Economics of Personal Airplane Operation

By

W. J. SKINNER

Instructor in Aeronautical Engineering

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TABLE OF CONTENTS

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3

ILLUSTRATIONS

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W. J. SKINNER*

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I. INTRODUCTION

1. **Purpose of study.** Comparatively recent surveys *(1)* *(2)*† have shown that one-third of all airplane owners continued ownership for only one year or less and that another 22 per cent continued for but two years. The mean period of ownership for all owners is indicated as less than four years. The surveys also revealed that over 50 per cent of the former owners gave financial difficulty as the reason for discontinuing, which may be interpreted as meaning that the expense of ownership was greater than anticipated.

The purpose of this publication is to discuss the factors that enter into the cost of operation and ownership of an airplane and to present in chart form one method of computing these costs with a reasonable degree of accuracy. It is believed that such information will be of value to present and prospective airplane owners in their efforts to anticipate costs or to compare operating costs of various planes.

At all times, except when specifically noted, discussion will be limited to the personal plane. This might be described roughly as including airplanes that have a maximum cost of approximately $8,000 and a maximum seating capacity of four or five persons including the pilot.

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† Italic numbers in parentheses refer to BIBLIOGRAPHY, page 43.

II. OPERATING COST FACTORS

The tangible cost factors involved in aircraft operation are generally broken down into two major groups. The titles given to these two groups vary considerably and in some cases are difficult to justify. In this discussion, cost factors will be regarded as belonging in either the "fixed-cost" group or the "variable-cost" group.

Fixed costs are those based on calendar time and continue even when the airplane is idle. In most cases these expenses will be stated on a yearly basis. Such fixed-operating-cost factors include depreciation, interest on initial investment, hangar rental, and insurance.

Variable costs are those based on flight time and therefore have a total that varies with the number of hours flown. These costs are expressed in terms of dollars per hour and include fuel, oil, maintenance, and overhaul costs.

Although seldom recognized or evaluated in terms of cost by personal airplane owners, a third group of expenses exists. This unnamed group includes ground transportation, that is, expenses incurred going to and from airports; delay expenses incurred when a pilot is grounded because of weather or mechanical difficulties; and in the case of commercial operation, overhead or business expenses. These expenses will be referred to as non-flying expenses.

In a tabulated form the various operating costs appear as follows:

1. Fixed costs
    a. Depreciation
    b. Interest on initial investment
    c. Hangar rental
    d. Insurance
2. Variable costs
    a. Fuel and oil
    b. Maintenance and overhaul
3. Non-flying expenses
    a. Ground transportation expenses
    b. Delay expense
    c. Business expenses for commercial operation

1. Fixed-Cost Items.

a. **Depreciation.** A private plane owner buys an airplane, flies it for a period of time, and then sells it for a price less than that which he originally paid for it. The difference between the initial purchase price and the selling price represents a definite loss

of money to the owner and must be considered as a part of his operating expense. It is this expense that is known as depreciation.

Depreciation, which may be expressed as reduction in value with passage of time, is caused by several things. The major cause of depreciation is normal wear and tear through use and abuse of the airplane. Airplanes do not fall apart, as did the "one-horse shay," at the end of a definite period of time, but they gradually wear out and require replacement of parts. If each part were replaced as it wore out there would come a time when the airplane would have no original parts left. The process is seldom, if ever, carried to this extent. Actually the life of the airplane is terminated either by a bad crash, being sold for scrap, or being left neglected until disposed of by the elements. There are many parts of an airplane that have a life expectancy influenced not only by wear and tear resulting from use, but by the mere passage of time. Such items as covering, shock cords, and tires deteriorate over a period of time regardless of whether the plane is being used or not. Assuming that the airplane has fairly regular use, the decrease in value resulting from wear and tear is approximately the same each year.

The term depreciation frequently includes obsolescence and inadequacy or supercession. The term obsolescence is used to describe airplanes that still have useful lives but are no longer economical to use or fashionable because of new developments in aviation. The matter of being fashionable is perhaps the most important in the case of an airplane. As styles change and new and better airplanes are produced, owners of older planes become dissatisfied with theirs and soon sell so that they may purchase one of the latest models. Sometimes, of course, the owner's family increases so that his present plane is no longer roomy enough, and he decides to purchase a larger one. The fact that an airplane becomes obsolete in the eyes of one owner and is sold is not a true indication that its life is ended. The percentage of potential plane owners who can afford to own and operate a second-hand airplane is approximately seven times as great as the percentage of those who can afford a new airplane (3). Thus airplanes that are considered obsolete by one owner will often be purchased and flown by a new owner. This has the effect of lengthening the active life of the airplane and therefore of reducing the overall rate of depreciation.

Regardless of the large number of potential buyers of second-hand airplanes, there is a definite general tendency for obsolescence to decrease the life of an airplane and thus increase depreciation. The decrease in value as a result of obsolescence is definitely greatest during the first year and less for each succeeding year. This is true

because of the general tendency for aircraft manufacturers, like automobile manufacturers, to produce new models or instigate major style changes each year. With each new change a certain number of owners immediately buy the new airplane. Some owners will wait two or three years before purchasing a new model.

Since depreciation is a result of wear and tear (a straight-line function) and obsolescence (a function whose slope decreases with time) it is obvious that the curve representing depreciation is steep during the early years of the plane's life but gradually flattens out as the airplane becomes older. Thus depreciation is greatest during the first year of the plane's life and becomes less as the airplane becomes older.

There are several systems for computing depreciation, the simplest of which is the straight-line method. The airplane, by this method, is depreciated on the basis of a certain number of years of useful life, and the yearly depreciation is considered the same regardless of the airplane's age. At the end of the certain number of years that represent its useful life the value of the airplane is considered to be zero. Civil Aeronautics Authority data show that the average life of all nonmilitary private aircraft, including those destroyed, at the end of 1938 was 7.4 years. With an active new-plane market tending to accent obsolescence this might appear to be too long a period over which to depreciate an airplane by the straight-line method as it reduces to only 13.5 per cent per year. Nevertheless some experts recommend this figure. The Bureau of Internal Revenue indicates that a 5-year write-off for private airplanes is acceptable, whereas the CAA considers a period of ten years as fair (4). The 5-year period is quite short but places the airplane's value more in line with market value. Its disadvantage lies in the fact that at the end of five years it indicates that the airplane has no residual value, which of course is untrue. The 10-year period, while indicating a residual value after 7.4 years causes the depreciated value to be considerably higher than the actual market value during the first few years of the airplane's life (3).

In some cases the airplane's value might be written off on an hourly basis. This would predicate a certain working life of so many flight hours and would become a straight-line method with regular use. This method is not generally used for the airplane as a whole, but it is quite applicable to the engines as they do not become obsolete by changing styles as the airframe does. The engines in lower-priced personal airplanes generally remain with the airframe for life and are seldom considered as separate units. They are not depreciated at different rates, therefore, nor by different methods.

In the case of higher-priced private aircraft, such as twin-engine airplanes, the engines and airframes are often considered as separate units and thus may be depreciated separately, and by different methods. In this case, the engines may be depreciated on an hourly basis and the airframe on a yearly basis.

Perhaps the best method of determining depreciation is by the percentage-on-diminishing-value, or declining-balance method. This method of depreciation reduces the annual depreciation charge because each year's depreciation is subtracted from the last year's value of the airplane to establish the new, reduced base for the ensuing year. The greatest depreciation is during the first year, therefore, and the depreciation for each succeeding year becomes less. In the same manner the airplane's value decreases most rapidly during its first year of life, with gradually less drop in value for each succeeding year. By this method, the airplane will always have some residual value indicated. Even a totally wrecked airplane usually has a residual scrap value. Another advantage is that the airplane's depreciated value, when reckoned by this method, reduces at a rate corresponding to the decline in the market price. This is to be expected in view of the reasons for and the actual process of depreciation as initially discussed.

An individual who is computing depreciation by the foregoing method faces but one problem—the selection of a reasonable percentage of reduction. Although this method of determining depreciation results in a curve of the same nature as that of market prices, it will approximate market prices only upon selection of the proper constant of reduction. It is believed that, in normal times, a 20 per cent annual reduction of the depreciated value will most nearly approximate market prices and at the same time agree with the depreciation permitted by insurance companies writing hull insurance. This figure will also result in a value at the end of five years that is approximately 33 per cent of the initial price, a level recommended by airplane cost experts.

In mathematical terms, the depreciated value of the airplane at the end of the nth year of operation equals the initial price multiplied by 0.8 to the nth power (Depreciated Value $=$ Price $\times 0.8^n$). The above method and the constant will be used in all curves and calculations in this circular.

Figure 1 shows both the straight-line methods and the declining-balance method curves plotted on a chart of depreciated value versus year of operation. Note that the 80 per cent declining-balance method is quite close to the 7.4 year straight-line method. Its major advantages are clearly shown as large depreciation the first year and a residual value after 7.4 years.
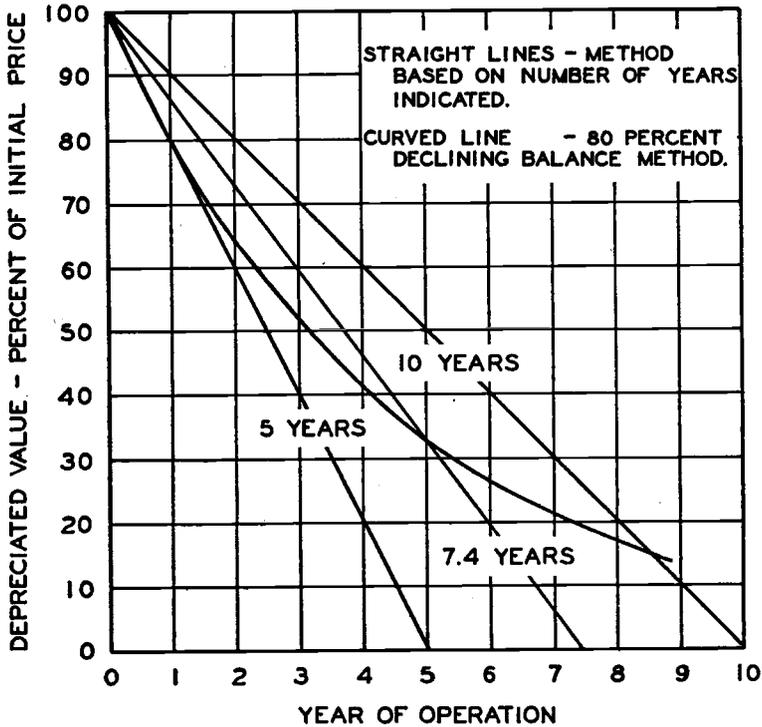
Figure 1. Depreciation Curves.

When depreciation, computed by the declining-balance method, is expressed in terms of percentage of initial price, it will have a value for each specific year of operation as indicated in the following table.

Year of operation	Depreciation *Per cent of initial price*	Depreciated value *Per cent of initial price*
1	20.0	80.0
2	16.0	64.0
3	12.8	51.2
4	10.2	41.0
5	8.2	32.8
6	6.6	26.2
7	5.2	21.0
8	4.2	16.8

The information in the foregoing table indicates that at the end of the fourth year of operation, for instance, the depreciated value is 41 per cent of the initial price and that for the fourth year the

depreciation is 10.2 per cent of the initial price of the airplane. This last figure would represent a definite part of the fixed cost of operation for the airplane during the fourth year, for example.

Many owners set aside each year an amount of money equal to their calculated depreciation for that year. When such an owner sells his airplane, he has saved a sufficient amount to purchase a new one. Another advantage of this procedure is that depreciation becomes a very real cost of operation requiring money from the owner's pocket each year. This makes certain that the owner will include depreciation as part of his cost of operation.

b. **Interest on initial investment.** A fixed cost item that is generally neglected is that of interest on the initial investment. When an individual purchases an airplane he must make an initial payment or investment of over $2,000, regardless of the fact that he figuratively absorbs this cost in small amounts over a period of years by considering depreciation as part of his cost of operation. If he does not purchase an airplane, he will have the money, which could be drawing interest or perhaps could be invested in some profitable enterprise. For example, an individual has $3,000 to buy an airplane. If he does not buy it he may invest this amount and realize $60 annually, assuming a simple interest rate of 2 per cent. If he uses the money to buy his airplane, on the basis assumed, he is depriving himself of a possible investment income of $60 per year. This should be considered as a part of his annual cost of operation. It is important that the owner realize that his loss, therefore his cost, is the interest he might realize on the amount of the initial investment, and not on the depreciated value of the airplane.

c. **Hangar rental.** Estimation of hangar rental is extremely difficult. Hangar rents for the same airplane might vary from $10 to $30 or more per month, depending upon the airport and the hangar operator. Some airports have only enough hangar space for shop facilities, and therefore owners must park their airplanes outside and leave them unprotected from weather. At other airports there may be large hangars but little available space for additional planes, so that hangar space would be extremely expensive. For the purpose of discussing factors other than that of geographical location that influence hangar rental, it must be assumed that rates for like airplanes are approximately the same at all airports. In a recent article (5) on rental charges for hangars, Joshua W. Rowe pointed out that the two main factors that should determine rental rates are the space occupied by the airplane and the expense involved in moving it in and out of the hangar. The space occupied by the airplane de-

pends not only on its plan dimensions but on the amount of over-
lapping and fitting together with other planes that can be accom-
plished.   For instance, a high-wing and a low-wing airplane may
be stored together more easily than two high-wing or two low-wing
airplanes. Other factors that affect overlapping and fitting are height
of wing and empennage, landing gear type, number of engines, height
of radio masts and antennae, etc. The cost of moving an airplane in
and out of the hangar depends on its weight, type of landing gear,
and the difficulty involved in passing its wings over or under those
of other airplanes. Few operators, from whom owners rent hangar
space, have determined a fair rental for each plane based on the two
factors mentioned above.   Instead, many have chosen an arbitrary
figure for each airplane model based upon past experience or on
what other operators are charging.

In some cases hangar rental rates for airplanes have been based
on horsepower, weight, or number of seats in the plane.   At first
glance, these might appear to be suitable bases on which to determine
rental, but cases for which they will not apply frequently arise.   For
this reason these methods are considered unreliable in determining
hangar rentals.

It is desirable to provide means for the user to substitute his
actual hangar rental figure in formulae or charts developed for use
in estimating and computing operating costs.   For those who have
no knowledge of their local hangar rental rates, it is reasonable to
assume $80 per year for each seat of the total seating capacity. Con-
sequently, a three-place airplane would have an annual hangar ex-
pense of $240, regardless of how many seats were actually installed.

In some cases an airplane owner might feel that he could not
afford the high cost of hangar space. He would be forced to tie
down his airplane on the parking ramp. He might be charged a
rental on the space he occupies, but it would be considerably less than
hangar rent at the same field. It is quite possible, however, for tie-
down rates at one field to be greater than hangar rates at another.
As mentioned before, this would depend on geographical location and
the relative amount of business at the fields. An owner who does not
rent hangar space might realize a reduction in his fixed costs by
reason of low tie-down rates but might well find that the weathering
of his airplane is such as to increase its depreciation to the point
where no real saving is made. Naturally this condition would be in-
fluenced by climatic conditions and aircraft construction.

At the present time, hangar space is at a premium as a result of
the building shortage. With the development of new building meth-
ods and more practical hangars, the present high hangar rates should

decrease somewhat, although large-scale reduction will be prevented by the increasing demand for hangar space as well as by the generally higher cost level in prospect.

d. **Insurance.** In 1944 the NAA reported that insurance premiums represented 30 per cent of all costs in operating a lightplane (6). This figure is excessively high and demands considerable explanation. In view of this fact it is believed advisable to include a fairly complete discussion of aircraft insurance at this point.

The two main types of aviation insurance are aircraft hull insurance, which indemnifies the owner against damage to the plane, and liability insurance, which protects him against liability for injuries to passengers or third persons outside the plane or for damage to property caused by the plane.

There are various opinions on the relative importance of these two types of insurance. It appears that liability insurance is the most important to the average plane owner because it protects him from possible losses of relatively large sums, whereas hull insurance protects him only from the loss of that amount which he has invested in his airplane. The term "hull" insurance was first used for airplanes by marine underwriters who wrote the early insurance for the aviation industry. Hull insurance included the airframe, engines, accessories, instruments, and extra equipment.

A little knowledge of airplane accident statistics will aid in explaining the need for hull insurance. For a typical year (1939), out of a total of 5,515 private airplanes in service, 1,133 or 20.5 per cent were involved in accidents. Of this 20.5 per cent, there were 188 or 16.6 per cent washouts, 370 or 32.7 per cent of which required an overhaul, and 549 or 43.5 per cent of which required major assembly. These figures should provide adequate proof of the need for hull insurance.

Aviation underwriters offer three main types of hull insurance coverages (6) (7) (8). The first of these is "complete coverage" which protects the owner against all risks of loss, including crash and fire following a crash. Crash coverage applied while the airplane is "in flight" (beginning of takeoff to completion of landing). For a $2,000 lightplane this coverage would cost approximately $250 yearly. The second type of coverage is less complete than the first and protects the owner against all risks of loss except crash. For the airplane mentioned above this would cost $70 annually with a deductible clause. The third type, called "named perils" is still less complete, protecting the owner against usual risks to which a plane is subject while not in flight. These risks include windstorm, taxiing, collision, mooring, storage, theft, and fire. The cost for the example

plane would be from $50 to $70 annually, depending upon the number and nature of the risks stipulated.

In the future insurance coverage for taxiing probably will be included in the "in flight" coverage and thus be more expensive. Such a probability exists because, of the large number of taxiing accidents which have occurred recently.

Various types of hull insurance coverages for airplanes are listed. Any one, or a combination of these may be obtained.

(a) Comprehensive—ground only, plus fire in flight but excluding fire following crash.

(b) Crash—including fire following crash.

(c) Fire, lightning, explosion and transportation, including fire in flight but excluding fire following crash.

(d) Theft, robbery, and pilferage.

(e) Windstorm, tornado, and cyclone.

(f) Damage while not in flight by hail, sleet, snow, collision, upsetting, earthquake, flood, or collapse of a hangar, shop, or similar structure.

The insurance rate on a particular airplane will depend on many factors other than the amount of coverage. Some of these factors, such as its weight, whether it is private or commercial, new or used, will be discussed later.

In general, airplanes weighing less than 2,000 pounds are considered as "lightplanes" and constitute a separate classification. This group is charged, by some insurance companies, a higher rate than that for heavier airplanes (approximately one-third higher for full coverage) because they are considered more fragile and are more often flown by beginners. Thus, for a $3,000 lightplane, complete coverage would cost approximately $400, while for a heavier airplane of the same price, it would cost but $315 annually. For less complete coverage the difference is less. Commercial planes are charged higher rates than private planes, those used for student instruction being the highest.

An airplane's age is an important factor in determining hull insurance rates. A new plane may be insured for full cost price and used planes for current market value. This cost, or price, in the case of a used airplane would include the cost or value of all extra equipment in the plane. In normal times the current market value of an airplane should be approximately its depreciated value if depreciation is determined as recommended previously. A new airplane of a certain type will be insured at a specifically assigned basic premium rate. This basic premium rate will be approximately 12 per cent for complete coverage, so that for a $2,000 airplane the annual premium will

be $240.   In the case of a used airplane (any airplane beyond its first year of use) a "loading rate" is added to the basic rate to offset depreciation.   One large aviation insurance company uses a loading rate of approximately 3 per cent.   This is multiplied by the difference between the amount of insurance and the original price.   The premium then consists of this product added to the product of the basic rate multiplied by the amount of insurance.   A $2,000 airplane during its second year of life would have a market value, and thus a maximum insurable value, of approximately $1,600.   By the insurance rate determination method just described, the owner would figure his insurance premium to be $1,600 $\times$ 12% plus $400 $\times$ 3%, or a total of $204 for full hull coverage during the second year of operation.   Some insurance companies merely add the loading rate to the basic rate and multiply this sum by the market value of the airplane.   Using the basic and loading rates of 12 per cent and 3 per cent results in a premium of $240 during the second year for the example airplane.

The necessity of a loading rate requires further explanation. In the event of total loss, payment is made in full on the depreciated value of the airplane.   The depreciated value is generally calculated to be 80 per cent of that for the previous year.   This is the method recommended in the discussion on depreciation.   If market value is the same as the depreciated value, and it should be in normal times, then this is the amount for which the plane has been insured. Partial losses, however, are paid without any deduction for depreciation. There are no deductions for depreciation on parts to be replaced. The insurance company pays the cost of the new parts.   It is for this reason that the loading rate must be applied.

In order that an airplane owner may obtain lower rates, the insurance companies impose part of the losses on them.   It is for this reason that deductible and participation provisions are designed.   The little accidents involving repair costs less than $50 to $100 far outnumber the expensive accidents.   The insurance rates necessary to cover the required processing and payment of these small sums would be excessively high.   Therefore, the insurance companies impose upon the airplane owners the expense of these small accidents.   In order to do this the insurance companies insert a deductible clause that provides that the insurance company will pay only for that part of the loss in excess of the deductible amount.   The deductible amount is usually $50 for all risks but crash, fire, and theft.   For crash risks the deductible amount generally will be 10 per cent of the insured value with a $100 minimum stipulated.   Fire and theft risks seldom carry a deductible clause.   When a deductible clause is used,

the owner, not the insurance company, pays all small losses due to damage. If our $2,000 example airplane were to suffer a $300 non-crash damage the owner would pay $50 and the insurance company would pay $250. If the damage were less than $50, the owner would pay the entire amount himself. If the plane suffered $300 crash damage, the owner would pay $200 and the insurance company $100. This is, of course, assuming that the deduction is as mentioned before.

When "ground" and "in flight" coverages are written on light-planes it is possible to substitute a participation clause for the de-ductible clause under "crash" coverage at a reduction in the combined coverage rates. With the participation clause the owner pays a cer-tain percentage of all crash losses regardless of how great or small they may be. It is better than the deductible clause where small damage is incurred, but not in an instance in which an extensive amount of damage is sustained.

In the case of private business and pleasure flying, the percent-age of participation depends on the pilot's previous flying experience, and generally the airplane must be operated only by specifically named pilots. Representative percentages are as follows:

	Per cent
Named private pilot with over 200 hours	20.0
Named private pilot with 100-200 hours	22.5
Named private pilot with under 100 hours	25.0
Named student pilot	27.5
Commercial, including instruction	33.3
Flying clubs	33.3

The rate for full coverage with such a participation clause will be approximately 7 per cent less than for a non-participation policy.

The private pilot will find it advisable to carry full hull insur-ance coverage. If he must fly and cannot afford full coverage, the next best thing is crash coverage alone which would cost him approxi-mately $180 for a $2,000 airplane. If this is still beyond his means he may obtain coverage other than crash for approximately $60. If he cannot afford this, then he cannot afford to fly.

The second, and perhaps the most important, type of aviation insurance is liability insurance which protects the plane owner against claims for injuries to passengers, to third persons outside the plane, or for plane-caused damages to property. Many claims for injuries or damages in case of an airplane crash are quite justi-fiable; many are not. In either case, the claims generally involve large amounts of money and the owners are considered liable and

must pay these themselves if they have no liability insurance. In the case of injury to a third person or damage to property caused by his airplane, the owner is imposed with absolute liability or presumed negligence in approximately a third of the 48 states (7). This means in most cases that he is liable for actual damages incurred by a forced landing and for all damages that are caused by the ascent, descent, or flight of his airplane, or dropping of any object therefrom. He is considered liable under the above-mentioned circumstances whether he is negligent or not, unless the person injured was contributorily negligent. In the remaining two-thirds of the states, the pilot or owner generally is held liable under tort law for damages even though he was not negligent in causing them. An owner is definitely liable if the accident occurred at a time when he is in violation of Civil Air Regulations, and most probably he is liable at all other times.

It is to be noted that the liability rests on the airplane owner. Insurance may be written for a specific airplane or for a specific pilot. Generally it is written for a specific airplane, as all damage suits may be brought against the owner. Thus, if an airplane owner lends his airplane to a friend who has an accident while flying, the owner may find himself sued for damages. This does not necessarily provide immunity for the pilot as he also may be sued. This depends mainly upon the circumstances of the accident.

The heaviest liability to which an owner is exposed, and therefore the most expensive to insure against, is his liability to passengers. There are only two states, California and South Carolina, that have statutes specifically providing that passengers who ride gratuitously in an airplane as guests shall have no cause for action for damages against the pilot unless such pilot has been guilty of gross negligence. In all other states, passenger liability is based on tort law and the pilot generally would be liable in all cases other than those involving accidents due to passenger negligence. Most cases involving liability to paying passengers have been settled out of court for amounts approximately $10,000, as court judgments usually result in higher payments.

An airplane owner should carry an amount of liability insurance somewhat proportional to his financial standing. Wealthy sportsman pilots usually are sued for many times the amount for which the average lightplane pilot would be sued under similar circumstances. Unfortunately an injured person will base the amount of his suit on how much the defendant is able to pay and not on the amount of injury or damage incurred.

The three types of liability coverage—public liability, property damage, and passenger liability—may be purchased separately, or all three may be purchased together in the form of single-limit liability.

Property damage liability insurance protects the owner against costs of damages his airplane may cause to another's property. The minimum limit of $5,000 may be purchased for $12.50 annually if the airplane is to be used for private business and pleasure. A $10,000 limit may be obtained for $14.13 and a $20,000 limit for $16.25. Thus, for but slightly more an owner can carry a limit he is sure will be sufficiently high.

Two main factors determine the limit he should carry. As explained previously, the more wealthy the owner, the higher the limit he should carry. The second factor is that which involves the locale of his intended flying. If the owner plans to use an airport within the limits of a large city, he may be certain that any damage to property will be quite high. If the owner is a farmer, it is entirely unlikely that he could cause more than a few dollars damage even in the event of a total crash. Thus, the city owner should carry a high limit and the farmer a low limit.

Public liability insurance, which protects the airplane owner if his plane injures or kills a person outside of the plane, is the least costly of the liability insurances. It will cost a private pilot $10 per year for the minimum coverage of $5,000/$10,000 limit. Such a limit provides up to $5,000 for any one person injured, or up to $10,000 for any one accident. A 10/20 limit may be purchased for $12.50 annually and a 20/40 limit for $14.80. Such insurance covers any of the many types of accident that may involve a third person. The pilot may injure or kill someone while taxiing, taking off, flying, making a normal or forced landing, or even while warming up. It is quite possible for someone to walk into his propeller while he is warming up his engine prior to flight. Public liability insurance would cover him. The same factors apply in this case as those which influence the amount of property damage liability he should carry. If the individual is wealthy or flies frequently near populated areas, he should carry a fairly large amount of public liability insurance as well as property damage insurance.

If an airplane owner has more than one seat in his airplane and if he occasionally carries passengers, he should by all means have passenger liability insurance. It is common for an owner to believe that since his passengers are always close friends of his, he need not fear being sued if one of them is injured while in his plane. Unfortunately, human nature is such that friendship seldom means very much when there is an opportunity to collect legally $5,000 or $10,000

from some individual. Plane owners find former friends suing in the majority of cases involving passenger injury.

In 1939 there were 1,133 private airplanes involved in accidents in which a total of 80 passengers were killed, 36 severely injured, and 62 who suffered minor injuries (7). Over 13 per cent of all the accidents in that year involved injuries to passengers. This is adequate proof of the necessity for passenger liability insurance. A limit of at least $10,000 is recommended, as this is an amount easily collected by an injured passenger or relatives of one who has been killed.

The cost of passenger liability insurance depends on the limit per passenger seat and the number of passenger seats. When such insurance is purchased it must be obtained for every passenger seat in the airplane. For a $10,000 limit per seat it would cost the owner $34 for one passenger seat and $47.60 if there were two passenger seats. For a $5,000 limit per seat the costs are $25 and $35 for one seat and two seats, respectively. These rates are for planes being used for private business, pleasure, and industrial activities. Rates for commercial planes are approximately three times as high. The reason for this is that there is *always* a liability to paying passengers, while there *may be* a liability to guest passengers.

In the case of "single-limit liability insurance" the limit represents the maximum amount the insurance company will pay in any one accident. It is responsible for claims against public, property damage, and passenger liability to the extent of the limit. If an owner has a single-limit policy of $25,000 (which costs him $71.90 annually) the underwriter will defend him against any one, or all three types of liability up to the total sum of $25,000. The single-limit type of liability insurance may be obtained without passenger liability for considerably less. In the case of $25,000 single-limit without passenger liability, the owner would pay but $29.40 annually. This might be a desirable policy to obtain on a one-place airplane where no passenger liability exists.

It is important that the airplane owner realize that the costs of insurance are not fixed, but are quite likely to be different for each airplane and each owner. It is because of this that insurance companies generally state that all forms of aviation insurance may be written only after submission of full particulars. In occupational flying, each risk is individually rated. In crop dusting and other especially hazardous types of flying, coverage must be obtained from Lloyd's of London.

The foregoing information on insurance obviously can be only general in nature. The premiums stated are those indicated by one

of the large aviation insurance companies and are accepted as repre-
sentative at the time of writing.   Some companies have recently
raised their rates but others have announced that they will retain
their present rates.   In any event, the figures stated in this circular
should not be taken as accurate values for any particular time or
place but rather as average values suitable for comparison purposes.
For accurate cost determination purposes the individual should con-
sult an insurance agent for current insurance rates.

In concluding this discussion of airplane insurance, it is advis-
able again to emphasize that insurance is imperative for the private
plane owner.   Regardless of the fact that it constitutes approxi-
mately one-third of the annual cost of operation, it should be ob-
tained.   If the owner cannot afford insurance, the sad fact is that
he cannot afford to fly.

2. Variable-Cost Items.

a. **Fuel and oil.**   Fuel and oil costs are the easiest costs to
determine.   Both of these costs are closely dependent upon the cruis-
ing horsepower of the airplane.   The larger the engine, the more
fuel and oil will be used.   It is important that cruising horsepower,
not rated horsepower, be the basis for fuel and oil cost determination.
Cruising horsepower is that power used in normal straight and level
flight, and is approximately 60 per cent of rated horsepower.

For the average personal type airplane the fuel consumption is
0.52 pound (0.0866 gal.) per horsepower per hour, and the oil con-
sumption will be 0.0055 pound (0.00294 quart) per horsepower per
hour.   In one hour, therefore, an airplane cruising at 50 horsepower
will use 26 pounds of fuel and 0.275 pound of oil.   In two hours it
will use twice this amount, in three hours three times this amount,
and so on.

The cost of fuel and oil depends mostly upon geographical loca-
tion.   The nation's average is approximately 26¢ per gallon for gaso-
line and 35¢ per quart for oil.   On the basis of these costs the 50
horsepower engine above would have an approximate fuel cost of
62¢ and an oil cost of 5.1¢ per hour.   The annual fuel and oil ex-
pense would be the sum of these costs multiplied by the number of
hours flown per year.

b. **Maintenance.**   The maintenance cost for a private airplane
is extremely difficult to predict as it depends upon so many factors.
At the present time labor and parts supply conditions are such as to
render accurate cost predictions virtually impossible.   In the follow-
ing discussion and cost factor determination no attempt will be made
to include the effect of fluctuating labor and parts costs.

Labor costs and thus the costs of maintenance vary from place to place. In some parts of the country labor is at a premium; in other parts there is little difficulty involved in locating a licensed mechanic who will inspect or repair an airplane for reasonable wages. In addition to the variation in wages, there is also a variation in the cost of replacement parts, depending upon the airplane's location. Since these variations are almost impossible to evaluate, this discussion must be confined to what might be considered as the nation's average for the above factors.

Some owners will fly an airplane which is in a deplorable state of disrepair. Fortunately, the majority keep their planes in good condition regardless of the cost. The Civil Air Regulations require that a private plane owner have his airplane inspected once a year, and that he keep it airworthy at all times. Satisfying only minimum requirements costs little but furnishes poor insurance for the owner. Owners should consider their own personal safety worth the extra expense necessary to have the 20- and 50-hour engine inspections, the 100-hour periodic inspection of the airplane, the 500-hour engine overhaul, and the major airframe overhaul after 5 years of operation. Although present regulations permit the private plane owner to aid in these inspections and checks, such work will require a considerable amount of the owner's time that might otherwise be gainfully employed, and therefore there is no actual reduction of maintenance cost realized.

The cost of maintenance, repairs, and replacement parts is dependent on the cruising horsepower of the plane and on its weight. The larger, heavier, and more powerful the airplane, the longer it will take for an inspection. Also, replacement parts are more expensive for larger airplanes and the time involved in repairs is increased. As the weight and size of an airplane determine, to a large extent, the cruising horsepower, it will be convenient to state these costs in terms of cruising horsepower alone.

All inspections, with the exception of the 5-year major airframe overhaul, are made at the conclusion of a specified number of flying hours. Thus in any given time, their cost is dependent upon the utilization of the airplane. This is also generally true of repairs and replacement parts costs. For this reason the maintenance, repair, and replacement parts costs are based on hours of flying time, in addition to the previously mentioned cruising horsepower, so that their total cost will be in the form of so many cents per cruising horsepower-hour. The 5-year major airframe overhaul should be based on horsepower and calendar time. Thus it would be so much per horsepower-year. In actual cost determination practice the 5-year

overhaul expense factor is included as part of the maintenance cost factor. The error which is introduced is negligible.

One authority on operating costs, Mr. Neil Berboth (*3*), has compiled cost averages for maintenance, repairs, and replacement parts for airplanes ranging from 65 to 250 horsepower. These he has translated into terms of dollars per cruising horsepower-hour. In doing so he has considered the effect of weight relationship of the airplane to the horsepower of the engine, since the cost factor includes airframe maintenance costs. He has not included the effect of a major airframe overhaul in the maintenance cost factor for the first year of operation but has included it in a sliding scale for the second, third, fourth, and fifth years of operation. This results in an increase in maintenance costs each year as the airplane grows older. He has stated that although the owner might not keep his airplane for a full five years, and thus not incur the actual expense of a major airframe overhaul, the airplane's resale value decreases with each year it gets closer to the overhaul. Although this cost effect might be considered either as an increasing maintenance cost or as a higher depreciation cost factor, he believes it more technically correct to consider it a maintenance cost factor.

Mr. Berboth's maintenance cost factors were compiled prior to 1945 and therefore are considered to be somewhat low. Cost factors for maintenance, repairs, and replacements parts that are considered to be representative of average present-day conditions are listed below. These are 50 per cent higher than those recommended by Mr. Berboth.

Year of operation	Cost per cruising horsepower-hour
1	2.01¢
2	2.62¢
3	3.24¢
4	3.85¢
5	4.47¢

On the basis of the above figures, an airplane that cruises on 50 horsepower would cost approximately $1 per hour for maintenance, repairs, and parts during its first year of operation. During its fifth year of operation the cost would be $2.24 per hour.

It must be emphasized that the individual owner should, to the best of his ability, determine the maintenance costs in his locality and in operating cost computation apply his figures rather than those given above.

3. Non-Flying Expenses.

a. **Ground transportation expenses.** There will be no attempt to evaluate nonflying expenses in terms of money, as they are extremely variable. These expenses, that are so often neglected, however, constitute a very definite, and often an excessively large, part of operating expense.

The survey of ex-owners (2) indicated that many people have given up flying because of the excessive amount of time necessary to travel to and from airports. As flying increases, airparks will be built closer to towns and cities, but seldom will they be within walking distance. There is little hope of an immediate solution of this problem.

Nonflying expenses consist of two parts, the first of which is the actual cost of driving a car or hiring transportation to and from the airport. It is reasonable to believe that the average airport is approximately five miles from the city it serves. Assuming average operational costs for cars, this results in a transportation expense of $0.50 for each round trip. If it is also assumed that a private pilot flies 200 hours per year and flies an average of two hours per flight, it is evident that 100 round trips will be required. This results in a $50 annual transportation expense. If an airplane owner uses his plane for cross-country trips or business trips, his ground transportation expense will probably increase as he will need to hire a taxi for transportation into the towns at most of his stops. Very few airport operators provide ground transportation for transient pilots.

b. **Delay expense.** Private plane owners do not figure their flying time and time spent waiting to fly in terms of money. For someone using his airplane for business transportation, flying time and waiting time due to delays might be considered strictly as nonprofit time. Delays may result because of mechanical failure of the airplane, refueling and inspection delays, or bad weather delays.

Delays resulting from mechanical failures are unpredictable but represent a fairly constant amount of time for each hour of flying, regardless of the airplane.

Refueling and inspection delays are predictable. Furthermore, they consist of a fairly large amount of time when based upon flying hours. Approximately one hour must be spent in refueling for every six hours of flying. An individual who uses his airplane for business transportation will be able to have the 20- and 50-hour engine checks performed during a time when his airplane is normally idle. This may not be possible in the case of the 100-hour periodic and annual inspection, or the 5-year overhaul which may take two days, four days, and a month respectively, to perform. Lost time

due to these delays should be considered as a part of the cost of operation.

Delays due to bad weather are unpredictable and represent perhaps the greatest delay factor. The average personal airplane is not suitable for flying except under contact conditions. Also, very few private pilots have an instrument rating. The average personal plane and owner, therefore, represent a strictly fair-weather combination. When an airplane is used for business transportation purposes, all delays resulting from bad weather may result in a monetary loss to the owner. The value of his time during the period of delay and the expense of additional meals and lodging add to the expenses resulting from such delays.

Regardless of the fact that delay expense may represent a large portion of the annual cost of operation, no attempt will be made to include it in cost determination formulae or charts because it is impossible to predict with any reasonable accuracy. Nevertheless, it should be kept in mind and may be included by the individual in his particular cost determination.

c. **Business expenses for commercial operation.** It is beyond the scope of this publication to discuss with any degree of completeness the business expenses encountered in a commercial operation. It is advisable, though, to mention them briefly so that an individual contemplating a business venture in the aviation field may be more conscious of their existence.

If the personal plane pilot uses his ship as a means of transportation only he will have little or no business expense, other than that necessary to record his operating expenses. Such records would be of value for income tax purposes and expense records if he travels on company business with transportation paid by the company. It has been found profitable by many private pilots to use an airplane for business transportation as well as for pleasure flying. By doing so, an appreciable fraction of the expense of ownership has been reduced in the form of income tax reduction allowable for business transportation expense.

In actual commercial operations such as pilot training and freight or passenger flying service the operator must include, in his operating costs, such expenses as office rent and supplies, telephone, advertising, and all additional help, both office and flying, which is necessary for successful operation. In short, all expenses incurred by the business either directly or indirectly must be charged to the operating expenses. It is important to note that, in cases of inefficient operation and organization, business expenses may represent a sizable percentage of the total cost of operation and thus failure to anticipate them may lead to eventual failure of the enterprise.

III. FACTORS AFFECTING OPERATING COST COMPARISONS

1. **Reduction of Costs to a Common Basis.** As indicated by the previous discussion, fixed-cost items are expressed generally in terms of dollars per year, and variable-cost items are expressed in terms of dollars per hour of flying time. Before adding these two groups of cost items they must be expressed in terms of a common denominator. The general procedure is to express the variable-cost items in terms of dollars per year. To do this the total cost per hour for fuel, oil, maintenance, and overhaul is multiplied by the number of hours flown per year. Then to this total variable cost per year is added the annual fixed cost total. This sum is the total operating cost per year. Operating cost per plane-mile may be obtained by dividing the cost per hour by the cruising speed of the airplane.

Unless the prospective purchaser of a plane is interested primarily in pleasure flying, costs based upon a yearly or hourly basis are not the most suitable for evaluation or comparison with those of other airplanes. For example, the operating expense of a twin-engine transport may be less than that of a "Cub" type airplane when computed on the seat-mile basis. Naturally it is much greater when computed on the yearly basis. This is an extreme example, but serves to illustrate that a customer who intends to use his airplane for the transportation of a group of people is interested in its cost per seat-mile; not per year or per hour.

Thus, when comparing two or more airplanes, the buyer must be certain that not only a common operating expense basis be selected, but that the condition of utilization be fully qualified. Operating expense may be determined on any of the following bases:

(a) Plane-calendar time. Cost would be based on the entire airplane regardless of number of seats, and would be expressed as cost per year, month, week, etc., for the airplane as a whole.

(b) Seat-calendar time. Cost based on each seat and expressed as cost per seat-year, seat-month, etc.

(c) Plane-flying time. Cost based on entire airplane and expressed in terms of hours flown, such as cost per 500 plane-hours, 200 plane-hours, plane-hour, etc. Normally, unless otherwise specified, the word "plane" in "plane-hour" is understood and is not included.

(d) Seat-flying time. Cost based on each seat and expressed in terms of hours flown, such as cost per 500 seat-hours, 200 seat-hours, or seat-hour.

(e) Plane-distance. Cost based on the entire plane and expressed in terms of distance flown, such as cost per 10,000 plane-miles, 5,000 plane-miles, or plane-mile.

(f) Seat-distance. Cost based on each seat and expressed in terms of distance flown, such as cost per 10,000 seat-miles, 5,000 seat-miles, or seat-mile.

(g) Baggage weight-distance. Cost based on each pound of freight or baggage and expressed in terms of distance flown, such as cost per ton-mile, per 1,000 pound-mile, or per pound-mile.

Although costs may be determined on any of the above bases, they are generally expressed as so much per year, per hour, per mile, per seat-mile or per pound-mile.

It is important that a buyer or operator select the proper basis on which to compute operating expense. His selection should be dependent upon his intended type of flying. A discussion of possible uses for costs as computed on various bases is as follows:

(a) Cost per plane-year basis. Any individual who attempts to live within his income will undoubtedly determine total operating costs on the entire airplane on a yearly basis for budget and tax purposes.

(b) Cost per seat-year basis. This method is seldom used but it will give an airplane owner an indication of the cost applicable to each seat, and then to each passenger or possible passenger. A group of men interested in buying a single airplane to carry them to and from their favorite fishing and hunting grounds would be interested in the yearly cost per man which would naturally be the cost per seat-year for the airplane if there were no more seats than men.

(c) Cost per plane-hour basis. For the private pilot interested only in local flying, with an occasional cross-country trip, this basis is excellent. He is not interested particularly in how far he can fly for a dollar, but in how long he can fly for a dollar. The time element is of great importance to him. If he is indifferent as to whether he carries passengers or not, then he had better use this basis and figure his costs per hour on the entire plane. Any individual engaged in renting airplanes generally will determine his costs and rates on this basis. When a non-owner pilot rents a plane for local flying he is charged on a plane-hour basis that will be the same whether he flies alone or takes

his friends. Instructional rates are determined on this basis also, with the total hourly cost being the instructor's hourly wage added to the hourly airplane cost.

(d) Cost per seat-hour basis. This method would apply to the private pilot in the same manner as the plane-hour basis, with the exception that a pilot would use this basis if, for instance, he always took his wife or a friend along as a passenger and considered each as receiving equal percentage of the derived pleasure. He thus would determine costs on each seat. This method is of greatest importance to a pilot who takes passengers up on sight-seeing hops. In order to determine a fair charge per passenger he must first know the cost per passenger or per seat. Therefore he would determine his costs on a seat-hour basis. It is a common practice to charge on an hourly basis, rather than on a distance basis for sight-seeing flights.

(e) Cost per plane-mile basis. Anyone using an airplane for personal transportation would compute operating costs on this basis. It would also apply to pilots who use their planes primarily for cross-country trips where distance rather than time is of great importance. Airplane operational expense on all jobs that require the plane and pilot or crew to fly set distances would be determined on the cost per plane-mile basis (9). This would include aerial photography, pipe or power line patrolling, etc.

(f) Cost per seat-mile basis. This method is used most extensively in cost determination for commercial transportation of passengers. It would be used also by private pilots who might purchase a plane on a group basis for use in transportation, or by a company using a plane for company transportation.

(g) Cost per pound-mile basis. Cost for freight planes would be computed on this basis. It may be used by anyone using an airplane for transportation of baggage, equipment, etc., where the job is to move so many pounds so many miles.

It is important that the pilot or owner realize that cost determination on any single basis may not be sufficient. Cost comparisons between any two or more airplanes may be made on one selected basis but would be more revealing if computed on two or three bases. In general they are computed on the plane-year and one or two other selected bases.

2. **The Effect of Utilization.** A personal type airplane provides a very economical means of transportation, but only if the owner utilizes it sufficiently. This is a fact not often realized by an owner or prospective owner of an airplane. It is a well-known fact to aircraft salesmen who may find it more profitable to say that an airplane is an economical means of transportation without qualifying their statement as to the utilization factor. As one of the most important factors in determining the cost of operation of airplanes, this utilization factor demands considerable explanation.

As already explained the total annual cost of operation is the sum of the yearly fixed costs and the yearly variable costs. The fixed costs are constant for the year while the variable costs are dependent directly upon the number of hours flown per year. If, for example, the airplane is not flown at all during the year, the total operating cost would consist of only the fixed costs. This, therefore, would represent the minimum annual cost of operation. If the airplane were flown but one hour a year, the yearly cost would consist of the fixed costs plus one hour of variable costs. If the airplane were flown two hours a year, the yearly cost would consist of the fixed costs plus two hours of variable costs. It can be seen that total yearly operating cost increases with the number of hours flown and that it has a minimum value represented by the fixed costs. Expressed mathematically, the total yearly cost of operation, y, equals $a + bx$, in which a represents the yearly fixed costs, b represents the variable costs per hour, and x is the number of hours flown per year.

When the total yearly cost of operation is reduced to hourly cost of operation, it is done so by dividing the yearly cost by the number of hours flown per year. Thus the equation for hourly cost of operation becomes $a/x + b$, in which a, b, and x are defined as previously. In this case, total hourly cost of operation is infinite if the airplane is not flown during the year. As utilization increases, the hourly cost decreases and gradually approaches the minimum value of the hourly variable cost as utilization approaches an infinite value. Since operating cost on a per mile basis is determined by dividing hourly operating cost by the cruising speed of the airplane, this cost will vary in a like manner with a varying utilization. This variation of operational costs with utilization may be understood more readily by reference to Figure 2. This figure was drawn for a three-place, \$3,287 airplane of approximately 77 cruising horsepower and 120 miles per hour cruising speed. With utilization of 50 hours per year, the total operating cost is approximately \$30 per hour, or \$0.25 per plane-mile. With 115 hours utilization per year these figures are reduced to half of their 50-hour values, and with
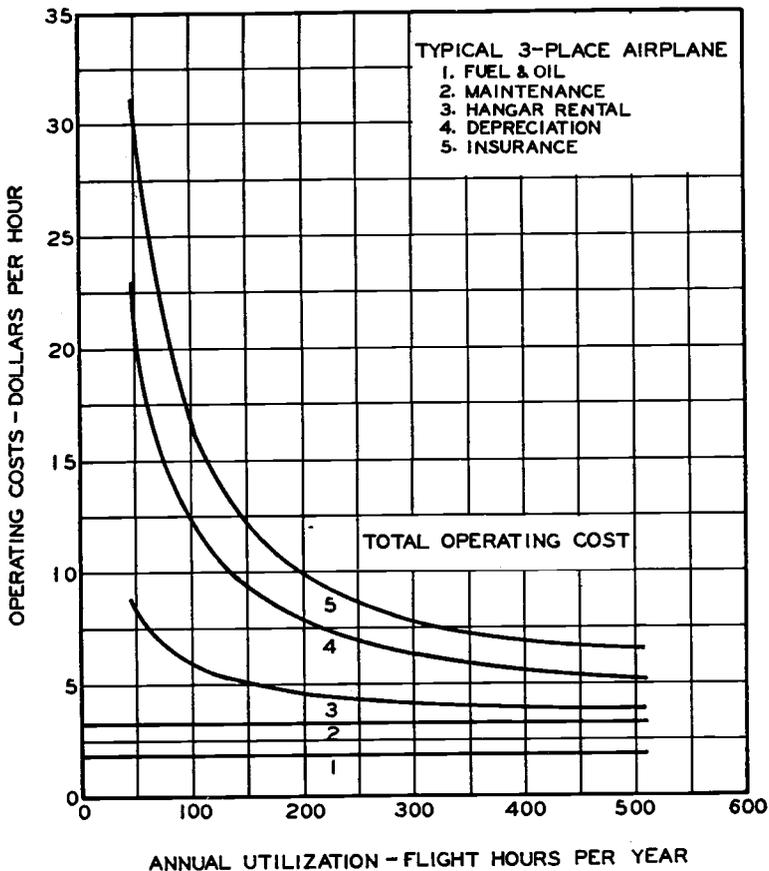
Figure 2. THE EFFECT OF UTILIZATION ON OPERATING COSTS.

a 500-hour utilization they are reduced to approximately 20 per cent of their 50-hour values. It is evident that with an increase in utilization there is a marked decrease in cost per hour and per plane-mile. It is to be noted in Figure 2 that the fuel and oil and the maintenance costs per hour and per plane-mile are constant for all values of annual utilization, whereas the fixed cost items vary with the utilization.

3. **Comparisons with Other Means of Transportation.** The costs of operation of personal airplanes have been discussed in the previous sections. From these discussions one might conclude that the cost of ownership of a personal type of airplane is prohibitively

high. In many cases this is entirely true. In other cases such a con-
clusion is reached without comparing the cost of this means of trans-
portation with other means, such as airlines, automobiles, and trains.
When such comparisons are made they are generally quite illogical.

One such comparison, recently published in a magazine, was
made between an airplane that had a 450 hour per year utilization
(50,500 miles per year), and an automobile that was driven but
11,250 miles annually. The objective of the comparison was to show
that the airplane cost less per mile to operate than the car—a simple
thing to do when such favorable conditions for comparison are
chosen. Anyone familiar with the cost of operation of aircraft
would realize instantly that an airplane operated at the high utilization
of 450 hours per year would have an extremely high utilization for
the average personal plane. Thus it is evident that a reasonable com-
parison may be made only after considerable thought has been given
to the selection of a sound basis.

Before discussing the comparison between various means of
transportation, it appears advisable to consider each separately. The
automobile is the most common means of transportation because it
provides almost ultimate utility. People use an automobile for
pleasure driving and transportation for distances ranging from a few
city blocks to several thousand miles. It is estimated (*10*) that 12
per cent of the annual auto mileage or 29 billion car miles is in trips
over 200 miles in length, of which 25 per cent is business travel.
Approximately 7 per cent of total car mileage, or 16½ billion car
miles annually, is used for trips of 30 to 40 miles, of which three-
fourths is Sunday driving and the balance business trips. About 19
per cent of the total annual car miles, therefore, can be said to repre-
sent potential mileage that may physically be performed by the per-
sonal plane. This leaves 81 per cent of the total annual passenger
car miles that falls into a group consisting of trips of less than 50
miles. At the present stage of development of airplanes, it is impos-
sible to consider them useful, much less profitable, for such short
trips even if there were adequate airport facilities at the place of use.
In fact, as shown by the growing rapid-transit systems in our major
population centers, the automobile, with all of its flexibility and
utility, is comparatively uneconomical for business transportation in
large cities and towns. Thus we see that 81 per cent of the transpor-
tation provided by cars cannot be provided by airplanes and there-
fore no logical comparison of costs of operation could be made on
the basis of this type of short trip transportation. It is also highly
unlikely that much of the 75 per cent of the 30 to 40 mile trip driving
that represents the Sunday driving, would be replaced by Sunday

flights in personal planes. The 30 to 40 mile Sunday drives take from one to two hours. If this time were spent in flight it would result in an annual utilization of but 50 to 100 hours. The hourly cost of flying under conditions of such low utilization is prohibitively high. The fact that the airplane covers considerably greater distances than a car in a given time is believed unimportant in this case as the length of Sunday drives is determined more by the time involved than by the distance covered. This leaves approximately 14 per cent of automobile transportation that actually may be compared logically with personal plane transportation. In many of these cases there is no doubt that the airplane is far superior to an automobile.

There are many places where a 200 or 300 mile trip by automobile might require an entire day, or where no transportation other than the personal plane is available. This is generally the case where hunting trips are involved. Unfortunately, one generally finds the best hunting and fishing in the more inaccessible spots, where perhaps only a float-equipped personal plane might land.

The personal plane is also of great value for business concerns that require frequent transportation for their personnel. There would be little argument as to which is the more economical, the automobile or the airplane, under circumstances where time spent en route represents a large monetary loss to a company.

We are concerned primarily, however, with that group which accounts for approximately 5 per cent of the automobile miles. To be more exact, this group is the border-line group that makes long and frequent trips in cars, at the present time. A comparison of the cost of transportation of automobiles and personal airplanes would be very logical for this group as their length of trip is within the range of both.

Before actually making such comparisons it is advisable to discuss the trains and airlines. Most automobile owners on long trips other than summer vacation trips leave their cars at home and travel by airline or train. This is because the length of the trip is such as to exceed the practical limits of the automobile, insomuch as physical discomfort and time involved are concerned. This is also quite true for the owner of a personal plane. Cross-country trips are virtually out of the question in a small plane. It would not take as long nor cost as much as in an automobile, but it would be much more tiring and just about as expensive as such a trip by train or airline. This is not the case for trips of 500 to 800 miles in length. Often trains and airlines are inconvenient for such trips, either because of a roundabout route and the time necessary to reach the destination, or because of a poor time schedule that places the traveler at his desti-

nation in the middle of the night. In such cases the personal plane will be advantageous; and if many such trips are necessary, considerably more economical.

The foregoing discussion might be summarized as follows: The personal plane cannot be compared logically with the automobile for short trips nor with the railroads or airlines for long trips, but for border line cases comparison is quite logical. Such border line cases consist of comparison with automobile travel where frequent trips of 200 to 500 miles are made, and with trains and airlines when frequent trips of 500 to 800 miles are made. Use of buses has not been considered because it is believed that few business trips of such length are made by bus.

Accurate comparisons between different means of transportation are impossible even when logical trip distances are selected, as mentioned in the preceding paragraph. Weather and its effect on trip time is an extremely variable and important item. The matter of time wasted and expense involved traveling to and from various airports is another variable that enters into the actual cost of transportation. Variables such as there are too numerous to mention. The only choice remaining is to assume constant values for the most important one and neglect the others. This will result in an approximate solution that is satisfactory for the purpose. In the comparisons that follow it is assumed that effect of weather and the expense and time involved going to and from airports is negligible, or is approximately constant for each method of transportation, and thus may be neglected.

Neil Berboth has made a comparison (9) between private planes and public transportation in an effort to show that the private plane is more economical for company transportation under certain conditions.

COMPARATIVE COSTS AND TIMES FOR A 400-MILE TRIP

Passengers to be carried	4-place single-engine $7,000 Time 2:45	5-place twin-engine $30,000 Time 2:00	Present airline average Time 3:05	First class train Time 8:00
	Cost	Cost	Cost	Cost
1	$30.00	$47.65	$19.20	$18.40
2	30.00	47.65	38.40	36.80
3	30.00	47.65	57.60	55.20
4	....	47.65	76.80	73.60

For purposes of estimating costs, Mr. Berboth assumed the planes to have an annual utilization of 1,000 hours and that a pilot was hired to fly them. It is admitted that the $30,000 plane is not in the personal plane class, but it is suitable to illustrate a few points.

The first of these is that for trips involving the transportation of but one man, airlines or trains are the most economical means.   With an increase in the number of individuals making each trip, there is no increase in flying expense when flying in privately owned aircraft. This is not true in the case of public transportation where the total trip cost is directly proportional to the number of persons making it. This is shown in the tables quite clearly.   Two passengers in the $7,000 airplane may make the 400-mile trip more economically than by airline or railroad, while three passengers in the $30,000 airplane may make the trip at a lower cost than by public transportation.   It is of interest to note that time is saved by use of private planes, even when compared with airline transportation.   In the case of train
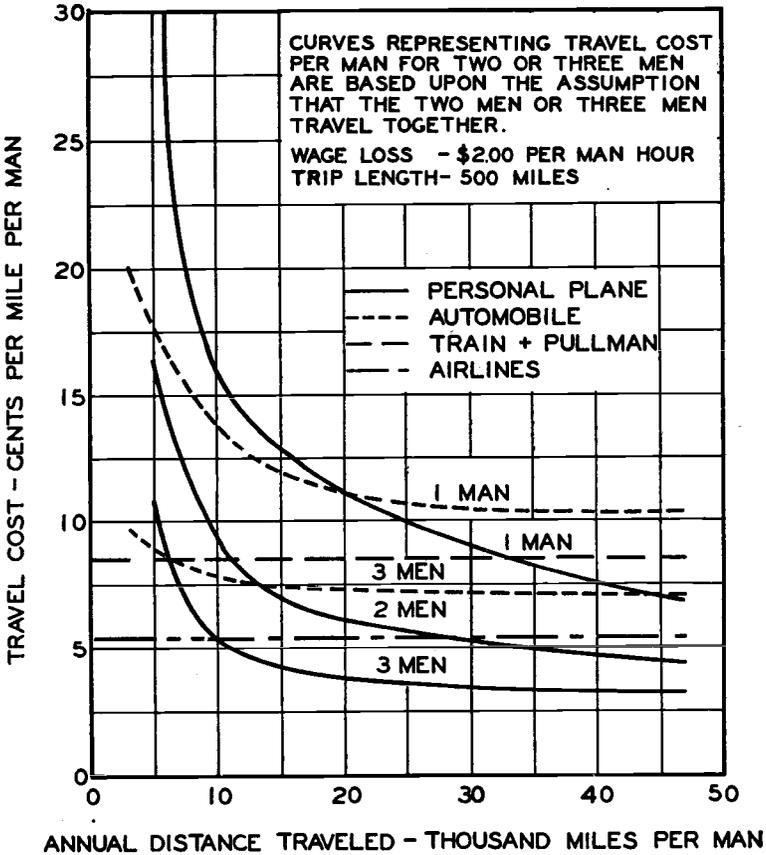

Figure 3. Transportation Cost Comparisons.

transportation, an excessive amount of time is involved. If the costs included, as they should, the value of the traveler's time, then the transportation by private plane would appear to be even more economical when compared with airlines and trains.

Figure 3 has been prepared as an example of transportation cost comparison. In this comparison the most unfavorable conditions possible for the personal plane have been assumed so as to demonstrate its minimum economical efficiency. The light plane chosen is the 120-mile-per-hour, three-place plane previously mentioned in Section III—2. The automobile chosen is a sedan priced at $1,600, and with the following approximate cost of operation break down:

Fixed costs per year
    Depreciation (5-year life assumed) $320.00
    Garage rent 60.00
    Insurance 60.00

Variable cost per mile
    Fuel and oil $0.02
    Maintenance 0.01

Four cents per mile is assumed to be the cost of transportation by both airline and by train. It is further assumed that the lengths of the trips are all within the previously mentioned physical limits of the various vehicles (500 miles), and that the average speeds for the trips are as follows:

                                                                          mph
    Automobile 30
    Personal plane 120
    Airline 150
    Train 45

The problem is of a type that might confront a small company or business concern, several members of whom travel regularly in performance of their duties. The company is assumed to be desirous of knowing the relative cost of transportation by privately owned and public vehicles for various annual trip distances, with an approximate loss of $2 per man-hour for travel time.

The costs have been computed on the basis of the assumptions made, and are shown in Figure 3 as cents per mile per man versus annual miles per man. In computing these costs it was further assumed that the privately-owned airplane and automobile were not used except in performing the required transportation. This necessarily limits the airplane to an annual utility range of below 300 hours per year, a particularly unfavorable range for airplanes.

It can be seen from Figure 3 that the cost per man-mile of travel by car or airplane is considerably reduced if trips are so arranged that two or three men may travel at the same time. Of course, under such circumstances, the cost per man-mile by public transportation is unchanged. When but one man is traveling by privately-owned airplane his transportation cost drops below that of an automobile at the 20,000 miles per year utilization point, and below railroads at the 33,000 miles per year utilization point. A total annual trip distance of approximately 55,000 miles must be realized before cost by privately-owned airplanes is lower than that by commercial airlines. This is not true if two or three men travel together. Two travelers can fly in a personal plane more economically than by airline if they each fly 30,000 miles per year, and three travelers if they each fly 10,000 miles per year.

Figure 3 also shows lost time due to slow transportation as an increase in traveling cost. Thus the automobile remains in the high cost range regardless of the utilization. As mentioned previously, the assumptions were such as to result in an unfavorable showing for the personal airplane. Regardless of this fact, the privately owned personal airplane shows up as the most economical means of transportation for a large proportion of the reasonable utilization range.

This has been an assumed case where any of the four methods of transportation would serve. There are many cases, such as around large population centers, where the privately owned personal airplane would be uneconomical. In many places, however, no trains or airlines operate, and the privately owned airplane or automobile is the only answer. Therefore each case must be investigated and tested separately. Only after this has been done and the personal plane has shown up well in comparison with other means of transportation, should the individual consider its purchase a safe economical venture.

The above discussion has been limited to cases in which the personal airplane is to be used primarily for business transportation. If pleasure flying alone is contemplated, similar cost comparisons may be made if desired, although perhaps in such a case the individual's time should not be charged.

IV. OPERATING COST DETERMINATION CHARTS

1. **Explanation of Assumed Constants.** It is almost impossible to develop a cost determination formula or chart that is not based upon several assumed constants, the values of which are correct only for the average airplane owner and for the average airplane. Any method by which exact operating costs may be predicted

or determined so as to eliminate all assumed constants is so complex as to be almost worthless to the average owner-pilot. Not only is it believed that certain constants should be assumed to simplify cost determination, but that a graphical means such as charts rather than formulae should be used. By use of such charts it is possible to permit a greater flexibility by reducing the number of constants necessary and to eliminate most of the mathematics necessary when computing costs by formulae.

Regardless of the reduction of constants possible by use of charts, it was necessary to assume several in the construction of the cost charts. The fuel and oil consumption were assumed to be 0.52 and 0.0055 pound per horsepower-hour. These are believed to be quite accurate for the average personal plane engine. Maintenance and overhaul costs were assumed per horsepower-hour for each year of operation as indicated in Section II-2-b. Liability insurance rates were taken from rate cards of a nationally known aviation insurance company and are believed to be quite representative of all insurance rates. To reduce the complexity of the insurance section of the chart it was assumed that the insurance limit purchased would be the same for public and passenger liability and for property damage liability. This results in a figure which is but slightly higher than that of a single-limit liability insurance coverage. Errors due to this assumption will be quite small as liability insurance premiums represent a fairly small proportion of the total annual cost of operation.

Depreciation is, as previously explained, assumed to be 20 per cent per year of the previous year's depreciated value.

The assumption that might possibly lead to the greatest error is that for hull insurance. It was assumed that hull insurance would be the comprehensive type (ground and in flight) and that its base rate, regardless of weight, would be $12 per hundred dollars, while its loading rate would be $3 per hundred. Actually rates are 12.5 per cent higher than this for airplanes under 2,000 pounds, and 12.5 per cent lower than this for airplanes over 2,000 pounds in weight. This might result in a total annual operating cost error of approximately 3 per cent, which is not excessive.

If, as in the case of some prospective owners, the individual has little or no knowledge of the local costs of such items as fuel, oil, hangar rent, etc., it is suggested that he use the following values that are believed representative of the present national average:

> Fuel cost, $0.26 per gallon
> Oil cost, $0.35 per quart
> Hangar rent, $80 per seat-year
> Liability insurance, $5,000 limit for each type

Cruising horsepower is approximately 60 per cent of rated horsepower. This 60 per cent value may be used in cases where rated horsepower only is given.

The foregoing average figures are presented only as a suggestion. In all cases of cost prediction or determination, the individual should investigate, and use with the cost charts, the local prices for these items. An individual wishing to determine the cost of operation of a specific airplane would first refer to the aircraft specifications to ascertain the selling price, cruising horsepower and speed, number of passenger seats, and the year of operation, if a used airplane. He would then visit his local airport and find out what he must pay for fuel, oil, and hangar rent. He also should determine the insurance limit he expects to purchase and estimate his expected annual utilization. By use of the cost charts and the above-mentioned data, he would be able to determine his operating costs within a limit of error of approximately 5 per cent, plus or minus.

2. **The Use of the Operating Cost Charts.** The operating cost charts consist of five charts the first of which is Figure 4, the
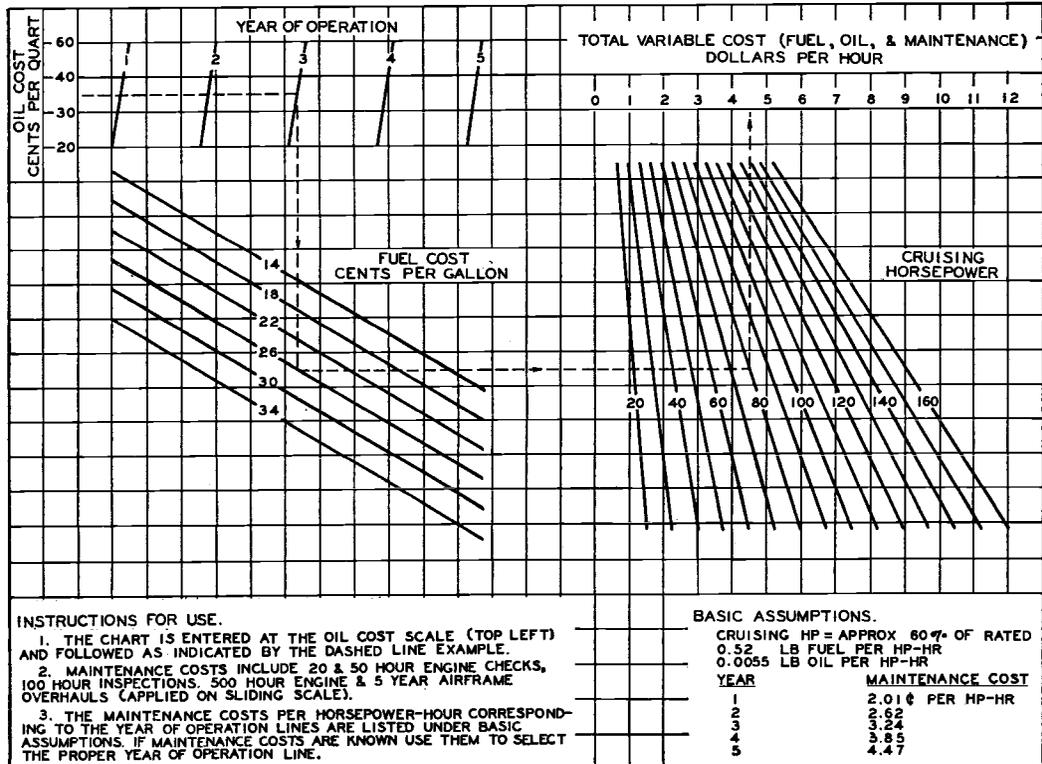

Figure 4. VARIABLE OPERATING COST CHART.

variable operating cost chart. With a knowledge of oil and fuel cost and the cruising horsepower of the airplane the individual may follow the chart as indicated by the instructions and the dashed line example on the chart and read on the corresponding scale the total variable operating cost of the airplane in dollars per hour.

Figure 5 is used to obtain the annual premium for liability insurance. To determine, for example, the premium for a $40,000 limit each for public, property, and passenger liability insurance on a three-place airplane, an individual would proceed horizontally from the $40,000 point on the insurance limit scale until he reached the line representing two passenger seats. Directly below this intersection and on the total annual premium scale he would read $100, his annual liability insurance premium.
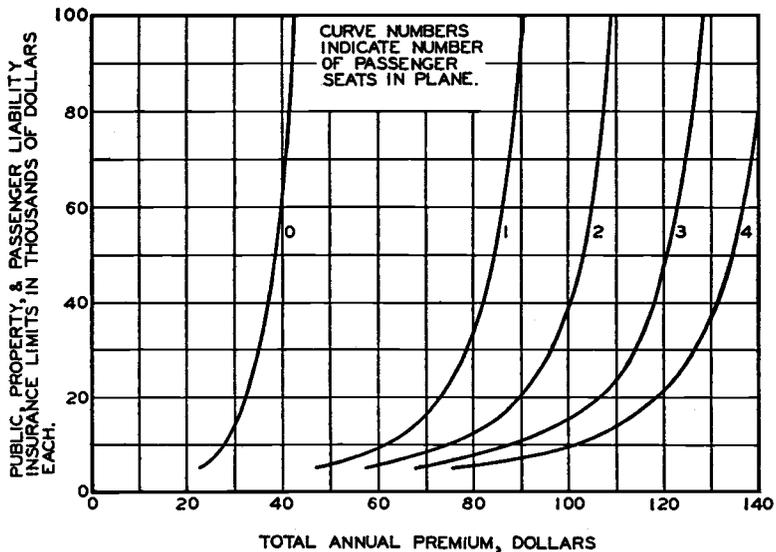

Figure 5. LIABILITY INSURANCE CHART.

Determination of hull insurance premiums is made by use of Figure 6. The annual premium is found directly below the intersection of the year of operation line and the horizontal line representing the list price of the airplane. For example, during the first year of operation of a $2,500 airplane the annual hull insurance premium would be $300.

By the same general method as used in the two previous cases the annual depreciation expense may be found by use of Figure 7.
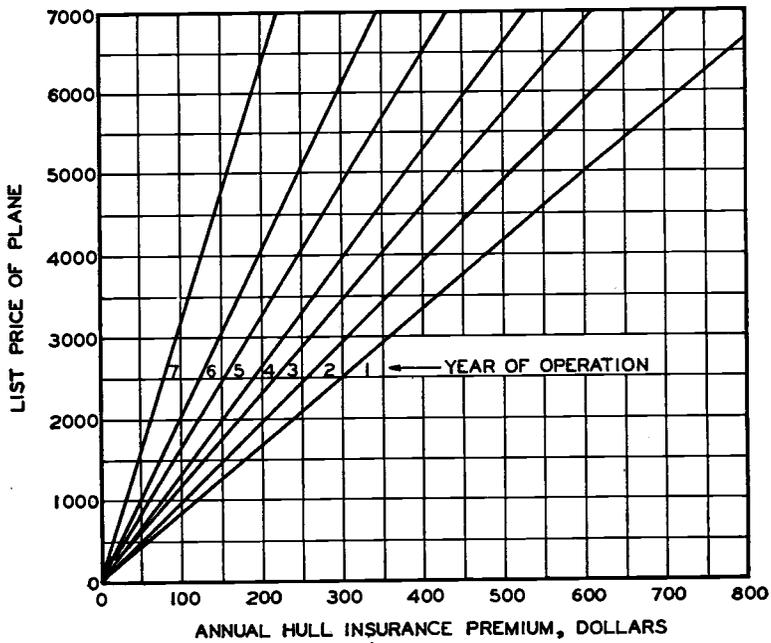
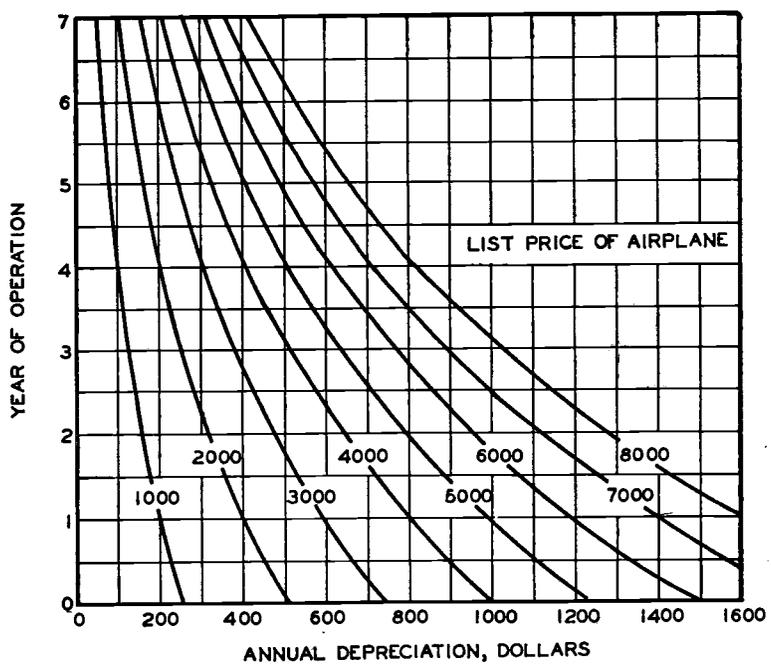Figure 6. COMPREHENSIVE (GROUND AND IN FLIGHT) HULL INSURANCE CHART.

Figure 7. DEPRECIATION EXPENSE CHART.

For example, the $2,500 airplane during its first year of operation would have a depreciation expense of $500.

The total annual fixed operating expense is the sum of the fixed cost items mentioned plus hangar rental. Thus, to the sum of the three values obtained from Figures 5, 6, and 7 must be added the yearly hangar rental to obtain the desired total annual cost.

As the nonflying expenses are generally computed on a yearly basis they too, if known, may be added to the fixed costs for final reduction to various bases.

By use of Figure 8, variable costs and fixed costs may be combined so that annual cost, cost per hour, and cost per mile may be obtained. This figure, the use of which merely reduces the amount of arithmetic the individual must perform, is easy and convenient to use but will not yield as accurate an answer as will the use of the simple mathematics. If the individual desires a more accurate answer than that obtainable from Figure 8 he may perform the following steps: Multiply the variable cost per hour by the annual utilization. This will yield the annual fuel, oil, and maintenance cost, which, when added to the annual fixed cost including nonflying expenses will give the total yearly cost of operation. This annual cost of operation may be reduced to hourly cost of operation by dividing it by the annual utilization. The hourly cost may be reduced to cost per mile by dividing it by the cruising speed of the airplane.

3. **Sample Calculations of Cost of Operation.** The following example problem will aid in further illustrating the use of the operating cost determination charts. This example is not the one indicated by the dashed lines on the charts.

It is assumed that an individual wishes to investigate the cost of operation of a new, typical two-place personal-type airplane. From a salesman or sales literature he obtains the following information:

List price:	$3,000
Cruising power:	80 hp
Cruising speed:	80 mph

Inquiry at his local airport yields the following:

Oil cost:	$ 0.35 per quart
Fuel cost:	$ 0.26 per gallon
Hangar rental:	$150.00 per year

It is further assumed that he wishes to purchase a $10,000 limit each of public and passenger liability and property damage insurance. He also plans to purchase full hull insurance coverage of the comprehensive type.

With the foregoing information and an estimation of a 300-hour annual utilization, the individual is ready to determine his operating costs from the cost charts as follows:

Figure 4, the variable operating cost chart, is entered at the oil cost of $0.35 per quart. From this point continue directly to the right until the line representing the year of operation is reached. (In this example problem the cost of operation will be based upon the third year of operation as this best approximates the average yearly cost of operation for a 5-year period. If he wishes to determine the cost for any particular year he would proceed to the corresponding line and would obtain a slightly different final figure). From the point of intersection of the horizontal line just drawn and the third-year-of-operation line, proceed down to the $0.26-per-gallon-fuel-cost line, then to the right to the 80-cruising-horsepower line. A vertical line upwards from this point intersects the total variable cost line at the $4.50-per-hour point. Thus the variable cost is determined.

INSTRUCTIONS FOR USE.
   1. THE CHART IS ENTERED AT THE TOP LEFT AND IS FOLLOWED AS INDICATED BY THE DASHED LINE EXAMPLE.
   2. ANNUAL, HOURLY, AND PER-MILE COSTS ARE DETERMINED BY THE INTERSECTION OF THEIR RESPECTIVE SCALES AND YOUR PLOTTED LINE.
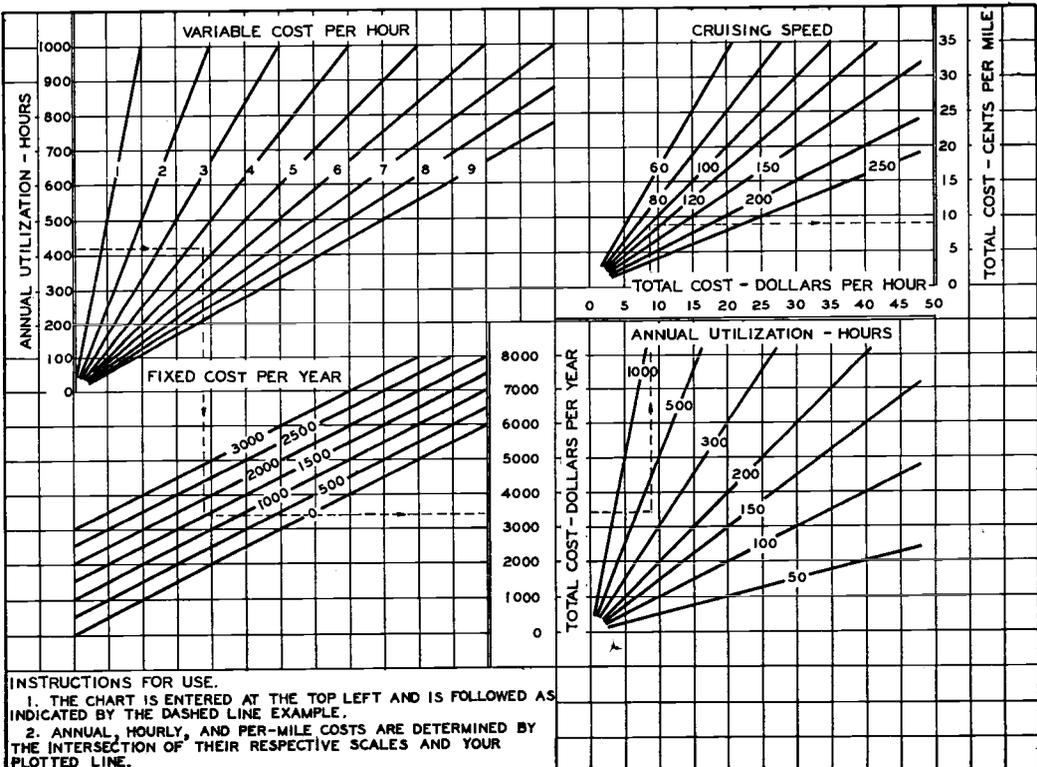
Figure 8. Total Operating Cost Chart.

As indicated in previous discussion several charts are necessary for the determination of fixed costs. First liability insurance premium is determined from Figure 5 by proceeding to the right from the $10,000 limit point on the vertical scale to the line representing one passenger seat. From this point a line projected downwards intersects the premium scale at $62 which will be the total annual premium for liability insurances. In Figure 6 the annual hull insurance premium is found to be $260. This is found on the hull insurance premium scale directly below the intersection of the $3,000-list-price line and the third-year-of-operation line. Depreciation is found from Figure 7 as being $380. This also is found directly below the intersection of the list-price and year-of-operation lines. To the sum of the above figures ($62, $260, and $380) must be added the hangar rent of $150. This results in a sum of $852 which is the fixed cost of operation of the airplane during the third year which was chosen as a representative year.

If there are no non-flying expenses to be added to the fixed cost of operation the two figures, $4.50 per hour and $852, may be combined immediately to give the required cost information by use of Figure 8. This chart is entered at the top left at the 300-hour annual utilization point. Proceed right to the $4.50-variable-cost-per-hour line (in this case an imaginary line midway between the $4 and $5-per-hour lines), down to the $852-fixed-cost line and right to the total annual cost scale, where a cost of $2,200 is obtained. Hourly cost can be obtained by continuing on to the right to the 300-hour utilization line and then up to the hourly cost scale where a cost of $7.34 is obtained. Cost on a mileage basis is obtained by proceeding on up to the cruising speed line of 80 mph and right to the total-cost-per-plane-mile scale, where a cost of $0.09 per plane-mile is obtained.

If Figure 8 is not used, the procedure indicated in the last part of Section IV-2 should be followed. As mentioned previously, this mathematical method will serve as a check and eliminate inaccuracies that might result from accidental error in the use of Figure 8.

Although at best, all cost determinations as here made are approximations which are most suitable for comparison purposes, it is possible to predict the cost of operation of a specific airplane if care is taken in obtaining the necessary data and in using the charts. To the average individual the personal airplane may appear to be an expensive luxury. The advisability of its purchase and its economy will depend on circumstances and be evident only after comparisons with other pleasure or business vehicles.

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