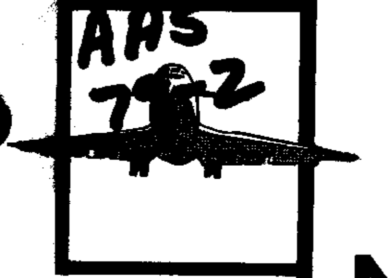

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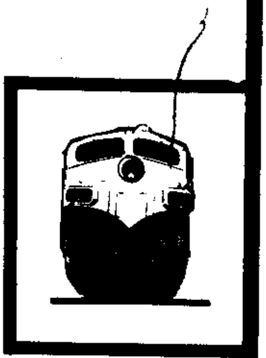
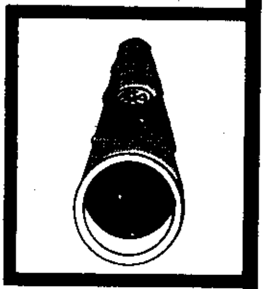


WASHINGTON, D.C. 20594

SPECIAL STUDY

LIGHT TWIN-ENGINE AIRCRAFT ACCIDENTS FOLLOWING ENGINE FAILURES, 1972-1976



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16. Abstract

The National Transportation Safety Board has studied the data collected during the investigation of 477 light-twin aircraft accidents from 1972 through 1976 which involved engine failure or malfunction. The complete records of particularly pertinent accidents were studied in detail. Pilot handbooks and other sources which provide information on engine-out performance and emergency procedures in light-twins were reviewed. A limited number of interviews with pilots and instructors were conducted. FAA training regulations were also studied.

A major conclusion of the study is that many of these accidents involved a lack of pilot proficiency in managing a light-twin after loss of power in one engine. Four recommendations are made to the FAA for corrective action and one previously made recommendation is reiterated.

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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

SPECIAL STUDY

Adopted: December 13, 1979

LIGHT TWIN-ENGINE AIRCRAFT ACCIDENTS FOLLOWING ENGINE FAILURES
1972-1976

INTRODUCTION

The National Transportation Safety Board found in a 1972 special study that accidents following engine failures or malfunctions in light twin-engine aircraft (light-twins) 1/ resulted in fatalities more than four times as often as similar accidents involving single-engine aircraft. This statistic dramatically illustrates the potentially fatal nature of accidents following loss of power in light-twins. Despite these findings by the Safety Board, as well as the publication of articles and other materials on the dangers of and the procedures for coping with power loss emergencies, such accidents continue to occur at the same rate.

In the 5 years 1972 through 1976, there were 477 accidents following engine failures or malfunctions in light-twins. Of these, 123 accidents were fatal, claiming 289 lives. An additional 374 persons received serious or minor injuries. These statistics, as well as the growing popularity of the light-twin aircraft in general aviation, prompted the Safety Board to examine some of the circumstances influencing this type of accident.

The purpose of this study is to determine if regulations regarding single-engine performance need modifications and to determine if training of multiengine pilots is adequate. The study involved a statistical review of data collected during investigations of light-twin accidents from 1972 through 1976. Accident records were studied in detail to determine specific acts (including failure to act) by the pilot and the contributing deficiencies in the aircraft that led to the accidents. Pilot and owner handbooks and other materials available to pilots which provide information on engine-out performance and emergency procedures in light-twins were reviewed to determine if such information was adequate to enable the pilot to cope with power loss emergencies. A limited number of interviews were conducted with light-twin pilots, certificated flight instructors, and FAA-designated check pilots to gain some insight into their knowledge, attitudes, and perceptions regarding management of power loss in light-twins. Federal regulations dealing with aircraft and pilot certification also were reviewed.

1/ Light-twins are defined as those aircraft weighing 12,565 lbs or less, and that have two engines.

LIGHT-TWIN ACCIDENTS

The Safety Board's aviation accident data system was used to generate data describing many factors involved in light-twin accidents. These data were reviewed with two objectives in mind. The first objective was to obtain a perspective of the magnitude of the light-twin accident problem in relation to other general aviation accidents, and, more specifically, the magnitude of the engine-failure accident problem as compared to other types of light-twin accidents. The other objective was to attempt to discover any trends in these accidents by learning more about the accidents, the pilots, and the aircraft.

The data specific to the understanding of the accidents involving engine failure in light-twins is presented in the text of this section. Additional information generated during this study is presented in tables in appendix A.

In the 5 years from 1972 through 1976, light-twins flew a total of 29.87 million hours. 2/ During that period, these aircraft were involved in a total of 2,229 accidents. Of these, 610 were fatal accidents. This provides an overall accident rate of 7.46 per 100,000 flying hours and a fatal accident rate of 2.04 per 100,000 hours for light-twins. By comparison, as reported in a Safety Board special study, 3/ during this same 5-year period, single-engine aircraft experienced an overall accident rate of 14.96 per 100,000 hours and a fatal accident rate of 2.31 per 100,000 hours.

Table 1 shows that the largest category of light-twin accidents is comprised of accidents associated with landing. The second largest category encompasses the accidents that occur following engine failures or malfunctions, with 477 or 21.3 percent of all light-twin accidents. Table 2 shows that 123 of these power loss accidents were fatal. This is equal to slightly more than 20 percent of the total number of fatal light-twin accidents. Thus, accidents following engine failures or malfunctions are shown to be a significant percentage of light-twin accidents.

Although engine failures and malfunctions occur most frequently during the en route portion of the flight, approximately 78 percent of the accidents subsequent to engine failures occur during the attempted landings. Further, 57 percent of these accidents are fatal. Additional information concerning the segment of flight in which power loss and the subsequent accidents occur can be found in appendix A.

Fatal Engine-Failure Accidents

The decision to be made by a pilot after an engine failure in a single-engine aircraft is simple: land the airplane. The light-twin, however, provides additional

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2/ Exposure data providing the number of hours flown annually by all general aviation aircraft for 1972 through 1976 were obtained from the Federal Aviation Administration. Changes in the data collection methods of the FAA during the period introduced some questions of data consistency. (See appendix B.)

3/ "Special Study—Single-Engine Fixed-Wing General Aviation Accidents, 1972-1976" (NTSB-AAS-79-1).

TABLE 1

TOTAL LIGHT TWIN-ENGINE AIRCRAFT ACCIDENTS, 1972-1976
TYPES OF ACCIDENTS BY PHASE OF OPERATION

ACCIDENT TYPE (FIRST TYPE)	PHASE OF OPERATION (FIRST PHASE)						
	UNKNOWN	STATIC	TAXI	TAKEOFF	INFLIGHT	LANDING	NUMBER OF AIRCRAFT IN TOTAL ACCIDENTS
Collisions With Ground/Water	-	-	-	25	134	72	231
Collisions With Obstacles	2	1	50	46	63	110	272
Stalls	-	-	-	32	39	59	130
Engine Failures Or Malfunctions	-	-	-	147	225	105	477
Midair Collisions	-	-	-	1	13	6	20
Inflight Airframe Failures	-	-	-	8	37	1	46
Fires	-	4	4	4	28	3	43
Landing Accidents	-	3	43	73	-	752	871
Other	25	13	21	25	37	18	139
TOTALS	27	21	118	361	576	1,126	2,229

TABLE 2

FATAL LIGHT TWIN-ENGINE AIRCRAFT ACCIDENTS, 1972-1976
TYPES OF ACCIDENTS BY PHASE OF OPERATION

	PHASE OF OPERATION (FIRST PHASE)						
ACCIDENT TYPE (FIRST TYPE)	UNKNOWN	STATIC	TAXI	TAKEOFF	INFLIGHT	LANDING	NUMBER OF AIRCRAFT IN TOTAL ACCIDENTS
Collisions With Ground/Water	-	-	-	15	126	42	183
Collisions With Obstacles	1	-	1	11	52	30	95
Stalls	-	-	-	8	36	41	85
Engine Failures Or Malfunctions	-	-	-	45	50	28	123
Midair Collisions	-	-	-	-	11	3	14
Inflight Airframe Failures	-	-	-	1	30	1	32
Fires	-	-	-	-	9	-	9
Landing Accidents	-	-	-	6	-	13	19
Other	21	4	-	6	16	3	50
TOTALS	22	4	1	92	330	161	610

options to the pilot after engine failure. In many cases, it can be flown successfully, while in other cases, due to inadequate aircraft performance, it cannot.

Engine failure accidents in light-twins occurred at the rate of 1.60 per 100,000 flying hours, and fatal engine-failure accidents occurred at the rate of 0.41 per 100,000 hours. In contrast, single-engine aircraft were involved in engine-failure accidents at the rate of 3.51 per 100,000 flying hours. Even though this rate is more than twice that for light-twins, the fatal rate for engine-failure accidents in single-engine aircraft is only 0.23 per 100,000 hours, about half the rate for light-twins. This shows that the percentage of fatal accidents involving engine failure is more than four times greater in light-twins than in single-engine aircraft. Two hypotheses have been offered to account for this difference in single-engine and light-twin fatal rates.

Due to unique aerodynamic qualities associated with engine failures in light-twins with wing-mounted powerplants, control of these aircraft can be lost if airspeed is allowed to dissipate. Accidents involving loss of control are very serious and often fatal. Thus, one hypothesis is that a greater percentage of these serious and often fatal accidents following an engine failure will occur in light-twins than in single-engine aircraft.

Two types of accidents associated with loss of control or near loss of control are collisions with ground/water and stalls. These types of accidents accounted for 72 percent of the 123 fatal light-twin accidents involving engine failures. The total number of fatal and nonfatal loss of control accidents which occurred after engine failures in light-twins is 165. (See table A3 in appendix A.) This results in a rate of 0.55 per 100,000 hours for light-twins. During this same period, accidents following engine failure in single-engine aircraft occurred at the rate of 0.57 per 100,000 hours. Thus, the accident data show that, contrary to the hypothesis discussed above, the serious types of accidents which involve loss of control or near loss of control occur about as often in single-engine aircraft following engine failure as in light-twins.

The other hypothesis offers the explanation that the considerably greater percentage of fatal light-twin accidents is related to their significantly higher speeds and greater weights. To test the validity of this hypothesis, the fatal percentages of these two serious types of accidents were compared for single-engine aircraft, high-performance single-engine aircraft, and light-twins. The following tabulation shows that the greater the average cruising speed, stall speed, and weight, the greater is the percentage of these accidents that are fatal.

	Cruise speed (mph)	Stall Speed (mph)	Gross takeoff weight (lbs)	Percentage fatal to total serious accidents
Single-engine aircraft	95-160	42-75	1,500-3,300	45
High-performance single	160-225	55-75	2,500-4,000	65
Light-twins	170-360	59-99	3,500-12,500	74

Under any circumstances, the high percentage of fatal accidents following engine failures in light-twins makes these accidents a major concern to the Safety Board.

Light-Twin Makes and Models in Engine-Failure Accidents

Table 3 on page 8 presents an alphabetical listing of light-twin makes and models (determined by type certificates) which were flown more than 250,000 hours during 1972-1976. The table also provides total accidents and engine-failure accidents and the rates of occurrence of these accidents per 100,000 hours. Table 4 on page 9 presents comparable data for all fatal accidents and fatal engine-failure accidents. The rates of total accidents vary from a low of 1.52 to a high of 12.85, and the rates of engine-failure accidents vary from zero to a high of 3.46. The considerable range in accident rates suggests that a closer look at the role of the aircraft in these accidents is warranted. An assessment of the single-engine performance of the aircraft is given on pages 13 through 18.

Kind of Flying—Professional vs. Nonprofessional

Two methods commonly used to classify accidents are by kind of flying and by pilot certificate. The categories used by the Safety Board to describe kinds of flying pertinent to this study include instructional, pleasure, business, air taxi, and corporate. The FAA, which provides the data on hours flown in aircraft makes and models (exposure data) according to kind of flying, uses a slightly different classification system. The corresponding FAA categories are instructional, personal, business, air taxi, and executive. These classifications are similar enough to justify the analysis performed here; however, there is some concern about the compatability between the FAA's "personal" flying and the Safety Board's "pleasure" flying categories.

Many in the general aviation industry believe that there is no real distinction between "pleasure" and "business" flying. It is possible that differences exist between the procedures used by the Safety Board for classifying accidents as "pleasure" or "business" flying and the procedures used by pilots in allocating the flying time which they provide to the FAA between "personal" and "business" flying. These differences, as well as possible additional differences in the definitions of the Safety Board's "pleasure" and the FAA's "personal" flying could result in distortions of the accident rates of business and pleasure flying. Therefore, a single classification combining pleasure and business flying accident data was developed, and the tabulation of total and fatal engine-failure accident rates by kind of flying is shown at the top of page 7.

An interesting point brought out in the tabulation is that over half of the accidents following engine failures or malfunctions involve pleasure and business flying.

Kind of flying	Hours flown 1/	Total engine-failure accidents	Total engine-failure accident rate 2/	Fatal engine-failure accidents	Fatal engine-failure accident rate 2/
Instructional	9.07	49	5.40	9	0.99
Pleasure and business	101.32	262	2.59	68	0.67
Air taxi/ commuter 3/	78.41	60	0.77	18	0.23
Executive or corporate	104.29	35	0.34	10	0.10

1/ 100,000 flying hours
2/ per 100,000 flying hours
3/ Accident data for these kinds of flying were recorded and filed under the classification "Air Taxi" during the years 1972, 1973, and 1974. During the years 1975 and 1976, these kinds of flying were recorded as "air taxi and commuter," which are combined in this study under the classification Air Taxi. The commuter data have been reconciled with FAA data.

When the total and fatal accidents of all types involving light-twins are classified in this manner, the following breakdown results:

Kind of flying	Total accident rate 1/	Fatal accident rate 1/
Instructional	14.88	2.98
Pleasure and business	12.10	3.51
Air taxi	4.83	1.45
Executive or corporate	2.37	0.53

1/ Per 100,000 flying hours.

These data indicate that, based on accident rates, two general areas of light-twin flying exist. One area includes instructional, pleasure, and business flying; the other includes air taxi and corporate flying. The former area probably involves many pilots who do not earn their living by flying and who are possibly less experienced and skilled than pilots in the later area, many of whom do earn their living by flying.

TABLE 3

TOTAL ACCIDENTS AND ENGINE-FAILURE ACCIDENTS BY MAKE AND MODEL

AIRCRAFT	FLIGHT HOURS	TOTAL ACCIDENTS	RATE OF TOTAL ACCIDENTS*	ENGINE FAILURE ACCIDENTS	RATE OF ENGINE FAILURE ACCIDENTS*
Aero Commander 500, 520, 560	751,741	78	10.38	26	3.46
Aero Commander 560F, 680E, 680F, FL, 700, 720	962,695	64	6.65	18	1.87
Beech 18	1,774,410	228	12.85	49	2.76
Beech 50	391,219	36	9.20	8	2.04
Beech 65, 65-90	2,443,546	62	2.54	21	0.86
Beech 95, 95-55, 56, 58	3,184,028	264	8.29	36	1.13
Beech 60	289,524	13	4,49	-	-
Beech 99, 100	771,653	17	2.20	3	0.39
Cessna 310	2,986,987	293	9.81	52	1.74
Cessna 320, 340	730,945	68	9.30	13	1.78
Cessna 337	1,046,156	109	10.42	25	2.39
Cessna 401, 411	1,979,084	109	5.51	16	0.81
Cessna 421	1,041,379	53	5.09	11	1.06
DeHavilland DHC-6	789,483	12	1.52	-	-
Mitsubishi	547,309	24	4.39	8	1.46
Piper PA-23	3,993,100	301	7.54	90	2.25
Piper PA-30, 39	1,463,106	172	11.76	29	1.98
Piper PA-31	1,766,471	67	3.79	13	0.74
Piper PA-34	844,096	84	9.95	10	1.18
Swearingen SA26T, SA226TC	411,019	13	3.16	-	-

*Per 100,000 flying hours.

TABLE 4

FATAL ACCIDENTS AND FATAL ENGINE-FAILURE ACCIDENTS BY MAKE AND MODEL

AIRCRAFT	FLIGHT HOURS	FATAL ACCIDENTS	RATE OF FATAL ACCIDENTS*	FATAL ENGINE FAILURE ACCIDENTS	RATE OF FATAL ENGINE FAILURE ACCIDENTS*
Aero Commander 500, 520, 560	751,741	25	3.33	6	0.80
Aero Commander 560F, 680E, 680F, FL, 700, 720	962,695	24	2.49	5	0.52
Beech 18	1,774,410	60	3.38	18	1.01
Beech 50	391,219	11	2.81	3	0.77
Beech 65,65-90	2,443,546	17	0.70	7	0.29
Beech 95, 95-55, 56, 58	3,184,028	90	2.83	16	0.50
Beech 60	289,524	7	2.42	-	-
Beech 99, 100	771,653	4	0.52	-	-
Cessna 310	2,986,987	65	2.18	10	0.33
Cessna 320, 340	730,945	21	2.87	6	0.82
Cessna 337	1,046,156	32	3.06	6	0.57
Cessna 401, 411	1,979,084	28	1.41	3	0.15
Cessna 421	1,041,379	17	1.63	5	0.48
DeHavilland DHC-6	789,483	5	0.63	-	-
Mitsubishi	547,309	10	1.83	3	0.55
Piper PA-23	3,993,100	104	2.60	21	0.52
Piper PA-30, 39	1,463,106	28	1.91	2	0.14
Piper PA-31	1,766,471	20	1.13	4	0.23
Piper PA-34	844,096	13	1.54	-	-
Swearingen SA26T, SA226TC	411,019	2	0.49	-	-

*Per 100,000 flying hours.

Pilot Certificate

The following tabulation of accidents by pilot certificate lists the type of pilots involved in these light-twin accidents following engine failure.

	Fatal engine-failure		Total engine-failure	
Certificate	Accidents	Percent	Accidents	Percent
Student	0	0	3	0.6
Private	38	30.9	128	26.8
Commercial	48	39.0	176	36.9
Airline transport	14	11.4	40	8.4
Flight instructor	23	18.7	124	26.0
Unknown	0	0	6	1.3
Total	123	100.0	477	100.0

In over 72 percent of these total accidents, a certificate above the level of private pilot was held by the pilot-in-command. About 26 percent were flight instructors and over 8 percent held airline transport certificates, the most advanced level of certificate obtainable. Clearly, light-twin accidents following engine failures are not unique to the private (or student) pilot but also involve pilots with advanced certificates.

Another indication of the experience level of pilots involved in engine-failure accidents in light-twins is provided by figures 1 and 2. Figure 1 presents accidents as a function of pilot total flight time segmented into six groups of hours. Figure 2 presents comparable data as a function of pilot flight time in type of aircraft.

Figure 1 shows that the largest number of accidents involved experienced pilots with 1,001 to 3,000 total flight hours. Further, almost half of the accidents involved pilots with more than 3,000 hours and over 27 percent had more than 5,000 hours. Figure 2 shows that considerably more than half (62 percent) of the pilots involved in these accidents had more than 100 hours flying experience in the aircraft make and model involved in the accident. Almost 40 percent had more than 300 hours in type.

A determination of which, if any, group of pilots based on level of experience had accidents greater than its statistically expected numbers cannot be made without appropriate exposure data (which is not currently collected by any government agency or industry organization). However, it is apparent from the data in figures 1 and 2 that light-twin accidents following engine failures are not unique to inexperienced pilots.

The data on pilot certificate level and pilot flight time combined with the data presented earlier on kind of flying suggests that these accidents involve high-level, experienced pilots as well as less experienced pilots. An assessment of the pilot role in these accidents is given on pages 19 through 33.

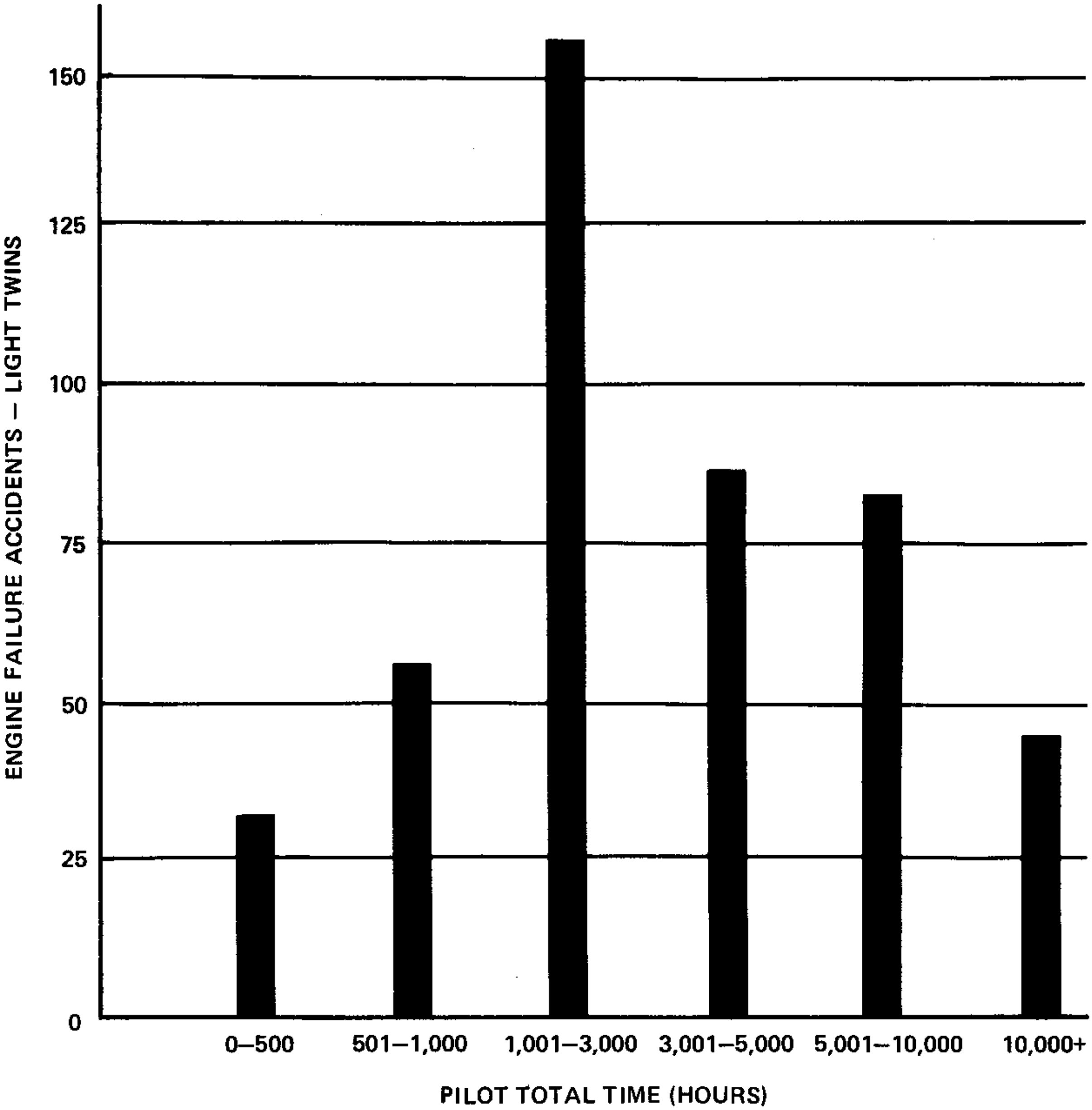


Figure 1. Light-twin accidents following engine failure
(as a function of pilot total time)

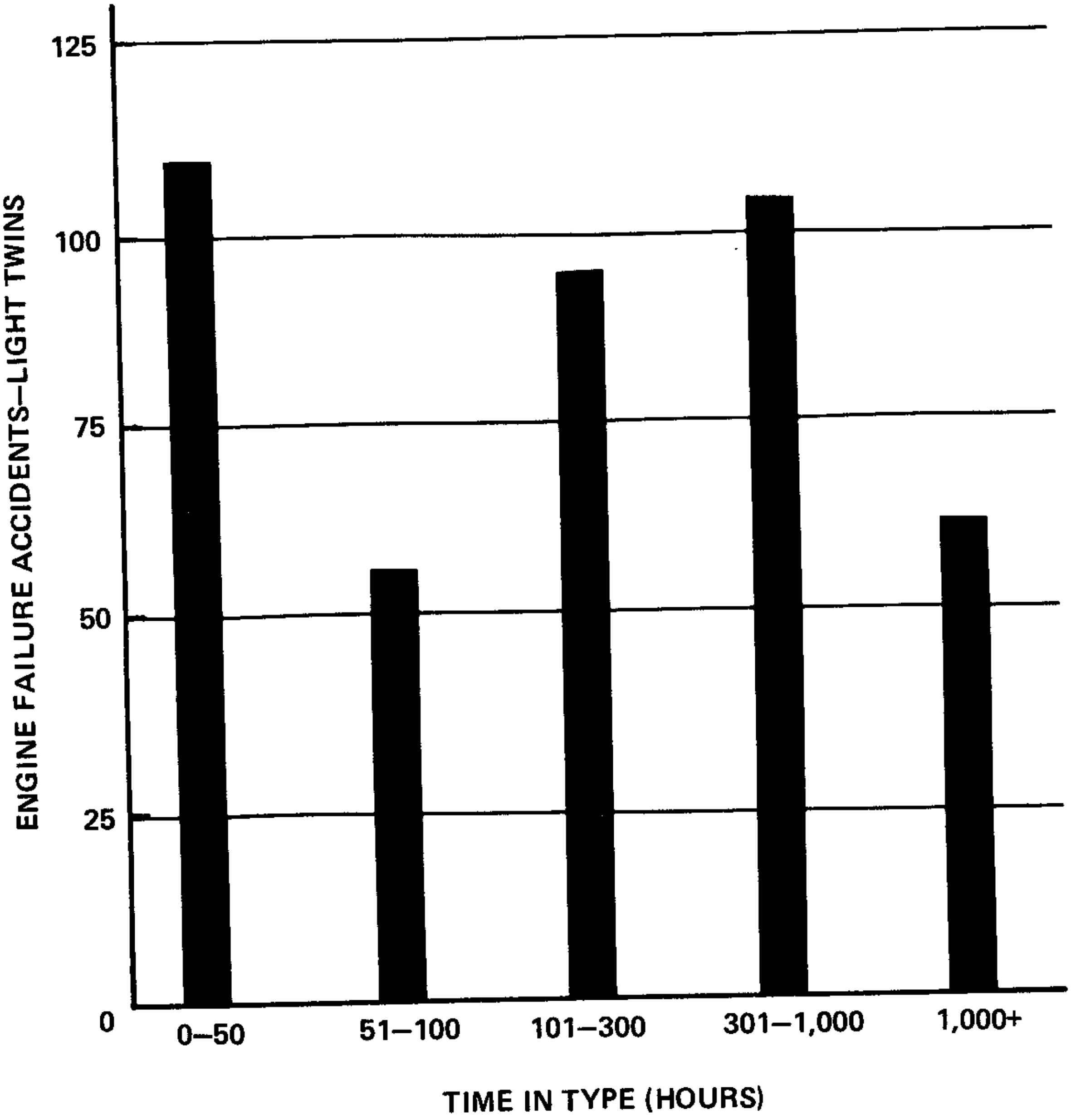


Figure 2. Light-twin accidents following engine failure (as a function of pilot time in type)

AIRCRAFT SINGLE-ENGINE PERFORMANCE

The wide range of accident rates for the various aircraft makes and models presented in table 3 prompted a review of the single-engine performance capabilities of these aircraft to determine the relationship, if any, between performance and accident rates.

The two principal factors affecting the safe single-engine flight of light-twins are airspeed and power. The directional control of a light-twin under single-engine conditions is highly dependent on airspeed. Loss of power on one side of the airplane results in asymmetrical thrust which creates a yawing moment (an unwanted turning motion of the aircraft) that must be corrected by the rudder. The minimum calibrated airspeed at which the rudder can develop sufficient force to balance the asymmetrical thrust forces, thereby allowing directional control of the aircraft to be maintained, is termed the minimum control speed (Vmc).

Vmc is determined by flight test when the critical engine is suddenly made inoperative with the aircraft in the following configuration: The aircraft will have takeoff or maximum allowable power, its rearmost allowable center of gravity (cg), flaps in takeoff position, landing gear retracted, and the propeller of the inoperative engine either windmilling with the propeller in the takeoff range, or feathered if the aircraft has an automatic feathering device. Recovery from loss of control under these conditions should be initiated without having to use exceptional skill, alertness, or strength, to prevent a heading change of more than 20°. In addition to this, and at the manufacturer's option, a bank angle into the operative engine of not more than 5° may be used to assist in counteracting yaw. Vmc varies with aircraft configuration (including power), its weight, center of gravity position, altitude, and outside air temperature. The minimum control speed published in the pilot or owner's handbook is the highest (worst) value possible for that aircraft. Adherence to the practice of never flying at or below this published speed will virtually eliminate loss of directional control as a problem in the event of an engine failure.

In addition to the creation of control problems, loss of power will substantially decrease the climb capability of a light-twin. The single-engine climb performance will often involve a decrease of 80 percent or more from twin-engine performance. In fact, except for aircraft used in air taxi or commercial operations and those capable of hauling 10 or more passengers, 14 CFR 23 does not require continued single-engine takeoff capability. In addition to this, if the aircraft weighs 6,000 pounds or less and has a stall speed in the landing configuration (Vso) of 61 knots or less, there is no requirement that light-twins have any single-engine rate of climb capability. For light-twins weighing more than 6,000 pounds or with Vso greater than 61 knots, a single-engine climb capability must be demonstrated. At an altitude of 5,000 feet with the propeller of the inoperative engine feathered and the aircraft in clean configuration, the aircraft must climb at a rate determined by the formula ROC = 0.027 Vso2. Thus, for a light-twin aircraft with a Vso of 65 knots, the rate of climb formula requires that this aircraft demonstrate a single-engine rate of climb of 114 ft/min in its optimal climb configuration.

Usually, single-engine climb performance is demonstrated with the aircraft in its most aerodynamically clean configuration, including a 3° to 5° bank into the operative engine to assist in eliminating yaw-induced drag. Often, these optimal conditions are difficult to obtain quickly when engine power is lost at or just after liftoff. At this critical point, maintaining airspeed above Vmc and control of the aircraft become the pilot's foremost concerns. This is followed by "cleaning up" the aircraft for climb, if it has climb capability under the conditions existing. The ability to fly the aircraft in precisely the proper attitude and configuration to achieve the maximum climb performance is difficult at best, and highly dependent on knowledge of, and proficiency in, the emergency situations. The single-engine rate of climb as determined under the optimal conditions for each series of aircraft models is presented in table 5. Note that for most of the piston-engine light-twins the rate of climb is only 200 to 400 ft/min at sea level under these optimal conditions. These aircraft, moreover, do not have to demonstrate a capability to continue to climb in a takeoff configuration at sea level, and some, in fact, will not climb. The turboprop aircraft generally have better single-engine climb performance, and many can demonstrate continued takeoff capability.

Climb performance is a function of engine horsepower available in excess of that necessary for straight and level flight of an aircraft. For a given light-twin, the greater the total available horsepower, the greater the excess thrust horsepower, and therefore, the greater the single-engine rate of climb capability of the aircraft. An obvious question would be whether there exists a relationship between excess horsepower, as a measure of single-engine climb capability, and accident rate. Since excess horsepower varies with aircraft weight, outside temperature, and altitude, it is difficult to determine and to use excess horsepower to compare the various aircraft. However, power loading—the ratio of the aircraft maximum gross weight to the total horsepower of the engines—is readily available and is fixed for a given aircraft. Power loading provides a useful comparison of power and accident rate for these light-twins. A larger power loading indicates less horsepower per pound of aircraft and, thus, lower excess horsepower available for climb capability.

The power loadings of the 24 light-twins studied are ranked in table 6 on the basis of accident rate. A review of these data reveals that the lower power loadings (higher power-to-weight ratio) are apparently associated, to some extent, with the lower accident rates. The 24 aircraft were divided into three equal groups based on accident rate. These groups consisted of a low, an intermediate, and a high rate group. The mean accident rate and the mean power loading of each of these groups were calculated and are shown in the following tabulation:

	Low rate group	Intermediate rate group	High rate group
Accident rate	0.50	1.25	2.94
Mean power loading	8.9	9.9	11.2

This tabulation shows more clearly the apparent relationship between accident rate and aircraft power loading. Note that the mean power loading of the high accident rate group is 25 percent greater than that of the low accident rate group.

TABLE 5

SINGLE-ENGINE RATE OF CLIMB FOR LIGHT-TWIN MAKES AND MODELS (IN ORDER OF ACCIDENT RATE)

AIRCRAFT	ENGINE-FAILURE ACCIDENT RATE (PER 100,000 HRS)	RATE OF CLIMB (FEET/MINUTE)	AVERAGE RATE OF CLIMB (FEET/MINUTE)
Beech 60	-	307-319	313
DeHavilland DHC-6	-	340	340
Swearingen SA26T, 226TC	-	520-700	610
Beech 99, 100	0.39	335-452	394
Aero Commander 680T, 681, 690	0.40	510-893	702
Beech 65-90	0.41	470-555	513
Piper PA-31	0.74	230-660	445
Cessna 401, 411	0.81	255-270	263
Beech 95-55, 56, 58	0.82	204-410	307
Piper PA-23-235, 23-250	0.93	220-240	230
Cessna 421	1.06	300	300
Piper PA-34	1.18	225-230	228
Mitsubishi	1.46	450-920	685
Cessna 310	1.74	330-440	385
Cessna 320, 340	1.78	250-500	375
Beech 65	1.95	180	180
Piper PA-30, 39	1.98	225-260	243
Beech 50	2.04	195-300	248
Cessna 337	2.39	325-450	388
Beech 18	2.76	260-340	300
Beech 95	2.87	205	205
Aero Commander 560F, 680E, 680F, FL, 700, 720	3.43	293-490	392
Aero Commander 500, 520, 560	3.46	266	266
Piper PA-23, -150, -160, -180	6.91	240	240

TABLE 6

POWER LOADINGS OF LIGHT-TWIN MAKES AND MODELS (IN ORDER OF ACCIDENT RATE)

AIRCRAFT	ENGINE-FAILURE ACCIDENT RATE (PER 100,000 HRS)	POWER LOADING (LBS/HP)	AVERAGE POWER LOADING (LBS/HP)
Beech 60	-	8.8- 8.9	8.9
DeHavilland DHC-6	-	9.6	9.6
Swearingen SA26T, 226TC	-	7.4- 8.4	7.9
Beech 99, 100	0.39	8.3- 9.3	8.8
Aero Commander 680T, 681, 690	0.40	7.3- 8.5	7.9
Beech 65-90	0.41	8.8- 9.3	9.0
Piper PA-31	0.74	7.3-10.5	8.9
Cessna 401, 411	0.81	9.6-10.5	10.1
Beech 95-55, 56, 58	0.82	7.8- 9.8	8.9
Piper PA-23-235, 23-250	0.93	9.6-10.4	10.0
Cessna 421	1.06	9.6	9.6
Piper PA-34	1.18	11.4	11.4
Mitsubishi	1.46	6.9- 8.1	7.6
Cessna 310	1.74	9.5- 9.8	9.7
Cessna 320, 340	1.78	10.0-10.5	10.2
Beech 65	1.95	11.1-12.8	11.9
Piper PA-30, 39	1.98	11.3-11.7	11.5
Beech 50	2.04	10.9-11.5	11.2
Cessna 337	2.39	10.0-10.7	10.3
Beech 18	2.76	10.8-11.0	10.9
Beech 95	2.87	11.1-12.8	11.9
Aero Commander 560F, 680E, 680F, FL, 700, 720	3.43	10.0-11.0	10.5
Aero Commander 500, 520, 560	3.46	11.0-12.0	11.5
Piper PA-23, -150, -160, -180	6.91	11.7-11.9	11.8

Using a simple, automated, linear regression routine, a regression equation was determined for the data in table 6. The resulting correlation coefficient of 0.52 indicates that some association exists between accident rate and power loading. The data in table 6 are shown graphically in figure 3, along with the computed regression line. This figure provides a visual display of the apparent association of power loading with accident rate.

Although it has not been established conclusively that accidents following engine failure or malfunction are the direct result of inadequate single-engine climb performance, it is apparent that there is some association between these accidents and power loading. Accordingly, the Safety Board believes that the general aviation industry and the FAA should consider this apparent relationship when designing new light-twins, when assessing the adequacy of existing airworthiness regulations, and when drafting new regulations. 4/

Even when there is climb capability, it might not be sufficient to clear obstacles such as terrain or buildings located around the airport. For this reason, it is extremely important for a pilot to carefully formulate a preflight plan. Accelerate-stop distance charts, when available, as well as single-engine climb charts should be used in preflight planning to decide, before starting the engines, whether sufficient runway would be available to stop the aircraft in the event of engine failure before liftoff. This planning should also include determining whether to abort if the engine failure occurs immediately after liftoff.

Another single-engine performance parameter to be considered is the single-engine service ceiling. This is the maximum altitude at which a light-twin will climb at a rate of 50 ft/min with one engine feathered. The single-engine service ceiling, which is a function of aircraft weight, outside temperature, and altitude, is useful in determining whether the light-twin can maintain terrain clearance under VFR flight, or minimum en route altitude in IFR flight, following an engine failure.

Clearly, light-twins are not without limitations when one engine fails. It is equally clear that not all of these limitations can be remedied by design improvements and certainly the current fleet of nearly 25,000 light-twins cannot be modified readily. To cope with these limitations, assuming no aircraft modifications are made, pilots must be adequately trained to recognize and respond to engine-failure emergencies, with special emphasis on climb performance as well as Vmc. In the following section, the Safety Board examines pilot factors associated with the operation of light-twins during an engine failure.

4/ An excellent discussion of the various aspects of the single-engine performance of light-twins, including the percentage of reduction in rate of climb with one engine inoperative, can be found in an article by Richard N. Aarons entitled "Always Leave Yourself An Out," Business and Commercial Aviation, July 1973, pp. 45-80. (See appendix C.)

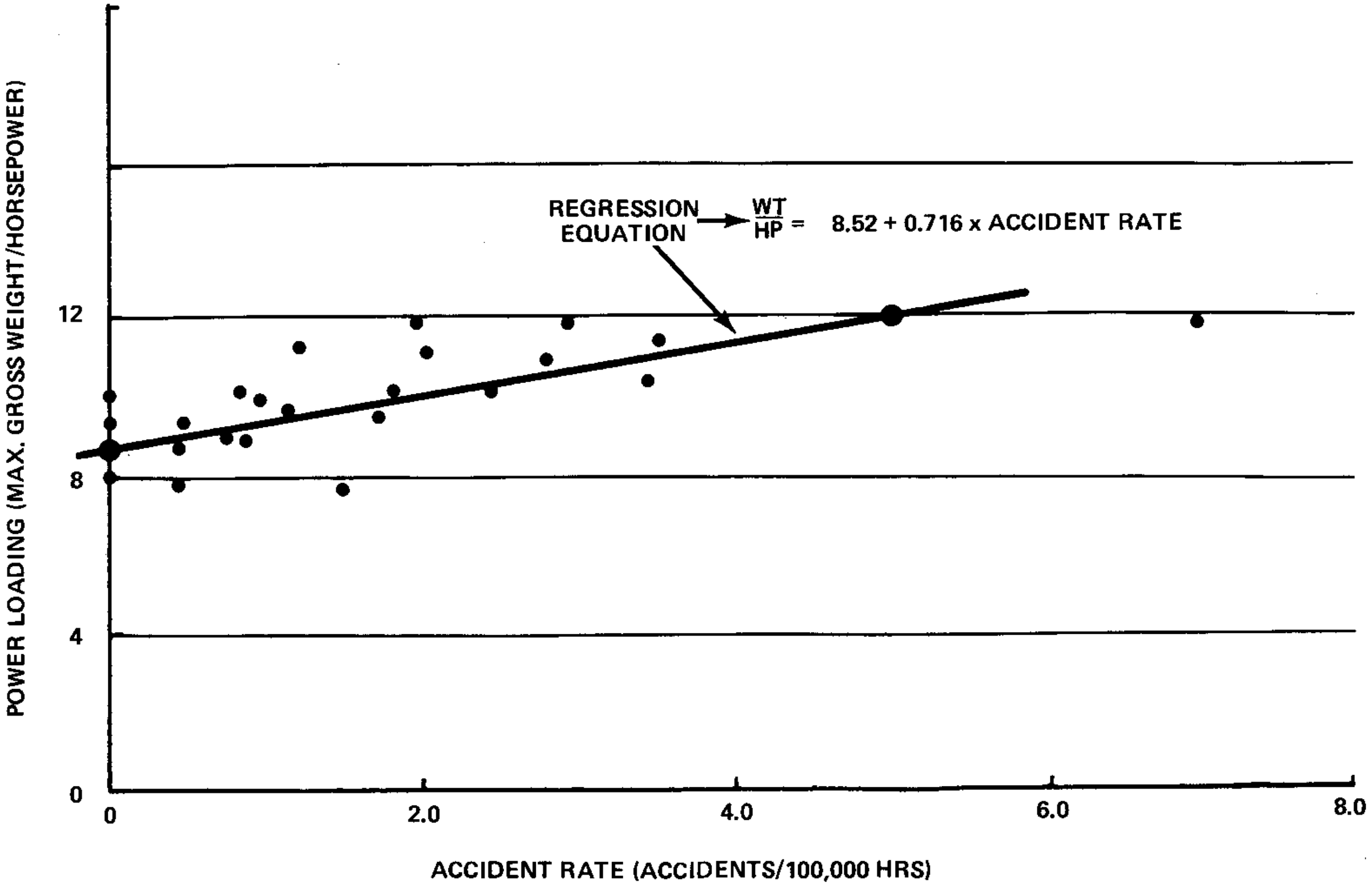


Figure 3. Power loading of light-twins.

PILOT KNOWLEDGE AND SKILLS

Sources of Information

The way the aircraft performs and the interaction of the pilot with the aircraft are always important, but during emergencies this performance and interaction are more critical. The pilot must have the proper knowledge and skills to enable him to get the best performance from his aircraft. While hands-on learning to control the aircraft in engine-out emergencies is the primary means to develop adequate skills, pilot handbooks, aircraft manuals, manufacturer bulletins, and articles are basic sources of knowledge.

The Safety Board examined many pilot handbooks for light-twins. The older handbooks provided only a minimum amount of operating information. Especially limited was the information about, and specific procedures for coping with, single-engine operation. During the 1960's, the handbooks were improved significantly. One of the most useful changes was the creation of separate sections dealing solely with emergency procedures and with aircraft performance. One evident and substantial deficiency in the new format, however, was that the emergency procedures were imbedded in the narrative presentation. Checklists and graphic presentations of emergency procedures and data were used infrequently. The information, although there, was difficult to extract from the text. Further, the provided information varied widely since each manufacturer decided what to include and the depth of the presentation. Some handbooks lacked accelerate-stop distance data or information on single-engine climb performance over obstacles. In many handbooks, takeoff and landing speeds shown were below Vmc, and no warning was given to the pilot regarding that fact. In addition to this, climb performance for critical situations such as an engine loss on takeoff was often given for zero yaw or near-zero yaw condition. This lower drag configuration generally requires up to 5° of bank into the operative engine. Despite the fact that reducing yaw in critical situations may mean the difference between establishing a climb or being unable to hold altitude, the pilot, in many cases, was not given this critical information.

Pilot handbooks continued to improve through the early 1970's, and in 1975, the General Aviation Manufacturers Association (GAMA) issued the "Specifications for Pilot's Operating Handbook." This document was designed to standardize pilot handbooks with respect to the arrangement of materials and to provide uniformity in definitions and performance information. Today, most pilot handbooks are well organized and contain most technical information on aircraft performance, including single-engine performance and emergency procedures, needed for safe operation of an airplane. Handbooks, of course, are effective only if they are read and understood by the pilots. It is important, therefore, not only that the information is complete, but that it is easy to comprehend and to use. Complex presentations frustrate the reader and often cause him to give up before he understands the content. Such responses defeat the purpose of the handbook.

Although the recent manuals are a vast improvement over their predecessors, the Safety Board found that the charts and graphs in some are difficult to understand.

Pilot handbooks for specific airplanes are the best sources of emergency information for those airplanes. However, they are not the only source of information. The FAA publishes a large amount of single-engine operating and emergency procedures information. The GAMA also contributes to the flow of information to pilots, and some of its publications are distributed by the FAA. Pilot organizations try to keep their members well informed, not only through mailings and magazine articles but also through clinics for the student pilot as well as the more advanced pilot. Clinics are also sponsored by local FAA offices, flying clubs, and associations. Probably the most readily available and most widely used source of information is the aviation magazine. These periodicals cover a wide range of topics including those concerned with single-engine performance. Two excellent examples are the previously mentioned "Always Leave Yourself An Out" by Richard N. Aarons, 5/ (see appendix C) and "Decision Points for Pros in Twin-Engine Performance" by John Lowery 6/ (see appendix D). Both of these articles discuss, in detail, the single-engine performance of light-twins and the techniques for handling engine-failure emergencies.

Case Histories

Despite the availability of information on single-engine performance and emergencies, the accident statistics suggest that this information is not used or referred to as often as necessary or to the extent necessary. To gain a better understanding of the aircraft and pilot factors involved in accidents following engine failure or malfunction in light-twins, the Safety Board reviewed, in detail, the complete records of more than 30 such accidents. Seven cases illustrating the difficulties in responding to loss of power in light-twins are presented.

Case 1.--The pilot of a PA-23-160 started the engines and taxied for takeoff on the 5,200-foot runway. Shortly after it became airborne (about 1,200 feet down the runway) the aircraft's left engine lost power. The aircraft entered a climbing turn to the left for about 180° to an altitude of 150 to 200 feet. At this point, the nose dropped abruptly, the left bank steepened, and after another 180° turn, the aircraft crashed into the ground. The pilot, according to tachometer time readings, did not take time to do a thorough preflight check and run-up. Based on length of takeoff run, the pilot apparently elected to rotate at or below Vmc. When engine failure occurred, he did not land on the 4,000 feet of available runway. The pilot had 5,100 hours of flying time. His times in multiengine aircraft and the PA-23-160 are unknown.

Rotating the aircraft at or below Vmc, not landing on the 4,000 feet of runway available when the engine failed, and not obtaining enough flying speed to maintain control of the aircraft indicate a lack of adequate knowledge of the single-engine performance of the aircraft and the emergency procedures to be followed and/or a lack of ability to identify and execute the proper responses.

5/ Ibid.

6/ John Lowery, "Decision Points For Pros in Twin-Engine Performance," Professional Pilot, February 1977, pp. 35-41.

Case 2.—The pilot of a Beech 58 taxied for takeoff. The preflight and engine run-up were observed to be normal. The takeoff was normal until the aircraft reached an altitude of 150 feet. At this time, witnesses reported seeing the aircraft fall to the ground and explode. The investigation showed that the pilot failed to retract the landing gear and possibly did not feather the left propeller promptly. Flight tests performed as part of the investigation showed that the aircraft could have been flown had proper emergency procedures been followed and had the pilot maintained control of the aircraft by maintaining flying speed. The pilot had 2,288 hours of flying time, of which 2,012 hours were in multiengine aircraft and 1,136 hours were in the Beech 58.

Power loss, in this case, was due to mechanical failure. It is highly probable that this pilot was no longer proficient in the mechanics of dealing with power loss on takeoff, and, caught by surprise, lost valuable time trying to decide what action to take first. Because of inattention during this time, he allowed the flying speed to fall, leading to subsequent loss of control.

Case 3.—The PA-30 had been vandalized about 1 week before this flight when its gas caps were removed and snow was stuffed in the tanks. The pilot was informed of this and it was recommended that the aircraft be moved into a heated hangar where all of the fuel could be drained. This was not done. Instead, on the morning of the flight, the pilot drained several quarts of fuel from his aircraft. Noting that it was clear, he started his engines and, encountering no problems, decided to go for a test flight. This was accomplished without incident, and upon his return, his passengers arrived and were boarded. The engines were restarted and the plane taxied for takeoff. After the run-up, takeoff was initiated. The aircraft lifted off at or before the midpoint of the 2,880-foot runway and the gear was retracted almost immediately. During rotation and lift-off, the left engine started to backfire and lose power. Both propellers were observed turning as the aircraft proceeded to slowly climb in a nose-high and unstable attitude to about 150 feet. As the aircraft passed the end of the field, the landing gear was extended and the airplane began a gentle left turn. The bank angle increased rapidly so that the airplane was almost 90° to runway heading and the wings were nearly vertical. At this time all engine noise ceased and the aircraft descended and crashed. Investigation showed that under the same loading conditions as found here, this airplane should have been able to be climbed, flown, and landed on one engine. The pilot had more than 1,700 hours of flying time, including more than 700 hours in multiengine aircraft and more than 700 hours in the PA-30.

Retracting the landing gear reduced the possibility of safely landing straight ahead in case of engine failure at liftoff if sufficient runway remained. Subsequent failure to obtain sufficient airspeed and to follow other emergency procedures, such as feathering the propeller on the bad engine, probably caused the airspeed to fall below Vmc or the stall speed (Vs), resulting in the crash. The gear was lowered, probably, to stabilize the aircraft. These actions suggest insufficient familiarity with the aircraft's performance capabilities and limitations. The gear-down action further suggests a lack of familiarity with the proper emergency procedures for this aircraft.

Case 4.—During pretakeoff procedures, the left engine of the C421 died twice. The pilot taxied back to the hangar where a mechanic determined that the problem was caused by an excessively rich fuel mixture when the boost pump was used. During this examination, the engine operated normally and the pilot elected to take off. Takeoff run was normal and the pilot was able to lift off and retract the gear. At this time, the left engine began to surge. The pilot attempted to make a 180° turn and return to the airport. He did not maintain airspeed and crashed in a field. When interviewed, the pilot stated that he had panicked. He did not try to identify the cause of the surge, and he did not feather the propeller, lean the mixture, or move the boost pump switch; he only attempted to turn back to the airport. He further stated that he had allowed the airspeed to fall below Vmc twice and that he was lucky to level the wings before impact. The pilot had 3,000 hours of flying time, including 600 hours of flying multiengine aircraft and 110 hours in the C421.

This pilot was apparently uncertain of the proper emergency procedures or his ability to carry them out. Had this pilot developed strongly imbedded responses to engine-out emergencies, it is less likely that the stress he felt when he lost an engine would have resulted in the panic which disrupted his ability to respond appropriately.

Case 5.—This was a training flight that was to include a single-engine landing with the propeller feathered. The PA-30 was observed in landing configuration with the right propeller feathered on short final. Witnesses state that the aircraft had excessive speed for that point in the approach. The aircraft was seen traveling down the runway without touching down. This condition would have resulted in an overshoot. Perhaps because of this, the pilot elected to attempt a go-around. Power was applied to the left engine approximately halfway down the 2,988-foot runway. The aircraft started to climb out with the gear retracted. It was seen shortly thereafter in a 30° nose-high right turn at an altitude of about 80 feet. The bank continued to the right and the nose rose to an abnormally high attitude. The aircraft then rolled to a near inverted attitude and dove almost vertically into the ground. The student pilot had 211 hours of flying time of which 4 hours had been in the multiengine PA-30. The instructor had an estimated 3,688 hours of flying time; his flying times in multiengine aircraft and the PA-30 are unknown.

The pilot's handbook for this airplane contained information and warnings about single-engine flight under the conditions found here. Additional information obtained from the manufacturer confirms the probability that this airplane, under the conditions described in this case, would hardly be able to maintain altitude, much less climb on one engine. It is understandable that a 4-hour pilot might be unfamiliar with both the aircraft and procedures. The instructor, however, also displayed a marked lack of familiarity with the aircraft's performance capabilities as well as the inability to recognize a critical situation and to take the proper corrective action.

Case 6.—This was a business flight to be flown by a company executive. At the last minute, the company's pilot decided to accompany the executive on this trip. As was their normal procedure, the company pilot was in charge of getting the C421A ready for flight with the executive doing a walk-around. The executive was flying the aircraft and the company pilot was handling the radios. The aircraft was taxied, and run-up was performed without problem. The aircraft was cleared for takeoff, and after power was applied, proceeded on takeoff roll. After liftoff, just after the gear was retracted, the company pilot pulled the mixture control on the left engine. The executive pilot stated that there was no warning or indication of a problem before or after power was cut. He also stated that it took everything he had to maintain control of the airplane. Efforts to control the aircraft were unsuccessful and it crashed. Investigation showed that the landing gear control and one wheel of the main gear were down, and that the flap control and indicator showed that partial flaps had been deployed.

The executive had an estimated 740 hours of flying time, of which 685 hours were in multiengine aircraft. His experience with the C421A is unknown. The company pilot had an estimated 2,475 hours of flying time, including 1,668 hours in multiengine aircraft. His experience in the C421A is unknown.

The executive speculated that the company pilot had been able to restart the engine and, in order to reduce stall speed and facilitate slow-flying the aircraft, had lowered the gear and flaps. This statement indicates a lack of understanding of aircraft performance and emergency procedures during single-engine flight. Adding to the problem was the executive's reluctance to initiate any action, and instead, his reliance on the company pilot to take corrective measures.

Case 7.—This noninstrument rated pilot-owner had been waiting for several days for the weather conditions to improve so that he could make this flight. On the day of the flight, the pilot made repeated calls to the tower about the weather until, finally, VFR conditions were reported. The pilot had some difficulty in starting the engines of the PA-23-250. His repeated attempts depleted the battery charge to the point where a jump start was necessary. The engines were finally started and the airplane was taxied for takeoff. Investigation indicates that the run-up procedures performed by the pilot were probably rushed. Takeoff clearance was given and takeoff was initiated at an intersection with approximately 5,200 feet of runway remaining. After liftoff, at about 50 feet, the aircraft reportedly moved abruptly to the right and pitched up violently. The pilot elected to continue around for a landing on the same runway. During this time, he was in almost continuous radio contact with the tower and was described as sounding panicky. The pilot stated that he pulled the throttle back on the right engine two times and found that he was getting partial power. He therefore elected to use the available power instead of feathering. On short final, the gear was selected up and there was a slight loss of performance associated with the gear retracting. The aircraft continued to lose altitude and crashed into an embankment. Further investigation revealed that this pilot had taken his biennial flight review about a year earlier but, due to lack of proficiency, especially in single-engine emergencies, had not completed it and had not been endorsed. The pilot had an estimated 3,000 to 4,000 hours of flying time, including 1,500 hours in multiengine aircraft. The time in the PA-23-250 is unknown.

Much of the background information on this accident is questionable. It is quite possible that the landing gear was raised and lowered more than once during the return for landing. Friends of the pilot said that he was "afraid" of the airplane. It is known that the propeller was not feathered and the pilot was panicky during this emergency. All of this tends to support the conclusion that this pilot lacked proficiency in single-engine emergency procedures. Although aircraft control was not lost and airspeed was kept above Vmc or Vs, the airplane was neither flown effectively nor efficiently once the power loss occurred. Further, although he took the required biennial flight review, it was not completed and the log was not endorsed. There was no apparent attempt to increase proficiency and retake the review. Additional training or practice on engine-out procedures would likely have provided more confidence and greater ability to manage the emergency and probably would have avoided the accident.

The Safety Board recognizes that there is seldom one single cause of an accident. Almost all of these case histories, as well as other cases that were studied, deal with lack of climb capability or with some loss of control of the aircraft associated with stall speed or minimum control speed. The Safety Board believes, however, that the problem goes deeper than the aerodynamic qualities of the aircraft. Although loss of control may be the ultimate cause of the accident, the principal concern here is the Vmc and Vs problem. The real issue is how these critical situations are allowed to develop. These cases consistently indicate that the degradation of conditions during power loss emergencies was due to the pilot's lack of ability to handle the emergencies in the short time available.

Common to these seven cases, which are representative of the other accident records reviewed by the Safety Board were:

- the presence of stress which disrupted the pilot's ability to recall procedures and make proper selections and interfered with the motor responses essential for the effective control of the aircraft,

and the lack of one or more of the following:

- knowledge of single-engine performance of the aircraft,
- understanding of the proper single-engine emergency procedures,
- proficiency in executing the proper emergency procedures.

These deficiencies suggest, at least, that the pilots did not adequately update or refresh their knowledge through reviewing the pilot handbook, materials made available by the FAA and industry, and articles published in aviation periodicals, and that the pilots did not practice sufficiently executing single-engine maneuvers. Case histories of an additional eight cases are presented in appendix E.

To assess the role of logged flight time in these 15 accidents, pilot total flight time, multiengine time, and time in type (make and model) from the seven cases discussed here and the eight cases which appear in appendix E have been tabulated and are presented in table 7. Consistent with the data on pilot flight time presented on page 10, no obvious trend emerges from a review of these flight hours. Certainly, these 15 cases do not suggest that these accidents are associated primarily with low pilot flying hours, either total, multiengine, or time in type. On the contrary, many of these pilots had substantial flight experience. As mentioned previously, the lack of appropriate pilot exposure data for the nonaccident population makes further conclusions impossible.

TABLE 7

FLIGHT TIME BREAKDOWN FROM CASE HISTORIES

CASE	TOTAL TIME (HOURS)	MULTIENGINE (HOURS)	MAKE/MODEL (HOURS)
1	5,100	*	*
2	2,288	2,012	1,136
3	1,700*	700*	700*
4	3,000	600	110
5	211 3,688	4 *	4 *
6	740* 2,475*	685* 1,668*	* *
7	3-4,000*	1,500*	*
8	3,988	188	69
9	1,798	221	221
10	400*	*	*
11	5,000*	*	1,500*
12	208 22,000	4 4,112	4 1,500
13	1,915* 1,748	* *	120* 15*
14	1,248 9,073	11 557	11 435
15	164 6,022	15 161	15 10

*Unknown or best estimate based on past records and witness statements.

Interviews

A limited number of interviews were conducted to determine if the information obtained from the records, FAA requirements, and handbooks was consistent with pilot views of single-engine operation of light-twins. The pilots interviewed included students, multiengine instructors, corporate pilots, and FAA-designated multiengine flight examiners. Their experience level ranged from 20 to 8,000 hours in multiengine aircraft. One-third of these pilots received their initial flight training from the military and the rest were civilian trained.

The interviews were conducted informally but with a prepared list of questions. Among the questions put to each pilot concerning certification and performance of light-twins was: Is Vmc a constant or a variable? The answers included: Vmc was constant, Vmc varied, Vmc could be lower than but not greater than the number given in the flight manual, and Vmc could not be less than the number in the manual.

Another question asked was: Do all light-twins have a single-engine climb capability? About 25 percent of the pilots said yes, about 65 percent of the pilots said no, and the remainder did not know. When asked if climb capability was required, about half of the pilots said yes, and half answered no. Generally, the pilots said that their training maneuvers consisted of Vmc and single-engine work. Of those commenting on their multiengine check flight, only one was sure that his check did include a Vmc demonstration.

In summary, the pilots interviewed displayed obvious exposure to the concepts of single-engine emergency procedures, Vmc, and climb performance degradation. However, they did not have a complete and thorough knowledge of FAA regulations regarding single-engine operations and limitations. There was also some lack of knowledge of relevant information in pilot handbooks and the specifics of emergency procedures. The pilots were acquainted with, but apparently not thoroughly knowledgable in, this critical area of light-twin flying.

Training

The findings reported in the sections on data analysis, the case studies, and interviews with pilots suggest that pilot training, especially recurrent training, apparently had not provided the level of knowledge and skill required for managing power-loss emergencies in light-twins. In exploring this possibility, the Safety Board examined the regulations and other sources regarding the initial training requirements of pilots for a light-twin rating, the requirements for qualifying instructors, and finally the requirements designed to assure that a high level of proficiency is maintained. The adherence of the actual training to the regulations and guidelines was not within the scope of this study. A complete analysis of pilot training would require a study of its own.

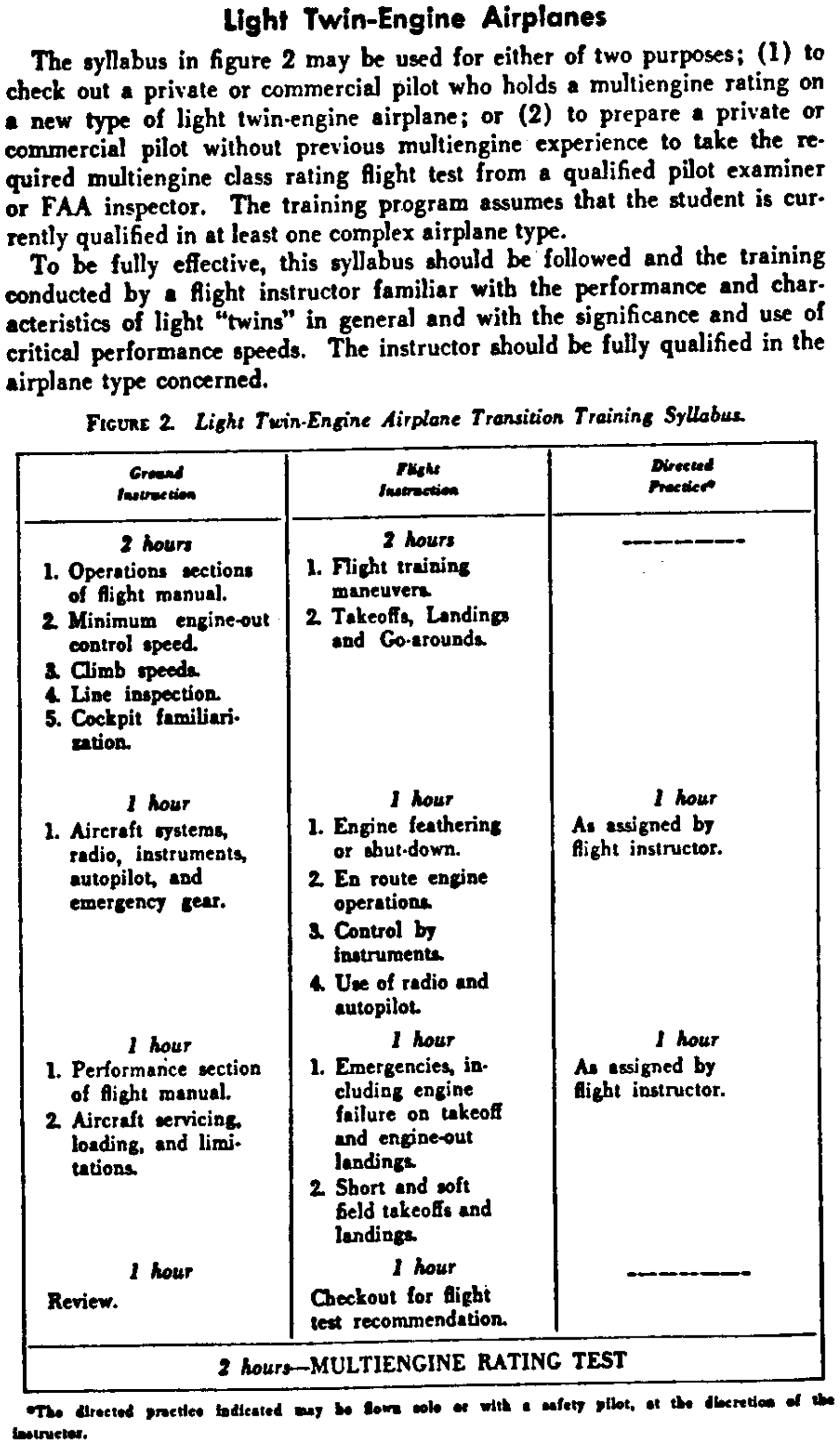
The literature that was reviewed included Federal Aviation Regulations, FAA flight test guides, biennial flight review guidelines as published by the National Association of Flight Instructors (NAFI), and other advisory circulars, some concerning pilot transition to light-twins as well as the flight training handbooks recommended for use by flight instructors.

Initial Training of Pilots.—The FAA regulates the initial training of pilots through 14 CFR Parts 61 and 141, which prescribe the requirements for issuing pilot and flight instructors certificates and ratings. The four levels of pilot certificates include the student, private, commercial, and airline transport pilot certificates. Six ratings can be placed on all pilot certificates except the student pilot certificate. The ratings applicable to light-twin flying are the airplane class rating for multiengine-land and multiengine-sea and the instrument rating for airplanes. Three sections covering general requirements, aeronautical knowledge, and flight proficiency define the requirements for each pilot certificate. In addition, as a supplement to the section on flight proficiency, the FAA issues flight test guides for each pilot certificate, which provide more details about the knowledge the pilot should possess and the specific performance expected. The requirements for aeronautical knowledge and the performance parameters to establish flight proficiency increase at each higher certificate level. The difficulty level of the examination to obtain these certificates also increases, with one important exception: The requirements concerned with emergency procedures for the control and management of a light-twin following engine failure are very similar for all pilot certificates. Similarities and differences in the guidelines included in the flight test guide for the candidates for private pilot and commercial pilot certificates can be found by reviewing the selected sections of these guidelines presented in appendixes F and G.

Figure 4 is a training syllabus recommended by the FAA for multiengine training. It is interesting to note that for power loss emergencies, approximately an hour of ground time and only 1 hour of flight time are included in the FAA syllabus. The Safety Board does not believe that this level of training in this dangerous and difficult area of light-twin operation is adequate to provide many candidates with the instinctive responses required for the safe handling of single-engine emergencies.

The Safety Board believes that the procedures and requirements recommended in the flight test guides for use in readying a pilot for the multiengine rating are probably sufficient. However, the Safety Board believes that the language in the guides provides opportunity for some variation in the proficiency level required by the individual instructors and examiners. It appears that if sufficient ground instruction and flight time were devoted to the study and performance of the procedures and maneuvers recommended in the flight test guides for use in preparation for a multiengine rating, the initial training program would be adequate.

Initial Training of Flight Instructors.—Not only is the content and the achievement level to be attained by a candidate for a multiengine rating important to his future safety, it is equally important that instructors are proficient in the necessary knowledge and skills. Further, they must be capable of addressing the critical trainable tasks and assuring that their students acquire the techniques for managing them to the appropriate level of competence for safe operation. To obtain a flight instructor certificate, an applicant must, in accordance with Subpart G of 14 CFR 61, hold a commercial pilot certificate with the appropriate aircraft rating, and an instrument rating if it is applicable to the rating he is seeking. A written test covering areas on ground instruction must be passed, as well as an oral and flight test in flight proficiency. The maneuvers, under this



Light Twin-Engine Airplanes

The syllabus in figure 2 may be used for either of two purposes; (1) to check out a private or commercial pilot who holds a multiengine rating on a new type of light twin-engine airplane; or (2) to prepare a private or commercial pilot without previous multiengine experience to take the required multiengine class rating flight test from a qualified pilot examiner or FAA inspector. The training program assumes that the student is currently qualified in at least one complex airplane type.

To be fully effective, this syllabus should be followed and the training conducted by a flight instructor familiar with the performance and characteristics of light "twins" in general and with the significance and use of critical performance speeds. The instructor should be fully qualified in the airplane type concerned.

FIGURE 2. *Light Twin-Engine Airplane Transition Training Syllabus.*

Ground Instruction	*Flight Instruction*	*Directed Practice**
2 hours 1. Operations sections of flight manual. 2. Minimum engine-out control speed. 3. Climb speeds. 4. Line inspection. 5. Cockpit familiarization.	*2 hours* 1. Flight training maneuvers. 2. Takeoffs, Landings and Go-arounds.	————————
1 hour 1. Aircraft systems, radio, instruments, autopilot, and emergency gear.	*1 hour* 1. Engine feathering or shut-down. 2. En route engine operations. 3. Control by instruments. 4. Use of radio and autopilot.	*1 hour* As assigned by flight instructor.
1 hour 1. Performance section of flight manual. 2. Aircraft servicing, loading, and limitations.	*1 hour* 1. Emergencies, including engine failure on takeoff and engine-out landings. 2. Short and soft field takeoffs and landings.	*1 hour* As assigned by flight instructor.
1 hour Review.	*1 hour* Checkout for flight test recommendation.	————————
2 hours—MULTIENGINE RATING TEST		

*The directed practice indicated may be flown solo or with a safety pilot, at the discretion of the instructor.

Figure 4. Light twin-engine airplane transition syllabus.

section, required for the flight instructor are those appropriate to the flight instructor rating sought. The FAA flight instructor test guide goes on to explain that, except for the spin, the required maneuvers are outlined in the FAA private, commercial, and instrument pilot flight test guides for the appropriate category and class rating being sought. The selection of specific maneuvers to be demonstrated during the flight test is at the discretion of the inspector/examiner.

The flight instructor applicant must have received his instruction from an instructor who has held his certificate during the 24 months immediately preceding the date of the instruction. He must also have given 200 hours of instruction as a certified flight instructor in airplanes. For additional ratings on the flight instructor certificate, the pilot must have the same ratings on an effective pilot certificate and must have had 15 hours of pilot-in-command time in category and class. He then must pass both the written and practical test outlined in this regulation. Even after attaining the rating, a flight instructor may not instruct in either multiengine aircraft or helicopters without at least 5 hours of pilot-in-command time in make and model.

The regulations and guidelines governing initial certification and the earning of additional ratings are designed with great flexibility. Also, these regulations provide only minimum standards. Of course, the quality of initial instruction resulting from these regulations and guidelines is dependent upon the competence and conscientiousness of the flight instructors. Whether these current regulations require modification must await a more detailed study.

As previously mentioned, it is evident from the data in the tabulation on page 10 that a large number of pilots certificated beyond the private license were involved in accidents following an engine failure. Additionally, the large number of pilots with high flight time (figures 1 and 2) involved in these accidents suggests that these accidents are not peculiar to the inexperienced pilot. These facts, along with the accident cases reviewed and interviews with pilots, leads the Safety Board to conclude that recurrent training for the maintenance of proficiency might be more important as a contributing cause than the level of initial training.

Recurrent Training of Pilots.—The minimum requirements for recurrent training are prescribed in 14 CFR 61.57 and 14 CFR 61.197. Part 61.57 concerns recency of experience for pilot-in-command, which applies to the light-twin pilots of this study. Part 61.197 concerns renewal of flight instructor certificates. It should be noted that pilot certificates (except for student certificates) are issued with no specific expiration dates. To act as pilot-in-command, a flight review in an aircraft for which a rating is held must have been completed within the preceding 24 months. The satisfactory completion of this review must be recorded in the pilot logbook by the flight instructor administering the review. The only exceptions to this are cases where the pilot has, within the same time- frame, completed a pilot proficiency check given by the FAA, by an approved check pilot, or by the U.S. Armed Forces for a certificate or rating.

According to 14 CFR 61.57, the flight review, commonly called the biennial flight review or "BFR," consists of two parts. The first part is a review of

14 CFR 91 which covers current general operating and flight rules. The second part is a review of maneuvers and procedures to demonstrate safe operation of the aircraft. This regulation is written in such a broad and nonspecific manner that it allows for wide interpretation by flight instructors charged with giving the review. Because of this, many of the first BFR's given were ineffective because little or nothing was done during the review, or they were extremely involved and thus expensive. In an attempt to rectify this situation, an industry committee convened in early 1975 and put together a pamphlet entitled "Guidelines for the Conduct of Biennial Flight Reviews." 7/ The participants in this committee included representatives from the GAMA, the NAFI, the Aircraft Owners and Pilots Association, the Experimental Aircraft Association, the National Air Transportation Association, the National Pilots Association, the Ohio State University Department of Aviation, and the General Aviation Division of the FAA.

The phamphlet is broken down into six sections:

I. The BFR Concept
II. The Pilot Profile
III. Review of Applicable Rules
IV. Preflight Procedures Review
V. Basic Flight Review
VI. Postflight Discussion and Recommendation

Although the concept of this industry guide is admirable, it in fact adds nothing concrete to what was already stated in 14 CFR 61.57.

Section I of the guide, "The BFR Concept," sets the tone for the entire review. It is stated here that the BFR is a periodic assessment of flying skills to determine deterioration in areas reasonably affecting safety. It is further stated that this should be a currency evaluation done in an economical and expeditious manner, and should provide a learning rather than a "check flight" atmosphere. Each BFR should be tailored to the pilot's needs. These will be determined by the flight instructor based on a prereview interview as discussed in Section II, "The Pilot Profile." It is also pointed out in Section I that a fixed set of guidelines or maneuvers would discourage the open approach desired. The instructors should not make the oral and flight reviews overly demanding and they should not require perfection in the subject areas and operations evaluated.

In the pilot profile section, the guide suggests that the instructor and pilot assess each other during a discussion of recent flight experience and BFR expectations. Necessary paperwork should also be accomplished here. The instructor will assess the needs of the pilot and formulate the makeup of the review. He will also inform the pilot of the approximate time required for the flight portion of the review. During the profile section, the pilot may decide to continue with this instructor or find another. It is again pointed out that the BFR should be accomplished in an economical and expeditious manner.

7/ The text of the guide is presented in appendix H.

Section III covers the review of rules. This review must cover those parts of 14 CFR 91 appropriate to the pilot receiving his BFR. It should not be a test situation, but rather an open discussion between pilot and instructor. A discussion of flight planning is included in Section IV. This may include weather analysis, aircraft preflight, weight and balance computations, and, although it is not mandatory, cross-country flight planning could be discussed.

Section V covers what may be considered the heart of the BFR. This is the flight review section. In this guide it is referred to as the basic flight review. The opening paragraph of this section states that the purpose of the flight portion of the BFR is to permit the instructor to observe and evaluate the pilot's habits, skills, and procedures, and is not intended to be a critique of the pilot's ability in flying maneuvers, especially those found in training or certification. The guide goes on to state that the objectives of this section may be met by, but not necessarily limited to, the pilot's demonstration of preflight procedures, traffic pattern and airport operations, what are referred to as abnormal operations such as crosswind and short field takeoffs and landings, and emergency procedures. Safety of flight operations instead of precision execution of maneuvers is stressed. It is recommended that the instructor give special attention to operations that are most difficult for the pilot or that generally tend to get most pilots in trouble. At this point, it is emphasized that, if agreed on in the initial interview, the instructor may provide instructional assistance instead of just evaluating.

Attention should once again be drawn to the title of this section--"Basic Flight Review." This becomes important in light of the information in the next portion of the flight review section. The guide now states that evaluation of skills and capabilities associated with advanced ratings and certificates is optional. The advanced ratings and certificates are generally taken to refer to anything more than a private-pilot, single-engine certificate. The guide goes on to state that during the initial interview, the instructor may want to point out that a more comprehensive review might be advisable if the advanced skills are currently being used by the pilot.

The final section in the guide deals with debriefing the flight. It is recommended that the instructor maintain a helpful, positive attitude and provide an honest, objective, and lucid appraisal of the pilot's abilities. Evaluation should be on the basis of "satisfactory/unsatisfactory." The logbook endorsement should in no way allude to anything unsatisfactory. If the overall performance were unsatisfactory, no logbook endorsement would be made. It is pointed out here that if the BFR were unsatisfactory, the pilot might stay with this instructor or find another for review, instruction, or another attempt at a satisfactory BFR.

In spite of the guidelines established by the industry committee, the BFR is no more effective in establishing the competence of a pilot to safely fly a twin-engine aircraft with one engine out than the FAA regulation which established the flight review. The message that comes through is: Accomplish the BFR in an economical and expeditious manner. In other words, do the minimum amount that will meet the requirements while keeping everyone happy. Although the guide repeatedly alludes to safety, can a pilot really be safe if his only recurrent training is not training at all, but instead, an evaluation of the most basic skills required of a student pilot? Keep in mind that since this review may be accomplished in any aircraft for which the pilot is rated, it is possible for a pilot rated in both single- and multiengine aircraft to take this review in the least complex single-engine aircraft to which he has access. By satisfactorily completing this review and having his logbook endorsed, this pilot may now legally fly for another 2-year period in both single - and multiengine aircraft.

Recurrent Training of Flight Instructors.—According to 14 CFR 61.197, flight instructors may renew their certificates for a period of 24 months by successfully completing the practical test for a flight instructor certificate and the rating involved, or only parts of the test as deemed necessary by the FAA Administrator to determine the pilot's competency as a flight instructor. The certificate may be renewed without taking the test if the record as a flight instructor shows that the instructor is competent. The certificate may also be renewed without taking the practical test if the pilot has a good record as a chief flight instructor, company check pilot, or pilot-in-command of an aircraft in a 14 CFR Part 121 operation, or any other activity that involves the regular evaluation of pilots, and the pilot passes an oral test demonstrating knowledge of current training and certification requirements and standards. Probably the most widely used method of renewing the flight instructor certificate is the completion of an approved flight instructor refresher course. The course must be completed within 90 days before applying for certificate renewal, and it must consist of not less than 24 hours of ground instruction or flight instruction, or both of these.

The regulations covering initial training are, for the most part, thorough. If each individual in the training chain (the student, the instructor, and the examiner) follows the rules and guidelines set out in the regulations, the system would produce more thoroughly trained, safer pilots, who are kept up to date on knowledge and techniques through their own efforts as well as the instructors' efforts. It is possible under these regulations for a single-engine pilot to receive training for a multiengine class rating that consisted solely of one Vmc demonstration, and just enough engine-out practice in the takeoff, inflight, and landing regimes as is necessary to please a particular examiner. The ground school portion of the training might be to memorize and be able to recite V speeds, definitions of Vmc and critical engine, and the five factors used to determine Vmc during certification. All of this may be accomplished without the student ever understanding the importance of this information or the implications of actions based on limited knowledge. Should the pilot pass the flight and oral exams, it would be legal for him to carry passengers and, if he already held a commercial certificate, he would be legally qualified to fly multiengine aircraft for hire. Without having flown a multiengine aircraft within 24 months, this pilot can take his recurrency training in a simple single-engine aircraft from a single engine-rated flight instructor who has recently renewed his instructor certificate by attending a 3-day clinic consisting of 24 hours of ground instruction. Now, having his logbook properly endorsed as having successfully completed his BFR, the pilot can do his three takeoffs and landings and again be legal to carry passengers, perhaps for hire, in his multiengine airplane.

In this situation, it is easy to perpetuate incompetence on all levels. Of course, the hypothetical situation put forth does not represent the highest level of professionalism on the part of instructors or examiners, but this might not be an isolated problem. Many flight instructors are young, limited in experience, and trying to build, through flight instructing, the time necessary to qualify for an airline position. All of these elements combined can result in less than optimal training. The one check in the system, the flight review, is ineffective because of the lack of specificity in the regulations and the reluctance of the FAA to define adequately what is required to demonstrate safe operation in the aviation environment. Without physically practicing emergency procedures, and without a requirement to periodically demonstrate proficiency in the procedures, some pilots will not remain proficient in handling emergencies. Since the flight review is already required, the Safety Board believes it is proper for the FAA to develop clear and concise rules for comprehensive, well-structured flight reviews to ensure that pilots remain proficient in all aspects of their flying. This is especially important in the demonstration by multiengine pilots of their proficiency in handling engine-failure emergencies in light-twins.

CONCLUSIONS

1. From 1972 through 1976, there were 477 light-twin accidents following engine failures; 123 of these were fatal accidents in which 289 persons died.

2. The percentage of fatal light-twin accidents following engine failures is still more than four times that in single-engine aircraft. Probably contributing to this substantial difference in percentage of fatal accidents are the considerably higher average cruise speeds, stall speeds, and generally greater weight of the light-twins, resulting in more severe crashes.

3. The accident rate in light-twins is much lower in the category involving professional flying than it is for the category involving primarily nonprofessional flying.

4. Landing types of accidents are the most prevalent kind of accidents following engine failure; however, they are almost never fatal. Stalls, collisions with the ground or water, and collisions with obstacles account for 92 percent of the fatal accidents following engine failures.

5. Accidents in light-twins following engine failures are apparently not unique to low-time pilots.

6. There is a relationship between the rate of occurrence of accidents following engine failures in light-twins and the power loading (ratio of gross weight to horsepower) of these aircraft. The Safety Board believes that this relationship should be considered carefully by the FAA in reviewing current airworthiness regulations and when drafting new regulations, especially in regard to 14 CFR Part 135 operations, where the increased use of light-twins for revenue-producing operations presents increased potential for serious consequences. The Safety Board also believes that the general aviation aircraft manufacturers should be cognizant of this apparent relationship when designing new light-twins.

7. The pilot operating handbooks have been improved over the years and now generally provide most of the information regarding single-engine performance of light twins and emergency procedures necessary for coping with power loss; however, some of the graphs or charts used to present some performance data are difficult to understand.

8. There is some excellent supplemental information in the form of FAA and industry publications and articles presented in the aviation media regarding the hazards of, and the techniques for coping with, power loss in light-twins.

9. The pilot handbooks and supplemental materials which are available are apparently not utilized to the extent necessary for pilots to remain knowledgeable about their aircraft's engine-out performance and the procedures for coping with the emergency.

10. Accidents following engine failures in light-twins generally involve a lack of proficiency in responding to these emergencies. Often these accidents involve some degree of panic, probably related to inadequate immediate recall of the exact emergency procedures or lack of confidence in one's ability to execute the emergency procedures. These symptoms are indicative of insufficient recurrent training in engine-failure emergencies.

11. It was not possible to assess, in sufficient detail, the precise role of the pilot in these accidents because of the lack of appropriate flight exposure data. The Safety Board concludes that the FAA should begin to collect adequate pilot exposure data.

RECOMMENDATIONS

Based on the results of this study, the National Transportation Safety Board recommended that the Federal Aviation Administration:

> Examine pilot handbooks for light twin-engine aircraft to determine if, for certain models, there is a need for any additional explanatory information, especially regarding single-engine performance and normal operation of the aircraft below Vmc and provide any such information to all pilots through accident prevention notices or other means at its disposal. (Class II, Priority Action) (A-79-94)
>
> Periodically disseminate to pilots, certificated flight instructors, and FAA inspectors and their designees, additional information on how to manage light twin-engine aircraft following an engine failure, using advisory circulars, safety seminars, or other means at its disposal. (Class II, Priority Action) (A-79-95)
>
> Amend 14 CFR Part 61.57 to require that to act as pilot-in-command of a multiengine aircraft a person must have successfully completed, within the last 24 months, a flight review in a multiengine aircraft. (Class II, Piority Action) (A-79-96)

> Amend 14 CFR Part 61.57 to require that during the multiengine flight review the pilot demonstrate the maneuvers that are required for a multiengine proficiency check in accordance with the flight test guide, especially those maneuvers related to power loss. (Class II, Priority Action) (A-79- 97)

The Safety Board also reiterated its recommendation of May 31, 1979, that the Federal Aviation Administration:

> Generate, through a stratified sampling of general aviation pilots, the date, duration, aircraft make and model, the geographical location of the flight, and the flight time in IFR, high density altitude, and wind conditions, all on a per flight basis; the data collected should include the pilot's total time, time in each type aircraft flown, age, occupation, certificate, and medical waivers. (Class II, Priority Action) (A-79-44)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JAMES B. KING
Chairman

/s/ ELWOOD T. DRIVER
Vice Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ PATRICIA A. GOLDMAN
Member

/s/ G. H. PATRICK BURSLEY
Member

December 13, 1979

APPENDIX A

ADDITIONAL LIGHT-TWIN ACCIDENT DATA

Appendix A contains the following additional accident data:

TABLE A1

TOTAL LIGHT TWIN-ENGINE AIRCRAFT ACCIDENTS, 1972-1976
TYPES OF ACCIDENTS BY KIND OF FLYING

ACCIDENT TYPE (FIRST TYPE)	INSTRUCTIONAL		NON-COMMERICAL				COMMERCIAL			MISCELLANEOUS	TOTAL ALL KINDS OF FLYING
	DUAL	TOTAL	PLEASURE	BUSINESS	CORPORATE	TOTAL	AIR TAXI PASSENGER	AIR TAXI CARGO	TOTAL		
Collisions With Ground/Water	2	3	99	45	23	167	33	18	52	9	231
Collisions With Obstacles	2	2	111	49	30	193	28	30	59	18	272
Stalls	10	13	50	20	9	83	8	17	27	7	130
Engine Failures Or Malfunctions	40	49	190	72	35	304	28	32	66	58	477
Midair Collisions	2	2	2	2	2	6	5	1	7	5	20
Inflight Airframe Failures	1	2	16	9	7	32	6	2	8	4	46
Fires	-	-	9	5	8	22	6	6	12	9	43
Landing Accidents	53	59	332	157	114	620	69	51	131	61	871
Other	2	5	36	22	20	80	26	13	40	14	139
TOTALS	112	135	845	381	248	1,507	209	170	402	185	2,229

TABLE A2

FATAL LIGHT TWIN-ENGINE AIRCRAFT ACCIDENTS, 1972-1976
TYPES OF ACCIDENTS BY KIND OF FLYING

ACCIDENT TYPE (FIRST TYPE)	INSTRUCTIONAL		NON-COMMERICAL				COMMERCIAL				
	DUAL	TOTAL	PLEASURE	BUSINESS	CORPORATE	TOTAL	AIR TAXI PASSENGER	AIR TAXI CARGO	TOTAL	MISCELLANEOUS	TOTAL ALL KINDS OF FLYING
Collisions With Ground/Water	1	1	80	38	19	137	21	16	38	7	183
Collisions With Obstacles	1	1	44	19	8	73	6	10	16	5	95
Stalls	10	13	30	13	6	52	4	11	16	4	85
Engine Failures Or Malfunctions	8	9	51	17	10	80	7	11	19	15	123
Midair Collisions	2	2	1	1	2	4	4	1	6	2	14
Inflight Airframe Failures	-	1	14	7	5	26	3	1	4	1	32
Fires	-	-	3	1	1	5	-	2	2	2	9
Landing Accidents	-	-	7	3	1	12	3	2	5	2	19
Other	-	-	21	6	3	30	8	4	13	7	50
TOTALS	22	27	251	105	55	419	56	58	119	45	610

TABLE A3

TOTAL LIGHT-TWIN ACCIDENTS FOLLOWING ENGINE FAILURE OR MALFUNCTION

ACCIDENT TYPE (SECOND TYPE)	PHASE OF OPERATION (SECOND PHASE)						
	STATIC	TAXI	TAKEOFF	INFLIGHT	LANDING	OTHER	TOTAL
Collisions With Ground/Water	-	-	11	12	46	-	69
Collisions With Obstacles	-	-	13	4	110	-	127
Stalls	-	-	26	14	56	-	96
Midair Collisions	-	-	-	-	-	-	-
Inflight Airframe Failures	-	-	-	1	-	-	1
Fires	-	-	-	7	4	-	11
Landing Accidents	-	1	14	-	135	-	150
Other	-	-	-	1	21	1	23
TOTALS	-	1	64	39	372	1	477

TABLE A4

FATAL LIGHT-TWIN ACCIDENTS FOLLOWING ENGINE FAILURE OR MALFUNCTION

ACCIDENT TYPE (SECOND TYPE)	PHASE OF OPERATION (SECOND PHASE)						
	STATIC	TAXI	TAKEOFF	INFLIGHT	LANDING	OTHER	TOTAL
Collisions With Ground/Water	-	-	6	12	10	-	28
Collisions With Obstacles	-	-	2	3	19	-	24
Stalls	-	-	15	13	33	-	61
Midair Collisions	-	-	-	-	-	-	-
Inflight Airframe Failures	-	-	-	1	-	-	1
Fires	-	-	-	1	-	-	1
Landing Accidents	-	-	-	-	1	-	1
Other	-	-	-	-	7	-	7
TOTALS	-	-	23	30	70	-	123

TABLE A5

TOTAL LIGHT-TWIN ACCIDENTS FOLLOWING ENGINE FAILURE DURING LANDING

LANDING PHASE OF OPERATION (SECOND)

SECOND TYPE ACCIDENT	TRAFFIC PATTERN	FINAL APPROACH	INITIAL APPROACH	LEVEL OFF TOUCHDOWN	ROLL	GO-AROUND	MISSED APPROACH	OTHER	TOTAL
Ground/Water Loop	-	-	-	-	7	-	-	-	7
Wheels Up	-	1	-	73	2	2	-	-	78
Gear Collapsed	-	-	-	8	26	-	-	-	34
Hard Landing	-	-	-	8	-	-	-	-	8
Other Landing Accidents	-	-	-	2	4	1	-	1	8
TOTAL LANDING ACCIDENTS	-	1	-	91	39	3	-	1	135
Collisions With Ground/Water	1	6	1	27	-	7	1	3	46
Collisions With Obstacles	2	35	-	21	41	7	1	3	110
Stalls	7	22	2	3	-	17	2	3	56
Fires	-	3	-	-	-	-	-	1	4
Other	-	-	-	21	-	-	-	-	21
TOTALS	10	67	3	163	80	34	4	11	372

TABLE A6

FATAL LIGHT-TWIN ACCIDENTS FOLLOWING ENGINE FAILURE DURING LANDING

LANDING PHASE OF OPERATION (SECOND)

SECOND TYPE ACCIDENT	TRAFFIC PATTERN	FINAL APPROACH	INITIAL APPROACH	LEVEL OFF TOUCHDOWN	ROLL	GO-AROUND	MISSED APPROACH	OTHER	TOTAL
Ground/Water Loop	-	-	-	-	1	-	-	-	1
Wheels Up	-	-	-	-	-	-	-	-	-
Gear Collapsed	-	-	-	-	-	-	-	-	-
Hard Landing	-	-	-	-	-	-	-	-	-
Other Landing Accidents	-	-	-	-	-	-	-	-	-
TOTAL LANDING ACCIDENTS	-	-	-	-	-	-	-	-	-
Collisions With Ground/Water	-	3	1	3	-	1	1	1	10
Collisions With Obstacles	1	7	-	4	5	2	-	-	19
Stalls	4	14	1	1	-	8	2	3	33
Fires	-	-	-	-	-	-	-	-	-
Other	-	-	-	7	-	-	-	-	7
TOTALS	5	24	2	15	6	11	3	4	70

TABLE A7

TOTAL LIGHT-TWIN ACCIDENTS FOLLOWING ENGINE FAILURE OR MALFUNCTION OCCURRING DURING TAKEOFF

ACCIDENT TYPE (SECOND TYPE)	PHASE OF OPERATION (SECOND PHASE)			
	TAKEOFF	INFLIGHT	LANDING	TOTAL
Collisions With Ground/Water	11	6	10	27
Collisions With Obstacles	13	1	23	37
Stalls	26	3	11	40
Midair Collisions	-	-	-	-
Inflight Airframe Failures	-	-	-	-
Fires	-	-	-	-
Landing Accidents	14	-	27	41
Other	-	-	2	2
TOTALS	64	10	73	147

TABLE A8

FATAL LIGHT-TWIN ACCIDENTS FOLLOWING ENGINE FAILURE OR MALFUNCTION OCCURRING DURING TAKEOFF

ACCIDENT TYPE (SECOND TYPE)	PHASE OF OPERATION (SECOND PHASE)			
	TAKEOFF	INFLIGHT	LANDING	TOTAL
Collisions With Ground/Water	6	6	1	13
Collisions With Obstacles	2	1	5	8
Stalls	15	3	6	24
Midair Collisions	-	-	-	-
Inflight Airframe Failures	-	-	-	-
Fires	-	-	-	-
Landing Accidents	-	-	-	-
Other	-	-	-	-
TOTALS	23	10	12	45

TABLE A9

TOTAL LIGHT-TWIN ACCIDENTS FOLLOWING ENGINE FAILURE OR MALFUNCTION OCCURRING IN FLIGHT

ACCIDENT TYPE (SECOND TYPE)	PHASE OF OPERATION (SECOND PHASE)					
	TAXI	TAKEOFF	INFLIGHT	LANDING	OTHER	TOTAL
Collisions With Ground/Water	-	-	6	23	-	29
Collisions With Obstacles	-	-	3	57	-	60
Stalls	-	-	11	21	-	32
Midair Collisions	-	-	-	-	-	-
Inflight Airframe Failures	-	-	1	-	-	1
Fires	-	-	7	3	-	10
Landing Accidents	1	-	-	73	-	74
Other	-	-	1	17	1	19
TOTALS	1	-	29	194	1	225

TABLE A10

FATAL LIGHT-TWIN ACCIDENTS FOLLOWING ENGINE FAILURE OR MALFUNCTION OCCURRING IN FLIGHT

ACCIDENT TYPE (SECOND TYPE)	PHASE OF OPERATION (SECOND PHASE)			
	TAKEOFF	INFLIGHT	LANDING	TOTAL
Collisions With Ground/Water	-	6	4	10
Collisions With Obstacles	-	2	7	9
Stalls	-	10	12	22
Midair Collisions	-	-	-	-
Inflight Airframe Failures	-	1	-	1
Fires	-	1	-	1
Landing Accidents	-	-	1	1
Other	-	-	6	6
TOTALS	-	20	30	50

TABLE A11

TOTAL LIGHT-TWIN ACCIDENTS FOLLOWING ENGINE FAILURE OR MALFUNCTION OCCURRING DURING LANDING

ACCIDENT TYPE (SECOND TYPE)	PHASE OF OPERATION (SECOND PHASE)			
	TAKEOFF	INFLIGHT	LANDING	TOTAL
Collisions With Ground/Water	-	-	13	13
Collisions With Obstacles	-	-	30	30
Stalls	-	-	24	24
Midair Collisions	-	-	-	-
Inflight Airframe Failures	-	-	-	-
Fires	-	-	1	1
Landing Accidents	-	-	35	35
Other	-	-	2	2
TOTALS	-	-	105	105

TABLE A12

FATAL LIGHT-TWIN ACCIDENTS FOLLOWING ENGINE FAILURE OR MALFUNCTION OCCURRING DURING LANDING

	PHASE OF OPERATION (SECOND PHASE)			
ACCIDENT TYPE (SECOND TYPE)	TAKEOFF	INFLIGHT	LANDING	TOTAL
Collisions With Ground/Water	-	-	5	5
Collisions With Obstacles	-	-	7	7
Stalls	-	-	15	15
Midair Collisions	-	-	-	-
Inflight Airframe Failures	-	-	-	-
Fires	-	-	-	-
Landing Accidents	-	-	-	-
Other	-	-	1	1
TOTALS	-	-	28	28

APPENDIX B

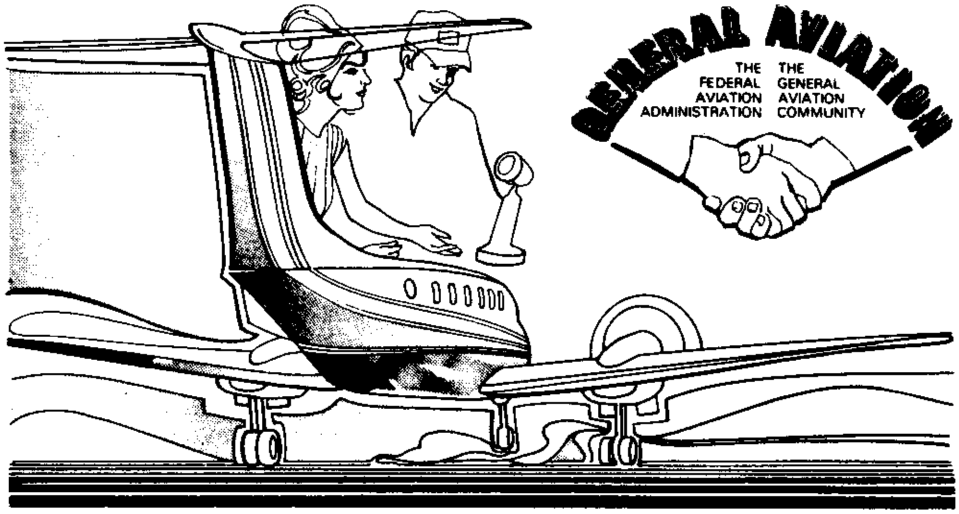
CHANGE IN EXPOSURE DATA COLLECTION PROCESS

Data on the annual number of hours flown in all general aviation aircraft by make and model and for specific kinds of flying were obtained from the FAA. Before 1977, the FAA requested this exposure data on the same form used annually by all aircraft owners to revalidate their aircraft registration. However, beginning in 1977, the FAA announced a new program for collecting exposure information on general aviation operations. This new statistical sampling procedure which was used for collecting the 1976 data, involved a survey questionnaire mailed to a random sample of 31,000—about 15 percent--of general aviation aircraft owners. The survey solicited information relating to hours flown, aircraft location, and other pertinent data. The FAA has found discrepancies between the results of this new survey technique and estimates based on the historical data collected using the prior methodology.

The errors in the exposure data used in this report have been determined by the FAA to amount to less than 4 percent over the period of this study. The Safety Board believes that these errors do not significantly affect the findings of this report. Further, these exposure data were the only such data available.

APPENDIX C

FAA-P-8740-25
AFO-800-1079



accident prevention program

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Washington, D.C.

Always Leave Yourself an Out

Richard N. Aarons

FOREWORD

The purpose of this series of publications is to provide the flying public with safety information that is handy and easy to review. Many of the publications in this series summarize material discussed at safety seminars that are presented through the General Aviation Accident Prevention Program.

Comments regarding these publication should be directed to the Department of Transportation, Federal Aviation Administration, General and Commercial Aviation Division, Accident Prevention Staff, AFO-806, 800 Independence Avenue, Washington, D.C. 20591.

This is an exact reprint. It does not necessarily reflect the Federal Aviation Administration's opinion on certain aircraft.

Always Leave Yourself An Out

While single-engine aircraft may not be safer, twins can be more dangerous/Richard N. Aarons

DESPITE heated scoldings from flight instructors and grim warnings from the National Transportation Safety Board, many pilots still seem to believe that implied in the fact that an aircraft has two engines is a promise that it will perform with only one of those engines operative. And the light-twin stall/spin accident rate further indicates that many multi-engine pilots have not come to grips with the facts that 1/Significantly more than half the climb performance disappears when one engine signs out, and 2/Exploration of the Vmc regime close to the ground is a sure way to kill yourself.

A while back, the NTSB reported that light multi-engine aircraft are involved in fewer engine-failure-related accidents than single-engine aircraft. However the same report observed that an engine-failure-related accident in a twin is four times more likely to cause serious or fatal injuries. An analysis of that report appeared in the June issue of B/CA (Cause and Circumstance).

This article is not intended to debate the relative merits of twins versus singles. The twin offers obvious safety advantages over the single, especially in the enroute phase, and if, only if, the pilot fully understands the real options offered by that second engine in the takeoff and approach phases as well.

Takeoff is the most critical time for a light-twin pilot, but if something goes wrong he *may* have the option of continued flight, an option denied his single-engine counterpart. More often than not that second engine will provide only a little more time to pick a soft spot. (This assumes that the engine is lost before the aircraft reaches maneuvering altitude of 300 to 500 feet.) But even those few extra seconds, representing a few hundred extra yards, can give the twin pilot a hell of a safety advantage over his single-engine counterpart. But I must stress again, this safety advantage exists *only* if the multi-engine pilot fully understands his machine.

In this article we're going to explore some of the design concepts and certification procedures applicable to current-production light twins and then take a look at light-twin performance tables and attempt to find ways of getting more realistic information out of them. Along the way, we'll establish five rules for technique. We use these rules at B/CA, pilots at the FAA Academy use them, and we're sure many readers are aware of them, but we'll throw them in anyway in hopes of picking up a few more converts.

Let's look first at the implied promise that a general-aviation twin will perform with one engine inoperative. Part 23 sets standards for the certification of light aircraft weighing 12,500 pounds or less. Multi-engine aircraft are further divided by Part 23 into two weight classes, split at 6,000 pounds with the group that weighs 6,000 pounds or less, subdivided into two, depending on Vso (stall speed in the landing configuration). The break comes at 61 knots CAS.

Only those twins that weigh more than 6,000 pounds or have a Vso higher than 61 knots need to demonstrate any single-engine climb performance at all for certification. And the requirement is pretty meager. Basically, the regulation says that these aircraft must demonstrate a single-engine climb capability at 5,000 feet (ISA) with the inoperative engine feathered and the aircraft in a clean configuration. The amount of climb performance required is determined by the formula $ROC = 0.027\ Vso^2$. The Rockwell Commander 500S (Shrike), for example, weighs over 6,000 pounds and therefore must meet this climb requirement. Vso for the Shrike is 63 knots, thus its minimum single-engine climb performance at 5,000 feet is 0.027×63^2 or 107.16 fpm. The Shrike's actual single-engine climb at 5,000 feet is 129 fpm, so the manufacturer bettered the Part 23 requirement, but not by much.

The Cessna 310 weighs less than 6,000 pounds, but stalls at 63.9 knots, so it too must meet the enroute single-engine climb standards. Plugging 63.9 knots into the $0.027\ Vso^2$ equation produces a requirement of 110.2 fpm. The 310's actual single-engine climb under Part 23 conditions is 119 fpm.

The Aztec, like the 310, weighs less than 6,000 pounds, but it slips under the Vso wire with a stall speed if 60.8 knots. The only requirement that an airplane in this group must meet is that its single-engine climb performance at 5,000 feet (positive or negative) be *determined.* The Aztec climbs at 50 fpm on one engine at that altitude, but the regulation doesn't require that it climb at all at that or any other altitude.

We can see then that where an enroute single-engine climb is required, it's minimal. Consider a hypothetical aircraft with an outrageous Vso of 100 knots CAS. The FAA requires only that such an aircraft demonstrate a paltry climb of 270 fpm on one engine at 5,000 feet.

There's another point to consider here. The FAA does not require continued single-engine takeoff capability for any light aircraft other than those designed for air-taxi work and capable of hauling 10 or more passengers. Stated another way, there is no reason to assume that an aircraft will exhibit positive single-engine performance in the takeoff configuration at sea level just because it had to meet a single-engine climb-performance requirement at 5,000 clean.

FAA Academy flight instructors are fully aware of this situation and believe it's important to stress it with the agency's GADO inspectors. An in-house white paper on light twins used at training courses for FAA pilots puts it this way:

"There is nothing in the FAR governing the certification of light multi-engine aircraft which says they must fly (maintain altitude) while in the takeoff configuration and with an engine inoperative. In fact, many of the light twins are not required to do this with one engine inoperative in any configuration, even at sea level . . . With regard to performance (but not controllability) in the takeoff or landing configuration, the light multi-engine aircraft is, in concept, merely *a single-engine aircraft with its power divided into two or more individual packages."* (Emphasis ours.)

While this concept of not putting all your eggs in one basket leads to certain advantages, it also leads to disadvantages should the eggs in one basket get broken.

You'll remember from your multi-engine transition training that the flight instructor and check pilot repeatedly insisted that when you lose one engine on a twin, performance is not halved, but actually reduced by 80 percent or more.

That 80-percent performance-loss figure is not just a number pulled out of the air for emphasis. It's easy to figure for any aircraft. Consider the Beech Baron B55 which has an all-engine climb rate (sea level, standard conditions, max gross weight) of 1,670 fpm and a single-engine climb rate under the same conditions of 318 fpm. The loss of climb performance in this case is

$$100 - \left(\frac{318}{1{,}670} \times 100\right)$$

or 80.96 percent. The climb performance remaining after the loss of one engine on the B55 is 19.04 percent.

Performance loss for the cabin twins, turboprops and business jets is similar. The Rockwell Commander 685, for example, loses 83.42 percent of its climb performance when one engine quits; the Swearingen Merlin III loses 75.49 and the Learjet 25C 71.07. The Lockheed JetStar loses 43.48 percent if its climb performance with the loss of one engine, but remember, it has four engines. The loss of one quarter of its thrust results in a loss of almost half its climb performance and if it were to lose half its thrust, climb performance would be cut by more than 75 percent. (The table on this page shows similar performance changes for other aircraft.)

Some turboprops and all turbojets demonstrate a continued takeoff capability with one engine inoperative. The turbojets do so because of the tougher certification requirements of FAR Part 25. Although loss of power in terms of percentage reduction is similar in all categories of business aircraft, the turbojets and some turboprops have much better single-engine performance because they're starting with higher numbers. While the Learjet 25C, for example, loses more than 71 percent of its climb performance when one engine is shut down, it begins with an all-engine rate of climb of 6,050 fpm. When this is reduced by 71 percent, it still climbs at 1,750, which is much better performance than you get out of many light-piston twins with both engines running.

Why the performance loss is greater than 50 percent with the failure of one engine needs a bit of explanation. Climb performance is a function of thrust horsepower (or simply thrust in turbojets) which is in excess of that required for straight and level flight. You can convince yourself that this is the case by trimming your aircraft for straight and level at its best all-engine rate-of-climb speed and checking the power setting. If you ease the stick back at this point, the airplane will not settle into a sustained climb. After a momentary climb it may, in fact, begin to descend. However, if you go back to straight and level flight at the best-rate-of-climb speed and slowly feed in power as you maintain airspeed, a climb will be indicated, and the rate of climb will depend on the power you add—which is power in excess of that required for straight and level.

Now trim for straight and level (in the clean configuration at about 1,500 feet) at the best single-engine rate-of-climb speed, adjust one engine to its zero-thrust setting (about 10 inches to simulate feather). You'll notice that the "good" engine, now carrying the full burden, is producing 75-percent power or more. If you increase the power on the good engine, your aircraft will begin a climb, but at a very modest rate. This is so because you've got much less "excess" horsepower available. If you are interested in the math behind this, an approximate formula for rate of climb is:

$$R/C = \frac{\text{ehp} \times 33{,}000}{\text{weight}}$$

(ehp is thrust horsepower in excess of that required for straight and level.) To determine ehp, rearrange the formula to read:

$$\text{ehp} = \frac{R/C \times \text{weight}}{33{,}000}$$

Using the Seneca as an example, with its maximum gross weight of 4,200 pounds and all-engine and single-engine climb rates of 1,860 and 190 fpm respectively, we find that this aircraft has about 236 thrust horsepower available for climb with both powerplants operating and only 24 excess thrust horsepower for climb on one engine. If you refer to the climb-performance-loss formula, you'll see that the Seneca loses about 89.78 percent of its climb performance when an engine stops:

$$100 - \left(\frac{190}{1{,}860} \times 100\right) = 89.78$$

If you examine the two figures above for excess horsepower and state them in terms of percentages, you'll see that an engine loss in the Seneca represents a loss of 89.83 percent of thrust horsepower available for climb.

Part 23 defines Vmc as "the minimum calibrated airspeed at which, when any engine is suddenly made inoperative, it is possible to recover control of the airplane with that engine still inoperative, and maintain straight flight, either with zero yaw, or, at the option of the manufacturer, with an angle of bank of not more than five degrees." Vmc may not be higher than 1.2 times the stall speed with flaps in takeoff position and the gear retracted. In flight-test work, Vmc is determined with takeoff or METO power on each engine, the rearmost allowable center of gravity, flaps in takeoff position, landing gear retracted and the propeller of th inoperative engine 1/ Windmilling with the propeller set in the takeoff range, or 2/ Feathered, if the airplane has an automatic feathering device. During recovery, the airplane may not assume any dangerous attitude or require exceptional piloting skill, alertness, or strength to prevent a heading change of more than 20 degrees.

Vmc is not at all mysterious. It's simply that speed at which airflow past the rudder is reduced to such an extent that rudder forces cannot overcome the asymmetrical forces caused by takeoff power on one side and a windmilling prop on the other.

When that speed is reached and the nose starts to swing toward the inoperative engine, the only hope of regaining control is to reduce thrust on the good engine (or increase speed). An increase in airspeed requires a change in momentum and thus a certain period of time to become effective. Thus, for practical purposes, the *only* method of regaining control is to reduce power on the operating engine—quickly.

Performance Loss of Representative Twins with One Engine Out

Pistons

	All engine climb (fpm)	S.E. climb (fpm)	Percent loss
Beech Baron 58	1,694	382	80.70
Beech Duke	1,601	307	80.82
Beech Queen Air	1,275	210	83.53
Cessna 310	1,495	327	78.13
Cessna 340	1,500	250	83.33
Cessna 402B	1,610	225	86.02
Cessna 421B	1,850	305	83.51
Piper Aztec	1,490	240	83.89
Piper Navajo Chieftain	1,390	230	83.45
Piper Pressurized Navajo	1,740	240	86.21
Piper Seneca	1,860	190	89.78

Turboprops

	All engine climb (fpm)	S.E. climb (fpm)	Percent loss
Beech King Air 90	1,870	470	74.87
Mitsubishi MU2-J	2,690	845	68.59
Rockwell Commander 690A	2,849	893	68.66
Swearingen Merlin III	2,530	620	75.49

Business Jets

	All engine climb (fpm)	S.E. climb (fpm)	Percent loss
Cessna Citation	3,100	800	74.19
Falcon F	3,300	800	75.76
Falcon 10	6,000	1,500	75.00
Gates Learjet 24D	6,800	2,100	69.12
Grumman Gulfstream II	4,350	1,525	64.94
Hawker Siddeley HS 125-600	3,550	663	81.32
IAI 1123 Westwind	4,040	1,100	72.77
Rockwell Sabre 75A	4,300	1,100	74.42

Vmc is not a static number like flap-operating speed or the never-exceed speed. It changes with conditions. The Part 23 test described above cites the worst conditions. Aft cg, for example, reduces the force of the rudder because it shortens the arm and thus the turning moment. Vmc will be lower with forward cg and all other factors being equal. Conversely if the aircraft is loaded slightly out of rear cg,Vmc will be higher. In normally aspirated aircraft Vmc decreases with an increase in density altitude primarily because the output of the operating engine decreases, thus the asymmetrical power situation decreases.

At first glance, this situation seems to be a good one. The hotter and higher the airport, the lower Vmc. But actually nothing about Vmc is good and there's a hell of a catch in it. As Vmc decreases (with a decrease in good-engine performance) it approaches the stall speed. This is especially bad news for flight instructors who must purposely explore the Vmc regime with their students. If Vmc and stall are reached simultaneously, a spin is almost inevitable and Part 23 twins are often impossible to get out of a spin. (One northeast flight school lost two aircraft in one summer because of this problem.)

Landing-gear extension seems to reduce Vmc for most light twins and this, like the density altitude situation, can be both good and bad.

Suppose a pilot gets himself in the unhappy situation of being 50 feet in the air, gear down, with one engine out, fullpower on the good side and full rudder to keep the nose from swinging. He doesn't like the look of the trees in front of him so he decides to make a go for it. He reaches down and retracts the gear to get rid of its drag, hoping that will enable the aircraft to accelerate to a climb speed. Suddenly he's looking at the trees through the top of the windshield. Why? Because he was on the edge of Vmc and sucked up the gear, which increased Vmc costing him control of the aircraft.

The prudent light-twin pilot, of course, would never find himself in that situation because he would know beforehand that his hopes of accelerating without altitude loss from Vmc to Vxse or Vyse are practically nil.

If your aircraft is relatively new, Vmc, as determined by the Part 23 certification test, is marked by a red line on the airspeed-indicator face. Indicated Vmc will never be higher than this line, so the slash can be used as a guide to keep you out of trouble. This does not mean that the airplane will spin out as soon as the line is reached. Under the circumstances described above (such as high density altitude) controlled flight with full power on the operative engine is possible when the indicated airspeed falls below the red line, but it certainly isn't advisable. Exploring this part of the flight envelope in an actual emergency can (and probably will) kill you. So let's establish our first rule for multi-engine flying.

Rule #1—Never allow the airspeed to drop below *published Vmc* except during the last few yards of the landing flare, and then only if the field if extremely short.

Some aircraft have an all-engine best-angle-of-climb speed (Vx) below Vmc. Using that climb speed under any circumstances can be extremely dangerous. The instructors at the FAA Academy have this to say about the use of Vx near the ground: "Trying to gain height too fast after takeoff can be dangerous because of control problems. If the airplane is in the air below Vmc when an engine fails, the pilot *might* avoid a crash by rapidly retarding the throttles, although *the odds are not in favor of the pilot.*" Thus we have another rule:

Rule #2—A best all-engine angle-of-climb speed that is lower than Vmc is an *emergency* speed and should be used near the ground *only* if you're willing to bet your life that one engine won't quit during the climb.

Manufacturers differ on the proper takeoff speed for a light twin. Piper, for example, recommends that most of its twins be rotated at Vmc. Cessna, on the other hand, suggests liftoff at a speed much higher than Vmc and very close to best single-engine angle-of-climb speed. In the case of the Cessna 310, Vmc is 75 knots, recommended rotation speed is 91 knots and best single-engine angle-of-climb speed is 94.

It's important to note that manufacturers who recommended liftoff at or near Vmc do not, as a rule, show figures for continued takeoff in event of an engine failure at the liftoff speed. The reason is simple. Most Part 23 twins cannot accelerate in the takeoff configuration from Vmc to best single-engine rate-of-climb speed while maintaining a positive climb rule. Conversely it is possible to accelerate them (under near sea-level conditions) from best single-engine angle-of-climb speed to best single-engine rate-of-climb speed while maintaining a positive, though meager, climb. Manufacturers who recommended liftoff well above Vmc usually show continued single-engine takeoff performance in their owners or flight manuals.

Engine-Out Angle of Climb
(degrees, at best-rate speed)

	ISA	ISA + 20
Piper Seneca	1.2	0.6
Cessna Skymaster	1.7	1.3
Piper Turbo Aztec	1.6	1.5
Cessna 402B	1.2	0.6
Piper Navajo	1.5	1.1
Cessna 340	1.4	0.8
Cessna 421	1.6	1.0
Rockwell International 685	1.2	0.7
Piper Navajo P	1.2	1.0
Mitsubishi MU2-K	4.2	2.4
King Air A100	2.1	1.0

NOTE: For comparison purposes, the average two engine rate of climb for the above aircraft is 8 degrees.

We have to recommend against lifting off at Vmc for the same reason most flight instructors recommend against "stalling" a single-engine aircraft off the ground. In the latter case, the single will fly to the edge of ground effect but could reach that point behind the power curve. An engine failure at that point could result in a stall and pitch over. In the case of the twin, an engine failure at liftoff at Vmc could produce such a rapid turning moment that control would be lost immediately. The FAA says, "Experience has shown that an unexpected engine failure surprises the pilot so that he will act as though he is swimming in glue." If a pilot rotates at Vmc, loses an engine and begins the "swimming in glue" routine, his odds of survival are minimal.

The alternative, of course, is to hold the aircraft on the ground a little longer. Most multi-engine instructors believe that Vmc-plus-five knots is a good compromise for use in those aircraft with a recommended liftoff at Vmc. Why not hold it down until almost reaching best single-engine angle-of-climb speed like the Cessna folks recommend? The reason again is controllability. Cessna light twins and most cabin twins of all manufacturers are designed to stay on the ground well beyond Vmc. But some of the light twins simply are not. For example, we've tried holding the Seneca and Aztec on the runway beyond Vmc-plus-five knots and have discovered that both aircraft begin to wheelbarrow. (Tests were at maximum gross weight, zero flaps.) High-speed wheelbarrowing can be just as dangerous as liftoff too close to Vmc, especially when we're talking about selecting an appropriate speed for every takeoff. Remember too that the takeoff-performance figures in the aircraft-owners or flight manual are invalid as soon as we use techniques different from those specified in the table footnotes. (More on this later.) Anyway, we've got a third rule now for light-twin operation:

Rule #3—Use the manufacturer's recommended liftoff speed or Vmc plus five knots whichever is greater.

Now that we're in the air, the first priority is to accelerate the aircraft to best single-engine angle-of-climb speed (if we're not already there), then best single-engine rate-of-climb speed and finally best all-engine rate-of-climb speed. Each of these speeds is a milestone in the takeoff and the realization of each reduces the decisions to be made in the event of an engine failure.

Many instructors recommended that best single-engine rate-of-climb speed (the blue line if it's marked on your airspeed indicator) be used for the initial climb to a safe maneuvering altitude. B/CA's pilots recommended the best all-engine rate-of-climb speed, when it is faster (it normally is), for two reasons. First, the swimming-in-glue syndrome is going to translate into speed lost. So if an engine does quit while you're holding best all-engine rate-of-climb speed, the deceleration while you're getting things straightened out will probably put you pretty close to best single-engine rate-of-climb speed which is where you want to be anyway. Second, the best all-engine rate speed will get you to maneuvering altitude and out of immediate danger.

One caution here is important. Avoid climbing to maneuvering altitude at a speed greater than best all-engine rate of climb—to do so is sloppy and inefficient. Here's why:

As we have seen, climb is a function of thrust horsepower in excess of that required for straight and level flight and drag increases as the square of the speed. At the same time, power required to maintain a velocity increases as the cube of the velocity.

The Cessna 421 has a best all-engine rate-of-climb speed of 110 knots, which produces a climb of 1,850 fpm at sea level. If the aircraft is climbing at 122 knots, drag would increase by 1.2 times and the powet required to maintain that velocity would increase 1.4 times with a resulting decrease of excess thrust horsepower available for climb. In this example the climb rate decreases to about 1,261 fpm; thus a 10-percent increase in speed over the best-rate speed produces a 32-percent decrease in climb performance. These exercises produce another rule:

Rule #4—After leaving the ground above Vmc, climb not slower than single-engine best rate-of-climb speed and not faster than best all-engine rate of speed. The latter speed is preferable if obstacles are not a consideration.

You may have gotten the impression by now that we're picking on Cessna and Piper in our examples. Piper twins and the Rockwell Commander 500S have shown up in our examples here because the Ziff-Davis Aviation Division operates (or operated in the case of the Shrike) these aircraft and our observations concerning them were gained from extensive first-hand knowledge. The Cessna twins are used as examples because Cessna, in our opinion, produces the best owners manuals in the industry. This is not to say that the Cessna manuals can't be improved—they are merely the best of a very poor lot. But in any event Cessna manuals provide most of the information a pilot needs to plan for emergencies. At this writing, a special committee of the General Aviation Manufacturer's Association is working on standardization and improvement of light-aircraft flight manuals. But until such time as the GAMA committee and the FAA improve the situation, we're stuck with the paper work that comes with the airplane. Here comes rule five:

Rule #5—Be a skeptic when reading the performance tables in your Part 23 aircraft-owners manual and be doubly sure you read the fine print. Add plenty of fudge factors.

You'll notice first when you look at light-twin takeoff-performance tables (in anybody's manual) that the takeoff is initiated after power has been run to maximum with the brakes locked and the mixtures adjusted to optimum settings. We've attempted to measure the difference in the takeoff roll for brakes held versus a normal throttles-up-smooth start and have come up with figures ranging from an extra 200 to 400 feet. Remember that these figures will increase in density altitude.

If the book figures for continued single-engine takeoff and accelerate/stop distances, you've really got it made, because now, by adding a few hundred feet here and there to compensate for real-time situations, you can get a good handle on what's going to happen if one quits—and what you're going to do about it.

We'll use a Cessna 421 for this exercise and remind you again that we're not picking on the 421. It's just that Cessna is honest enough to try to tell it like it is in its owners manuals.

On a standard day at 7,450 pounds, a 421 needs 2,500 feet to get off and over a 50-foot obstacle. This assumes a rotate speed of 106 knots, well above Vmc. If an engine is lost at rotation and the pilot elects to go anyway, he'll need a total of 5,000 feet to clear the obstacle. The ground run in both cases is about 2,000 feet. In the case of both engines operating, the climb from rotation to 50 feet requires a horizontal distance of only 500 feet; but in the case of the single-engine takeoff, the climb to 50 feet requires a horizontal distance of 3,000 feet, a six-fold increase. And keep in mind that we're still only 50 feet above ground and that to get this far we've made split-second decisions all along the way.

Let's get some real-life factors into the single-engine takeoff equation. Suppose, as is usually the case, we begin the takeoff roll about 75 feet from the approach end of the runway and do so without holding the brakes. This could add 475 feet to the handbook figure. Next, suppose we lose the engine at rotation, but it takes us three seconds to recognize the situation and react. (This, by the way, is a very conservative figure.) The reaction time will cost us about 537 feet. Now the total horizontal distance from the beginning of the runway to a point at which the aircraft is 50 feet above the surface (assuming engine loss at rotation) is 6,012 feet, an increase of 20 percent. The 421's sea-level, single-engine climb rate is about 305 fpm. Assuming that we want to get at least 500 feet under us before trying anything fancy like returning for a landing, we must continue more or less straight ahead for one minute and 28 seconds. This climb will cover a horizontal distance of some 16,485 feet bringing the total distance covered from the rotation point to 19,485 feet, or *3.7 miles.*

If all this happens at a sea-level airport on a hot day (ISA plus 20 degrees C.), we will not reach the 50-foot level until the aircraft has covered a horizontal distance of 7,040 feet from the point of rotation and engine failure. Assuming calm air the aircraft will reach 500 feet some *5.9 miles* from the rotation point or *6.6 miles* from the runway beginning. If the hot condition brought convective turbulence with it, the effective climb rate would be reduced by 100 fpm. Under these conditions, the aircraft would reach 500 feet some *9.9 miles* from the rotation point and *10.6 miles* from the runway beginning.

I've been stating these horizontal distances in terms of miles to stress a point. If your flight manual gives figures for continued single-engine takeoff, make sure you look at the climb performance beyond the 50-foot altitude to be certain that continued takeoff is a viable alternative if an engine quits. You might be able to live with that 10.6-mile hot-day figure on a departure from JFK where you could head out over the Atlantic, but the same departure from Teterboro would make collision with obstacles almost a certainty. In the case of the Teterboro departure, a rejected takeoff within the boundaries of the airport or stuffing it into the first available parking lot might be your only survivable alternative. You certainly aren't going to survive if you run into something, or fall out of the air trying to get performance from the aircraft that the manufacturer never built into it.

So, on the subject of rejected takeoffs, check the accelerate/stop tables and the landing-distance charts before each takeoff. Remember to add 500 feet or so to the accelerate/stop distance to compensate for the runway left behind you when you moved into position and the rolling (rather than brakes-held) ground run; add another 500 feet or so for your reaction time and then another 200 feet for "technique." Part 23 sets no standards for the determination of accelerate/stop distances in light twins. The stopping distances are often determined by a 10,000-hour test pilot who does everything short of retracting the gear to stop the aircraft. Even in an emergency situation, you're probably not going to get the same stopping performance he does. (Remember to get the flaps up to increase the weight on the wheels.)

If you're lucky enough to have normal takeoff, single-engine takeoff and accelerate/stop tables in your airplane manual, another check you should make before takeoff is the total distance (adding our real-life factors, of course) for takeoff with both engines operating, climb to 50 feet, then to land from that 50-foot altitude and bring the aircraft to a complete stop. This figure for the 421 (adding all our fudge factors) comes to 5,689 feet. This is less than the distance required (6,012 feet) to climb to 50 feet assuming an engine loss at rotation under the same conditions.

Knowing this number gives you another alternative. If you have 5,700 feet of runway and overrun, you might decide to put the aircraft back on the runway even if the engine failure occurs well after takeoff as you're going through 50 feet. Even if you don't have the full 5,700 feet, you may have enough runway to get the wheels back on the hard surface and begin some serious braking before you run off the end of the runway. B/CA's philosophy, which was copied from that of the flight department of a major manufacturer of light twins, is that it's always better to go through the fence at 50 knots than to hit the trees at 120.

To the best of my knowledge, a takeoff to 50 feet followed by an immediate landing is not taught in twins, although a similar maneuver is taught in single-engine aircraft. It should be, but before you go out and try it, take your aircraft to altitude and practice the transition from climbing flight to gliding flight until you can make the transition without significant loss of airspeed. And it might be a good idea to take an instructor along. If you decide to try it on a runway allow a good 8,000 to 10,000 feet for the first few attempts—and take your time.

If your aircraft-owners manual does not show performance figures for continued single-engine takeoff, chances are that the airplane simply is not capable of accelerating from liftoff speed to a reasonable climb speed in the takeoff configuration. In this case, your decisions are pretty limited. You really don't have a go-situation until the aircraft is cleaned up and has reached at least best single-engine angle-of-climb speed. An engine failure before that time (on the ground or in the air) dictates an immediate *controlled* descent to a landing. The surviving engine, in this case, can be used to help maneuver to a suitable (nearby) landing place if all of the runway is gone.

You can calculate your own accelerate/stop distances by running the aircraft up to takeoff speed and then bringing it to a stop. (Make sure you start these tests on a good long runway). Do this several times at max gross weight counting runway lights (the airport operator can tell you the distance between lights) and you'll get a good ball-park figure for accelerate/stop. Then use that figure in your future takeoff planning.

To sum it up, we've seen that:

☐ The loss of an engine on a Part 23 twin will decrease sea-level climb performance by at least 80 percent and can decrease it by as much as 90 percent.

☐ There is no requirement for continued single-engine takeoff capability for Part 23 twins, nor, in fact, is there a requirement for any positive single-engine climb at all for twins which weigh less than 6,000 pounds and have a stall speed of 61 knots or less in the landing configuration.

☐ It is vital to know all you can about your aircraft's performance in normal and emergency situations *before* the takeoff is attempted. To arrive at reasonable performance predictions you must adjust the information provided by the manufacturer to take into account real-life factors such as reaction time, runway condition and obstacles, including obstacles five or more miles beyond the airport boundary.

☐ A well-executed Part 23-twin takeoff is one in which the aircraft leaves the ground at least at Vmc-plus-five knots and climbs at a speed of at least Vxse and not more than Vy.

One final comment should be made on the single-engine takeoff. Your personal IFR takeoff minimums should include factors for an engine failure. Certainly your go-no go decision with an engine failure immediately after rotation or in the initial climb segment is strongly affected by weather. Consider the case of the 421 we discussed above which, in the event of engine failure at rotation, requires about 10.6 miles on a hot day from the start of the runway to a point where maneuvering altitude (500 feet) is reached. Poor visibility and low ceilings could make that situation almost hopeless in any but the most sparsely built-up areas.

Single-engine landings, as you'll remember from your check rides, are not difficult at all. Single-engine go-arounds in Part 23 twins are, on the other hand, damn near impossible unless they are begun from an altitude several hundred feet above the terrain and at an airspeed at or slightly above the best single-engine rate-of-climb speed. The situation is doubly bad if you start a go-around and *then* lose an engine. If you want proof, go to altitude and set up a 500 fpm rate of descent at a speed 10 percent below the best single-engine rate-of-climb speed. Continue the descent until you are within 200 feet of a cardinal altitude, then simulate a single-engine go-around. Attempt to clean up the airplane, and accelerate to best single-engine climb speed without sinking through the cardinal altitude. It can't be done with Part 23 twins—we've tried it in just about everything from the Seneca to the King Air A100. At or above single-engine climb speed it can be done if you're sharp. But don't bank on being sharp after a long flight involving an engine shutdown somewhere along the way.

So establish a single-engine I'll-land-come-hell-or-high-water altitude (agl) and minimum-airspeed combination for your aircraft and stick to it. If you find yourself below that speed or altitude and a truck shows up on the runway, pick a soft spot to hit on the airport. Because it's much better to wipe out the gear by landing off the runway than to wipe out the whole airplane by spinning into the middle of it.

Summing it up—stay proficient (an annual check is a good idea), stay constantly aware of your airplane's performance by analyzing the flight-manual information under realistic conditions, and have a plan of action before things start to come unglued. The key philosophy of that plan of action is easy to remember and may save your bottom—*always leave yourself an out.* □

APPENDIX D

Decision Points for Pros in Twin-Engine Performance

In this two-part article John Lowery discusses finesse in better understanding and handling general aviation twin-engine aircraft . . .especially during critical engine-out procedures.

By John Lowery

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PART I.

Light-Medium Recip Twins and Turboprops

There is serious misunderstanding of aircraft takeoff performance in our light twins, turboprop and jet powered corporate aircraft. This misunderstanding has caused fatal accidents particularly during training. A portion of the problem lies with inadequate and confusing information in the flight manual or operations manual.

For a transport category aircraft, i.e. one certified under FAR 25, performance charts look quite complicated at first; but once mastered they provide quick load and flight planning information. If the charts are followed for takeoff gross weight then the aircraft can lose an engine at decision speed and the crew can be assured of the capability to successfully continue takeoff.

The light twins, certified under FAR 23, are another story. Their ever increasing stall-spin accident history is alarming. Three factors appear involved with this increasing accident trend. First, the owner's manual of most twins is not clear about single engine takeoff capability. The clue to the pilot is that if the aircraft has no published "Single Engine Takeoff" charts then the manufacturer is subtly telling him that, should an engine fail at takeoff, then ". . . the light multiengine aircraft is, in concept, merely a single engine aircraft with its power divided into two or more individual packages." This quote from an FAA safety publication states further: "There is nothing in the FAR governing the certification of light multiengine airplanes which says they must fly (maintain altitude) while in the takeoff configuration and with one engine inoperative." Yet, as we know some of these twins will, under temperate conditions and when lightly loaded with only two crew members, takeoff and fly when the instructor pulls an engine at rotation, assuming the runway is long enough.

The instructor is wrong, of course, but in his (or her) defense he feels obligated by the second factor in these takeoff-stall-spin accidents, the requirements of FAA flight test guide AC61-55A which states: "The applicant may be asked to demonstrate engine failure procedures during the takeoff operation . . ."

True, the flight test guide goes on to say "After giving due consideration to the airplanes' characteristics, runway length, surface conditions, wind direction and any other factors . . ." But how many check rides are given without this engine cut?

With light recip twins both engines are normally needed for T/O, with T/O flaps and gear down.

NOW comes the third factor in our light twin takeoff accidents. The instructor or examiner, who is trained in or perhaps actively flying transport category airplanes, forgets that the light twin under FAR 23 certification rules does not have to fly on one engine in takeoff configuration, i.e. gear down and takeoff flaps, if used. He unconsciously mixes the two in his mind and at rotations off comes at wrong throttle, or worse, the mixture. We now have the ingredients for a practice accident.

If this sounds far fetched consider the fact that NTSB statistics show that one third of the light twin stall-spin accidents are dual.

Conversely, Cessna has long published what equates to transport category takeoff data for their light twins (See Diagram 1.) The Cessna 310 for example, at a gross weight of 5300 lbs. on an 80°F day, taking off from a sea level airport has an accelerate stop distance airspeed of 92 kts. This equates to a "T" category V1 speed or decision speed.

The "single engine takeoff distance" chart shows that one engine takeoff speed, which is also safe single engine speed, is 92 kts. This equates roughly to Vr speed for FAR 25 aircraft. (In a "T" category airplane Vr can be the same as V1 or decision speed, but never less.) So here we have a light twin with a decision and rotate speed that are equal.

The charts indicate also that single engine takeoff distance is about 5500 feet. So, in practice or on a check ride, any runway shorter than 5500 feet is an automatic abort should an engine fail or be cut up to 92 kts.

While holding 92 kts. and with an indication of climb gear is retracted and, assuming an obstruction problem, airspeed is increased to 95 kts. or *best angle of climb speed,* found in the *Emergency Procedures* section. In transport category this speed equates to V2 speed, except that in our light twin we hold it to only 50 ft. altitude. This is a noteworthy difference from FAR 25 certification rules.

A transport aircraft must climb to at least 400 feet at V2 speed. The Cessna 310 and similar light twins climb only to 50 feet at *best angle of climb* then they must accelerate to *best rate of climb speed,* 106 kts. for our example, the Cessna 310. This speed, which equates to a transport's final segment speed (Vfs) must be obtained on schedule otherwise the lift over drag ratio can deteriorate and result in a behind the power curve situation.

Significantly, the Cessna 310 requires 5500 feet for a single engine takeoff given the conditions stated. This distance does not fit many general aviation airports. And if you are departing on an 8 to 10,000 foot runway and one quits, why take off at all—unless you need a practice emergency?

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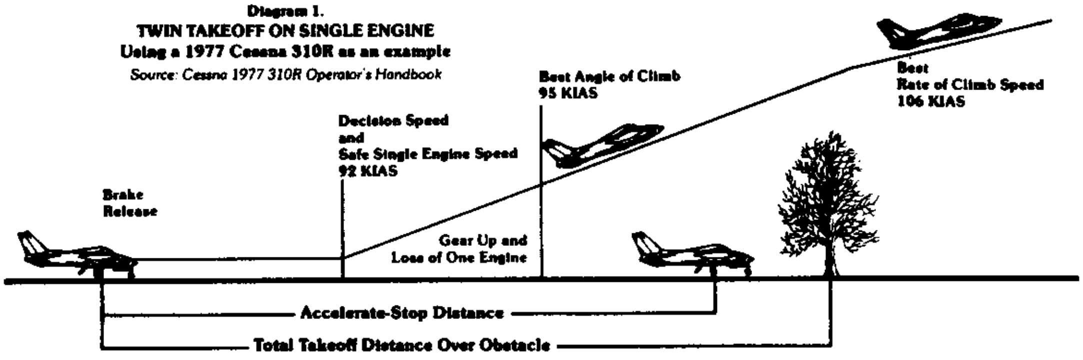


Diagram 1.
TWIN TAKEOFF ON SINGLE ENGINE
Using a 1977 Cessna 310R as an example
Source: Cessna 1977 310R Operator's Handbook

It is noteworthy also that at 86°F and an airport pressure altitude of 3000 feet the Cessna 310 will not take off on one engine at its 5500 lb. maximum gross weight. In transport terms this equates to a second segment limit. Obviously, strict attention to temperature and pressure altitude is important to safe flight since a good many of our eastern and southern airports are 600 to 1500 feet above sea level. Out west, of course, elevations are much higher meaning careful attention to loading is required.

Rotation at Vmc

AN AIRCRAFT that rotates at Vmc, despite its beauty and twin engine performance, warrants close attention. Most of these aircraft have no single engine takeoff capability which the manufacturers indicate indirectly in that single engine takeoff performance charts *are not* provided in the owners manual. In effect, with gear down and one engine lost at Vmc (rotation), the remaining engine will not provide enough thrust to give the aircraft a positive climb gradient while the gear is retracting and simultaneously accelerate to safe single engine speed (Vsse). In short, to use transport category terms, the aircraft has no first segment capability. (See Diagram 2.)

This is unfortunate since it again places the flight instructor or the passenger carrying pilot in a position of "do I" or "don't I" continue with an engine failure at takeoff. Yet a big statement in the aircraft certificate limitations: "AN ENGINE LOSS BEFORE SINGLE ENGINE CLIMB CONDITIONS ARE ACHIEVED REQUIRES A PROMPT ABORT," would resolve all doubt.

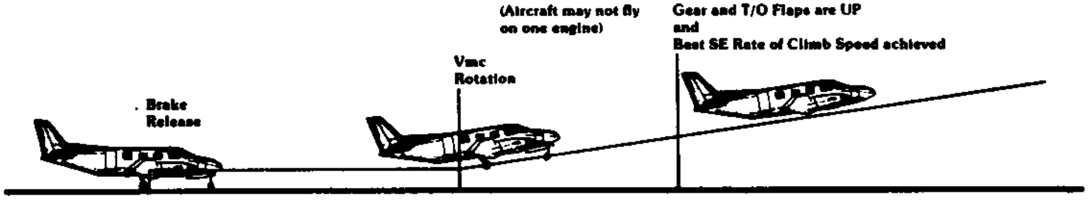
Beechcraft published a safety communique (April 26, 1976) which established a Vsse, or, safe one engine inoperative speed, for their light twins. This was necessitated it appears by the confusion generated by the flight manual and the FAA multiengine flight test requirements, previously addressed.

Many light twin salesmen also make the new owner or pilot believe that he has purchased double safety for that most critical "engine failure at takeoff." The facts are that *in most light twins, between 80% and 90% of the climb capability is lost when one engine is lost.* For the turboprops and twin jets the figure is between 70% and 75% of climb, with two exceptions. The Gulfstream II loses a reported 65% while the HS 125-600 with one engine experiences a climb performance loss of about 81%. Of course, the "T" category twin jets have so much climb capability that a 75% climb loss still provides a respectable 1000 to 1200 fpm rate of climb, provided they are not overloaded for existing temperature and pressure altitude conditions.

Turboprops

THE SLEEK high performance FAR 23 certified Merlin III Model SA226-T provides a classic example of the prob-

Diagram 2.
LT.-MED. TWIN SINGLE ENGINE PROFILE
(Certified under FAR 23)
AIRCRAFT ROTATES AT VMC



lem involved. The Merlin is used only because a flight manual was available, not to throw rocks at a fine machine; but it is typical of the FAR 23 twin turboprop aircraft.

The flight manual performance section shows that rotate speed Vr is Vmc or Vs1 (stall speed under special conditions, in this case with full power) whichever is higher. At sea level on an ISA+10°C (77°F) day Vr is 102 knots. This figure comes from the Vmc table since stall speed for 12,500 maximum gross takeoff is 96 knots. After takeoff and upon reaching 500 feet (both engines operating) airspeed should be 117 knots. Climb out from sea level is shown as 145 knots.

The FAA approved emergency procedures reflect an engine failure at rotation (Vmc) capability by requiring the pilot to (1)Set power. (2)Landing gear. Retract. (3)Inoperative engine. Secure. (4)Airspeed. Best *single engine rate of climb*. Note that best angle of climb speed is not used.

Referring to flight manual performance data we find that there is no single engine takeoff chart. It is not required under FAR 23 certification rules.

The Merlin III does have a chart for single engine climb; and to the unwary pilot who reads the FAA approved emergency procedure for engine failure at Vr, the assumption would be that it will takeoff, at maximum gross weight, and climb on one engine until gear is retracted and airspeed increased to best rate of climb; all in a reasonable amount of runway.

In transport terms there is no first segment information available so a one engine takeoff at maximum gross should not be expected. Further verification of this fact is that the "conditions" for single engine climb call for gear and flaps *up* and best *rate* of climb airspeed. And at maximum gross this equates to 140 knots. (For this speed the pilot must flip from emergency procedures, Section III to the Single Engine climb chart, Section IV.)

Realistically, however, without the single engine takeoff charts, an engine failure at Vr or liftoff should be rejected. Only if the gear is up and airspeed has reached the best *rate* of climb, Vsse, or the airspeed noted on the FAA approved single engine climb charts, can single engine climb capability be legally demonstrated or in fact expected.

At least two light twins that we know of roll quite rapidly when, at a respectable altitude (5000 feet or above), an engine is cut at Vmc with the other developing full power. This sets the stage for the classic stall spin accident unless the pilot very quickly reduces power on the operating engine. The elevator, of course, must also be neutralized or unloaded to counter a stall. Failure to reduce power promptly almost guarantees a spin, and most likely a flat spin, from which recovery is unlikely. At traffic pattern altitude recovery is obviously impossible.

As for demonstrating a light twin's single engine capabilities with a load of passengers, remember that loading the passenger seats and perhaps baggage compartment moves the CG aft. An accidental loss of control, even with prompt corrective action, may be a serious problem: Because as Beechcraft, Cessna, NASA and FAA publications all emphasize, *an aft CG prolongs spin recovery and encourages a flat spin.*

With an aft CG the wing stalls more completely or goes deeper into the stall. When an aircraft accidentally snaps out of control with asymmetrical power *and* an aft CG loading, should the pilot be slow reducing power to idle, then all the ingredients for a flat spin are present. Therefore with a loaded airplane it is only smart to avoid single engine demonstrations.

Landing performance

IN the FAR 23 twins the best policy for single engine approach and landing is as stated in the Cessna 310 flight manual: "Maintain an approach speed at least equal to best angle of climb with excessive altitude available if needed. Speed is decreased only after the landing is assured." For the transport pilot this best angle of climb speed equates to *approach climb* which will be discussed in Part II.

While a single engine go-around is not recommended for any of the light twins you could be reasonably sure of this capability if the owners manual shows that it has single engine takeoff capability. But what of the other aircraft?

The FAA *Commercial Pilot Flight Test* guide is very clear ". . . a go-around with an engine out will not be performed unless there is an actual emergency." One speaker at a recent flight instructor clinic said, "Plan your single engine landing to be correct the first time. Otherwise that second engine takes you to the scene of the accident."

As for the aircraft that rotates at Vmc and has no published single engine takeoff data, the problem returns for a one engine landing. Again, using the Merlin III (Model SA226T) as our example, the two engine landing approach speed at 10,000 lbs. gross is 98 knots. With an engine out, landing procedures are the same as with both operating; except that flaps are extended when landing is assured. Yet a single engine go-around requires 140 kts IAS. Therefore, in order to get the job done, it will be necessary to have excess altitude to exchange for the 42 knots additional airspeed needed to successfully go-around on one engine. In short, either the go-around requirement becomes obvious early in the approach or it will not be possible.

So, as you can see the single engine performance of our light twins is marginal to nonexistent in the critical areas of takeoff and landing. Unlike the heavier transports the decision point is less flexible.

PART II.

Transport Category Jets

UNLIKE the lighter twins licensed under FAR 23, i.e. less than 12,500 lbs., transport category twin engine aircraft are required to have single engine takeoff and climb capability. These heavier, more sophisticated aircraft are certified under FAR 25. Certification is based on the aircraft's capability to lose an engine at decision speed (V1), using a balanced field, i.e. no runway slope and no wind; and either reject or continue takeoff. If takeoff is continued the pilot accelerates to Vr, lifts off, and climbs at V2 speed, gear down, with a positive climb gradient to 35 ft. (See diagram 3.) With a balanced field whether he rejects or

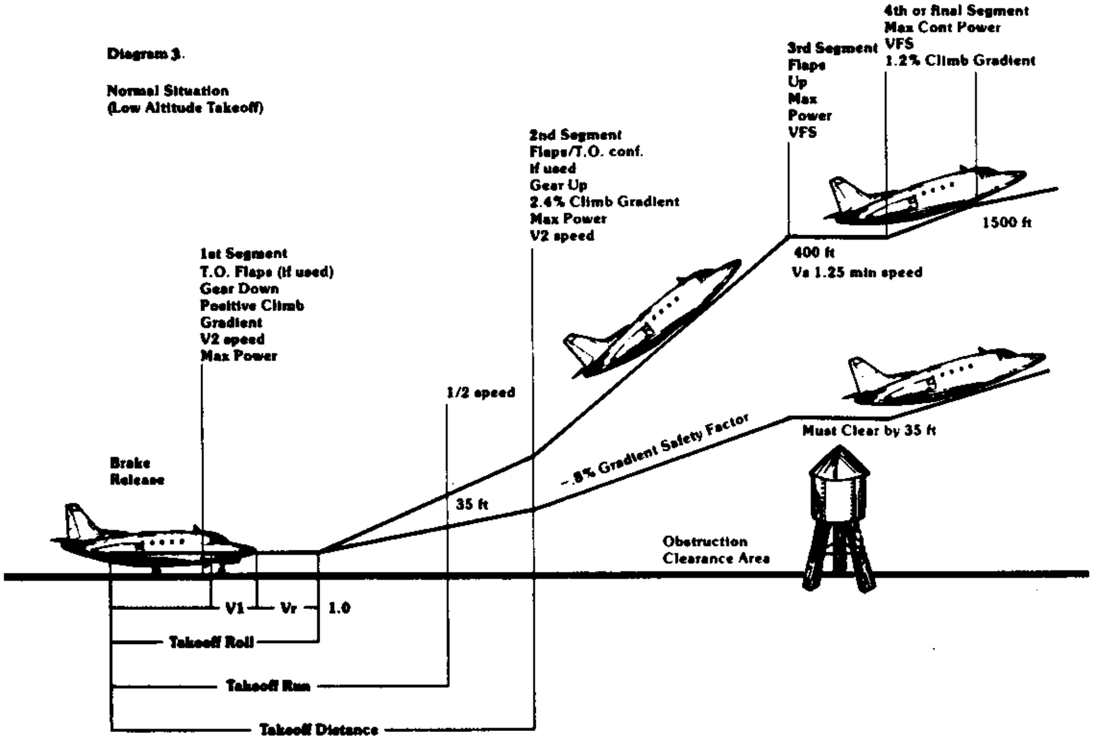


Diagram 3.

Normal Situation
(Low Altitude Takeoff)

continues takeoff the runway required will be the same. This is "Takeoff Distance."

An alternative to this takeoff distance planning is to increase two engine takeoff distance by 115%; however, the single engine figure is usually greater for twin engine aircraft. FAR 91.37 directs that computed takeoff distance cannot exceed runway and stopway length, and clearway if available. It states further that takeoff run can be no greater than runway length. This is an important and usually overlooked factor. *Takeoff run* is *not* ground roll. Rather it is ground roll plus half the distance from liftoff to 35 ft.

First segment of climb

WHILE takeoff distance begins at brake release, the first segment of the single engine climb profile starts at liftoff (see Diagram 3). In this segment the aircraft must climb with a positive gradient, gear down, to 35 ft. altitude. Simultaneously airspeed must be increased from liftoff to V2 by the time 35 ft. is achieved. Normally landing gear is retracted during the latter part of this segment.

Using the aircraft checklist and assuming a balanced sea level airfield, on a 70°F day, you can accelerate a Sabreliner 60 at 20,000 lbs. gross weight to a V1 speed of 124 kts. and abort without the reverser, or climb to 35 ft. using 5500 ft. of runway. The chart shows that the Takeoff Ground Roll is about 1000 ft. less.

Meanwhile we approach a runway intersecton awaiting takeoff clearance and the tower asks if an intersection departure with 5000 ft. remaining is satisfactory.

A quick computation shows that takeoff run (ground roll plus half the 1000 ft. required to reach 35 ft. altitude) is 5000 ft. (4500 ft. plus 500 ft. = 5000 ft.) With a clearway which is an obstruction-free area 500 ft. wide and not longer than half the runway length and having an upward slope not greater than 1.25%, this would be legal technically. (It's frequently a cemetery.) But this downtown airport has buildings at the end. So without a clearway "Takeoff Run" cannot be considered.

The pilot decides on the intersection departure anyway and makes his usual rolling takeoff "for passenger comfort."

Now he has twice jeopardized "takeoff distance." First he planned on getting airborne using the shorter ground roll figure. Next, with a runway now limited by an intersection departure he makes a rolling takeoff.

The "Takeoff Ground Roll" and "Takeoff Distance" charts are computed from a full power condition at brake release (except for those aircraft whose brakes will not hold at full power). The rolling takeoff consumes about 500 ft.

to get maximum thrust and now the pilot must rotate and fly on the last foot of runway.

If he's too slow and smooth on initial throttle application he may not achieve maximum power because EPR increases as airspeed builds on takeoff roll. And computed static EPR is as far as he dares push the throttles.

Most corporate jets have no problem with takeoff distance on today's metropolitan airports—intersection departures excepted. But as surface temperatures rise in spring and summer it is a disregard of the second segment weight limit that can jeopardize the flight, since most biz jets are second segment limited.

The second segment of climb begins at 35 ft. altitude when the gear is fully retracted. With maximum power on the remaining engine and at V2 speed the aircraft must climb at a gross gradient of 2.4%; or for every 100 ft. over the surface horizontally it climbs 2.4 ft. vertically. Takeoff flaps, if used, remain extended. The net gradient shown on the diagram is a minus .8% safety factor allowed for pilot technique.

Our example, the Sabre 60 begins to encounter a second segment weight limit on an 80°F day at 2500 ft. pressure altitude. Incidentally, for all practical purposes field elevation can be used in place of actual pressure altitude computations. Even extreme pressure variations will not vary from field elevation by more than 400 ft.

Perhaps the second segment weight limit is ignored by many pilots because the information is not available in most aircraft checklists. In addition, some pilots believe erroneously that second segment limits are only for FAR 121 operators. What they fail to note is that FAR 91.37 requires that the aircraft be operated according to the FAA approved Flight Manual which includes both takeoff and the climb segments.

Because the Sabre 60 is typical of the corporate jet fleet with lots of power and weight carrying capability we will continue using it to illustrate a first and second weight limitation problem. The airport we'll use is Hot Springs, VA with a near 4000 ft. elevation. Under no-wind conditions the checklist takeoff distance chart shows that on a 70°F day, gross weight must not exceed 18,000 lbs. if we are to have balanced field length on 5600 ft. runway 24/06. This also presumes that brakes are held to full power before takeoff roll begins. With a full cabin load this equates to a 2000 lb. fuel reduction, or about one hour less flying time. This is a *runway limitation*.

Conversely, the Flight Manual second segment chart reflects a modest 200 lb. weight limitation. Consequently Hot Springs under the conditions cited is *first segment limited* for the Sabreliner 60 due to runway length.

Now move to El Paso, TX where airport elevation is also approximately 4000 ft. With two long runways, 12,103 and 9000 ft., obviously we could not be first segment or takeoff distance limited unless of course we had a strong tailwind, at which point the brakes would no doubt become the limiting factor (Vbe).

When we landed at 11:00 a.m. the surface temperature read 85°F. With a 12 noon departure scheduled we are hopefully flying non-stop to Los Angeles. El Paso surface temperature is forecast to be 90°F.

Before refueling, the Flight Manual performance data is checked and the second segment chart shows that a takeoff with pressurization "on" limits aircraft weight at brake release to 18,450 lbs. With all passenger seats filled, zero fuel weight of 13,800 lbs., fuel will be limited to 4650 lbs. or about 2 hours and 35 minutes without reserves. This is barely adequate since the IFR flight requires 1 + 45 enroute.

If you abide by the second segment weight limit, then with an engine failure at V1 you can continue takeoff and, after gear retraction, continue climb to 400 ft. at V2 speed. If you ignored the second segment weight limit then stand by for a practice accident.

Now comes the third climb segment which is the transition point. If you were correctly loaded at brake release then with the good engine at full power and having attained 400 ft. altitude rate of climb is reduced to allow the aircraft to accelerate to its published final segment climb speed (Vfs). The performance charts show this segment as being level, however, the regulation reflects a diminished climb. This final segment speed, which is roughly equivalent to the light twin best-rate-of-climb, can be as low as Vs1.25, but in the Sabre 60, it is 180 kts. at the sample weight. This is the Sabre's best lift-over-drag angle of attack.

A misguided attempt to climb to our objective altitude of 1500 ft. at V2 speed without accelerating to Vfs, under these hot-high conditions, will probably result in the rate of climb dropping to zero somewhere between 400 and 1500 ft. What happens is that induced drag overcomes thrust and the aircraft reaches the power curve, unable to climb in this low climb gradient situation.

Once Vfs is reached, or five minutes at maximum engine thrust, power is reduced to maximum continuous and the fourth or final climb segment is completed to 1500 ft. Climb gradient in this final segment must be 1.2% and most twin jets do this with ease.

High climb gradient

AN ALTERNATIVE to this relatively slow single engine climb may be realized by tailoring fuel loads to the trip—if you can rely on ATC not to replan your flight when you're number one for takeoff. On a cool day, with a partial fuel or passenger load, many corporate jets have a "high climb gradient" situation. In this case an engine loss at V1 proceeds as described previously except that the pilot hangs on to V2 speed until reaching 1500 ft. (see Diagram 4). At that point he retracts takeoff flaps if used and with maximum power still applied accelerates to Vfs. Then upon reaching single engine climb speed or at the end of five minutes, engine power is reduced to maximum continuous and the climb profile is complete.

To find out whether you are in the high or low climb gradient area the Sabreliner manual has this information in the "Net Take Off Flight Path" chart. The lighter Lear 24E manual shows only one chart with a 400 ft. climb at V2 as a minimum requirement, since it will climb directly to 1500 ft. in the second segment at all weights.

Landing performance

THERE are three basic aspects to landing performance in twin engine transport aircraft. First is a normal landing wherein the aircraft crosses 50 ft. above the runway threshold at an airspeed of 1.3 stall (Vs1.3). This is the so called landing bug speed or Vref. Touchdown is usually

Landing in excess of charted speeds means an increased ground roll and, if the runway is wet, a greater chance for the hydroplaning. On a dry runway, the rule of thumb is that 5 kt. excess landing speed increases landing distance by at least 10%. Statistically, this is a major factor in pilot caused landing accidents.

With gusty winds, however, excess speed may be worth the risk. At least one airline recommends holding the gust factor to touchdown and accept the longer landing roll. Better chance the reversers than a hand landing.

Approach climb

THE SECOND aspect of landing performance is "Approach Climb." This refers to a single engine balked landing wherein the operating engine is at maximum thrust, gear is retracted, with flaps in the approach or takeoff position. Actually you can equate this to a second segment takeoff situation since it begins presumably from at least 35 ft. and the aircraft, at landing weight, must climb with a gradient of at least 2.1%. Once obstructions are cleared, clean up and begin acceleration with single engine climb speed (Vse) regained.

As a rule of thumb both Vfs and Vse can be found for the Sabreliner by taking V2 plus 50 kts. for Vfs, and Vref plus 50 kts. for Vse. This works quite well since it provides the best lift-over-drag speed based on gross weight.

Coincidentally Vse is also the best two engine endurance speed, a fact that is worthwhile knowing in the northeast considered to occur at Vs1.2 which is about 7-10 kts. less than bug speed.

The "Landing Distance" charts include the 1000 ft. float to touchdown which, lest you forget, is marked on the runway by the solid landing zone blocks. The actual deceleration and stop is determined by brakes alone since reverse thrust is not allowed during certification.

Ground roll for the Sabre is found in the Pilots Handbook. A WAG of ground roll can be made by simply subtracting the float designed by the FAA to prevent short landings.

U.S. where "holding" is not unusual. A chart of endurance speed is provided in the Sabreliner manual and checklist.

Landing climb

THE THIRD and final phase of landing performance is "Landing Climb." This refers to a balked landing with both engines at maximum power and landing configuration, or gear down and landing flaps. The minimum climb gradient for FAA certification is 3.2%, however most twin jets at landing weight have infinitely more power than required. The go-around speeds published for the Sabre are 1.2% of stall (Vs1.2). This is about 8 kts. less than landing Vref speed.

Takeoff and landing performance can be a confusing subject. But a careful understanding of the performance charts is required if every flight is to be safe and successful. Don't get caught without all your segments—your insurance company cares.

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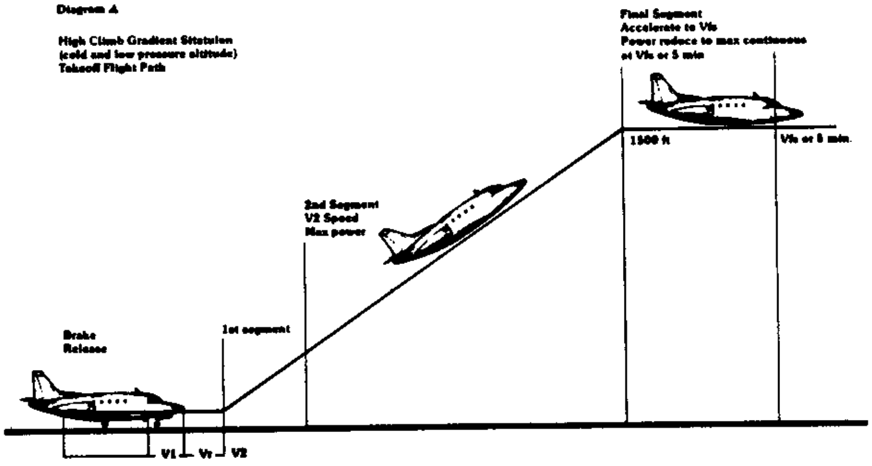

Diagram 4

High Climb Gradient Situation
(cold and low pressure altitude)
Takeoff Flight Path

APPENDIX E

ADDITIONAL CASE HISTORIES

Case 8

The pilot made the preflight and engine run-up check of the C411 with everything normal. He started takeoff from the midfield intersection of a 9,000-foot runway. At the time of takeoff, the airplane was estimated to be 153 pounds below maximum gross weight. Takeoff was normal until the airplane was about 100 feet in the air, at which time the right engine surged, then lost power. The pilot did not feather the engine but tried to maintain flying speed with the left engine. The airplane, which appeared to be in a normal climb attitude, started to bank to the right and, as the airspeed was rapidly depleted, began to descend until impact. The pilot, who was properly certificated for this flight, had failed to pass his multiengine instructor's check ride twice due to lack of proficiency in emergency procedures. The pilot had 3,988 hours of flying time, including 188 hours in multiengine aircraft and 69 hours in the C411.

Case 9

The PA-31-350 was owned by the pilot and was on lease back to a Part 135 operator. Two days before this flight, the aircraft was ferried for routine maintenance, a 100-hour inspection, and other maintenance, including an inoperative right electric boost pump. The pilot called to schedule the aircraft and was informed of this. Since the pilot was operating the aircraft under Part 91, the maintenance was not required. He elected to fly the airplane as it was. Before the flight, the pilot was unable to start the right engine without the boost pump and requested assistance. A mechanic suggested that he try crossfeeding and he successfully started the engine. The pilot, who had already boarded five passengers, proceeded to another airport to pick up three more passengers. The engines continued to run the entire time. The pilot took off, reopened his IFR flight plan, and was cleared to 7,000 feet. The aircraft proceeded to its next destination without a problem, landed, and shut down. When they were ready to return, the pilot filed, showing eight persons on board, but did not receive a weather briefing. They took off and were cleared to 8,000 feet. En route, the pilot declared an emergency, stating that he had lost a fuel pump and was going to lose an engine. He chose to land at an airport closer than his intended destination and was cleared to descend to 4,000 feet. The aircraft was then cleared for a VOR approach and the pilot was given current weather. He overshot the VOR and was cleared to the localizer at which time he requested and was given the localizer frequency.

The pilot then advised the controller that he was losing the other engine and did not have the airport in sight. He also stated that his altitude was 1,000 feet. With this, radio contact ended and the controller was unable to establish radar contact. Passengers in the airplane heard the pilot say that he was going to land on a highway. A witness on the ground stated that he first saw the aircraft descending, wings level, along the edge of the highway. He saw the plane start a bank with the right wing up. The engine sounded like it was at full power. The wing continued up until it was near vertical and the plane was very low to the ground. Just after it passed his house, the witness heard the impact. Investigation showed that all approach plates were still stored in their book, the fuel selector was still on crossfeed, and the aircraft had impacted out of control. Because of his cancellation of IFR prior to approaches on this flight, as well as the overshoot of the VOR, the pilot's instrument proficiency was questionable. He had not followed proper single-engine procedures or he would have discovered the crossfeed problem. In addition to this, he demonstrated a lack of familiarity with his airplane from the start. This pilot had taken his BFR only 2 months before in a Cessna 177RG. The pilot had 1,798 hours of flying time, of which 221 hours were in multiengine aircraft and 221 hours were in the PA-31-350.

Case 10

The pilot departed Scottsdale, Arizona, for a flight to Fullerton, California. En route, the pilot informed Blythe flight service station that he had an oil leak in the left engine of his PA-23-250. His altitude was 14,500 feet. He subsequently reported shutting down the left engine and feathering the propeller. The pilot elected to land at Blythe and descended to pattern altitude. He entered a pattern for the active runway and was observed by a charter pilot also in the pattern to be too far away from the airport for a single-engine approach. The witness also observed that final approach was established too low and too long. About 1 mile from the runway, the aircraft was observed to pitch up and enter a slow climbing left turn. It then rolled left and spiraled into the ground. Although the pilot's actions were proper until he entered the pattern, he allowed the airplane to get low and slow. With the extension of landing gear and flaps, the aircraft's speed fell below Vmc and control was lost. The pilot had an estimated 400 hours of flying time. His times in multiengine aircraft and the PA-23-250 are unknown.

Case 11

The C310D departed from a 6,606-foot runway. Immediately after liftoff, witnesses observed the landing gear retract and the airplane began a flat right turn at a slow airspeed and at low altitude. The tower controller noticed this and cleared the aircraft to land on another runway. The aircraft attained an altitude of about 800 feet. The aircraft continued its yaw to the right, entered a steep right bank, and descended into the ground. Investigation showed that the pilot failed to preflight the aircraft and therefore failed to note that the right engine contained only 3 quarts of oil. This low amount of oil was insufficient to keep the propeller from feathering and resulted in an unwanted propeller feather with the engine at full power. The pilot failed to recognize the problem and so failed to follow the proper emergency procedures. The pilot had 5,000 hours of flying time, of which more than 1,500 hours were in the C310D. His time in multiengine aircraft is unknown.

Case 12

This was a training flight which was to include simulated engine failure during takeoff. The C310 was cleared for takeoff and requested permission to remain in the pattern. The aircraft was cleared for a touch-and-go landing. Upon completion of the touch-and-go, the airplane began to climb out and entered a steep left bank and roll. It then assumed a nose-down attitude and dove to the ground. Examination showed the left engine to be at idle speed with the propeller blades in the unfeathered position. The student pilot had 208 hours of flying time with 3 1/2 hours in the multiengine C310. The instructor had 22,000 hours of flying time with 4,112 hours in multiengine aircraft and 1,500 hours in the C310.

Case 13

The purpose of this flight was to provide a check of the C310P for a prospective partner. Neither of the pilots was a flight instructor. After spending about an hour going over books, documents, and checklists, the pilots started the engines and taxied for takeoff. They asked for and recieved an IFR departure to "on top." After takeoff, they reported "on top" and cancelled the IFR clearance. The aircraft was next reported requesting an ILS approach to the same airport. The flight was handed off to the tower at the outer marker inbound where the pilot requested clearance for a go-around. At an altitude of about 20 feet the aircraft was cleared to go around. At this time, without notifying anyone, the pilot feathered the right propeller and continued around the pattern. He was cleared to land and upon landing, was requested by the controller to advise him the next time they were going to make a single-engine operation. The pilot acknowledged this transmission, restarted the right engine, and taxied back for takeoff. The tower was informed that the airplane would remain in the pattern. They were cleared for takeoff. Witnesses state that there was nothing unusual about the takeoff or liftoff. The speed and distance were comparable with normal two-engine performance. Just after liftoff, the aircraft was observed to yaw sharply to the right. The yaw was not controlled immediately, and the right wing was allowed to drop. Corrective action was taken, the wings were leveled and witnesses assumed the aircraft was under control. By this time, however, the aircraft was low, to the right of the course, and headed for trees with the gear still down. As the aircraft reached the trees, the gear was retracted and the pilot pulled up, barely clearing the treetops. The airplane seemed level for perhaps 2 seconds before the left wing raised up, the plane turned and headed straight down. Because of the inexperience of one pilot and the lack of instructor qualifications of the other, the aircraft's performance was not properly monitored and airspeed fell below Vmc, resulting in loss of control at an altitude too low to effect recovery. The pilot-in-command had an estimated 1,915 hours of flying time, including 120 hours in the C310P. His total time in multiengine aircraft is unknown. The other pilot had an estimated 1,748 hours of flying, of which more than 15 hours were in the C310P. His total time in multiengine aircraft is unknown.

Case 14

This instruction flight was to serve as a final progress check for this multiengine student. The preflight checks and run-up were uneventful and the C310D was cleared for takeoff from the 2,400-foot runway. On takeoff roll, the instructor felt that the student had his feet on the brakes and told him to take them off. At this point, the student reached up and retarded the throttles. The instructor advanced the throttles and took control of the airplane. The aircraft became airborne at less than 90 mph indicated airspeed and immediately started drifting to the left. The instructor stated that he felt a power loss on the left engine and was attempting to achieve directional control of the aircraft before feathering. He was unable to maintain a positive rate of climb, flew under power lines, and crashed on a highway adjacent to the airport. The instructor failed to abort this takeoff and lifted off below Vyse. He then failed to follow emergency procedures by feathering the propeller and retracting the gear. He also failed to discover a mispositioned fuel selector valve which caused the loss of power. The student pilot had 1,284 hours of flying, including 11 hours in the multiengine C310D. The instructor had 9,073 hours of flying time, including 557 hours in multiengine aircraft and 435 hours in the C310D.

Case 15

This was a training flight for the owner of the C411. It was the second flight day and consisted of pattern work. After some touch-and-go landings, the instructor pilot requested and was granted clearance for a simulated single-engine approach on a different, longer runway. The aircraft was observed in the pattern in a clean configuration. At this time, the aircraft appeared to be lower than the standard 800-foot pattern. The aircraft turned final with a bank of about 45° and simultaneously the gear started to come down. The aircraft immediately flipped or rolled to the right, culminating in a near vertical dive.

Although it is not known for sure which engine was throttled back, it is possible that the left engine was the simulated engine out and that the student, due to gusty wind conditions, misjudged his turn to final, making it steeper than normal and causing the airspeed to fall off. This, along with lower than normal altitude, caused one of the pilots to add power on the left side. The rapid application of asymmetrical power in a slow flight near stalled condition would result in the type of maneuver described by this aircraft. The student pilot had 164 hours of flying time, including 15 hours in the C411. The instructor had 6,022 hours of flying time, of which 161 hours were in multiengine aircraft and 10 hours were in the C411.

APPENDIX F

A COMPARISON OF EXCERPTS FROM FAA FLIGHT TEST GUIDES FOR PRIVATE AND COMMERCIAL PILOTS - AIRPLANE

PRIVATE

A. Maneuvering at Minimum Controllable Airspeed

1. Description The applicant may be asked to maneuver in various configurations and at such airspeeds that controllability is minimized to the point that if the angle of attack is further increased by an increase in load factor or a decrease in airspeed, an immediate stall would result. The maneuver should be accomplished in straight flight, turns, climbs, and descents, using various flap settings (if applicable).

2. Acceptable Performance Guidelines The applicant shall be evaluated on the ability to establish the minimum controllable airspeed, to positively control the airplane, to use proper torque corrections, and to reconize incipient stalls. Primary emphasis shall be placed on airspeed control. During straight-and-level flight at this speed, the applicant shall maintain altitude within ±100 ft. and heading within ±10° of that assigned by the examiner. Inadequate surveillance of the area prior to and during the maneuver or an applicant-induced unintentional stall shall be disqualifying.

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COMMERCIAL

A. Maneuvering at Minimum Controllable Airspeeds

1. Description The applicant may be asked to maneuver at such an airspeed that controllability is minimized to the point that if the angle of attack or load factor is further increased, an immediate stall would result. The maneuver should be accomplished in medium-banked level, climbing and descending turns, and straight-and-level flight with various flap settings in both cruising and landing configurations.

2. Acceptable Performance Guidelines The applicant shall be evaluated on competence in establishing the minimum controllable airspeed, in positively controlling the airplane, and in recognizing incipient stalls. Primary emphasis shall be placed on airspeed control. During straight-and-level flight at this speed, the applicant shall maintain altitude within ±50 ft. and heading within ±10° of that assigned by the examiner. Inadequate surveillance of the area prior to and during the maneuver, or an applicant-induced unintentional stall shall be disqualifying.

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PRIVATE

E. Eights Around Pylons

1. Description The applicant may be requested to perform right and left turns around two ground reference points or pylons. A turn should be made in each direction, varying bank to correct for wind drift, resulting in a constant distance from each point. The ground track should be in the form of a figure "8".

2. Acceptable Performance Guidelines The applicant shall maneuver the airplane so that both loops of the "8" are of equal size. Performance shall be evaluated on proper wind drift correction, airspeed control, coordination, altitude control, and vigilance for other aircraft. Deviation of ±100 ft. from the selected altitude shall be considered disqualifying unless corrected promptly. Also, excessively steep banks, flight below minimum safe altitude prescribed by Regulations, or inadequate clearance from other aircraft shall be disqualifying.

* * * * *

B. Normal and Crosswind Landings (Landplanes)

1. Description The applicant may be asked to demonstrate normal and crosswind landings. Normal landings should be made using a final approach speed equal to 1.3 times the stalling speed in landing configuration (1.3 V_{so}), or the final approach speed prescribed by the manufacturer. Power should be progressively reduced so that the throttle is closed when the desired touchdown point is assured, or while rounding-out for touchdown. If the airplane is equipped with flaps, landings may be made with full flaps, partial flaps, or no flaps. Forward slips and a slip-to-a-landing may be performed with or without flaps, unless prohibited by the airplane's operating limitations.

COMMERCIAL

F. Lazy Eights

1. Description The applicant may be asked to perform a lazy eight. This consists of two 180° turns in opposite directions, with a symmetrical climb and dive performed during each turn. The airplane should be constantly rolled from one bank to the other, while the pitch attitude is constantly changed from climbs to dives. The loops should be symmetrical with portions above and below the horizon equal in size. At no time during the maneuver should the airplane attitude, control positions, or control forces be held constant.

2. Acceptable Performance Guidelines The applicant's performance shall be evaluated on planning, coordination, smoothness, attitude, and airspeed control. A persistent gain or loss of altitude at the completion of each lazy eight, or repeated slipping or skidding, shall be disqualifying.

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B. Normal and Crosswind Landings (Landplanes)

1. Description The applicant may be asked to accomplish normal and crosswind landings using a final approach speed equal to 1.3 times the power-off stalling speed in landing configuration (1.3 V_{so}), or the final approach speed prescribed by the manufacturer. The landings may be accomplished with or without power, with touchdowns being made within the area specified by the examiner. Landings may be made with full flaps, partial flaps, or no flaps. Forward slips and a slip to a landing may be performed with or without flaps, unless prohibited by the airplane's operating limitations.

PRIVATE

In a tailwheel type airplane, the main wheels and tailwheel should touch the runway simultaneously at or near power-off stalling speed. In a nosewheel type airplane, the touchdown should be on the main wheels with little or no weight on the nosewheel. In strong, gusty surface winds, in a tailwheel type airplane, the round-out should be made to an attitude which permits touchdown on the main wheels only. In crosswind conditions, wind drift corrections should be made throughout the final approach and touchdown. Adequate corrections and positive directional control should be maintained during the after-landing roll.

The applicant may be asked to make at least one crosswind landing with sufficient crosswind to require the use of crosswind techniques, but not to exceed the crosswind limitations of the airplane.

The applicant may be asked to discontinue a landing approach at any point and execute a go-around.

2. Acceptable Performance Guidelines The applicant's performance of normal and crosswind landings shall be evaluated on landing technique, judgment, wind drift correction, coordination, power technique, and smoothness. The proper final approach speed should be maintained within ±5 knots and touch down in the proper landing attitude within the portion of the runway or landing area specified by the examiner.

Touching down with an excessive side load on the landing gear and poor directional control shall be disqualifying.

On go-arounds the applicant shall maintain positive airplane control, appropriate airspeeds, and operate the flaps and gear (if applicable) in proper sequence.

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COMMERCIAL

In a tailwheel type airplane, the main wheels and tailwheel should touch the runway simultaneously at or near power-off stalling speed. In a nosewheel type airplane, the touchdown should be on the main wheels with little or no weight on the nosewheel. In strong gusty surface wind, in a tailwheel type airplane, the round-out should be made to an attitude which permits touchdown on the main wheels only. In crosswind conditions, wind drift corrections should be made throughout the final approach and touchdown. Adequate corrections and positive directional control should be maintained during the after-landing roll.

The applicant may be asked to make at least one crosswind landing with sufficient crosswind to require the use of crosswind techniques but not to exceed the crosswind limitations of the airplane.

2. Acceptable Performance Guidelines The applicant's competence in performing normal and crosswind landings shall be evaluated on the basis of landing technique, judgment, wind drift correction, coordination, power technique, and smoothness. Proper final approach speed shall be maintained within ±5 knots, and touchdown accomplished in the proper landing attitude beyond and within 200 ft. of a line or mark specified by the examiner.

Improper or incomplete pre-landing procedures, touching down with an excessive side loading on the landing gear, and poor directional control shall be disqualifying.

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PRIVATE

D. Turns About a Point

1. Description The applicant may be asked to perform a ground track maneuver in which a constant radius of turn is maintained by varying the bank to compensate for wind drift, so as to circle and maintain a uniform distance from a prominent reference point on the ground. A constant altitude should be maintained throughout the maneuver. This maneuver should be performed both to the right and to the left.

2. Acceptable Performance Guidelines The applicant shall maneuver the airplane so that the ground track is a constant distance from the reference point. Performance shall be evaluated on proper wind drift correction, airspeed control, coordination, altitude control, and vigilance for other aircraft. Deviation of more than ±100 ft. from the selected altitude shall be considered disqualifying unless corrected promptly. Also, excessively steep banks, flight below minimum safe altitude prescribed by Regulations, or inadequate clearance from other aircraft shall be disqualifying.

* * * * *

COMMERCIAL

I. Steep Spirals

1. Description The applicant may be asked to perform a steep spiral around a selected ground reference point and continue for a minimum number of turns specified by the examiner. Recovery should be made at a specified point relative to the ground reference. A constant radius around the point should be maintained by varying the bank to correct for wind effect.

2. Acceptable Performance Guidelines The applicant shall be competent in entering, maintaining, and recovering from steep spirals using smooth coordinated controls. Loss of orientation, descending below a safe altitude, or excessive variation of pitch attitude shall be disqualifying. Observance of the following limits will be accepted as competent performance:

a. Airspeed within ±10 knots of that recommended.

b. Steepest bank between 50° and 55°.

c. Recovery at the specified point or at a safe altitude.

d. Uniform radius around the reference point.

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APPENDIX G

A COMPARISON OF EMERGENCY PROCEDURES FROM FAA FLIGHT TEST GUIDES FOR PRIVATE AND COMMERCIAL PILOTS - AIRPLANE

PRIVATE

X. EMERGENCY OPERATIONS

Objective

To determine that the applicant can react promptly and correctly to emergencies which may occur during flight.

Procedures/Maneuvers

A. Power Malfunctions

1. Description The applicant may be asked to demonstrate a knowledge of corrective actions for: (1) partial loss of power; (2) complete power failure; (3) rough engine; (4) carburetor or induction system ice; (5) fuel starvation; and (6) fire in the engine compartment. The examiner may, with no advance warning, reduce power to simulate engine malfunction.

2. Acceptable Performance Guidelines Performance shall be evaluated on the applicant's prompt analysis of the situation and on the remedial course of action taken. The emergency procedures shall be performed in compliance with the manufacturer's published recommendations. Any action which creates unnecessary additional hazards shall be disqualifying.

B. Lost Procedures

1. Description The applicant may be asked to explain the proper courses of action to be taken in the event of becoming lost or trapped on top of an overcast, losing radio communications, or encountering unanticipated adverse weather.

2. Acceptable Performance Guidelines Performance shall be evaluated on the applicant's ability to promptly and correctly analyze the situation and describe the appropriate remedial action.

C. Maneuvering With One Engine Inoperative

1. Description The applicant may be asked to demonstrate engine shutdown procedures and flight with one engine inoperative (propeller feathered, if possible). This includes straight-and-level flight and 20° to 30° banked turns toward and away from the inoperative engine. Also included are descents to prescribed altitudes and, in airplanes which are capable of climbing under the existing conditions, climbs to prescribed altitudes.

NOTE: The feathering of one propeller should be demonstrated in any multiengine airplane equipped with propellers which can be safely feathered and unfeathered in flight. Feathering for pilot flight test purposes should be performed only under such conditions and at such altitudes and positions where safe landings on established airports can be readily accomplished in the event difficulty is encountered in unfeathering.

If the airplane used is not equipped with propellers which can be safely feathered and unfeathered in flight, the applicant may be asked to shut down one engine in flight in accordance with the procedures in the manufacturer's published recommendations. The regulations do not specifically require an applicant to unfeather a propeller on a flight test. Accordingly, he is not required to do so if he elects to land with a propeller feathered. If he desires to use this procedure, he should arrange it in advance with the examiner concerned, who will permit it unless he considers that an undue hazard would be involved.

2. Acceptable Performance Guidelines The applicant shall use prescribed propeller operating procedures as well as the recommended emergency settings of all ignition, fuel, electrical, hydraulic, and fire extinguishing systems appropriate to an engine failure. The applicant shall maintain a heading within ±20° of the original heading during the feathering and unfeathering procedures, and an altitude within ±100 feet of the original altitude if it is within the capability of the airplane used; he shall promptly identify the inoperative engine after a simulated power failure; and use accurate shutdown and restart procedures, as prescribed in the manufacturer's published recommendations. In an airplane not capable of maintaining altitude with an engine inoperative under existing circumstances, the applicant shall maintain an airspeed within ±5 knots of the engine-out best rate-of-climb speed and shall use prescribed operating procedures and proper trim settings.

D. Engine-Out Minimum Control Speed Demonstration

1. Description The applicant may be asked to demonstrate airplane controllability problems associated with attempted flight with one engine inoperative at less than minimum engine-out control speed (V_{mc}), and to recognize imminent loss of control and to apply proper recovery techniques.

NOTE: There is a density altitude above which the stalling speed is higher than the engine-out minimum control speed. When this density altitude exists close to the ground because of high elevations or temperatures, an effective flight demonstration is impossible and should not be attempted. When a flight demonstration is impossible, the significance of the engine-out minimum control speed should be emphasized on the oral, including the results of attempting engine-out flight at below this speed, the recognition of imminent loss of control, and recovery techniques.

2. Acceptable Performance Guidelines The applicant shall demonstrate a complete and accurate knowledge of the cause, effect, and significance of the engine-out minimum control speed, of the clues to be watched for by the pilot, and the safe recovery procedures.

The engine-out minimum control speed flight demonstration is subject to so much variation because of differences in airplane flight characteristics, circumstances of flight, and density altitude that definitive performance standards cannot be prescribed. The basic criteria are the prompt recognition of imminent loss of control and the prompt initiation of correct recovery actions. An attempt at any time during the flight test to continue level or climbing flight with an engine out at less than the engine-out minimum control speed, except as necessary for this demonstration, shall be disqualifying.

E. Use of Engine-Out Best Rate-of-Climb Speed

1. Description The applicant may be asked to establish and maintain the best possible rate of climb (or minimum rate of sink) with one engine throttled to simulate the drag of a feathered propeller, or with a propeller feathered by mutual agreement between the applicant and examiner.

2. Acceptable Performance Guidelines The applicant shall determine (from the manufacturer's published recommendations) and shall maintain the prescribed engine-out best rate-of-climb speed and shall maintain a climb within ±5 knots of the best rate-of-climb speed and within ±10° of the desired heading.

F. Effects of Airplane Configuration on Engine-Out Performance

1. Description The applicant may be asked to demonstrate the effects of various configurations on engine-out performance. This includes the results of the extension of the landing gear, the flaps, and both; the application of carburetor heat on the operating engine(s); and windmilling of the inoperative engine.

2. Acceptable Performance Guidelines The applicant shall maintain an airspeed within ±5 knots of the best rate-of-climb speed and a heading within ±10° of the assigned heading while controlling the airplane in the various configurations.

G. Engine Failure on Takeoff

1. Description The applicant may be asked to demonstrate engine failure procedures during takeoff operations. After giving due consideration to the airplane's characteristics, runway length, surface conditions, wind direction and velocity, and any other factors which may affect safety, the examiner may, at least once during the flight test, throttle an engine on takeoff, and expect the applicant to proceed as he would in the event of an actual power failure.

The feathering of the propeller and securing of the throttled engine should be simulated to keep it available for immediate use, but all other settings should be made as in the case of an actual power failure.

NOTE: If it has been determined that the engine-out rate of climb will *not* be at least 50 feet per minute at 1,000 feet above the airport, the engine failure should be simulated at a point on the takeoff roll which will permit the airplane to be safely stopped on the remaining portion of the runway.

2. Acceptable Performance Guidelines If it has been determined that the engine-out rate of climb under existing circumstances is at least 50 feet per minute at 1,000 feet above the airport, and has attained at least the engine-out, best angle-of-climb speed when the engine is throttled, the applicant shall continue takeoff with one engine throttled.

If the airspeed is **below** the engine-out best angle-of-climb speed and the landing gear has **not** been retracted, the takeoff shall be abandoned immediately. If the best angle-of-climb speed has been obtained and the landing gear is in the retract cycle, the applicant shall climb out at the engine-out best angle-of-climb speed to clear any obstructions, and thereafter stabilize the airspeed at the engine-out, best rate-of-climb speed while cleaning up the airplane and resetting all appropriate systems.

H. Engine-Out Approach and Landing

1. Description The applicant may be asked to make an approach and landing with one engine inoperative. In the event the applicant has elected to land with a propeller feathered after demonstrating propeller feathering, no further demonstration should be required. Otherwise, the landing may be made with an engine throttled to simulate the drag of a feathered propeller or, if feathering propellers are not installed, with an engine throttled to idling. The approach should be continued to a normal landing, and a go-around with an engine out will not be performed unless there is an actual emergency.

2. Acceptable Performance Guidelines The applicant shall use the correct procedures for the operation of the airplane systems, use appropriate trim settings, observe the regular traffic pattern or approach path, maintain airspeed and aircraft control during touchdown and landing roll. Any reduction of airspeed below the engine-out minimum control speed before the landing flare is initiated shall be disqualifying.

I. Systems or Equipment Malfunctions

1. Description The applicant may be asked to demonstrate the emergency operation of the retractable gear, flaps, and electrical, fuel, deicing, and hydraulic systems if operationally practical. Emergency operations such as the use of CO_2 pressure for gear extension, or the discharge of a pressure fire extinguisher system should be simulated only.

On flight tests in pressurized airplanes, this demonstration should include an emergency descent as might be necessitated by a loss of pressurization. The descent should be initiated and stabilized, but no prolonged descent is required. The airspeed or Mach number for the demonstration of an emergency descent should be approximately 10 percent less than the airplane's structural limitation, to provide a safety margin. When a Mach limitation is the controlling factor at operational altitudes for the airplane used, the descent should be arranged, if practicable, to require the transition from the observance of the Mach limitation to an airspeed limitation. A simulated emergency descent through or near clouds is prohibited.

2. *Acceptable Performance Guidelines* The applicant shall respond to emergency situations in accordance with procedures prescribed by the manufacturer's published recommendations. The applicant's performance shall be evaluated on the basis of knowledge of the emergency procedures for the airplane used, the judgment displayed, and the accuracy of the operations.

COMMERCIAL

VI. EMERGENCY PROCEDURES

Objective

To determine that the applicant has a thorough knowledge of, and can competently perform emergency procedures for all systems and equipment installed in the airplane used on the flight test.

Procedures/Maneuvers

A. Power Loss

1. *Description* The applicant may be asked to demonstrate knowledge of corrective actions for: (1) partial loss of power, (2) complete power failure, (3) rough engine, (4) carburetor/induction system ice, and (5) fuel starvation. The examiner will, with no advance warning, reduce the power to simulate engine malfunction.

2. *Acceptable Performance Guidelines* The applicant shall be able to immediately recognize the loss of power and take prompt remedial action, and shall use good judgment and techniques to minimize the danger to occupants and the airplane. The applicant shall perform emergency procedures for loss of power in compliance with the manufacturer's published recommendations. Any action which creates an unnecessary hazard shall be disqualifying.

B. Equipment Malfunctions

1. *Description* The applicant may be asked to demonstrate the emergency operation of the retractable gear, flaps, and electrical, fuel, deicing, and hydraulic systems if operationally practical. Emergency operations such as the use of CO_2 pressure for gear extension, or the discharge of a pressure fire extinguisher system should be simulated only.

On flight tests in pressurized airplanes, this demonstration should include an emergency descent as might be necessitated by a loss of pressurization. The descent should be initiated and stabilized, but no prolonged descent is required. The airspeed or Mach number for the demonstration of an emergency descent should be approximately 10 percent less than the airplane's structural limitation, to provide a safety margin. When a Mach limitation is the controlling factor at operational altitudes for the airplane used, the descent should be arranged, if practicable, to require the transition from the observance of the Mach limitation to an airspeed limitation. A simulated emergency descent through or near clouds is prohibited.

2. *Acceptable Performance Guidelines* The applicant shall respond to emergency situations in accordance with procedures prescribed by the manufacturer's published recommendations. The applicant's performance shall be evaluated on knowledge of the emergency procedures for the airplane used, the judgment displayed, and the accuracy of the operations.

C. Fire In Flight

1. *Description* The applicant is expected to recognize the symptoms of electrical fires and fuel fires. When the examiner describes the symptoms of a fire situation, the applicant is expected to follow emergency procedures appropriate for combating the type of fire.

2. *Acceptable Performance Guidelines* The applicant shall be able to recognize the type of fire described, determine its location, and explain the proper procedure for extinguishing the fire or for safely terminating the flight.

D. Collision Avoidance Precautions

1. Description The applicant is expected to exercise conscientious and continuous surveillance of the airspace in which the airplane is being operated to guard against potential mid-air collisions. In addition to "see and avoid" practices, applicant is expected to use VFR Advisory Service at nonradar facilities, Airport Advisory Service at nontower airports or FSS locations, and Radar Traffic Information Service where available.

2. Acceptable Performance Guidelines The applicant shall maintain continuous vigilance for other aircraft and take immediate actions necessary to avoid any situation which could result in a mid-air collision. Extra precautions shall be taken, particularly in areas of congested traffic, to ensure that other aircraft are not obscured by his aircraft's structure. When traffic advisory service is used, the applicant shall understand terminology used by the radar controller in reporting positions of other aircraft. Failure to maintain proper surveillance shall be disqualifying.

E. Maneuvering With One Engine Inoperative

1. Description The applicant may be asked to demonstrate engine shutdown procedures and flight with one engine inoperative (propeller feathered, if possible). This includes straight-and-level flight and 20° to 30° banked turns toward and away from the inoperative engine. Also included are descents to prescribed altitudes and, in airplanes which are capable of climbing under the existing conditions, climbs to prescribed altitudes.

NOTE: The feathering of one propeller should be demonstrated on a flight test in any multiengine airplane equipped with propellers which can be safely feathered and unfeathered in flight. Feathering for pilot flight test purposes should be demonstrated only under such conditions and at such altitudes and positions where safe landings on established airports can be readily accomplished in the event difficulty is encountered in unfeathering.

If the airplane used is not equipped with propellers which can be safely feathered and unfeathered in flight, the applicant may be asked to shut down one engine in flight in accordance with the procedures in the manufacturer's published recommendations. The regulations do not specifically require an applicant to unfeather a propeller on a flight test. Accordingly, the applicant is not required to do so and may elect to land with a propeller feathered. If desired, this procedure should be arranged in advance with the examiner concerned, who will permit its use unless it is considered that an undue hazard would be involved.

2. Acceptable Performance Guidelines The applicant shall use prescribed propeller operating procedures as well as the recommended emergency settings of all ignition, fuel, electrical, hydraulic, and fire extinguishing systems appropriate to an engine failure. Applicant shall maintain heading within ±20° of the original heading during the feathering and unfeathering procedures, and altitude within ±100 feet of the original altitude if it is within the capability of the airplane used; applicant shall promptly identify the inoperative engine after a simulated power failure; and use accurate shutdown and restart procedures, as prescribed in the manufacturer's published recommendations. In an airplane not capable of maintaining altitude with an engine inoperative under existing circumstances, the applicant shall maintain an airspeed within ±5 knots of the engine-out best rate-of-climb speed and shall use prescribed operating procedures and proper trim settings.

F. Engine-Out Minimum Control Speed Demonstration

1. Description The applicant may be asked to demonstrate airplane controllability problems associated with attempted flight with one engine inoperative at less than minimum engine-out control speed (V_{mc}), recognition of imminent loss of control and application of proper recovery techniques.

> Note: There is a density altitude above which the stalling speed is higher than the engine-out minimum control speed. When this density altitude exists close to the ground because of high elevations or temperatures, an effective flight demonstration is impossible and should not be attempted. When a flight demonstration is impossible, the significance of the engine-out minimum control speed should be emphasized on the oral, including the results of attempting engine-out flight at below this speed, the recognition of imminent loss of control and recovery techniques.

2. Acceptable Performance Guidelines The applicant shall demonstrate a complete and accurate knowledge of the cause, effect, and significance of the engine-out minimum control speed, of the clues to be watched for by the pilot, and the safe recovery procedures.

The engine-out minimum control speed flight demonstration is subject to so much variation because of differences in airplane flight characteristics, circumstances of flight, and density altitude that definitive performance standards cannot be prescribed. The basic criteria are the prompt recognition of imminent loss of control and the prompt initiation of correct recovery actions. An attempt at any time during the flight test to continue level or climbing flight with an engine out at less than the engine-out minimum control speed, except as necessary for this demonstration shall be disqualifying.

G. Use of Engine-Out Best Rate-of-Climb Speed

1. Description The applicant may be asked to establish and maintain the best possible rate of climb (or minimum rate of sink) with one engine throttled to simulate the drag of a feathered propeller, or with a propeller feathered by mutual agreement between the applicant and examiner.

2. Acceptable Performance Guidelines The applicant shall determine (from the manufacturer's published recommendations) and shall maintain the prescribed engine-out best rate-of-climb speed. Applicant shall maintain a climb within ±5 knots of the best rate-of-climb speed and within ±10° of the desired heading.

H. Effects of Airplane Configuration on Engine-Out Performance

1. Description The applicant may be asked to demonstrate the effects of various configurations on engine-out performance. This includes the results of the extension of the landing gear, the flaps, and both; the application of carburetor heat on the operating engine(s); and windmilling of the inoperative engine.

2. Acceptable Performance Guidelines The applicant shall maintain an airspeed within ±5 knots of the best rate-of-climb speed and a heading within ±10° of the assigned heading while controlling the airplane in the various configurations.

I. Engine Failure on Takeoff

1. Description The applicant may be asked to demonstrate engine failure procedures during takeoff operations. After giving due consideration to the airplane's characteristics, runway length, surface conditions, wind direction and velocity, and any other factors which may affect safety, the examiner may, at least once during the flight test, throttle an engine on takeoff, and expect the applicant to proceed as in the event of an actual power failure.

The feathering of the propeller and securing of the throttled engine should be simulated to keep it available for immediate use, but all other settings should be made as in the case of an actual power failure.

> Note: If it has been determined that the engine-out rate of climb will *not* be at least 50 feet per minute at 1,000 feet above the airport, the engine failure should be simulated at a point on the takeoff roll which will permit the airplane to be safely stopped on the remaining portion of the runway.

2. Acceptable Performance Guidelines If it has been determined that the engine-out rate of climb under existing circumstances is at least 50 feet per minute at 1,000 feet above the airport, and applicant has attained at least the engine-out best angle-of-climb speed when the engine is throttled, the applicant shall continue takeoff with one engine throttled.

If the airspeed is **below** the engine-out best angle-of-climb speed and the landing gear has **not** been retracted, the takeoff shall be abandoned immediately. If the best angle-of-climb speed has been obtained and the landing gear is in the retract cycle, the applicant shall climb out at the engine-out best angle-of-climb speed to clear any obstructions, and thereafter stabilize the airspeed at the engine-out best rate-of-climb speed while cleaning up the airplane and resetting all appropriate systems.

J. Engine-Out Approach and Landing

1. Description The applicant may be asked to make an approach and landing with one engine inoperative. In the event the applicant has elected to land with a propeller feathered after demonstrating propeller feathering, no further demonstration should be required. Otherwise, the landing may be made with an engine throttled to simulate the drag of a feathered propeller or, if feathering propellers are not installed, with an engine throttled to idling. The approach should be continued to a normal landing, and a go-around with an engine out will not be performed unless there is an actual emergency.

2. Acceptable Performance Guidelines The applicant shall use the correct procedures for the operation of the airplane systems, use appropriate trim settings, observe the regular traffic pattern or approach path, maintain airspeed and aircraft control during touchdown and landing roll. Any reduction of airspeed below the engine-out minimum control speed before the landing flare is initiated shall be disqualifying.

APPENDIX H

GUIDELINES FOR THE CONDUCT OF BIENNIAL FLIGHT REVIEWS

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PREFACE

Guidelines for the Conduct of Biennial Flight Reviews is the product of an ad hoc industry committee convened in the Spring of 1975 to seek resolutions to some of the issues surrounding the relatively new BFR requirement contained in the revised FAR Part 61. The committee was made up of representatives from the AOPA Foundation, EAA, GAMA, NATA, NAFI, NPA, the Ohio State University Department of Aviation, and the General Aviation Division of the FAA who served as hosts for the committee meetings.

These Guidelines reflect the committee's collective thinking; they are designed for use by any segment of the aviation community involved in the conduct of Biennial Flight Reviews. As explained in the text of the Guidelines, these recommendations are purposely not specific. They are intended to encourage individuality and flexibility in the BFR process, while at the same time providing some scope and definition to a concept that until now was strictly a "roll-your-own" operation.

GUIDELINES
For The Conduct of
BIENNIAL FLIGHT REVIEWS

I The BFR Concept

The Biennial Flight Review is a cooperative endeavor to provide the pilot with a periodic assessment of his flying skills and to determine if there has been deterioration in areas which may reasonably affect his safety. The BFR should be a currency evaluation accomplished in an economical and expeditious manner, and at the same time, provide a learning situation rather than a "check flight" atmosphere.

The character of any Biennial Flight Review should be established in a pre-review discussion between the pilot and flight instructor. The BFR's basic character, including the elements to be covered in both the oral and flight portions, should be understood by both the pilot and flight instructor prior to initiating any phase of the review. The principal point of these guidelines is to reinforce the attitude that each Biennial Flight Review will be unique to each pilot/instructor combination, and that uniqueness will be the product of the pre-review dialogue between the pilot and the instructor.

The Biennial Flight Review is not a "test" or a "check ride", it is a review where assistance and instruction may be given as necessary to improve the pilot's demonstrated performance and assist in the satisfactory completion of the review. The availability and extent of dual instruction provided during the flight should be determined during the pre-review discussion.

Each Biennial Flight Review should be individually tailored to meet, in the reasonable discretion of the reviewing flight instructor, the basic safe operating demands of the pilot being reviewed. The primary objective of any BFR should be to assess the pilot's ability to successfully perform, and be knowledgeable of, safe flight operations. Rather than using standard guidelines or a list of maneuvers, flight instructors are encouraged to determine the safe operating needs of each pilot, and then formulate a meaningful Biennial Flight Review tailored to meet those needs. The review should assess the pilot's broad awareness of applicable regulations, procedures, and good operating practices as opposed to committing rote specifics to memory. Finally, reviewing flight instructors should not make the oral and flight reviews overly demanding in terms of the total number of operations, nor should they require perfection in those subject areas and operations evaluated during those reviews.

II The Pilot Profile

The first step in the conduct of a Biennial Flight Review should incorporate a review of the pilot's background. This initial discussion portion of the BFR will serve two basic purposes:

> First, it provides both pilot and instructor with an opportunity to assess each other. Additionally, it gives both parties a chance to discuss individual experience, recent flight experience, and what each person expects to encounter and gain during the BFR. Second, the "pilot profile" session serves the purpose of providing a point in the review process to make sure that all necessary paperwork is in order; this should also include all documents necessary for the operation of the aircraft.

During this phase of the BFR the flight instructor should review the pilot's flight experience to provide a basis for being of most assistance to that pilot. Following the assessment of flight experience the instructor can begin to formulate the character of the oral and flight review most appropriate for that pilot. At this point it should be possible for the reviewing flight instructor to provide the pilot with an estimate of the approximate length of time that will be required to accomplish the flight portion of the BFR. Since no two Biennial Flight Reviews will be the same, each pilot and flight instructor for each particular BFR should recognize that this review will be designed specifically for the person being evaluated based on the pilot's individual characteristics and qualifications, as well as the nature of the aircraft involved in the Biennial Flight Review.

This planning phase of a Biennial Flight Review may be accomplished prior to the actual oral and flight review. Preliminary discussion can provide an opportunity for the pilot to correct any paperwork problems; furthermore, it gives the flight instructor a chance to suggest 1) regulations to review, 2) books to read, and 3) manuals and charts to obtain, if necessary. While Biennial Flight Reviews are adaptable to segmented sessions, users of this approach should continue to bear in mind that BFR's are also intended to be accomplished in an economical and expeditious manner.

Generally speaking, this stage of the BFR can be of practical value to both individuals for at least one other significant reason. During this phase both the pilot and the instructor can begin to determine, and probably even decide, if either of them wants to proceed any further with this particular review. If it appears that there may be discernible, or potentially irreconcilable, conflicts of philosophies, personalities, etc.; this is the time to consider a different instructor, fixed base operator, pilot, or just another time.

III Review of Applicable Rules

The second step in any pilot's Biennial Flight Review should involve a review of applicable Federal Aviation Regulations. This review must encompass those operational and flight provisions of FAR Part 91 appropriate to the operations of the pilot receiving the BFR. As with the actual flight review, this portion of the Biennial Flight Review should not be conducted on a strictly test basis, rather it is an opportunity for the reviewing instructor to assist the pilot through a discussion of regulations and their relationship to operational safety. Prior to or following this phase of the review, flight instructors may want to refer pilots to the appropriate "Advisory Circular Checklist and Status of Federal Aviation Regulations" notice and various other materials as reference sources for additional study and review.

IV *Preflight Procedures Review*

The preflight procedures segment of a Biennial Flight Review should include an assessment of all those activities which the pilot would normally be expected to engage in prior to actually starting the engine of the aircraft. This phase of the Review could include, but not necessarily be limited to, an analysis of current and forecast weather, flight planning procedures, and preflight of the aircraft in general and for the particular flight anticipated. A review of fuel considerations, weight and balance computations, as well as performance and navigation charts appropriate for the flight could all be included at this point in the evaluation.

While it is certainly not mandatory, the planning of a cross-country flight could be included to illustrate the practical advantages of obtaining weather information, planning a suitable route and altitude, estimating elapsed time, determining fuel required and allowable, and completing weight and balance computations.

In this preflight procedures phase, as in all other phases of the BFR, the instructor should render assistance by questioning, correcting and instructing rather than testing.

V *Basic Flight Review*

The purpose of the flight portion of the Biennial Flight Review is to permit the flight instructor to observe and evaluate those flight operations necessary for a review of a pilot's habits, skills and procedures. It is not intended to be a critique of the pilot's ability to execute specific maneuvers such as those found in flight training or in testing for certificate or rating qualifications.

The objectives of the flight segment of a Biennial Flight Review can be accomplished through the pilot's demonstration of, but not limited by, such operational activities as preflight procedures, airport and traffic pattern operations, abnormal (cross-wind and short-field landings and take-offs, etc.) and emergency procedures (including inadvertent weather penetration).

The actual selection of flight operations and procedures the pilot is asked to demonstrate should be left to the discretion of the reviewing flight instructor; thereby enabling him to tailor the flight review to the needs of the individual pilot. Emphasis on overall safety of flight operations should be stressed more than precision execution of pure training maneuvers. Furthermore, since there will seldom be time in a Biennial Flight Review to evaluate all flight operations, it is recommended that particular attention be given to those operations that seem to cause greatest difficulty to the pilot being reviewed or have the greatest tendency to get most pilots into trouble.

Both the pilot and reviewing flight instructor should be aware that Biennial Flight Reviews need not be limited to evaluation only, but may also be instructional. That intent can be realized if, as a product of the initial pilot/instructor discussion session, the instructor agrees to provide instructional assistance as necessary when both he and the pilot identify "weak areas" in need of additional practice. It is generally accepted that a reasonable number of instructor-performed "demonstrations" of proper technique are a realistic expectation following an initial marginal or unsatisfactory pilot-performed flight operation.

Holders of advanced ratings and certificates may desire an evaluation of their capabilities and skills not included in the basic oral and flight reviews; such evaluations are optional, but pilots are encouraged to seek maximum benefits from the Biennial Flight Review process. During the pre-review or "pilot profile" phases of the BFR, flight instructors may want to point out the advisability of a more comprehensive review if such advanced ratings and skills are currently relied on during flights typical of that pilot's normal operations.

Evaluation of the total flight operations should be made to determine a pilot's satisfactory performance, and that evaluation should be made on the basis of a simple satisfactory vs. unsatisfactory system. The word "satisfactory" is used even though a Biennial Flight Review is not an official flight check. The term is used only to provide the reviewer with a minimum standard baseline on which to base a decision and comments regarding the review.

VI Post Flight Discussion and Recommendation

This phase of the Biennial Flight Review is potentially the most important part of the entire evaluation process because it is here that the reviewing flight instructor gets a chance to discuss with the pilot what the entire review has revealed. In order for the BFR to be of any real value, the pilot must realize the importance of listening to this appraisal of his skills with an open mind, not with one closed to any hint of criticism. On the other hand, the person giving the appraisal must make a real effort to provide a clear and constructive debriefing of the BFR which has just taken place.

All Biennial Flight Reviews, whether accomplished satisfactorily or not, should be concluded with a helpful, positive discussion and suggestions for any remedial or improvement actions that the instructor considers beneficial. This post-flight discussion should provide an honest, objective, and lucid appraisal of the pilot's current ability to successfully perform, and be knowledgeable of, safe flight operations, at least to the extent that such abilities were capable of evaluation during this particular Biennial Flight Review.

The logbook entry is the proper form of proof of compliance with the Biennial Flight Review requirement. There should be no endorsement, or any indication of any kind, in the pilot's logbook reflecting the unsatisfactory nature of a Biennial Flight Review; nor should a satisfactory endorsement allude to any unsatisfactory part of the BFR. If, in the opinion of the reviewing instructor, the pilot's Biennial Flight Review performance cannot be considered as having been satisfactory, no logbook entry will be made; furthermore, the instructor should recommend the appropriate remedial action necessary to bring the pilot up to an acceptable level of performance or knowledge. At this point, if the BFR was unsatisfactory, the pilot has the option of continuing with that instructor or choosing another instructor for review, assistance, or an attempt at another complete Biennial Flight Review.

NOTE: It is anticipated that the Federal Aviation Administration will soon permit flight instructors to conduct Biennial Flight Reviews involving single-place aircraft.

The National Association of Flight Instructors, founded in 1967, is a non-profit organization dedicated to raising and maintaining the professional standing of the flight instructor in the aviation community. Working with pilots, fixed base operators, manufacturers, governmental agencies, and flight instructors; NAFI encourages a creative atmosphere for the development and conduct of quality education programs for all segments of the aviation community.

Additional information regarding NAFI activities and membership can be obtained by contacting the National Association of Flight Instructors, Ohio State University Airport, P.O. Box 20204, Columbus, Ohio 43220.

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