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OPERATING EXPERIENCES OF RETARDANT BOMBERS DURING FIREFIGHTING OPERATIONS

By

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16. Abstract

Data are presented on operational practices and maneuver accelerations experienced by two Douglas DC-6B airplanes converted to retardant bombers and used in firefighting operations. The data cover two fire seasons in the mountainous regions of the northwestern United States.

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OPERATING EXPERIENCES OF RETARDANT BOMBERS

DURING FIREFIGHTING OPERATIONS

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SUMMARY

An analysis has been made from NASA VGH data taken from two Douglas DC-6 airplanes that were converted to retardant bombers and used in forest firefighting operations. The data were taken during two fire seasons in the mountainous regions of the northwest section of the United States.

The majority of the retardant drops occurred from 10 to 40 minutes after lift-off, with the average elapsed time being 25 minutes. For given time intervals required to reach a fire, there was a rather broad range of dash speeds used. Rates of descent in a retardant drop run ranged from zero for flat approaches up to 9,000 feet per minute for steep approaches needed to reach fires in canyons or along canyon walls. The design maneuver limit load factor was equaled or exceeded during recovery from 10 percent of the retardant drops. The ultimate load factor was exceeded once. The most frequent number of retardant drops made per flight was three. Although the time interval between drops ranged from 1 to 20 minutes, the majority was between 2 and 4 minutes. There were no exceedances of the placard never-exceed speed during the firefighting operations.

INTRODUCTION

Forest firefighting methods and techniques have undergone considerable change in the past few decades. One of the most significant of these changes has been the introduction of aircraft into the firefighting system. The size of the aircraft range from the small crop-duster type initially used to the large four-engine aircraft in service today. In the later category, the majority of the airplanes were originally designed as bomber or cargo planes for the military service, or, as commercial transports in civilian service. Because these aircraft are used in operations not considered in the design loads analysis, NASA has initiated a program to measure the operational characteristics of firefighting missions and the maneuver and gust loads experienced in these operations. For a period covering two summer fire seasons, data were obtained from NASA VGH flight recorders installed on two Douglas DC-6B airplanes converted to retardant bombers and used in firefighting service. This report provides information related to aircraft firefighting mission characteristics and gives data on the maneuver loads experienced during retardant drops.

SYMBOLS

M_{LLF} maneuver limit load factor

M_{ULF} maneuver ultimate load factor

V_F design flap speed, knots

V_{NE} placard never-exceed speed, knots

INSTRUMENTATION AND SCOPE

The data were collected with NASA VGH recorders which provide time-history records of indicated airspeed, normal acceleration, and pressure altitude. A detailed description of the VGH recorder is given in reference 1. Normal accelerations were sensed by an accelerometer mounted on the wing's center spar 0.91 meters (3 ft) to the right of the fuselage centerline. Dynamics and static pressure for the recorder were sensed from the dynamic and static sources leading to the copilot's instrumentation.

Data from both airplanes were obtained during firefighting operations for two fire seasons in mountainous terrain. The majority of the operations were conducted within the area bounded by Salt Lake City, Utah; Sacramento, California; and the northern boundary of Washington and Idaho. A small portion of the data was recorded during firefighting operations in the mountainous areas of the southeastern section of the United States. The scope of the data for each airplane is summarized in table I.

EVALUATION OF RECORDS

All flights were considered to extend from lift-off to the instant of touchdown. Only flights with retardant drop runs were evaluated. All data used in the evaluation were obtained by handreading VGH records with a calibration overlay.

Average speed to the first drop was estimated to the nearest knot by visually integrating the indicated airspeed trace on the VGH record. The maximum indicated airspeed for each flight was also identified and measured to the nearest knot for comparison with the aircraft's never-exceed speed.

Rates of descent were determined by obtaining the difference, to the nearest 100 feet, between the altitude where the steepest portion of the run began and the altitude at pullout and dividing this difference by the lapsed time in seconds. Since flaps were sometimes used to slow the descent rate during the retardant runs, values of indicated airspeed were also read at the start of the steepest rate of descent and at pullout, for comparison with the design flap speed.

Flight duration, time from lift-off to first drop, and time from last drop to touchdown, were read to the nearest minute. The number of retardant drops per flight was determined and the time between drops for given flights was measured to the nearest quarter of a minute.

Acceleration data were read in 0.1g intervals. Only the maximum positive acceleration recorded during pullout from a retardant drop and the maximum negative acceleration that occured, either at pushover to begin the run, or in rounding out after the pullout, were read. These acceleration data were cumulated by number of runs from each aircraft for comparison with each other and with the design maneuver limit and ultimate load factors. The acceleration data from both aircraft were also combined and cumulated by the frequency of occurrence per hour of flight for comparison with maneuver accelerations experienced by the same type of airplane flown in commercial transport operations.

RESULTS AND DISCUSSION

The variation in flight duration of 415 flights made by two retardant bombers used in forest firefighting operations is shown in figure 1. The shortest flight was 12 minutes in duration, and the longest was 147 minutes. The average flight lasted 49 minutes and 68.3 percent of the flights, or the one-sigma value, were between 28 and 70 minutes in duration.

Elapsed time from lift-off to the first retardant drop for 191 flights is shown in figure 2. Drops were made from as soon as 4 minutes to as long as 65 minutes after lift-off. The majority of the drops occurred from 10 to 40 minutes after lift-off and the average elapsed time was 25 minutes.

The variation in dash speed to the first drop is given in figure 3. Dash speeds measured during 191 flights ranged from 143 to 195 knots. The average dash speed was 168 knots. The relationship of time and dash speed to the first retardant drop is shown in table II. In flights to fires that require less than 20 minutes to reach, dash speeds of up to 180 knots were used. For flights in which more than 20 minutes were needed to reach the fire, dash speeds of up to 195 knots were used. In general, table II indicates that for a given time interval required to reach a fire, a rather broad range of dash speeds is used.

The rates of descent recorded in 401 runs to drop fire retardant are shown in figure 4. Approaches for the drops varied from flat runs having zero rates of descent to extremely steep runs in which descent rates of up to 9,000 feet per minute were recorded. The average rate of descent was 2,483 feet per minute. Discussions with personnel flying the retardant bombers indicate that descent rates were affected to a large extent by the physical characteristics of the terrain near the fire. Fires along hill tops or on ridges could be approached for the retardant drop at relatively shallow angles, whereas, steep approaches were necessary to reach fires along sides of ridge walls or on canyon bottoms. Based on the data of figure 4, it was calculated that 30 percent of the runs made by retardant bombers in mountainous areas can be expected to equal or exceed rates of descent of 3,000 feet per minute.

Figure 5 shows the airspeeds at the start of the highest descent rate in the retardant drop run and at pullout for 401 runs in which retardant drops were made. The results are shown as the summation of the number of drops made in each 5-knot increment of airspeed. The design flap speed, V_F, is also noted on the figure for comparative purposes.

Start speeds ranged from as low as 100 knots to as high as 211 knots. The low-start speeds were normally recorded during the second and succeeding retardant runs in a flight since the aircraft at such time was near the top of a climbing recovery from a preceding run and was, therefore, at a relatively low airspeed. The higher start speeds were usually experienced on the first run.

Pullout speeds ranged from 116 knots to 236 knots. The speed at the instant of pullout was dependent to a large extent on the type of approach required to reach the fire. Lower pullout speeds were usually recorded during flat or shallow approaches and the higher pullout speeds during steep approaches. The pilots indicated that approach speeds were sometimes controlled by using flaps as speed brakes in order to arrive over the drop area at the desired drop speed of 155 to 160 knots. Figure 5 shows that 105, or about 26 percent, of the pullouts from retardant drop runs were made at airspeeds of 160 knots or higher. Thirty-five of the pullout speeds and five of the start speeds exceeded the design flap speed; however, since the VGH record does not indicate flap position, it cannot be assumed that flaps were used during these runs.

The frequency distribution of the maximum positive and negative load factors recorded during 1,175 retardant drops is given in table III. Figure 6 shows a plot of these maximum load factors for each airplane as a summation of the number of runs for each 0.1 value of load factor. The aircraft design maneuver limit and ultimate load factors are also shown. A comparison of the load factors experienced by the two airplanes indicates that values up to 3.1 were experienced more often by airplane 2 than by airplane 1. Since both airplanes were flown by each of four pilots (ages 35 to 55) no reason for the difference in load factors could be attributed to differences in piloting techniques. Because the differences are relatively small, however, they are not considered significant.

The most severe positive load factor, 3.90, was recorded by airplane 1 and the largest negative load factor, -0.50, was recorded by airplane 2. Approximately 7 percent of the load factors recorded during pullout from a retardant drop by airplane 1, and about 14 percent by airplane 2, equaled or exceeded the design maneuver limit load factor. The ultimate load factor exceedance by airplane 1 was a mandatory maneuver executed after the retardant drop to avoid a collision with a canyon wall obscured during the approach by a smoke pall. Although the recorded load factor exceeded the ultimate load factor, no visible structural damage was detected. The absence of damage was probably due to the fact that the airplane was well below the maximum gross weight, since two retardant drops had been made prior to the incident.

The cumulative frequency of occurrence per hour of flight of maneuver load factors experienced by aircraft used in firefighting operations is compared in figure 7 with a similar distribution from the same aircraft type flown in commercial transport operations. Data for the commercial transports, obtained from reference 2, included all the operational and check-flight maneuvers recorded in the period the data sample was taken. Data from the firefighting operations, however, included only the one maximum positive and the one maximum negative acceleration recorded during each retardant run. The maneuver limit load factor, M_{LLF}, and the maneuver ultimate load factor, M_{ULF}, for the aircraft are also shown on figure 7 for comparative purposes.

The severity of the maneuver loads experienced by airplanes involved in firefighting operations is well illustrated by comparison with the maneuver load experience for aircraft flown in commercial transport service. Where the firefighting aircraft exceeded both the maneuver limit and ultimate load factors, the aircraft flown in commercial transport service, with almost six times as many flight hours, recorded no maneuvers at, or above, the maneuver limit load factor. The rate that maneuver load factors between 2.0 and 2.4 were experienced by firefighting aircraft was almost 1,000 times that for aircraft flown as commercial transports. Because the maneuver loading, in both the repeated and high-magnitude applications, is so severe relative to the design loads, shortening of the structural life of the aircraft should be expected.

The frequency of occurrence with which specific numbers of retardant drops per flight were made is shown in figure 8. Although the aircraft were capable of making from one to six drops, the most frequent number released per flight was three. Only 19 percent of the flights sampled made four or more drops per flight.

The variation of elapsed time between retardant drops in a given flight is shown in figure 9. The time intervals ranged from 1 to 20 minutes, with the most frequent number occurring between 2 and 3 minutes. Of the 361 time intervals examined, only 11, or 3 percent, were more than 8 minutes in duration.

The elapsed time from the last retardant drop on a flight to landing touchdown is shown in figure 10. Data for the figure were grouped into 5-minute time intervals from 191 flights. One-hundred sixty-eight, or 88 percent of the flights, required from 5 to 30 minutes to return to the base. The average time to return was 19 minutes. The average time from lift-off to the first retardant drop for the same 191 flights was 25 minutes. The 6-minute difference between the two suggests a possible holding on station prior to the retardant drop while the proper drop area, run angle, and turbulence levels were determined.

The relationship of the maximum indicated airspeed recorded during a firefighting flight to the placard never-exceed speed is shown in figure 11. The data, taken from 191 flights, indicate there were no exceedances of the never-exceed speed. Maximum airspeeds recorded during the flights ranged from a low of 165 knots to a high of 275 knots. Speed exceedances during firefighting operations do not appear to be significant.

CONCLUDING REMARKS

An analysis has been made of 337 hours of flight data obtained from NASA VGH recorders installed on two Douglas DC-6B airplanes converted to retardant bombers and used in forest firefighting operations. The majority of these operations were over mountainous terrain in the northwestern part of the United States.

High rates of descent, ranging from 0 to 9,000 feet per minute and averaging over 2,400 feet per minute, occurred during the run to drop the retardant.

The maximum positive and negative load factors measured during the retardant drop and recovery were 3.9 and -0.50, respectively.

The design maneuver limit load factor was equaled or exceeded in 10 percent of the pullouts from retardant drop runs and the design ultimate load factor was exceeded once. The severity of maneuver load applications, in both magnitude and frequency of occurrence, is such that significant shortening of the structural life of the aircraft should be expected.

Dash speeds to the first retardant drop extended from 142 knots to 195 knots. There were no exceedances of the placard never-exceed speed during the firefighting operations.

Flight lengths varied from 12 to 147 minutes. Retardant drops were made from as soon as 4 minutes to as long as 65 minutes after lift-off. The most frequently used number of retardant drops per flight was three with 97 percent of the drops being made less than 8 minutes apart.

REFERENCES

1. Richardson, Norman R.: NACA VGH Recorder. NACA TN 2265, 1951.

2. Copp, Martin R.; and Coleman, Thomas L.: An Analysis of Acceleration, Airspeed, and Gust-Velocity Data From One Type of Four-Engine Transport Airplane Operated Over Two Domestic Routes. NACA TN 3475, 1955.

TABLE I. - SCOPE OF DATA

Item	Airplane		
	1	2	1 & 2
Flight time, hr	175.1	161.6	336.7
Number of flights	216	199	415
Number of drops	601	577	1178
Recording period	June 1972 to Sept. 1973	June 1972 to Aug. 1973	

TABLE II. - FREQUENCY DISTRIBUTION OF TIME AND DASH SPEED TO THE FIRST RETARDANT DROP

IAS knots \ Time min	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	Total
140-145		2	2	1											5
145-150				3	1										4
150-155		2	7	2	1		1								13
155-160		2	5	4	4	1		1			1				18
160-165	1	4	9	3	1	6	1	1	1						27
165-170		3	4	4	2	3	4	3	1	2					26
170-175		1	5	4	4	4	3	1	1		3	1	1		28
175-180			3	1	7	8	8	4	1	2	1		2	1	38
180-185					5	4	4	1		1			1		16
185-190					3	3	2	1							9
190-195					1	2	1	1		1					6
195-200						1									1
Total	1	14	35	22	29	32	24	13	4	6	5	1	4	1	191

TABLE III. - FREQUENCY DISTRIBUTION OF MANEUVER LOAD FACTORS EXPERIENCED IN RETARDANT DROPS

Load factor	Airplane 1	Airplane 2	Airplane 1 & 2
-0.5 to -0.6	1	0	1
-0.4 to -0.5	0	0	0
-0.3 to -0.4	0	0	0
-0.2 to -0.3	1	0	1
-0.1 to -0.2	1	1	2
0.0 to -0.1	2	0	2
0.0 to 0.1	3	6	9
0.1 to 0.2	22	4	26
0.2 to 0.3	39	10	49
0.3 to 0.4	48	24	72
0.4 to 0.5	103	55	158
0.5 to 0.6	159	76	235
0.6 to 0.7	109	157	266
0.7 to 0.8	61	152	213
0.8 to 0.9	24	80	104
0.9 to 1.0	4	36	40
1.0 to 1.1	0	1	1
1.1 to 1.2	0	3	3
1.2 to 1.3	2	9	11
1.3 to 1.4	6	16	22
1.4 to 1.5	33	18	51
1.5 to 1.6	86	18	104
1.6 to 1.7	92	35	127
1.7 to 1.8	73	51	124
1.8 to 1.9	61	63	124
1.9 to 2.0	53	53	106
2.0 to 2.1	51	50	101
2.1 to 2.2	41	57	98
2.2 to 2.3	33	56	89
2.3 to 2.4	19	42	61
2.4 to 2.5	9	22	31
2.5 to 2.6	10	25	35
2.6 to 2.7	9	18	27
2.7 to 2.8	8	12	20
2.8 to 2.9	2	10	12
2.9 to 3.0	3	4	7
3.0 to 3.1	3	9	12
3.1 to 3.2	2	2	4
3.2 to 3.3	1	1	2
3.3 to 3.4	0	1	1
3.4 to 3.5	2	0	2
3.5 to 3.6	0	1	1
3.6 to 3.7	1	0	1
3.7 to 3.8	0	0	0
3.8 to 3.9	0	0	0
3.9 to 4.0	1	0	1

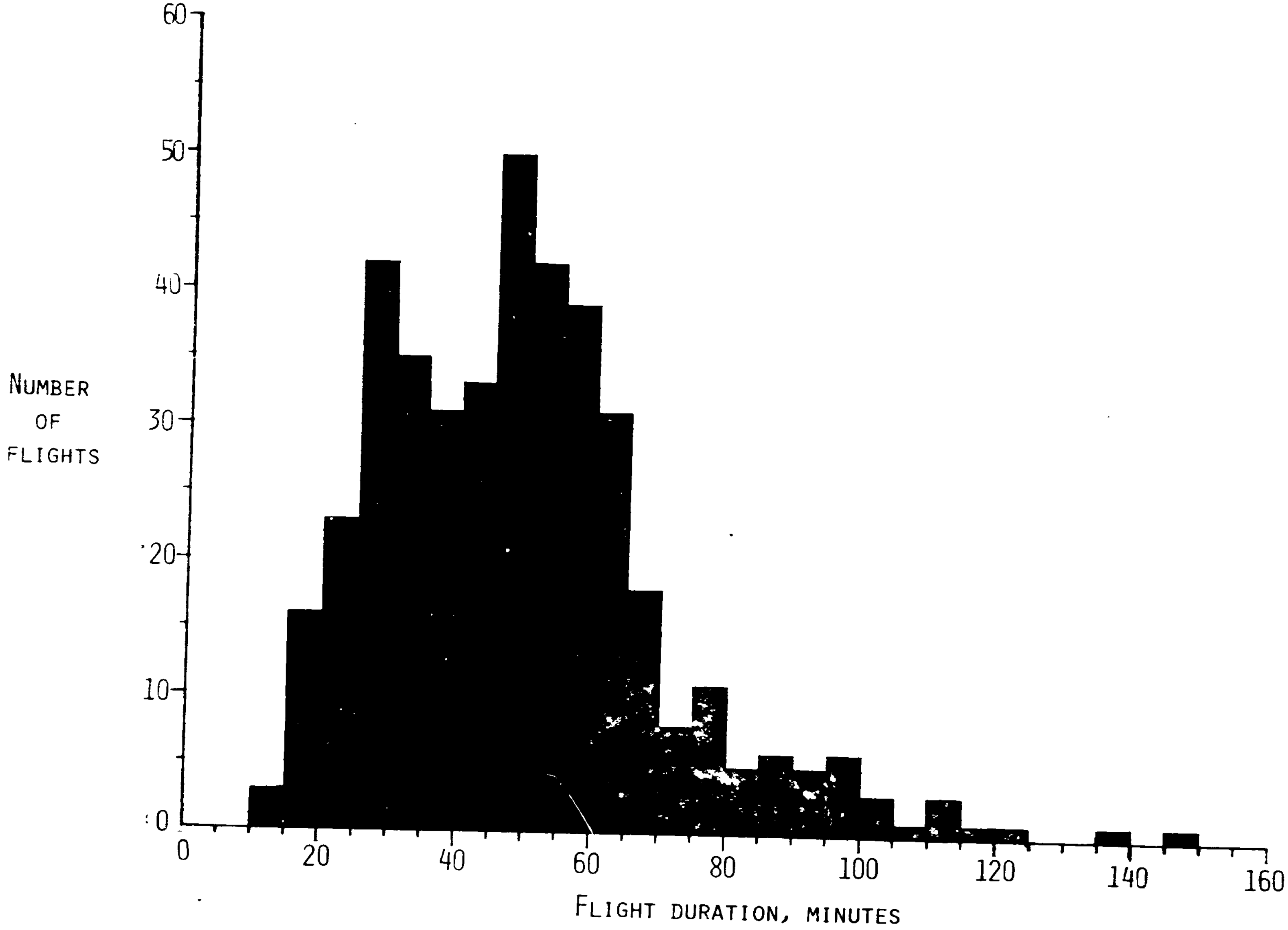

FIGURE 1. - VARIATION OF FLIGHT DURATION FOR FIRE FIGHTING OPERATIONS

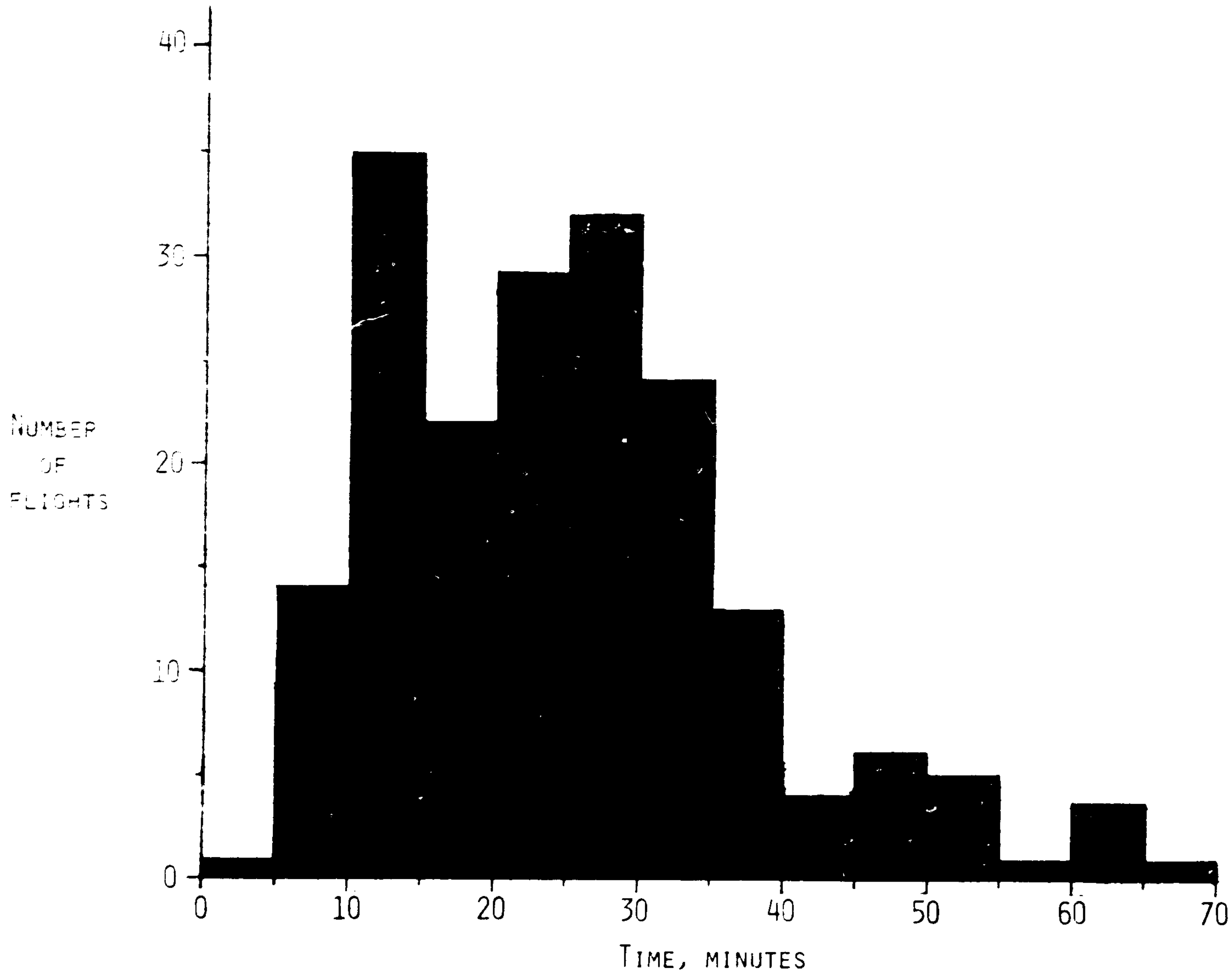

FIGURE 2. - VARIATION OF FLIGHT TIME TO FIRST RETARDANT DROP.

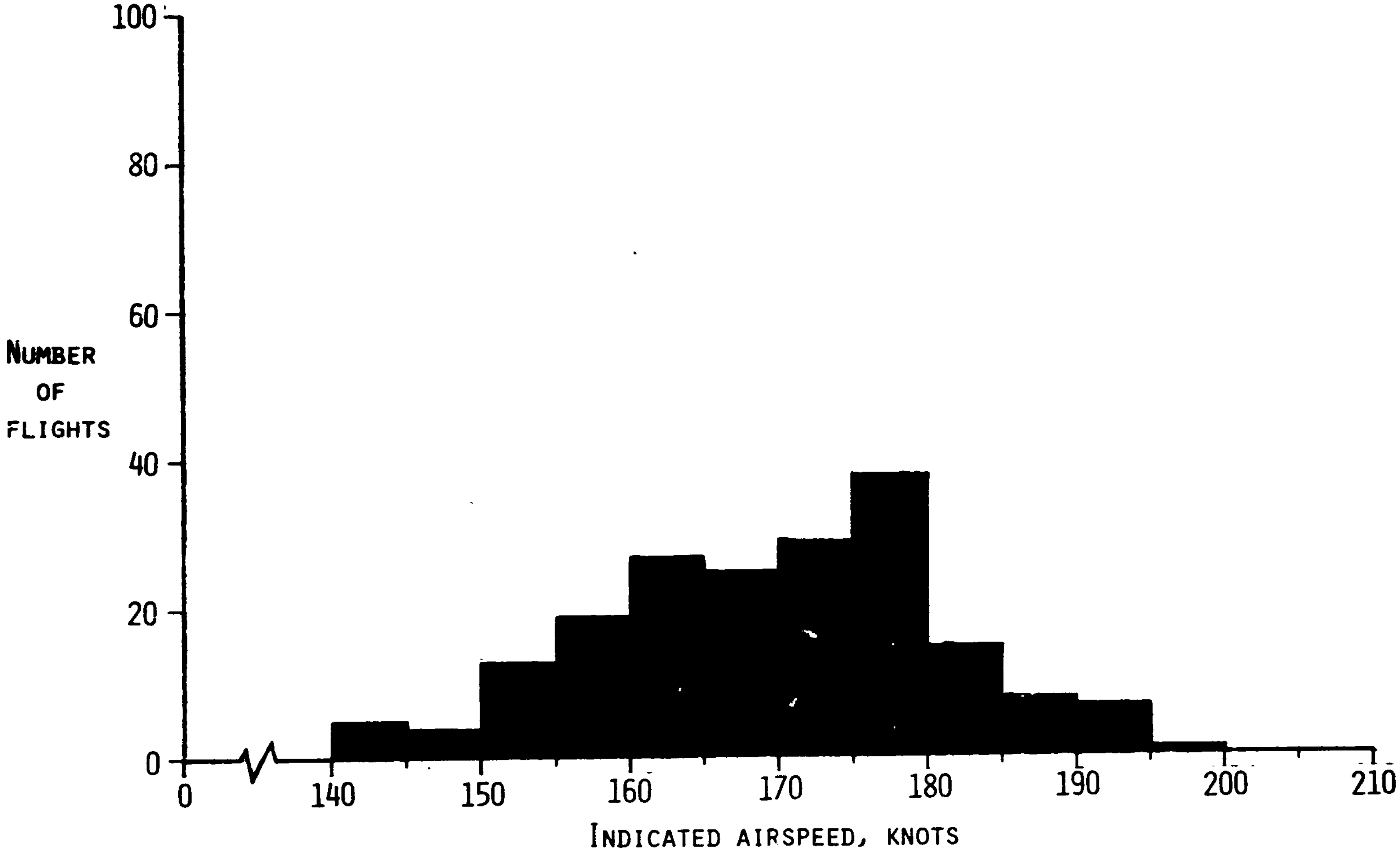

FIGURE 3. - VARIATION OF DASH SPEED TO FIRST RETARDANT DROP.

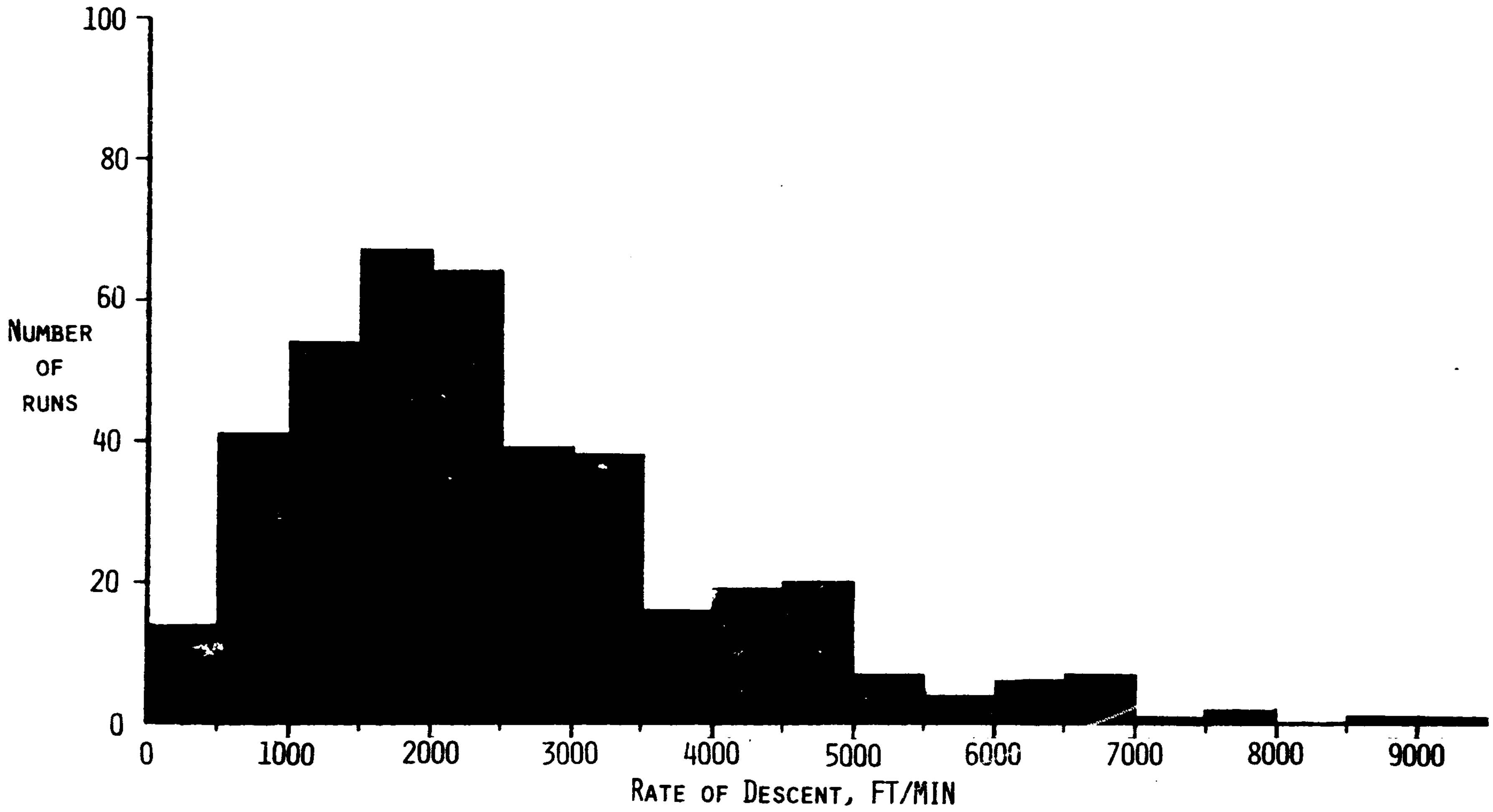

Figure 4. - Rates of descent experienced during retardant drop run.

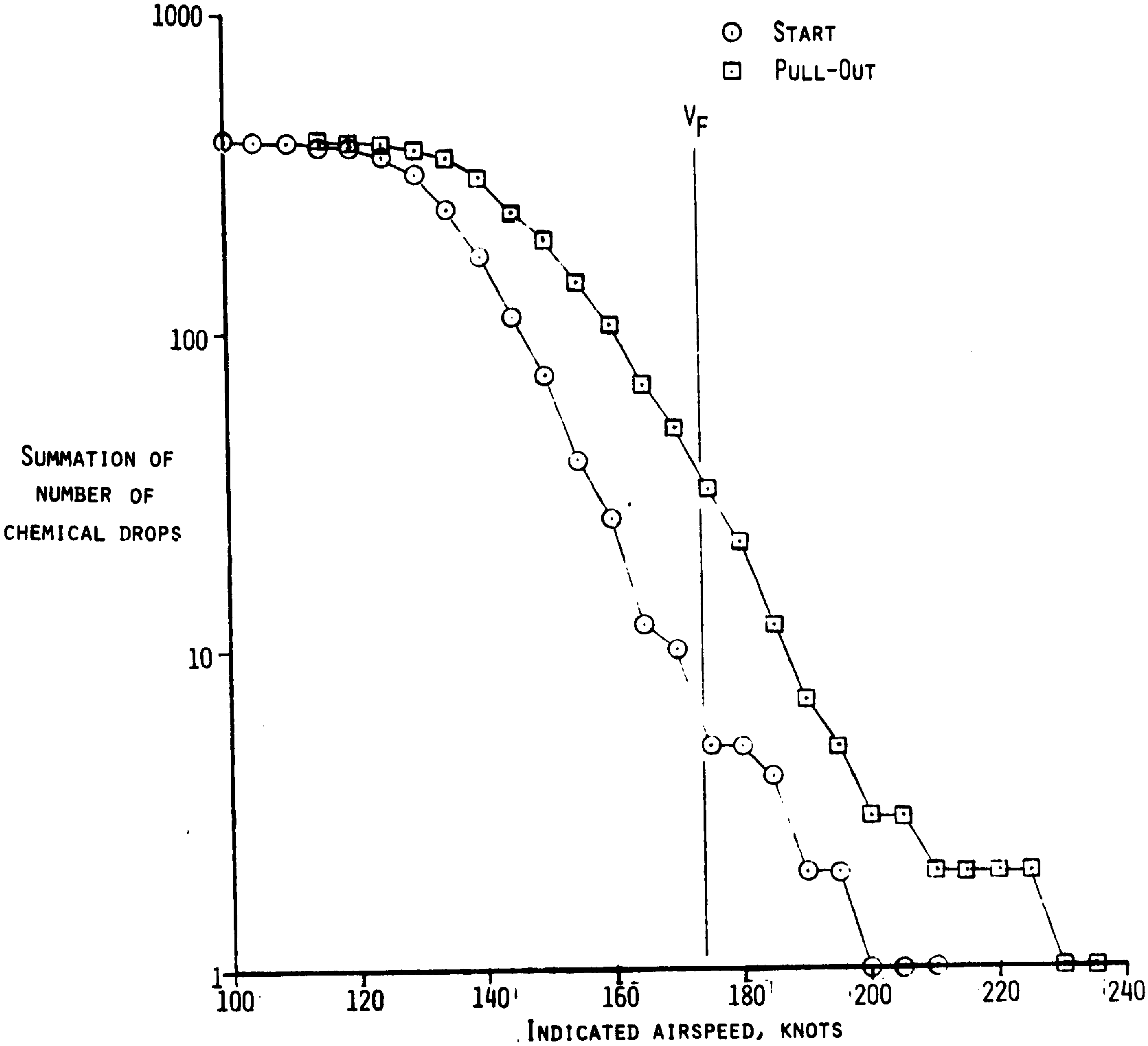

Figure 5. - Relationship of speed during retardant drop run to the design flap speed.

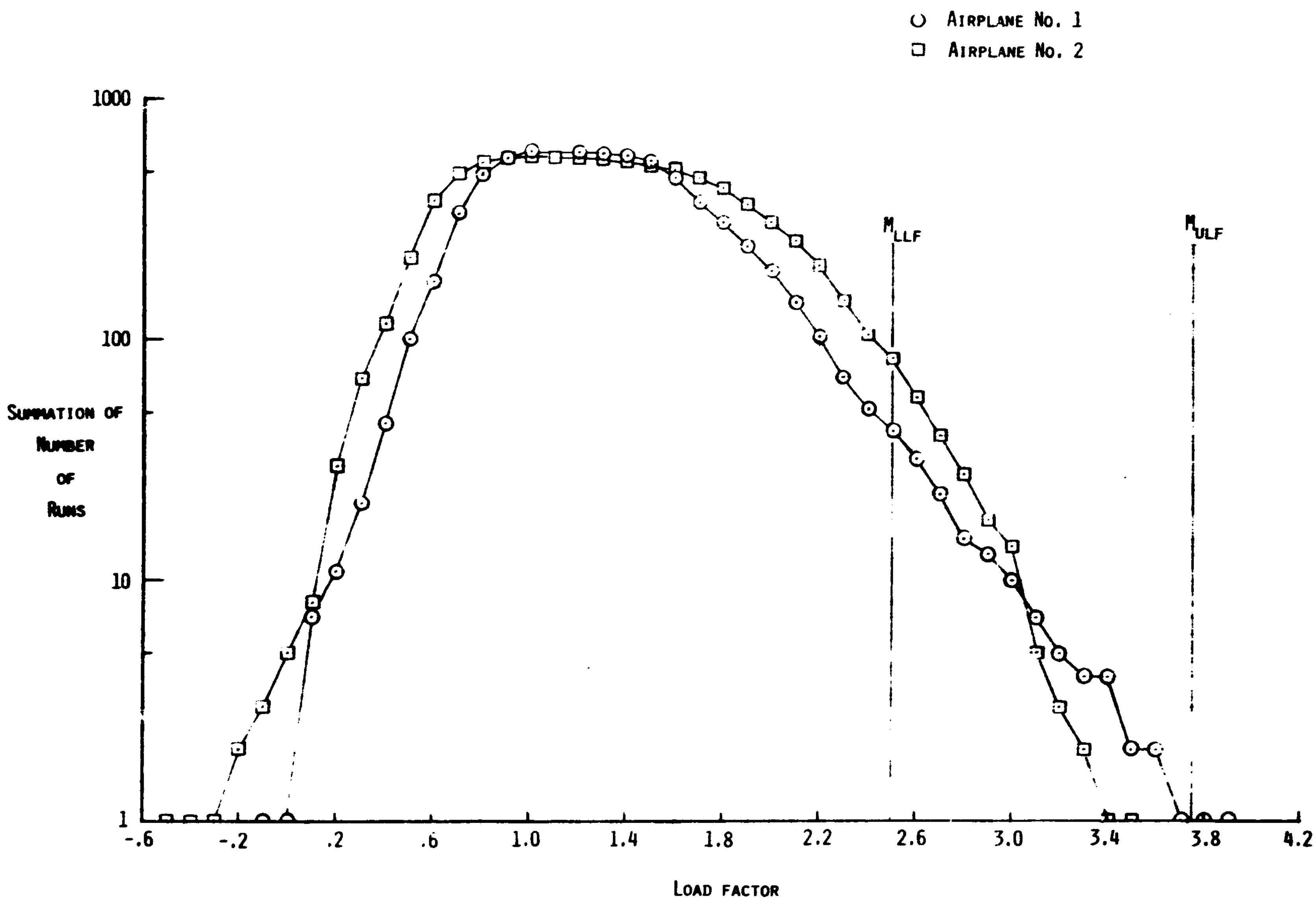

Figure 6. - Comparison of Maximum Positive and Negative Load Factors Experienced by Two Aircraft During Retardant Drop Runs with the Design Maneuver Limit and Ultimate Load Factors.

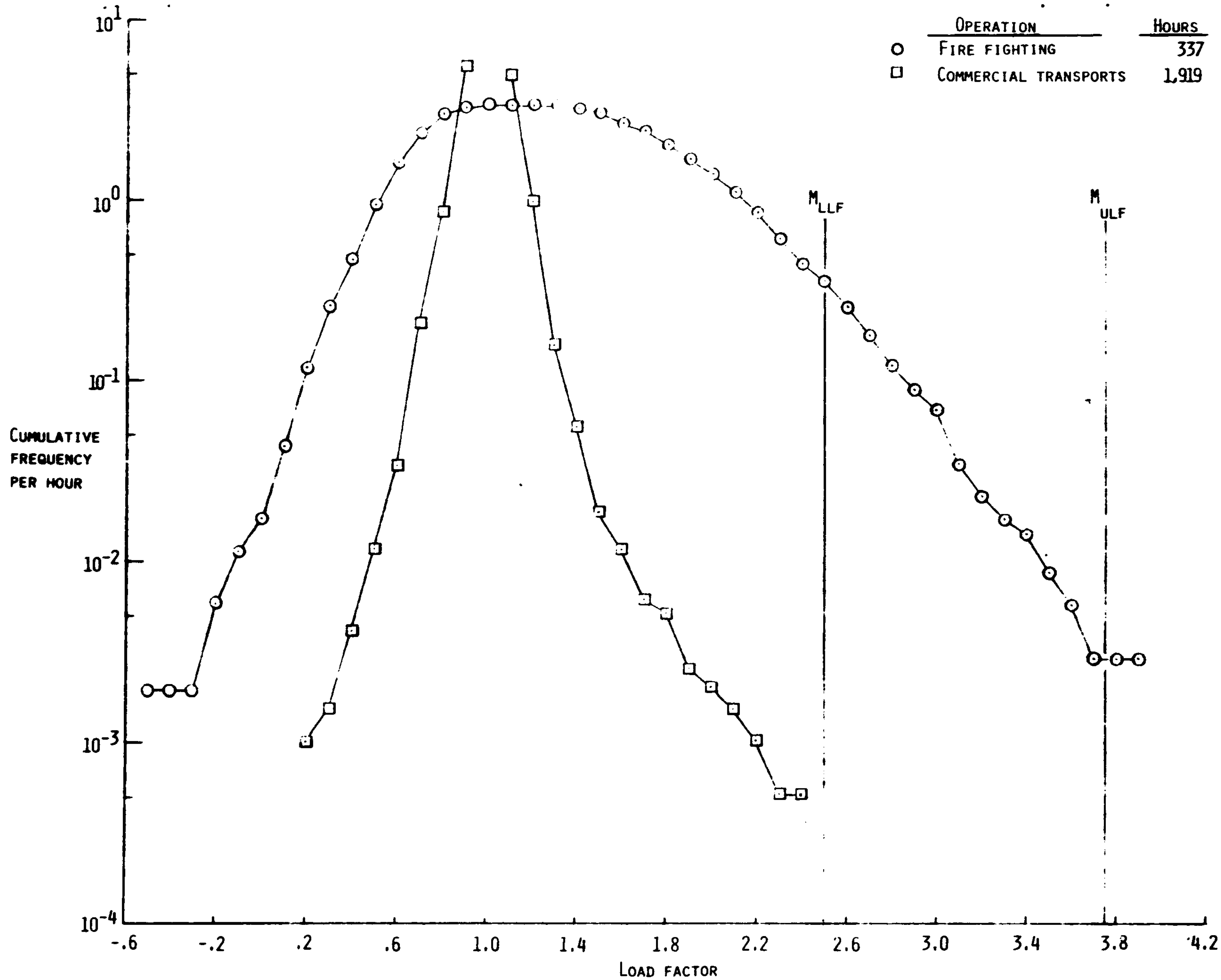

Figure 7. - Comparison of the cumulative frequency of occurrence per hour of flight of maneuver load factors experienced by the same type of aircraft used in two different types of operations.

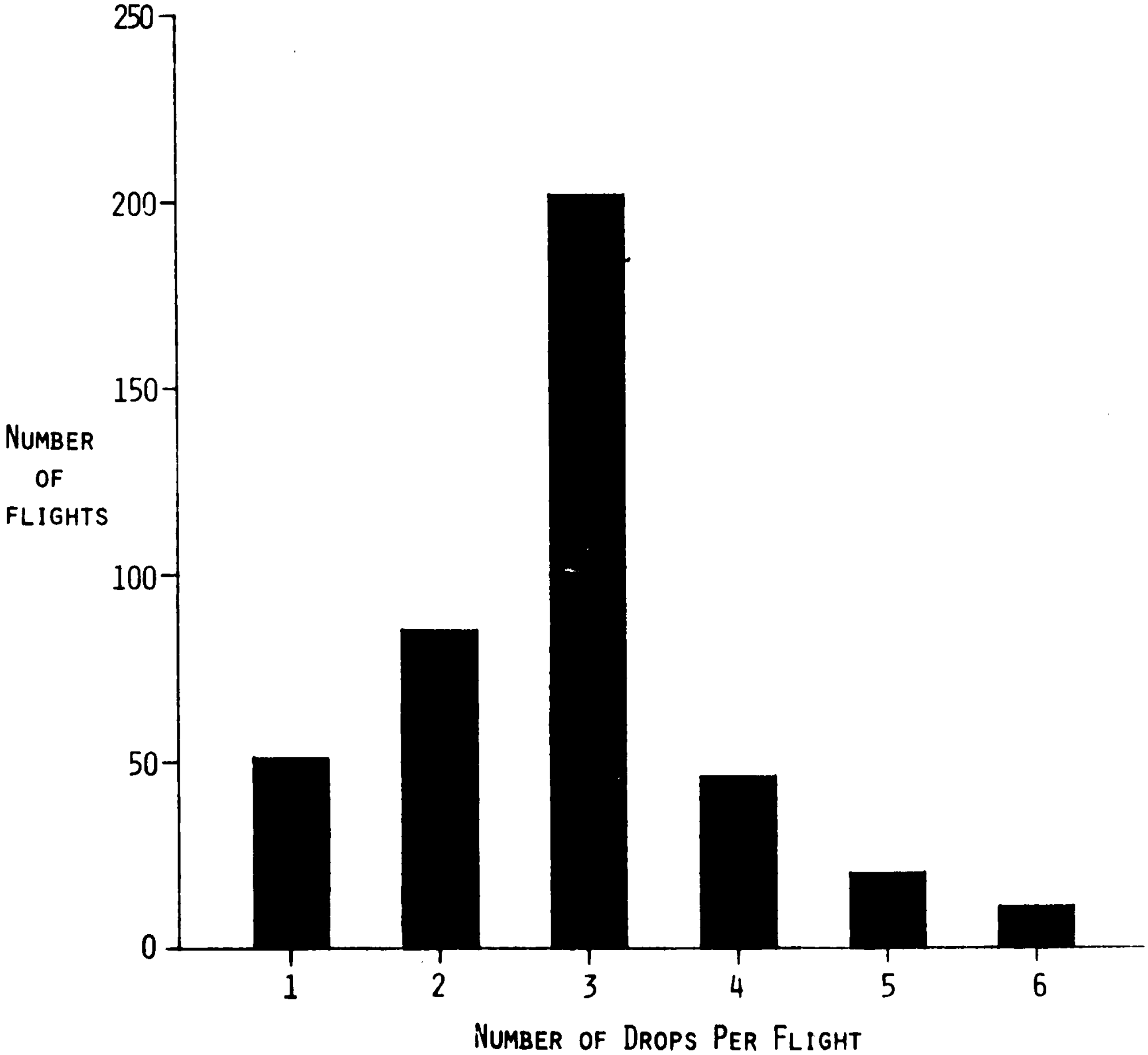

Figure 8. - Variation of the number of retardant drops made per flight.

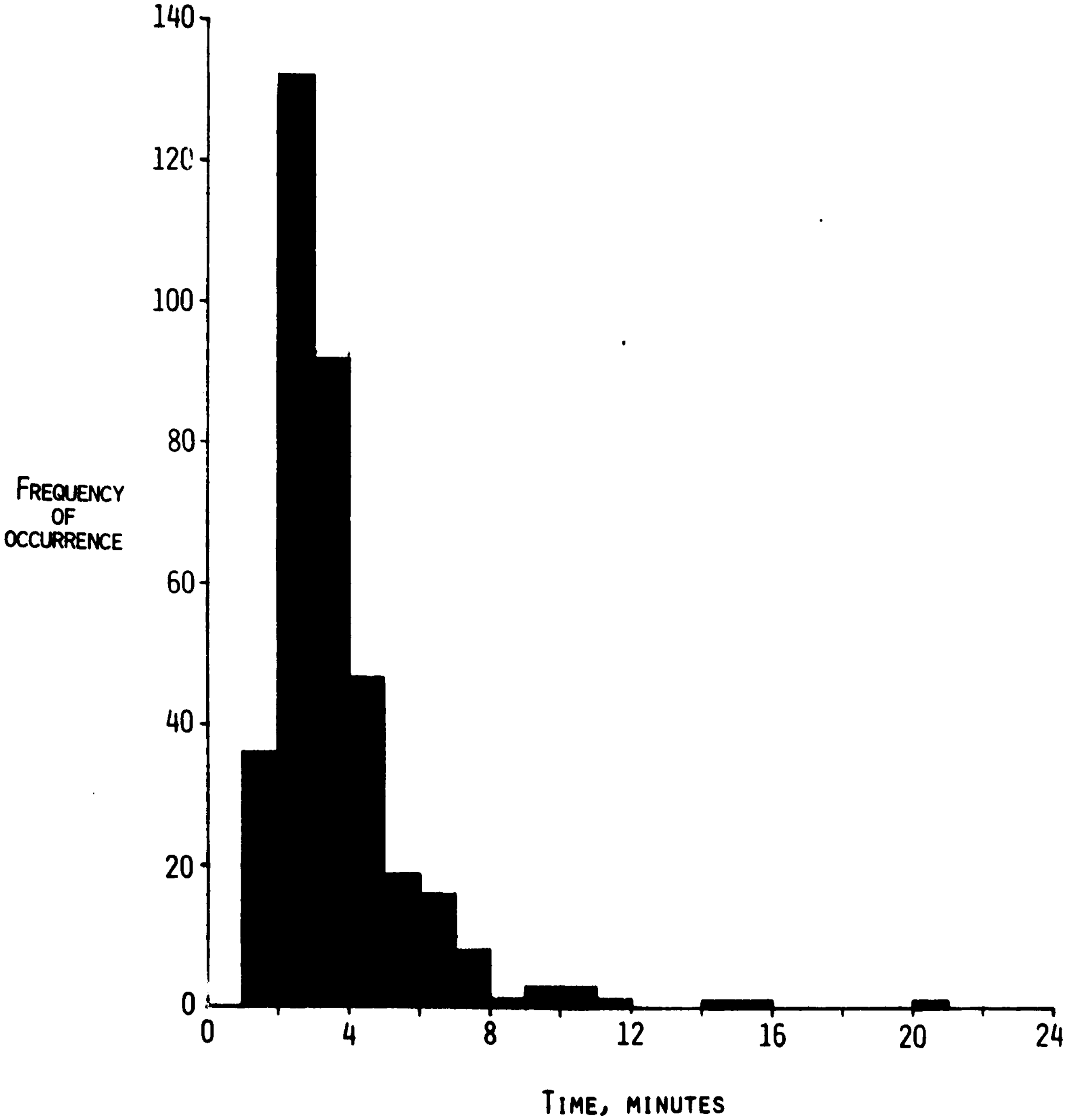

FIGURE 9. - VARIATION OF TIME BETWEEN RETARDANT DROPS ON A GIVEN FLIGHT.

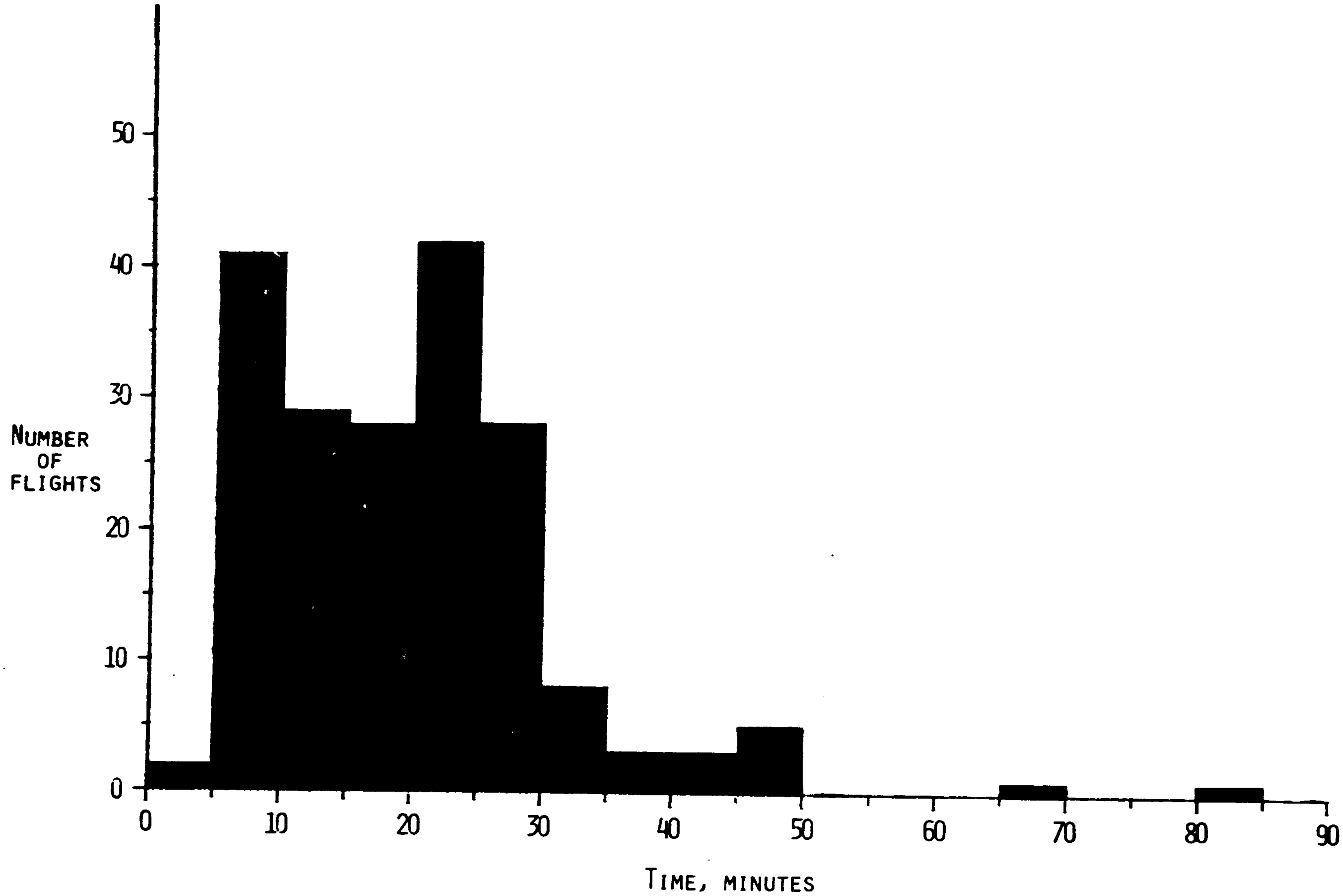

Figure 10. - Variation of time from last retardant drop to landing touch-down.

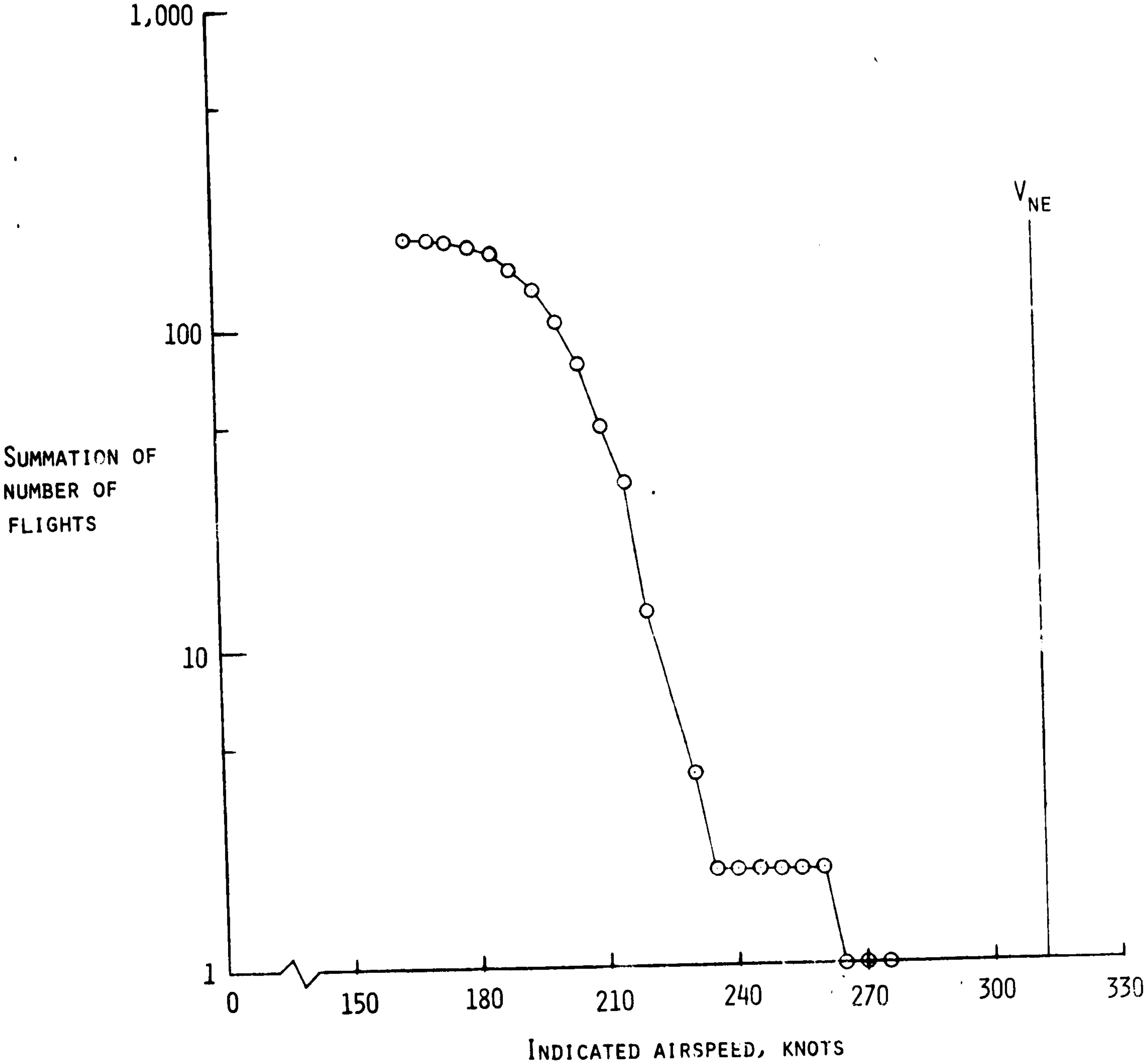

FIGURE 11. - RELATIONSHIP OF THE MAXIMUM INDICATED AIRSPEED RECORDED DURING A FIRE FIGHTING FLIGHT TO THE PLACARD NEVER-EXCEED SPEED.