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AIRPLANES FOR AIR FREIGHT

WILLIAM M. SHEEHAN

INTRODUCTION

To many, the need of airplanes for hauling freight cargo may seem remote. The usual understanding is that demand for such aircraft is limited to particular situations, where impenetrable jungles or ice-locked mountain ranges make transportation of goods by air definitely advantageous. And in these situations of little or no surface competition, anything that flies, an eight or ten year old passenger liner, appears adequate.

Yet such an understanding does not accord with the facts. Besides the growing demand from abroad where hundreds of obsolete aircraft used for freighting must be replaced within the next few years, two important, albeit latent, markets for efficient cargo-hauling equipment merit attention.

One is suggested by the lightning-swift German invasions of neighboring territories facilitated by the transportation of great numbers of men and supplies, including guns, trucks and tanks, in airplanes specially suited to the purpose. This new and effective use of the airplane promises to revolutionize military strategy just as surely and completely as has the formidable bomber. Possession of an armada of heavy cargo airplanes must be a matter of concern to governments the world over. It should be a fundamental consideration in our own national defense plans.

Another potential demand for freight-hauling airplanes lies in our domestic transportation services. At present the only movement of goods by air in this country is as express on regular passenger liners. That air express shipments average only seven or eight pounds each is undoubtedly due to rates approximately eight times those of rail express, necessitated by the high cost of passenger airplane operation. Almost everybody familiar with transportation problems in this country agrees that a huge demand exists for air freight service midway in speed between the express train and express airplane, provided expenses of the new service can be reduced appreciably from present airline operating costs. A study[1] of the usefulness of one available type of airplane as a freighter has shown that a satisfactory and profitable long distance air freight service is possible today with rates but a third or a quarter those of air express. Probably even more favorable results could be had if some other type of airplane, more efficient for freighting, were employed.

Whether large scale air freight operations are to be inaugurated here, as in other countries, with existing types of equipment, or development of a new and more efficient type of airplane will precede such commencement, resembles the question of whether the hen or the egg came first. Airline executives attribute their lack of enterprise in the air freight field to want of the proper type of equipment. Manufacturers, on the other hand, insist that an assured market for specially designed freightplanes must precede their construction.

As a contribution to the better understanding of these problems, the following survey seeks to show, first, what equipment can be employed for air freighting today, and, second, what sort of specialized freight equipment may be hoped for in the reasonably near future.

I. EXISTING EQUIPMENT

Although war demands may alter the situation insofar as military aircraft are concerned at any time, it is still a safe statement that the manufacture of airplanes is a highly individualistic activity. Unlike locomotives and automobiles, standardization of which has been made necessary by mass production methods, airplanes are constructed as different from each other as engineering ingenuity can make them. Models intended for the same purpose, or even subsequent editions of the same model, are likely to have important differences of shape, wing loading, power loading, speed, range and other aeronautical characteristics. There are almost as many classes of airplanes as there are approved type certificates.

Airplanes of small load capacity, such as the sport plane, trainer or pursuit ship, obviously have little adaptability to ordinary freight

1. W. M. Sheehan, "Air Freight for the United States", (1939) 10 JOURNAL OF AIR LAW 454.

hauling requirements. The various types whose load carrying capacities are sufficiently large to warrant consideration may, for the purposes of this study, be grouped in three general classes: 1) obsolescent passenger models, 2) new passenger models, 3) patrol boats and bombers.

A distinction is made between passenger airplane models which are obsolescent and likely to be available in used condition at small cost and those which are new. In theory, a used airplane sells at a price that measures the difference in its condition from that of the same airplane new. In practice, however, a passenger airplane several years old may be purchased for much less than its real value. Passenger airlines, for competitive reasons, try to employ only the latest equipment and are constantly replacing old types with new. Thus, after only four or five of a possible ten or twelve years of "useful life" and despite an excellent operating condition at the time of resale, used passenger liners generally sell at from 25 to 60 percent of their initial value. Purchase of cheap used airline equipment makes possible a very significant economy in the usually heavy burden of depreciation expense, an advantage which does not exist for latest model equipment.

1. Obsolescent Passenger Models

According to the records of the Civil Aeronautics Authority, our domestic airlines on December 31, 1939, employed 263 airplanes, of which 35 were Lockheed 10's, 41 Boeing 247-D's, 43 Douglas DC-2's and 128 Douglas DC-3's (including DST's). The first three models were originally produced in 1934, the fourth in 1936. Since all major airlines have arranged for delivery of larger faster models in the near future, it is a fair assumption that each of the above four types of passenger aircraft will soon be available for use as freighters on advantageous terms. Their chief characteristics appear in the following Table 1.

It should be noted that the data presented in Table 1 relate to the use of the four models listed therein as passenger aircraft. Employed as freighters, they would operate under different conditions which make for two important changes in the flight characteristics stated.

First, by hauling freight only, advantage may be taken of 04.700 of the Civil Air Regulations which permits an appreciably larger aircraft gross weight for non-passenger use. Some of the increased gross weight would undoubtedly be for heavier landing

TABLE 1

Characteristics of Obsolescent Passenger Airplanes[2]

Item	Lockheed 10-A	Boeing 247-D	Douglas DC-2	Douglas DC-3
1. Seats	10	10	14	21
2. Engines	2-WaspJrSB	2-S1H1G	2-WF52	2-G102A
3. Rated Power (HP)	800	1100	1520	1800
4. Gross Weight (Lbs.)	10,500	14,000	18,560	24,400
5. Empty Weight (Lbs.)	6,350	8,940	12,000	15,900
6. Useful Load (Lbs.)	4,150	5,060	6,560	8,500
7. Maximum Speed (MPH)	202 (5000 ft.)	202 (8000 ft.)	210 (6800 ft.)	215 (7700 ft.)
8. Cruising Speed at 65% Power (MPH)	181 (12,000 ft.)	189 (12,000 ft.)	185 (10,000 ft.)	185 (10,000 ft.)
9. Cargo and Cabin Space (cu. ft.)	369	690	1164	1365
10. Price New (in quantity)	$52,000	$69,000	$90,000	$111,400
11. Percentage of Gross Weight Useful	39.6	36.2	35.3	34.8
12. Useful Load Ratio (Lbs.) Useful Load/HP Rated Power)	5.2	4.6	4.3	4.7

gear and so forth, but much of it would constitute an increase in payload. There has been discussion in governmental circles about the adoption of a new method of determining gross weights allowable. But a change of this character in 04.700 would in all probability strengthen rather than impair the validity of the conclusions hereinafter presented. Second, the reduced cruising speed and diminished distances between refueling stops of freight service would enable further important increases in the payloads of the four airplanes listed in Table 1. These changes with their effects upon flight characteristics are shown in the following Table 2.

A comparison of Tables 1 and 2 reveals that as freighters each of the four airplanes under consideration experiences an appreciable improvement in useful load ratio and percentage of gross weight useful. Item 9 of Table 2 indicates that a much smaller space-weight allotment may have to be made for these airplanes when used as freighters than the 400 cubic inches per pound of

2. Figures checked by manufacturers, except those for Boeing 247-D. Items 12 and 13 are derivative.

TABLE 2

Characteristics of Obsolescent Passenger Airplanes Used as Freighters[3]

Item	Lockheed 10-A	Boeing 247-D	Douglas DC-2	Douglas DC-3
1. Gross Weight (Lbs.)	12,180	15,792	21,530	28,180
2. Empty Weight (Lbs.)	6,461	8,918	12,000	14,905
3. Useful Load (Lbs.)	5,719	6,874	9,530	13,275
4. Brake Horsepower at 120 MPH and Gross Weight	365	500	610	770
5. Weight of Crew and Fuel[4] for 500 Miles at 120 MPH (Lbs.)	1,114	1,442	1,600	2,040
6. Maximum Payload (Lbs.)	4,575	5,432	7,930	11,235
7. Percentage of Gross Weight Useful	47.0	43.5	44.3	47.1
8. Useful Load Ratio (Lbs. of Useful Load/HP of Rated Power)	7.1	6.2	6.3	7.4
9. Space-Weight Ratio[5] (Cu. In. of Cargo and Cabin Space/Lb. of Maximum Payload)	139	219	254	210

shipment allowed now by the domestic air express tariff. However, freight commodities are likely to be denser than air express shipments and a space-weight allowance of 200 cubic inches per pound would appear to be adequate.[6] Even after provision for passageway and other operating space this allowance should be within the space-weight capacities of all four airplanes, with the possible exception of the Lockheed 10.

The foregoing tables give but a partial picture of the four obsolescent passenger models as freighters. Our chief interest in a potential freightplane should be its cost of performing a ton-mile of freight transport service. In the absence of available data of this character, it is necessary to predicate a suitable freight operation and estimate the costs on the basis of general airline experience and practices. As a step toward this end, the following Table 3 indi-

3. First two items based upon figures of manufacturers, except in the case of the Boeing 247-D. In the case of the Lockheed 10, 20% of the increased gross weight permitted by C.A.R. 04.700 has been allocated for structural purposes.

4. 340 lbs. for pilot and co-pilot; fuel and oil 0.5 lbs. per brake horsepower hour with 6% extra for manoeuvering, warming up, etc.

5. Passageway space not provided for.

6. Officials of Pan American Airways advise that their 200 cu. in. per lb. limit for foreign express shipments is rarely exceeded.

cates various estimated costs per mile of operating six of each of the four types of airplanes in a daily round-trip transcontinental freight service. The bases and assumptions employed in determining these costs are presented in detail hereinafter in the Appendix.

TABLE 3

Estimated Costs of Operation of Obsolescent Passenger Airplanes Used as Freighters (cents per mile)

Item	Lockheed 10-A	Boeing 247-D	Douglas DC-2	Douglas DC-3
1. Personnel	14.08	14.97	16.23	17.28
2. Fuel and Oil	3.75	5.14	6.26	7.87
3. Overhaul and Repair (Materials)	0.78	1.07	1.48	1.75
4. Depreciation	2.17	2.87	3.75	4.64
5. Insurance	1.29	1.55	2.01	2.58
6. All Other Operating Supplies and Expenses	14.55	17.27	25.21	35.72
Total	36.62	42.87	54.94	69.84

The above table still leaves our analysis of old passenger planes incomplete. For each model has a different payload capacity and the total costs shown in Table 3 have yet to be divided by their respective probable payloads. A useful yardstick appears in Table 4 which shows the estimated cost of carrying one ton a distance of one mile under the operating conditions described in the Appendix with each plane loaded to within 75 percent of its payload capacity. The latter percentage seems reasonable in view of current passenger traffic experience and the likelihood of a steadier, more favorable traffic load factor in freight service.[7]

TABLE 4

Estimated Cost of Operation of Obsolescent Passenger Airplanes Used as Freighters (cents per ton-mile)[8]

Lockheed 10-A	Boeing 247-D	Douglas DC-2	Douglas DC-3
21.3	21.0	18.5	16.5

It would appear from Tables 3 and 4 that obsolescent passenger airplanes as a class are practicable for low cost, long distance

7. The subject of demand for air freight service is beyond the scope of this article. However, it may be stated that the largest amount of traffic assumed herein, that of the Douglas DC-3, is a small fraction of 1% of the air and rail express shipments now moving between New York and Los Angeles. For a more exhaustive treatment of this subject, the reader is referred to "Air Freight for the U. S." Cf. Note 1 supra.

8. Total costs shown in Table 3 divided by 75% of maximum payloads shown in Table 2.

freighting. It would further appear from these tables that freight operating costs *per mile* tend to increase with the size of the airplane employed, but freight operating costs *per ton-mile* tend to decrease with the size of airplane used.

Of no small interest is a comparison of the operating costs indicated in Table 4 with the average rates per ton-mile for existing types of commodity transportation service: viz., air express, 80 cents; first class rail express, 11 cents; less-than-carload rail freight, five cents; highway freight, four cents.[9] Since the costs of Table 4 are based on a single round-trip transcontinental schedule per day and operating costs tend to decrease with increased operations, a considerably more favorable comparison for air freight may be expected whenever operations are large enough to justify multiple schedules.

2. New Passenger Models

The constant striving of passenger airlines to supply the public with new and faster types of airplanes results in periodic replacement of standard equipment. Judging from the large and extensive orders placed with manufacturers in the past few months, our passenger airlines appear to be on the verge of another elaborate replacement program. The following Table 5 presents essential characteristics of four new models, one or more of which seem destined to become standard airline equipment in the near future.

Table 5

Characteristics of New Passenger Airplanes

Item	Curtiss-Wright (Transport)	Lockheed (Excalibur)	Douglas DC-4	Boeing 307 (Strato-liner)
1. Seats	36	34	40	38
2. Engines	2-Wr. Cy.	4-Wr. Cy.	4-Wr. Cy.	4-Wr. Cy.
3. Rated Power (HP)	3,400	4,000	4,800	4,400
4. Gross Weight (Lbs.)	38,000	40,000	47,000	45,000
5. Empty Weight (Lbs.)	24,750	25,080	34,546	29,760
6. Useful Load (Lbs.)	13,250	14,920	12,454	15,240
7. Maximum Speed (MPH)	243 @13,000 ft.	294 @15,300 ft.	257	240 @6000 ft.
8. Cruising Speed (MPH)	210 @10,000 ft.	262 @19,000 ft.	235	215 @10,000 ft.
9. Percentage of Gross Weight Useful	34.9	37.5	26.5	33.9
10. Useful Load Ratio (Lbs. of Useful Load/HP of Rated Power)	3.9	3.8	2.6	3.5

9. *Fortune* survey.

A comparison of Tables 1 and 5 shows that the principal features of the new passenger airplanes are greater size and speed. The latter is reflected in a very low value of useful load ratios. Although they have large useful loads, new passenger airplane load ratios are smaller than those of obsolescent passenger airplanes because of a tremendous increase in power required to achieve greater speeds. Moreover, present information tends to confirm the opinion that these new passenger models will cost more per pound of maximum payload to purchase than did their predecessor models. These factors do not augur well for aircraft in this classification as immediate or future freighters.

3. Patrol Boats and Bombers

The United States military services have been most progressive in causing to be developed distinctly new types of aircraft. In particular, efforts to procure equipment having long range observation and striking power have resulted in patrol boats and bombers whose useful load capacities sound almost incredible. Performance statistics for the most recent and probably most effective types are not yet available. However, the following Table 6 presents data for two bombers and two flying boats, the characteristics of which are available and may be presumed to be conservatively representative of airplanes in this category.

Table 6

Characteristics of Long Range Patrol Boats and Bombers[10]

Item	Boeing B-Y299 Flying Fortress	Consolidated 29	Martin 156	Douglas B-19
1. Landplane or Flying Boat	Lp.	F.B.	F.B.	Lp.
2. Engines	4	4	4	4
3. Rated Power (HP)	4,000	4,200	3,400	6,000
4. Gross Weight (Lbs.)	45,470	65,000	80,000[11]	140,000
5. Empty Weight (Lbs.)	26,143	29,000[11]	37,572[11]	84,000
6. Useful Load (Lbs.)	19,327	36,000	42,428	56,000
7. Maximum Speed (MPH)	268	226	183	Over 210
8. Cruising Speed (MPH)	220	210	150	200
9. Percentage of Gross Weight Useful	42.5	55.4	53.0	40.0
10. Useful Load Ratio (Lbs. of Useful Load/HP of Rated Power)	4.8	8.6	12.5	9.3

10. Data furnished by manufacturers, except those for Douglas B-19 which were released by U. S. Army.

11. For freighting.

It should be noted that, of the four airplanes listed in the above Table 6, each larger slower bomber or flying boat enjoys a definitely greater advantage in respect to percentage of gross weight useful and useful load ratio than does its smaller faster counterpart. It may further be seen from Tables 2, 5 and 6 herein that airplanes in this classification may be capable of more favorable freighting performance than either obsolescent or new passenger aircraft. This type of aircraft, designed rather for useful load capacity than speed, may ultimately prove of great use in developing low cost air freight service in this country.

II. FUTURE EQUIPMENT

American aircraft manufacturers build equipment of surpassing quality for almost every conceivable purpose. Our airliners dominate skylanes the world over, our bombers and pursuit ships are sought after by nations engulfed in war. Yet despite this excellent record, despite frequent claims of producers, nothing has ever been built which from nose to tail and wing tip to wing tip was intended solely for freighting. Every so-called cargo or freight airplane has been simply a modified version of some model originally designed for passenger or military purposes.

A made-over passenger airplane may be expected to haul freight just as inefficiently as would a Pullman car with its seats taken out and its windows boarded up. The head of one of our largest and most progressive airlines recently explained,[12] in discussing plans of his company for air freight service: "The railroads, in the conduct of their cargo business, do not use in that service modified passenger cars; they use equipment designed and most effective for the transportation of cargo. That we must do in this business."

Considerations in true freightplane design include such obvious features as large conveniently accessible hatches, strong floors, ample space, adjustable compartments, center of gravity and temperature controls, derrick and loading ramp attachments. The extra expense and loss of structural strength due to windows are no more necessary than in boxcars and trailers. Freight operating experience with made-over passenger airplanes is adding to our knowledge of these details. Not so self-evident are two further factors, which are essential if the future freightplane is to have a distinctly lower operating cost per ton-mile than has been attainable with existing aircraft. These fundamental factors are slow speed and large size.

12. C. R. Smith, President of American Airlines, in *American Aviation*, April 1, 1940.

1. Slow Speed

Almost any airplane can be operated more *economically* over a given distance at a slow rather than high speed. For engine power required varies almost directly with the cube of the speed; and maintenance, overhaul, fuel and depreciation costs tend, or can be made to, decrease with the power required. This has been proved true of existing aircraft designed for maximum efficiency at high speeds. Even greater economy could be achieved if airplanes, engines and propellers were designed for maximum efficiency at the slow cruising speeds a freight service requires.

A limit of increased economy with decreased speed of operation is imposed only by the necessity of offering schedules fast enough to compete with other vehicles of transportation. It is believed by many experts that air freight schedules as low as 120 miles per hour normal cruising speed can be fixed. At this economical speed, air freight schedules would still be more than twice as fast as those of the fastest express train.

Practically all large modern airplanes are designed for a high cruising speed. Hence the aerodynamic properties and general appearance of the future freightplane, with maximum efficiency intended for a distinctly lower speed, may be quite different from that to which we are accustomed.

For example, although "cleanness" or streamlining are necessary freightplane ideals, parasite drag need not be quite the bugbear it is for high-speed passenger aircraft design. More wing area and, possibly, a lower wing loading may be tolerated in the interest of greater lift at take-off, with consequent increased useful and revenue loads.

Moreover, the wings of the freightplane may be made thicker, particularly at the root, than those of comparable high-speed airplanes. This enables greater structural strength, more span and, very likely, more useful space. Greater span makes possible reduced drag and more efficient conversion of engine energy into forward motion. More useful space fills the need created by bulky cargo. There is no reason why the wings should not be designed to hold bulky stuff such as cut flowers, dresses and hats. Wingfoil characteristics may be selected for efficiency over a narrower speed range than has been necessary for existing passenger and military airplanes. Greatest lift at 70 miles per hour for take-off and least drag at 120 miles per hour for cruising calls for much less compromise than maximum lift at 65 miles per hour and least drag at 220 miles per hour.

2. Large Size

The second principle that may influence freightplane construction is large size.

It must be admitted that the weight of most objects tends to increase faster than any one of their surfaces — weight being a matter of three dimensions and area of two. A solid cube weighs eight times as much when its lineal dimensions are doubled and the area of the bottom surface increased only four-fold. But an airplane is not solid and its shape is more like that of a saucer than a cube. Hence this physical rule does not operate with such deadly effectiveness in increasing sizes of airplanes. Moreover, this factor is offset by operation of an opposite tendency.

Airplanes of the same design and speed but different size have many components that weigh approximately the same, viz., instruments, indicators, radios, navigation lights, propellers, carburetors, magnetoes and other engine accesories. Even the engine weights are not proportional to the sizes of the respective airplanes, for larger engines usually have a smaller weight per rated horsepower. Consequently, the percentage of airplane gross weight that is useful (i.e. non-structural) tends to be greater with airplanes of larger size. Or, to put this in a slightly different way, an airplane twice as large as another of the same design and speed should have more than twice its useful load.

A comparison of Tables 1 and 6, showing the percentage of gross weight useful for obsolete passenger and military aircraft respectively, indicates that so far increased size has resulted in increased percentage of gross weights useful. To be sure, Table 5 reveals that the much larger passenger airplanes of today have not quite the same percentages of gross weight useful as the passenger aircraft of six years ago shown in Table 1. But modern passenger airliners have sacrificed what might have been an improved percentage of gross weight useful for greatly increased speed. Where cruising and maximum speeds of larger airplanes have not been changed greatly from those of the obsolescent passenger airplanes (patrol ships and bombers, Table 6), percentages of gross weight useful and useful load ratios of a most favorable character have been obtained.

Quite apart from the above advantage of increased percentage of gross weight useful enjoyed by larger airplanes is that of decreases in certain operating costs. Many airline operating costs are constant in that no matter how much traffic is experienced, operating expenditures tend to remain the same. Thus, although a 12 ton airplane may haul as much payload as two six ton ships, piloting, ground personnel, fuel and oil, overhaul and repair, airport and office rentals, communications and many other operating expenses of the 12 ton craft tend to be somewhat less than the same costs for the two smaller airplanes.

Discussion of freightplane design is hardly complete without mention of one phase of it that belongs to the more remote future. By analogy to other forms of transportation, the ultimate freightplane ideal would seem to be a train of one power unit, to provide propulsive energy, and a number of engineless units, to haul cargo. In theory, this arrangement should make possible much larger useful load ratios than are likely for any single-unit freightplane. Extended consideration of this fascinating problem is beyond the scope of this study, yet it may be pointed out that, following the example of other countries, our own government might do well to provide funds for exploring freight-glider possibilities.[13]

III. CONCLUSION

A careful analysis of the situation reveals that there is at home and abroad today a real need of airplanes for hauling freight exclusively. By various economies, such as slow flying speeds, large payloads, use of second-hand aircraft, three classes of existing types of airplanes may be employed for this purpose, viz., obsolescent passenger airplanes, modern passenger airplanes and patrol boats and bombers. The first group appears to be the most practicable because of availability at prices enabling a small depreciation burden. The second class appears to be too expensive, from both capital and operating costs points of view, to hold much hope of present or future usefulness as freighters. The last does give promises of being ultimately the most economical class of existing airplanes for freighting.

All present types of airplanes can at best be no more than makeshift freighters. Real operating efficiency and economy can be hoped for only when a radically different kind of airplane is produced for air freight. Aside from the more obvious features of freightplane construction, such as doors, loading facilities, spacers, etc., the prime requisite of low cost of operation appears to suggest two fundamental principles: 1) large size and 2) maximum operating efficiency of airplane, engine and propeller at a relatively low cruising speed.

13. It is stated in reliable quarters that Russians have experimented successfully with a string of as many as 21 sailplanes pulled by a single airplane over considerable distances, with units being taken on and let off during progress of the train.

The specially designed freightplane of the future merits the careful consideration of our aircraft manufacturers. In an age that places terrible risks upon nations unprepared for modern aerial warfare, no matter how great their size or desire to avoid war, the freightplane stands out as a vehicle of unlimited military importance. As a potential instrument of peaceful economic development, it gives promise of being to air freight transportation what boxcars and trailers have been to rail and highway commodity transportation.

APPENDIX

The methods by which the various operating costs of Table 3 have been estimated are produced herewith. No pretense is made that the estimates are an exact index or are suitable for every kind of air freight operation. However, airline practices and statistics have been employed as far as possible and the estimates are presented as a reasonably accurate approximation of the cost of operating the service described below.

Operation over one of the four present transcontinental airways is assumed with a total route distance, allowing for minor deviations to tap additional traffic centers, of approximately 3,000 miles. One flight daily east and west except Sundays and holidays, involving about 600 flights per year, is scheduled. Normal cruising speed is 120 miles per hour, which, with 18 or 20 intermediate stops, allows a coast to coast over-all time schedule of 30 hours, or "second morning" delivery, compared with "first morning" for air express and "fourth morning" for fast rail express.

Six airplanes are used making an average daily burden on each of 1,000 miles, slightly higher than high speed passenger airline practice permits. Hangar facilities, a repair shop and traffic office are provided for at each terminus—as well as traffic space at each intermediate station and an extra traffic office in Chicago, the nation's freight center. In keeping with *freight* standards, equipment, locations, number and dress of personnel etc. are influenced more by considerations of utility and economy than of style or appearance. To minimize capital requirements all equipment other than airplanes and tools, including hangars, offices, refueling and communication facilities are leased rather than purchased.

The various items of operating expense are budgeted pursuant to the classifications generally employed by airlines. However, no distinction is made between direct and indirect expense, nor between flying and other personnel. Sales costs are not provided for, since traffic would doubtlessly be mostly with industrial companies whose business could be solicited directly by the traffic department. Nor is any provision made for passenger expense for obvious reasons.

(1) *Personnel.* The following Table 7 shows the approximate numbers, types and salaries of the personnel of the transcontinental service described herein.

TABLE 7

Air Freight Personnel
(Cost per Month)

Number	Type	Salary	Total
1	President and General Manager	$500	$500
1	Operations Manager	300	300
1	Traffic Manager	250	250
3	Division Traffic Managers	175	525
9[14]	Traffic Solicitors	125	1,125
3	Traffic Control Clerks	150	450
3	Stenographer—Secretaries	140	420
3	Stenographers	100	300
1	Bookkeeper-Accountant	160	160
18	Field Attendants	140	2,520
6	Meteorologists	150	900
18[14]	Mechanics	140	2,520
15	First Pilots	500	7,500
15	Second Pilots	250	3,750
97			$21,220[14]

The 18 field attendants are men at intermediate stations capable of assisting in refueling, loading and unloading the two daily flights, as well as soliciting and caring for traffic at each station.

Item 1 of Table 3 is obtained by dividing the total monthly payrolls shown in Table 7 by 150,000, the number of miles scheduled to be flown in a month.

(2) *Fuel and Oil.* Item 2 of Table 3 is based upon the actual power requirements at a freight cruising speed of 120 miles per hour (block-to-block speed about 110 miles per hour) of each airplane as shown in Table 2. A specific fuel consumption of 0.48 and a specific oil consumption of 0.02 pounds per horsepower are taken. Fuel weight of six pounds per gallon and oil weight of 7.5 pounds are assumed. Six percent has been added for warming up, take-off, and manoeuvering. Gasoline is computed at 12 cents a gallon, oil at 40 cents a gallon.[15]

14. The above personnel is required for the six Lockheed 10's. 2, 7 and 13 traffic solicitors (one for each 500 lbs. of additional payload capacity), as well as 7, 16, and 22 mechanic (cf. *Overhaul and Repair*) are added for the Boeing 247-D, Douglas DC-2 and Douglas DC-3 respectively.

15. Fuel and oil requirements err on the high side, since full capacity payloads are provided for, whereas only a three-quarters capacity payload is expected normally.

(3) *Overhaul and Repair (Materials).* An exhaustive analysis[16] or airline maintenance costs, based upon the operating procedure of the largest passenger airlines in the United States, shows that overhaul and repair requirements of the Lockheed 10 for each major overhaul period of 400 hours were 1,882 mechanic hours of labor and $686 of materials and supplies. These requirements are for passenger airline cruising speed taking 65 or more percent of rated engine power. With a slower freight cruising speed taking a much smaller percentage of engine power, it may be assumed that the same maintenance requirements will suffice over twice as great an overhaul period. Thus a normal cruising speed of 120 miles per hour, with an average ground speed of about 110 miles per hour, will produce 88,000 revenue miles between major overhauls, or, on the basis of the above materials' cost, 0.78 cents per mile for the Lockheed 10. The other figures of Item 3, Table 3 bear the same relation to that for the Lockheed as do their respective rated engine powers to the rated engine power of the Lockheed.[17]

(4) *Depreciation.* The investment cost of each type of airplane is taken at half the cost new, as shown in Table 1, with four years of freight "life" remaining. Division of the annual depreciation by 300,000, the revenue miles to be flown each year by each airplane, gives the figure shown in Item 4 of Table 3.

(5) *Insurance.* The law permits a common carrier in effect to limit liability for loss or injury to goods in its care.[18] Following the example of the rail and air express service, a freight airline may place a liability limit of $50 per shipment and compel shippers to pay an extra fee (which is virtually self-insurance) for valuations above this at the rate of ten cents per $100. If the Lockheed 10, Boeing 247-D, Douglas DC-2 and Douglas DC-3 when three-quarters loaded (cf. Item 6, Table 2) carry packages averaging 25 pounds and going a distance of 1,000 miles,[19] they will entail

16. *Analysis of Characteristics and Estimated Basic Operating Costs of Various Lockheed Models for Airline Operation,* Lockheed Aircraft Corporation, May 21, 1937.

17. It may be seen that with 1,882 mechanic hours required for each 88,000 miles, and with 6,000 miles scheduled per day, a crew of 18 mechanics is required for the Lockheed 10. 25 for the Boeing 247-D, 34 for the Douglas DC-2, 40 for the Douglas DC-3 are the numbers of mechanics required for those planes, employing the same rule of proportionality used in determining materials' costs. Cf. *Personnel.*

18. G. W. Ball, "Compulsory Aviation Insurance", (1933) 4 JOURNAL OF AIR LAW 52.

19. The average weight and distance of shipments in a future freight service are difficult to predict. However, it would seem that the type of traffic to be catered to by air freight should be something in weight between present rail and air express averages (50 and 7 lbs. respectively) and in distance greater than present rail and air express averages (both approximately 800 miles). Tariffs may be devised to attract the type of traffic desired.

cargo liabilities (at ten cents per $100 value) of 0.57, 0.68, 0.99 and 1.40 cents per revenue mile respectively.

Full hull coverage including crash is nine percent per annum of the value of the airplanes averaged over their four years of freight "life." This annual cost is divided by 300,000, the number of revenue miles per plane per year, for a crash insurance cost of 0.39, 0.52, 0.67 and 0.83 cents per mile respectively.

Public liability insurance to the extent of $50,000 per person and $100,000 per accident together with property damage coverage up to $5,000 is generally quoted at about 0.25 cents per mile.

For all other insurance, such as employees' fidelity and property, an arbitrary allowance of 0.1 cents per mile is made.

The figures shown in Item 5, Table 3 are the respective totals of the four above classes of insurance.

(6) *All Other Operating Supplies and Expenses.* These may be subdivided into rentals, supplies and materials, communications, pick-up and delivery, taxes and legal expenses.

(a) Rentals of hangar facilities and shops at each terminus and some convenient intermediate point, $1,500 per month. Landing rights and use of field equipment, servicing and traffic department space at 20 airports, $2,000 per month. Offices for traffic departments in New York, Chicago and Los Angeles, $350 per month.

(b) Supplies and materials, including maintenance of tools, machines, field and office equipment, printing, stationery, traveling expense and incidentals, $2,500.

(c) Communications, including emergency radio, telegraph, telephone and TWX teletype service, $1,500 per month.

(d) Pick-up and delivery service, 75 cents per shipment.[20] With a 25 pound, 1,200 mile average shipment, a three-quarters capacity payload and 150,000 revenue miles per month, pick-up and delivery costs of the Lockheed 10 fleet should amount to $12,870 per month.

(e) Taxes, including social security and property, $600 per month.

(f) Legal expenses, $500 per month.

20. With a surcharge for shipments of more than 40 lbs. each. The average pick-up and delivery cost in the collaborative air express service of the passenger airlines and the railway express agency is approximately one dollar. Whether similar collaboration is to be had with the Railway Express Agency or an independent service arranged, 75 cents for freight pick-up and delivery seems an adequate amount for this purpose. The cost of collection and delivery to the Railway Express Agency in its own express business is 22 cents per shipment, according to the Federal Coordinator's *Merchandise Traffic Report,* U. S. Government Printing Office, Washington, D. C., 1934.

Adding the above items and dividing by 150,000, the number of revenue miles scheduled to be flown each month, indicates a total cost in this category of 14.55 cents per mile for Lockheed 10.

The remaining figures of Item 6, Table 3 bear the same relation to this figure as their respective freight payload capacities do to that of the Lockheed 10.