile flown by an airplane, and, in the interest of uniformity and convenience, the various expenses incurred are arranged under headings similar to those outlined by the Civil Aeronautics Board.

II. SIGNIFICANT OPERATING COST EQUATIONS

In the course of their association with United Air Lines, Mentzer and Nourse (9) developed the significant operating equations that have been accepted by the Air Transportation Association and used by most airlines and airplane manufacturing companies. Since these equations vary directly with increasing expenses, the Lockheed

Company (8) in 1945 corrected the coefficients of the equations to correspond with the costs of that year. The curves herein plotted are an interpretation of these equations, and are detailed and evaluated hereafter on the basis of current costs.

A. Basic Definitions.

Significant expenses may be defined as those expenses resulting directly from the aircraft flight, and depend upon the power, size, initial cost, and fluctuation in expenses.

Block speed, which is the distance from station to station divided by the time required to fly this distance, is one of the basic factors. In computing the block speed, certain assumptions (2) are required which will cover the average transport conditions. These assumptions are:

1. All station airports are at sea level
2. The average cruising altitude is 14,000 feet
3. The total time lost in the climb and descent is 0.06 hours
4. The wind velocity is zero
5. The total taxi and maneuvering time is 0.084 hours
6. The distance is increased by two percent because of deviations from the true course

Block speed in terms of miles per hour units may then be expressed in the following equation:

$$V_b = \frac{D}{K_1(D/V) + K_2},$$

where,

V_b = block speed

D = distance from station to station

V = velocity of the airplane at cruising altitude

K_1 = increase in distance due to deviations from the true course

K_2 = sum of the total time lost in the climb and descent, and the taxi and ground maneuvering time

For the purpose of this investigation, as stated in the assumptions, the increase in distance due to deviations from the true course is two percent. The constant K_1 will then be 1.00 plus 2 percent. The sum of 0.06 hours, which is the time lost in the climb and descent, and 0.084 hours taxi and maneuvering time, make a total of 0.144 hours. The block speed equation, using these values, will be:

$$V_b = \frac{D}{1.02\ (D/V) + 0.144} .$$

Airplane utilization, a second basic factor, is generally expressed in terms of hours of flight per year. The determining factors of utilization are:

1. Unexpected contingencies occuring during the flight
2. The frequency of the service
3. The length of the flight
4. Seasonal fluctuations

The general considerations of such utilization will be taken into account later and a numerical estimate of hours per year will be determined.

B. Development of Significant Cost Equations.

The method of depreciation of an airplane, less the engines, is set by the Civil Aeronautics Board. In accounting practice it is sometimes referred to as the "straight line" method, which is based upon the initial cost of an airplane less the cost of the engines, minus the salvage value of the airplane only, with a division factor of the number of years the airplane is to be fully depreciated, multiplied by the block speed, and multiplied by the utilization. The general cost of the depreciation equation may then be written:

$$C_1 = \frac{(C_a - K_3 C_a)}{(Y)(V_b)(U)},$$

where,

C_1 = depreciation cost per mile of an airplane less engines

C_a = initial cost of the airplane less engines

K_3 = salvage value as a fraction of the initial cost of the airplane

Y = depreciation period in years

V_b = block speed

U = utilization in hours per year

In general practice, the constant K_3 is ten percent of the initial cost, and the airplane is fully depreciated in five years. (Five years is the minimum period required to depreciate fully an airplane). The equation may then be written:

$$C_1 = \frac{(0.90)(C_a)}{(5)(V_b)(U)}.$$

Engine depreciation, which is similar to airplane depreciation, is also based on the "straight line" method. The difference is in the period of depreciation, which is computed in units of hours instead of years. The engine depreciation equation may then be written as:

$$C_2 = \frac{N(C_e - K_4C_e)}{HV_b},$$

where,

C_2 = depreciation cost per mile of all engines

C_e = initial cost of one engine

K_4 = salvage value as a fraction of the initial cost of one engine

N = number of engines

H = utilization of the engine in hours

V_b = block speed

General experience, based on past engine performance, has proved that an engine has no salvage value after an expected run of approximately 5,000 hours. Thus the equation actually appears:

$$C_2 = \frac{(N)(C_e)}{(5000)(V_b)}.$$

Airplane overhaul and repair costs are based on two items; labor and material expenses. A correlation was found by Mentzer and Nourse to exist between the cost of labor per hour the airplane was flown, and the number of seats and engines. The cost of the materials was shown by them to be proportional to the sum of the weight of the airplane less the engine weight, plus the initial cost of the airplane.

From the latest information available (8) the cost of labor per hour the airplane was flown is $3.10. When these equations were first derived, the only cost figures at that time were taken from the Douglas Transport DC-3. Therefore, in order to make these equations applicable to all types of transport airplanes, a linear proportional relationship was expressed in factors which varied with different types of airplanes. The cost of the materials per hour the airplane was flown is $2.50. Both factors, labor and material expenses, are given equal weight in the equation, hence the coefficient of two appears in the denominator. The accepted equation is:

$$C_3 = \frac{3.10\left(\frac{M}{21} + \frac{N}{2}\right) + 2.50\left(\frac{W_1}{13800} + \frac{C_a}{100000}\right)}{2\,V_b},$$

where,

C_3 = cost per mile of airplane overhaul and repair

M = number of seats in the airplane

N = number of engines

W_1 = airplane weight less engines

C_a = initial cost of the airplane less the cost of the engines

V_b = block speed

The engine overhaul and repair equation is similar to the above, where the cost of labor depends upon the two variables, weight of the engines, and number of cylinders. The expenses of the materials per hour of flight depend upon the weight and the initial unit cost of an engine. Reducing this to actual practice, the engine overhaul and repair equation takes the form:

$$C_4 = \frac{N\left[1.25\left(\frac{W_2}{1400} + \frac{P}{14}\right) + 2.80\left(\frac{W_2}{1400} + \frac{C_e}{12000}\right)\right]}{4\ V_b},$$

where,

C_4 = cost per mile of engine overhaul and repair

N = number of engines

W_2 = weight of an engine

P = number of cylinders per engine

C_e = cost of one engine

V_b = block speed

Airplane and engine ground service expenses also include such items as cleaning and washing, checking and inspection of engines and airplane, cargo loading, and supplies for ground services.

Experience has shown that the sum of the labor and supply cost is \$5.49. Twice as much weight is given to the engines as to the airplane, hence three occurs in the denominator. The airplane and engine ground service cost equation now appears:

$$C_5 = \frac{5.49\left(N + \frac{W_2}{13800}\right)}{3\ V_b},$$

where,

C_5 = cost per mile of the airplane and engine ground service

N = number of engines

W_2 = weight of an engine

V_b = block speed

Airplane insurance costs include coverage on the entire airplane in the event of any accident due to crash, fire, or wind. Public liability and property damage insurance are quoted by the underwriters on a mileage basis, which makes up the protection required by most airlines. The combined insurance for airplanes will have an equation as follows:

$$C_6 = \frac{rR(C_a + NC_e)}{UV_b} + Pl + Pd,$$

where,

C_6 = cost per mile of airplane insurance

r = average insurance premium on the dollar valuation

R = ratio of the insured value to the total cost of the airplane

C_a = cost of the airplane less the engines

N = number of engines

C_e = cost of one engine

U = utilization of the airplane in hours per year

V_b = block speed of the airplane

Pl = public liability premium

Pd = property damage premium

In actual practice the insurance premium on the dollar valuation is \$0.08, and the ratio of the insured value to the total cost of the airplane has a numerical value of 0.9. Public liability and property damage insurance is quoted at \$0.0013 per mile of flight. The insurance equation will then read:

$$C_6 = \frac{(0.9)(0.08)(C_a + NC_e)}{UV_b} + 0.0013.$$

Fuel expenses, including taxes which vary directly with the number of hours of flight, may be based on the horsepower of the engine, specific fuel consumption, and cost of the fuel. The fuel cost equation may be expressed as follows:

$$C_7 = \frac{(F_c)(sfc)(bhp)(N)}{K_5V_b},$$

where,

C_7 = cost per mile of the fuel, including tax

F_c = cost of fuel per gallon, including tax

sfc = specific fuel consumption

bhp = brake horsepower per engine

N = number of engines

V_b = block speed

K_5 = constant of pounds of fuel in a gallon, the numerical value being six

The oil cost equation is similar to the fuel cost equation, which depends upon the oil cost in dollars per gallon, including tax, specific oil consumption, engine brake horsepower, and block speed. The oil cost equation actually appears:

$$C_8 = \frac{(O_c)(soc)(bhp)(N)}{K_6V_b},$$

where,

C_8 = cost per mile of oil, including tax

O_c = cost of oil per gallon, including tax

soc = specific oil consumption

bhp = brake horsepower per engine

N = number of engines

V_b = block speed

K_6 = constant of the pounds of oil in a gallon, the numerical value being 7.5

Senior pilots' salaries (5) are based on five factors:

1. Insurance, which includes compensation insurance, group life insurance, federal old age benefits, and unemployment insurance
2. A day-night rate factor due to the hazards and additional training involved in night flying
3. An hourly rate factor which takes into account the flight time
4. A mileage differential
5. Annual base pay

The equation is:

$$C_9 = \frac{I(dn + hr + mr + bp)}{V_b},$$

where,

C_9 = cost per mile of senior pilots' pay

I = one plus the insurance rate

dn = day-night factor

hr = hour factor

mr = mileage rate factor

bp = annual base pay

V_b = block speed

From experience, the insurance rates are proportional to the total payroll costs of the senior pilot. Mentzer and Nourse ascertained these as seven percent above the total salary. Because of the reasons mentioned before, fifty percent more is paid for night flying than for day flying. It is estimated that approximately one-third of the total flying is done at night, thus the day-night factor becomes 1.33. The hourly rate factor in terms of block speed, which was set up by the Federal Labor Board, is the average slope of the cost per hour versus the block speed curve. The numerical value is 3.55 added to the product of 0.0067, multiplied by the block speed. The Civil Aeronautics Board has approved $0.087 for each mile an hour above 150 miles per hour. The annual base pay was set at $2,400 per year for a maximum of 900 hours of flying. The senior pilot's salary equation then becomes:

$$C_{10} = \frac{1.07\left[1.33(3.55 + 0.0067\ V_b) + 0.087(V_b - 150) + \frac{2400}{900}\right]}{V_b}.$$

The first pilot's salary includes the insurance rate, the annual base pay, and a velocity factor. The equation for the first pilot's salary cost equation may be stated as:

$$C_{10} = \frac{(I)(bp_1)(vf)}{V_b},$$

where,

C_{10} = cost per mile of first pilot's pay

I = one plus the insurance rate

bp_1 = annual base pay

vf = velocity factor

V_b = block speed

The insurance rate is seven percent above the total salary.

The annual base pay for the first pilot is $3,700 per year for a maximum of 850 hours of flying. Since the velocity factor takes into account any block speed above the average block speed of the route flown, the first pilot's pay equation may then be written:

$$C_{10} = \frac{1.07(\frac{3700}{850}\left(\frac{1 + \frac{V_b}{V_{b_1}}}{2}\right)}{V_b},$$

where,

V_{b_1} = average block speed

The engineer's salary is similar to the first pilot's salary with the one exception that the annual base pay is $2,400 per year. The engineer's salary is, therefore:

$$C_{11} = \frac{(1.07)(\frac{2400}{850})\left(\frac{1 + \frac{V_b}{V_{b_1}}}{2}\right)}{V_b}.$$

The cabin boy's pay follows the engineer's salary, with the exception of the annual base pay. The cabin boy receives $1,420 per year for 900 hours of flying. The cabin boy's pay equation is:

$$C_{12} = \frac{(1.07)\left(\frac{1420}{900}\right)\left(\frac{1 + \frac{V_b}{V_{b_1}}}{2}\right)}{V_b} .$$

The steward's pay is also similar to the above. His annual base pay is $1,620 for 900 hours of flying per year. The steward's pay equation is:

$$C_{13} = \frac{(1.07)\left(\frac{1620}{900}\right)\left(\frac{1 + \frac{V_b}{V_{b_1}}}{2}\right)}{V_b} .$$

The interest on the amount of money invested, which is figured in the direct cost equation, is computed on the total investment in the airplane. This equation may be written:

$$C_{14} = \frac{(ir)(ai)(C_a + NC_e)}{UV_b} ,$$

where,

C_{14} = interest on the investment per mile

ir = current interest rate

ai = a fraction of the average amount of money invested

C_a = cost of the airplane less engines

N = number of engines

C_e = cost of one engine

U = utilization

V_b = block speed

In actual practice, interest is computed on 0.7 of the money originally invested, which is considered a fair return. Three percent interest is the current rate. The interest on the investment will then be:

$$C_{14} = \frac{(0.03)(0.7)(C_a + NC_e)}{UV_b}.$$

Crew expenses, which include equipment, hotel and food costs, et cetera, are divided into two parts; cockpit and cabin. Expenses are the product of the cost per mile of the crew times the number of crew members, and may be expressed as:

$$C_{15} = (EM)(CM),$$

where,

C_{15} = cockpit crew expense per mile

EM = cost per mile

CM = number of crew members

The expense of the cockpit crew, based on past operations, actually appears as:

$$C_{15} = (0.00225)(CM).$$

The expense of the cabin crew, based on past operations, may be computed from the following equation:

$$C_{16} = (0.0034)(CM),$$

where,

C_{16} = cost per mile of cabin crew expenses

The passenger volume expense, which includes such items as passenger liability insurance, supplies, telephone and telegraph reservations, food and food supplies, commissions to ticket agents, et cetera, applies largely to transcontinental service, but it may be considered in computing the total operating expense. Passenger volume expense then is the product of the service costs multiplied by the number of passengers. The equation takes the form:

$$C_{17} = (SC)(NP),$$

where,

C_{17} = cost per mile of the passenger volume costs

SC = service costs

NP = number of passengers

The latest figures available show 0.005 to be the numerical value for service costs. The passenger volume expense may be expressed in the following equation:

$$C_{17} = (0.005)(NP).$$

Each of the above equations, as seen in the Appendix, has been plotted with suitable flexibility in the variables to aid the reader in readily obtaining the significant operating costs for any given type of airplane. To facilitate the use of these curves, an example is given on each individual plotting.

III. OVERHEAD COSTS

With respect to overhead costs, the sole source of information available to the public is the annual copies of the Civil Aeronautics Board's "Annual Airline Statistics of Domestic Airlines" (1). Instructions for the making of this report are given in the Civil Aeronautics Board's, Form Forty-One Manual, January 1, 1947, entitled "Uniform System of Accounts for Air Carriers" (2). The name of the manual is descriptive of the contents of the form which covers both overhead and significant expenses.

At the present time, the overhead cost is determined by totaling the estimated expenses for each station of the individual items (15) which are available from the Civil Aeronautics Board. The total indirect cost per mile is then obtained by dividing the total overhead cost by the total number of scheduled air miles.

The estimation of individual station expenses may be made accurately, but they must be kept within the boundaries of established experience. A study of reported overhead costs (1) of the various airlines indicates that such costs do not vary directly with the extent of individual operations, but depend generally upon management policies. However, if an average of the overhead costs per mile for all of the airlines in the United States were made, it would be reasonable to conclude that this figure would be a boundary which is established from the experience of past operations. The average overhead cost per mile is $0.474.

IV. THE APPLICATION OF THE SIGNIFICANT COSTS

The application of the significant cost equations and curves is of fundamental importance in this investigation which covers a postulate situation for a proposed air route. In order to illustrate better the flexibility of the curves, a hypothetical airline will be promoted in this thesis.

A. Establishing a Hypothetical Airline.

In considering the air transport business there are five general facts (16) of which the aspects should be determined:

1. Is there a need for the proposed air service?
2. What is a reasonable potential traffic figure?
3. What expenses are incurred in airline operation?
4. What air mail income can be expected?
5. Is there a reasonable prospect for profitable operation?

These are the most difficult problems facing prospective airline operators, and unless accurate estimates can be made, the promotion of an airline should not be undertaken. The problem is to promote a hypothetical airline that will satisfy all of these five conditions.

The proposed route taken for illustration will originate at Eugene, Oregon, flying across Central Oregon, making stops as indicated in Table 1, and ending at Boise, Idaho.

1. Need for the airline.

Throughout the central part of Oregon, individual towns are isolated from each other by geographical and seasonal weather conditions. For this reason the proportion of people to automobiles, according to Table 1, is one car for every 2.6 people (12). At first perusal of these statistics, it would seem that the existing large number of automobiles is the solution to the transportation problem. However, the distance between towns is far, and the condition of the roads is often definitely poor. In addition, the physical strain of making long trips is to be considered. People find the expense and upkeep of automobiles considerably greater in this area than in other parts of Oregon. This high proportion of automobiles per capita definitely shows a need for outside transportation.

Table 1. Automobile Ratio to Population of Cities Along Proposed Route

City	City Population	County Population	Automobile Registrations in County	Ratio of Automobiles to County Population
Eugene	20,838	69,096	25,992	1 to 2.7
Bend	10,021	18,631	7,415	1 to 2.5
Burns	2,566	5,374	2,230	1 to 2.4
Canyon City John Day	1,010	6,380	2,653	1 to 2.4
LaGrande	7,747	17,399	6,497	1 to 2.7
Baker	9,342	18,297	6,205	1 to 2.9
Ontario	3,551	19,767	6,515	1 to 3.0
Boise	26,130	----	---	----

As far as competition from other types of transportation, such as the train or bus, is concerned, a survey of the schedules indicates a limited number of trips per day--all arranged to arrive or leave distant larger cities at convenient times, without consideration for the intervening towns.

With respect to the proposed Eugene to Boise route, there is at present no direct means of transportation between the two points. A circuitous trip by train or bus is necessary. Therefore the establishment of an airline would greatly shorten the hours of travel time, and would be an advantage to the communities being served by maintaining convenient schedules of arrivals and departures. Farmers, lumber men, miners, and business men of the area covered by the proposed air route would prefer to travel by air for business, shopping, and personal reasons.

2. <u>A reasonable potential traffic figure</u>.

The second question in considering an airline route, "What is a reasonable potential traffic figure?" may be answered by estimating accurately the passenger potential. James Ray, Executive Vice President of Southwest Airlines (13), has suggested an acceptable method of estimating the number of passengers to be expected from a given proposed route.

By grouping according to the population all of the cities in the United States receiving air service, and dividing the total number of passengers, air mail or express, by the number of cities in each population group, a per capita factor may be obtained. The most logical data to be used would be the last year of normal traffic conditions (before World War II), which was the Civil Aeronautics Board's, "Report of 1940". This per capita factor varies considerably for different areas, according to their geographical location, economic indices, and other circumstances. For this reason corrections and adjustments must be made.

The first compensation or adjustment is made because of the fact that 1947 and 1948 traffic, which is being measured by formula, is based on the 1940 data. The Civil Aeronautics Board has indicated that travel on the airlines is from 200 to 500 percent greater than it was in 1940. Moreover, air traffic increased 62.5 percent more than the air mail volume between the period from 1935 to 1940. Between the years of 1940 and 1943, air mail gained 348 percent. By proportion, if the passenger travel had been allowed to increase (it could not because of military necessity) the passenger total would have increased 565 percent in 1943 over 1940. In view of this, the 1947-48 traffic will be, very conservatively, an increase of about 300 percent of the 1940 traffic.

The second adjustment to be made will indicate what percent of the population will use the airline. It may consistently be shown that smaller towns generate more traffic in proportion to their size than do larger cities. The 1940 survey of the Civil Aeronautics Board reports that towns having less than 10,000 population produced 62 percent more passengers than the overall average. On the Pacific Coast 22 airline stops averaged 0.412 passengers per day per thousand population. It is interesting to note that four stations on the Pacific coast with less than 10,000 population, averaged 1.22 passengers, or nearly three times the overall national average.

A fair average of air travel by people of cities of 2,500 or less population in comparison to air travel by people of the larger cities, is estimated to be about 50 percent greater. Table 2 shows the above data.

The reason for the higher percentage of traffic from the smaller towns is that with their limited economy they are not provided with complete shopping facilities, professional services, hospitals, and entertainment. The ground transportation also is generally poor in regions outside of the metropolitan areas because of road conditions and infrequent and inconvenient bus or train schedules.

Another important factor for which to account is the seasonal variation in the number of passengers. This can be made only on a comparative basis with variations reported by operating airlines. Table 3 shows the passenger traffic analysis of a California flight, considering seasonal variation and daily passenger patronage per 1,000 population.

Correcting the daily passenger patronage per 1,000 population for seasonal variation, for increase of traffic over 1940, and for the small town factor, Table 4 classifies into town groups the total passenger patronage per 1,000 population.

There are two other conditions which will influence air traffic and also should be included. These are:

1. Local adjustment, or the influence determined by the community's distance from its trade center
2. Isolation adjustment, which is dependent upon the number and convenience of the community's ground transportation schedules to the metropolitan trade center.

The local adjustment is divided into three parts:

1. Through airline traffic, which is about 40 percent of the traffic connecting with other airlines flying to more distant parts of the country
2. Trade center traffic, which is about 40 percent of the traffic moving to the larger cities for trade purposes
3. Intra-trade area traffic, which is about 20 percent of the air travel between the communities.

Table 2. Airline Passenger Analysis by Population

Population Classification	No. of Cities		Aggregate Population		Aggregate Passengers		Passengers Per Day Per 1,000 Population	
	USA	Pacific Coast	USA	Pacific Coast	USA	Pacific Coast	USA	Pacific Coast
Under 10,000	21	4	115,038	24,093	2,029	894	0.580	1.220
10,000 to 25,000	39	5	622,795	73,161	9,478	2,096	0.500	0.942
Under 50,000	90	13	1,780,826	219,815	23,434	4,337	0.433	0.649
All others	188	22	38,470,426	3,990,743	421,799	49,971	0.361	0.412

Table 3. Passenger Traffic Analysis of a California Flight

Station	Population	Passenger Patronage by CAB Survey of Sept. 1940	Passenger Patronage Corrected For Seasonal Variation	Daily Passenger Patronage	Daily Passenger Patronage Per 1,000
San Francisco	936,699	6,699	5,257.2	175.30	0.187
Fresno	60,685	455	357.1	11.90	0.196
Sacramento	105,958	324	254.3	8.46	0.080
Del Monte	10,834	240	188.4	6.26	0.578
Red Bluff	3,824	28	22.6	0.73	0.192
Total	1,118,000	7,746	6,079.6	202.65	(Av) 0.182

Table 4. Correction for Passenger Patronage with Population Classification

Population Classification	Passenger Patronage Per 1,000	Traffic Increase Over 1940 (%)	Correction for Increase Over 1940 Passenger Patronage Per 1,000	Small Town Factor (In %)	Correction for Small Town Factor Passenger Patronage Per 1,000	Total Passenger Patronage Per 1,000
Under 10,000	0.252	300	0.755	50	0.126	0.881
10,000 to 50,000	0.252	300	0.755	40	0.101	0.856
Over 50,000	0.178	300	0.535	—	———	0.535

If the communities are within a 50 mile radius, each of the above items would be reduced about one-half of the above estimate. The reason would be, of course, that it would be cheaper to travel on the ground. If the communities are within a 50 to 100 mile radius of a large city, the local adjustment would be reduced about 20 percent, or to 80 percent of the above estimate.

For the second adjustment, isolation, if the ground transportation is normal, about 80 percent of the potential traffic is considered in order. If, however, the ground transportation is subnormal, the potential may be taken at 120 percent. Table 5 shows a preliminary estimate of the number of passengers for the proposed airlines using the basic factors and the two required adjustments. Thus the total passenger potential of 22 is very conservatively made.

This estimate of passengers may be substantiated by considering the economic status of the people in this area. The income of these individuals indicates to some extent their financial ability to travel by air. Ehelich determined in a recent survey (4) that 23 percent of the people making a net income above $1,000 stated a preference for travel by air, and 43 percent contemplated such travel in the near future.

Because a majority of the population along the proposed route is engaged in some type of farming, a survey by Professor Mumford (11) of incomes of these people presents interesting possibilities. Table 6 indicates nearly 4,000 farms had an average income per farm in 1940 of $5,900. However, there has been a considerable national increase

+Table 5. Preliminary Estimate of Total Passenger Potential

City	Population	Convection Factor For Passenger Patronage Per 1,000	Passenger Potential	Local Adjustment (%)	Correction Factor For Local Adjustment of Passenger Patronage	Correction For Isolated Adjustment of Passenger Patronage	Adjustment For Passenger Patronage x 10^2	Total Passenger Potential Per Day
Eugene	20,838	0.856	17.85	—	17.85	14.30	33.3	4.76
Bend	10,021	0.856	8.57	80	6.86	5.50	—	5.50
Burns	2,566	0.881	2.26	—	2.26	1.81	—	1.81
Canyon City John Day	1,010	0.881	0.89	80	0.71	0.57	—	0.57
LaGrande	7,747	0.881	6.82	40	2.73	2.18	—	2.18
Baker	9,342	0.881	8.22	80	6.67	5.34	—	5.34
Ontario	3,551	0.881	3.13	40	1.25	1.00	—	1.00
Boise	26,130	0.856	22.40	—	22.40	17.90	25.0	4.48

+Note: Computed for isolated adjustment factor of 80 percent. (Total passenger potential 22.64)

Table 6. Survey of Gross Incomes of Farms in the Proposed Area

Gross Income Group ($)	No. of Farms in Oregon Reporting	Percent of all Farms in the Area				Total % of Farms in the Area	No. of Farms in the Area	Total Gross Income ($)
		State	Willamette Valley	Central Oregon	Blue Mountains			
Under 250	14,825	24.2	26.1	19.4	12.8	58.3	2,090	522,000
250 to 399	7,373	12.0	13.1	8.6	7.7	29.4	260	84,500
400 to 599	6,843	11.2	11.8	9.4	9.5	30.7	222	77,600
600 to 999	8,683	14.2	14.8	13.5	16.2	54.5	672	504,000
1000 to 1499	6,483	10.6	10.5	11.4	13.7	35.6	244	304,000
1500 to 2499	6,943	11.3	10.3	14.2	16.6	41.1	322	644,000
2500 to 3999	4,498	7.3	6.4	8.7	9.9	25.0	82	26,700
4000 to 5999	2,405	3.9	3.4	5.1	5.5	14.0	13	65,000
6000 to 9999	1,749	2.8	2.1	4.9	4.1	11.1	5	37,500
Over 10,000	1,513	2.5	1.5	4.8	4.0	10.3	4	40,000
Totals	61,315	100	100	100	100	----	3,914	2,305,300

(Average income $5,900)

in farm income in the last seven years. Hence it is natural to assume that a minimum of 22 individuals in this area would prefer to travel daily by air if a route were established.

3. Costs of airline operation.

The size and cost of operating an airplane will be considered next. At the present time the only airplanes available for the proposed route are government surplus cargo transports, commercially known as the DC-3. The cost of this airplane ranges between $65,000 and $70,000. It will be necessary, however, to convert it into a 24 seat airline transport with sufficient space for mail and express, or cargo, and to obtain an airworthiness certificate. This will require approximately an additional $10,000; bringing the total cost of the converted airplane to about $80,000. The DC-3 is large enough to take care of a reasonable increase in air travel, and still be able to take off and land within 2,500 feet on an airport runway.

Table 7 is a tabulation of the air miles, the actual block speeds, and the hours between stations. The air miles covered in one flight are 556, which requires a total time of 4.55 hours. The average block speed, based on an average cruising velocity of 160 miles per hour at 50 percent of the total brake horsepower, is 122 miles per hour. The utilization, which is the number of hours the

Table 7. Tabulation of Cities, Air Miles, Block Speed, and Time in Flight

City	Air Miles	Block Speed	Time (Hours)
Eugene	0	-----	-----
Bend	92	125.7	0.732
Burns	118	131.7	0.896
Canyon City John Day	108	129.9	0.832
LaGrande	80	122.5	0.653
Baker	42	102.0	0.412
Ontario	68	117.7	0.578
Boise	48	106.7	0.451
Average	---	122.0	-----
Total	556	-----	4.55

airplane is used in a year, is important because it affects such significant costs as depreciation, insurance, and interest on the investment. In the computation of airplane utilization, hours per day of flight, days of operation throughout the year, and number of airplanes used, are factors that are considered. It is proposed, in setting up the hypothetical airline, that two round trip flights be made, requiring 18.2 hours of flight per day. Three airplanes will be required, one a "stand by" in the event of any mechanical failures occuring on either of the other two airplanes. The number of days flying permitted without excessive danger due to weather, and based on experience of airports in Central Oregon, is 95 percent of the year.

Taking these factors into account, an utilization of about 2,100 hours per year for an airplane can be depended upon. It may be pointed out, to show the importance of utilization, that if one round trip flight were made per airplane each day, with three airplanes available, the hours flown per year per airplane would be exactly one-half of the above 2,100 hours per year, and the significant cost would be twice as great. For that reason it is profitable for any airline to utilize all of its airplanes to their greatest extent.

Other constants appearing in the assumptions of Table 8 are factors pertaining only to the DC-3. Similar factors

Table 8. Total Significant Cost Per Mile for One Flight

Item	Assumption	Cost Per Mile
Airplane depreciation	$C_a = \$50{,}000$ $V_b = 122$ $U = 2100$	0.03340
Engine depreciation	$N = 2$ $H = 5000$ $C_e = \$15{,}000$ $V_b = 122$	0.04920
Airplane overhaul and repair	$M = 24$ $C_a = \$50{,}000$ $N = 2$ $V_b = 122$ $W_1 = 13{,}800$	0.04330
Engine overhaul and repair	$W_2 = 1800$ $P = 14$ $V_b = 122$ $C_e = \$15{,}000$	0.03610
Airplane and engine ground service cost	$N = 2$ $V_b = 122$ $W_1 = 13{,}800$	0.04500
Airplane insurance	$C_a = \$50{,}000$ $U = 2100$ $V_b = 122$ $C_e = \$15{,}000$ $N = 2$	0.02250
Fuel	$F_c = \$0.15$ bhp = 600 $N = 2$ SFC = 0.45 $V_b = 122$	0.01120
Oil	$O_c = \$0.45$ bhp = 600 $N = 2$ SOC = 0.012 $V_b = 122$	0.00707
Senior pilot's pay	$V_b = 122$	0.05330
First pilot's pay	$V_b = 122$	0.03460
Cabin boy's pay	$V_b = 122$	0.01260
Interest on investment	$C_a = \$50{,}000$ $U = 2100$ $V_b = 122$ $N = 2$ $C_e = \$15{,}000$	0.00625
Crew expense	CM = 3	0.00675
Passenger service cost	NP = 6	0.0030
	Total	0.36417

may be obtained for any airplane from the manufacturer of that particular type (3).

Using the significant cost curves given in this investigation and totaling the individual items, as shown in Table 8, the total expense for one flight from Eugene to Boise is $0.37 per mile flown.

In order to obtain an overhead cost of an airline, the individual station's expenses are estimated separately, following the accounting form required by the Civil Aeronautics Board. In the Appendix are listed the various costs occuring each month in the proposed airline operation. The salaries and expenses were obtained from Hinkel's and Baron's book, "An Education Guide in Air Transportation" (7), and from information obtained in a discussion with Mr. Munter, Executive Vice President of West Coast Airlines. The total overhead cost is $29,800 per month. This amount divided by the number of days in a month, and by the miles traveled in a day, gives $0.447, the overhead cost per mile traveled in a day.

The total expenses for one flight from Eugene to Boise are divided into two parts; the significant and overhead costs which, when added, give the sum of $0.489 per mile.

4. Air mail income expected.

The last two items in the development of an airline pertain to gross income. The amount of mail pay to be expected cannot be accurately estimated as there are no guides as to what the government is willing to pay. In considering applications for certification the Civil

Aeronautics Board decides what the postal needs are for the area covered, determines the inconvenience for the airlines, and the interference in the scheduled airline operation. Payments are generally made by the average pounds of air mail carried on a mileage basis. However, there is an element known as the "minimum capacity factor" which guarantees a minimum payment regardless of the air mail load. The average subsidy of $0.005 a pound mile is granted throughout the country by the Civil Aeronautics Board. This figure will be used for the proposed airline. Thus the problem is to estimate the amount of mail to be carried.

The average air mail loadings (Table 9) from three Pacific Coast airlines are indicated for the years of 1945 and 1946. Table 9 shows a 38.7 percent decrease in 1946 over 1945. Based on average figures compiled by the Civil Aeronautics Board, a town with a population of 5,000 will send approximately 20 pounds of air mail per day, and a town of 2,100 will send ten pounds of air mail. Using this relationship, Table 10 was computed. From the above information, as applied to cities along the route, 248 pounds of air mail per day may be expected. This would bring a total revenue from air mail of $693 per day.

Table 9. Percent Air Mail Decrease in 1946 Over 1945.

1945 Average Mail Load in Pounds Per Trip From Three Pacific Coast Airlines	1946 Average Mail Load in Pounds Per Trip From Three Pacific Coast Airlines	Percent Decrease Over 1945
399	155	38.8
1100	354	32.2
456	209	45.8
	Average	38.7

Table 10. Estimated Pounds of Air Mail Per Day
Along Proposed Air Route

City	Population	Pounds Air Mail Per Day
Eugene	20,838	63.70
Bend	10,021	30.60
Burns	2,566	7.84
Canyon City John Day	1,010	3.09
LaGrande	7,747	23.60
Baker	9,342	28.50
Ontario	3,551	10.85
Boise	26,130	79.90
	Total pounds of mail	248.08

5. Reasonable prospect for profitable operation.

The last factor of the five general aspects that should be considered in promoting an airline, is whether there is a reasonable prospect for profitable operation. The theoretical profit to be obtained from an airline is limited to the accuracy in selecting the current expenses to be incurred, the revenue received from passenger travel, and air mail pay from the government.

It was found from the significant cost curves and overhead costs that the total expense of operation per mile is $0.489. A majority of the airlines charge between five and six cents per passenger mile (14). Using six cents per passenger mile, and a potential traffic of 22 passengers, the revenue would amount to $1.32 per mile for one day of flight. Considering the average number of passengers to travel on one flight as 5.5, the revenue would amount to $0.330 per mile, and $693 income from the government for mail pay would be $0.078 per mile, the sum of which is $0.408 per mile. Therefore it is obvious that the hypothetical airline operates at a $0.079 loss for every mile of flight from Eugene to Boise. A passenger potential of 28 would be required to break even, and additional income from passengers and air mail could be considered as net profit.

B. Scheduling of Proposed Airline.

A suitable schedule on which the hypothetical airline is to run (14) requires an arrival and departing time at the individual towns during convenient daylight hours. From the schedule shown in Table 11 it is evident that the proposed airline connects the individual towns between Eugene and Boise at reasonable daylight hours.

Table 12 is a summary of one-way fares to any town along the route. Round-trip fares are twice the amount of the one-way fares. A stipulated government tax is paid by the passenger.

Table 11. Time Schedule for Proposed Airline Route

City	Air Miles	Time (Hours)	Time Eastbound (Read down)				Air Miles	Time (Hours)	Time Westbound (Read up)			
			Ar	Lv	Ar	Lv			Ar	Lv	Ar	Lv
Eugene	—	—	—	7:00	—	12:00	92	0.732	11:28	—	4:28	—
Bend	92	0.732	7:39	7:44	12:39	12:44	118	0.896	10:45	10:50	3:45	3:50
Burns	118	0.896	8:33	8:38	1:33	1:38	108	0.832	9:51	9:56	2:51	2:56
Canyon City John Day	108	0.832	9:23	9:28	2:23	2:28	80	0.653	9:01	9:06	2:01	2:06
LaGrande	80	0.653	10:01	10:06	3:01	3:06	42	0.412	8:22	8:27	1:22	1:27
Baker	42	0.412	10:26	10:31	3:26	3:31	68	0.578	7:57	8:02	12:57	1:02
Ontario	68	0.578	11:01	11:06	4:01	4:06	48	0.451	7:22	7:27	12:22	12:27
Boise	48	0.451	11:28	—	4:28	—	—	—	—	7:00	—	12:00

Note: All flights are between the daylight hours of 7:00 AM and 4:28 PM.

Table 12. One-Way Fares to Towns Along the Proposed Route

From ↓ To →	Eugene	Bend	Burns	Canyon City John Day	LaGrande	Baker	Ontario	Boise
Eugene	—	$ 5.40	$12.60	$19.10	$23.90	$26.40	$30.50	$33.40
Bend	$ 5.40	—	7.08	13.58	18.40	20.90	25.00	27.80
Burns	12.60	7.08	—	6.48	11.30	13.80	17.90	20.80
Canyon City John Day	19.10	13.58	6.48	—	4.80	7.32	11.40	14.30
LaGrande	23.90	18.40	11.30	4.80	—	2.52	6.60	9.49
Baker	26.40	20.90	13.80	7.32	2.52	—	4.08	6.96
Ontario	30.50	25.00	17.90	11.40	6.60	4.08	—	2.88
Boise	33.40	27.80	20.80	14.30	9.49	6.96	2.88	—

V. DISCUSSION AND CONCLUSIONS

The development of the significant operating cost equations may be made to cover all types of airplanes, but it is impossible to include such important factors as size of airline and current expense variations.

Production line maintenance, overhaul, and repair costs will decrease with an increase in the size of an airline. The smaller airline would, of course, find large-scale production line methods impracticable. A large airline would undoubtedly use more complicated equipment which would require a greater maintenance expense than a smaller airline would have.

The passenger volume cost was taken as $0.005, a figure which is applicable for a transcontinental flight and very probably incorrect for a smaller airline. This factor can be obtained only from the actual experience of operating an air carrier.

The crew expense cost is another factor similar to the above situation, making the numerical constants undoubtedly incorrect. However, in the operation of an airline these are important costs that should always be included.

It is readily apparent that an attempt to calculate seventeen cost equations for any one given type airplane would be tedious detail. It may be noted further that the greater number of airline companies own varied types and models of airplanes. This variation would result in extended computations. In order to overcome this difficulty, curves that cover the present day transport type airplane are constructed with adequate flexibility in the significant cost equation variables.

Because of the proportional relationships of the curves, they may be accurately constructed and read directly to three places, and may be estimated to the fourth place. Errors will occur in interpolation between any two curves. However, with practice and reasonable precautions they may be reduced to a minimum.

The question of the overhead costs for an airline is rather indefinite, but it is of fundamental importance to all air transport companies. In this thesis the individual costs of each station for the proposed airline were found and converted to a cost per mile basis for the convenience of comparing this figure with those reported by the Civil Aeronautics Board. A study of the report (1) will indicate that a ratio of the individual overhead cost items vary considerably for the listed air transport companies. However, when the cost is converted to a mileage basis it may be shown that the size of the airline is not a major factor. For example, the average overhead cost per mile for companies operating less than five air carriers is approximately the same as the larger airlines which are operating fifty airplanes. If the average overhead cost per mile of the proposed airline is within the limits of established cases, which are profiting by its operation, it is therefore reasonable to believe that this will indicate a basis for overhead costs from which to work.

The overhead cost per mile, as in the case of the significant cost per mile, will also be affected by the current price fluctuations.

In establishing an airline, the five general factors given on page 17 must be satisfactorily determined. The conditions assumed in the promotion of the hypothetical airline, as may be seen, were conservatively selected.

The first two considerations facing prospective airline operators were adequately determined from past successful experiences of established airlines. However, in considering the most desirable size of the air carrier for the proposed route, the DC-3 airplane may be found too large. A passenger potential per day of 22 was determined, but there are 96 seats available. This would indicate that a seven to ten passenger airplane may be more advisable. In the event of an increase in traffic, the smaller airplane would be insufficient and would require more frequent flights. Thus the significant operating costs would be greater for the smaller airplane with more flights than for the larger airplane with less frequent flights. Space should always be available for such items as fluctuations in the air mail load, and probable increase in the cargo and express when the airline is fully established.

At the present time the operating cost of a DC-3 is about $0.50 per mile. This is considerably higher than the estimated $0.37 per mile. The estimated significant cost for the hypothetical airline is subjected to price fluctuations, and the values used in the assumptions of Table 8 are not current expenses. For this reason the cost of airplane operation is not necessarily correct. However, the method used in obtaining these significant costs is concrete and may be used as an example for future airline promotion.

As mentioned before, the subsidy used on the proposed route was an average that is granted to airlines throughout the country. It should be noted that the figure quoted is for the larger airlines and may be considered above average for the smaller airlines.

Thus, by the use of the significant cost curves and overhead costs, airline expenses may readily be determined with a reasonable degree of accuracy. However, whether or not an airline is practical must be determined within the promotion period. From then on management must assume the responsibility for success.

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VII. APPENDIX

Table 13. Overhead Operating Costs Per Month for Proposed Airline

City	Overhead Items	Cost Per Month
Eugene	<u>Ground operations</u>	
	1. Chief flight dispatcher	$ 400.00
	2. Meteorologist	350.00
	3. Communication superintendent	350.00
	4. Station manager	350.00
	5. Passenger, cargo, and ticket agent	250.00
	6. Service employees	200.00
	7. Rent	
	(a) Office and hangar	1000.00
	(b) Waiting room	200.00
	8. Telephone and telegraph	180.00
	<u>Ground maintenance equipment, direct</u>	
	1. Station communication equipment repairs	800.00
	2. Motorized vehicles and equipment	500.00
	3. Other ground equipment	500.00
	<u>Ground maintenance equipment, indirect</u>	
	1. Chief maintenance dispatcher	450.00
	2. Hangar chief	300.00
	3. Line mechanic	250.00
	4. Airplane and instrument mechanic	300.00
	5. Engine and propeller mechanic	300.00
	6. Radio repair mechanic	200.00
	7. Material and supplies	1400.00
	8. Shop supplies and expenses	1375.00
	<u>Depreciation of ground equipment</u>	1000.00
	<u>General and administrative expenses</u>	
	1. President	750.00
	2. Vice president	600.00
	3. Stenographer	180.00
	4. Secretaries	900.00
	5. Switchboard operator	175.00
	6. Typist	160.00

Table 13. (Cont'd)

City	Overhead Items	Cost Per Month
Eugene (Cont'd)	7. Accountant	175.00
	8. Secretary and treasurer	550.00
	9. Purchasing agent	350.00
	10. Memberships and publications	100.00
	<u>Traffic and sales</u>	
	1. Traffic manager	450.00
	2. Telephone and telegraph	500.00
	3. Ticket agent	200.00
	<u>Advertising and publicity</u>	5630.00
Bend	<u>Ground operation</u>	
	1. Ticket and cargo agent	200.00
	2. Telephone and telegraph	200.00
	3. Rent	200.00
	4. Incidental expenses	500.00
Burns	<u>Ground operation</u>	
	1. Ticket and cargo agent	100.00
	2. Telephone and telegraph	200.00
	3. Rent	150.00
	4. Incidental expenses	500.00
Canyon City John Day	<u>Ground operation</u>	
	1. Ticket and cargo agent	200.00
	2. Telephone and telegraph	200.00
	3. Rent	150.00
	4. Incidental expenses	500.00
LaGrande	<u>Ground operation</u>	
	1. Ticket and cargo agent	200.00
	2. Telephone and telegraph	200.00
	3. Rent	150.00
	4. Incidental expenses	500.00
Baker	<u>Ground operation</u>	
	1. Ticket and cargo agent	200.00
	2. Telephone and telegraph	200.00
	3. Rent	150.00
	4. Incidental expenses	500.00

Table 13. (Cont'd)

City	Overhead Items	Cost Per Month
Ontario	<u>Ground operation</u>	
	1. Ticket and cargo agent	200.00
	2. Telephone and telegraph	200.00
	3. Rent	150.00
	4. Incidental expenses	500.00
Boise	<u>Ground operation</u>	
	1. Agent's salary	275.00
	2. Assistant agent's salary	200.00
	3. Telephone and telegraph	200.00
	4. Rent	500.00
	5. Incidental expense	1000.00
	Total Overhead Cost	$29,800.00

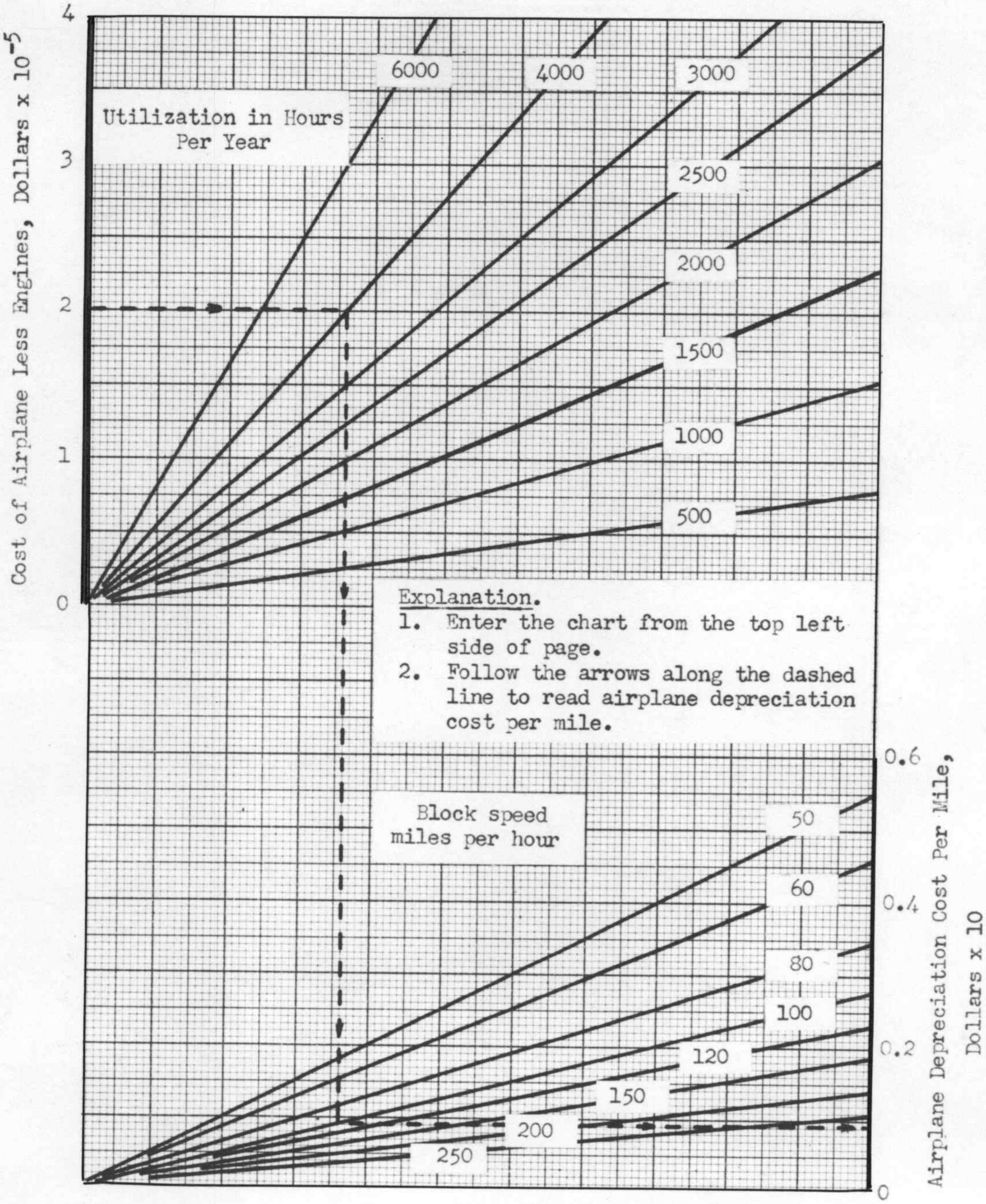

CHART 1. AIRPLANE DEPRECIATION COST PER MILE.

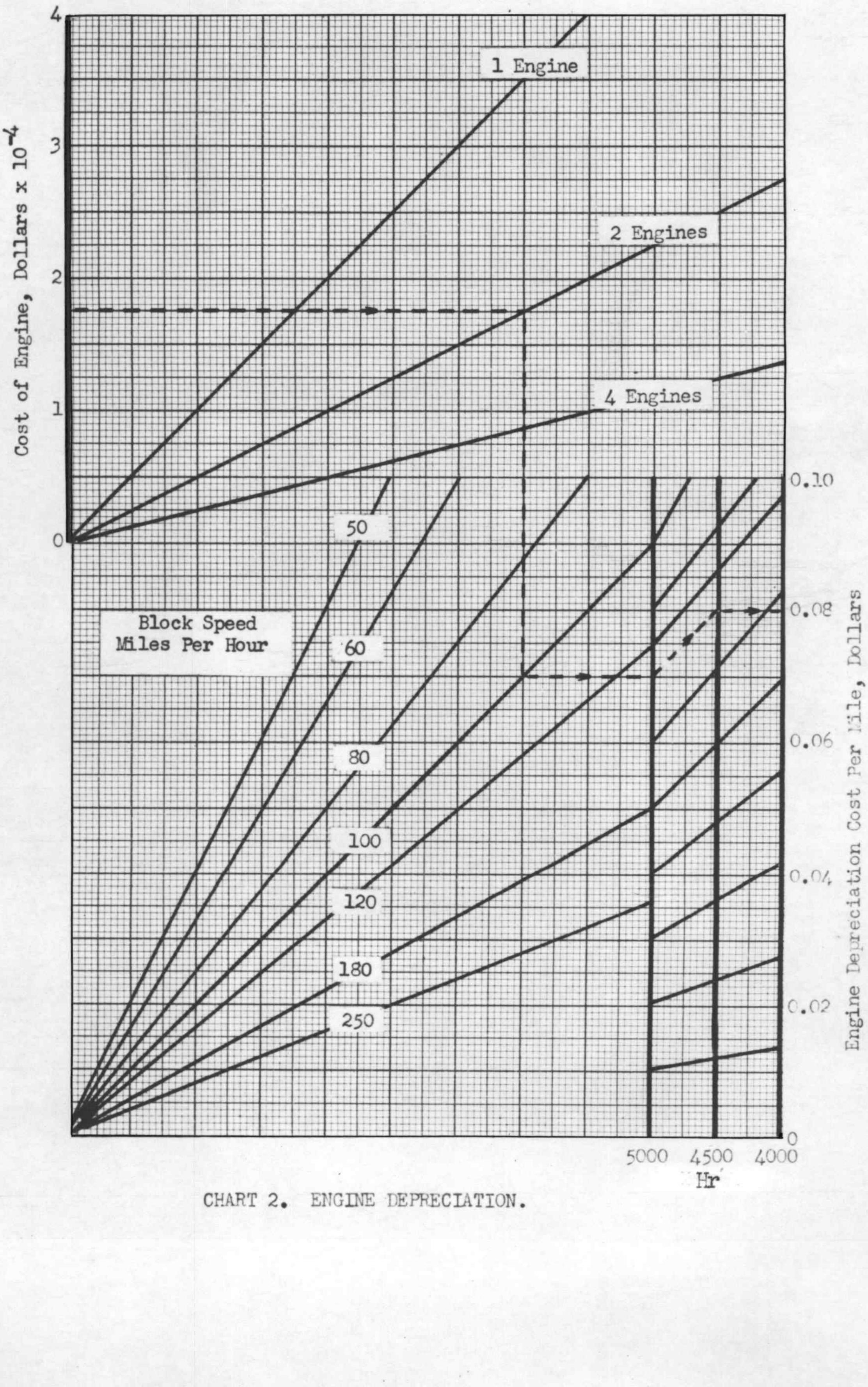

CHART 2. ENGINE DEPRECIATION.

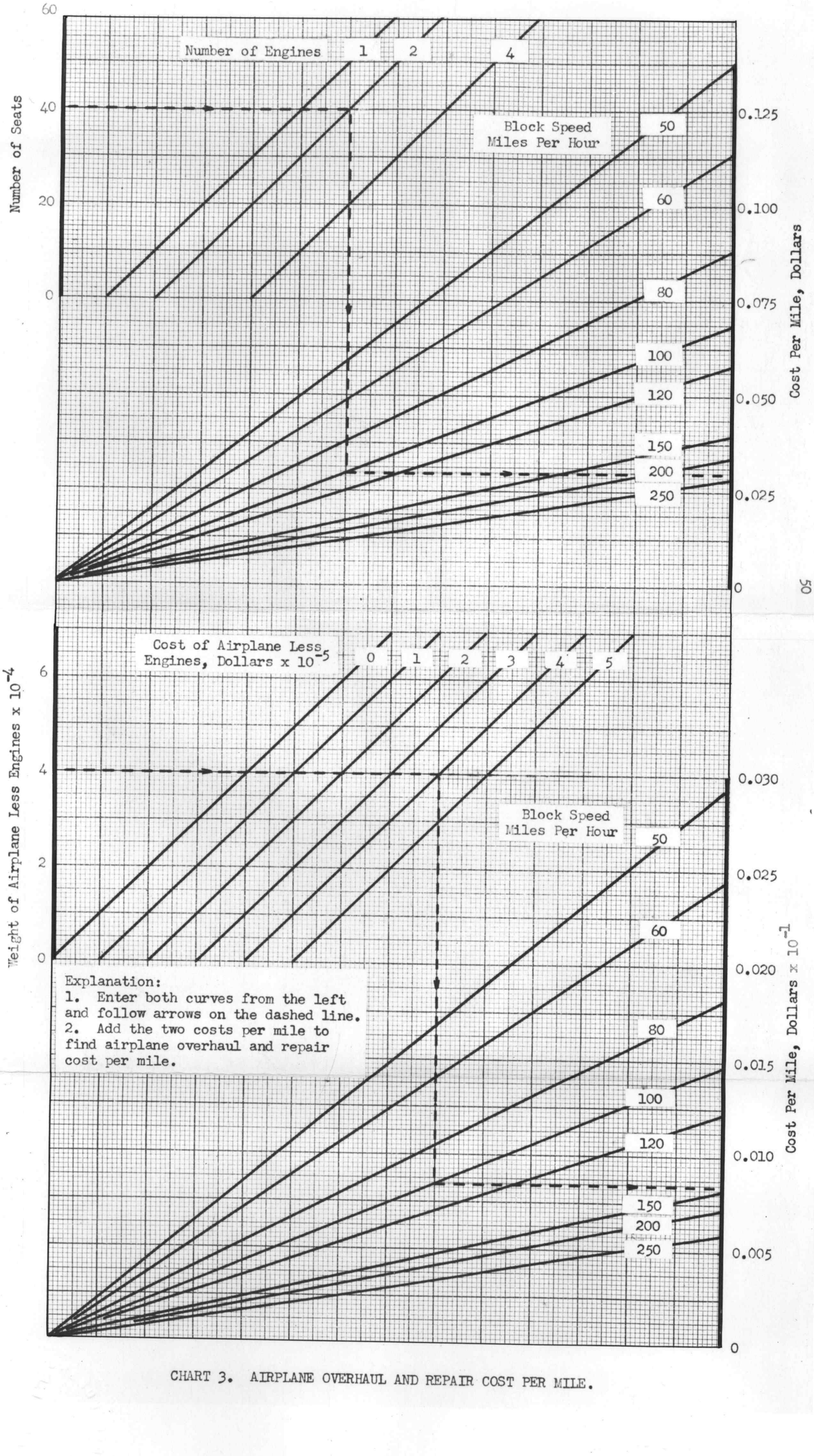

CHART 3. AIRPLANE OVERHAUL AND REPAIR COST PER MILE.

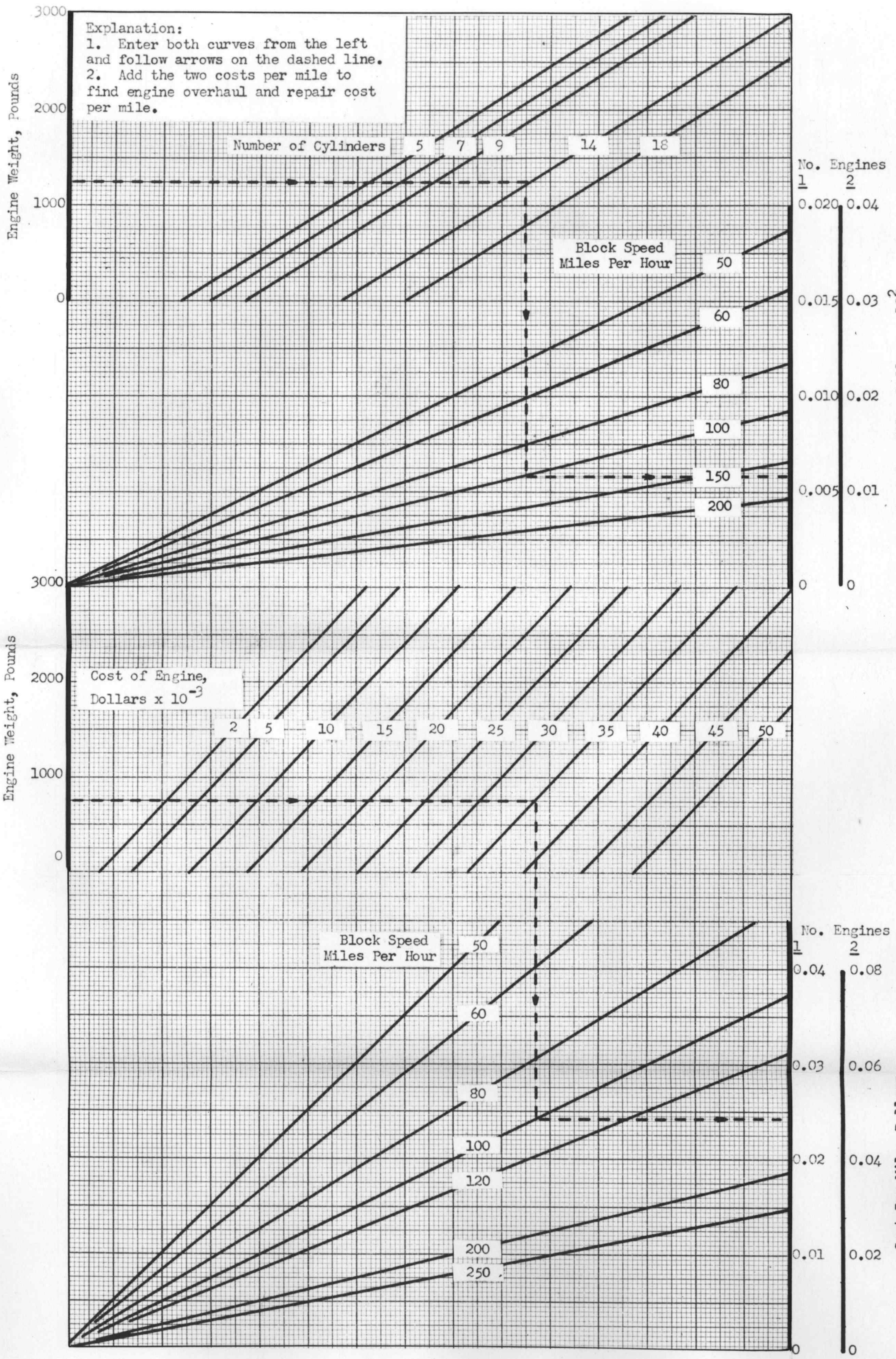

CHART 4. ENGINE OVERHAUL AND REPAIR COST PER MILE.

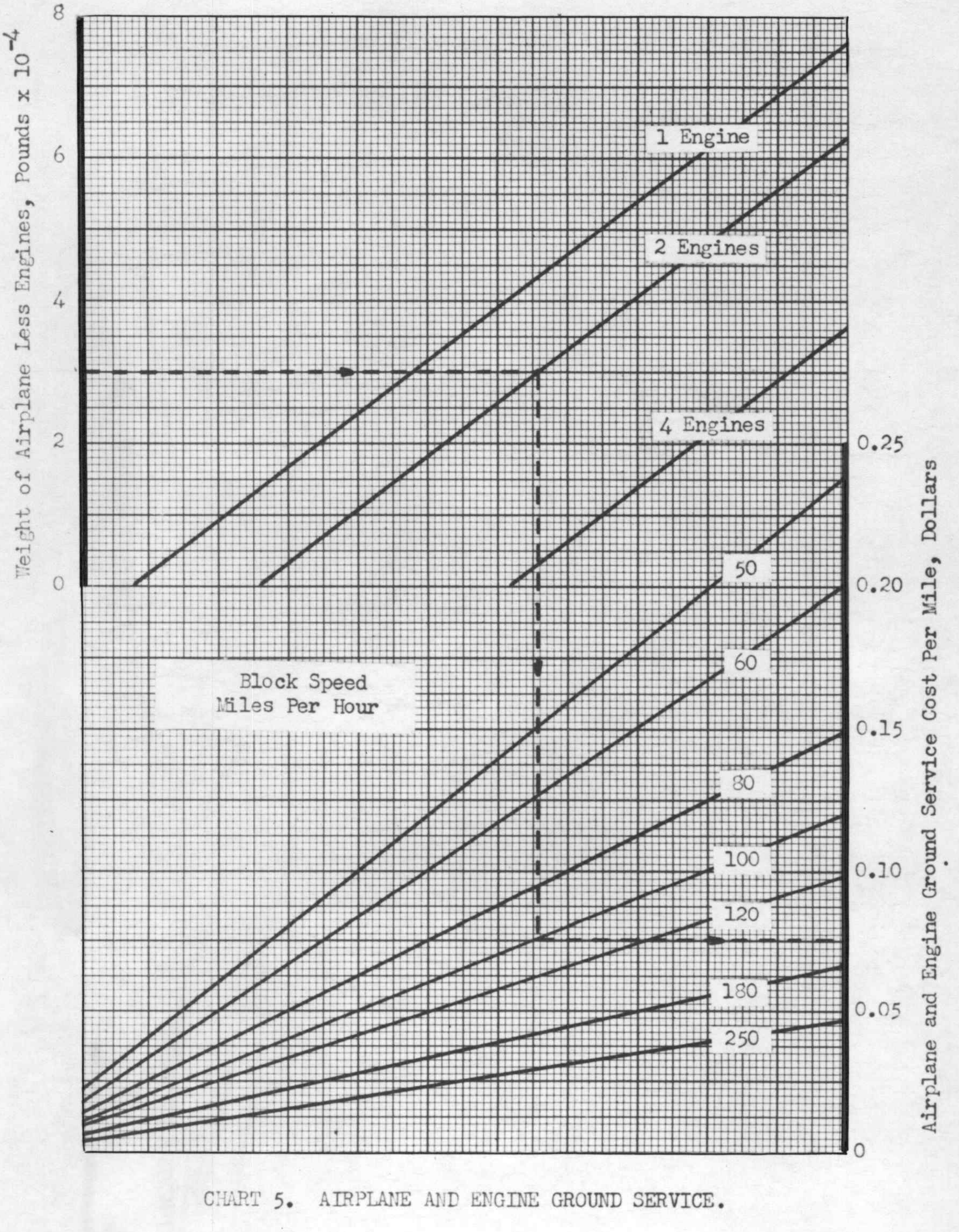

CHART 5. AIRPLANE AND ENGINE GROUND SERVICE.

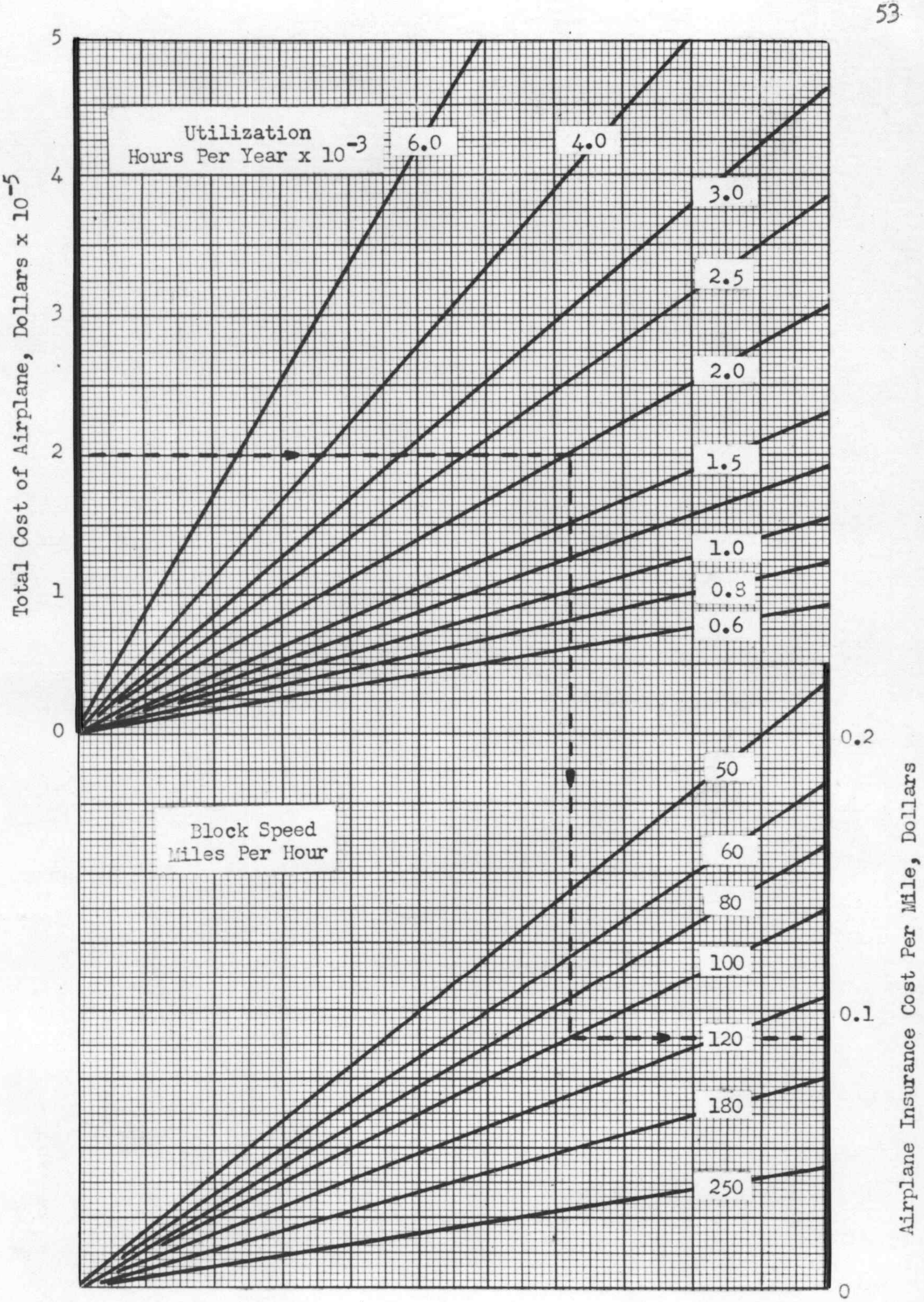

CHART 6. AIRPLANE INSURANCE COST PER MILE.

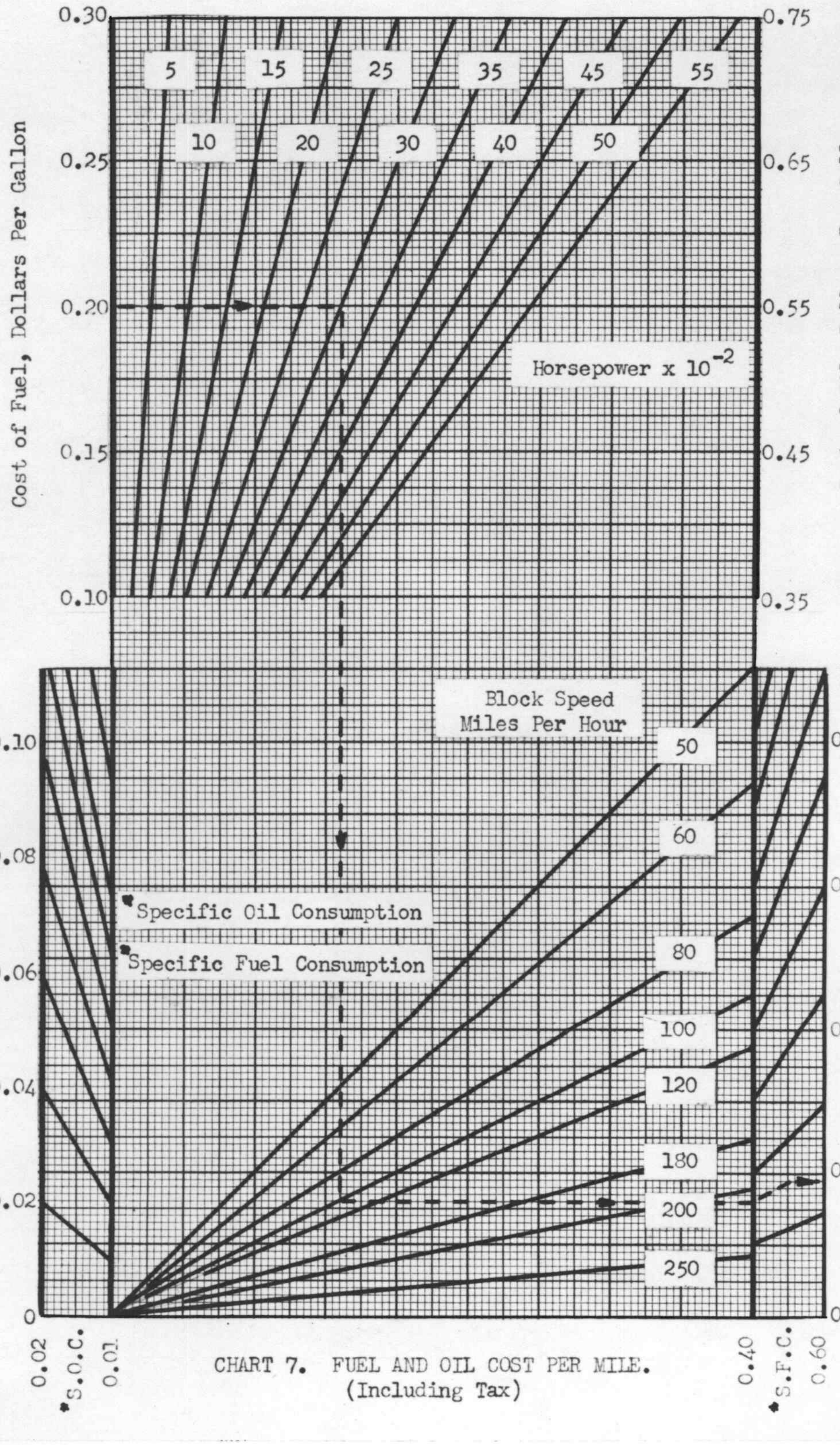

CHART 7. FUEL AND OIL COST PER MILE.
(Including Tax)

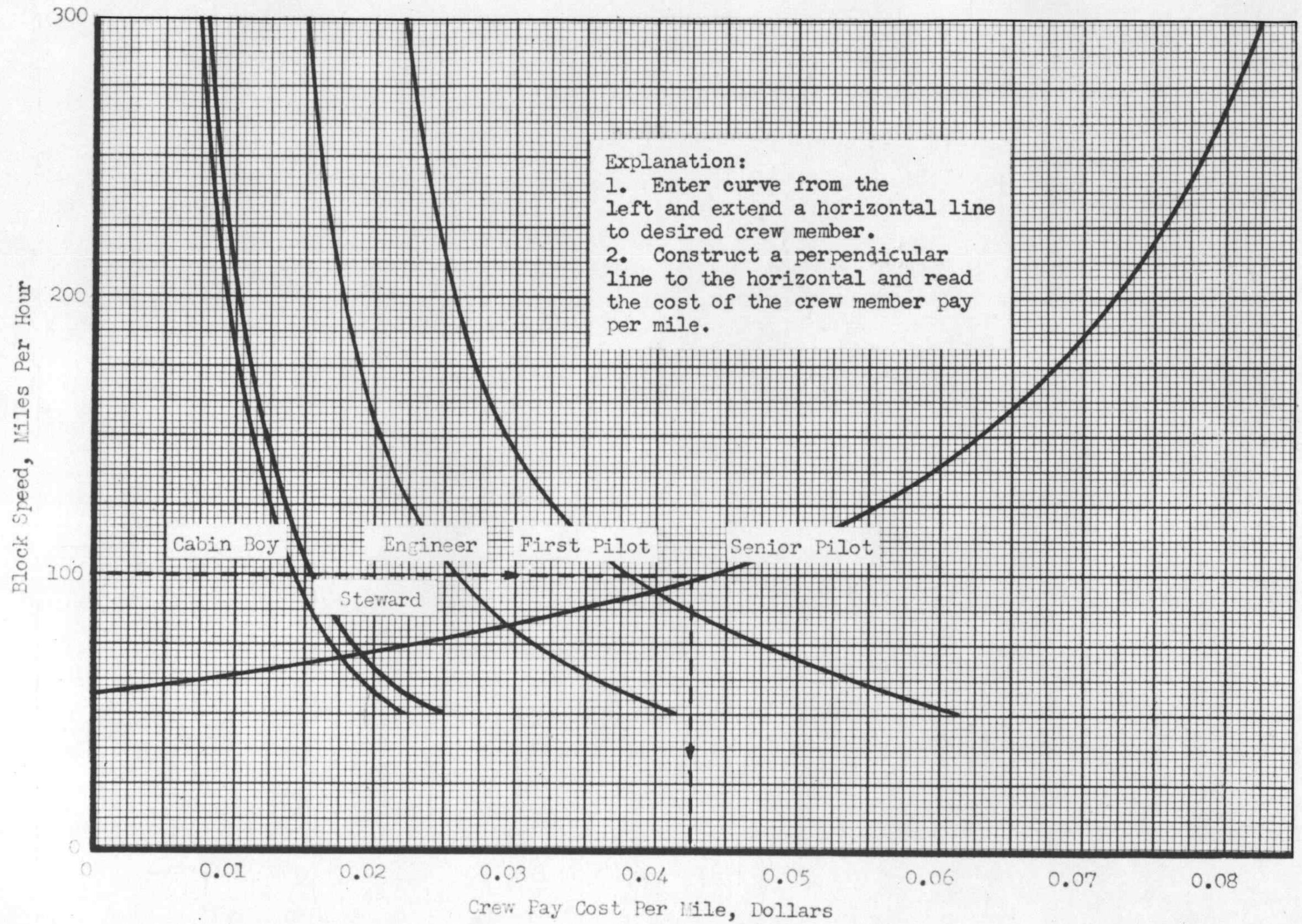

CHART 8. CREW PAY COST PER MILE.

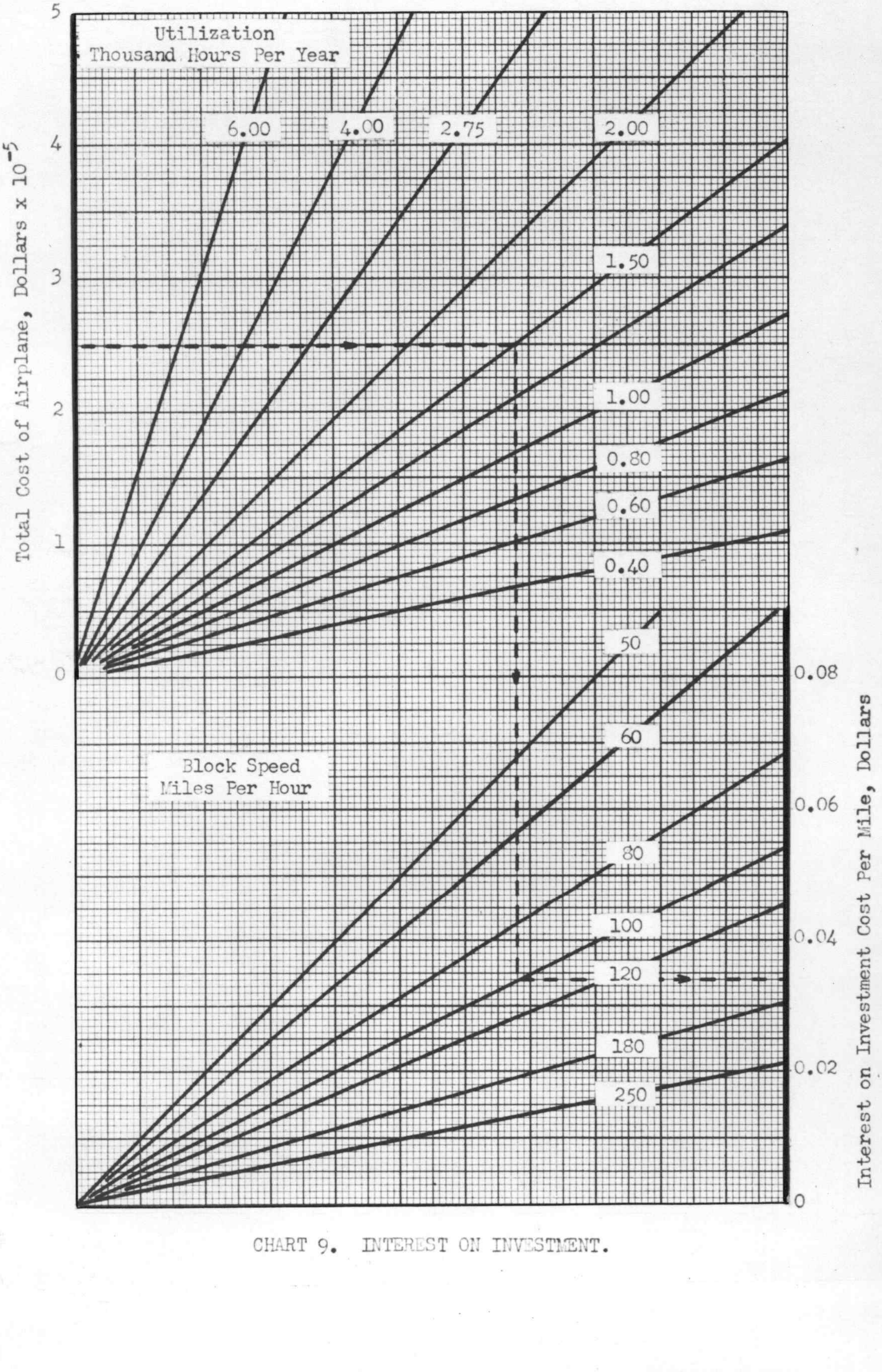

CHART 9. INTEREST ON INVESTMENT.

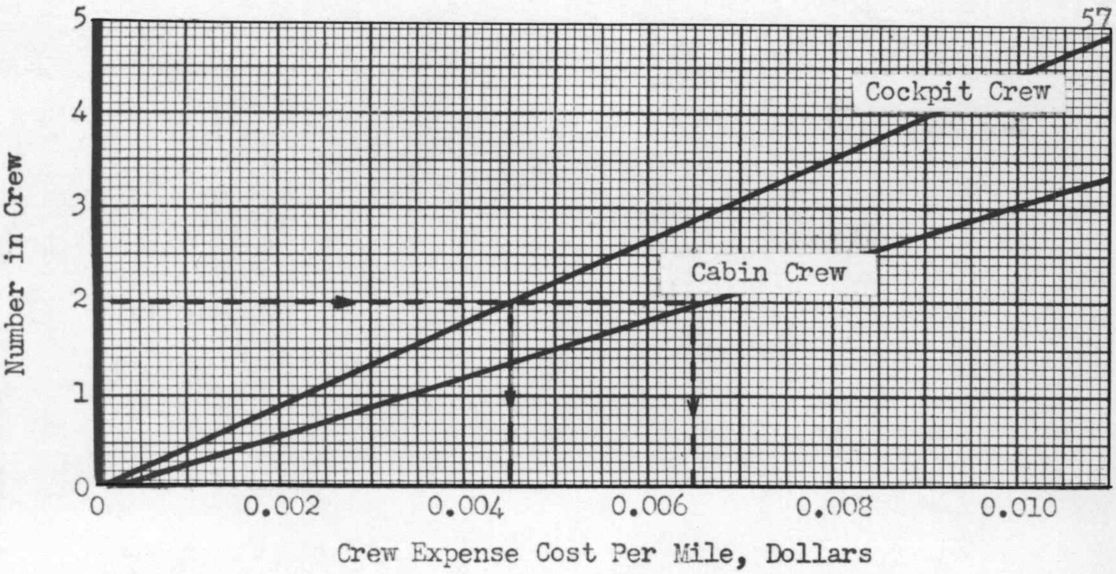

CHART 10. CREW EXPENSE AND PASSENGER VOLUME COSTS PER MILE.