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U.S. Commercial Fleet Usage of Antimisting Fuels: Survey and Analysis

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16. Abstract
This report presents a data base and a methodology for analyzing the feasibility of using antimisting fuel in the commercial aviation fleet and includes: a classification scheme developed to analyze major portions of the aircraft fleet; review of the available information on antimisting fuel; analysis of data collected on aircraft operations; and use of life-cycle costing techniques to analyze the potential impacts of introducing antimisting fuel on a fleet-wide basis and segmentally.

Aircraft were classified by number of engines and type of service. For each aircraft group, data were collected on the physical, operational, and economic factors that could facilitate or impede the introduction of antimisting fuel into specific portions of the fleet. These data were analyzed to determine if there are significant advantages to segmental introduction of antimisting fuel and, if so, which portions of the fleet are the most likely candidates for early introduction of antimisting fuel.

Analytical findings indicate that fleetwide introduction of antimisting fuel would maximize the benefit in terms of increased safety. However, segmental introduction may be preferable in terms of lower costs and potential capacity constraints. Furthermore, the importance of two-engined, regular-bodied turbofan aircraft in the fleet, combined with the relatively low anticipated cost impacts in this segment, suggest that these aircraft may be the best candidates for early introduction of antimisting fuel.

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Aircraft profiles
Life-cycle costing
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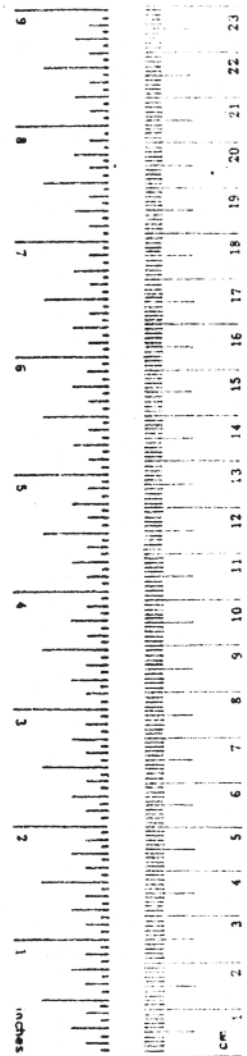
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

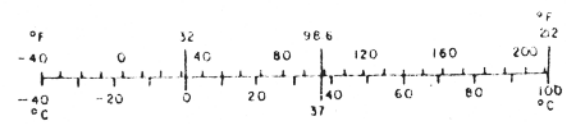
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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The work was performed under the direction of Mr. Joseph Wilson of the Federal Aviation Administration (FAA) Technical Center. The FAA Technical Center's staff provided technical guidance and advice throughout the project and kept us informed of progress on other research projects within the Antimisting Fuel Program.

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EXECUTIVE SUMMARY

This document reports the results of research performed to develop a data base and a methodology for analyzing the feasibility of using antimisting fuel in the U.S. commercial aviation fleet in order to determine (1) whether there are significant advantages to segmental introduction of antimisting fuel in the fleet; and (2) which portions of the fleet are the most likely candidates for the early introduction of antimisting fuel.

The work involved three major tasks: identification of aircraft operations to by surveyed; development of operational profiles; and analysis to determine the most likely candidates for the use of antimisting fuel. In accordance with the goals of each task, the methodology was designed to include a classification scheme for analyzing major portions of the aircraft fleet; collection and analysis of data on aircraft operations; review of the available information on antimisting fuel; and use of life-cycle costing techniques to analyze the potential impacts of introducing antimisting fuel on a fleet-wide basis and segmentally.

Several alternative classification schemes for analyzing major portions of the commercial fleet were reviewed before a two-way classification system was developed based on number of engines and type of service (i.e. domestic trunk and local service). Data on the physical, operational, and economic factors that could facilitate or impede the introduction of antimisting fuel into specific portions of the fleet were collected and analyzed to develop operational profiles for each segment of the fleet.

The analysis to determine the most likely candidates for use of antimisting fuel encompassed background on fuel-related aircraft and airport systems including performance deterioration of components and restoration of the performance properties of the fuel; potential fuel problems related to the operating environment, i.e. temperature, water, and humidity; operational factors focusing on the composition of the U.S. commercial fleet, utilization of the aircraft, and types of service; and economic data on capital cost, operating expenses, and maintenance costs. A life-cycle cost analysis was performed to determine the potential impacts of introducing antimisting fuel.

The following conclusions were drawn:

- While fleet-wide introduction of antimisting fuel would maximize the benefits in terms of increased safety, segmental introduction may be preferable.

- Segmental introduction of antimisting fuel can result in higher benefit/cost ratios in the fleet segments with newer equipment. The longer expected life of newer aircraft provides a longer period for the amortization of retrofit costs, and more importantly, since newer aircraft are more fuel efficient, the additional annual fuel cost of antimisting fuel will be lower.

- Four- and three-engined aircraft will have higher fuel cost impacts than the more efficient two-engined aircraft. Similiarly, wide-bodied aircraft will have higher cost impacts than regular-bodied aircraft.

- Cost impacts per revenue passenger enplanement for similar types of aircraft are also similar across types of service (i.e. domestic trunk vs. nontrunk).

- Introduction of antimisting fuel into the two-engined, turboprop fleet will have the lowest unit cost impact but will not encompass enough of the total departures or revenue passenger enplanements to significantly effect increased safety levels.

- Introduction of antimisting fuel in the two-engined, regular-bodied turbofans will increase safety on a larger proportion of departures and revenue passenger enplanements, and combined with the relatively low anticipated cost impacts in this segmment, suggests that these aircraft may be the best candidates for early introduction of antimisting fuel.

1. INTRODUCTION

PURPOSE.

The objective of this research is to develop a data base and a methodology for analyzing the feasbility of using antimisting fuel in the U.S. commerical aviation fleet in order to determine (1) whether there are significant advantages to segmental introduction of antimisting fuel into the fleet; and (2) which portions of the fleet are the most likely candidates for the early introduction of antimisting fuel.

RESEARCH METHODOLOGY.

The work involved three major tasks: identification of aircraft operations to by surveyed; development of operational profiles; and analysis to determine the most likely candidates for the use of antimisting fuel. The methodology was designed in accordance with the goals defined for each task and includes: the development of a classification scheme for analyzing major portions of the aircraft fleet; review of the available information on antimisting fuel; collection and analysis of data on aircraft operations; and use of life-cycle costing techniques to analyze the potential impacts of introducing antimisting fuel on a fleet-wide basis and segmentally.

A basic classification system was developed for analyzing major portions of the commercial fleet. Several alternative classification schemes were reviewed before selection of a two-way classification system based on number of engines and type of service (i.e. domestic trunk and local service). The results of the identification task are presented in the Identification Report (Reference 1) and are incorporated in the analyses performed under subsequent tasks.

Data on aircraft operations were collected and analyzed to develop operational profiles for each segment of the fleet. Data was collected on the physical, operational, and economic factors that could facilitate or impede the introduction of antimisting fuel into specific portions of the fleet. These data are presented in Appendices A, B, and C. The analysis to determine the most likely candidates for use of antimisting fuel included: background on fuel-related aircraft and airport systems including operational performance changes of components and restoration of the performance properties of the fuel (Chapter 2); potential fuel problems related to the operating environment, i.e. temperature, water, and humidity (Chapter 3); operational factors focusing on the composition of the U.S. commercial fleet, the utilization of the aircraft, and the types of service (Chapter 4); and economic data on capital cost, operating expenses, and maintenance costs (Chapter 5).

The results of the life-cycle cost analysis to determine potential impacts of introducing antimisting fuel are presented in Chapter 6. Chapter 7 summarizes the conclusions drawn from the analysis.

2. BACKGROUND ON FUEL-RELATED AIRCRAFT AND AIRPORT SYSTEMS

The introduction of antimisting fuel on a wide scale requires an assessment of its compatibility with existing and future proposed aircraft and airport systems including: airframe fuel systems, engine fuel systems, and fuel delivery mechanisms of airports. To assess this compatibility, the FAA has sponsored research (Reference 2) to determine the extent, if any, of modifications which may be required to aircraft and airport systems, and the fuel itself. This Chapter addresses such modifications qualitatively. Only a qualitative treatment of these modifications is possible at this time since several characteristics and properties of antimisting fuel are still being investigated, and the actual modifications to the systems which may be required can only be determined when results of this research becomes available.

The principal components that may be affected by the introduction and use of antimisting fuel, include:

<u>Aircraft</u>

- Airframe Fuel System
    - Fuel Tank
    - Fuel Boost Pump
    - Fuel Heating System
    - Emergency Fuel Shut-off Valve
    - Temperature Sensors
    - Low Pressure Filter
    - Fuel Pressure Sensor
    - Jet Pumps, Fill Valves
- Engine Fuel System
    - Fuel Control System
    - Fuel-Oil Heat Exchanger
    - Pressurizing and Dump Valve
- Engine System
    - Fuel Manifold (e.g., Nozzle Assembly)
    - Burner Section (e.g., Combustor)

<u>Airport</u>

- Fuellers and Hydrants
    - Storage Tanks
    - Stationary Pumps
    - Transfer Vehicles
    - Fuel Pits
    - Mobile Dispensers

This list is not exhaustive; rather, it indicates some of the major systems and components for fuel storage, transfer, handling, and use which may require modification as a result of introduction of antimisting fuel. These components are shown in Figure 1 (Reference 3) for a typical turbofan-engined aircraft. The actual specifications of these components may vary among different aircraft, however, the functions are performed by the same basic hardware.

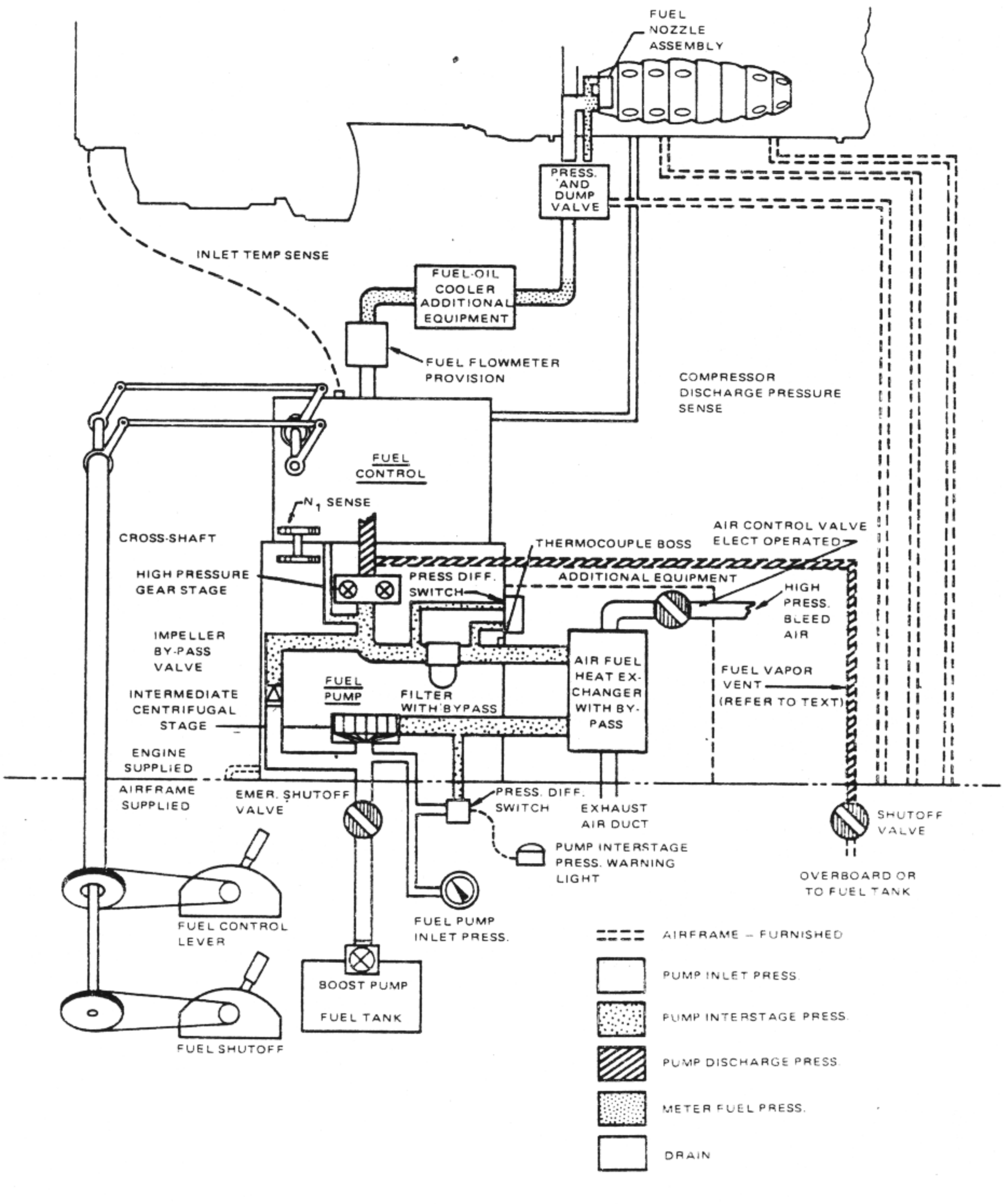

FIGURE 1. TYPICAL TURBINE-POWERED ENGINE FUEL SYSTEM LAYOUT (taken from Reference 3)

The fuel is delivered to the aircraft at the airport via either of two mechanisms: fuellers or hydrants. The fueller system consists of storage tanks, stationary pumps, and transfer vehicles. The transfer vehicle is usually equipped with a fuel pump capable of delivering large quantities of fuel into the aircraft at high speed, and a flowmeter and control devices to prevent contamination and regulate the flow. The hydrant system includes central storage tanks, stationary pumps, pits located at loading bays, and fuel dispensers. Fuel is pumped from the storage tanks to the pits via an underground pipeline, then a mobile fuel dispenser transfers fuel from the pit to the aircraft.

To address the impact of the introduction of antimisting fuel and any corresponding modifications, a knowledge of baseline hardware and performance characteristics is necessary. Accordingly, summary aircraft profiles have been compiled. These present basic data including airframe model, engine model, passenger capacity, fuel capacity, speed, altitude, and cruising range for the principal types of aircraft in the U.S. commercial fleet. These summary aircraft profiles appear in Appendix B of this report.

Before antimisting fuel is used, at least two areas related to the interaction of the fuel with aircraft and airport systems must be addressed:

- potential performance deterioration of components due to use of antimisting fuel; and
- restoration of fuel (i.e., restoring fuel to its original form) and unintended deterioration of the antimisting property of the additive.

The remaining sections of this Chapter provide a generic treatment of the effects of antimisting fuel on hardware components and additional information on the problems of restoration and degradation of antimisting fuel.

OPERATIONAL PERFORMANCE CHANGES OF COMPONENTS.

It has been established on a preliminary basis (Reference 4) that the use of antimisting fuel with existing hardware can lead to reduced performance of several components, principally those related to pumping, spraying, and combustion. The performance of fuel pumps is expected to be affected due to the extra power required to degrade the antimisting fuel (Reference 5). The flow properties of antimisting fuel are different from those of Jet A due to the antimisting polymer additive. In particular, the apparent viscosity of antimisting fuel is variable due to its non-Newtonian nature resulting in an increase in the amount of work that is required to pump the fluid. Further, due to the existence of the polymer additive, antimisting fuel may exhibit a potential gel-forming tendency that can result in clogging of the filters.

The spray/atomization action usually achieved through the use of a spray nozzle may be affected, depending on the level of fuel degradation. The polymer additive, due to its antimisting properties, inhibits the spray action and would reduce the mist formation in the combustor (Reference 6). Some modifications to the existing fuel nozzle may be necessary.

The combustion performance may be affected in several ways including combustion efficiency, emission levels, high altitude relight, deposit formation, and sea level ignition (Reference 7). Comparison of Jet A with antimisting fuel has shown that Jet A has lower emission levels and higher combustion efficiency. The emission and combustion characteristics of antimisting fuel, however, can be improved with higher restoration levels. Antimisting fuel has also exhibited poorer relight and sea level ignition characteristics than those of Jet A. In addition, post-test observations have shown that deposits are formed on the louver lips of the combustor and on all upstream lips when antimisting fuel is used (Reference 8).

Other possible areas of performance deterioration have been identified as: increased response time because of small fluid passages in automatic shut-off valves; reduction in heat transfer efficiency of heat exchangers; increased response time for temperature sensors; reduced accuracy of flowmeters; and reduced accuracy of capacitance fuel level gauging (Reference 9).

RESTORATION AND DEGRADATION.

In relation to performance deterioration of aircraft components discussed above, restoration refers to any process or procedure that is used to restore the original performance properties to the fuel or produce the equivalent effect as Jet A. The preliminary investigations on methods of restoration have revealed that shear and elongational flows are effective means of restoring the original mechanical properties (Reference 10). Shear flow is characterized by a velocity gradient perpendicular to the direction of motion such as that in a long capillary tube. Elongational flow, on the other hand, has a velocity gradient in the direction of motion. Examples of elongational flows occur in the entrance region to a capillary tube, flow through an orifice, and flow in porous media (Reference 11). The major restoration indices have been designated as viscosity ratio and filtration ratio. Viscosity ratio is the ratio of antimisting fuel viscosity to Jet A, and filtration ratio is the flow time of antimisting fuel relative to Jet A. Both of these indices are measured with respect to some parameter such as the specific degrader power required to restore the fuel to some level with respect to the original properties.

Both shear and elongational flows can be used to degrade the polymer, and thus restore the mechanical properties of the fuel. It is, however, expected that elongational flows will be more effective in restoring these properties. Laboratory tests by the Southwest Research Institute (Reference 12) on elongational restoration methods, particularly by porous media (metal screens and packed tubes), have produced some experimental results concerning the power requirements. Figures 2 and 3 (Reference 13) illustrate the variations in restoration levels (viscosity ratio and filtration ratio) as a result of application of various power levels. Generally, to achieve a better restoration level, more power has to be applied (the specific power being defined as the pressure differential).

The level of modification necessary to achieve a particular level of restoration is important in assessing the effect of introducing antimisting fuel into the commercial aircraft fleet due to: higher captial costs; higher maintenance costs; and higher operational costs.

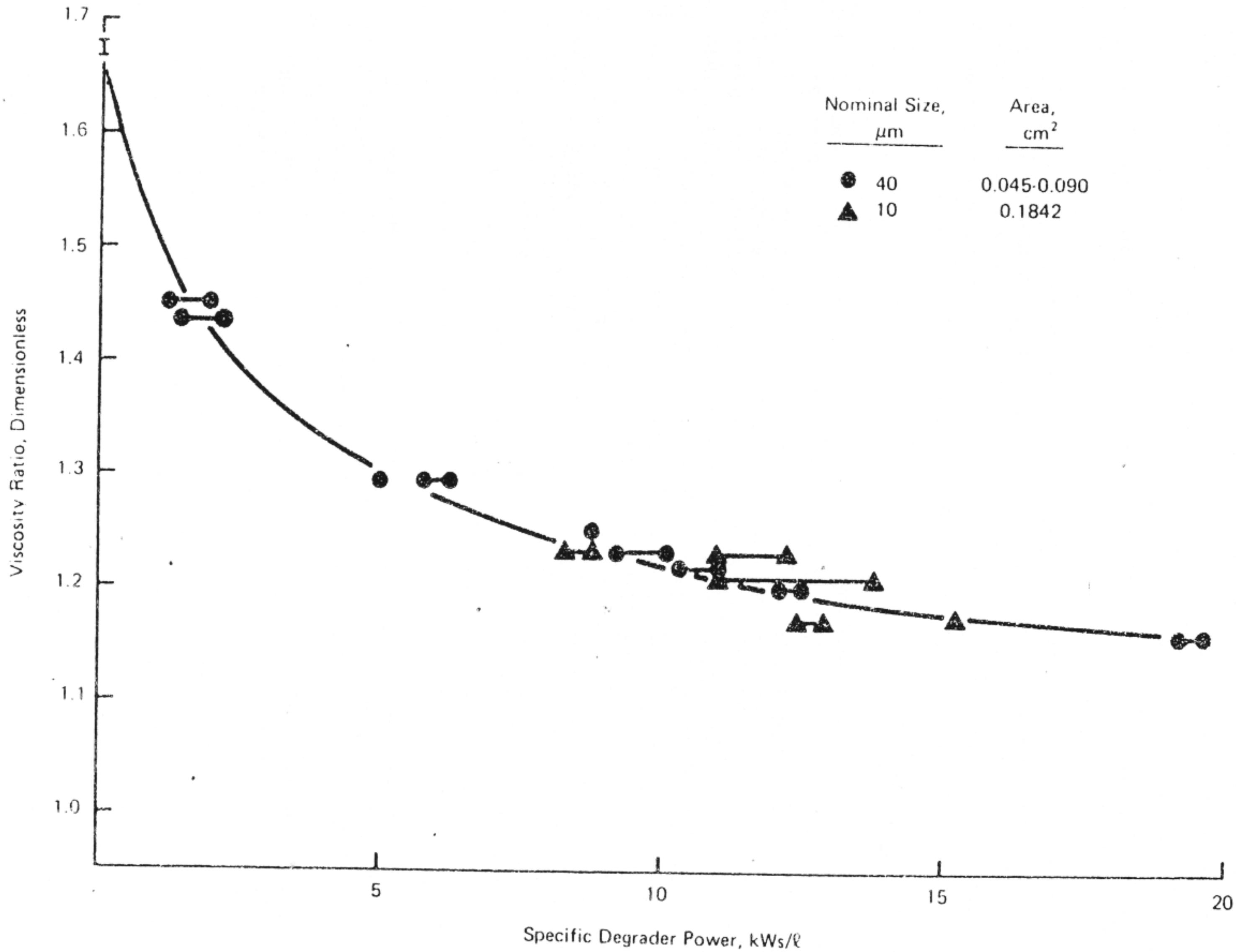

FIGURE 2. EFFECT OF SPECIFIC DEGRADER POWER THROUGH METAL SCREENS ON THE VISCOSITY RATIO
(taken from Reference 13)

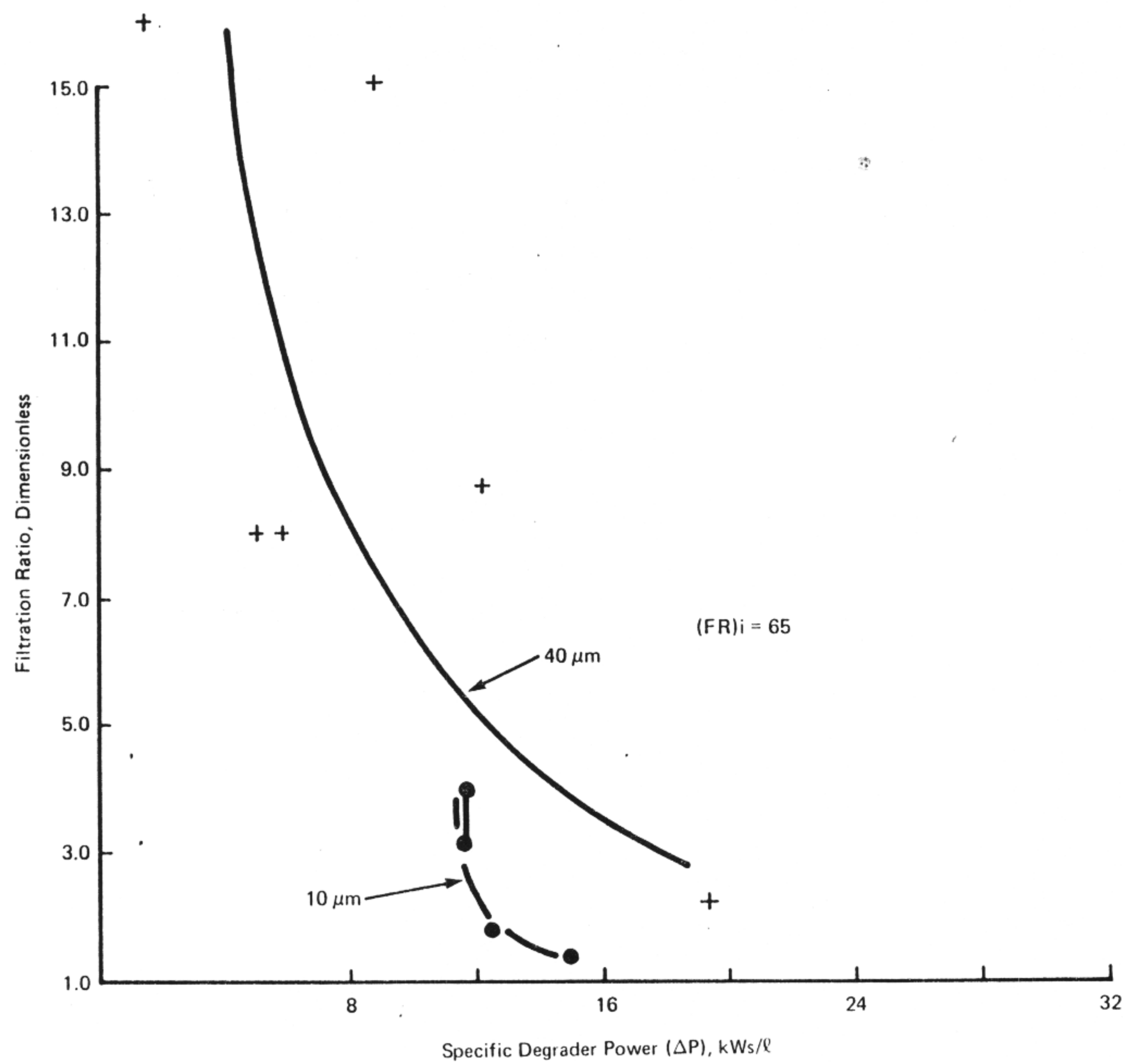

FIGURE 3. EFFECT OF SPECIFIC DEGRADER POWER THROUGH METAL SCREENS ON THE FILTRATION RATIO
(taken from Reference 13)

The objective in adding a polymer to jet fuel is to prevent post-crash fireballs by means of its antimisting property. It is, however, possible that certain operational procedures related to hardware can cause unintentional degradation and render the antimisting property less effective. This could be caused by both airport and aircraft equipment. The degradation occurs primarily by pumping/filtering actions. Simmonds Precision Products (Reference 14) has identified several components that can cause potential degradation of antimisting fuel: (a) multiple passes through high rotations-per-minute (RPM) boost pumps; (b) flow through the pressure refueling valve; and (c) flow through the high shear pump in the auxiliary power unit (APU).

3. POTENTIAL FUEL PROBLEMS RELATED TO THE OPERATING ENVIRONMENT

Two important issues related to the introduction of antimisting fuel are fuel temperatures during different phases of flight and water content of the aircraft fuel tanks. Extremes of temperature and/or excessive water in the fuel can cause operational problems and may alter the effectiveness of the antimisting additive. Each of these concerns is discussed below in a general way in the context of the current operating environment, and where possible, the implications for the use of antimisting fuel are noted.

IN-TANK FUEL TEMPERATURE VARIATIONS DURING PHASES OF FLIGHT.

The in-tank fuel temperature variations during flight may be modeled using thermodynamic principles of conservation of mass and energy, assuming quasi-steady state phenomena. The assumption of a steady state will approximately hold over a small time interval if the variables change with respect to time, but the parameters (or physical properties) vary less appreciably. The primary factors affecting the rate of change of in-tank fuel temperature are ambient altitude temperature, aircraft speed, and fuel-tank heat transfer characteristics. The secondary factors include fuel transfer procedure, initial fuel temperature, and heat transfer characteristics of fuel pumps, lines, and heat exchangers. It is possible to write the energy and mass balance equations and solve them over small time intervals.

A less elaborate method that can yield a reasonable estimate of temperature variation can be obtained by reducing the model to an energy balance equation and transforming it to a one-dimensional time-dependent heat transfer equation by eliminating the less significant terms (Reference 15). This is equivalent to assuming that: there is no fuel transfer or recirculation to the main tank; internal heat sources in the tank have negligible effects; and the net effects of radiation between the external surfaces of the tank and space, earth and sun, and the radiation heat exchange between the dry tank walls and the fuel, are negligible. The resulting model will be:

$$\frac{dT_F}{dt} = \frac{UF_f}{C_p\rho}\,\frac{A_w}{V}\,(T_R - T_F)$$

where T_F is the temperature of the fuel.

Assuming that the overall air-to-fuel heat transfer coefficient (U), the fin factor effect (F_f), the wetted area to fuel volume ratio (A_w/V), the specific heat-density product ($C_p\rho$), and recovery temperature T_R do not vary during the time interval from t_o to t_1, then the above equation may be integrated to yield:

$$\frac{UF}{C_p\rho}\,\frac{A_w}{V}\,(t_o - t_1) = \int_{T_{Fo}}^{T_{F1}} \frac{dT_F}{T_R - T_F}$$

Consequently,

$$T_{F1} = T_R - (T_R - T_{Fo})\,[\exp - (\frac{U\,F_f}{C_p\rho}\,\frac{A_w}{V}\,\Delta t)]$$

where

Δt = $t_1 - t_0$ (time interval)

T_{F0} = initial temperature of fuel (at t_0)

T_{F1} = temperature of fuel at t_1

$C_p\rho$ and T_{F0} are known. T_R can be obtained based on altitude temperature according to:

$$T_R = (1 + 0.18M^2)\ T_{ALT}$$

where M is the mach number (Reference 16). The flight-aircraft variables are U and A_w/V with

$$U = \left[\frac{1}{H_A} + \frac{1}{C_w} + \frac{1}{H_F} \right]^{-1}$$

where

H_A = aerodynamic skin heat transfer coefficient;

C_w = tank wall conduction heat transfer coefficient; and

H_F = fuel film heat transfer coefficient.

H_A and H_F can be calculated based on fluid properties, Reynolds, Prandtl, and Nusselt numbers. C_w can be obtained from the geometry and physical properties of the tank wall.

A_w/V is a function of aircraft fuel tank capacity and a particular fuel consumption pattern (based on the flight profile). Figure 4 (Reference 17) illustrates the wetted area to fuel volume ratio as a function of fuel volume for several aircraft.

Prediction of T_{F1} by the above equation is based on the estimate of U which requires detailed knowledge of fuel tank construction and components. However, the value of U may be estimated based on the available information on in-tank fuel temperature for some particular flights (Reference 18). Using this approximate value, the minimum in-tank fuel temperature can then be estimated. The minimum in-tank fuel temperature is of interest here since phase separation or emulsification of water in antimisting fuel may occur at low temperatures. Since this estimate can contain a large error component, it can only be used for comparison across aircraft categories and flight missions.

Table 1 presents the results of several calculations for minimum in-tank fuel temperatures based on the above approximation and the following assumptions. First, the minimum in-tank fuel temperature is assumed to occur just prior to the beginning of descent (BOD). Second, based on Figure 4, the ratio of the wetted area to the volume of fuel, AW/V, is 2.0 ft. -1 at the BOD. Third the Mach numbers for the given flight

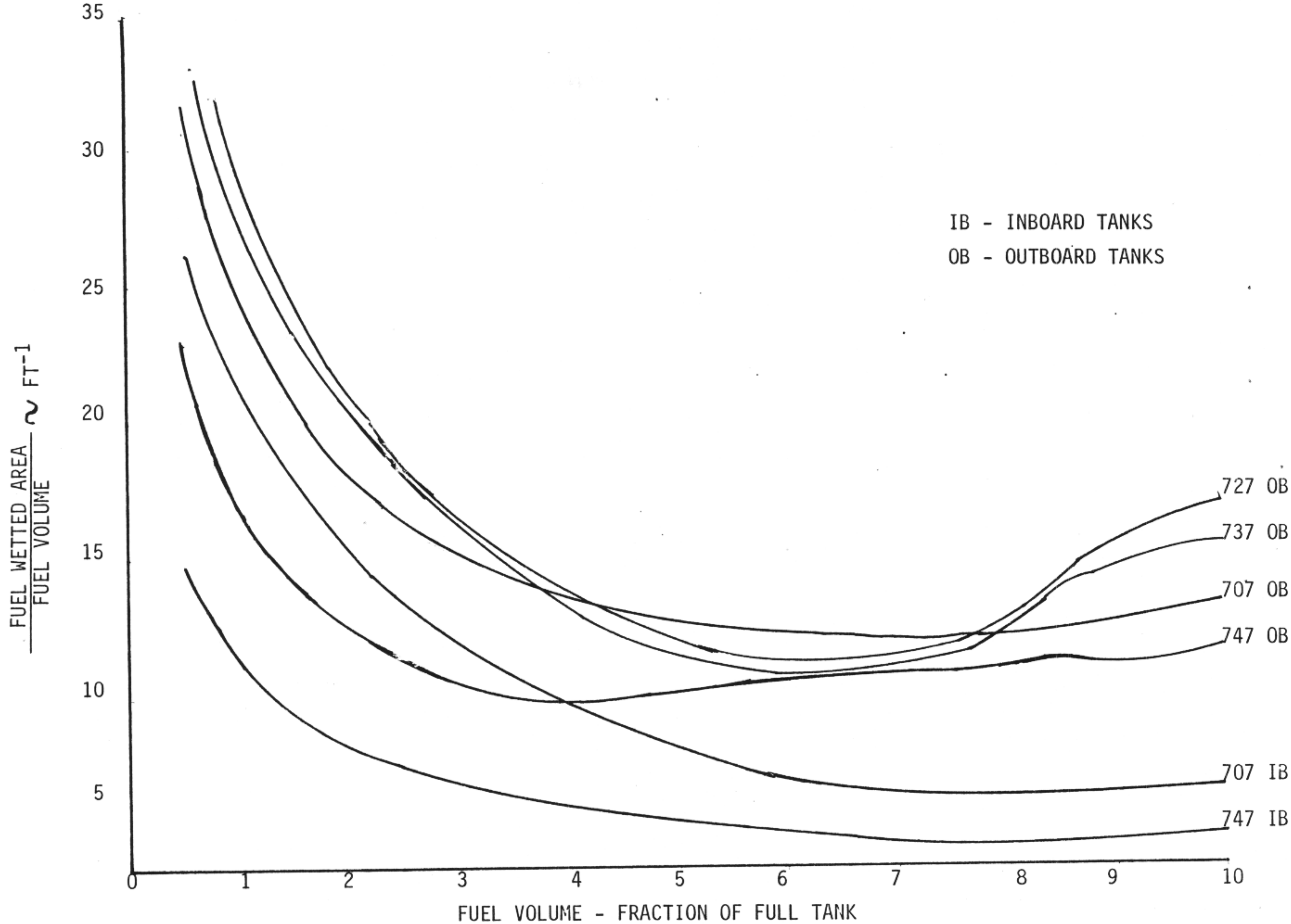

FIGURE 4. A_W/V VERSUS FUEL FRACTION IN TANK (taken from Reference 17)

missions are assumed to be 0.78 for transport and 0.38 for commuter aircraft (See Chapter 4, <u>Flight Profiles</u>.). Fourth, the specific heat-density product ($C_p\rho$) remains constant with temperature changes and is equal to 21.85 BTU/ft^3°F. Fifth, airport and altitude temperatures are based on standard day atmospheric data, and the initial fuel temperature is nominally 10°F lower than the airport temperature. Geographical locations of large U.S. air traffic hubs and their corresponding normal, minimum daily temperatures are given in Figure 5 (Reference 19) and Table 2 (Reference 20) respectively. Finally, the average value for U is assumed to be 2.0 BTU/hr.°F with a range from 1 to 4.5 BTU/hr.°F.

TABLE 1. ESTIMATES OF MINIMUM IN-TANK FUEL TEMPERATURE DURING FLIGHT FOR VARIOUS STAGE LENGTHS AND AIRCRAFT CATEGORIES

	Selected Stage Length (nm)	Total Flight Time (hrs.)	Time to BOD (hrs.)	ALT at BOD (1000 ft)	T_{ALT} (°F)	T_R (°F)	T_{F_0} (°F)	T_{F_1} (°F)
TRANSPORT AIRCRAFT	200 short range mission	0.50	0.20	21	-15.8	-17.5	50	46.6
							40	37.2
	1,000 medium range mission	2.37	2.00	35	-65.6	-72.7	50	4.6
							40	-1.7
	1,500 medium-long range mission	3.50	3.11	35	-65.6	-72.7	50	-12.6
							40	-17.5
	3,000 long range mission	7.00	6.50	39	-69.7	-77.4	50	-49.3
							40	-51.5
COMMUTER AIRCRAFT	50 short range flight	0.33	0.20	4	44.7	47.8	50	50.0
							40	40.0
	150 medium range flight	1.00	0.73	8	30.5	32.6	50	47.3
							40	38.8
	275 long range flight	1.80	1.45	10	23.3	25.0	50	43.0
							40	35.6

KEY:
nm: nautical miles
hrs: hours
BOD: beginning of descent
ALT: altitude
T: temperature

SUBSCRIPTS:
R: recovery
F_0: initial fuel
F_1: minimum fuel

FIGURE 5. U.S. AIR TRAFFIC HUBS (taken from Reference 19)

TABLE 2. NORMAL DAILY MINIMUM TEMPERATURE - LARGE U.S. AIR TRAFFIC HUBS*
(taken from Reference 20)

State	City (Airport)	Temperature (°F)
Arizona	Phoenix	37.6
California	Los Angeles	45.4
	San Diego	N/A
	San Francisco	41.2
Colorado	Denver	16.2
D.C.	Washington	27.7
Florida	Miami	58.7
	Orlando	N/A
	Tampa	N/A
Georgia	Atlanta	33.4
Hawaii	Honolulu	65.3
Illinois	Chicago	14.7
Louisiana	New Orleans	43.5
Massachusetts	Boston	22.5
Michigan	Detroit	19.2
Minnesotta	Minneapolis-St. Paul	3.2
Missouri	Kansas City	19.3
	St. Louis	22.6
Nevada	Las Vegas	N/A
New Jersey	Newark	N/A
New York	New York	25.9
Ohio	Cleveland	20.3
Pennsylvania	Philadelphia	24.4
	Pittsburgh	20.8
Texas	Dallas-Fort Worth	33.9
	Houston	41.5
Washington	Seattle-Tacoma	33.0

*Large U.S. Air Traffic Hubs are defined by FAA as those with 1% or more of total enplanements. The Large Air Traffic Hubs collectively account for 70% of the enplanements.

As can be seen from Table 1, several patterns may be detected:

(a) For a given aircraft category and initial fuel temperature (50°F), the minimum in-tank fuel temperature (T_{F1}) is lower for longer stage lengths.

(b) For a given stage length or flight range mission, the minimum in-tank fuel temperature during flight is lower when the initial fuel temperature is lower. However, a cross comparison of minimum in-tank temperatures (T_{F1}) for various stage lengths within one aircraft type indicates that the initial fuel temperature is more important for shorter stage lengths. For example, with a 200 nautical mile stage length, other factors being equal, a decrease of 10°F in the initial fuel temperature results in a 9.2°F decrease in minimum in-tank fuel temperature. On the other hand, if the stage length is 3000 nautical miles, the same decrease in initial temperature only results in a 2.2°F decrease in minimum in-tank fuel temperatures. Therefore, the initial fuel temperature becomes a less important factor in the determination of minimum in-tank fuel temperatues for longer range flights.

(c) A comparison of the T_{F1} values in Table 1 for a 150-nautical mile commuter aircraft and a 200-nautical mile transport aircraft shows no appreciable difference in minimum in-tank fuel temperatures between commuter and transport categories of aircraft for a comparable stage length.

(d) In general, transport aircraft will encounter lower minimum in-tank fuel temperatures than commuter aircraft due to their greater exposure to lower ambient atmospheric temperatures. The lower in-tank temperatures for transport aircraft reflect the differences in operations; namely, longer flight times at higher altitudes.

Based on the analysis above, some implications for use of antimisting fuel should be noted. First, physical properties of antimisting fuel may be such that its use below a certain minimum temperature is undesirable due to unwanted physical changes. Some modifications to the airframe fuel system may be necessary and could take three general forms: insulation, auxiliary heating, or a combination of both depending on the compatibility of other antimisting fuel properties with such modifications.

Overall, assuming that antimisting fuel cannot be used in an operating environment with temperatures below a minimum T_M, then it can be expected that aircraft in the transport category are more likely to require some type of action, namely, aircraft modifications, based on their operating environment.

WATER AND HUMIDITY.

The presence of water in jet fuels has always been a concern since it can lead to malfunction of fuel controls, ice plugging of fuel filters, freezing of fuel boost pump and transfer pumps, and an increased phase separation tendency at low temperatures (below $-20^{\circ}F$). In addition, certain microbial and fungal growths thrive on the interface provided by the water environment and the hydrocarbon fuel. These growths can result in a buildup of bacterial slime which can clog small metering orifices and penetrate the coatings and sealants used in fuel tanks, thus exposing the metal surfaces to corrosion.

In general, water in fuel may take two forms: dissolved water and free water. Dissolved water is similar to humidity in the atmosphere, and is a function of the temperature and specifications of the fuel. The amount of dissolved water may reach up to 0.03% by volume of fuel. Figure 6 (Reference 21) shows the potential dissolved water content of various jet fuels as a function of temperature. Free water, on the other hand, can be in two forms: (1) entrained water, which refers to water suspended in fuel in minute droplets invisible to the naked eye; or (2) water slugs, the visible droplets or pools of water which have separated from fuel.

Current storage and handling methods for fuel are designed to minimize the amount of dissolved water in fuel tanks. Free water, however, is continually

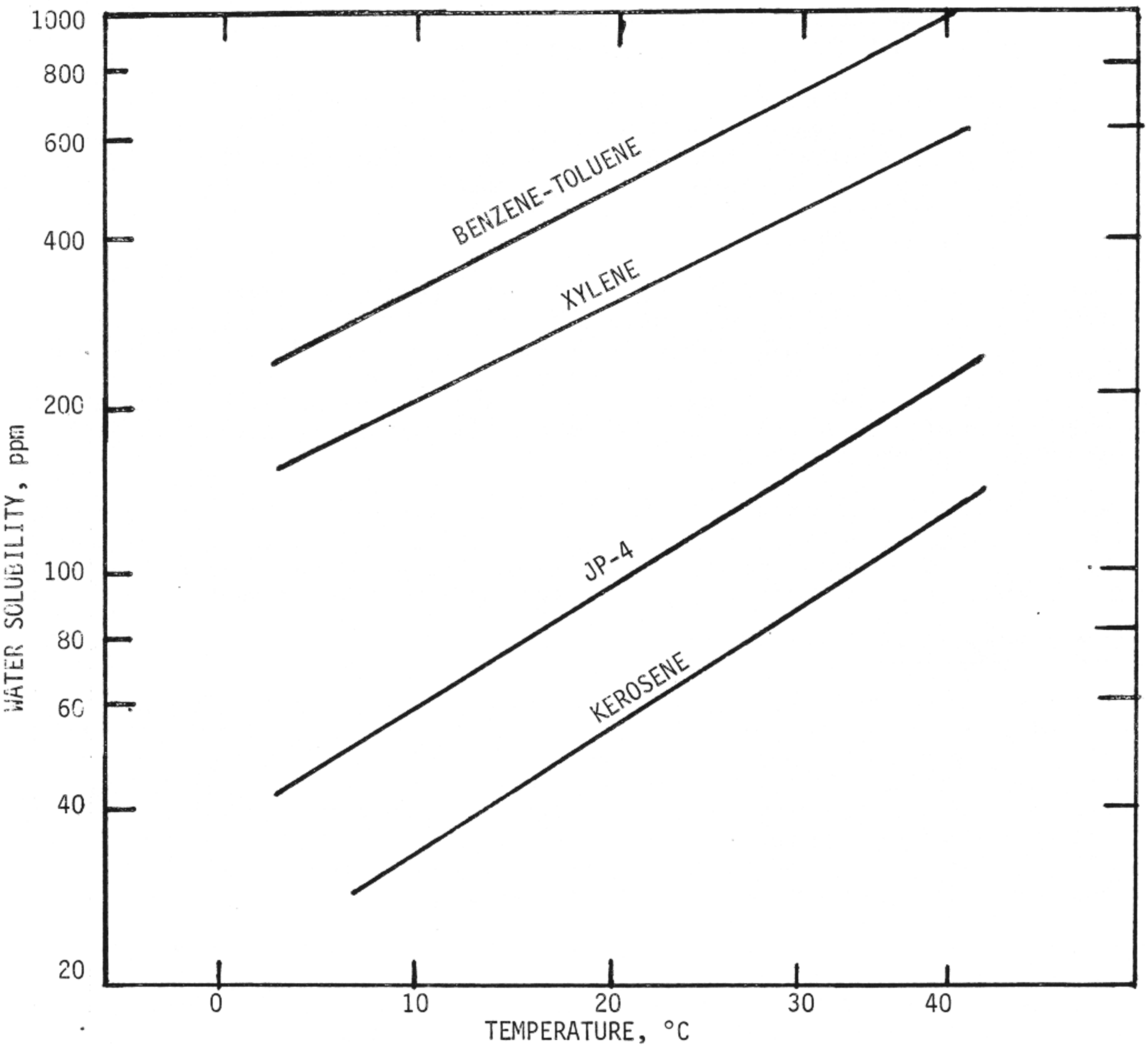

FIGURE 6. VARIATION OF WATER SOLUBILITY OF HYDROCARBONS WITH TEMPERATURE (taken from Reference 21)

generated during operation of the aircraft. That is, every time an aircraft ascends to altitude the dissolved water cools and separates from the solution. A general estimate is that 0.5 liters of water per 4,000 liters of fuel is released from the fuel during the ascent (Reference 22). In addition, each time an aircraft descends to land, moist air is sucked into the tanks and approximately 0.125 liters of water per 4,000 liters of fuel is released (Reference 23) due to condensation on cold surfaces and structural members. As a general rule, it may be expected that an aircraft with larger fuel tank capacity, and thus more fuel on-board, will generate a larger volume of free water. Aircraft flying at higher altitudes will also generate a larger volume of free water since they are exposed to more severe atmospheric extremes.

On the other hand, preliminary experiments with antimisting fuel have shown that it absorbs more water than Jet A fuel, due to presence of the antimisting polymer FM-9, and the carrier fluids, i.e., glycol and amine (Reference 24). Figure 7 (Reference 25) illustrates water absorption characteristics of antimisting fuel at two temperatures (12°C and 22°C). The maximum potential water absorption of antimisting fuel at 12·C is approximately 0.13% by volume, which is almost 22 times the maximum potential water absorption of Jet A (i.e., 0.006%) at the same temperature (c.f. Figures 6 and 7).

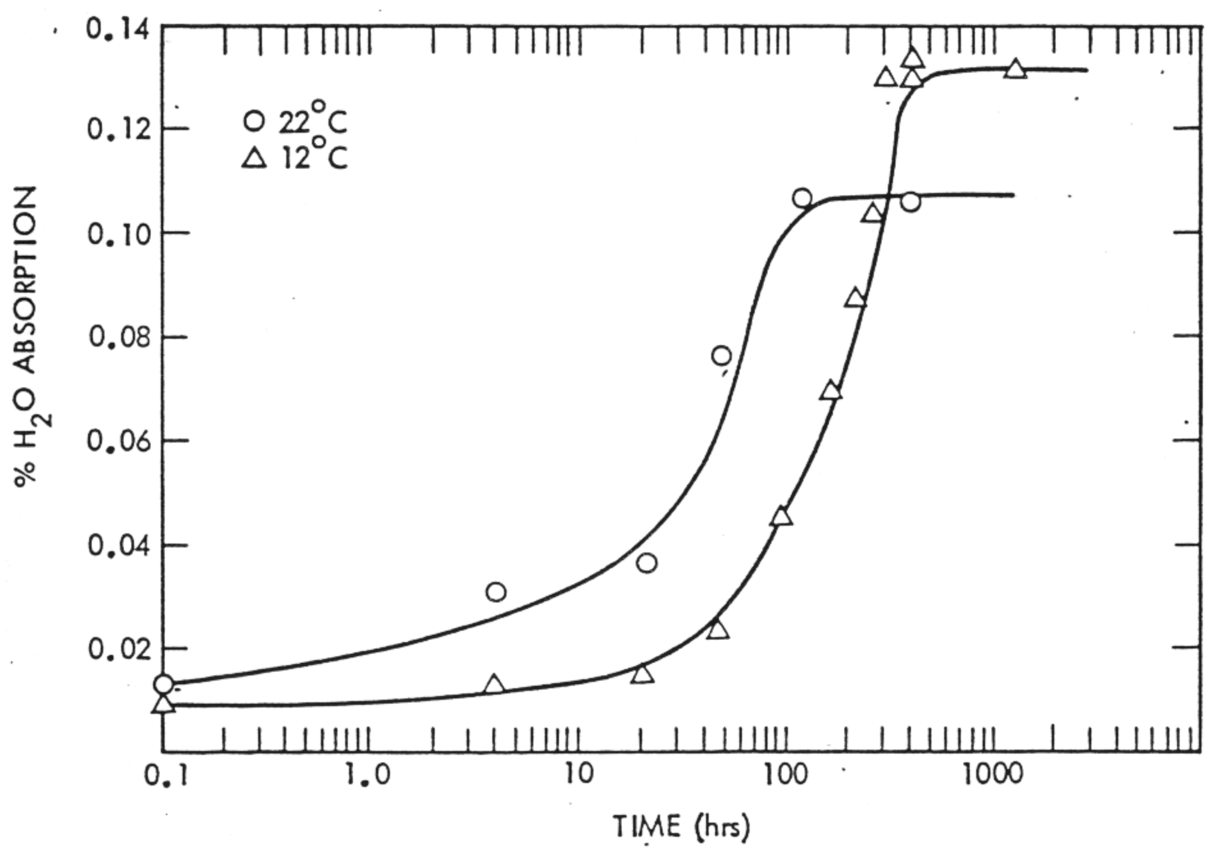

FIGURE 7. UPTAKE OF WATER BY AMK
(taken from Reference 25)

Therefore, in relative terms, use of antimisting fuel with larger capacity and higher flying aircraft will generate more free water than for smaller range aircraft. The free water problem has traditionally been alleviated by frequent drainage (Reference 26). There are several questions, however, regarding the effectiveness of this method for antimisting fuel. Preliminary tests indicate a more pronounced and localized phase separation between water and antimisting fuel. These tests have also indicated that, as a result of low temperature exposure, free water may separate into emulsified droplets which can adhere to the tank walls even after the temperature rises (Reference 27).

4. COMPOSITION AND UTILIZATION OF THE COMMERCIAL FLEET

The U.S. commercial aircraft fleet in 1981 was composed of more than 3,000 turbine-powered aircraft which must conform to the airworthiness standards promulgated by the FAA. This research focused on Commuter, Transport, and Rotorcraft as specified in the Code of Federal Regulations (CFR) at Title 14, Parts 23, 25, and 29.

Turbine-powered aircraft utilized by domestic trunk air carriers are manufactured primarily by U.S. firms, including the Boeing Commercial Airplane Company, McDonnell-Douglas Corporation, and Lockheed Corporation. Airbus Industrie, a European consortium, is also a supplier of aircraft to these major carriers. The aircraft operated by local service, commuter, and other carriers are manufactured by a more diverse group of U.S. and foreign companies. Overall, manufacturers of the aircraft in the commercial fleet include some 50 domestic and foreign firms. For the analysis, we divided the commercial fleet into two major groups of aircraft based on the type of power plant. These two groups include turbofan- and turbojet-powered aircraft; and turboprop-engined aircraft.

The major engine manufacturer is the Pratt and Whitney Aircraft Group of United Technologies Corporation, supplying 57.7% of the engines for the aircraft fleet. The U.S.-based Commercial Products Division manufactures the type of jet engines used for transport category aircraft. Another division of the Aircraft Group, Pratt and Whitney, Canada, manufactures turboprop engines used to power commuter category aircraft. Other major engine manufacturers include General Electric, Rolls-Royce, and Garrett-AiResearch. General Electric is also involved in a consortium with the French firm, SNECMA, for the production and marketing of the CFM-56 engine. The group of engine manufacturers is smaller than the number of participants in the airframe field, but there is representation of both U.S.-based and foreign firms in each group.

DATA SOURCES AND PROBLEMS.

Appendix A presents a recent inventory of the U.S. commercial fleet by air carrier. The data presented include both the number of aircraft in the fleet and on order, and power plants for each aircraft, by manufacturer. A summary of the composition of the fleet by major equipment group is presented in Table 3 (Reference 28).

TABLE 3. COMPOSITION OF U.S. AIR CARRIER FLEET, 1979 and 1981 (taken from Reference 28)

	1979	1981
Fixed Wing		
Turbofan/Jet		
4-engine	511	424
3-engine	1256	1276
2-engine	719	764
Sub-total	2486	2464
Turboprop		
4-engine	80	98
2-engine	486	700
Sub-total	566	798
Rotary Wing		
Turbine-Powered	1	19
TOTAL FIXED AND ROTARY WING	3053	3281

These data provide a comparison of the 1981 fleet inventory published in the Air World Survey with the 1979 census of aircraft in the commercial fleet published by the FAA in the Statistical Handbook of Aviation. This inventory indicates that, as of mid-1981, the commercial fleet was composed of 3,281 turbine-powered aircraft, including 19 rotary-wing aircraft in commercial service.

The apparent dramatic growth in the number of helicopters in the commercial fleet between 1979 and 1980 points out a potential problem with the data. Specifically, since the data are not taken from the same sources, they may not be directly comparable. Therefore, care should be taken in drawing inferences from any comparison of these data. The increase in the number of rotary-wing aircraft is due in part to the institution of helicopter service by New York Helicopters. Most other turbine-powered helicopters are engaged in commercial nonpassenger operations such as servicing offshore facilities. The use of a single data source is more appropriate for examining trends in the fleet.

Table 4 (Reference 29) shows the composition of the commercial aircraft fleet by manufacturer, as reported by the FAA for the period 1977-1979. For turbofan/jet-powered aircraft, these data indicate growth in the size of this fleet segment of about 11% (Reference 30) during the period. The more dramatic increase in turboprop aircraft is attributable in large measure to the inclusion of aircraft operated by commuter carriers, air taxis, and others.

It is clear that the most significant portion of the fleet, in terms of the number of aircraft, is the turbofan/jet group, which are operated primarily by the trunk and local service air carriers, with some operations by charter and other carriers. While the trunk airlines operate jet-engined aircraft exclusively, some local service carriers also operate turboprop aircraft. The composition of the air carrier fleet by manufacturers and airlines is presented in Tables 5 and 6 (Reference 31) for trunk and local service carriers respectively. The number and type of aircraft on order are also included in these Tables to show how the composition of the fleet may be altered in the near-term. At this point, aircraft orders indicate a major role for the new Boeing 757 and 767 aircraft in air carrier operations by the mid-1980's. The orders for the Boeing 727-200 series indicate a continuing, important role for this aircraft in the near-term.

AIRCRAFT USE CHARACTERISTICS.

The examination and comparison of measures of aircraft usage is important in determining how the introduction of antimisting fuel may affect the operations of aircraft in the commercial fleet and examining the economic factors related to use of antimisting fuel (See Chapter 5). Aircraft usage is also part of the analysis to determine which portions of the fleet may be given priority in commercial introduction of antimisting fuel (See Chapter 6). In this Section, we examine the principal measures of aircraft usage which are currently available. The air carriers have been required to collect data on usage of their aircraft and file periodic reports with the Civil Aeronautics Board (CAB) concerning traffic and other operational data, as well as information on the costs of operations. Several of these data elements, which are useful to the analysis of introduction of antimisting fuel in the commercial fleet, are presented in Appendix C: Operational Profiles. These data are reported by aircraft for a base year of 1979.

TABLE 4. COMPOSITION OF TURBINE-POWERED AIR CARRIER FLEET BY TYPE, MAKE AND MODEL OF AIRCRAFT (taken from Reference 29)

TYPE OF AIRCRAFT AND MANUFACTURER	MODEL	NUMBER OF ENGINES	1977	1978	1979
Turbojet					
Airbus	A 300	2	2	6	12
Boeing	707	4	225	201	175
"	720	4	18	14	7
"	727	3	865	931	1,029
"	737	2	160	173	206
"	747	4	108	115	131
British Aircraft Corp.	BAC 111	2	31	30	28
Cessna	C 500	2	-	-	4
Convair	CV 30	2	-	-	6
Dassault	MD 20	2	45	45	44
Douglas	DC 8	4	193	178	188
"	DC 9	2	362	373	381
"	DC 10	3	127	133	140
Grumman	G 1159	2	5	6	6
Hamburger/Flugzenbau	HFB 320	2	3	6	4
Israel Aircraft	1123	2	-	1	1
"	1124	2	-	1	1
Lear Jet	LR 23	2	NA	NA	5
"	LR 24	2	NA	NA	3
"	LR 25	2	NA	NA	6
"	LR 35	2	NA	NA	4
Lockheed	L-1011	3	77	82	87
"	L-1329	4	-	1	1
Rockwell Int'l	NA 265	2	NA	NA	2
Sud Aviation	SB 210	2	NA	NA	2
SN Concorde		4	-	-	9
Turbojet Subtotal			2,221	2,296	2,486
Turboprop					
Beech	BE 9	2	-	-	3
"	BE 99	2	-	-	85
"	BE 200	2	-	-	4
Convair	CV 580	2	76	69	105*
"	CV 600	2	8	8	15
"	CV 640	2	14	14	-*
DeHavilland	DHC 6	2	13	14	78
"	DHC 7	2	-	-	8
"	DHC 104	2	-	-	2
Embraer	EMB 110	2	-	-	4
Fairchild	F 27	2	4	7	6
"	F 277	2	23	22	22
GAF Nomad	N 24	2	-	-	1
Grumman	G 159	2	1	1	15
Handley-Page	HP 137	2	-	-	13
"	SAHP 37	2	-	-	3
Hawker-Sidley	HS 748	2	1	1	1
Lockheed	L 188	4	40	46	52
"	L 382	4	20	21	20
Nihon	YS 11	2	23	14	18
Nord	ND 262	2	5	9	20
"	STC 262	2	-	-	4
Shorts	SD 3	2	-	4	-
"	SD 330	2	-	1	21
Swearingen	SA 26	2	-	-	1
"	SA 226	2	6	8	65
Turboprop Subtotal			237	242	567
Rotary Wing					
Kawasaki	KV 107		-	-	1
Sikorsky	S 61		3	3	-
Turbine-Powered Total			2,458	2,538	3,052

NA: Data Not Available
- : None
*CV 580 total for 1979 includes CV 640.

TABLE 5. TURBINE-POWERED AIRCRAFT FLEET OF DOMESTIC TRUNK AIRLINES 1980* (taken from Reference 31)

MANUFACTURERS AND MODELS	AIRLINES AA	BN	CO	DL	EA	NW	PA	TW	UA	W	TOTAL
AIRBUS INDUSTRIE											
A300					19(6)						19(6)
BOEING											
B-767	(30)							(45)	(69)	(6)	(150)
B-767-200				(20)							(20)
B-757	(15)				(27)						(42)
B-757-253				(60)							(60)
B-747	8						29	18	18		73
B-757F	6					5	6				17
B-747-100		2				12					14
B-747-200		3				12					15
B-747-SP		2					10				12
B-737-200									48	15	63
B-727								90			(0
B-727-023	56										56
B-727-200		63	41(4)	126	80(12)	50(2)	24(8)			44	428(26)
B-727-223	102(23)								104		206(23)
B-727-100		5	17		62	16	33		69		202
B-727-100C		12									12
B-707-323B	7										7
B-707-323C	18										18
B-707-323F	9										9
B-707								70			70
LOCKHEED											
L-1101					29			32(5)			61(5)
L-1101-1				31							31
L-1101-200				1							1
L-1101-500				3			7(6)				10(6)
MCDONNELL-DOUGLAS											
DC-8-61				13					29		42
DC-8-62		10									10
DC-8F									14		14
DC-9-30				38							38
DC-9-31					58						58
DC-9-50					(4)						(4)
DC-9-51					17						17
DC-10	34					22			42(10)	12	110(10)
DC-10-30			2				5				7
DC-10-10			12				11				23
TOTAL	240 (68)	97	72 (14)	212 (80)	265 (49)	117 (2)	125 (14)	210 (50)	324 (79)	71 (6)	1616 (352)

*Numbers in parentheses indicate aircraft on order.

AA = American Airlines
BN = Braniff International
CO = Continental Airlines
DC = Delta Airlines
EA = Eastern Airlines
NW = Northwest Orient Airlines
PA = Pan-American (National Airlines)
TW = Trans World Airlines
UA = United Airlines
W - Western Airlines

TABLE 6. TURBINE-POWERED AIRCRAFT FLEET OF LOCAL SERVICE CARRIERS 1980*
(taken from Reference 31)

MANUFACTURERS AND MODELS	AIRLINES OC	QH	ZV	NE	FJ	AP	ZW	FL	MI	ML	OZ	PS	PI	RC	RW	NV	TI	AL	FW	TOTAL
BRITISH AEROSPACE																				
BAC-111					3													27		30
BOEING																				
B-737					1								(3)							1(3)
B-737-100	2	4						43(6)												49(6)
B-737-200	14	8											36			24(6)				82(6)
B-737-200A		8(6)																		8(6)
B-737-300																(10)				(10)
B-727-100												3	6					11		20
B-727-200												23		10(3)				2(3)		35(6)
B-727-200A															6					6
EMBRAER																				
Bandierante					4															4
GENERAL DYNAMICS																				
Convair 580				1		10		20	2					22						55
Convair 600																			5	5
MCDONNELL-DOULGAS																				
DC-8									3											3
DC-9										8										8
DC-9-10											7			125			18			150
DC-9-15		4																		4
DC-9-10/15															10					10
DC-9-30											31				31		14(20)	55(16)		131(36)
DC-9-30LR											2			14						16
DC-9-80	(4)											1(19)								1(23)
DC-10-30		1																		1
DE HAVILLAND																				
DHC-6				6																6
DCH-7							5(4)													5(4)
FAIRCHILD-HILLER																				
FH-277				6																6
SWEARINGEN																				
Metro			15				13													28
FAIRCHILD-SAAB																				
SF-340			(5)																	(5)
NIHON																				
YS-11													6							6
TOTAL	16	25	15	13	8	10	18	63	5	8	40	27	48	171	47	24	32	95	5	670
		(6)	(5)				(4)	(6)				(19)	(3)	(3)		(16)	(20)	(19)		(150)

OC=AIR CALIFORNIA
QH=AIR FLORIDA
ZV=AIR MIDWEST
NE=AIR NEW ENGLAND
FJ=AIR PACIFIC
AP=ASPEN
ZW=AIR WISCONSIN
FL=FRONTIER
MI=MACKEY INTERNATIONAL
ML=MIDWAY
OZ=OZARK
PS=PSA
PI=PIEDMONT
RC=REPUBLIC
RW=REPUBLIC WEST
NV=SOUTHWEST
TI=TEXAS INTERNATIONAL
AL=US AIR
FW=WRIGHT

The extent to which the use of antimisting fuel affects the utilization of aircraft in revenue passenger service will be reflected in changes in the number of hours flown and the number of passengers carried. There are several alternative measures of number of hours including: total flight hours; total revenue flight hours; block hours; and average daily utilization.

Total flight hours include all accumulated flight time in both revenue and nonrevenue service. For most major air carriers, flight hours in nonrevenue service (e.g. training activity or shipment of aircraft to maintenance base) are a small percentage of total flight time. Total revenue flight hours, therefore, represent a good approximation to total flight hours. Revenue flight hours indicate which segments of the fleet are utilized most in revenue service, and hence provide a basis for the relative ranking of aircraft in the fleet. Block hours encompass both flight and nonflight portions of revenue service. It therefore includes time from gate departure to take-off, and from landing to gate return. This nonflight portion of block time can account for upwards of 15% of total hours in revenue service. Average daily utilization indicates the number of revenue hours each aircraft in the fleet is operated on a daily basis. Since average daily utilization differs among carriers and across aircraft types, such a characterization can be useful in describing how the use of antimisting fuel may effect revenue operations in different segments of the fleet.

Total revenue flight time could be affected by the introduction of antimisting fuel. For example, the conversion of existing aircraft to an antimisting fuel-compatible state could temporarily reduce the number of aircraft assigned to carrier operations, if the conversion process cannot be completed within normal maintenance cycles. Such a reduction in the number of aircraft in service could affect the annual cumulative flight time through either an increase in the average annual flight time for available aircraft or in an overall reduction in the number of airborne hours. Such changes in aircraft utilization would also affect air carrier revenue, costs, and the profitability of the aviation industry.

Total flight time logged in turbine-powered aircraft of the domestic commercial fleet exceeded 7.3 million hours in 1979, according to the FAA. Of this total, certificated route carriers accounted for 6.7 million flight hours, or about 92% of total flight hours. According to data published by the CAB, the domestic operations of the trunk carriers in 1979 involved approximately 4.1 million airborne hours in revenue service. Approximately 1 million hours were also logged in the international and territorial operations of the trunk carriers. In addition, local service passenger carriers logged approximately 1 million airborne hours. Intra-Alaskan, Intra-Hawaiian, and other carriers logged an estimated 150,000 hours in revenue service.

Table 7 (Reference 32) details airborne hours in revenue utilization by type of aircraft for the trunk and local service carriers. These data indicate that the most extensively used aircraft is the Boeing 727. In 1979, the domestic trunk airlines logged over 60% of the total revenue airborne hours in the various versions of this aircraft.

TABLE 7. REVENUE UTILIZATION BY AIRCRAFT (1979)
(taken from Reference 32)

Trunk Carrier Aircraft	Total Revenue Flight Hours	Hours Per Day
B-727-200	1,747,437	8.59
B 727-100	700,105	7.72
DC-9-30	286,572	7.52
DC-10-10	260,554	9.28
L-1011	218,313	8.62
B-707-100B	214,130	8.35
B-737-200	159,826	6.44
B-747	127,688	10.64
B-727-100C/QC	125,639	8.36
DC-8-61	116,348	8.48
DC-8-50	62,349	7.05
B-707-300B	57,711	7.49
DC-9-50	53,620	8.62
B-707-300C	50,256	8.51
DC-10-40	47,534	6.28
DC-9-10	43,375	8.37
DC-8-62	28,632	8.88
A-300B	22,839	8.37
Local Service		
DC-9-30	380,672	7.68
B-737-200	170,963	7.82
DC-9-10	157,427	7.77
CV-580	99,027	5.70
BAC-111-200	75,267	6.95
DC-9-50	47,412	7.36
YS-11	35,610	6.66
FH-227	17,223	3.63
B-727-200	12,543	7.95
Metro II	12,348	4.87
DHC-6	7,086	6.49
MO-298	3,998	4.74

While the 727 is clearly the aircraft most extensively used, it is the Boeing 747 which is utilized the most hours per day. As shown in Table 7, the 747 is, on average, engaged in revenue service over 10.5 hours per day. This is consistent with the design characteristics for the aircraft. The 747 was conceived and designed for long-range heavy transport. While the 747 is typically airborne longer than other aircraft, its use in long-haul transport and average daily utilization implies that the aircraft makes fewer takeoffs and landings than aircraft which are operated less hours, but over shorter stage lengths.

Consideration of distance flown is important to the development of flight profiles for aircraft operations. Distance is generally described in terms of a stage length, which is defined as the number of miles between takeoff and subsequent landing. Important elements of flight operations, including cruising altitude and cruising speed, are determined on the basis of the stage length over which operations will occur. In addition, other factors such as environmental conditions (e.g. temperature) which may affect use of antimisting fuel are influenced by the operational decisions which are in turn determined by the length of the flight stage. Table 8 (Reference 33) compares stage lengths across aircraft use in trunk and local service operations.

TABLE 8. AVERAGE STAGE LENGTH BY AIRCRAFT (1979)
(taken from Reference 33)

	Stage Length (miles)	
Aircraft	Trunk	Local Service
B-747	2,020	-
DC-10-10	1,497	-
DC-8-62	1,430	-
B 707-300C	1,214	-
DC-8-50	1,088	-
B-707-300B	1,030	-
B-707-100B	1,013	-
L-1011	1,000	-
DC-8-61	975	-
A 300B	893	-
DC-10-40	782	-
B-727-100	645	-
B-727-200	574	552
DC-9-50	403	232
DC-9-30	356	316
DC-9-10	346	315
B-737-200	309	327
BAC 111	-	231
CV 580	-	117
YS 11	-	116
FH 227	-	110
DHC 6	-	106

Table 9 (Reference 34) compares the total annual departures and average departures per aircraft for the domestic trunk and local service carriers. These data confirm that the local service carriers generally execute more departures on a per aircraft basis than their trunk counterparts. For example, comparison of aircraft which are in the fleets of both the trunk and local service carriers (especially the B-737 and DC-9) indicate that the local service carriers perform between 15% and 34% more departures per aircraft than do the trunk carriers operating similar aircaft. Within the local service category, turboprop aircraft have a higher departure per aircraft average than turbofan equipment.

While the operations of local service carriers result in a higher average number of departures per aircraft, the domestic trunk carriers performed a far greater number of departures because of a higher traffic volume and greater number of aircraft in service. Since antimisting fuel has the potential to reduce fire fatalities resulting from accidents during takeoff and landing, the number of departures is an important consideration.

Another consideration with respect to the impact of antimisting fuel on both safety and air carrier economic performance is how heavily aircraft are utilized in providing revenue passenger service. The principal measures of passenger traffic include the total number of revenue passengers enplaned, the number of revenue passenger-miles generated, and the average number of revenue passengers per aircraft mile. Enplanements measure the total number of passengers using

TABLE 9. ANNUAL DEPARTURES BY AIRCRAFT (1979)
(taken from Reference 34)

Domestic Trunk	Total Annual Departures (ooo)	Average Departures Per Aircraft
A300 B	11.5	1909
B-707-100B	97.4	1385
B-707-300	2.3	1180
B-707-300B	25.5	1209
B-707-300C	19.6	1210
B-727-100	474.3	1909
B-727-100C/QC	93.0	2258
B-727-200	855.7	1535
B-737-200	190.0	2794
B-747	32.0	973
L-1101	103.3	1488
DC-8-50	27.5	1136
DC-8-61	54.2	1441
DC-8-62	9.6	1091
DC-9-10	47.4	2618
DC-9-30	301.3	2892
DC-9-50	51.4	3041
DC-10-10	85.0	1105
DC-10-40	27.4	1317
Local Service		
Turbofan		
B-727-100	43.9	2613
B-727-200	10.1	2349
B-737	196.5	3280
BAC-111-200	104.3	3510
DC-9-10	184.9	3332
DC-9-30	450.5	3315
DC-9-50	72.3	4085
Turboprop		
CV 580	198.9	4179
DHC-6	11.4	3800
FH-227	30.4	2338
Metro II	22.2	3217
MO 298	5.2	2260
YS 11	64.2	4397

air travel services. Consideration of this variable is critical in examining the potential benefits of antimisting fuel introduction, as well as providing a unit basis for assessing cost impacts. Alternatively, cost impacts could be normalized based on revenue passenger-miles.

Annual revenue passenger traffic is highest for the 727, for which over 113.8 million enplanements and 85 billion revenue passenger miles were recorded in 1979. The wide-bodied jets, with significantly larger capacities, account for fewer revenue passenger miles because there are fewer of such aircraft in service. The Boeing 747, for example, generated 16.7 billion revenue passenger miles with 8.3 million enplanements in 1979. The McDonnell-Douglas DC-10-10 generated 19 billion revenue passenger miles with 15.4 million enplanements the same year. Moreover, for the wide-bodied jets, passengers per mile traveled is higher, due to the higher number of available seats per mile. The DC-10-10 averaged over 150 revenue passengers per aircraft mile, while the B-747 recorded 259 passengers per aircraft mile.

Figure 8 shows the trend in revenue passenger enplanements during the 1970's. Passenger enplanements have exhibited an upward trend and reached an all time high in 1979 with approximately 293 million passengers carried in domestic travel. The number of enplanements is largely determined by the general level of economic activity and prices, which influences business and discretionary leisure travel.

TYPES OF SERVICE.

While the aviation industry currently offers a broad range of air travel services, a basic distinction can be drawn between passenger (including combination passenger/cargo) and all-cargo services. Although the use of antimisting fuel may also reduce damage to property, its most significant potential impact will be in reducing the probability of fatalities in aviation accidents. Hence, passenger services are a logical focus of the analysis.

Within the category of passenger services, a distinction can be drawn between the scheduled and nonscheduled services. Scheduled services include the operations of the trunk airlines (including the major and national airlines) and local service carriers (i.e. small and medium regionals). In addition, intrastate airlines and commuters which operate on the basis of a published schedule are also included in the scheduled services. Carriers offering nonscheduled services include the supplemental carriers, (e.g. charter airlines), air taxi companies, air travel clubs, and other commercial aircraft operators. Appendix C lists companies operating aircraft in each of these categories.

While the domestic trunk and local service carriers also offer nonscheduled services, such services constitute a relatively insignificant portion of their total business. For all the domestic trunk carriers, nonscheduled services represented only about 1% of total revenue passenger-miles generated in 1980. Such services represented about 2% of total revenue passenger-miles for local service carriers (Reference 35).

Industry deregulation has already begun to blur the distinctions between these carrier groups. For example, members of the supplemental carrier group, including Capitol International and World Airways, have expanded their activities to offer more scheduled services.

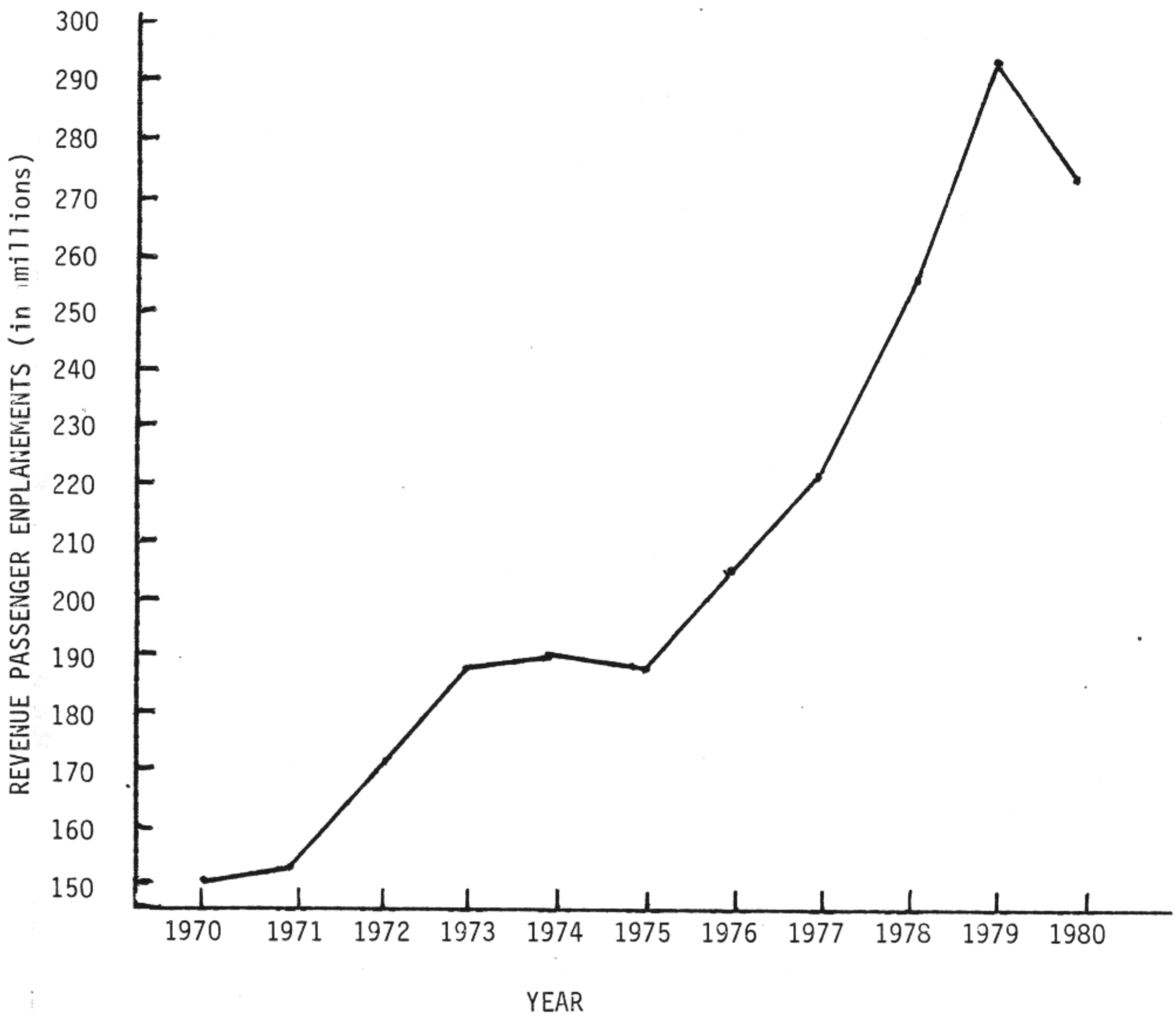

FIGURE 8. REVENUE PASSENGER ENPLANEMENTS: 1970-1980

A category of service which has demonstrated substantial growth in recent years has been commuter services. Annual growth in the number of passengers enplaned for this group of carriers averaged 10.4% per year from 1970 to 1980. For the 12 months ending June 1980, commuter air carriers reported about 11 million origin and destination passengers, accumulating about 1.4 billion passenger miles.

As with other air carrier groups, the commuter group is also in a state of flux. The number of carriers reporting to the CAB increased by 9.0%. While a number of new carriers entered the commuter market, other carriers which had formerly been designated commuters joined the ranks of the certificated carriers. Table 10 (Reference 36) summarizes commuter operations.

TABLE 10. COMMUTER AIR CARRIER PROFILE
(taken from Reference 36)

	1980	1979
Number of Carriers	291	267
Passenger	253	N/A
All-cargo	38	N/A
Passengers (thousands)	11322	10516
Passenger-miles (millions)	1359	1207
Airports Served	822	819
Total Passenger Markets	2126	1888
Average Trip (miles)	120	115

N/A: Not Available

Table 11 (Reference 37) presents data on the top ten commuter carriers, ranked in terms of total number of passengers and revenue passenger miles.

TABLE 11. MAJOR COMMUTER AIR CARRIERS, 1980
(taken from Reference 37)

Carrier	No. of Turbine-Powered Aircraft	Passengers No.	Passengers Rank	Passenger-Miles No.(ooo)	Passenger-Miles Rank
Prinair*	2	761447	1	61376	3
Ransome Airlines	19	752913	2	89614	1
Rio Airways	24	472783	3	66192	2
Metro Airlines	21	420090	4	35013	9
Pennsylvania Commuter	16	410979	5	47636	5
Henson Aviation	12	385052	6	36924	8
Provincetown-Boston**	5	308493	7	33038	10
Cascade Airways	13	297355	8	49804	4
Rocky Mountain	4	255900	9	26311	14
Swift Aire	8	255509	10	39628	7
Bar Harbor	16	201522	13	41115	6

* Fleet includes 24 Piston engine aircraft.
** Fleet includes 33 Piston engine aircraft.

The top ten commuter carriers (based on revenue passenger miles) generated about 37% of total commuter carrier revenue passenger-miles. The top twenty commuters generated more than 50% of the revenue passenger-miles and more than 50% of the enplaned passengers. While a few commuter carriers may thus be considered to be dominant, the market for commuter services is quite fragmented, as evidenced by the large number of carriers and passenger markets. A majority of these markets, however, are quite small. About 75% of the city-pairs generated only about ten passengers per day. Fewer than 10% of the city-pairs generated 40 or more passengers per day.

Many of the smaller commuter carriers operate only piston-engined aircraft, and hence would not be directly affected by a requirement to use antimisting fuel. However, many commuter carriers do operate turbine-powered aircraft, and may be required to use antimisting fuel. It is significant to note that the commuter carriers reporting the most enplanements and revenue passenger miles accounted for less than 25% of turboprop aircraft in the commercial fleet. An undetermined proportion of the remaining turboprop aircraft in the fleet are operated by a group of commuter carriers whose operations may be characterized as marginal. These carriers as a group have a weaker revenue base in comparison to the top commuter carriers and represent a relatively insignificant proportion of the total revenue passenger traffic, measured on either an enplanement or revenue passenger-mile basis. Hence, they may be more adversely affected by the costs of converting to use of antimisting fuel. Moreover, limited data availability constrains a more detailed review of their operations.

FLIGHT PROFILES.

The flight profiles are important elements of the analysis of fleet operations, since they describe the various phases of flight and the operational and environmental factors appropriate to a flight over a specified stage length. The flight profiles presented below are based on typical flight plans for selected aircraft. Figure 9 (Reference 38) illustrates the phases of flight which the flight plan must anticipate including: takeoff; climb; acceleration; cruise; descent; approach; and landing.

The sequence from climb to cruise at altitude may include intermediate steps to initial cruise altitude and a series of step climbs to final cruise altitude. The flight plan typically includes, as a contingency, a plan for flight to an alternate airport. An important part of the flight plan for both the destination and alternative airport is the calculation of total fuel requirements. This calculation is based on factors including wind speed, cruise speed and altitude, and gross weight of the aircraft. In addition to the fuel to destination and to alternate, the total fuel complement also includes a typical reserve, estimated at 45 minutes flight time. This reserve is maintained as a safety margin against unanticipated in-flight delays.

Three flight profiles for the 727 developed for stage lengths of 1500, 1000, and 200 nautical miles and representing long, medium, and short flights, are presented in Tables 12 through 14. Each profile presents estimated values for critical external and operating parameters at various phases of flight. Three additional flight plans for the De Havilland DH6-6 Twin Otter are presented in Tables 15 through 17.

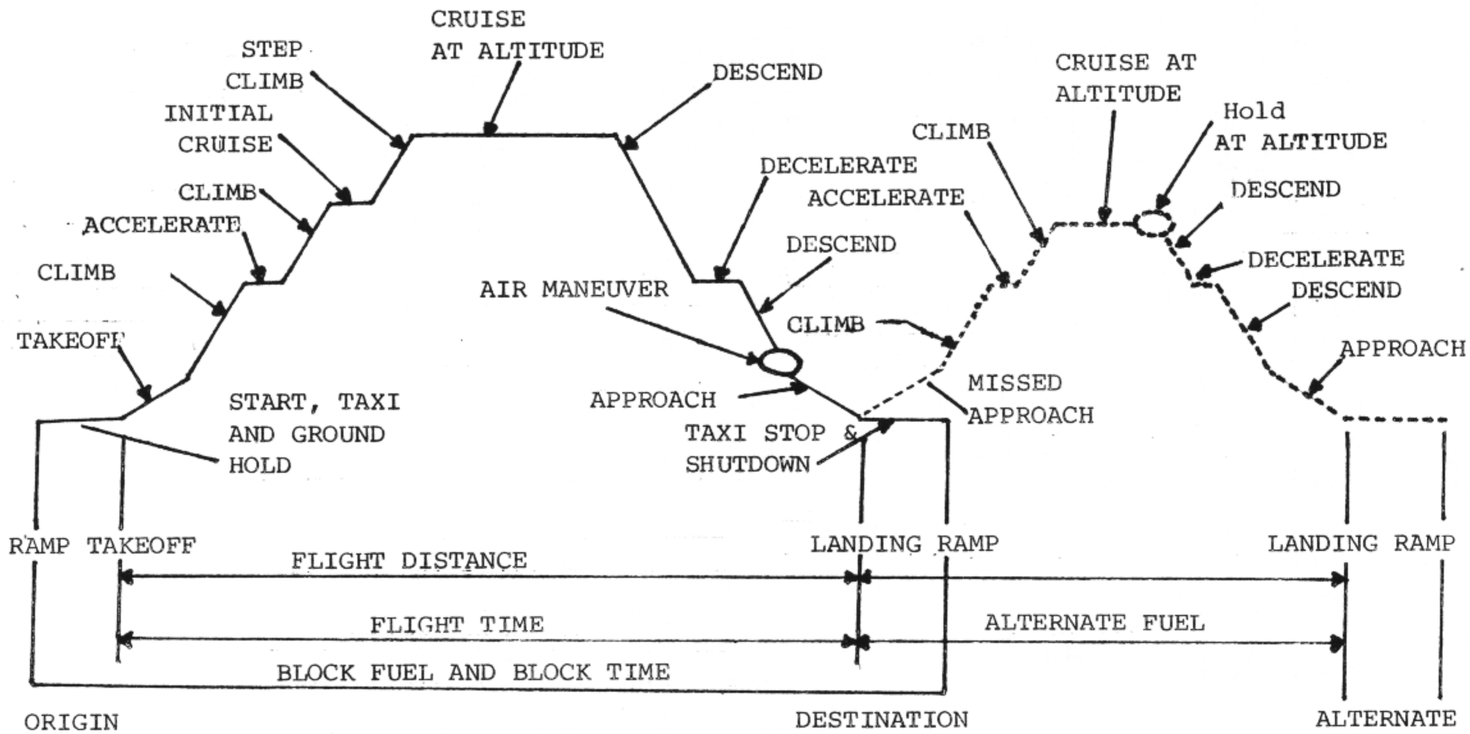

FIGURE 9. FLIGHT PROFILE (TYPICAL) (taken from Reference 38)

TABLE 12. SAMPLE LONG-RANGE FLIGHT PLAN 727-200*: 1500 NAUTICAL MILES

To:	Alt (100ft)	Temp** (°C)	Wind	Ground Speed (kts)	Segment Distance (nm)	Total Dist (nm)	Segment Time (min)	Total Time (min)	Segment Fuel (lbs)	Total Fuel (lbs)	Fuel Remaining (lbs)
TOC	280	-40	0	375	158	158	25	25	7500	7500	37000
PtA	280	-40	0	460	152	310	20	45	3300	10800	33700
PtB	310	-46	0	458	458	768	60	105	9200	20000	24500
BOD	350	-54	0	450	617	1385	82	187	11400	31400	13100
Dest	0		0	324	115	1500	22	209 3:29 (hr:min)	1600	33000	11500

Alt : Altitude
BOD : Beginning of descent
Dest: Destination
Dist: Distance
hr : Hours
kts : Knots
min : Minutes
nm : Nautical miles
PtA : Enroute point to
PtB : Climb to most efficient altitude
Temp: Temperature
T/O : Take-off
TOC : Top of climb

Fuel to destination	33000
Alternate	5700
Reserve	5800
Total required fuel (lbs)	44500

* Assumptions: No wind, i.e., averaging east- and west-bound flight plans; standard temperature day; gross weight at T/O 177,900 lbs max; 0.78 Mach cruise.

** Altitude and altitude temperature will approximately hold for most transport aircraft flying over the given stage length.

TABLE 13. SAMPLE MEDIUM-RANGE FLIGHT PLAN 727-200*: 1000 NAUTICAL MILES

To:	Alt (100ft)	Temp** (oC)	Wind	Ground Speed (kts)	Segment Distance (nm)	Total Dist (nm)	Segment Time (min)	Total Time (min)	Segment Fuel (lbs)	Total Fuel (lbs)	Fuel Remaining (lbs)
TOC	310	-46	0	382	140	140	22	22	6700	6700	27300
PtA	350	-46	0	458	168	308	22	42	3300	10000	24000
BOD	350	-54	0	450	577	885	78	120	10900	20900	13100
Dest	0		0	324	115	1000	22	142 2:22 (hr:min)	1600	22500	11500

Alt : Altitude
BOD : Beginning of descent
Dest: Destination
Dist: Distance
hr : Hours
kts : Knots
min : Minutes
nm : Nautical miles
PtA : Enroute point to
Temp: Temperature
T/O : Take-off
TOC : Top of climb

Fuel to destination	22500
Alternate	5700
Reserve	5800
Total Fuel required (lbs)	34000

* Assumptions: No wind, i.e., averaging east- west-bound flight plans; standard temperature day; gross weight at T/O 160,000 lbs; 0.78 Mach cruise.

** Altitude and altitude temperature will approximately hold for most transport aircraft flying over the given stage length.

TABLE 14. SAMPLE SHORT-RANGE FLIGHT PLAN 727-200*: 200 NAUTICAL MILES

To:	Alt (100ft)	Temp** (°C)	Wind	Ground Speed (kts)	Segment Distance (nm)	Total Dist (nm)	Segment Time (min)	Total Time (min)	Segment Fuel (lbs)	Total Fuel (lbs)	Fuel Remaining (lbs)
TOC	210	-27	0	332	66	66	12	12	4400	4400	14800
Dest	210	-27	0	477	134	200	17	29	3300	7700	11500

Alt : Altitude
Dest: Destination
Dist: Distance
hr : Hours
kts : Knots
min : Minutes
nm : Nautical miles
Temp: Temperature
TOC : Top of climb

Fuel to destination	7700
Reserve 45 min	5800
Alternate	5700
Total fuel (lbs)	19200

* Assumptions: Standard temperature day; gross weight 150,000 lbs; 0.78 Mach cruise; alternate fuel includes missed approach at dest, climb cruise to alternate.

** Altitude and altitude temperature will approximately hold for most transport aircraft flying over the given stage length.

TABLE 15. SAMPLE LONG-RANGE FLIGHT PLAN DHC-6-100 OR 200*: 275 NAUTICAL MILES

To:	Alt (100ft)	Temp** (°C)	Wind	Ground Speed (kts)	Segment Distance (nm)	Total Dist (nm)	Segment Time (min)	Total Time (min)	Segment Fuel (lbs)	Total Fuel (lbs)	Fuel Remaining (lbs)
TOC	100	-5	0	90	15	15	10	10	100	100	1644
BOD	100	-5	0	158	203	218	77	87	642	742	1002
Dest	0	15	0	171	57	275	20	107 1:47 (hr:min)	180	922	822

Alt : Altitude
BOD : Beginning of descent
Dest: Destination
Dist: Distance
hr : Hours
kts : Knots
min : Minutes
nm : Nautical miles
Temp: Temperature
T/O : Take-off
TOC : Top of climb

Fuel for taxi and runup	100
Fuel to destination	922
Fuel to alternate	330
Fuel for reserve	392
Total required (lbs)	1744

(Approx 2550 lbs payload available)

* Assumptions: No wind; standard temperature day; gross weight 11,579 lbs at T/O; 100 lbs fuel for taxi and runup; 30 minutes to alternate @ 5,000; maximum power used for T/O and climb; 45 minutes reserve fuel at normal cruise; 500/min rate of descent for unpressurized aircraft.

** Altitude and altitude temperature will approximately hold for most commuter aircraft flying over the given stage length.

TABLE 16. SAMPLE MEDIUM-RANGE FLIGHT PLAN DHC-6-100 OR 200*: 150 NAUTICAL MILES

To:	Alt (100ft)	Temp** (°C)	Wind	Ground Speed (kts)	Segment Distance (nm)	Total Dist (nm)	Segment Time (min)	Total Time (min)	Segment Fuel (lbs)	Total Fuel (lbs)	Fuel Remaining (lbs)
TOC	800	-1	0	94	11	11	07	07	75	75	1267
BOD	800	-1	0	155	93	104	37	44	300	375	967
Dest	0	15	0	172	46	150	16	60	145	520	822

Alt : Altitude
BOD : Beginning of descent
Dest: Destination
Dist: Distance
kts : Knots
min : Minutes
nm : Nautical miles
Temp: Temperature
T/O : Take-off
TOC : Top of climb

Fuel for taxi and runup	100
Fuel to destination	520
Fuel to alternate	330
Fuel for reserve	392
Total required (lbs)	1342

(Approx 2,950 lbs payload available)

* Assumptions: No wind; standard temperature day; gross weight 11,579 lbs @ T/O; 100 lbs fuel for taxi and runup; max power used for T/O and climb; 45 min reserve fuel at normal cruise; 500/min rate of descent for unpressurized aircraft.

** Altitude and altitude temperature will approximately hold for most commuter aircraft flying over the given stage length.

TABLE 17. SAMPLE SHORT-RANGE FLIGHT PLAN DHC-6-100 OR 200*: 50 NAUTICAL MILES

To:	Alt (100ft)	Temp** (°C)	Wind	Ground Speed (kts)	Segment Distance (nm)	Total Dist (nm)	Segment Time (min)	Total Time (min)	Segment Fuel (lbs)	Total Fuel (lbs)	Fuel Remaining (lbs)
TOC	40	7	0	100	5	5	03	03	40	40	1002
BOD	40	7	0	149	73	28	09	12	105	145	897
Dest	0	15	0	164	22	50	08	20	75	220	822

Alt : Altitude
BOD : Beginning of descent
Dest: Destination
Dist: Distance
hr : Hours
kts : Knots
min : Minutes
nm : Nautical miles
Temp: Temperature
T/O : Take-off
TOC : Top of climb

Fuel for taxi and runup	100
Fuel to destination	220
Fuel to alternate	330
Fuel for reserve	392
Total required (lbs)	1042

(Approx 3250 lbs payload available)

* Assumptions: No wind; standard temperature day; gross weight 11,579 lbs @ T/O; 100 lbs fuel burn for taxi and runup; 30 min to alternate @ 5000; max power used for T/O and climb; 45 min reserve fuel at normal cruise; 500/min rate of descent for unpressurized aircraft.

** Altitude and altitude temperature will approximately hold for most commuter aircraft flying over the given stage length.

Some basic assumptions are built into these flight plans. These assumptions include the following:

- standard temperature day;
- zero wind speed;
- optimal cruise speed at altitude; and
- full payload, including specific fuel complement.

For flight planning purposes, a standard temperature day is one where sea level temperature is approximately 59°F. Variations from the standard are measured and may influence the pilot's decisions with respect to cruise altitude or other operational considerations. In practice, actual flying conditions are likely to vary from the standard. The assumption of zero wind is made in order to simplify the calculations and reflect the differences between east- and west-bound traffic. Head (or tail) winds may necessitate the use of more (or less) fuel, and add to flight time. Table 18 presents a list of selected variables which can alter the composition of a flight plan.

TABLE 18. VARIABLES FOR A TYPICAL FLIGHT PLAN

1. Gross weight of aircraft including payload and fuel
2. Temperature-ground, aloft
3. Restricted altitude, unable to use most efficient route due to traffic
4. Winds aloft
5. Forecast turbulence at altitude
6. Choice of, and distance to, alternate
7. Enroute weather deviations
8. Expected traffic delays

An emergency procedure which may be of concern with respect to aircraft utilizing antimisting fuel is fuel dump at altitude in the case of emergency landings. For flights aborted shortly after take off, a standard procedure involves the jettisoning of unburned fuel. With Jet A, the dumped fuel is vaporized and dispersed in the atmosphere. Further examination of how the properties of antimisting fuel would effect this emergency procedure may be warranted.

5. ECONOMIC FACTORS

The economic factors which are of concern with respect to the introduction and use of antimisting fuel may be viewed from several different perspectives. For example, innovation and change in fuel and aircraft technology may profoundly affect aircraft manufacturers and other suppliers. One economic effect of technological change may be the entry of new firms supplying antimisting additives, carrier fluids, or devices to restore physical properties of the fuel. From the viewpoint of aircraft operators, the use of antimisting fuel may have significant impacts on the costs of providing air travel services. To consumers of these services, the use of the new fuel may increase demand for the services by increasing the safety of air travel or decrease the amount of discretionary travel due to the higher cost.

From among these various perspectives, the principal concern is with how the use of antimisting fuel in the commercial aircraft fleet may affect the operations of domestic airlines. In order to understand and address this concern, we examined specific costs of airline operations which may be affected by the introduction and use of antimisting fuel. While the economic factors related to industry suppliers, consumers, and the government are also important, the focus in this Section will be on the aircraft operators. Factors relating to suppliers to the airlines and consumers of air carrier services will be addressed in these discussions concerning the carriers.

The introduction of antimisting fuel may affect several elements of costs for air transportation including capital, operating, servicing, and maintenance costs. Increased capital cost may result from increases in the price of new aircraft, retrofit expenditures for existing aircraft, or retrofit expenditures for the modification or addition of ground facilities. The major operating cost element will be the cost of antimisting fuel. Aircraft servicing and maintenance costs may also be increased. The impact of introducing antimisting fuel on each of these cost elements is discussed briefly below.

CAPITAL COSTS.

The introduction of antimisting fuel could require additional capital expenditure by aircraft operators and aircraft manufacturers. These capital expenditures are discussed below for four major categories of expenditure including: aircraft currently in use in the commercial fleet; aircraft in production; new, proposed aircraft, not yet in production; and ground facilities.

The introduction of antimisting fuel could affect the capital expenditure programs of aircraft operators by requiring the retrofit of existing aircraft to accomodate use of the new fuel. This retrofit of aircraft currently in the commercial fleet may be necessary to provide performance characteristics comparable to those attained with existing fuel types. A retrofit program would result in modification of existing aircraft systems (i.e., the airframe fuel and engine systems) through the redesign, replacement, or addition of components. The necessity of such a retrofit program would involve trade-offs against other uses of capital. For example, the allocation of capital resources could be shifted from expansion of the fleet through acquisition of new aircraft toward modifying existing aircraft to meet the requirements of antimisting fuel. Alternatively, modernization of the fleet could be accelerated if portions of the fleet are retired early due to the costs of retrofitting existing aircraft. Clearly, the extent and direction of such trade-offs would be determined primarily by the costs of a major retrofit program.

Modification programs have, in the recent past, involved a significant capital commitment by aircraft operators. Examples of such modification programs are the re-engining of the McDonnell-Douglas DC-8, and the engine noise reduction program for the Boeing 707. A recent proposal for another major modification program involves a reconfiguration of the Boeing 727 from a 3-engine to a 2-engine aircraft to improve fuel efficiency. A program such as this is attractive to aircraft operators since it allows for the modernization of portions of the fleet at a capital cost substantially less than the cost of new aircraft purchases. However, such modifications do not typically allow for growth in fleet capacity, which is achieved primarily through acquisition of new aircraft. Similarly, the use of capital to convert aircraft to antimisting fuel use will not directly induce growth in airline capacity or productivity. Hence, the modification of existing aircraft in response to the introduction of antimisting fuel will compete for capital resources that might otherwise be used to finance expansion.

The extent to which such competition will occur will depend on the current utilization of capacity by aircraft operators, and the anticipated growth in demand for air travel. In the past, the industry has faced situations of overcapacity which have necessitated the disposal of aircraft well before the end of the typical 20-year useful life of modern aircraft. The response of the industry to mandated introduction of antimisting fuel in a situation of overcapacity might be to reduce capacity through early retirement of underutilized aircraft, rather than to incur the expense of retrofit. Such economic decisions depend critically on the actual costs of achieving compatibility between existing aircraft operating systems and the flow, atomizing, and burn characteristics of antimisting fuel.

At this stage, precise information on the extent of these costs is not available. While detailed information on the costs of retrofit are uncertain, there is information available on other capital commitments of the airlines. Consideration of these financial commitments is useful, particularly since a major component of capital expenditure is the acquisition of new aircraft.

Capital requirements for new aircraft acquisition are composed of two principal elements. These include the need to replace aircraft rendered obsolete by advances in aviation technology and other factors, and the need to expand capacity through the addition of aircraft to the fleet. For the period 1977-1989, the capital requirements of the domestic trunk airlines have been estimated at about $83.8 billion (Reference 39). Of this, $33.4 billion are required for replacement purposes, and $50.4 billion are estimated to be necessary to meet the expected growth in demand.

At the end of the third quarter of 1979, the airlines had reported financial commitments to equipment suppliers in excess of $24 billion, including aircraft on order, modifications, spare parts, and ground property and equipment. Of this total, $10.6 billion was committed for the acquisition of new aircraft (Reference 40). Included in these acquisitions were 21 Boeing 757 and an estimated 91 Boeing 767 aircraft. By mid-1981, about 100 orders for the 757 were expected to be placed, with about 170 orders for the 767 (Reference 41).

Commitments for the purchase of these aircraft represent a major fleet modernization and/or expansion effort by the large trunk air carriers. Many of these new aircraft will enter revenue service by the mid-1980's. Hence, the introduction of antimisting fuel will affect many of these aircraft in a manner similar to aircraft already in operation. That is, existing commitments to design, production tooling, and delivery schedules will mean that retrofit will be required for aircraft delivered before commercialization or promulgation of regulations mandating use of antimisting fuel. Opportunities may exist for incorporation of aircraft-fuel design compatibility in the production stage for aircraft scheduled to be delivered in the latter part of the 1980's or early 1990's.

A different set of capital costs will be encountered for existing aircraft designs and those developed after the introduction of antimisting fuel. For the latter group, aircraft manufacturers may initially bear a portion of the total capital cost, since incorporating antimisting fuel-compatible design into production aircraft may entail changes in production equipment and tooling. However, any such changes in the manufacturers' fixed costs are likely to be reflected in the pricing structure. Similarly, any changes in production schedules or manufacturers' variable costs, including labor and materials, will also be reflected in delivered aircraft prices. The capital cost for pre-production aircraft should be less than that expected for existing aircraft due to the greater efficiency of designing and manufacturing an aircraft with an antimisting fuel-compatible design rather than modifying an aircraft with an incompatable design. While obtaining such efficiencies would add to the development and pre-production costs of aircraft manufacture, they should result in lower costs for producing an aircraft with the capability of using antimisting fuel, when compared to converting existing aircraft to an antimisting fuel-compatible state. Thus, an important consideration in the implementation of antimisting fuel use in the commercial fleet is the impact of the timing of its introduction on the design and production of new aircraft. While antimisting fuel may accelerate the phase-out of older aircraft for which retrofit is not cost-effective, it could also alter the time-frame for the introduction of new aircraft in the latter half of the 1980's and beyond. Such an alteration could come about as advances in fuel system and engine technology, which have recently emphasized fuel efficiency, adjust to the fuel safety emphasis of the antimisting fuel program. This adjustment process, which seeks a new level of compatibility between aviation systems and fuel technology, will take time and impose economic costs, including higher costs of aircraft, fuel, and air travel. Assessment of the magnitude of these costs requires further research.

FUEL COSTS.

The component of operating costs most likely to be affected by the introduction of antimisting fuel is fuel costs. Fuel costs may be affected in three principal ways. First, the unit cost of antimisting fuel will be higher than that of Jet A, primarily due to the additional material, processing, and blending costs of the polymeric additive and carrier fluid. Second, consumption of antimisting fuel may be greater than that of Jet A because of additional power requirements associated with in-line devices used to restore the properties of the fuel. As a result of the increased level of fuel consumption, total fuel costs will be increased.

In recent years, fuel has come to represent an increasingly significant cost element for aircraft operations. For example, between 1970 and 1980 domestic trunk and local service carriers experienced a compound rate of increase in total fuel costs (in nominal terms) of approximately 24% per year. Over this period, fuel costs for carriers increased from $1.1 billion to $9.2 billion (Reference 42). By 1980, at least one carrier was forecasting fuel costs for its operations alone to reach $1 billion before 1982 (Reference 43).

While fuel costs were rising so dramatically, the efficiency of fuel use by air carriers also increased significantly. One measure of the efficiency of fuel consumption in commercial aviation operations is the number of available seat-miles generated per gallon of fuel. In 1970, the scheduled carriers produced 27.6 available seat-miles per gallon. In 1980, over 42 available seat-miles per gallon were produced. It is of interest to note that during this period fuel consumption increased at a rate of only 0.6% per year. The low rate of increase in fuel consumption reflects the more conservative use of fuel, given higher and rising prices. This increase in efficiency was due in large measure to the increasing use of more fuel-efficient power plants. Another trend associated with the rise in fuel efficiency has been the introduction and use of wide-bodied aircraft, which have enabled carriers to generate substantially more available seat-miles.

In spite of these trends indicating slow growth in fuel consumption and improvement in fuel efficiency, the airlines are faced with a growing burden of fuel costs. In 1970, fuel costs represented about 13% of operating expenses for trunk and local service airlines. By 1980, the proportion of fuel costs in total operating expenses had increased to over 30%. Fuel costs represent an even higher percentage of expenses for flying operations (Reference 44). For example, for the Boeing 747, fuel costs (including oil) accounted for over 77% of flying operation expenses, and over 51% of total aircraft operating expenses. Table 19 (Reference 45) presents data on fuel costs as a percentage of operating costs based on flying operations alone and total aircraft operations for trunk carriers and local service carriers.

In the face of such increasing costs, the response of the carriers has been to control fuel costs through increased efficiency of operations. For example, more careful flight planning and operational decisions by flight personnel can significantly reduce fuel consumption. More frequent maintenance of the airframe and engines are also important in improving fuel efficiency. Since such operational and maintenance decisions are to an extent discretionary, there is variation among the airlines in the success achieved in reducing fuel consumption. A more important factor in determining the extent to which fuel consumption can be improved is the composition of an airline's fleet. Carriers operating older, less efficient aircraft are constrained in their efforts to conserve fuel through improved operational procedures by the physical limitations of the aircraft. As a result, major capital programs are undertaken to obtain more dramatic improvements in fuel use. Examples are the previously mentioned re-engining of the DC-8 and the recently proposed re-engining of the B-727. In addition to the number and type of engines, other factors on which fuel consumption for a particular aircraft and hence total average fuel costs depend include physical factors such as the age, weight, and condition of the equipment.

TABLE 19. FUEL COSTS AS A PERCENTAGE OF OPERATING COSTS (taken from Reference 45)

	Flying Operations*		Total Aircraft Operating Expenses**	
	1979 (percent %)	1978	1979 (percent %)	1978
Trunk Carriers				
A-300B	67.0	60.7	45.6	41.3
B-707-100B	68.7	63.0	47.7	41.0
B-707-300	63.2	66.5	52.7	49.6
B-707-300B	70.0	64.1	49.2	43.0
B-707-300C	66.8	61.0	49.4	43.6
B-720B	61.1	59.1	41.5	36.5
B-727-100	62.2	58.6	46.1	40.2
B-727-100C/QC	68.1	60.5	50.2	41.7
B-727-200	68.0	61.8	42.9	43.5
B-737-200	53.1	48.2	36.7	33.8
B-747	77.3	72.9	51.7	42.9
L-1011	73.4	67.2	45.1	37.0
DC-8-50	67.3	62.3	49.0	43.5
DC-8-61	68.1	64.0	48.3	43.0
DC-8-62	66.0	60.0	46.4	37.0
DC-9-10	58.6	52.0	42.0	34.8
DC-9-30	63.1	56.7	46.7	39.1
DC-9-50	65.0	56.8	47.9	39.2
DC-10-10	68.9	66.0	42.9	39.4
DC-10-30	N/A	68.3	N/A	44.4
DC-10-40	75.5	67.1	50.0	37.9
Local Service				
Aerospatiale MO 298	28.8	37.7	10.0	13.2
BAC 111	59.9	54.7	41.3	34.8
B-727-200	62.2	52.2	46.6	39.0
B-737-200	64.9	58.0	45.6	38.0
DHC-6	31.3	22.0	20.0	14.0
FH-227	45.8	47.1	22.9	23.5
F-27	N/A	36.9	N/A	17.5
CV-580	51.4	44.2	30.3	23.7
CV-600	N/A	43.0	N/A	26.9
DC-9-10	66.2	60.1	46.9	41.1
DC-9-30	64.3	54.6	44.8	39.5
DC-9-50	67.5	58.4	52.3	42.6
NAMC-YS-11	52.4	47.0	29.3	25.1
Swearingen Metro II	37.0	40.0	11.3	17.1

* Includes fuel, flight crew, insurance, and other costs directly related to flying operations.

** Includes in addition to flying operations: maintenance depreciation, and amortization costs.

N/A: Not Available

The efforts of operators to optimize consumption through controlling physical and operational variables have succeeded in slowing the growth rate of fuel consumption. As shown in Table 20 (Reference 46), the aggregate level of jet fuel consumption for certificated route carriers was relatively stable throughout the 1970's. The wide variation in fuel consumption characteristics of turbine-powered aircraft of domestic carriers is shown in Tables 21 (Reference 47) and 22 (Reference 48).

TABLE 20. CERTIFICATED CARRIER JET FUEL CONSUMPTION (taken from Reference 46) (million gal.)

Year	Trunk	Local Service	Other*	Total
1969	7272	542	70	7884
1970	7105	609	68	7782
1971	7050	610	68	7728
1972	7172	642	72	7886
1973	7451	728	85	8264
1974	6612	720	90	7422
1975	6650	726	100	7476
1976	6945	786	108	7839
1977	7240	860	N/A	8100
1978	7500	900	N/A	8400
1979	7900	1000	N/A	8900
1980	7400	1100	N/A	8500

*Includes Intra-Alaskan, Intra-Hawaiian, etc.

Note: Totals may not sum due to rounding.

N/A: Not Available

Table 21 compares fuel consumption characteristics of selected aircraft under three different operating regimes: maximum cruising speed, cost-economical operations, and long-range operations. These data show differences in fuel consumption between various types of aircraft, as well as indicating such differences for the same aircraft operating under different conditions. In addition, for certain aircraft, the effect of the power plant option on fuel consumption is also indicated.

Table 22 presents data on fuel consumption characteristics of various aircraft in certificated route service based on operational data for 1979. For all trunk aircraft during that year, the range of fuel consumption varied between 834 gallons/block hour (for the Boeing 737-200) and 3,238 gallons/block hour (for Boeing 747). The average rate of fuel consumption for the trunk operations of the Boeing 727-200, for example, was 1,325 gallons/hour in 1979. The range of fuel consumption for this aircraft among trunk carriers varied from 1,282 to 1,384 gallons/hour.

The degree of success in minimizing fuel consumption is indicated by the fact that between 1978 and 1979, the rate of fuel consumption in the commercial fleet decreased at an average rate of about 0.6% for the trunk carriers in domestic operations (Reference 49). For local service operations, fuel consumption rates for jet aircraft were decreased by an average of about 1.6%, although the rate

TABLE 21. FUEL CONSUMPTION OF SELECTED TRANSPORT AIRCRAFT IN U.S. COMMERCIAL FLEET (taken from Reference 47)

Aircraft Mfr/Model	Fuel consumption					
	Max. Cruise		Cost-Economical		Long-Range	
	lb/hr	kg/hr	lb/hr	kg/hr	lb/hr	kg/hr
AIRBUS INDUSTRIE						
A300B2-200	16,905	(7,665)	12,600	(5,715)	12,070	(5,475)
A300B2-300	16,210	(7,350)	12,858	(5,705)	12,035	(5,460)
A300B4-100	14,350	(6,510)	13,285	(6,025)	12,900	(5,850)
A300B4-200	14,770	(6,700)	13,800	(6,260)	13,580	(6,160)
A310-200	13,870	(6,290)	10,330	(4,685)	9,650	(4,375)
BOEING						
727-200	15,000	(6,804)	10,000	(4,536)	9,500	(4,309)
737-200	9,880	(4,481)	5,815	(2,638)	5,295	(2,048)
747-100B SR	28,200	(12,790)	23,000	(10,430)	23,000	(10,430)
747-200B (PW JT9D07J)	28,200	(12,790)	23,000	(10,430)	23,000	(10,430)
747-200B (PW JT9D-7R4G)	30,300	(13,740)	23,700	(10,750)	24,300	(10,980)
747-200B (GE CF-50)	29,500	(13,380)	24,500	(11,260)	25,100	(11,390)
747-200C (RR RB.211)	30,300	(13,740)	23,700	(10,750)	24,200	(10,980)
747-200F	30,300	(13,740)	23,700	(10,750)	24,200	(10,980)
747SP	26,100	(11,840)	20,800	(9,435)	21,000	(9,525)
767-200 (P&W JT8D)	15,900	(7,212)	9,500	(4,309)	9,500	(4,309)
767-200 (GE CF6-80A)	14,700	(6,663)	9,400	(4,264)	9,400	(4,264)
767-200 (P&W JT9D)	15,500	(7,212)	9,700	(4,400)	9,700	(4,409)
757-200 Basic	11,630	(5,275)	N/A	N/A	8,144	(3,892)
BRITISH AEROSPACE CORP.						
One-Eleven	6,059	(2,746)	N/A	N/A	4,300	(1,850)
One-Eleven	6,111	(2,772)	N/A	N/A	4,993	(2,247)
146-100	5,140	(2,331)	3,960	(1,796)	3,778	(1,714)
146-200	5,531	(2,509)	4,443	(2,015)	4,386	(1,989)
FOKKER						
F.28 Mk 3000	14,700	(6,663)	9,400	(4,264)	9,400	(4,264)
F.28 Mk 4000	4,980	(2,260)	4,784	(2,180)	3,252	(1,475)
LOCKHEED						
L-1011-1 TriStar	18,000	(8,165)	15,700	(7,121)	15,400	(6,985)
L-1011-100	17,500	(7,938)	15,200	(6,895)	15,200	(6,895)
L-1011-200	17,500	(7,938)	15,500	(7,031)	15,800	(7,167)
L-1011-500	17,300	(7,847)	15,300	(6,940)	16,000	(7,258)
MCDONNEL-DOUGLAS						
DC-8-71	15,500	(7,030)	10,200	(4,630)	9,610	(4,360)
DC-8-72	15,180	(6,890)	9,870	(4,480)	9,350	(4,240)
DC-8-73	15,580	(7,070)	10,110	(4,590)	9,590	(4,350)
DC-9-30	8,770	(3,980)	6,250	(2,835)	5,040	(2,280)
DC-9-40	8,770	(3,980)	6,250	(2,835)	5,040	(2,280)
DC-9-50	9,980	(4,525)	6,650	(3,015)	6,850	(2,650)
DC-9 Super 80	8,990	(4,077)	6,240	(2,830)	4,910	(2,227)
DC-9 Super 81	9,030	(4,096)	6,240	(2,830)	5,200	(2,357)
DC-10-10	20,882	(9,445)	15,623	(7,086)	15,257	(6,920)
DC-10-15	20,699	(9,389)	16,196	(7,346)	15,976	(7,202)
DC-10-30	21,480	(9,743)	16,447	(7,460)	16,121	(7,313)
DC-10-40	25,819	(11,711)	18,296	(8,299)	18,456	(8,372)

N/A: Not Available.

TABLE 22. AIRCRAFT FUEL CONSUMPTION CHARACTERISTICS FOR 1979 (taken from Reference 48)

Trunk	Gal/Block Hour	RPM*/Gal
A-300B	1822	28.9
B-707-100B	1546	24.1
B-707-300	2093	17.6
B-707-300B	1700	23.1
B-707-300C	1771	24.2
B-720B	1483	23.6
B-727-100	1199	21.3
B-727-100C/QC	1239	19.8
B-727-200	1325	23.0
B-737-200	834	24.1
B-747	3238	36.0
L-1011	1329	29.0
DC-8-50	1699	20.6
DC-8-61	1884	25.2
DC-8-62	1683	26.9
DC-9-10	836	19.2
DC-9-30	872	22.3
DC-9-50	981	26.3
DC-10-10	2191	30.0
DC-10-40	2315	19.2
Local Service		
Aerospatiale MO 298	117	17.6
BAC111	286	17.4
B-727-200	1309	23.7
B-737-200	855	22.8
BHC-6	81	17.0
FH-227	275	15.2
CV-580	333	15.8
DC-9-10	841	18.0
DC-9-30	867	21.5
DC-9-50	952	19.0
NAMC-YS-11	317	16.5
Swearingen Metro II	92	16.1

*Revenue Passenger Miles

of turboprop fuel use increased by about 6%. It is likely that as aircraft operators seek to control costs, incremental improvements in fuel efficiency will continue to be found.

With the introduction of antimisting fuel, fuel cost may become an even more important factor in airline operating expenses. Although antimisting fuel is expected to have an energy value similar to other jet fuels, additional power will in all likelihood be required to restore to antimisting fuel the characteristics of Jet A in the engine. This requirement suggests that the efficiency of conversion of the energy content of antimisting fuel into motive thrust will be less than that for Jet A. Consequently, a higher rate of fuel consumption for antimisting fuel is likely, compared to Jet A, and will result in higher fuel costs for aircraft operations.

Another source of higher fuel costs is associated with the composition of antimisting fuel itself. The addition of the antimisting additive (FM-9 or other additives imparting similar properties) and carrier fluids to jet fuel will increase fuel cost. The extent of the increase in unit fuel cost will depend on factors such as the additive raw material costs and economies of scale possible in production of the additive. The combined effects of potentially higher fuel consumption and higher unit fuel costs due to the introduction of antimisting fuel could reinforce the trend toward the increasing share of fuel costs in operating costs. High fuel costs, combined with highly competitive pricing policies which inhibit the passing through of increased costs to consumers, are among the reasons cited by the airlines for poor financial performance (Reference 50). It is clear that the potential impact of antimisting fuel on operating costs through the fuel component could be of significant magnitude. The magnitude of the impact, in the absence of additional information on the increased costs associated with antimisting fuel, cannot be estimated. However, the sensitivity of costs to changes in fuel costs can be analyzed parametrically (as illustrated in Chapter 6).

MAINTENANCE COSTS.

Other potential increases in operating costs resulting from the introduction of antimisting fuel involve service and maintenance costs for flight equipment. The effect of antimisting fuel on maintenance costs will depend upon the extent to which the behavior of antimisting fuel in the fuel tank and engine systems differs from that of other fuels. Aircraft maintenance consists of two major elements: routine servicing, which occurs during the ground stop at the conclusion of each flight stage; and scheduled maintenance, which involves a periodic, thorough check and repair of aircraft systems. In addition, unscheduled maintenance may also be required to address specific, unanticipated mechanical problems in order to keep the aircraft in safe, airworthy condition. The introduction of antimisting fuel may impose additional operating costs through required changes in routine servicing and scheduled maintenance procedures. Unforeseen maintenance may also increase during the transition from Jet A to antimisting fuel.

One of the routine servicing procedures which may be modified as a result of the introduction of antimisting fuel is the fuel tank refilling procedure. Present fuel tank filling procedures involve the use of a pumper-tanker fuel truck or in-ground hydrant system. With present fuel filling systems and fuel types, fuel tank refilling time depends on factors such as the type of aircraft, the amount of fuel required (including emergency and reserve fuel supplies), and the type of pumping equipment used. The efficiency of aircraft operations through maximization of revenue capacity on an available seat-mile basis is contingent on minimizing the cost of nonrevenue-generating aircraft operations. In particular, minimizing ground stop time in a manner consistent with safety considerations is an important element in overall operational efficiency. Activities which prolong ground stop time can exert an adverse influence on the costs of operations.

If fuel tank filling procedures for antimisting fuel require significantly more time than existing procedures, it is clear that airlines will experience a cost impact. These costs, which will be determined in part by the method used to blend the additive with the fuel, will be in addition to other fuel-related costs associated with antimisting fuel. Three blending scenarios have been proposed. The first, a one-step blending at the refinery, would have the least impact on aircraft refueling procedures. Unfortunately, this scenario is unlikely since frequent pumping and filtering from the refinery to the aircraft could result in unintentional degradation of the fuel. The second blending scenario is in-line mixing of the additive at the aircraft refueling point. This blending scenario has the disadvantage of increasing the energy required to restore the combustion properties of the fuel. The third scenario involving a two-step blending process currently appears more likely. This process includes blending of glycol and polymer in holding tanks, and addition of amine at the aircraft refueling point. Both in-line and two-step blending will involve modifications to the airport fuel delivery mechanisms and may increase the time required for refueling the aircraft.

6. IDENTIFICATION OF CANDIDATES FOR USE OF ANTIMISTING FUEL

The most likely candidates for the use of antimisting fuel can be identified based on the physical, operational, and economic constraints identified in the development of operational profiles, and the potential for reducing fatalities in each segment of the fleet. Since the benefits (and costs) of using antimisting fuels will continue over the life of the aircraft, new equipment will generally have a higher benefit/cost ratio. Benefits are also expected to be greater for aircraft carrying large numbers of passengers or making frequent stops at airports with the most adverse take-off and landing conditions.

It would be premature to do a detailed cost analysis at this time, since specific data on fuel cost increases and retrofit costs are not available. However, a preliminary parametric analysis of possible antimisting fuel-related cost increases is presented below to determine the sensitivity of the impact to economic considerations. The primary benefit of introducing antimisting fuel into the fleet is the potential for reducing injuries and fatalities and fire damage to aircraft. Since the data on post-crash fires is extremely limited (Reference 51), we have not attempted to analyze the differential accident rates in each fleet segment. Differential benefits may also result from differences in aircraft operations which may lower the effectiveness of the antimisting additive under extremes of temperature or other factors. A more comprehensive examination of the potential costs and benefits of introducing antimisting fuel should be conducted prior to the final selection of candidates for use of antimisting fuel.

Two related issues which will affect the introduction of antimisting fuel into the U.S. commercial aviation fleet were addressed:

1. Are there significant advantages to segmentally introducing antimisting fuel into the fleet?

2. Which portions of the fleet are the most likely candidates for the early introduction of antimisting fuel?

The introduction of antimisting fuel presents several potential problems related to the fuel, its compatability with existing aircraft, and its compatability with existing fuel systems. The differences between the physical properties of antimisting fuel and current aviation fuels may require some modifications to the aircraft, airframe fuel system, engine fuel system, engine components, and/or the airport fuel delivery mechanisms.

The extent of these modifications is not yet determined. If the modifications require major changes to the airframe or engine fuel systems or airport operations which are incompatible with the use of currently used aviation fuels, then segmental introduction of antimisting fuel may be necessary to allow sufficient time to retrofit the aircraft and/or airports.

<u>FLEET-WIDE INTRODUCTION OF ANTIMISTING FUEL.</u>

The major advantage to simultaneously introducing antimisting fuel in all segments of the U.S. commercial fleet is that the number of potential lives saved will be maximized. The major disadvantages are that, even with a reasonable lead time, there may be capacity constraints on the number of aircraft which can be modified for the use of antimisting fuel, the number of airports which can be adapted to antimisting fuel use, or the amount of antimisting fuel which can be produced. A further constraint exists if the modifications are not compatible with the use of standard jet fuels (i.e. once an aircraft is modified it cannot switch back and forth between antimisting fuel and Jet A).

The FAA (Reference 52) forecasts an increase in domestic revenue passenger enplanements of 26% by 1984 (6% per year) with a 28% increase in domestic revenue passenger miles. The larger increase in domestic revenue passenger miles reflects a small increase in average trip length from 695 to 709 miles. Similar increases are expected in cargo and international passenger services. Total aircraft in service, including passenger and cargo on domestic and international flights, are also expected to increase but at a much slower rate of 0.8% per year or 3.2% by 1989. Jet fuel consumption for the 1984 air carrier fleet, which includes supplemental, contract and interstate carriers, is estimated to be 11.1 billion gallons (or 42.0 billion liters). Current jet fuel consumption for the 1980 fleet is 10.4 billion gallons (or 39.2 billion liters). The FAA forecast (Reference 53) is summarized in Table 23.

TABLE 23. SUMMARY OF FAA FORECAST
(taken from Reference 53)

	1980	1984	% Change
Revenue Passenger Enplanements (millions)			
Air Carrier			
- Domestic	290.5	365.7	+25.9
- International	25.1	30.6	+21.9
Total	315.6	396.3	+25.6
Commuter Carriers	13.8	20.4	+47.8
Revenue Passenger Miles (billions)			
Air Carrier			
- Domestic	201.9	259.3	+28.4
- International	55.2	67.9	+23.0
Total	257.1	327.2	+27.3
Commuter	1.7	2.5	+47.0
Aircraft in Service			
Carrier			
- Turboprop			
2-engine	175	183	+4.6
4-engine	76	68	-10.5
- Turbojet/Turboprop			
2-engine	665	829	+24.7
3-engine	1262	1349	+6.9
4-engine	501	369	-26.3
- Helicopter	0	0	0
Total	2679	2798	+4.4
Jet Fuel Consumption (millions of gallons)			
Domestic Air Carrier	10370	11097	+7.0
International	2835	2906	+2.5
Total	13205	14003	+6.0

The FAA forecast predicts a shift from 4-engine to 2-engine aircraft in both the turboprop and turbofan fleet. The total number of turboprop aircraft is expected to remain constant, while the number of turbofan aircraft increases by 4.9%. The number of 2-engine aircraft is expected to increase by 20.4%, with a 6.9% increase in 3-engine aircraft, and the number of 4-engine aircraft decreasing by 24.3%. Our review of the 1980 fleet and the number of aircraft on order, as summarized in Table 24 (Reference 54), confirms this trend toward 2-engine aircraft.

TABLE 24. 1980 PASSENGER FLEET AND AIRCRAFT ON ORDER (taken from Reference 54)

	1980 Fleet	Aircraft On Order	Orders as % of Fleet
Turbojet/Turbofan			
4-engine			
Trunk	301	0	0
Local Service	3	0	0
Total	304	0	0
3-engine			
Trunk	1237	70	5.7
Local Service	65	6	9.2
Total	1302	76	5.8
2-engine			
Trunk	195	282	144.6
Local Service	490	90	18.4
Total	685	372	54.3
Turboprop			
4-engine			
Trunk	0	0	0
Local Service	5	4	80.0
Total	5	4	80.0
2-engine			
Trunk	0	0	0
Local Service	110	9	8.2
Total	110	9	8.2

Based on these projections for 1984 and the assumptions used by the Aerospace Corporation (Reference 55) for fuel and retrofit costs (6.9¢ per gallon for fuel and $100,000 for each aircraft retrofit), the annual fuel cost impact of introducing antimisting fuel into the total U.S. fleet, including cargo and international flights, would be $766 million. The aircraft retrofit cost would be $279.8 million. These results are presented to illustrate the methodology used in the analysis to determine the most likely candidates for use of antimisting fuel. The same methodology can be used to determine the sensitivity of cost impacts to a range of capital and fuel cost increases as shown in Table 25.

Since the retrofit cost is an initial capital expense which will result in benefits over the lifetime of the aircraft, it should be amortized over the physical life of the aircraft. (Appendix D presents a brief summary of the principles of discounted cash flow analysis used to calculate the annualized cost of capital expenditures and the present value of the stream of future fuel costs.) Assuming a real interest rate of 10% and an aircraft life of 20 years, the annualized retrofit cost would be $11,746 per aircraft or $32.85 million for the fleet. The annualized retrofit cost is significantly lower than the annual fuel cost increase of $766 million. (The real interest rate is the cost of borrowing. The current interest rate reflects the rate of inflation as well as the cost of borrowing.)

Alternatively, we can compare the present value of the future stream of fuel costs over a 20-year period with the retrofit costs. The present value of the additional fuel cost discounted at 10% is $6.52 billion for 20 years. Retrofit costs of $279.8 million are approximately 4% of increased fuel costs. Combining the capital costs and the present value of future fuel costs over a 20-year life, yields a present value of total cost of 6.8 billion or $0.86 per revenue passenger enplanement. Cost impacts were normalized by revenue passenger enplanements to reflect the differences in the number of passengers carried.

Table 25 shows the cost of introducing antimisting fuel into the total U.S. fleet in 1984 under a range of assumptions. These include a high and low forecast for commercial aviation activity. The high forecast is based on the FAA forecast for 1984 presented in Table 23. The low forecast assumes no growth in commercial aviation activity from the 1980 level and uses the FAA estimates for 1980. The major differences between the two forecasts are that the higher growth scenario results in a 7% increase in fuel consumption, a 25% increase in revenue passenger enplanements, and a 4% increase in the number of aircraft in service. The high growth in revenue passenger enplanements significantly reduces the present value of total cost per revenue passenger enplanement (Column 5). Given the present macroeconomic conditions of continuing high inflation and unemployment, the high price of fuel, and the limitations on expanding passenger service due to the reduced number of air traffic controllers, the outlook for the commercial aviation industry is not optimistic. The no-growth scenario, based on FAA estimates for 1980 levels of activity, may therefore be more appropriate than the higher growth in revenue passenger enplanments forecast for 1984. The high and low growth scenarios shown in Table 25 are based on averages of the high and low forecasts for number of revenue passenger enplanements that are held constant for each year of the 20-year period.

The most important parameter is clearly the additional cost of fuel. We have selected a high-cost scenario of an additional 6.9¢ per gallon for antimisting fuel and a low-cost scenario of an additional 1.0¢ per gallon. Additional first year fuel costs (Column 2) are calculated by multiplying additional fuel cost per gallon and forecasted fuel consumption for 1984. The present value of additional fuel costs (Column 3) is then computed by dividing Column 2 by the capital recovery factor for the scenario's aircraft life and discount factor.

Another important parameter is the average retrofit cost for adapting existing aircraft to use of antimisting fuel. We have selected a low retrofit cost of $100,000 per aircraft and a high retrofit cost of $500,000 per aircraft. The capital cost (Column 1) is the product of the retrofit cost per aircraft and the number of aircraft forecasted for the 1984 fleet. The present value of total cost (Column 4) is the sum of capital cost and the present value of additional fuel costs (i.e. Columns 1 and 3).

SENSITIVITY ANALYSIS.

The cost impact of introducing antimisting fuel into the entire U.S. commercial fleet is clearly more sensitive to additional fuel cost which extends over the life of the aircraft than to the initial retrofit cost. The trade-off between

TABLE 25. PARAMETRIC ANALYSIS OF IMPACT OF FLEETWIDE INTRODUCTION OF ANTIMISTING FUEL

	SCENARIOS		(1)	(2)	(3)	(4)	(5)
Growth of Aviation Activity	Retrofit Cost (dollars)	Additional Fuel Cost (cents)	Capital Cost (millions$)	Addt'l 1st Year Fuel Cost (millions$)	Pres. Val. of Addt'l Fuel Cost (millions$)	Present Value of Total Cost (millions$)	Pres. Val. of Total Cost Per Rev. Passenger Enplanement ($)
1. Low	500000	6.9	1339.5	911.1	7756.7	9096.2	1.44
2. Low	100000	6.9	267.9	911.1	7756.7	8024.6	1.27
3. Low	500000	1.0	1339.5	132.0	1123.8	2463.3	0.39
4. Low	100000	1.0	267.9	132.0	1123.8	1391.7	0.22
5. High	500000	6.9	1399.0	966.2	8225.8	9624.8	1.21
6. High	100000	6.9	279.8	966.2	8225.8	8505.6	1.07
7. High	500000	1.0	1399.0	140.1	1192.8	2591.8	0.33
8. High	100000	1.0	279.8	140.1	1192.8	1472.6	0.19

fuel, retrofit, and operational and maintenance (O & M) costs varies with the assumed discount rate and aircraft life as well as the forecast for fleet size, revenue passenger enplanements, and fuel consumption.

Assuming a 20-year aircraft life and a 10% discount rate for a fleet of 2,679 aircraft consuming 13.2 billion gallons of fuel per year with 315.6 million revenue passenger enplanements per year, the cost impact per revenue passenger enplanement is:

$0.04 for each $100,000 of retrofit cost per aircraft;
$0.18 for each $0.01/gallon of additional fuel cost; and
$0.04 for each $10,000 increase in annual O & M costs per aircraft.

The tradeoff for this scenario is shown in Figure 10. Each $120,000 of retrofit costs has the same impact ($0.05/revenue passenger enplanement) as $0.0028 additional fuel cost or $14,000 additional O & M cost. The impact analysis of segmental introduction (discussed below) is even more sensitive to additional fuel cost due to differences across fleet segments in fuel consumption and aircraft utilization. Retrofit and O & M costs are also likely to vary across fleet segments depending on the type of aircraft used for that portion of the fleet.

Figures 11 through 13 graphically depict the cost impact per revenue passenger enplanement for a range of retrofit, additional fuel, and additional O & M costs.

SEGMENTAL INTRODUCTION OF ANTIMISTING FUEL.

There are two approaches to segmenting the fleet for the analysis of antimisting fuel use in specific portions of the fleet. The first is based on aircraft type. The fleet can be divided into three major portions and subdivided by the number of engines:

1. Rotorcraft

2. Turboprop
   - 2-engine
   - 4-engine

3. Turbojet/Turbofan
   - 2-engine
   - 3-engine
   - 4-engine

The second approach is to divide the fleet based on operations:

1. International

2. Domestic
   - Trunk
   - Local Service
   - Helicopter Carrier
   - Intra-Alaskan
   - Intra-Hawaiian
   - Other Carrier
   - Regional
   - All-Cargo (not included in this project)

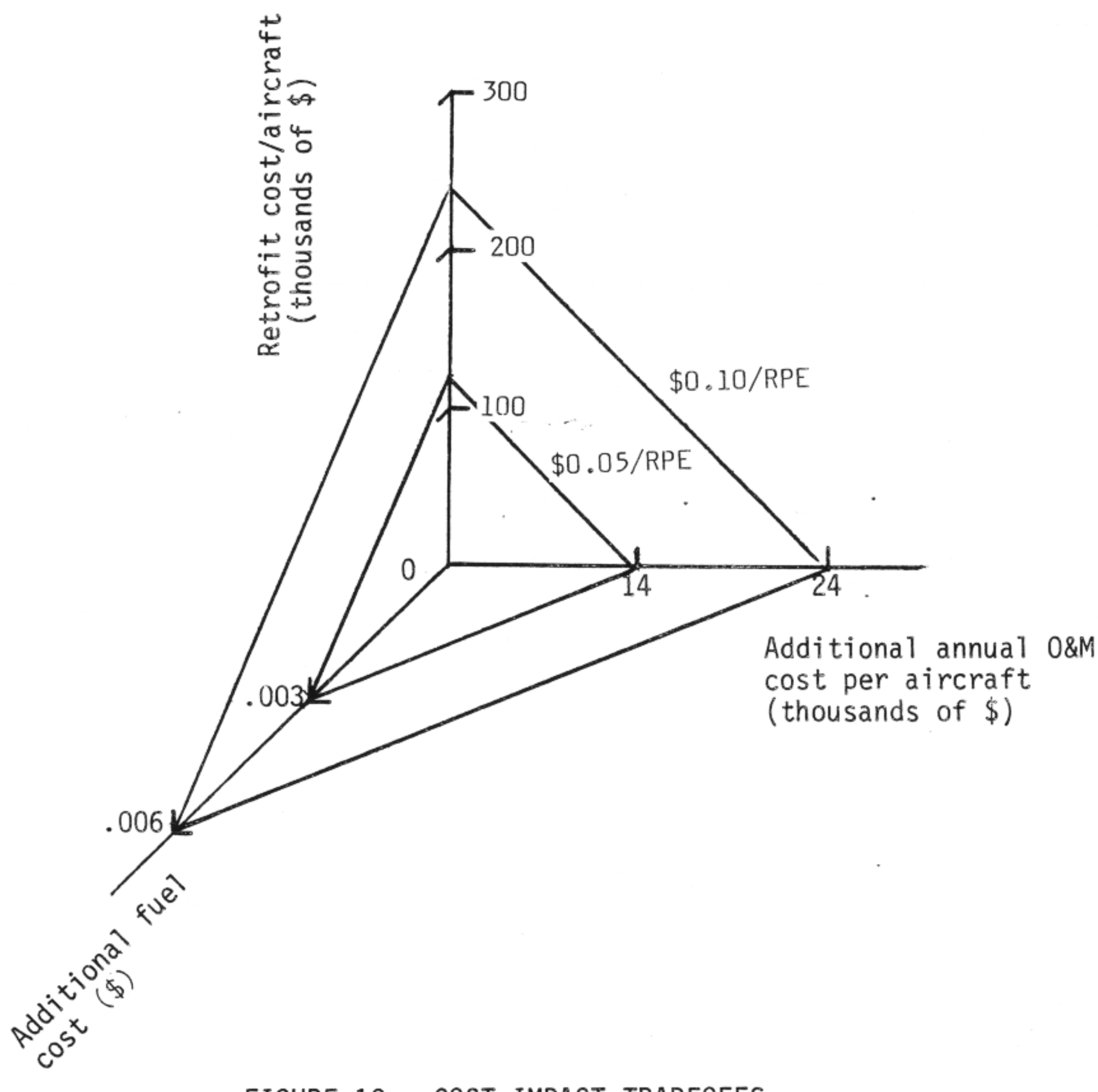

FIGURE 10. COST IMPACT TRADEOFFS
(BASED ON 1980 PASSENGER FLEET)

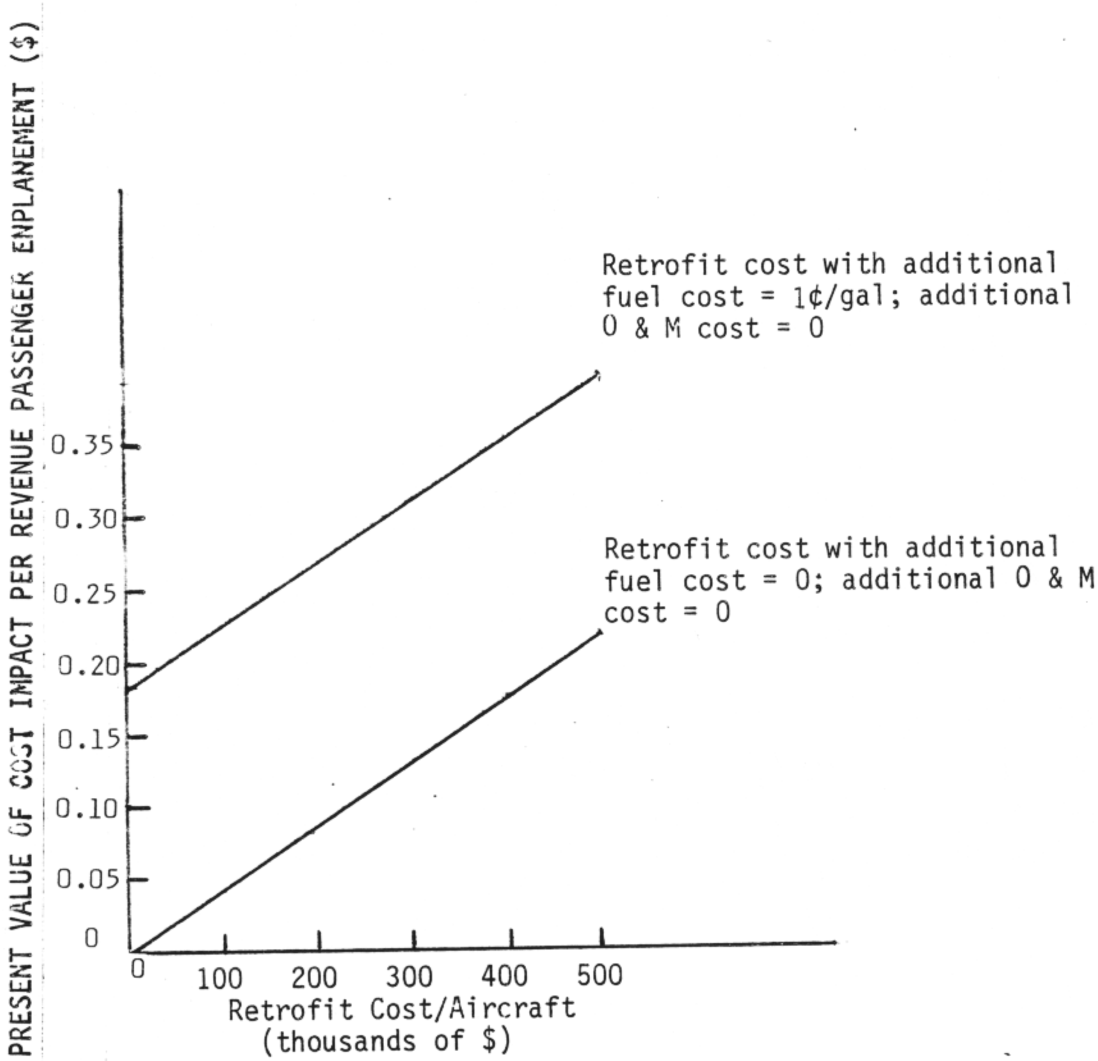

FIGURE 11. IMPACT OF RETROFIT COST
(BASED ON 1980 PASSENGER FLEET)

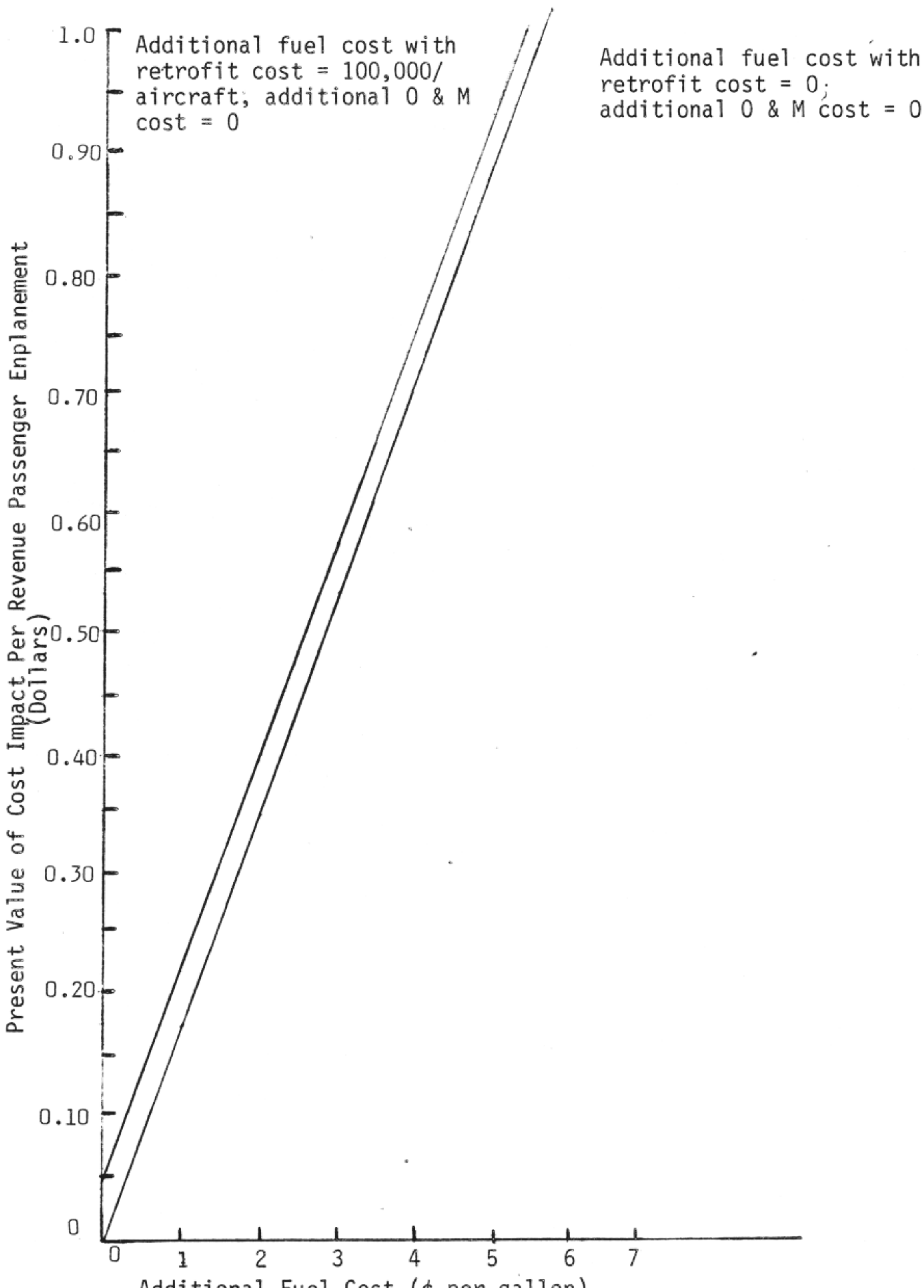

FIGURE 12. IMPACT OF ADDITIONAL FUEL COST
(BASED ON 1980 PASSENGER FLEET)

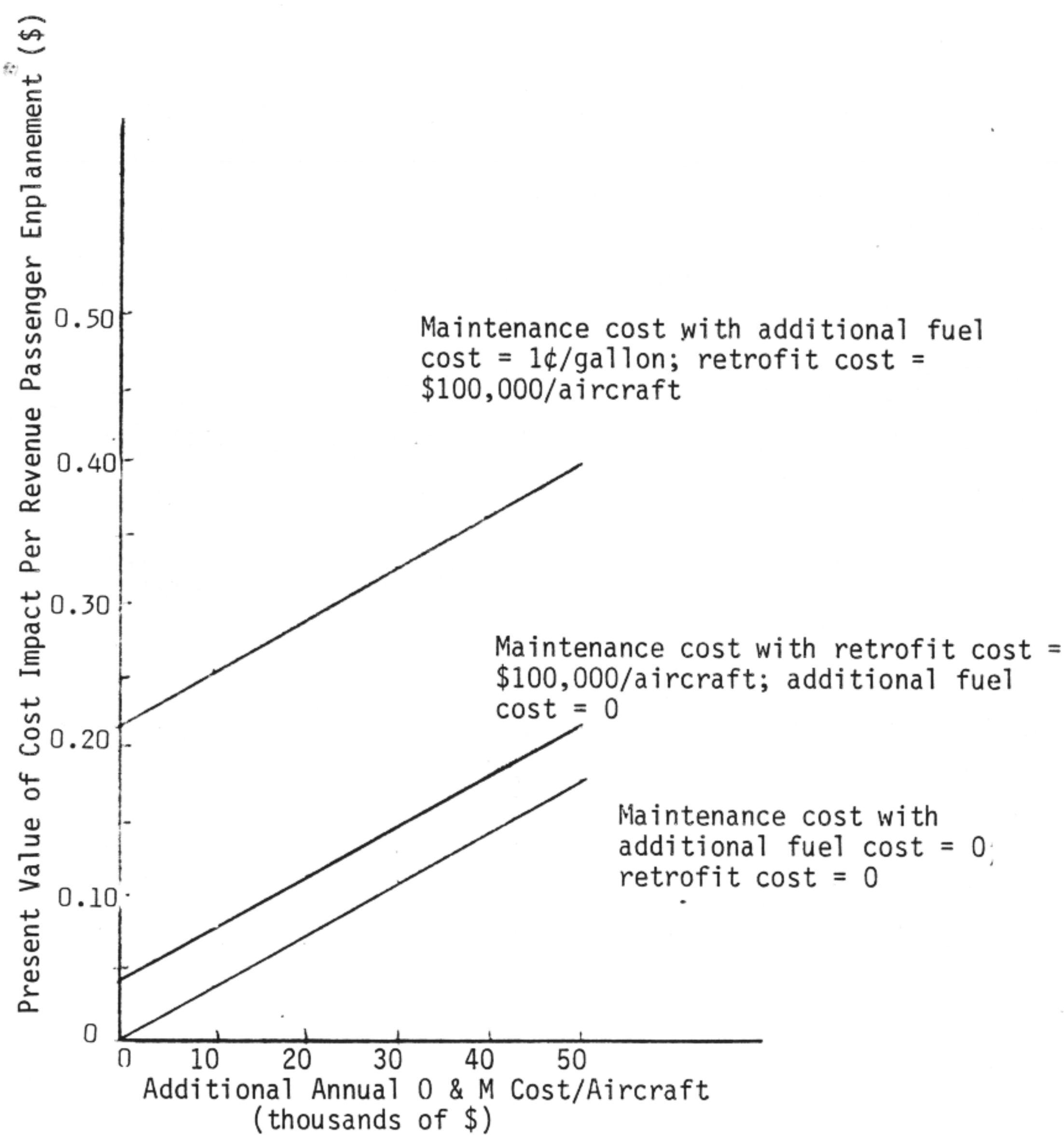

FIGURE 13. IMPACT OF ADDITIONAL MAINTENANCE COST
(BASED ON 1980 PASSENGER FLEET)

The first approach, by aircraft type, is preferable from an engineering point of view. The second approach, by operations, can provide more detailed economic data.

We began by segmenting the fleet by aircraft type to identify for each segment:

- the number of aircraft affected;
- the amount of fuel required; and
- the number of passengers affected (as measured by number of revenue passengers enplaned).

This information is presented in Table 26, compiled from data presented in Reference 56. We can then estimate which segments of the fleet will have the most negative impacts in terms of number of aircraft which may require modifications and increased fuel costs, and the most positive impacts in terms of potential lives saved. Since we did not collect data on the probability of post-crash fire fatalities, we have not calculated the expected value of lives saved. Instead, revenue passenger enplanements was selected as an indicator of potential lives saved.

TABLE 26. SUMMARY OF OPERATIONAL DATA FOR SEGMENTS OF THE 1980 PASSENGER FLEET (taken from Reference 56)

Fleet Segment by Aircraft and Service Type	No. of Aircraft	Mill. of Gal. of Fuel/Year	Total Departures	Total Revenue Passenger Enplanements (Millions)
Turbofan/Turbojet				
4-engine				
wide body - Domestic Trunk	34.9	472.1	34367	8.51
regular body - Domestic Trunk	181.9	1023.7	239339	23.35
3-engine				
wide body- Domestic Trunk	167.1	1366.3	215616	33.10
regular body - Domestic Trunk	847.0	917.7	1870327	147.39
regular body - Non-Trunk	21.2	7.9	54083	3.71
regular body - Alaskan	10.0	40.8	22323	1.49
2-engine				
wide body - Domestic Trunk	7.5	49.1	11483	1.59
regular body - Domestic Trunk	207.4	583.1	591127	38.99
regular body - Non-Trunk	298.6	858.9	1009693	58.30
regular body - Hawaiian	18.1	41.3	82258	7.14
Turboprop				
2-engine				
regular body - Non-Trunk	87.5	63.2	334577	8.69
regular body - Other*	36.5	5.9	101199	1.56

*Other includes Aspen, Wright, Air New England, and Air Midwest.

The capital cost of retrofit and the annual fuel cost of antimisting fuel were then combined using present value analysis to generate the present value of antimisting fuel-related costs per revenue passenger enplaned. Table 27 compares these costs over several segments of the fleet for one scenario; namely, no growth in commercial airline activity, 10% discount rate, 20-year aircraft life, retrofit cost equal to 1% of initial aircraft cost, and 6.9¢ per gallon additional fuel cost.

Under this scenario, the antimisting fuel-related cost impacts are higher for 4-engine aircraft than for 3-engine aircraft, with 2-engine aircraft having the lowest cost. This is due to the greater fuel efficiency of 2-engine aircraft as measured by gallons per revenue passenger enplanement. Within each engine group, wide-bodied aircraft also have higher cost impacts due to their greater fuel consumption levels. The lower cost impacts for non-trunk service reflect the differences in fleet consumption. Within each aircraft type, the present value of total cost per revenue passenger enplaned is virtually the same for the trunk and nontrunk service. For 2-engine, regular-body, turbofan aircraft, the cost impact is estimated at $0.48/revenue passenger enplanement for trunks and $0.47 for nontrunks; for 3-engine, regular-body, turbofan aircraft the cost estimates are $0.82 for trunk service and $0.74 for nontrunk service. Cost impacts for Hawaiian service are much lower reflecting the low fuel consumption rates for Hawaiian passenger service.

SELECTION OF CANDIDATES FOR USE OF ANTIMISTING FUEL.

The analysis presented above demonstrates the methodology used for the selection of candidates for early introduction of antimisting fuel for a single scenario. In this scenario, retrofit cost per aircraft was assumed to be 1% of the initial cost of the aircraft, and additional antimisting fuel-related fuel cost was assumed to be 6.9¢ per gallon. Table 28 presents cost data for this and a few other scenarios with lower retrofit cost and/or lower additional fuel cost.

For each combination of retrofit and fuel costs, we calculated the present value of total cost per departure and per revenue passenger enplanement. These results are presented in Tables 29 and 30 respectively. The conclusions are similar across these various scenarios. The cost impacts are highest for 4-engine aircraft and lowest for 2-engine aircraft. Within each engine group wide-bodied aircraft have higher cost impacts than regular-bodied aircraft. The cost impacts per revenue passenger enplanement for similar types of aircraft are also similar across types of service (i.e. domestic trunk vs. nontrunk).

The introduction of antimisting fuel into the 2-engine, turboprop fleet (the lowest cost impact segment) would contribute to increased safety levels on only 9% of the total departures and cover only 3% of total revenue passenger enplanements. The next lowest cost impact segment is 2-engine, regular-bodied turbofans. The introduction of antimisting fuel to this fleet segment includes an additional 37% of all departures and an additional 32% of all revenue passenger enplanements. The importance of 2-engine, regular-bodied turbofan aircraft in the fleet combined with the relatively low antimisting fuel-related cost impacts in this segment suggests that these aircraft may be the best candidates for early introduction of antimisting fuel.

TABLE 27. COMPARISON OF ANTIMISTING FUEL-RELATED COST BY 1980 FLEET SEGMENT

Fleet Segment by Aircraft and Service Type	1 Capital Cost† (Mill. $)	2 1st Year Fuel Cost†† (Mill. $)	3 Present Value of Cost††† (Mill. $)	4 Present Value of Total Cost (Mill. $)	5 Present Value of Total Cost/ Departure	6 Present Value of Total Cost/Revenue Passenger Enplanement
Turbofan/Turbojet						
4-engine*						
wide body - Domestic Trunk	19.20	32.57	277.29	296.49	431.36	1.74
3-engine						
wide body - Domestic Trunk	58.49	94.27	802.61	861.10	199.68	1.30
regular body - Domestic Trunk	127.05	270.32	2301.39	2428.44	64.92	0.82
regular body - Non-Trunk	3.18	6.07	51.64	54.82	50.68	0.74
regular body - Alaskan	1.50	2.82	23.97	25.47	57.05	0.85
2-engine						
wide body - Domestic Trunk	2.25	3.39	28.84	31.09	135.37	0.98
regular body - Domestic Trunk	29.04	40.23	342.53	371.57	31.43	0.48
regular body - Non-Trunk	41.80	59.26	504.55	546.35	27.06	0.47
regular body - Hawaiian	2.53	2.85	24.26	26.79	16.28	0.19
Turboprop						
2-engine						
regular body - Non-Trunk	2.80	4.36	37.13	39.93	5.97	0.23
regular body - Other**	1.17	0.41	3.47	4.64	2.29	0.15

† Calculated as 1% of initial aircraft cost times number of aircraft in fleet segment.
†† Calculated at 6.9¢ per gallon times the number of gallons consumed by the fleet segment.
††† Present value calculations are based on a twenty-year life with a 10% discount rate.

* Comparative data on capital cost for 4-engined, regular-bodies aircraft are not available.
** Other includes Aspen, Wright, Air New England, and Air Midwest.

TABLE 28. COST DATA FOR ALTERNATIVE SCENARIOS (BY 1980 FLEET SEGMENT)

Fleet Segment by Aircraft and Service Types	Capital Cost Scenarios % of Aircraft Cost X No. of Aircraft = Millions of $			Fuel Cost Scenarios (Millions of $)		
	1%	½%	¼%	6.9¢ PV of Fuel Cost	3¢ PV of Fuel Cost	1¢ PV of Fuel Cost
Turbofan/Turbojet						
4-engine						
wide body - Domestic Trunk	19.20	9.60	4.80	277.29	120.56	40.19
regular body - Domestic Trunk	N/A	N/A	N/A	601.40	261.46	87.15
3-engine						
wide body - Domestic Trunk	58.49	29.24	14.62	802.61	348.96	116.32
regular body - Domestic Trunk	127.05	63.53	31.76	2301.39	1000.60	333.53
regular body - Non-Trunk	3.18	1.59	0.80	51.64	22.45	7.48
regular body - Alaskan	1.50	0.75	0.38	23.97	10.42	3.47
2-engine						
wide body - Domestic Trunk	2.25	1.13	0.56	28.84	12.54	4.18
regular body - Domestic Trunk	29.04	14.52	7.26	342.53	148.93	49.64
regular body - Non-Trunk	41.80	20.90	10.45	504.55	219.37	73.12
regular body - Hawaiian	2.53	1.27	0.63	24.26	10.55	3.52
Turboprop						
2-engine						
regular body - Non-Trunk	2.80	1.40	0.70	37.13	16.14	5.38
regular body - Other*	1.17	0.58	0.29	3.47	1.51	0.50

N/A: Comparable cost data for 4-engined, regular-bodied aircraft are not available since these aircraft are being phased out of the fleet.

*Other includes Aspen, Wright, Air New England, and Air Midwest.

TABLE 29. PRESENT VALUE OF TOTAL COST/DEPARTURE (BY 1980 FLEET SEGMENT)

Fleet Segment by Aircraft and Service Type	1% Retrofit Cost With Additional Fuel Cost Of:			½% Retrofit Cost With Additional Fuel Cost Of:			¼% Retrofit Cost With Additional Fuel Cost Of:		
	6.9¢	3¢	1¢	6.9¢	3¢	1¢	6.9¢	3¢	1¢
Turbofan/Turbojet									
4-engine*									
wide body - Domestic Trunk	431.36	203.33	86.41	417.39	189.37	72.44	410.41	182.38	65.46
3-engine									
wide body - Domestic Trunk	199.68	94.49	40.54	192.90	87.70	33.75	189.51	84.31	30.36
regular body - Domestic Trunk	64.92	30.15	12.31	63.22	28.45	10.61	62.37	27.60	9.77
regular body - Non-Trunk	50.68	23.70	9.86	49.21	22.23	8.39	48.48	21.49	7.66
regular body - Alaskan	57.05	26.70	11.13	55.37	25.02	9.45	54.54	24.19	8.62
2-engine									
wide body - Domestic Trunk	135.37	64.40	28.00	130.50	59.52	23.12	128.02	57.04	20.64
regular body - Domestic Trunk	31.43	15.05	6.66	30.20	13.83	5.43	29.59	13.21	4.81
regular body - Non-Trunk	27.06	12.93	5.69	26.02	11.90	4.66	25.50	11.38	4.14
regular body - Hawaiian	16.28	7.95	3.68	15.52	7.18	2.91	15.13	6.80	2.52
Turboprop									
2-engine - Non-Trunk	5.97	2.83	1.22	5.76	2.62	1.01	5.65	2.52	1.02
2-engine - Other**	2.29	1.32	0.83	2.00	1.03	0.53	1.86	0.89	0.39

* Comparable data on capital cost for 4-engined, regular-body aircraft are not available.

**Other includes Aspen, Wright, Air New England, and Air Midwest.

TABLE 30. PRESENT VALUE OF TOTAL COST/REVENUE PASSENGER ENPLANEMENT ($)

Fleet Segment by Aircraft and Service Type	1% Retrofit Cost With Additional Fuel Cost Of:			½% Retrofit Cost With Additional Fuel Cost Of:			¼% Retrofit Cost With Additional Fuel Cost Of:		
	6.9¢	3¢	1¢	6.9¢	3¢	1¢	6.9¢	3¢	1¢
Turbofan/Turbojet									
4-engine*									
wide body - Domestic Trunk	1.74	0.82	0.35	1.69	0.76	0.29	1.66	0.74	0.26
3-engine									
wide body - Domestic Trunk	1.30	0.62	0.26	1.26	0.57	0.22	1.23	0.55	0.20
regular body - Domestic Trunk	0.82	0.38	0.16	0.80	0.36	0.13	0.79	0.35	0.12
regular body - Non-Trunk	0.74	0.35	0.14	0.72	0.32	0.12	0.71	0.31	0.11
regular body - Alaskan	0.85	0.40	0.17	0.83	0.38	0.14	0.82	0.36	0.13
2-engine									
wide body - Domestic Trunk	0.98	0.47	0.20	0.94	0.43	0.17	0.92	0.41	0.15
regular body - Domestic Trunk	0.48	0.23	0.10	0.46	0.21	0.08	0.45	0.20	0.07
regular body - Non-Trunk	0.47	0.22	0.10	0.45	0.21	0.08	0.44	0.20	0.07
regular body - Hawaiian	0.19	0.09	0.04	0.18	0.08	0.03	0.17	0.08	0.03
Turboprop									
regular body - Non-Trunk	0.23	0.11	0.05	0.22	0.10	0.04	0.22	0.10	0.04
regular body - Other**	0.15	0.09	0.05	0.13	0.07	0.03	0.12	0.06	0.03

*Comparable data on capital cost for 4-engined, regular-bodied aircraft are not available.

**Other includes Aspen, Wright, Air New England, and Air Midwest.

7. CONCLUSIONS

The data assumptions, and analysis presented in the previous chapters lead to the following conclusions:

- Fleet-wide introduction of antimisiting fuel would maximize the benefit interms of increased safety. However, segmental introduction of antimisting fuel can result in higher benefit/cost ratios in the fleet segments with newer equipment. The longer expected life of newer aircraft provides a longer period for the amortization of retrofit costs. More importantly, since newer aircraft are more fuel efficient, the additional annual fuel cost of antimisting fuel will be lower.

- Four-engined aircraft and three-engined aircraft will have higher fuel cost impacts than the more efficient two-engined aircraft. Similiary, wide-bodied aircraft have higher cost impacts than regular-bodied aircraft.

- Cost impacts per revenue passenger enplanement for similar types of aircraft are also similar across types of service (i.e. domestic trunk vs. nontrunk).

- Introduction of antimisting fuel into the two-engined, turboprop fleet would have the lowest unit cost impact, but would not cover enough of the total departures or revenue passenger enplanements, to significantly effect increased safety levels.

- The impact of introducing antimisting fuel in the two-engined, regular-body turbofans would increase safety on a larger proportion of departures and revenue passenger enplanements, and combined with the relatively low anticipated cost impacts in this segment suggests that these aircraft may be the best candidates for early introduction of antimisting fuel.

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31. Source: Air Transport World, May 1980.

32. Source: Aircraft Operating Cost and Performance Report, Vol. XIV, Civil Aeronautics Board, July 1980.

33. Ibid.

34. Ibid.

35. Traffic Data of Certificated Route Air Carriers, Civil Aeronautics Board, Washington, D.C., 1981, pp. 7-9.

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APPENDIX A

U.S. COMMERCIAL FLEET AIRCRAFT AND ENGINE INVENTORY*

Airline	Aicraft	Engine	In Service 6/30/81	On Order 6/30/81
Aeroamerica	Boeing 707-138B	4x P&W JT3D-1	1	-
	Boeing 707-227	4x P&W JT4A-3	1	-
	Boeing 707-321	4x P&W JT4A-12	1	-
	Boeing 707-331	4x P&W JT4A-12	1	-
	Boeing 720-022	4x P&W JT3C-7	1	-
	Boeing 720-027	4x P&W JT3C-7	3	-
	Boeing 720-048	4x P&W JT3C-7	1	-
	Boeing 720-062	4x P&W JT3C-7	1	-
Aeromech	Beech 99A	2x P&WC PT6A-27	3	-
	Beech B99	2x P&WC PT6A-27	2	-
	Embraer EMB-110P1	2x P&WC PT6A-34	3	6
	Embraer EMB-110P2	2x P&WC PT6A-34	2	-
	Embraer EMB-120	2x P&WC PW1002A	-	6
Airborne Express	Aerospatiale Caravelle VIR	2x RR Avon 533R	5	-
	Aerospatiale Corvette 100	2x P&WC JT15D-4	1	-
	Cessna 500 Citation 1	2x P&WC JT15D-1	6	-
	Convair 600	2x RR Dart 542-4	2	-
	Douglas DC-9-32	2x P&W JT8D-7A	1	-
	Gates Learjet 23	2x GE CJ610-4	3	-
	MBB HFB-320 Hansa Jet	2x GE CJ610-9	5	-
	NAMC YS-11A-200	2x RR Dart 542-10K	1	-
	NAMC YS-11A-500	2x RR Dart 542-10K	6	-
Air California-Aircal	Boeing 737-159	2x P&W JT8D-7	2	-
	Boeing 737-2H4	2x P&W JT8D-7	1	-
	Boeing 737-222	2x P&W JT8D-7A	3	-
	Boeing 737-247	2x P&W JT8D-9	2	-
	Boeing 737-293	2x P&W JT8D-7	8	-
	Douglas DC-9-81	2x P&W JT8D-209	-	6
Air Fleets Int'l	Douglas DC-8-33	4x P&W JT4A-11	1	-
Air Florida	Boeing 737-122	2x P&W JT8D-9	4	-
	Boeing 737-222	2x P&W JT8D-7A	7	-
	Boeing 737-2Q9 Advanced	2x P&W JT8D-15	1	-
	Boeing 737-2T4 Advanced	2x P&W JT8D-15	7	5
	Douglas DC-9-15F	2x P&W JT8D-7	5	-
	Douglas DC-10-30CF	3x GE CF6-50C2	3	-

*Source: Exxon, "Turbine Powered Fleets of World's Airlines: 1981," Air World Survey, July 1981.

Airline	Aircraft	Engine	In Service 6/30/81	On Order 6/30/81
Air Illinois	BAe HP-137 Jetstream	2x P&WC PT6A-34	2	-
	BAe HS-748 Series 2A	2x RR Dart 532-2L	1	-
	BAe HS-748 Series 2B	2x RR Dart 536-2	1	-
	DH Canada DHC-6-200	2x P&WC PT6A-20	2	-
	DH Canada DHC-6-300	2x P&WC PT6A-27	2	-
Air Kentucky	Beech 99A	2X P&WC PT6A-27	2	-
	Beech B99	2x P&WC PT6A-27	1	-
Airlift Int'l	Douglas DC-8-33F	4x P&W JT4A-9	2	-
	Douglas DC-8-54F	4x P&W JT3D-3B	3	-
	Douglas DC-8-63F	4x P&W JT3D-7	3	-
Air Miami	CASA C-212-5	2x AiR TPE331-5-251C	1	-
	CASA C-212-200	2x AiR TPE331-10-501C	2	2
Air Midwest	Saab-Fairchild 340	2x GE CT7-5	-	5
	Swearingen SA-226TC MetroII	2x AiR TPE331-3UW-303G	15	-
Air Nebraska	Embraer EMB-110P1	2x P&WC PT6A-34	1	1
Air New England	Convair 580	2x Asn 501-D13D	1	-
	DH Canada DHC-6-100	2x P&WC PT6A-20	2	-
	DH Canada DHC-6-200	2x P&WC PT6A-20	2	-
	DH Canada DHC-6-300	2x P&WC PT6A-27	6	-
	Fairchild FH-227B	2x RR Dart 532-7	2	-
	Fairchild FH-227C	2x RR Dart 532-7	4	-
Air North	Cessna 500 Citation 1	2x P&WC JT5D-1	1	-
	DH Canada DHC-6-100	2x P&WC PT6A-20	2	-
	Grumman G-159 Gulfstream I-C	2x RR Dart 529-8	1	-
	Shorts 330	2x P&WC PT6A-45B	4	-
Air Oregon	Swearingen SA-226TC MetroII	2x AiR TPE331-3UW-303G	6	-
Air US	BAe HP-137 Jetstream	2x AiR TPE331-3UW-303G	3	-
	Grumman G-159 Gulfstream I-C	2x RR Dart 529-8	1	-
Air Virginia	BAe HS-748 Series 2B	2x RR Dart 536-2	-	1
	Swearingen SA-226TC MetroII	2x AiR TPE331-3UW-303G	4	2
Air Wisconsin	DH Canada DHC-7-102	4x P&WC PT6A-50	5	-
	Swearingen SA-226TC Metro	2x AiR TPE331-3UW-303G	7	-
	Swearingen SA-226TC MetroII	2x AiR TPE331-3UW-303G	6	-
Alaska Aero-nautical Ind.	DH Canada DCH-6-100	2x P&WC PT6A-20	4	-
	DH Canada DHC-6-200	2x P&WC PT6A-20	1	-

Airline	Aircraft	Engine	In Service 6/30/81	On Order 6/30/81
Alaska Airlines	Boeing 727-121	3x P&W JT8D-7A	1	-
	Boeing 727-127	3x P&W JT8D-7A	1	-
	Boeing 727-190C	3x P&W JT8D-7A	3	-
	Boeing 727-290 Advanced	3x P&W JT8D-17	2	2
	Boeing 737-200C	2x P&W JT8D-17	1	-
Alaska Central Airways	Govt Acft Factories N024A	2x Asn 250-B17B	1	-
Alaska Int'l Air	Boeing 767-200	2x P&W JT9D-7R4D	-	2
	Lockheed L-382G	4x Asn 501-D22A	5	-
Aloha Airlines	Boeing 737-297	2x P&W JT8D-9	3	-
	Boeing 737-284 Advanced	2x P&W JT8D-9	2	-
	Boeing 737-297 Advanced	2x P&W JT8D-9	4	3
Altair Airlines	Aerospatiale (Nord) 262A	2x Tbm Bastan VIC	7	-
	Beech 99	2x P&WC PT6A-20	3	-
	Beech 99A	2x P&WC PT6A-27	2	-
	Fokker F-28-4000	2x RR Spey 555-15H	6	3
Ambassadair	Boeing 707-123B	4x P&W JT3D-I-MC7	1	-
	Boeing 720-025	4x P&W JT3C-12	1	-
	Boeing 720-048	4x P&W JT3C-7	1	-
American Airlines	Boeing 707-323B	4x P&W JT3D-3	7	-
	Boeing 707-323C	4x P&W Jt3D-3	27	-
	Boeing 727-123	3x P&W JT8D-1	51	-
	Boeing 727-135	3x P&W JT8D-1	3	-
	Boeing 727-195	3x P&W JT8D-1	1	-
	Boeing 727-1A7C	3x P&W JT8D-9	1	-
	Boeing 727-2A7	3x P&W JT8D-9	1	-
	Boeing 727-223	3x P&W JT8D-9	87	-
	Boeing 727-223 Advanced	3x P&W JT8D-15	10	12
	Boeing 727-227 Advanced	3x P&W JT8D-9	15	-
	Boeing 747-123	4x P&W JT9D-3A	8	-
	Boeing 747-123F	4x P&W JT9D-3A	6	-
	Boeing 757-232	*	-	15
	Boeing 767-223	2x GE CF6-80A	-	30
	Douglas DC-10-10	3x GE CF6-6D	34	-
Apollo Airways	BAe HP-137 Jetstream	2x Tbm Astazou XV1F1	6	-
Arctic Circle Air Service	Embraer EMB-110P1	2x P&W PT6A-34	1	-

*The Exxon data base reports that the Boeing 757-232 aircraft on order are equipped with 2x P&W PW2037 engines. The data available from Jane's indicates that the engines ordered for this aircraft are Rolls-Royce RB.211 or GE CF6-32.

Airline	Aircraft	Engine	In Service 6/30/81	On Order 6/30/81
ASAP Air	Govt Acft Factories N-22B	2x Asn 250-B17B	1	-
	Govt Acft Factories N-24A	2x Asn 250-B17B	3	-
Aspen Airways	Convair 580	2x Asn 501-D13H	10	-
Atlantic South East Airlines	DH Canada DHC-6-100	2x P&WC PT6A-20	1	-
	DH Canada DHC-6-200	2x P&WC PT6A-20	2	-
	DH Canada DHC-6-300	2x P&WC PT6A-27	-	1
	Embraer EMB-110P1	2x P&WC PT6A-34	2	-
Atlantis Airlines	DH Canada DHC-6-300	2x P&WC PT6A-27	3	-
Bar Harbor Airways	Beech 99	2x P&WC PT6A-20	12	-
	CASA C-212-200	2x AiR TPE331-10-501C	-	2
	Convair 600	2x RR Dart 542-4	4	-
Bass Aviation	BAe Viscount 745D	4x RR Dart 510	4	-
Big Sky Airlines	BAe HP-137 Jetstream	2x Tbm Astazou XV1F1	3	-
	Swearingen SA-226TC MetroII	2x AiR TPE331-3UW-303G	2	-
Blue Bell Aviation	Canadair CL-44D-6	4x RR Tyne 515-10	1	-
	Mitsubishi MU-2B-30(MU-2G)	2x AiR TPE331-10-501	1	-
	Mitsubishi MU-2B-35(MU-2J)	2x AiR TPE331-10-501	1	-
Braniff Airways	Boeing 727-127	3x P&W JT8D-7A	1	-
	Boeing 727-191	3x P&W JT8D-7A	4	-
	Boeing 727-127C	3x P&W JT8D-7A	7	-
	Boeing 727-130C	3x P&W JT8D-7A	2	-
	Boeing 727-162C	3x P&W JT8D-7A	2	-
	Boeing 727-172C	3x P&W JT8D-7A	1	-
	Boeing 727-2B7	3x P&W JT8D-9	2	-
	Boeing 727-214	3x P&W JT8D-9	1	-
	Boeing 727-227	3x P&W JT8D-9	2	-
	Boeing 727-291	3x P&W JT8D-9	3	-
	Boeing 727-227 Advanced	3x P&W JT8D-9	40	5
	Boeing 727-227 Advanced	3x P&W JT8D-17R	14	5
	Boeing 747-127	4x P&W JT9D-7A	1	-
	Boeing 747-130	4x P&W JT9D-7A	1	-
	Boeing 747-227B	4x P&W JT9D-7Q	1	2
	Boeing 747-230B	4x P&W JT9D-7A	1	-
	Boeing 747SP-27	4x P&W JT9D-7J	1	-
	Douglas DC-8-62	4x P&W JT3D-3B	9	-
	Douglas DC-8-62F	4x P&W JT3D-3B	1	-
Britt Airways	Beech 99	2x P&WC PT6A-20	12	-
	Fairchild FH-227C	2x RR Dart 532-7	2	-
	Swearingen SA-226TC MetroII	2x AiR TPE331-3UW-303G	7	-

Airline	Aircraft	Engines	In Service 6/30/81	On Order 6/30/81
Cape Smythe Air Service	DH Canada DHC-6-100	2x P&WC PT6A-20	1	-
	DH Canada DHC-6-200	2x P&WC PT6A-20	1	-
Capitol Airlines	DH Canada DHC-6-300	2x P&WC PT6A-27	1	-
Capitol Int'l Airlines	Douglas DC-8-61	4x P&W JT3D-3B	5	-
	Douglas DC-8-63F	4x P&W JT3D-3B	2	-
	Gates Learjet 23	2x GE CJ610-4	1	-
Cascade Airways	BAe HS-748 Series 2B	2x RR Dart 536-2	-	4
	Beech 99	2x P&WC PT6A-20	7	-
	Beech 99A	2x P&WC PT6A-27	3	-
	Embraer EMB-110P1	2x P&WC PT6A-34	3	-
Catalina Airlines	Sikorsky S-58ET	1x P&WC PT6T-6	2	-
	Sikorsky S-62A	1x GE CT58-100-1	1	-
Century Airlines	Govt Acft Factories N-24A	2x Asn 250-B17B	2	-
Chaparral Airlines	Beech 99	2x P&WC PT6A-20	1	-
	Beech 99A	2x P&WC PT6A-27	3	-
	CASA C-212-200	2x AiR TPE331-10-501C	2	-
Chautauqua Airlines	Beech 99	2x P&WC PT6A-20	1	-
	Beech 99A	2x P&WC PT6A-27	1	-
	Beech B99	2x P&WC PT6A-27	2	-
	Shorts 330	2x P&WC PT6A-45	2	-
	Shorts 360	2x P&WC PT6A-65R	-	2
Cochise Airlines	Swearingen SA-226TC MetroII	2x AiR TPE331-3UW-303G	3	-
Coleman Air Transport	Douglas DC-9-15C	2x P&W JT8D-7A	1	-
	Grumman G-159 Gulfstream I	2x RR Dart 529-8E	1	-
Colgan Airways	Beech 99	2x P&WC PT6A-20	1	-
	Beech 99A	2x P&WC PT6A-27	1	-
Comair	Embraer EMB-1101P	2x P&WC PT6A-34	2	-
Combs Airways/ Freightair	Cessna 500 Citation 1	2x P&WC JT15D-1	1	-
	Gates Learjet 24D	2x GE CJ610-6	1	-
	Gates Learjet 25	2x GE CJ610-6	1	-
	Gates Learjet 35A	2x AiR TFE731-2-2B	1	-
	Grumman G-159 Gulfstream 1	2x RR Dart 529-8E	1	-
	Lockheed L-188A	4x Asn 501-D13	1	-
	Lockheed L-188A(F)	4x Asn 501-D13	1	-

Airline	Aircraft	Engines	In Service 6/30/81	On Order 6/30/81
Combs Airways/ Freightair (cont.)	Lockheed L-1329 Jetstar 6	4x P&W JT12A-6	1	-
	Lockheed L-1329 Jetstar 731	4x AiR TFE731-3-1F	1	-
Command Airways	Shorts 330	2x P&WC PT6A-45	5	-
Commuter Airlines	Convair 600	2x Asn 501-D13D	2	-
	Swearingen SA-226TC MetroII	2x AiR TPE331-3UW-303G	4	-
Concord Int'l Airlines	Douglas DC-8-21	4x P&W JT4A-9	1	-
	Douglas DC-8-31F	4x P&W JT4A-9	1	-
Continental Airlines	Boeing 727-122	3x P&W JT8D-9	3	-
	Boeing 727-130	3x P&W JT8D-9	2	-
	Boeing 727-151	3x P&W JT8D-9	2	-
	Boeing 727-176	3x P&W JT8D-9	1	-
	Boeing 727-122C	3x P&W JT8D-9	6	-
	Boeing 727-214 Advanced	3x P&W JT8D-9	1	-
	Boeing 727-224	3x P&W JT8D-9	21	-
	Boeing 727-224 Advanced	3x P&W JT8D-9	15	-
	Boeing 727-224 Advanced	3x P&W JT8D-15	4	5
	Douglas DC-10-10	3x GE CF6-6D	7	-
	Douglas DC-10-10F	3x GE CF6-6D	5	-
	Douglas DC-10-30	3x GE CF6-50C2	2	-
Coral Air	Govt Acft Factories N-22B	2x Asn 250-B17B	1	-
	Govt Acft Factories N-24A	2x Asn 250-B17B	4	-
	Shorts 330	2x P&WC PT6A-45B	1	1
Crown Airways	DH Canada DHC-6-200	2x P&WC PT6A-20	1	-
	DH Canada DHC-6-300	2x P&WC PT6A-27	1	-
	Shorts 330	2x P&WC PT6A-45	2	-
Cumberland Airlines	Beech 99	2x P&WC PT6A-20	1	-
Danbury Airways	DH Canada DHC-6-100	2x P&WC PT6A-20	1	-
	Gates Learjet 24A	2x GE CJ610-4	1	-
Delta Air Lines	Boeing 727-291	3x P&W JT8D-15	2	-
	Boeing 727-295	3x P&W JT8D-15	11	-
	Boeing 727-232 Advanced	3x P&W JT8D-15	113	3
	Boeing 757-232	*	-	60
	Boeing 767-232	2x GE CF6-80A	-	42
	Douglas DC-8-51	4x P&W JT3D-1	4	-

*Per Exxon data as noted earlier.

Airline	Aircraft	Engines	In Service 6/30/81	On Order 6/30/81
Delta Air Lines (cont.)	Douglas DC-8-61	4x P&W JT3D-3B	13	-
	Douglas DC-9-32	2x P&W JT8D-7A	36	-
	Lockheed L-1011-1	3x RR RB.211-22B	30	8
	Lockheed L-1011-200	3x RR RB.211-524	1	-
	Lockheed L-1011-500	3x RR RB.211-524B	3	-
Dorado Wings	BAe HP-137 Jetstream	2x AiR TPE331-3U-303G	3	-
Duncan Aviation	DH Canada DHC-6-300	2x P&WC PT6A-27	2	-
	Swearingen SA-226T(B) Merlin 111B	2x AiR TPE331-10U-501G	1	-
Eastern Air Lines	Airbus A300B2-201	2x GE CF6-50C	2	-
	Airbus A300B4-103	2x GE CF6-50C2	17	15
	Boeing 727-125	3x P&W JT8D-7B	44	-
	Boeing 727-125C	3x P&W JT8D-7B	13	-
	Boeing 727-214	3x P&W JT8D-7	4	-
	Boeing 727-225	3x P&W JT8D-7	25	-
	Boeing 727-225 Advanced	3x P&W JT8D-15	41	21
	Boeing 757-225	2x RR RB.211-535C	-	27
	Douglas DC-9-31	2x P&W JT8D-7B	59	-
	Douglas DC-9-51	2x P&W JT8D-15	21	-
	Lockheed L-1011-1	3x RR RB.211-22B	26	-
Eastern Orient Airlines	Boeing 720-027	4x P&W JT3C-7	1	-
Emerald Airlines	Fairchild F-27	2x RR Dart 514-7	1	-
	Fairchild F-27B	2x RR Dart 514-7	1	-
	Fairchild FH-227C	2x RR Dart 532-7	2	-
	Grumman G-159 Gulfstream 1	2x RR Dart 529-8E	1	-
Empire Airlines	Fokker F-28-4000	2x RR Spey 555-15H	1	1
	Swearingen SA-226TC MetroII	2x AiR TPE331-3UW-303G	5	-
Era Helicopters	Convair 580	2x Asn 501-D13H	2	-
	DH Canada DHC-6-100	2x P&WC PT6A-20	5	-
	DH Canada DHC-6-200	2x P&WC PT6A-20	3	-
	Gates Learjet 24B	2x GE CJ610-6	1	-
	Gates Learjet 24D	2x GE CJ610-6	2	-
	Swearingen SA-226TC MetroII	2x AiR TPE331-3UW-303G	1	-
Evergreen Helicopters	Aerospatiale SA-318C	1x Tbm Astazou 11A	4	-
	Bell 212	1x P&WC PT6T-3 Twin-Pac	3	-
	DH Canada DHC-6-30	2x P&WC PT6A-27	8	-
	Gates Learjet 24D	2x GE CJ610-6	1	-
	Sikorsky S-64E	2x P&W JFTD12-4A	1	-

Airline	Aircraft	Engines	In Service 6/30/81	On Order 6/30/81
Evergreen Int'l Airlines	Boeing 727-130C	3x P&W JT8D-7A	1	-
	Douglas DC-8-52	4x P&W JT3D-3B	1	-
	Douglas DC-8-61F	4x P&W JT3D-3B	1	-
	Douglas DC-8-63F	4x P&W JT3D-7	1	-
	Douglas DC-9-32F	2x P&W JT8D-7	3	-
	Lockheed L-188A	4x Asn-501-D13	3	-
	Lockheed L-188A(F)	4x Asn 501-D13	2	-
	Lockheed L-188C	4x Asn 501-D13	1	-
Fairways	Beech 99	2x P&WC PT6A-20	1	-
	DH Canada DHC-6-200	2x P&WC PT6A-20	1	-
	Grumman G-159 Gulfstream 1	2x RR Dart 529-8E	1	-
Federal Express	Boeing 727-022C	3x P&W JT8D-7	13	-
	Boeing 727-024C	3x P&W JT8D-7	1	-
	Boeing 727-025C	3x P&W JT8D-7	7	-
	Boeing 727-116C	3x P&W JT8D-7	1	-
	Boeing 737-252C Advanced	2x P&W JT8D-17	1	-
	Dassault Falcon 20	2x GE CF700-2D	8	-
	Dassault Falcon 20D	2x GE CF700-2D	23	-
	Dassault Falcon 20E	2x GE CF700-2D	1	-
	Douglas DC-10-10CF	3x GE CF6-6D	3	-
Fischer Brothers Aviation	CASA C-212-200	2x AiR TPE331-10-501C	3	-
Fleming Int'l Airways	Douglas DC-8-33F	4x P&W JT4A-9	1	-
	Lockheed L-188A(F)	4x Asn 501-D13	1	-
	Lockheed L-188C	4x Asn 501-D13	3	-
	Lockheed L-188C(F)	4x Asn 501-D13	4	-
Flying Tiger Line	Boeing 747-123F	4x P&W JT9D-7A	3	-
	Boeing 747-132F	4x P&W JT9D-7A	3	-
	Boeing 747-245F	4x P&W JT9D-70A	6	-
	Boeing 747-249F	4x P&W JT9D-7Q	4	-
	Douglas DC-8-61F	4x P&W JT3D-3B	7	-
	Douglas DC-8-63F	4x P&W JT3D-7	19	-
Freedom Airlines	Convair 580	2x Asn 501-D13D	3	-
Frontier Airlines	Boeing 737-200	2x P&W JT8D-9	5	-
	Boeing 737-214	2x P&W JT8D-9	1	-
	Boeing 737-214	2x P&W JT8D-9	4	-
	Boeing 737-222	2x P&W JT8D-9	3	-
	Boeing 737-247	2x P&W JT8D-9	2	-
	Boeing 737-291	2x P&W JT8D-9	5	-
	Boeing 737-2A1 Advanced	2x P&W JT8D-17	2	-

Airline	Aircraft	Engines	In Service 6/30/81	On Order 6/30/81
Frontier Airlines (cont.)	Boeing 737-212 Advanced	2x P&W JT8D-9	1	-
	Boeing 737-291 Advanced	2x P&W JT8D-9	9	-
	Boeing 737-291 Advanced	2x P&W JT8D-17	12	1
	Convair 580	2x Asn 501-D13D	20	-
	DH Canada DHC-6-300	2x P&WC PT6A-27	1	-
	Douglas DC-9-82	2x P&W JT8D-217	-	3
Gibbs Lease Air	DH Canada DHC-6-100	2x P&WC PT6A-20	2	-
Gifford Aviation	Shorts SC-7 Skyvan Srs 3	2x AiR TPE331-201	2	-
Global Int'l Airways	Boeing 707-323B	4x P&W JT3D-3B	1	-
	Boeing 707-331C	4x P&W JT3D-3B	3	-
Golden Gate Airlines	Convair 580	2x Asn 501-D13D	5	-
	DH Canada DHC-7-102	4x P&WC PT6A-50	4	8
	Swearingen SA-226TC MetroII	2x AiR TPE331-3UW-303G	8	3
Golden West Airlines	DH Canada DHC-6-100	2x P&WC PT6A-20	2	-
	DH Canada DHC-6-200	2x P&WC PT6A-20	10	-
	DH Canada DHC-7-102	4x P&WC PT6A-50	3	2
	Shorts 330	2x P&WC PT6A-45	4	-
Great Western Airlines	Convair 580	2x Asn 501-D13D	2	-
Hammonds Air Service	Embraer EMB-110P1	2x P&WC PT6A-34	1	-
Hawaiian Airlines	DH Canada DHC-7-100	4x P&WC PT6A-50	-	3
	Douglas DC-9-32CF	2x P&W JT8D-9A	1	-
	Douglas DC-9-51	2x P&W JT8D-17	8	-
	Douglas DC-9-81	2x P&W JT8D-209	-	6
Henson Aviation	Beech 99A	2x P&WC PT6A-27	3	-
	Beech B99	2x P&WC PT6A-27	2	-
	DH Canada DHC-7-102	4x P&WC PT6A-50	3	-
	Shorts 330	2x P&WC PT6A-45	4	-
Imperial Airlines	Embraer EMB-110P1	2x P&WC PT6A-34	5	-
Inland Empire Airlines	Swearingen SA-226TC MetroII	2x AiR TPE331-3UW-303G	4	-
	Swearingen SA-227AC MetroIII	2x AiR TPE331-11U-601G	-	2
Intercontinental Airways	Douglas DC-8-33	4x P&W JT4A-12	2	-
	Douglas DC-8-33(F)	4x P&W JT4A-12	1	-

Airline	Aircraft	Engines	In Service 6/30/81	On Order 6/30/81
Interstate Airways	Convair 580	2x Asn 501-D13D	11	-
Jamaire	Embraer EMB-110P1	2x P&WC PT6A-34	1	-
Mall Airways	Beech 99	2x P&WC PT6A-20	1	-
Mesaba Airlines	Beech 99	2x P&WC PT6A-20	2	-
Metro Airlines	DH Canada DHC-6-100	2x P&WC PT6A-20	2	-
	DH Canada DHC-6-200	2x P&WC PT6A-20	8	-
	DH Canada DHC-6-300	2x P&WC PT6A-27	6	-
	Shorts 330	2x P&WC PT6A-45	5	-
Metro Int'l Airways	Boeing 747-212B	4x P&W JT9D-7A	3	-
Mid Pacific Airlines	NAMC YS-11A-600	2x RR Dart 542-10K	2	-
Mid-South Commuter Airlines	Embraer EMB-110P1	2x P&WC PT6A-34	1	-
	Embraer EMB-110P2	2x P&WC PT6A-34	1	-
Midstate Airlines	Swearingen SA-226TC MetroII	2x AiR TPE331-3UW-303G	4	-
	Swearingen SA-226TC MetroIIA	2x AiR TPE331-3UW-303G	2	-
	Swearingen SA-227AC MetroIII	2x AiR TPE331-11U-601G	-	1
Midway Airlines	Douglas DC-9-14	2x P&W JT8D-7	1	-
	Douglas DC-9-15	2x P&W JT8D-7	7	-
Mississippi Valley Airlines	Beech 99	2x P&WC PT6A-20	6	-
	Fokker F-27-500	2x RR Dart 532-7	1	3
	Shorts 330	2x P&WC PT6A-45	6	-
Montauk Carribean Airways/Ocean Reef Airways	Bell 206A	1x Asn 250-C18	1	-
	DH Canada DHC-6-100	2x P&WC PT6A-20	1	-
Mountain West Airlines	Embraer EMB-110P1	2x P&WC PT6A-34	4	-
New Air	Embraer EMB-110P1	2x P&WC PT6A-34	2	-
New York Air	Douglas DC-9-32	2x P&W JT8D-9A	6	2
N.Y. Helicopter	Aerospatiale SA-360C	1x Tbm Astazou XVIIIA	7	-

Airline	Aircraft	Engines	In Service 6/30/81	On Order 6/30/81
Northwest Airlines	Boeing 727-151	3x P&W JT8D-7B	4	-
	Boeing 727-151C	3x P&W JT8D-7B	10	-
	Boeing 727-251	3x P&W JT8D-7B	23	-
	Boeing 727-251 Advanced	3x P&W JT8D-15	29	-
	Boeing 747-135	4x P&W JT9D-7	2	-
	Boeing 747-151	4x P&W JT9D-7	10	-
	Boeing 747-251B	4x P&W JT9D-7Q	12	-
	Boeing 747-251F	4x P&W JT9D-7Q	5	-
	Douglas DC-10-40	3x P&W JT9D-20	22	-
Ocean Airways	Beech 99	2x P&WC PT6A-20	1	-
Overseas Nat'l Airways	Douglas DC-8-31	4x P&W JT4A-11	1	-
	Douglas DC-8-33	4x P&W JT4A-11	1	-
	Douglas DC-8-55F	4x P&W JT3D-3B	1	-
Ozark Air Lines	Douglas DC-9-15	2x P&W JT8D-7	7	-
	Douglas DC-9-31	2x P&W JT8D-9	19	-
	Douglas DC-9-32	2x P&W JT8D-9	11	-
	Douglas DC-9-33F	2x P&W JT8D-9	1	-
	Douglas DC-9-34	2x P&W JT8D-17	2	-
Pacific Alaska Airlines	Fairchild F-27F	2x RR Dart 514-7	1	-
Pacific Southwest Airlines	Boeing 727-151	3x P&W JT8D-7	1	-
	Boeing 727-214	3x P&W JT8D-7	10	-
	Boeing 727-254	3x P&W JT8D-7	4	-
	Boeing 727-2Q8 Advanced	3x P&W JT8D-7	1	-
	Boeing 727-214 Advanced	3x P&W JT8D-7	7	-
	Douglas DC-9-81	2x P&W JT8D-209	4	16
Pan American World Airways	Boeing 707-321B	4x P&W JT3D-3B	9	-
	Boeing 727-121	3x P&W JT8D-1	10	-
	Boeing 727-135	3x P&W JT8D-7B	13	-
	Boeing 727-151	3x P&W JT8D-7B	6	-
	Boeing 727-121C	3x P&W JT8D-1	2	-
	Boeing 727-235	3x P&W JT8D-7B	24	-
	Boeing 727-2D4 Advanced	3x P&W JT8D-17R	2	-
	Boeing 727-221 Advanced	3x P&W JT8D-17R	-	8
	Boeing 747-121	4x P&W JT9D-7A	28	-
	Boeing 747-132	4x P&W JT9D-7A	1	-
	Boeing 747-121 Combi	4x P&W JT9D-1	3	-
	Boeing 747-123 Combi	4x P&W JT9D-1	1	-
	Boeing 747-221F	4x P&W JT9D-7A	2	-
	Boeing 747SP-21	4x P&W JT9D-7A	10	-
	Douglas DC-10-10	3x GE CF6-6D	11	-

Airline	Aircraft	Engines	In Service 6/30/81	On Order 6/30/81
Pan American World Airways (cont.)	Douglas DC-10-30	3x GE CF6-50C	4	-
	Lockheed L-1101-500	3x RR RB.211-524B	7	5
Pennsylvania Airlines	Beech 99	2x P&WC PT6A-20	2	-
	Beech 99A	2x P&WC PT6A-27	3	-
	Beech B99	2x P&WC PT6A-27	1	-
	DH Canada DHC-6-300	2x P&WC PT6A-27	3	-
	Mohawk (Nord) 298	2x P&WC PT6A-45	4	-
	Shorts 330	2x P&WC PT6A-45	3	-
People Express Airlines	Boeing 737-130	2x P&W JT8D-7	4	10
Piedmont Airlines	Boeing 727-122	3x P&W JT8D-7B	1	-
	Boeing 727-130	3x P&W JT8D-7B	1	-
	Boeing 727-151	3x P&W JT8D-7B	2	-
	Boeing 727-195	3x P&W JT8D-7B	2	-
	Boeing 737-2H5	2x P&W JT8D-9A	2	-
	Boeing 737-201	2x P&W JT8D-9A	12	-
	Boeing 737-222	2x P&W JT8D-9A	5	-
	Boeing 737-247	2x P&W JT8D-9A	1	-
	Boeing 737-281	2x P&W JT8D-9A	1	-
	Boeing 737-2A1 Advanced	2x P&W JT8D-9A	1	-
	Boeing 737-2Q9 Advanced	2x P&W JT8D-9A	2	-
	Boeing 737-201 Advanced	2x P&W JT8D-9A	14	13
	NAMC YS-11A-500	2x RR Dart 542-10J	6	-
Pilgrim Aviation and Airlines	Beech 99	2x P&WC PT6A-20	2	-
	DH Canada DHC-6-100	2x P&WC PT6A-20	6	-
	Fokker F-27-100	2x RR Dart 514-7	2	-
	Fokker F-27-700	2x RR Dart 514-7	1	-
Pinehurst Airlines	NAMC YS-11A-500	2x RR Dart 542-10K	4	-
	NAMC YS-11A-600	2x RR Dart 542-10S	2	-
Pioneer Airways	Beech 99	2x P&WC PT6A-20	3	-
	Beech 99A	2x P&WC PT6A-27	1	-
Pocono Airlines	Beech 99	2x P&WC PT6A-20	1	-
	Beech B99	2x P&WC PT6A-27	2	-
	Swearingen SA-226TC MetroII	2x AiR TPE331-3UW-303G	2	-
	Swearingen SA-227AC MetroIII	2x AiR TPE331-11U-601G	-	1
Precision	Convair 600	2x RR Dart 542-4	2	-
	DH Canada DHC-6-200	2x P&WC PT6A-20	1	-
	DH Canada DHC-6-300	2x P&WC PT6A-27	1	-

Airline	Aircraft	Engines	In Service 6/30/81	On Order 6/30/81
Prinair	Convair 580	2x Asn 501-D13D	2	-
Princeton Av.	Govt Acft Factories N-24A	2x Asn 250-B17B	1	-
Princeville Airways	DH Canada DHC-6-300	2x P&WC PT6A-27	2	1
Provincetown-Boston Airline	Embraer EMB-110-1	2x P&WC PT6A-34	5	1
Ransome Airlines	Aerospatiale (Nord) 262A	2x Tbm Bastan VI C-1	8	-
	DH Canada DHC-7-102	4x P&WC PT6A-50	5	-
	Mohawk (Nord) 298	2x P&WC PT6A-45	4	-
Reeve Aleutian Airways	Lockheed L-188A(F)	4x Asn 501-D13	1	-
	Lockheed L-188C	4x Asn 501-D13	2	-
	NAMC YS-11A-600	2x RR Dart 542-10K	3	-
Republic Airlines	Boeing 727-2M7 Advanced	3x P&W JT8D-17R	7	-
	Boeing 727-2S7 Advanced	3x P&W JT8D-17	7	-
	Convair 580	2x Asn 501-D13D	20	-
	Douglas DC-9-14	2x P&W JT8D-7	21	-
	Douglas DC-9-15	2x P&W JT8D-7	8	-
	Douglas DC-9-15F	2x P&W JT8D-7	9	-
	Douglas DC-9-31	2x P&W JT8D-9	52	-
	Douglas DC-9-32	2x P&W JT8D-9	6	-
	Douglas DC-9-32F	2x P&W JT8D-9	1	-
	Douglas DC-9-51	2x P&W JT8D-17	28	-
	Douglas DC-9-82	2x P&W JT8D-217	4	10
Rio Airways	Beech 99A	2x P&WC PT6A-27	2	-
	Beech 200	2x P&WC PT6A-41	2	-
	DH Canada DHC-6-300	2x P&WC PT6A-27	10	-
	Swearingen SA-226TC MetroII	2x AiR TPE331-3UW-303G	8	-
	Swearingen SA-226TC MetroIIA	2x AiR TPE331-3UW-303G	2	-
Rocky Mountain Airways	DH Canada DHC-6-300	2x P&WC PT6A-27	2	-
	DH Canada DHC-7-102	4x P&WC PT6A-50	2	-
Royale Airlines	Beech 99A	2x P&WC PT6A-27	1	-
	Beech B99	2x P&WC PT6A-27	3	-
	Embraer EMB-110P1	2x P&WC PT6A-34	5	-
	Shorts 330	2x P&WC PT6A-45	1	-
Ryan Aviation	Cessna 500 Citation 1	2x P&WC JT15D-1	9	-
	Gates Learjet 25B	2x GE CJ610-6	2	-
	Gates Learjet 35	2x AiR TFE731-2-2B	1	-

Airplane	Aircraft	Engines	In Service 6/30/81	On Order 6/30/81
Scheduled Skyways	Beech 99	2x P&WC PT6A-20	2	-
	Beech B99	2x P&WC PT6A-27	1	-
	Swearingen SA-226TC MetroII	2x AiR TPE331-3UW-303G	7	-
Sea Airmotive-Seair	Beech E90	2x P&WC PT6A-27	1	-
	Beech 200	2x P&WC PT6A-41	1	-
	Convair 580	2x Asn 501-D13D	3	-
	DH Canada DHC-2 MK.III	1x P&WC PT6A-20	5	-
	DH Canada DHC-6-100	2x P&WC PT6A-20	2	-
	DH Canada DHC-6-300	2x P&WC PT6A-27	8	-
Sierra Pacific Airlines	Convair 580	2x Asn 501-D13D	3	-
	DH Canada DHC-6-300	2x P&WC PT6A-27	3	-
Silver State Airlines	Embraer EMB-110P1	2x P&WC PT6A-34	1	-
Simmons Airlines	Embraer EMB-110P1	2x P&WC PT6A-34	1	-
Sky West Aviation	Swearingen SA-226TC MetroII	2x AiR TPE331-3UW-303G	3	-
SMB Stage Lines	Convair 600	2x RR Dart 542-4	9	-
Soonair Lines	Swearingen SA-226TC Metro	2x AiR TPE331-3UW-303G	1	-
Southeast Airlines	Fairchild F-27	2x RR Dart 514-7	1	-
	Grumman G-159 Gulfstream I	2x RR Dart 529-8E	1	-
Southern Air Transport	Lockheed L-382E	4x Asn 501-D22A	1	-
	Lockheed L-382F	4x Asn 501-D22A	1	-
Southern Jersey Airways	DH Canada DHC-6-300	2x P&WC PT6A-27	5	-
	DH Canada DHC-8	2x P&WC PW108A	-	4
Southwest Airlines	Boeing 737-2H4 Advanced	2x P&W JT8D-9A	23	4
	Boeing 737-3H4 Advanced	2x G/S CFM56-3	-	10
Suburban Airlines	DH Canada DHC-6-300	2x P&WC PT6A-27	1	-
	DH Canada DHC-8	2x P&WC PW108A	-	3
	Shorts 330	2x P&WC PT6A-45	5	-
	Shorts 360	2x P&WC PT6A-65R	-	4
Summit Airlines	Convair 580	2x Asn 501-D13D	5	-
Sun Aire Lines	Swearingen SA-226TC Metro	2x AiR TPE331-3UW-303G	1	-
	Swearingen SA-226TC MetroII	2x AiR TPE331-3UW-303G	4	-

Airplane	Aircraft	Engines	In Service 6/30/81	On Order 6/30/81
Sunbird Airlines	Beech 99A	2x P&WC PT6A-27	1	-
	Beech C99	2x P&WC PT6A-34	-	10
Swift Aire Lines	Aerospatiale (Nord) 262A	2x Tbm Bastan VIC	4	-
	Fokker F-27-500	2x RR Dart 536-7B	1	1
	Fokker F-27-600	2x RR Dart 536-7R	3	-
Tejas Airlines	Swearingen SA-226TC MetroII	2x AiR TPE331-3UW-303G	3	-
Tennessee Airways	Embraer EMB-110P1	2x P&WC PT6A-34	3	1
	Embraer EMB-120	2x P&WC PW102A	-	2
Texas Int'l Airlines	Douglas DC-9-14	2x P&W JT8D-7A	15	-
	Douglas DC-9-15	2x P&W JT8D-7A	1	-
	Douglas DC-9-15F	2x P&W JT8D-9A	2	-
	Douglas DC-9-32	2x P&W JT8D-9A	16	-
TigerAir	BAe HS-125 Series 400A/731	2x AiR TPE731-3R	1	-
	BAe One-Eleven Srs 401AK	2x RR Spey 511-14	1	-
	Boeing 707-123B	4x P&W JT3D-1-MC-6	5	-
	Boeing 707-1388	4x P&W JT3D-3B	1	-
	Boeing 747-212B	4x P&W JT9D-7A	3	-
	Douglas DC-10-30F	3x GE CF6-50C1	1	-
	Gates Learjet 35	2x AiR TPE731-2-2B	1	1
Transamerica Airlines	Boeing 747-271C	4x GE CF6-50E	2	3
	Douglas DC-8-63F	4x P&W JT3D-7	9	-
	Douglas DC-10-30F	3x GE CF6-50C	3	-
	Lockheed L-188C	4x Asn 501-D13	8	-
	Lockheed L-382G	4x Asn 501-D22A	12	-
Trans Central Airlines	Swearingen SA-226TC MetroII	2x AiR TPE331-3UW-303G	4	-
Trans World Airlines	Boeing 707-131B	4x P&W JT3D-3B	39	-
	Boeing 707-331B	4x P&W JT3D-3B	30	-
	Boeing 707-331C	4x P&W JT3D-3B	1	-
	Boeing 727-131	3x P&W JT8D-1	26	-
	Boeing 727-231	3x P&W JT8D-9	36	-
	Boeing 727-231 Advanced	3x P&W JT8D-9	10	-
	Boeing 727-231 Advanced	3x P&W JT8D-15	10	-
	Boeing 727-131C	3x P&W JT8D-1	6	-
	Boeing 727-180C	3x P&W JT8D-1	2	-
	Boeing 747-131	4x P&W JT9D-3A	11	-
	Boeing 747-156	4x P&W JT9D-7	2	-
	Boeing 747SP-31	4x P&W JT9D-7A	3	-
	Boeing 767-231	2x P&W JT9D-7R4D	-	10
	Lockheed L-1101-1	3x RR RB.211-22B	22	-

Airline	Aircraft	Engines	In Service 6/30/81	On Order 6/30/81
Trans World Airlines (cont.)	Lockheed L-1011-100	3x RR RB.211-22B	5	2
	Lockheed L-1101-200	3x RR RB.211-524	1	-
United Airlines	Boeing 727-122	3x P&W JT8D-7A	59	-
	Boeing 727-222	3x P&W JT8D-7A	28	-
	Boeing 727-222 Advanced	3x P&W JT8D-15	76	-
	Boeing 727-122C	3x P&W JT8D-7B	1	-
	Boeing 737-222	2x P&W JT8D-7A	49	-
	Boeing 767-222	2x P&W JT9D-7R	-	30
	Douglas DC-8-54F	4x P&W JT3D-3B	14	-
	Douglas DC-8-61	4x P&W JT3D-3B	30	-
USAir	BAe One-Eleven Srs 203AE	2x RR Spey 506-14	10	-
	BAe One-Eleven Srs 204AF	2x RR Spey 506-14	15	-
	BAe One-Eleven Srs 215AU	2x RR Spey 506-14	3	-
	Boeing 727-122	3x P&W JT8D-7	10	-
	Boeing 727-122C	3x P&W JT8D-7	1	-
	Boeing 727-2B7 Advanced	3x P&W JT8D-17	3	2
	Boeing 737-2B7 Advanced	2x P&W JT8D-15A	-	15
	Boeing 737-3B7	2x G/S CFM56-3	-	10
	Douglas DC-9-31	2x P&W JT8D-7A	52	16
	Douglas DC-9-32	2x P&W JT8D-7A	3	-
Viking Int'l Airlines	Convair 600	2x RR Dart 542-4	2	-
Walker's Cay Airlines	DH Canada DHC-6-100	2x P&WC PT6A-20	1	-
Western Airlines	Boeing 727-247	3x P&W JT8D-9	6	-
	Boeing 727-2Q8 Advanced	3x P&W JT8D-9	1	-
	Boeing 727-247 Advanced	3x P&W JT8D-9	37	3
	Boeing 737-247	2x P&W JT8D-9	12	-
	Boeing 767-247	2x P&W JT9D-7R4D	-	6
	Douglas DC-10-10	3x GE CF6-6D	12	-
Wheeler Airlines	Beech 99	2x P&WC PT6A-20	2	-
	Fokker F-27	2x RR Dart 514-7	1	-
Wien Air Alaska	Boeing 737-222	2x P&W JT8D-7A	2	-
	Boeing 737-210 Advanced	2x P&W JT8D-17	1	-
	Boeing 737-291 Advanced	2x P&W JT8D-9	1	-
	Boeing 737-202C	2x P&W JT8D-17	1	-
	Boeing 737-210C	2x P&W JT8D-17	3	-
	Boeing 737-210C Advanced	2x P&W JT8D-17	4	-

Airline	Aircraft	Engines	In Service 6/30/81	On Order 6/30/81
World Airways	Boeing 747-124F	4x P&W JT9D-7A	1	-
	Boeing 747-273C	4x P&W JT9D-7A	3	-
	Douglas DC-8-63F	4x P&W JT3D-7	4	-
	Douglas DC-10-30CF	3x GE CF6-50C2	8	-
Wright Air Lines	Convair 600	2x RR Dart 542-4	4	-
Zantop Airways	Grumman G-159 Gulfstream 1	2x RR Dart 529-8E	7	-
Zantop Int'l	Convair 640(F)	2x RR Dart 532-4	14	-
	Douglas DC-8-21F	4x P&W JT4A-11	1	-
	Douglas DC-8-33	4x P&W JT4A-9	2	-
	Douglas DC-8-33F	4x P&W JT4A-9	4	-
	Douglas DC-8-54F	4x P&W JT3D-3B	1	-
	Lockheed L-188A(F)	4x Asn 501-D13A	19	-
	Lockheed L-188C(F)	4x Asn 501-D13A	6	-
	TOTAL		3280	541

APPENDIX B

AIRCRAFT PROFILES*

AIRCRAFT INCLUDED IN AIRCRAFT PROFILES**

AEROSPATIAL: CARAVELLE, MOHAWK 298 (NORD 262), SA-36 DAUPHIN
AIRBUS INDUSTRIES: A300
BEECH AIRCRAFT: BEECH 99A,B,C
BELL HELICOPTER: 212
BOEING: B-707/720, B-727, B-737, B-747, B-757, B-767
BOEING VERTOL: SIKORSKY S-58 to 64
BRITISH AEROSPACE CORPORATION: BAC-111, HP-137, HS-125, 748
CASA: C212
CESSNA: CITATION
COMMUTER AIRCRAFT CORPORATION: CAC-100
DE HAVILLAND: DHC-2, DHC-6, DHC-7, DHC-8
EMBRAER: EMB-110, EMB-120
FAIRCHILD: F-27 (FH-227)
FOKKER: F-27, F-28
GATES LEARJET: LEARJET 23 to 26, 35
GENERAL DYNAMICS: CONVAIR 580, 600/640
GOVERNMENT AIRCRFAT FACTORIES: N22/24
GRUMMAN: G-159 GULFSTREAM
LOCKHEED: L-1011, L-188A/C
MBB: HFB-320 HANSA JET
MCDONNELL-DOUGLAS: DC-8, DC-9, DC-9 SUPER 80, DC-10
MITSUBISHI: MU 2G/J
NIHON (NAMC): YS-11
SAAB-FAIRCHILD: SF-340
SHORTS: 330/360, SKYVAN 7
SWEARINGEN: SA-226 (MERLIN & METRO)
WESTLAND: WG30

*The primary source for this Appendix is: J.W.R. Taylor, et.al., Jane's All the World's Aircraft, 1980-1981, and earlier editions, (London: Jane's Publishing Co.). This data was supplemented by information obtained from: "Regional/Commuter: Aircraft Inventory," Air Transport World, November 1981. Aircraft were selected for inclusion in the Profiles based on Exxon, "Turbine-Engined Fleets of the World's Airlines: 1981," Air World Survey, July 1981.

**Profiles include the characteristics of the baseline model.

AIRCRAFT PROFILE FOR

AEROSPATIALE: CARAVELLE

Year Introduced: 1956

Fleet Size:
- Total no. in domestic service: 5
- Total no. on order: None

Engine:
- No. of engines: 2
- Type of engine: Turbofan
- Engine Mfr: Pratt & Whitney
- Engine model: JT8D-9
- Rating: 14,500 lb

Passenger Capacity:
- Crew: 2 (3)
- Basic: 128
- Max: 128

Aircraft Weight:
- Operating weight (empty): 31,800 kg (70,100 lb)
- Max payload: 13,200 kg (29,100 lb)
- Max T-O weight: 58,000 kg (127,870 lb)
- Max Zero-fuel weight: 45,000 kg (99,200 lb)
- Max landing weight: 49,500 kg (109,130 lb)

Fuel System:
- Capacity: 19,000 liters (4,180 gal)
- No. of tanks: 4
- Location: Wing

Speed:
- Max operating speed: N/A
- Max cruising speed at 7,670 m (25,000 ft): 445 knots (512 mph)
- Optimal cruising speed: N/A

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: N/A
- Range with max fuel and 11,240 kg payload: 1,710 nm (1,970 miles)

N/A = Not available.

AIRCRAFT PROFILE FOR

AEROSPATIALE: MOHAWK 298*

Year Introduced: N/A

Fleet Size:
- Total no. in domestic service: 27
- Total no. on order: None

Engine:
- No. of engines: 2
- Type of engine: Turboprop
- Engine Mfr: Lycoming
- Engine model: T53-L-15
- Rating: 820 kW (1,100 hp)

Passenger Capacity:
- Crew: 2
- Basic: N/A
- Max: N/A

Aircraft Weight:
- Operating weight (empty): 5,020 kg (11,067 lb)
- Max payload: 8,722 kg (19,230 lb)
- Max T-O weight: 6,197 kg (13,650 lb)
- Max Zero-fuel weight: N/A
- Max landing weight: N/A

Fuel System:
- Capacity: 1,125 liters (297 U.S. gal)
- No. of tanks: 2
- Location: Fuselage

Speed:
- Max operating speed: 354 knots (308 mph)
- Max cruising speed: 352 knots (306 mph)
- Optimal cruising speed: 207 mph

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 9,235 m (30,300 ft)
- Range with fuel tank and 10% reserve: 1,410 miles

*Same as N262, Nord.

AIRCRAFT PROFILE FOR

AEROSPATIALE: SA360 DAUPHIN

Year Introduced: 1972

Fleet Size:
- Total no. in domestic service: 11
- Total no. on order: None

Engine:
- No. of engines: 1
- Type of engine: Turboshaft
- Engine Mfr: Turbomeca Astazou
- Engine model: XVIIIA
- Rating: 783 kW (1,050 hp)

Passenger Capacity:
- Crew: 2
- Basic: 13
- Max: 13

Aircraft Weight:
- Operating weight (empty): 1,560 kg (3,428 lb)
- Max payload: N/A
- Max T-O weight: 3,000 kg (6,613 lb)
- Max Zero-fuel weight: N/A

Maxlandingweight: N/A

Fuel System:
- Capacity: N/A
- No. of tanks: N/A
- Location: N/A

Speed:
- Max operating speed: 170 knots (196 mph)
- Max cruising speed: 147 knots (169 mph)
- Optimal cruising speed: N/A

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 3,850 m (12,630 ft)
- Range: 367 nm (422 miles)

AIRCRAFT PROFILE FOR

AIRBUS INDUSTRIES: A300

Year Introduced: 1974

Fleet Size:
 Total no. in domestic service: 19
 Total no. on order: 15

Engine:
 No. of engines: 2
 Type of engine: Turbofan
 Engine Mfr: GE, Pratt & Whitney, Rolls-Royce
 Engine Model: CF6-50C(C2), JT9D-59A(B), CF6-80C1, JT9D7R4H, RB.211-524D4
 Rating: 50,000 lbs-53,000 lbs

Passenger Capacity:
 Crew: 3
 Basic: 220/320
 Max: 320

Aircraft Weight:
 Operating weight (empty): 89,700 kg (197,755 lb)
 Max payload: 34,590 kg (76,258 lb)
 Max T-O weight: 165,000 kg (363,760 lb)
 Max Zero-fuel weight: 124,000 kg (273,375 lb)
 Max landing weight: 136,000 kg (295,420 lb)

Fuel System:
 Capacity: 59,700 liters (13,133 U.S. gal)
 No. of tanks: 4-5
 Location: Wing

Speed:
 Max operating speed: 345 knots (0.86 Mach)
 Max cruising speed: 492 knots (at 25,000 ft)
 Optimal cruising speed: N/A

Altitude/Range:
 Cruising altitude: 7,620 m (25,000 ft) - 10,675 m (35,000 ft)
 Service ceiling: N/A
 Range with 269 passengers, max fuel: 1,800-2,750 nm (2,074-3,165 miles)

AIRCRAFT PROFILE FOR

BEECH AIRCRAFT: BEECH A-99, B-99, C-99

Year Introduced: 1968 (1981 model C)

Fleet Size:
- Total no. in domestic service: 101
- Total no. on order: 10

Engine:
- No. of engines: 2
- Type of engine: Turboprop
- Engine Mfr: Pratt & Whitney of Canada
- Engine model: PT6A-28
- Rating: 507 kW (680 hp)

Passenger Capacity:
- Crew: 2
- Basic: 15
- Max: 15

Aircraft Weight:
- Operating weight (empty): 2,620 kg (5,777 lb)
- Max payload: N/A
- Max T-O weight: 4,944 kg (10,900 lb)
- Max Zero-fuel weight: N/A
- Max landing weight: N/A

Fuel System:
- Capacity: 1,393 liters (368 U.S. gal)
- No. of tanks: 2
- Location: Wing

Speed:
- Max operating speed: N/A
- Max cruising speed: 247 knots (285 mph)
- Optimal cruising speed: N/A

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 8,020 m (26,313 ft)
- Range with 1,393 liters and 45 min reserves: 723 nm (832 miles)

AIRCRAFT PROFILE FOR

BELL HELICOPTER: BELL 212

Year Introduced: 1971

Fleet Size:
- Total no. in domestic service: 3
- Total no. on order: None

Engine:
- No. of engines: 2
- Type of engine: Turboshaft
- Engine Mfr: Pratt & Whitney of Canada
- Engine model: PT6T-3 Twin Pac
- Rating: 962 kW (1,290 hp)

Passenger Capacity:
- Crew: 1
- Basic: 14
- Max: 14

Aircraft Weight:
- Operating weight (empty): 2,787 kg (6,143 lb)
- Max payload: N/A
- Max T-O weight: 5,080 kg (11,200 lb)
- Max Zero-fuel weight: N/A
- Max landing weight: N/A

Fuel System:
- Capacity: 814 liters (215 U.S. gal)
- No. of tanks: 5
- Location: Fuel cells

Speed:
- Max operating speed: 140 knots (161 mph)
- Max cruising speed: 124 knots (142 mph)
- Optimal cruising speed: N/A

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 4,330 m (14,200 ft)
- Range: 227 nm (261 miles)

AIRCRAFT PROFILE FOR

BOEING: 707/720

Year Introduced: 1955

Fleet Size:
- Total no. in domestic service: 137
- Total no. on order: None

Engine:
- No. of engines: 4
- Type of engine: Turbofan
- Engine Mfr: Pratt & Whitney
- Engine model: JT3D-7
- Rating: 84,500 N (19,000 lbs)

Passenger Capacity:
- Crew: N/A
- Basic: 219
- Max: 219

Aircraft Weight:
- Operating weight (empty): 66,406 kg (146,400 lb)
- Max payload: 40,324 kg (88,900 lb)
- Max T-O weight: 151,315 kg (333,600 lb)
- Max Zero-fuel weight: 104,330 kg (230,000 lb)
- Max landing weight: 112,037 kg (247,000 lb)

Fuel System:
- Capacity: 90,299 liters (23,855 U.S. gal)
- No. of tanks: 7
- Location: Wing and center section

Speed:
- Max operating speed: 545 knots (627 mph)
- Max cruising speed: 525 knots (605 mph)
- Optimal cruising speed: 478 knots (550 mph)

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 11,885 m (39,000 ft)
- Range with max fuel: 5,000 nm (5,755 miles)

AIRCRAFT PROFILE FOR

BOEING: B-727-200

Year Introduced: 1972

Fleet Size:
- Total no. in domestic service: 1066
- Total no. on order: 66

Engine:
- No. of engines: 3
- Type of engine: Turbofan
- Engine Mfr: Pratt & Whitney
- Engine model: JT8D-9A, JT8D-15, JT8D-17, JT8D-12R
- Rating: 14,000-17,400 lbs

Passenger Capacity:
- Crew: 3 on flight deck
- Basic: 145
- Max: 189

Aircraft Weight:
- Operating weight (empty): 45,132 kg (99,500 lb)
- Max payload: 18,144 kg (40,000 lb)
- Max T-O weight: 86,405 kg (190,800 lb)
- Max zero-fuel weight: 63,800 kg (140,000 lb)
- Max landing weight: 70,800 kg (154,500 lb)

Fuel System:
- Capacity: 30,623 liters (8,090 U.S. gal) standard
- With optimal fuselage tanks: 39,000 liters (10,182 U.S. gal)
- No. of tanks: 3 + options
- Location: Wing (fuselage optional)

Speed:
- Max operating speed: 0.90 Mach
- Max cruising speed at 7,530 m: 520 knots (599 mph)
- Optimal cruising speed at 9,145 m: 495 knots (570 mph)

Altitude/Range:
- Cruising altitude: 10,060 m (33,000 ft)
- Service ceiling: N/A
- Range at full payload w/8,090 gal fuel: 1,450 nm (1,670 mile)
- Range at 2/3 payload with 8,090 gal fuel: 2,000 nm (2,303 mile)

AIRCRAFT PROFILE FOR

BOEING: B-737

Year Introduced: 1967

Fleet Size:
- Total no. in domestic service: 224
- Total no. on order: 49

Engine:
- No. of engines: 2
- Type of engine: Turbofan
- Engine Mfr: Pratt & Whitney
- Engine model: JT8D
- Rating: 64,000 N (15,500 lbs)-75,600 N (17,000 lbs)

Passenger Capacity:
- Crew: 2
- Basic: 115-130
- Max: 130

Aircraft Weight:
- Operating weight (empty): 27,760 kg (61,200 lb)
- Max payload: 15,331 kg (33,800 lb)
- Max T-O weight: 56,472 kg (124,500 lb)
- Max Zero-fuel weight: 44,906 kg (99,000 lb)
- Max landing weight: 48,534 kg (107,000 lb)

Fuel System:
- Capacity: 19,532 liters (5,160 U.S. gal)
- No. of tanks: 5
- Location: Wing and wing center section

Speed:
- Max operating speed: 0.84 Mach
- Max cruising speed: 500 knots
- Optimal cruising speed: 0.73 Mach

Altitude/Range:
- Cruising altitude: 22,600 ft
- Service ceiling: 23,500 ft
- Range at 116,000 lb with reserve fuel: 1,900 nm (2,188 miles)
- Range at 128,600 lb with reserve fuel: 2,400 nm (2,648 miles)

AIRCRAFT PROFILE FOR

BOEING: B-747*

Year Introduced: 1970

Fleet Size:
- Total no. in domestic service: 137
- Total no. on order: 5

Engine:
- No. of engines: 4
- Type of engine: Turbofan
- Engine Mfrs: Pratt & Whitney, GE, Rolls-Royce
- Engine model: JT9D, CF6-50E, RB.211-5243
- Rating: 213,500 N (48,000 lbs)

Passenger Capacity:
- Crew: 3
- Basic: 442
- Max: 516

Aircraft Weight:
- Operating weight (empty): 175,995 kg (388,000 lbs)
- Max payload: 87,090 kg (192,000 lb)
- Max T-0 weight: 377,840 kg (833,000 lb)
- Max Zero-fuel weight: 267,620 kg (590,000 lb)
- Max landing weight: 285,760 kg (630,000 lb)

Fuel System:
- Capacity: 198,385 liters (52,409 U.S. gal)
- No. of tanks: 7
- Location: Wing

Speed:
- Max operating speed: 522 knots
- Max cruising speed: N/A
- Optimal cruising speed: N/A

Altitude/Range:
- Cruising altitude: 30,000 ft
- Service ceiling: 13,715 m (45,000 ft)
- Range 100B at 340,195 kg T-0 weight: 4,700 nm (5,417 miles)
- Range 200B at 365,140 kg T-0 weight: 5,300 nm (6,103 miles)
- Range 200B at 377,840 kg T-0 weight: 5,700 nm (6,563 miles)

*The data given here characterizes the baseline B-747.

AIRCRAFT PROFILE FOR

BOEING: B-757

Year Introduced: 1983-4

Fleet Size:
Total no. in domestic service: None
Total no. on order: 92

Engine:
No. of engines: 2
Type of engine: Turbofan
Engine Mfr: Rolls-Royce, GE
Engine model: RB.211-535, CF6-32
Rating: 160,000 N (36,000 lbs)

Passenger Capacity:
Crew: N/A
Basic: 196
Max: 196

Aircraft Weight:
Operating weight (empty): 59,430 kg (131,020 lb)
Max payload: N/A
Max T-O weight: 108,860 kg (240,000 lb)
Max Zero-fuel weight: 83,460 kg (184,000 lb)
Max landing weight: 89,810 kg (198,000 lb)

Fuel System:
Capacity: 41,185 liters (10,880 U.S. gal)
No. of tanks: 5
Location: Wing

Speed:
Max operating speed: 0.8 Mach
Max cruising speed: 0.8 Mach
Optimal cruising speed: N/A

Altitude/Range:
Cruising altitude: N/A
Service ceiling: N/A
Range: 2,340 nm (2,695 miles)

AIRCRAFT PROFILE FOR

BOEING: B-767

Year Introduced: 1984

Fleet Size:
- Total no. in domestic service: None
- Total no. on order: 120

Engine:
- No. of engines: 2
- Type of engine: Turbofan
- Engine Mfr: Pratt & Whitney, GE, Rolls-Royce
- Engine model: JT9D-7R4D, JT9D-7R4A, CF6-80A, RB.211
- Rating: N/A

Passenger Capacity:
- Crew: 2 to 3
- Basic: 211
- Max: 289

Aircraft Weight:
- Operating weight (empty): 81,890 kg (180,540 lb)
- Max payload: N/A
- Max T-O weight: 140,615 kg (310,000 lb)
- Max Zero-fuel weight: 112,490 kg (242,000 lb)
- Max landing weight: 122,470 kg (257,000 lb)

Fuel System:
- Capacity: 58,900 liters (15,560 U.S. gal)
- No. of tanks: 2
- Location: Wing

Speed:
- Max operating speed: 0.80 Mach
- Max cruising speed: 0.80 Mach
- Optimal cruising speed: N/A

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 12,100 m (39,700 ft)
- Range at full payload: 3,200 nm (3,685 miles)

AIRCRAFT PROFILE FOR

BOEING VERTOL: SIKORSKY S-58 to 64

Year Introduced: 1971

Fleet Size:
- Total no. in domestic service: 4
- Total no. on order: None

Engine:
- No. of engines: 2
- Type of engine: Turboshaft
- Engine Mfr: Pratt & Whitney of Canada
- Engine model: PT6T-3 Twin Pac
- Rating: 1,342 kW (1,800 hp)

Passenger Capacity:
- Crew: 2
- Basic: 10
- Max: 16

Aircraft Weight:
- Operating weight (empty): 3,437 kg (7,577 lb)
- Max payload: N/A
- Max T-O weight: 5,896 kg (13,000 lb)
- Max Zero-fuel weight: N/A
- Max landing weight: 5,896 kg (13,000 lb)

Fuel System:
- Capacity: 1,109 liters (293 U.S. gal)
- No. of tanks: 12
- Location: Metal cells

Speed:
- Max operating speed: 120 knots (138 mph)
- Max cruising speed: 110 knots (127 mph)
- Optimal cruising speed: N/A

Altitude/Range:
- Cruising altitude: 1,980 m (6,500 ft)
- Service ceiling: 1,280 m (4,200 ft)
- Range with 1,071 liters including 20 min reserves: 242 nm (278 miles)

AIRCRAFT PROFILE FOR

BRITISH AEROSPACE CORPORATION: BAC-111

Year Introduced: 1971

Fleet Size:
- Total no. in domestic service: 29
- Total no. on order: None

Engine:
- No. of engines: 2
- Type of engine: Turbofan
- Engine Mfr: Rolls-Royce
- Engine model: Spey Mk 512 DW
- Rating: 55,800 N (12,550 lbs)

Passenger Capacity:
- Crew: 2
- Basic: 65-89
- Max: 89-119

Aircraft Weight:
- Operating weight (empty): 24,454 kg (53,911 lb)
- Max Payload: 12,286 kg (27,089 lb)
- Max T-O weight: 47,400 kg (104,500 lb)
- Max Zero-fuel weight: 36,741 kg (81,000 lb)
- Max landing weight: 39,462 kg (87,000 lb)

Fuel System:
- Capacity: 14,024 liters (3,085 gal)
- No. of tanks: 4
- Location: Wing

Speed:
- Max operating speed: 410 knots
- Max operating speed: 470 knots
- Optimal cruising speed: 400 knots

Altitude/Range:
- Cruising altitude: 6,400 m (21,000 ft)
- Service ceiling: N/A
- Range with 98,500 lb with reserves: 1,619 nm (1,865 miles)
- Range with 104,500 lb with reserves: 1,480 nm (1,705 miles)

AIRCRAFT PROFILE FOR

BRITISH AEROSPACE CORPORATION: BAe-HP-137

Year Introduced: 1966

Fleet Size:
- Total no. in domestic service: 17
- Total no. on order: None

Engine:
- No. of engines: 2
- Type of engine: Turboprop
- Engine Mfr: Turbomeca
- Engine model: Astazou XIV
- Rating: 634 kW (850 hp)

Passenger Capacity:
- Crew: 2
- Basic: 4
- Max: 18

Aircraft Weight:
- Operating weight (empty): 3,833 kg (8,450 lb)
- Max payload: 1,510 kg (3,330 lb)
- Max T-O weight: 5,670 kg (12,500 lb)
- Max Zero-fuel weight: N/A
- Max landing weight: 5,670 kg (12,500 lb)

Fuel System:
- Capacity: 1,727 liters (380 gal)
- No. of tanks: 2
- Location: Wing

Speed:
- Max operating speed: N/A
- Max cruising speed: 306 mph
- Optimal cruising speed: 250 mph (at 30,000 ft)

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 9,160 m (30,000 ft)
- Range with max payload, 45 min reserves: 240 miles

AIRCRAFT PROFILE FOR

BRITISH AEROSPACE CORPORATION: BAe-HS-125

Year Introduced: N/A

Fleet Size:
- Total no. in domestic service: 1
- Total no. on order: None

Engine:
- No. of engines: 2
- Type of engine: Turbofan
- Engine Mfr: Garrett-AiResearch
- Engine model: TFE731-3-1H
- Rating: 16.46 kN (3,700 lb)

Passenger Capacity:
- Crew: 2
- Basic: 8
- Max: 14

Aircraft Weight:
- Operating weight (empty): 5,826 kg (12,845 lb)
- Max payload: 1,010 kg (2,228 lb)
- Max T-O weight: 11,566 kg (25,000 lb)
- Max Zero-fuel weight: 7,280 kg (16,050 lb)
- Max landing weight: 9,979 kg (22,000 lb)

Fuel System:
- Capacity: 4,628 liters (1,018 gal)
- No. of tanks: Integral
- Location: Wing

Speed:
- Max operating speed: N/A
- Max cruising speed at 8,380 m (27,500 ft): 436 knots (502 mph)
- Optimal cruising speed at 12,500 m (41,000 ft): 390 knots (449 mph)

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 12,500 m (41,000 ft)
- Range with max fuel: 2,420 nm (2,785 miles)

AIRCRAFT PROFILE FOR

BRITISH AEROSPACE CORPORATION: BAe-HS-748

Year Introduced: 1976 (new engine 1979)

Fleet Size:
- Total no. in domestic service: 2
- Total no. on order: 5

Engine:
- No. of engines: 2
- Type of engine: Turboprop
- Engine Mfr: Rolls-Royce
- Engine model: Dart RDa.7 Mk 536-2
- Rating: 1,700 kW (2,280 hp)

Passenger Capacity:
- Crew: 2
- Basic: 40
- Max: 58

Aircraft Weight:
- Operating weight (empty): 11,577 kg (25,524 lb)
- Max payload: 5,886 kg (12,976 lb)
- Max T-O weight: 21,092 kg (46,500 lb)
- Max Zero-fuel weight: 17,463 kg (38,500 lb)
- Max landing weight: 19,504 kg (43,000 lb)

Fuel System:
- Capacity: 6,550 liters (1,440 gal)
- No. of tanks: 2
- Location: Wing

Speed:
- Max operating speed: N/A
- Max cruising speed: 244 knots (281 mph)
- Optimal cruising speed: N/A

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 6,620 m (25,000 ft)
- Range with max payload: 925 nm (1,066 miles)

AIRCRAFT PROFILE FOR

CASA: C212

Year Introduced: 1978

Fleet Size:
- Total no. in domestic service: 8
- Total no. on order: 4

Engine:
- No. of engines: 2
- Type of engine: Turboprop
- Engine Mfr: Garrett-AiResearch
- Engine model: TPE331-10-501C
- Rating: 671 kW (900 hp)

Passenger Capacity:
- Crew: 2
- Basic: 24
- Max: 26

Aircraft Weight:
- Operating weight (empty): 3,915 kg (8,631 lb)
- Max payload: 2,250 kg (4,960 lb)
- Max T-O weight: 7,300 kg (16,093 lb)
- Max Zero-fuel weight: 6,550 kg (14,440 lb)
- Max landing weight: 7,000 kg (15,432 lb)

Fuel System:
- Capacity: 2,100 liters (462 gal)
- No. of tanks: 4
- Location: Wing

Speed:
- Max operating speed: N/A
- Max cruising speed: 208 knots (240 mph)
- Optimal cruising speed: N/A

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 8,535 m (28,000 ft)
- Range with max payload, no reserves: 410 nm (472 miles)

AIRCRAFT PROFILE FOR

CESSNA: CITATION III

Year Introduced: N/A

Fleet Size:
- Total no. in domestic service: None
- Total no. on order: N/A

Engine:
- No. of engines: 2
- Type of engine: Turbofan
- Engine Mfr: Garrett-AiResearch
- Engine model: TFE731-3B-1005
- Rating: 16.24 kN (3,650 lb)

Passenger Capacity:
- Crew: 2
- Basic: 8
- Max: 8

Aircraft Weight:
- Operating weight (empty): 4,968 kg (10,951 lb)
- Max payload: N/A
- Max T-O weight: 9,072 kg (20,000 lb)
- Max Zero-fuel weight: N/A
- Max landing weight: 7,486 kg (16,500 lb)

Fuel System:
- Capacity: 2,826 kg (6,230 lb)
- No. of tanks: 2
- Location: Wing

Speed:
- Max operating speed: N/A
- Max cruising speed at 10,060 m (33,000 ft): 469 knots
- Optimal cruising speed: N/A

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 15,545 m (51,000 ft)
- Range with 45 min reserves: 2,500 nm (2,877 miles)

AIRCRAFT PROFILE FOR

COMMUTER AIRCRAFT CORPORATION: CAC-100

Year Introduced: 1983

Fleet Size:
- Total no. in domestic service: None
- Total no. on order: N/A

Engine:
- No. of engines: 4
- Type of engine: Turbofan
- Engine Mfr: Pratt & Whitney of Canada
- Engine model: PT6A-45A
- Rating: 875 kW (1,173 hp)

Passenger Capacity:
- Crew: 2
- Basic: 50
- Max: 60

Aircraft Weight:
- Operating weight (empty): 8,901 kg (19,623 lb)
- Max payload: 5,443 kg (12,000 lb)
- Max T-O weight: 15,422 kg (34,000 lb)
- Max Zero-fuel weight: 13,437 kg (29,623 lb)
- Max landing weight: 14,969 kg (33,000 lb)

Fuel System:
- Capacity: 4,353 liters (1,150 U.S. gal)
- No. of tanks: 4
- Location: Wing

Speed:
- Max operating speed: N/A
- Max cruising speed at 4,570 m (15,000 ft): 300 knots (365 mph)
- Optimal cruising speed: N/A

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: N/A
- Range with max fuel: 1,250 nm (1,439 miles)

AIRCRAFT PROFILE FOR

DE HAVILLAND: DHC-2

Year Introduced: N/A

Fleet Size:
- Total no. in domestic service: 1
- Total no. on order: None

Engine:
- No. of engines: 1
- Type of engine: Turboprop
- Engine Mfr: Pratt & Whitney
- Engine model: PT6A-6
- Rating: 578 hp

Passenger Capacity:
- Crew: 1 (2)
- Basic: 7
- Max: 7

Aircraft Weight:
- Operating weight (empty): 1,252 kg (2,760 lb)
- Max payload: N/A
- Max T-O weight: 2,435 kg (5,370 lb)
- Max Zero-fuel weight: N/A
- Max landing weight: 2,313 kg (5,100 lb)

Fuel System:
- Capacity: 723 liters (159 gal)
- No. of tanks: 3
- Location: Fuselage, cabin

Speed:
- Max operating speed: 170 mph
- Max cruising speed: 157 mph
- Optimal cruising speed: 160 mph

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 6,250 m (20,500 ft)
- Range with max fuel: 677 miles

AIRCRAFT PROFILE FOR

DE HAVILLAND: DHC-6

Year Introduced: 1965

Fleet Size:
- Total no. in domestic service: 129
- Total no. on order: 2

Engine:
- No. of engines: 2
- Type of engine: Turboprop
- Engine Mfr: Pratt & Whitney of Canada
- Engine model: PT6A-27
- Rating: 486 kW (652 hp)

Passenger Capacity:
- Crew: 2
- Basic: 13/20
- Max: 20

Aircraft Weight:
- Operating weight (empty): 3,363 kg (7,415 lb)
- Max payload: 1,941 kg (4,289 lb)
- Max T-O weight: 5,670 kg (12,500 lb)
- Max Zero-fuel weight: N/A
- Max landing weight: 5,577 kg (12,300 lb)

Fuel System:
- Capacity: 1,446 liters (382 gal)
- No. of tanks: 2
- Location: Under floor

Speed:
- Max operating speed: N/A
- Max cruising speed: 182 knots (210 mph)
- Optimal cruising speed: N/A

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 8,140 m (26,700 ft)
- Range at 2,500 lb payload: 700 nm (806 miles)
- Range at 1,900 lb payload: 920 nm (1,059 miles)

AIRCRAFT PROFILE FOR

DE HAVILLAND: DHC-7

Year Introduced: 1978

Fleet Size:
- Total no. in domestic service: 22
- Total no. on order: 13

Engine:
- No. of engines: 4
- Type of engine: Turboprop
- Engine Mfr: Pratt & Whitney of Canada
- Engine model: PT6A-50
- Rating: 835 kW (1,120 hp)

Passenger Capacity:
- Crew: 2
- Basic: 50
- Max: 50

Aircraft Weight:
- Operating weight (empty): 12,542 kg (27,650 lb)
- Max payload: 5,148 kg (11,350 lb)
- Max T-O weight: 19,958 kg (44,000 lb)
- Max Zero-fuel weight: 17,690 kg (39,000 lb)
- Max landing weight: 19,050 kg (42,000 lb)

Fuel System:
- Capacity: 5,602 liters (1,480 U.S. gal)
- No. of tanks: 2
- Location: Wing

Speed:
- Max operating speed: N/A
- Max cruising speed at 2,440 m (15,000 ft): 231 knots (266 mph)
- Optimal cruising speed: N/A

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 6,400 m (21,000 ft)
- Range at 4,570 m with standard fuel and 3,040 kg (6,700 lb): 1,160 nm (1,335 miles)

AIRCRAFT PROFILE FOR

DE HAVILLAND: DHC-8

Year Introduced: 1983

Fleet Size:
- Total no. in domestic service: None
- Total no. on order: 7

Engine:
- No. of engines: 2
- Type of engine: Turboprop
- Engine Mfr: Pratt & Whitney of Canada
- Engine model: PT7A-2R
- Rating: 1,342 kW (1,800 hp)

Passenger Capacity:
- Crew: 2
- Basic: 32
- Max: 36

Aircraft Weight:
- Operating weight (empty): N/A
- Max payload: N/A
- Max T-O weight: N/A
- Max Zero-fuel weight: N/A
- Max landing weight: N/A

Fuel System:
- Capacity: N/A
- No. of tanks: N/A
- Location: N/A

Speed:
- Max operating speed: 260 knots (300 mph)
- Max cruising speed: N/A
- Optimal cruising speed: N/A

Altitude/Range:
- Cruising altitude: 7,620 m (25,000 ft)
- Service ceiling: N/A
- Range: N/A

AIRCRAFT PROFILE FOR

EMBRAER: EMB-110 BANDEIRANTE

Year Introduced: 1973

Fleet Size:
- Total no. in domestic service: 44
- Total no. on order: 9

Engine:
- No. of engines: 2
- Type of engine: Turboprop
- Engine Mfr: Pratt & Whitney of Canada
- Engine model: PT6A-34
- Rating: 559 kW (750 hp)

Passenger Capacity:
- Crew: 2
- Basic: 21
- Max: 21

Aircraft Weight:
- Operating weight (empty): 3,516 kg (7,751 lb)
- Max payload: 1,681 kg (3,706 lb)
- Max T-O weight: 5,679 kg (12,500 lb)
- Max Zero-fuel weight: 5,450 kg (12,015 lb)
- Max landing weight: N/A

Fuel System:
- Capacity: 1,720 liters (378 gal)
- No. of tanks: 4
- Location: Wing

Speed:
- Max operating speed: N/A
- Max cruising speed at 10,000 ft: 225 knots (259 mph)
- Optimal cruising speed at 10,000 ft: 176 knots (203 mph)

Altitude/Range:
- Cruising altitude:
- Service ceiling: 7,350 m (24,100 ft)
- Range at 10,000 ft, 45 min reserves, with max fuel: 1,025 nm (1,180 miles)

AIRCRAFT PROFILE FOR

EMBRAER: EMB-120 BRASILIA

Year Introduced: 1984

Fleet Size:
- Total no. in domestic service: None
- Total no. on order: 8

Engine:
- No. of engines: 2
- Type of engine: Turboprop
- Engine Mfr: Pratt & Whitney of Canada
- Engine model: PT7A-1
- Rating: 1,118 kW (1,500 hp)

Passenger Capacity:
- Crew: 2
- Basic: 30
- Max: 30

Aircraft Weight:
- Operating weight (empty): 5,576 kg (12,295 lb)
- Max payload: 3,024 kg (6,666 lb)
- Max T-O weight: 9,600 kg (21,165 lb)
- Max Zero-fuel weight: 8,600 kg (18,960 lb)
- Max landing weight: 9,600 kg (21,165 lb)

Fuel System:
- Capacity: 3,348 liters (368 gal)
- No. of tanks: 2
- Location: Wing

Speed:
- Max operating speed: N/A
- Max cruising speed at 6,400 m (21,000 ft): 294 knots (338 mph)
- Optimal cruising speed: 250 knots (288 mph)

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 9,750 m (32,000 ft)
- Range with max payload: 545 nm

AIRCRAFT PROFILE FOR

FAIRCHILD: F-27*

Year Introduced: N/A

Fleet Size:
- Total no. in domestic service: 23
- Total no. on order: None

Engine:
- No. of engines: 2
- Type of engine: Turboprop
- Engine Mfr: Rolls-Royce
- Engine model: Dart RDa.7
- Rating: N/A

Passenger Capacity:
- Crew: 2
- Basic: 40
- Max: 52

Aircraft Weight:
- Operating weight (empty): 10,313 kg (22,736 lb)
- Max payload: 5,080 kg (11,200 lb)
- Max T-O weight: 19,730 kg (43,500 lb)
- Max Zero-fuel weight: 17,640 kg (39,000 lb)
- Max landing weight: 19,500 kg (43,000 lb)

Fuel System:
- Capacity: 7,810 liters (2,063 U.S. gal)
- No. of tanks: 2
- Location: Wing

Speed:
- Max operating speed: 249 knots (287 mph)
- Max cruising speed at 20,000 ft: 237 knots (273 mph)
- Optimal cruising speed at 25,000 ft: 224 knots (258 mph)

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 8,535 m (28,000 ft)
- Range with max payload, 45 min reserves, at 10,000 ft: 533 nm (614 miles)

*Same basic aircraft as FH-227.

AIRCRAFT PROFILE FOR

FOKKER: F-27-100 to 700

Year Introduced: 1955

Fleet Size:
- Total no. in domestic service: 9
- Total no. on order: 4

Engine:
- No. of engines: 2
- Type of engine: Turboprop
- Engine Mfr: Rolls-Royce
- Engine model: Dart M 536-7R
- Rating: 1,596 kW (2,140 hp)

Passenger Capacity:
- Crew: 2
- Basic: 44
- Max: 48

Aircraft Weight:
- Operating weight (empty): 11,164 kg (24,612 lb)
- Max payload: 6,148 kg (13,553 lb)
- Max T-O weight: 20,410 kg (45,000 lb)
- Max fuel weight: 5,870 kg (12,941 lb)
- Max landing weight: 19,731 kg (43,500 lb)

Fuel System:
- Capacity: 5,136 liters (1,130 gal)
- No. of tanks: 4
- Location: Wing

Speed:
- Max operating speed: 259 knots (278 mph)
- Max cruising speed: N/A
- Optimal cruising speed: N/A

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 8,990 m (29,500 ft)
- Range: 1,020 nm (1,082 miles)

AIRCRAFT PROFILE FOR

FOKKER: F-28

Year Introduced: 1969

Fleet Size:
- Total no. in domestic service: 7
- Total no. on order: 4

Engine:
- No. of engines: 2
- Type of engine: Turbofan
- Engine Mfr: Rolls-Royce
- Engine model: RB.1822 Spey M 555-15H
- Rating: 44,000 N (9,900 lbs)

Passenger Capacity:
- Crew: 2 or 3
- Basic: 55/60/65
- Max: 85

Aircraft Weight:
- Operating weight (empty): 17,359 kg (38,269 lb)
- Max payload: 8,963 kg (19,760 lb)
- Max T-O weight: 33,110 kg (73,000 lb)
- Max Zero-fuel weight: 28,118 kg (62,000 lb)
- Max landing weight: 30,160 kg (66,500 lb)

Fuel System:
- Capacity: 9,740 liters (2,143 gal)
- No. of tanks: 2
- Location: Wing

Speed:
- Max operating speed: 0.75 Mach
- Max cruising speed: 455 knots (523 mph)
- Optimal cruising speed: 366 knots (421 mph)

Altitude/Range:
- Cruising altitude: 10,675 m (35,000 ft)
- Service ceiling: N/A
- Range with 85 passengers and reserves: 1,000 nm (1,151 miles)

AIRCRAFT PROFILE FOR

GATES LEARJET: LEARJET 23 to 26

Year Introduced: 1963

Fleet Size:
- Total no. in domestic service: 13
- Total no. on order: None

Engine:
- No. of engines: 2
- Type of engine: Turbojet
- Engine Mfr: GE
- Engine model: CJ610-8A
- Rating: 13,100 N (2,950 lbs)

Passenger Capacity:
- Crew: 2
- Basic: 10
- Max: 10

Aircraft Weight:
- Operating weight (empty): 3,204 kg (7,064 lb)
- Max payload: 1,134 kg (2,500 lb)
- Max T-O weight: 6,123 kg (13,470 lb)
- Max fuel weight: 2,553 kg (5,628 lb)
- Max landing weight: 5,388 kg (11,880 lb)

Fuel System:
- Capacity: 3,180 liters (840 U.S. gal)
- No. of tanks: 3
- Location: Wing and fuselage

Speed:
- Max operating speed: 475 knots (547 mph)
- Max cruising speed: 451 knots (519 mph)
- Optimal cruising speed: 428 knots (493 mph)

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 15,545 m (51,000 ft)
- Range with 4 passengers, max fuel, 45 min reserves: 1,474 nm (1,697 miles)

AIRCRAFT PROFILE FOR

GATES LEARJET: LEARJET 35

Year Introduced: 1974

Fleet Size:
- Total no. in domestic service: 1
- Total no. on order: None

Engine:
- No. of engines: 2
- Type of engine: Turbofan
- Engine Mfr: Garrett-AiResearch
- Engine model: TFE731-2-2B
- Rating: 15.6 kN (3,500 lb)

Passenger Capacity:
- Crew: 2
- Basic: 8
- Max: 8

Aircraft Weight:
- Operating weight (empty): 4,342 kg (9,571 lb)
- Max payload: 1,587 kg (3,500 lb)
- Max T-O weight: 7,711 kg (17,000 lb)
- Max Zero-fuel weight: N/A
- Max landing weight: 6,960 kg (15,300 lb)

Fuel System:
- Capacity: 4,201 liters (1,110 U.S. gal)
- No. of tanks: N/A
- Location: Wing, fuselage

Speed:
- Max operating speed: N/A
- Max cruising speed at 12,500 m (41,000 ft): 460 knots (529 mph)
- Optimal cruising speed at 13,700 m (45,000 ft): 418 knots (481 mph)

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 13,715 m (45,000 ft)
- Range with 4 passengers, max fuel: 2,289 nm (2,636 miles)

AIRCRAFT PROFILE FOR

GD, PAC,* ALLISON: CONVAIR 580

Year Introduced: 1959 (conversions)

Fleet Size:
- Total no. in domestic service: 87
- Total no. on order: None

Engine:
- No. of engines: 2
- Type of engine: Turboprop
- Engine Mfr: Allison
- Engine model: 501-D13
- Rating: N/A

Passenger Capacity:
- Crew: 2
- Basic: 56
- Max: 56

Aircraft Weight:
- Operating weight (empty): N/A
- Max payload: N/A
- Max T-O weight: N/A
- Max landing weight: 23,586 kg (52,000 lb)

Fuel System:
- Capacity: 7,874 liters (2,080 U.S. gal)
- No. of tanks: 2
- Location: Wing

Speed:
- Max operating speed: 297 knots (342 mph)
- Max cruising speed: 297 knots (342 mph)
- Optimal cruising speed: 297 knots (342 mph)

Altitude/Range:
- Cruising altitude: 6,100 m (20,000 ft)
- Service ceiling: N/A
- Range: 2,866 miles

* GD: General Dynamics; PAC: Pacific Airmotive Corporation.

AIRCRAFT PROFILE FOR

GD, PAC*: CONVAIR 600/640

Year Introduced: 1965 (Conversions)

Fleet Size:
- Total no. in domestic service: 35
- Total no. on order: None

Engine:
- No. of engines: 2
- Type of engine: Turboprop
- Engine Mfr: Rolls-Royce
- Engine model: Dart RDa.10 M 542-4
- Rating: 2,050 kW (2,750 hp)

Passenger Capacity:
- Crew: 2
- Basic: 40
- Max: 40

Aircraft Weight:
- Operating weight (empty): 13,732 kg (30,275 lb)
- Max payload: N/A
- Max T-O weight: 24,950 kg (55,000 lb)
- Max Zero-fuel weight: 22,680 kg (50,000 lb)
- Max landing weight: 23,815 kg (52,500 lb)

Fuel System:
- Capacity: 11,147 liters (2,945 U.S. gal)
- No. of tanks: 2
- Location: Wing

Speed:
- Max operating speed: 268 knots (308 mph)
- Max cruising speed: 268 knots (308 mph)
- Optimal cruising speed: 268 knots (308 mph)

Altitude/Range:
- Cruising altitude: 7,315 m (24,000 ft)
- Service ceiling: 7,315 m (24,000 ft)
- Range: 1,068 nm (1,230 miles)

*GD: General Dynamics; PAC: Pacific Airmotive Corporation.

AIRCRAFT PROFILE FOR

GOVERNMENT AIRCRAFT FACTORIES: N-22/24

Year Introduced: 1972

Fleet Size:
- Total no. in domestic service: 14
- Total no. on order: None

Engine:
- No. of engines: 2
- Type of engine: Turboprop
- Engine Mfr: Allison
- Engine model: 250-B17B
- Rating: 298 kW (400 hp)

Passenger Capacity:
- Crew: 1 or 2
- Basic: 13
- Max: 13

Aircraft Weight:
- Operating weight (empty): 2,377 kg (5,241 lb)
- Max payload: N/A
- Max T-O weight: 4,263 kg (9,400 lb)
- Max fuel weight: 1,066 kg (2,350 lb)
- Max landing weight: 4,263 kg (9,600 lb)

Fuel System:
- Capacity: 1,018 liters (224 gal)
- No. of tanks: 2-4
- Location: Wing and wing-tip

Speed:
- Max operating speed: N/A
- Max cruising speed: N/A
- Optimal cruising speed: 168 knots (193 mph)

Altitude/Range
- Cruising altitude: N/A
- Service ceiling: 6,400 m (21,000 ft)
- Range: 730 nm (840 miles)

AIRCRAFT PROFILE FOR

GRUMMAN: G-159 GULFSTREAM

Year Introduced: 1965

Fleet Size:
- Total no. in domestic service: 7
- Total no. on order: None

Engine:
- No. of engines: 2
- Type of engine: Turbofan
- Engine Mfr: Rolls-Royce
- Engine model: Spey Mk 511-8
- Rating: 50,623 N (11,400 lbs)

Passenger Capacity:
- Crew: 1 or 2
- Basic: 19
- Max: 19

Aircraft Weight:
- Operating weight (empty): N/A
- Max payload: N/A
- Max T-O weight: 28,122 kg (62,000 lb)
- Max Zero-fuel weight: 19,050 kg (42,000 lb)
- Max landing weight: 26,535 kg (58,500 lb)

Fuel System:
- Capacity: 10,205 kg (22,500 lb)
- No. of tanks: 2
- Location: Wing

Speed:
- Max operating speed: 0.85 Mach
- Max cruising speed: 511 knots (588 mph)
- Optimal cruising speed: N/A

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 13,100 m (43,000 ft)
- Range with max fuel: 3,375 nm (3,886 miles)

AIRCRAFT PROFILE FOR

LOCKHEED: L-1011-TRISTAR-500

Year Introduced: 1979

Fleet Size:
- Total no. in domestic service: N/A
- Total no. on order: N/A

Engine:
- No. of engines: 3
- Type of engine: Turbofan
- Engine Mfr: Rolls-Royce
- Engine model: RB.211-22B
- Rating: 187 kN (42,000 lb)

Passenger Capacity:
- Crew: 3
- Basic: 256
- Max: 400

Aircraft Weight:
- Operating weight (empty): 111,311 kg (245,400 lb)
- Max payload: 42,006 kg (92,608 lb)
- Max T-O weight: 228,610 kg (504,000 lb)
- Max Zero-fuel weight: 153,315 kg (338,000 lb)
- Max landing weight: 166,920 kg (368,000 lb)

Fuel System:
- Capacity: 119,774 liters (31,642 U.S. gal)
- No. of tanks: 2 +
- Location: Wing

Speed:
- Max operating speed: N/A
- Max cruising speed at 9,145 m (30,000 ft): 525 knots (605 mph)
- Optimal cruising speed at 10,670 m (35,000 ft): 680 knots (553 mph)

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 13,100 m (43,000 ft)
- Range with max fuel: 6,080 nm (6,996 miles)

AIRCRAFT PROFILE FOR

LOCKHEED: L-188A/C

Year Introduced: 1959

Fleet Size:
- Total no. in domestic service: 52
- Total no. on order: None

Engine:
- No. of engines: 4
- Type of engine: Turboprop
- Engine Mfr: Allison
- Engine model: 501-D13
- Rating: 2,796 kW (3,750 hp)

Passenger Capacity:
- Crew: 2
- Basic: 74
- Max: 88

Aircraft Weight:
- Operating weight (empty): 25,990 kg (57,300 lb)
- Max payload: 12,020 kg (26,500 lb)
- Max T-O weight: 52,664 kg (116,000 lb)
- Max Zero-fuel weight: 39,010 kg (86,000 lb)
- Max landing weight: 43,385 kg (95,650 lb)

Fuel System:
- Capacity: 20,842 liters (5,520 U.S. gal)
- No. of tanks: 4
- Location: Wing

Speed:
- Max operating speed: 389 knots (448 mph)
- Max cruising speed: 352 knots (405 mph)
- Optimal cruising speed: N/A

Altitude/Range
- Cruising altitude: N/A
- Service ceiling: 8,655 m (28,400 ft)
- Range with 2-hr reserves: 3,460 miles

AIRCRAFT PROFILE FOR

MBB: HFB 320 HANSA JET

Year Introduced: 1966

Fleet Size:
- Total no. in domestic service: 5
- Total no. on order: None

Engine:
- No. of engines: 2
- Type of engine: Turbojet
- Engine Mfr: GE
- Engine model: CJ610-9
- Rating: 13,766 N (3,100 lbs)

Passenger Capacity:
- Crew: 2
- Basic: 12
- Max: 12

Aircraft Weight:
- Operating weight (empty): 5,425 kg (11,960 lb)
- Max payload: 1,775 kg (3,913 lb)
- Max T-O weight: 9,200 kg (20,280 lb)
- Max Zero-fuel weight: 7,450 kg (16,424 lb)
- Max landing weight: 8,800 kg (19,400 lb)

Fuel System:
- Capacity: 4,410 liters (915 gal)
- No. of tanks: 5
- Location: Wing

Speed:
- Max operating speed: N/A
- Max cruising speed: 446 knots
- Optimal cruising speed at 35,000 ft: 365 knots (420 mph)

Altitude/Range:
- Cruising altitude: 10,670 m (35,000 ft)
- Service ceiling: N/A
- Range with 6 passengers, 45 min reserves: 1,278 nm (1,472 miles)

AIRCRAFT PROFILE FOR

MCDONNELL-DOUGLAS: DC-8-61,62,63,71,72,73

Year Introduced: N/A

Fleet Size:
- Total no. in domestic service: 150
- Total no. on order: None

Engine:
- No. of engines: 4
- Type of engine: Turbofan
- Engine Mfr: Pratt & Whitney, GE/SNECMA
- Engine model: JT3D, JT8D-209, CFM56
- Rating: 98,100 N (22,050 lbs)

Passenger Capacity:
- Crew: N/A
- Basic: N/A
- Max: N/A

Aircraft Weight:
- Operating weight (empty): 75,115 kg (165,600 lb)
- Max payload: 30,240 kg (66,665 lb)
- Max T-O weight: 161,025 kg (355,000 lb)
- Max Zero-fuel weight: 104,325 kg (230,000 lb)
- Max landing weight: 124,740 kg (275,000 lb)

Fuel System:
- Capacity: N/A
- No. of tanks: N/A
- Location: Wing

Speed:
- Max operating speed: 521 knots (598 mph)
- Max cruising speed: 0.80 Mach
- Optimal cruising speed: N/A

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: N/A
- Range: N/A

AIRCRAFT PROFILE FOR

MCDONNELL-DOUGLAS: DC-9-20,30,40,50

Year Introduced: 1968

Fleet Size:
- Total no. in domestic service: 401
- Total no. on order: 18

Engine:
- No. of engines: 2
- Type of engine: Turbofan
- Engine Mfr: Pratt & Whitney
- Engine model: JT8D
- Rating: 64,500 N (14,500 lbs)

Passenger Capacity:
- Crew: 2
- Basic: 119
- Max: 119

Aircraft Weight:
- Operating weight (empty): 28,068 kg (61,880 lb)
- Max payload: 15,617 kg (34,430 lb)
- Max T-O weight: 54,885 kg (121,000 lb)
- Max Zero-fuel weight: 44,678 kg (98,500 lb)
- Max landing weight: 49,895 kg (110,000 lb)

Fuel System:
- Capacity: 19,074 liters (5,039 U.S. gal)
- No. of tanks: N/A
- Location: Wing

Speed:
- Max operating speed: 537 knots (618 mph)
- Max cruising speed: 495 knots (569 mph)
- Optimal cruising speed: 443 knots (509 mph)

Altitude/Range:
- Cruising altitude: 9,145-10,675 m (30,000-35,000 ft)
- Service ceiling: N/A
- Range: 1,795 nm (2,067 miles)

AIRCRAFT PROFILE FOR

MCDONNELL-DOUGLAS: DC-9 SUPER 80

Year Introduced: 1980

Fleet Size:
- Total no. in domestic service: 10
- Total no. on order: 43

Engine:
- No. of engines: 2
- Type of engine: Turbofan
- Engine Mfr: Pratt & Whitney
- Engine model: JT8D-209
- Rating: 82,300 N (18,500 lbs)

Passenger Capacity:
- Crew: 2
- Basic: 137
- Max: 172

Aircraft Weight:
- Operating weight (empty): 36,534 kg (80,543 lb)
- Max payload: N/A
- Max T-O weight: 66,568 kg (147,000 lb)
- Max Zero-fuel weight: 53,524 kg (118,000 lb)
- Max landing weight: 58,060 kg (128,000 lb)

Fuel System:
- Capacity: 21,876 liters (5,779 U.S. gal)
- No. of tanks: N/A
- Location: Wing

Speed:
- Max operating speed: 500 knots (575 mph)
- Max cruising speed: 0.80 Mach
- Optimal cruising speed: 0.76 Mach

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: N/A
- Range: 2,657 nm (3,060 miles)

AIRCRAFT PROFILE FOR

MCDONNELL-DOUGLAS: DC-10

Year Introduced: 1971

Fleet Size:
- Total no. in domestic service: 115
- Total no. on order: None

Engine:
- No. of engines: 3
- Type of engine: Turbofan
- Engine Mfr: GE, Pratt & Whitney
- Engine model: CF6-50 series & JT9D series
- Rating: 233,500 N (52,500 lb)

Passenger Capacity:
- Crew: 3
- Basic: 255/270
- Max: 380

Aircraft Weight:
- Operating Weight (empty): 122,951 kg (271,062 lb)
- Max payload: 48,330 kg (106,550 lb)
- Max T-O weight: 259,744 kg (555,000 lb)
- Max Zero-fuel weight: 166,922 kg (368,000 lb)
- Max landing weight: 182,798 kg (403,000 lb)

Fuel System:
- Capacity: 138,165 liters (36,500 U.S. gal)
- No. of tanks: 6
- Location: Wing

Speed:
- Max operating speed: 0.95 Mach
- Max cruising speed: 0.88 Mach
- Optimal cruising speed: 489 knots (562 mph)

Altitude/Range:
- Cruising altitude: 9,145 m (30,000 ft)
- Service ceiling: 10,730 m (35,200 ft)
- Range: 4,050 nm (4,663 miles)

AIRCRAFT PROFILE FOR

MITSUBISHI: MU-2G/J

Year Introduced: 1966

Fleet Size:
- Total no. in domestic service: 2
- Total no. on order: None

Engine:
- No. of engines: 2
- Type of engine: Turboprop
- Engine Mfr: Garrett-AiResearch
- Engine model: TPE331-10-501M
- Rating: 533 kW (715 hp)

Passenger Capacity:
- Crew: 2
- Basic: 7
- Max: 9

Aircraft Weight:
- Operating weight (empty): 3,470 kg (7,650 lb)
- Max payload: 1,220 kg (2,690 lb)
- Max T-O weight: 5,250 kg (11,575 lb)
- Max fuel weight: 4,513 kg (9,950 lb)
- Max landing weight: 5,000 kg (11,025 lb)

Fuel System:
- Capacity: 1,526 liters (403 U.S. gal)
- No. of tanks: 5
- Location: Wing

Speed:
- Max operating speed: 0.57 Mach
- Max cruising speed: 308 knots (355 mph)
- Optimal cruising speed: 313 knots (360 mph)

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 10,210 m (33,500 ft)
- Range with max fuel, 45 min reserves, at 9,450 m: 1,600 nm (1,842 miles)

AIRCRAFT PROFILE FOR

NIHON (NACM): YS-11-100/200

Year Introduced: 1965

Fleet Size:
- Total no. in domestic service: 24
- Total no. on order: None

Engine:
- No. of engines: 2
- Type of engine: Turboprop
- Engine Mfr: Rolls-Royce
- Engine model: Dart Mka.542-10K
- Rating: 2,282 kW (3,060 hp)

Passenger Capacity:
- Crew: N/A
- Basic: 60
- Max: N/A

Aircraft Weight:
- Operating weight (empty): 15,419 kg (33,993 lb)
- Max payload: 6,581 kg (14,508 lb)
- Max T-O weight: 24,500 kg (54,010 lb)
- Max Zero-fuel weight: N/A
- Max landing weight: N/A

Fuel System:
- Capacity: 7,270 liters (2,090 gal)
- No. of tanks: 4
- Location: Wing

Speed:
- Max operating speed: N/A
- Max cruising speed: 253 knots (291 mph)
- Optimal cruising speed at 6,100 m (20,000 ft): 244 knots (281 mph)

Altitude/Range:
- Cruising altitude: 6,100 m (20,000 ft)
- Service ceiling: N/A
- Range with max payload, reserves: 590 nm (680 miles)

AIRCRAFT PROFILE FOR

SAAB-FAIRCHILD: SF-340

Year Introduced: 1984

Fleet Size:
  Total no. in domestic service: None
  Total no. on order: 5

Engine:
  No. of engines: 2
  Type of engine: Turboprop
  Engine Mfr: GE
  Engine model: CT7
  Rating: 1,230 kW (1,650 hp)

Passenger Capacity:
  Crew: 2
  Basic: 34
  Max: 34

Aircraft Weight:
  Operating weight (empty): 6,600 kg (14,550 lb)
  Max payload: 3,400 kg (7,495 lb)
  Max T-O weight: 11,350 kg (25,020 lb)
  Max Zero-fuel weight: 10,000 kg (22,045 lb)
  Max landing weight: 11,110 kg (24,495 lbs)

Fuel System:
  Capacity: 3,331 liters (733 U.S. gal)
  No. of tanks: 4 (2 integral for each wing)
  Location: Wing

Speed:
  Max operating speed: 260 knots
  Max cruising speed: N/A
  Optimal cruising speed: N/A

Altitude/Range:
  Cruising altitude: N/A
  Service ceiling: N/A
  Range with 34 passengers with IFR reserves: 800 nm (920 miles)
  Range with 23 passengers with IFR reserves: 1,570 nm (1,805 miles)

AIRCRAFT PROFILE FOR

SHORTS: SHORTS 330/60

Year Introduced: 1976

Fleet Size:
- Total no. in domestic service: 42
- Total no. on order: 7

Engine:
- No. of engines: 2
- Type of engine: Turboprop
- Engine Mfr: Pratt & Whitney of Canada
- Engine model: PT6A-45 B
- Rating: 862 kW (1,156 hp)

Passenger Capacity:
- Crew: 2
- Basic: 30
- Max: 36

Aircraft Weight:
- Operating weight (empty): 6,690 kg (14,750 lb)
- Max payload: 2,653 kg (5,850 lb)
- Max T-O weight: 10,250 kg (22,600 lb)
- Max Fuel weight: 1,741 kg (3,840 lb)
- Max landing weight: 10,115 kg (22,300 lb)

Fuel System:
- Capacity: 2,182 liters (680 gal)
- No. of tanks: 3
- Location: Wing and fuselage

Speed:
- Max operating speed: N/A
- Max cruising speed: 190 knots (218 mph)
- Optimal cruising speed: 160 knots (184 mph)

Altitude/Range:
- Cruising altitude: 3,050 m (10,000 ft)
- Service ceiling: 3,500 m (11,500 ft)
- Range with max fuel at 3,050 m, no reserves: 435 nm (500 miles)

AIRCRAFT PROFILE FOR

SHORTS: SKYVAN SC7

Year Introduced: 1967

Fleet Size:
- Total no. in domestic service: 1
- Total no. on order: None

Engine:
- No. of engines: 2
- Type of engine: Turboprop
- Engine Mfr: Garrett-AiResearch
- Engine model: TPE331-201
- Rating: 533 kW (715 hp)

Passenger Capacity:
- Crew: 1 (or 2)
- Basic: 19
- Max: 19

Aircraft Weight:
- Operating weight (empty): 3,356 kg (7,400 lb)
- Max payload: 2,358 kg (5,200 lb)
- Max T-O weight: 6,216 kg (13,700 lb)
- Max Zero-fuel weight: N/A
- Max landing weight: 6,123 kg (13,500 lb)

Fuel System:
- Capacity: 1,332 liters (293 gal)
- No. of tanks: 4
- Location: Fuselage

Speed:
- Max operating speed: N/A
- Max cruising speed at 3,050 m (10,000 ft): 169 knots (195 mph)
- Optimal cruising speed at 3,050 m (10,000 ft): 150 knots (173 mph)

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: 6,705 m (22,000 ft)
- Range at long range cruising speed, 45 min reserves: 580 nm (670 miles)

AIRCRAFT PROFILE FOR

SWEARINGEN: SA-226 (METRO & MERLIN)

Year Introduced: 1966

Fleet Size:
- Total no. in domestic service: 114
- Total no. on order: 9

Engine:
- No. of engines: 2
- Type of engine: Turboprop
- Engine Mfr: Garrett-AiResearch
- Engine model: TPE331-3UW-304G
- Rating: 701 kW (940 hp)

Passenger Capacity:
- Crew: 2
- Basic: 19-20
- Max: 20

Aircraft Weight:
- Operating weight (empty): 3,379 kg (7,450 lb)
- Max payload: N/A
- Max T-O weight: 5,670 kg (12,500 lb)
- Max Zero-fuel weight: N/A
- Max landing weight: 5,670 kg (12,500 lb)

Fuel System:
- Capacity: 2,452 liters (648 U.S. gal)
- No. of tanks: 2
- Location: Wing

Speed:
- Max operating speed: 255 knots (294 mph)
- Max cruising speed: 255 knots (294 mph)
- Optimal cruising speed: 242 knots (197 mph)

Altitude/Range:
- Cruising altitude: 6,100 m (20,000 ft)
- Service ceiling: 8,230 m (27,000 ft)
- Range: 595 nm (685 miles)

AIRCRAFT PROFILE FOR

WESTLAND: WG30

Year Introduced: 1982/3

Fleet Size:
- Total no. in domestic service: None
- Total no. on order: N/A

Engine:
- No. of engines: 2
- Type of engine: Turboshaft
- Engine Mfr: Rolls-Royce
- Engine model: Gem 41-1
- Rating: 835 kW (1,120 hp)

Passenger Capacity:
- Crew: 2
- Basic: 17
- Max: 22

Aircraft Weight:
- Operating weight (empty): 3,030 kg (7,037 lb)
- Max payload: N/A
- Max T-O weight: 5,443 kg (12,000 lb)
- Max Zero-fuel weight: N/A
- Max landing weight: N/A

Fuel System:
- Capacity: 499 kg (1,100 lb)
- No. of tanks: 2
- Location: Cabin

Speed:
- Max operating speed: N/A
- Max cruising speed at S/L: 130 knots (150 mph)
- Optimal cruising speed: N/A

Altitude/Range:
- Cruising altitude: N/A
- Service ceiling: N/A
- Range with 1,815 kg (4,000 lb) payload: 123 nm (142 miles)

APPENDIX C

AIRCRAFT OPERATIONAL PROFILES: DOMESTIC TRUNK, LOCAL SERVICE, INTRA-STATE, AND OTHER CARRIERS - 1979†

CATEGORIES OF AIR CARRIERS††

*Domestic Trunk
American
Braniff
Continental
Delta
Eastern
Northwest
Pan American
Trans World
United
Western

*Local Service
Frontier
Ozark
Piedmont
Republic
Texas International
USAir

*Intra-Alaskan
Alaska
Alaska International
Kodiak-Western Alaska
Munz Northern
Reeve Aleutian
Wien Air Alaska

*Intra-Hawaiian
Aloha
Hawaiian

All Cargo
Airlift International
Flying Tiger

Other
Aeromech
AirCal
Air Florida
*Air Midwest
*Air New England
Air North
Air Wisconsin
Altair
Apollo
*Aspen
Big Sky
Capitol Int'l
Cascade
Cochise
Coleman
Empire
Evergreen Int'l
Golden Gate
Golden West
Great American
Imperial
Mackey Int'l
Mid-South
Midway
Mississippi Valley
New Haven
New York Air
Pacific Southwest
Sky West
Southeast
Southwest
Swift
Transamerica
World
*Wright

**Commuters
Ransome Airlines
Rio Airways, Inc.
Puerto Rico Int'l Airlines
Pennsylvania Commuter Airlines
Bar Harbor Airways
Henson Aviation, Inc.
Metro Airlines-Metroflight
Provincetown-Boston Airline
Britt Airways, Inc.
Air Oregon
Rocky Mountain Airways
Air Illinois
Fayetteville Flying Service
Commuter Airlines (Binghamton, NY)
Royale Airlines, Inc.
Pilgrim Aviation & Airlines
Air North, Inc. (Burlington, VT)
Chautauqua Airlines, Inc.
Command Airways, Inc.
Midstate Airlines
Suburban Airlines
Sun Aire Lines (Borrego Springs)
Chaparral Airlines
Tejas Airlines, Inc.
Aero Virgin Is. Corp.
Alaskan Aeronautical Ind.
Mountain West Airlines
Pocono Airlines, Inc.
Comair, Inc.
S. New Jersey Airways
Inland Empire Airlines
Ocean Airways, Inc.
Precision Valley Aviation
Wheeler Flying Service
Crown Airways, Inc.

*Included in Profiles. Data for other carriers unavailable.

**35 commuter carriers operating turbine-engined aircraft, based on total revenue passenger-miles and enplanements. See Chpater 4 for data.

†Source: Reference 57.

††Source: Reference 58.

PERFORMANCE AND CHARACTERISTICS	DOMESTIC TRUNK PASSENGER SERVICE					
	A-300B	B-707-100B	B-707-300	B-707-300B	B-707-300C	B-720B
Assigned to Service	7.5	70.3	2.0	21.1	16.2	3.7
Total Airborne Hours (All Revenue Service)	22839	214130	5114	57711	50256	9490
Average Stage Length (miles)	893	1013	981	1030	1214	678
Average Airborne Speed	449	461	455	456	473	452
Total Block Hours	26950	241752	5825	65675	56287	10885
Gallons of Fuel Per Block Hour	1822	1546	2093	1700	1771	1483
Gallons of Fuel Consumed (millions)	49.1	373.8	12.2	111.6	99.7	16.1
Revenue Passenger Miles (million)	1418	8697	215	2576	2408	380
Revenue Aircraft Miles (millions)	10.3	98.7	2.3	26.3	23.8	4.3
No. of Departures (thousands)	11.5	97.4	2.4	25.5	19.6	6.3
No. of Revenue Passenger Enplanements (millions)	1.6	8.6	0.2	2.5	2.0	0.6
Average Revenue Passenger Per Aircraft Mile (Revenue Passenger Enplanements Per Departure)	138.3	88.1	92.3	97.9	101.3	88.5
Revenue Passenger Enplanements Per Aircraft (thousands)	213.3	122.3	109.5	118.5	123.5	151.3

PERFORMANCE AND CHARACTERISTICS	DOMESTIC TRUNK PASSENGER SERVICE					
	B-727-100	B-727-100C/QC	B-727-200	B-737-200	B-747	L-1011
Average Aircraft Assigned to Service	248.4	41.2	557.5	68.0	32.9	69.4
Total Airborne Hours (All Revenue Service)	700105	125639	1747437	159826	127688	218313
Average Stage Length (miles)	645	574	574	309	2020	1000
Average Airborne Speed	437	425	428	369	506	473
Total Block Hours	816322	148003	2079450	197685	143521	255645
Gallons of Fuel Per Block Hour	1199	1239	1325	834	3238	2329
Gallons of Fuel Consumed (millions)	978.8	183.4	2755.3	164.9	464.7	595.4
Revenue Passenger Miles (million)	20896	3631	62375	3975	16740	17255
Revenue Aircraft Miles (millions)	305.9	53.4	747.9	59.0	64.6	103.3
No. of Departures (thousands)	474.3	93.0	1303.0	190.9	32.0	103.3
No. of Revenue Passenger Enplanements (millions)	32.4	6.3	108.7	12.9	8.3	17.3
Average Revenue Passengers Per Aircraft Mile (Revenue Passenger Enplanements Per Departure)	68.3	68.0	83.4	67.4	259.1	167.1
Revenue Passesnger Enplanement Per Aircraft (thousands)	130.4	152.9	194.9	189.2	252.0	248.7

PERFORMANCE AND CHARACTERISTICS	DC-8-50	DC-8-61	DC-8-62	DC-9-10	DC-9-30	DC-9-50
			DOMESTIC TRUNK PASSENGER SERVICE			
Average Aircraft Assigned to Service	24.2	37.6	8.8	18.1	104.4	16.9
Total Airborne Hours (All Revenue Service)	62349	116348	28632	43375	286572	53260
Average Stage Length (miles)	1088	975	1430	346	356	403
Average Airborne Speed	465	454	480	378	375	386
Total Block Hours	70018	132869	31724	53655	355636	64551
Gallons of Fuel Per Block Hour	1699	1884	1683	836	872	981
Gallons of Fuel Consumed (millions)	119.0	250.0	53.4	44.8	310.1	63.3
Revenue Passenger Miles (million)	2456	6302	1436	861	6931	1667
Revenue Aircraft Miles (millions)	29.9	52.8	13.7	16.4	107.5	20.7
No. of Departures (thousands)	26.6	54.2	9.6	47.4	301.9	51.0
No. of Revenue Passenger Enplanements (millions)	2.3	6.5	1.0	2.5	19.5	4.1
Average Revenue Passenger Per Aircraft Mile (Revenue Passenger Enplanements Per Departure)	84.7	119.3	104.5	52.5	64.5	81.1
Revenue Passenger Enplanements Per Aircraft (thousands)	93.3	172.9	113.6	138.1	186.8	244.8

PERFORMANCE AND CHARACTERISTICS	DOMESTIC TRUNK PASSENGER SERVICE	
	DC-10-10	DC-10-40
Average Aircraft Assigned to Service	76.9	20.8
Total Airborne Hours (All Revenue Service)	260554	47539
Average Stage Length (miles)	1497	782
Average Airborne Speed	488	451
Total Block Hours	291560	57284
Gallons of Fuel Per Block Hour	2191	2315
Gallons of Fuel Consumed (millions)	639.0	132.6
Revenue Passenger Miles (million)	19136	2393
Revenue Aircraft Miles (millions)	127.2	21.4
No. of Departures (thousands)	85.0	27.4
No. of Revenue Passenger Enplanements (millions)	12.8	3.1
Average Revenue Passenger Per Aircraft Mile (Revenue Passenger Enplanements Per Departure)	150.5	111.6
Revenue Passenger Enplanements Per Aircraft (thousands)	166.2	147.1

PERFORMANCE AND CHARACTERISTICS	B-727-100	B-727-200	DOMESTIC LOCAL PASSENGER SERVICE B-737	BAC 111-200	DC-9-10	DC-9-30	DC-9-50
Average Aircraft Assigned to Service	16.8	4.3	59.9	29.7	55.5	135.9	17.7
Total Airborne Hours (All Revenue Service)	46839	12543	170963	75267	157427	380672	47412
Average Stage Length (miles)	428	552	327	231	315	316	232
Average Airborne Speed	402	444	378	320	370	374	354
Total Block Hours	54708	14098	203788	93030	188283	457568	59360
Gallons of Fuel Per Block Hour	1270	1309	855	786	841	867	952
Gallons of Fuel Consumed (millions)	69.5	18.5	174.2	73.1	158.3	396.7	56.5
Revenue Passenger Miles (million)	1248	440	3968	1274	2848	8528	1072
Revenue Aircraft Miles (millions)	18.8	5.6	64.6	24.1	58.2	142.4	16.8
No. of Departures (thousands)	43.9	10.1	197.6	104.3	184.9	450.5	72.3
No. of Revenue Passenger Enplanements (millions)	2.9	0.8	12.1	5.5	9.0	27.0	4.6
Average Revenue Passenger Per Aircraft Mile (Revenue Passenger Enplanements Per Departure)	66.3	78.6	61.4	52.9	48.9	59.9	63.9
Revenue Passenger Enplanements Per Aircraft (thousands)	172.6	184.4	202.6	185.7	162.2	198.6	261.4

PERFORMANCE AND CHARACTERISTICS	DOMESTIC LOCAL PASSENGER SERVICE					
	CV-580	DHC-6	FH-227	Metro II	MO 298	YS11
Average Aircraft Assigned to Service	47.6	3.0	13.0	6.9	2.3	14.6
Total Airborne Hours (All Revenue Service)	99027	7086	17223	12348	3998	35610
Average Stage Length (miles)	117	106	110	119	136	116
Average Airborne Speed	235	171	194	214	178	209
Total Block Hours	122893	8007	21701	14892	4850	43480
Gallons of Fuel Per Block Hour	333	81	275	92	117	317
Gallons of Fuel Consumed (millions)	40.9	0.6	6.0	1.4	0.6	13.8
Revenue Passenger Miles (million)	647	11	91	22	10	228
Revenue Aircraft Miles (millions)	23.3	1.2	3.3	2.6	0.7	7.4
No. of Departures (thousands)	198.9	11.4	30.4	22.2	5.2	64.2
No. of Revenue Passenger Enplanements (millions)	5.5	0.1	0.8	0.2	0.1	2.0
Average Revenue Passenger Per Aircraft Mile (Revenue Passenger Enplanements Per Departure)	27.8	8.9	27.3	8.3	13.8	30.6
Revenue Passenger Enplanements Per Aircraft (thousands)	115.5	33.3	61.5	26.7	31.4	137.0

PERFORMANCE AND CHARACTERISTICS	B-727-100C/QC	INTRA-ALASKAN B-727-200	B-737-200C/QC	INTRA-HAWAIIAN B-737-200	DC-9-50
Average Aircraft Assigned to Service	8.0	2.1	7.6	8.7	9.4
Total Airborne Hours (All Revenue Service)	22097	6462	21653	14539	16399
Average Stage Length (miles)	550	626	443	123	121
Average Airborne Speed	440	450	396	329	320
Total Block Hours	25257	7341	24771	19642	21663
Gallons of Fuel Per Block Hour	1222	1351	873	919	1075
Gallons of Fuel Consumed (millions)	30.9	9.9	21.6	18.0	23.3
Revenue Passenger Miles (million)	615	231	340	387	482
Revenue Aircraft Miles (millions)	9.7	2.9	8.6	4.8	5.2
No. of Departures (thousands)	17.6	4.6	19.3	38.8	43.3
No. of Revenue Passenger Enplanements (millions)	1.1	0.4	0.8	3.1	4.0
Average Revenue Passenger Per Aircraft Mile (Revenue Passenger Enplanements Per Departure)	63.3	79.7	39.6	80.7	92.8
Revenue Passenger Enplanements Per Aircraft (thousands)	139.9	176.3	100.8	360.7	428.1

PERFORMANCE AND CHARACTERISTICS			OTHER CARRIERS		
	CV-580	CV-600	DHC-6	FH-227	Metro II
Average Aircraft Assigned to Service	9.1	3.6	9.8	8.0	5.4
Total Airborne Hours (All Revenue Service)	9294	4819	18116	11133	16209
Average Stage Length (miles)	141	135	76	115	122
Average Airborne Speed	225	191	138	180	220
Total Block Hours	11292	5773	22228	14372	18397
Gallons of Fuel Per Block Hour	307	282	74	249	90
Gallons of Fuel Consumed (millions)	3.5	1.6	1.6	3.6	1.6
Revenue Passenger Miles (million)	54	21	27	50	30
Revenue Aircraft Miles (millions)	2.1	0.9	2.5	2.0	3.6
No. of Departures (thousands)	14.8	6.8	32.9	17.4	29.2
No. of Revenue Passenger Enplanements (millions)	0.4	0.2	0.3	0.4	0.2
Average Revenue Passenger Per Aircraft Mile (Revenue Passenger Enplanements Per Departure)	25.7	23.5	10.7	24.9	8.3
Revenue Passenger Enplanements Per Aircraft (thousands)	41.9	44.5	35.9	54.2	44.9

APPENDIX D

PRESENT VALUE OF FUTURE COSTS AND ANNUALIZED COST OF CAPITAL

Whenever an investment project is undertaken, a series of costs (and benefits) are generated which accrue into the future. The capital cost will be incurred early in the project, but the operating costs will occur at different points over the life of the project. However, it is not enough simply to add the costs incurred in the future to the inital capital costs. The reason is that a dollar to be received next year does not represent the same value as a dollar in hand today; all future dollars must be discounted to reflect the cost of competing investment opportunities which can earn a positive return.

If future costs (or benefits) are presented in nominal terms the appropriate discount rate "d" is composed of an inflation factor "i" and the real opportunity cost of capital "r." For example, the present value (PV) of a stream of future costs "C" can be calculated as:

$$PV(C) = \sum_{t=o}^{T} \frac{C(t)}{(1 + d)^t} \qquad (1)$$

where

$1 + d = (1 + i)(1 + r)$

T = life of investment project

and

$C(0)$ = initial capital costs

$C(t = 1,2,..,T)$ = annual cost of antimisting fuel

If the future costs $C(t)$ are presented in real terms (i.e. constant dollars), then the discount factor must only account for the real cost of capital.

$1 + d = 1 + r$

If the future costs are assumed constant in each year, as may be appropriate for fuel costs, then we can rewrite Equation (1)* as:

---

* Equation (1) presents a geometric series with the first term equal to C and a constant ratio between terms of $\frac{1}{1 + d}$. Equation 2 is derived from the formula for the sum of a finite geometric series.

$$PV(C) = C(t) \left[\frac{1 - (1 + d)^{-T}}{d} \right] \quad (2)$$

The expression in brackets is the reciprocal of the capital recovery factor, explained below. Other cost such as increased maintenance costs can be included in the present value analysis. However, due to the lack of data at this time, these costs have been omitted.

The benefits of introducing antimisting fuel can be similarly analyzed where:

$$PV(B) = \sum_{t=o}^{T} \frac{B(t)}{(1 + d)^t} \quad (3)$$

Where B represents the value of lives saved due to the use of antimisting fuel, and any reductions in insurance or damage costs. We have not yet attempted to quantify the benefits of introducing antimisting fuel due to the lack of data for forecasting expected lives saved.

An alternative methodology for evaluating the effectiveness of investments is the technique of levelized costs. This method can be used to find the series of annual payments (AP) over a period of time (T) which is equivalent to a lump sum investment (S).

$$AP = S \left[\frac{d}{1 - (1 + d)^{-T}} \right] \quad (4)$$

The expression in brackets is commonly called the capital recovery factor.

The present value analysis described above discounts the future stream of costs to a single point in time; the levelized cost analysis distributes costs at the present time over a series of payments in the future. These annual payments (AP) are equivalent to the payments on a self-amortizing loan of value (S) where each payment is a mix of principal and interest repayment. Table D-1 presents capital recovery factors for a range of interest rates and investment periods.

TABLE D-1. CAPITAL RECOVERY FACTORS

t \ d	6%	8%	10%	12%	15%	20%	25%
1	1.06000	1.08000	1.10000	1.12000	1.15000	1.20000	1.25000
2	0.54544	0.56077	0.57619	0.59170	0.61512	0.65455	0.69444
3	0.37411	0.38803	0.40211	0.41635	0.43798	0.47473	0.51230
4	0.28859	0.30192	0.31547	0.32923	0.35027	0.38629	0.42344
5	0.23740	0.25046	0.26380	0.27741	0.29832	0.33438	0.37184
6	0.20336	0.21632	0.22961	0.24323	0.26424	0.30071	0.33882
7	0.17914	0.19207	0.20541	0.21912	0.24036	0.27742	0.31634
8	0.16101	0.17401	0.18744	0.20130	0.22285	0.26061	0.30040
9	0.14702	0.16008	0.17364	0.18768	0.20957	0.24808	0.28876
10	0.13587	0.14903	0.16275	0.17698	0.19925	0.23852	0.28007
11	0.12679	0.14008	0.15396	0.16842	0.19107	0.23110	0.27349
12	0.11928	0.13270	0.14676	0.16144	0.18148	0.22526	0.26845
13	0.11296	0.12652	0.14078	0.15568	0.17911	0.22062	0.26454
14	0.10758	0.12130	0.13575	0.15087	0.17469	0.21689	0.26150
15	0.10296	0.11683	0.13147	0.14682	0.17102	0.21388	0.25912
16	0.09895	0.11298	0.12782	0.14339	0.16795	0.21144	0.25724
17	0.09544	0.10963	0.12466	0.14046	0.16537	0.20944	0.25578
18	0.09236	0.10670	0.12193	0.13794	0.16319	0.20781	0.25459
19	0.08962	0.10413	0.11955	0.13576	0.16134	0.20646	0.25366
20	0.08718	0.10185	0.11746	0.13388	0.15976	0.20536	0.25292
25	0.07823	0.09368	0.11017	0.12750	0.15470	0.20212	0.25090
30	0.07265	0.08883	0.10608	0.12414	0.15230	0.20085	0.25031
40	0.06646	0.08386	0.10226	0.12130	0.15056	0.20014	0.25003
50	0.06344	0.08174	0.10086	0.12042	0.15014	0.20002	0.25000
100	0.06018	0.08004	0.10001	0.12000	0.15000	0.20000	0.25000
∞	0.06000	0.08000	0.10000	0.12000	0.15000	0.20000	0.25000

t = number of years

d = discount rate

APPENDIX E

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