# WEATHER CONDITIONS AFFECTING VTOL AIRBUS OPERATIONS IN THE NORTHEAST CORRIDOR

R.W. Simpson

FT-66-4

DEPARTMENT
OF
AERONAUTICS
&
ASTRONAUTICS

FLIGHT TRANSPORTATION LABORATORY

Prepared for the U.S. Department of Commerce under Contract C-85-65

NOVEMBER 1966

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

FLIGHT TRANSPORTATION LABORATORY

Technical Report FT-66-4

December 1966

# Weather Conditions Affecting VTOL Airbus Operations in the Northeast Corridor

Robert W. Simpson

This work was performed under Contract C-136-66 for the Office of High Speed Ground Transport, Department of Commerce. This report is one of a series of reports given in the Bibliography.

# TABLE OF CONTENTS


| Page | | |
|---|---|---|
| 1 | I. | INTRODUCTION |
| 5 | II. | RESULTS |
| 6 | | a) Low Visibilities |
| 8 | | b) Low Ceilings |
| 12 | | c) High Winds |
| 14 | | d) High Temperatures |
| 16 | | e) Wind Speed versus Visibility |
| 20 | | f) Percentage IFR Operations at Northeast Corridor Airports |
| 22 | | g) Low Ceiling versus Low Visibility |

## ABSTRACT

A detailed study of hourly weather observations in the Northeast Corridor during the periods 0600-2400 for a ten year period 1944-1958 was made to study the implications of weather affecting the operations of a VSTOL Airbus transportation system. As a result, specifications for an automatic approach to a hover ending at 75 feet above ground, and within 350 feet visibility were determined to achieve weather reliable operations of over 99.5% throughout the year. Examination of high temperatures indicated that a criterion of operation at 95° F at 1000 feet elevation should be used to ensure 99.5% reliability through the summer months over the corrider. The frequency of high winds indicated that a step gust of 30 mph could be used for specifying the aircraft's displacement from a hover position while under an inertially stabilized automatic control system.

As a by product, this study indicates that Category II all weather operations occur about 0.9% of the time, and Category III about 1.3% of the time in the Northeast Corridor. These percentages were lower at major stations like New York, Boston, Philadelphia, and Washington.

## I. INTRODUCTION

In order to examine the problems of all weather operations for an Airbus system in the Corridor, selected weather data was gathered. The prime purpose was to determine the frequency of occurrence of ceiling and visibility in order to achieve a 99.5% landing and takeoff reliability. It is likely that the VTOL aircraft will perform the final air taxiing and touchdown visually with the aid of high intensity lighting and perhaps fog dispersion in the pad area. This would mean that limitations in ceiling and visibility would have to be established for blind approaches which would end in a hover at a given height and visual range from touchdown. The cost, capability and accuracy of the automatic navigation, guidance and stabilization systems are dependent upon the ceiling and visibility limitations, and it is important to determine the benefits in terms of expected additional landings as the limits are lowered.

As well, because of economics of short haul operations, it is intended that the Airbus system should fly "VFR direct" whenever possible in order to avoid delays. Considerations of ceilings and visibilities determine the percentage of time this would be possible.

A third purpose of the weather study was to collect some hot weather temperature data to ensure that the VTOL aircraft would not be hampered by offloading passengers at peak times during summer months.

The NWRC at Asheville, N.C. was asked to supply the weather data as outlined in Table I. The tabulations are completely supplied in Reference 1. Selected weather data over the ten year period 1949 to 1958 was collected and analyzed. The data consisted of the weather observations at the 23 weather stations in the Corridor given in Table II. The weather observations are taken hourly, and for purposes of this study, data covering the period 0600-2400 were taken to coincide with the active airline day. The variations throughout the year were covered by dividing the data into 6 groupings of 2 months - January-February, March-April, etc.

There is sufficient statistical evidence in this sample to be a reliable measure of the frequency of occurrence of weather conditions. At any given station, some 68000 observations were recorded during this period. For the Corridor as a whole, the 23 stations constitute over 1.6 million observations.

TABLE I

FREQUENCY OF SELECTED WEATHER CONDITIONS FOR 23 STATIONS

(Based on hourly observations 0600-2400 LST, January 1949-December 19

ion Group or Number : WBAN number of station or number used to designate group of

SEASON: 1 = Jan-Feb, 2 = Mar-Apr, 3 = May-Jun, 4 = Jul=Aug, 5 = Sep-Oct, 6 = No

lation 1: Visibility-Frequency, cumulative frequency, relative cumulative frequen of visibility observations - statute miles (cumulative high to low)

lation 2: Ceiling-Frequency, cumulative frequency, relative cumulative frequency of ceiling observations - (in feet) 30000 category includes all ceiling reported as 888-cirroform clouds (unknown = card incorrectly punched or missing) (cumulative high to low)

lation 3: Wind Speed-Frequency, cumulative frequency, relative cumulative frequen of wind speeds - miles per hour (cumulative low to high) speeds 4, 11, 27, 34, 42 and 49 not used due to conversion from knots to mph

lation 4: Temperature-Percentage of observations of temperature greater than indi headings - $^{o}$F

lation 5: Wind Speed vs Visibility - mean scalar wind speed in miles per hour vs. visibility in statute miles

lation 6: IFR vs VFR - Bi-monthly computations. IFR = ceiling 1000 ft. and/or vi 3 miles VFR = ceiling 1000 ft., and/or visibility 3 miles. N = numb observations, in thousands (11.6 = 11,600). o/o = IFR/N

lation 7: Ceiling vs visibility - Occurrences of specified ceiling heights at sel visibilities Tot line = Total obs for each ceiling classification T frequency = Total obs for all ceilings 300 ft. Total observations Total number of obs. examined.

## TABLE II

## STATION LIST - 1949-58

| | |
|---|---|
| 13739 | Philadelphia, Pa. |
| 13740 | Richmond, Va. |
| 13743 | Washington National Airport |
| 13750 | Norfolk, Va. |
| 13781 | Wilmington, Del. |
| 14732 | New York, N.Y. (LGA) |
| 14734 | Newark, N.J. |
| 14735 | Albany, N.Y. |
| 14737 | Allentown, Pa. |
| 14739 | Boston, Mass. |
| 14740 | Windsor Locks, Conn. |
| 14745 | Concord, N.H. |
| 14751 | Harrisburg, Pa. |
| 14756 | Nantucket, Mass. |
| 14764 | Portland, Me. |
| 14765 | Providence, R.I. |
| 14777 | Scranton, Pa. (Wilkes Barre) |
| 93720 | Salisbury, Md. (FAA) |
| 93721 | Baltimore, Md. |
| 93730 | Atlantic City, N.J. |
| 94702 | Bridgeport, Conn (1953-58 16 obs/day) |
| 94746 | Worcester, Mass. |
| 94789 | New York, N.Y. (JFK) |

## II. RESULTS

Various selected data are presented here in graphical and tabular form, along with a discussion of the implications of the results on a VTOL Airbus operation.

a) Occurrence of Low Visibilities

The probabilities of visibilities greater than a given range are given in Figure 1 for the airline day in the Northeast Corridor. It can be seen that the winter months have the lowest visibilities. Interpolation of the curves gives the following visibilities which will be exceeded more than 99.5% of the time.

| | |
|---|---|
| Jan-Feb | 1/16 statute miles |
| Mar-Apr | 1/8 |
| May-Jun | 3/16 |
| Jul-Aug | 1/4 |
| Sep-Oct | 1/8 |
| Nov-Dec | 1/16 |

The lowest value is 1/16 of a statute mile, or about 350 feet.

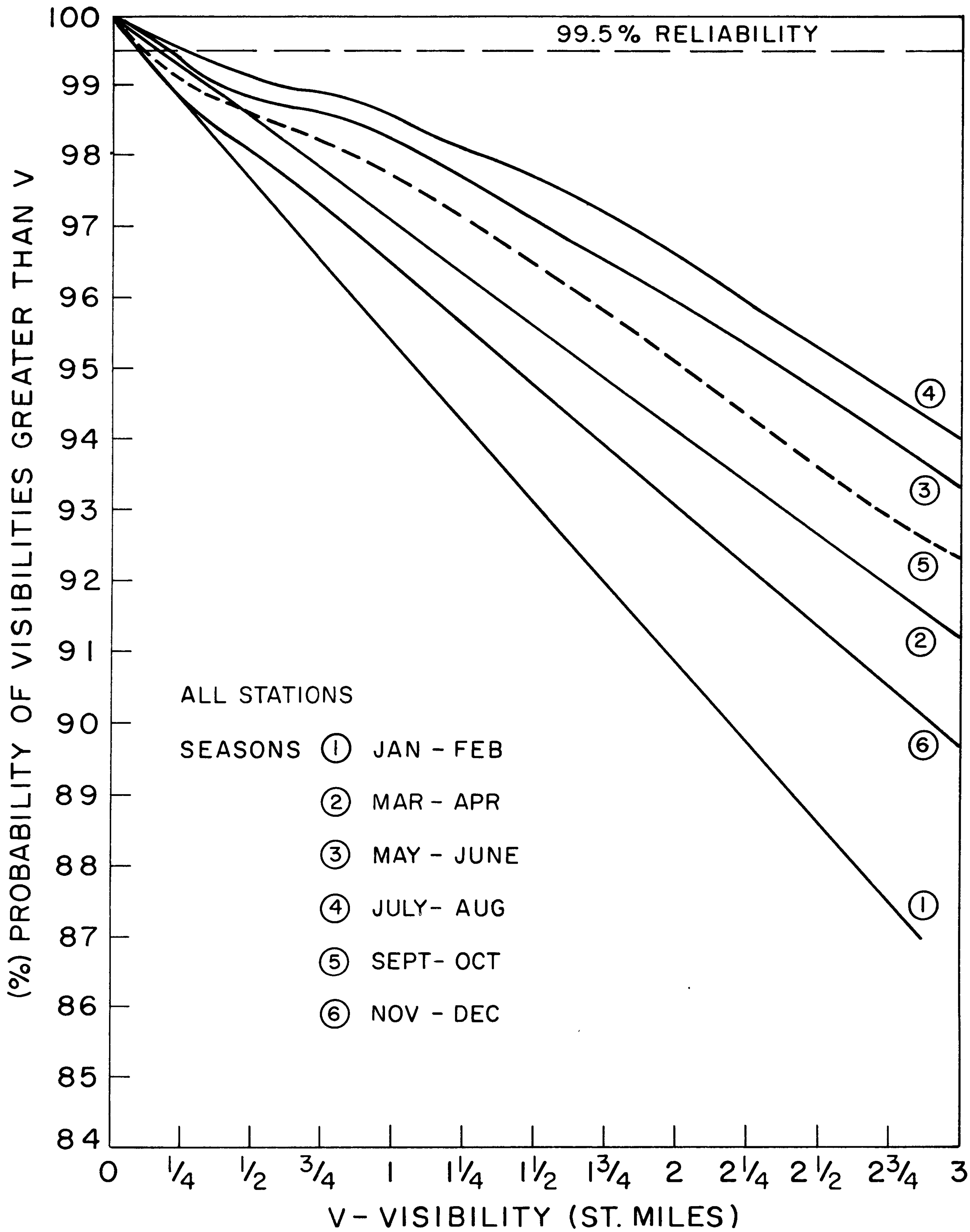


FIGURE I PROBABILITY OF LOW VISIBILITIES

b) Occurrence of Low Ceilings

The frequency of low ceilings is shown in Figure 2. Jan-Feb and Nov-Dec are the worst seasons, with a ceiling of about 75 feet required to ensure 99.5% reliability. The seasonal variations are given below for the total Northeast Corridor.

| | |
|---|---|
| Jan-Feb | 75 feet |
| Mar-Apr | 150 |
| May-Jun | 120 |
| Jul-Aug | 150 |
| Sep-Oct | 100 |
| Nov-Dec | 85 |

The results show that very low ceilings occur even during summer months and that an operational ceiling below 100 feet would be required for the Airbus system.

Figure 3 shows the probability of all ceilings and provides some idea of the percentage of time VFR trips could be achieved for a given cruise altitude. For example, a ceiling of over 10,000 feet would be available about 50% of the time even during the winter months.

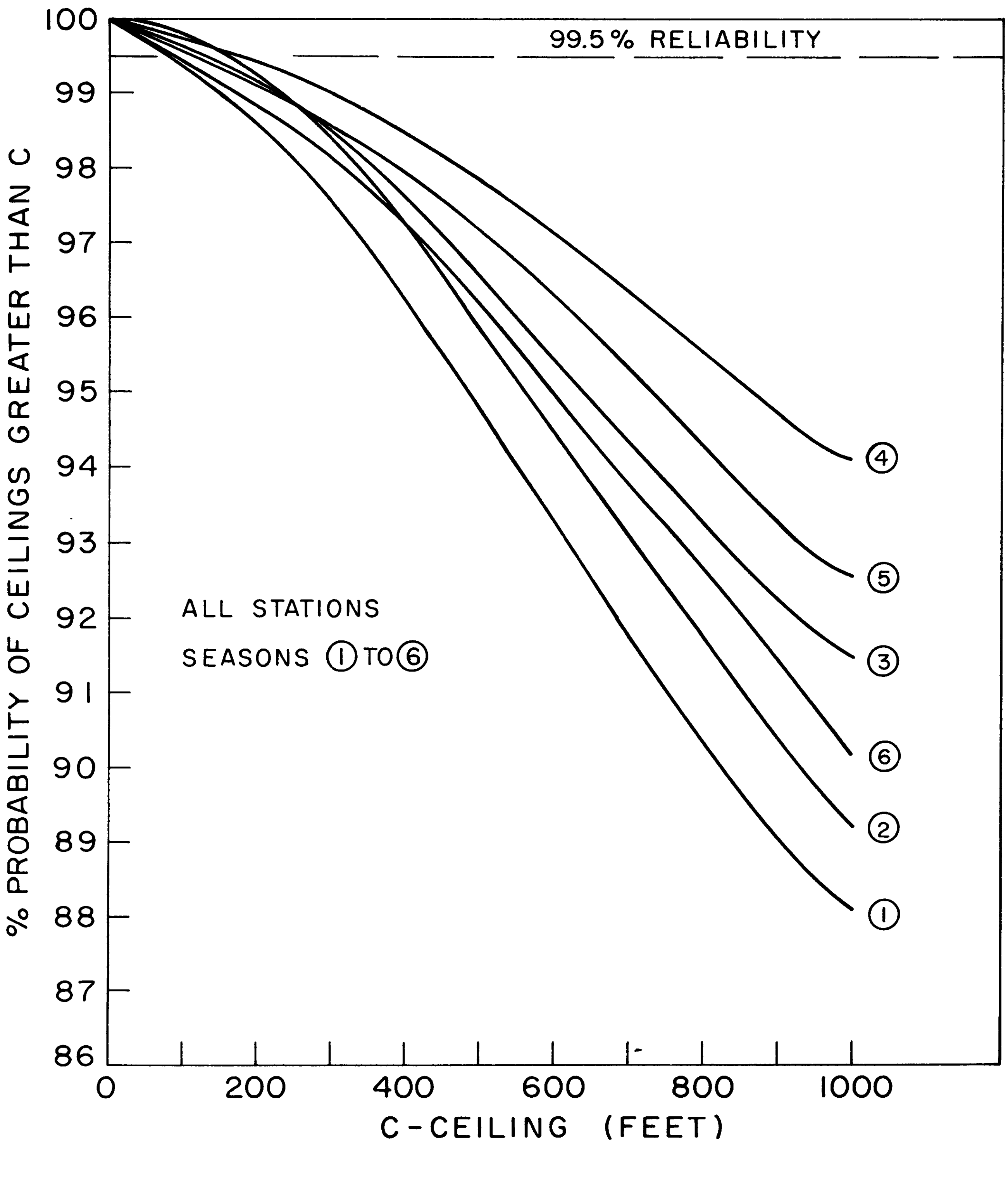


FIGURE 2 OCCURRENCE OF LOW CEILINGS

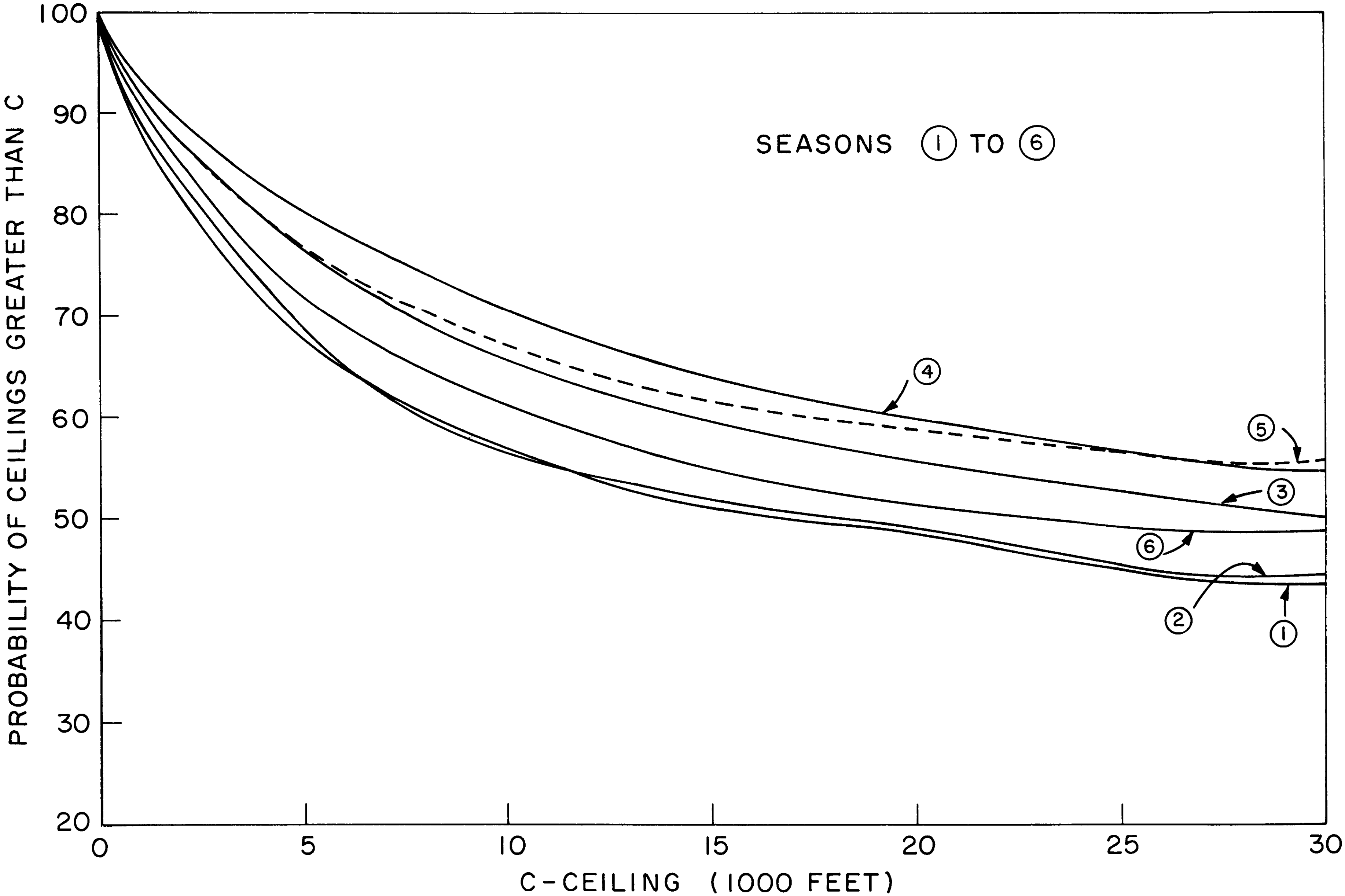


FIGURE 3 OCCURRENCE OF ALL CEILINGS - NE CORRIDOR

c) Occurrence of High Winds

Figure 4 gives the frequency of occurrence of winds less than a given speed. It shows that 99.5% of the time we can expect winds of less than 30 miles per hour. The critical case for VTOL aircraft would be landing, takeoff, and air taxiing in the gusty conditions which accompany high average wind speeds. Landing on rooftop sites, and air taxiing at close quarters requires a vehicle which is stabilized in hover with respect to inertial space, and whose lateral or longitudinal movements are small in response to a change in wind speed. From this data, a critical design case can be specified (which overstates the requirement) such as that the vehicle response be less than a few feet in any direction for a step gust of 30 miles per hour.

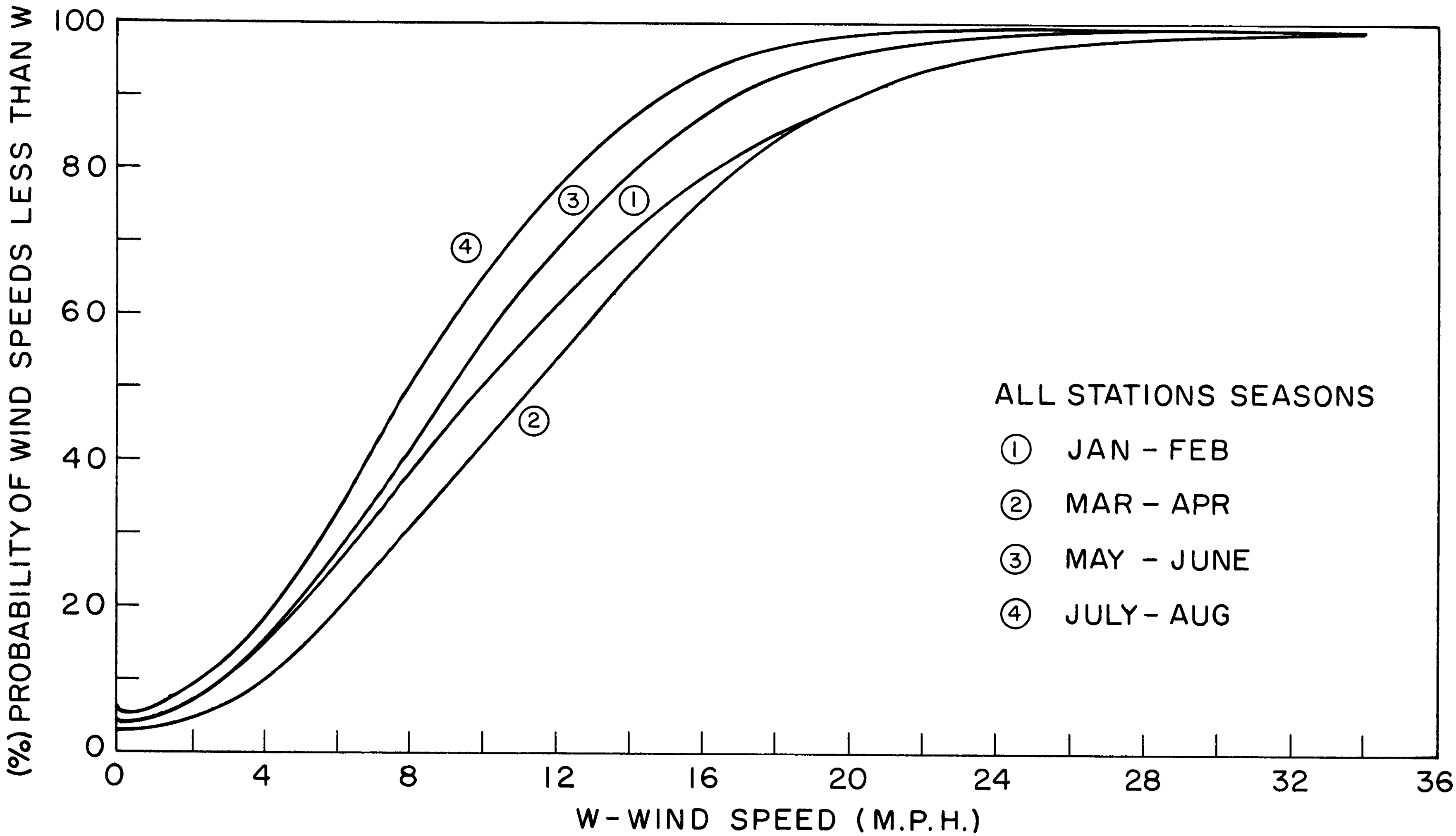


FIGURE 4 OCCURRENCE OF HIGH WIND SPEEDS

d) Occurrence of High Temperatures

Because of the power loss of turbine engines with high ambient temperatures, and the resultant off loading of revenue passengers at certain stations during peak summer months, it is important to ensure that sufficient power is installed in Airbus VTOL vehicles. Figure 5 shows the distribution of temperatures in the Corridor for the summer months of June through September. For the Corridor as a whole, these results would indicate that takeoff capability at 1000 foot elevation at $95^{\circ}$ F would suffice to give 99.5% reliability. Examination of all the stations reveals Newark and Richmond to be the two hottest stations. It would require about $99^{\circ}$ F to ensure 99.5% reliability at Richmond through the summer months. Since altitude is another important variable, a more detailed examination of individual stations may be required.

One might specify temperatures at the hottest and perhaps the busiest times of the day (4 pm to 7 pm) as a criterion. The average load expected out of such an individual station at the hottest part of the day during the summer months would also be a factor.

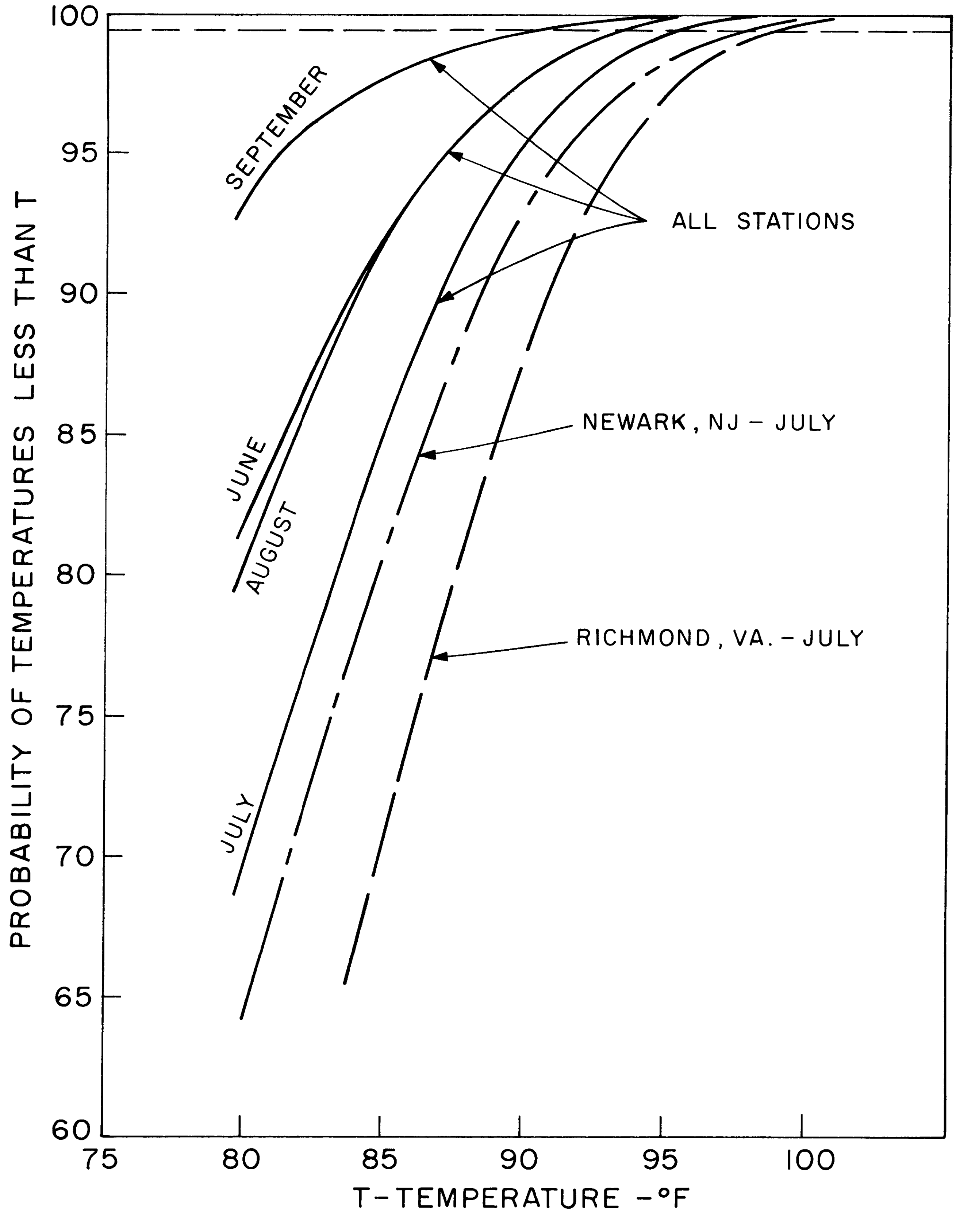


FIGURE 5 OCCURRENCE OF HIGH TEMPERATURES - SUMMER MONTHS

e) Wind Speed versus Visibility

In examining the weather reliability aspects of an air transport system, it is not sufficient to look at ceiling, visibility, wind speed, etc. alone. In Figures 6 and 7, the variation of wind strength with visibility is plotted, to ascertain if there is any evidence that low visibilities are accompanied by low wind speeds. Figure 6 shows that between 1 and 7 miles visibility, average wind strength is constant at about 9 mph, and that higher visibilities are accompanied by stronger winds. Figure 7 examines the low visibility range, and shows some evidence of a sharp reduction in wind strength at visibilities less than ¼ miles. However, the average speed is still 5 mph and the average plus or minus one standard deviation gives speeds ranging from zero to about 12 mph. There are certain kinds of reduction in visibility such as rain and snow, where winds can be expected to be high and gusty. On the average, however, we may say that very low visibilities will tend to be accompanied by lower wind speeds.

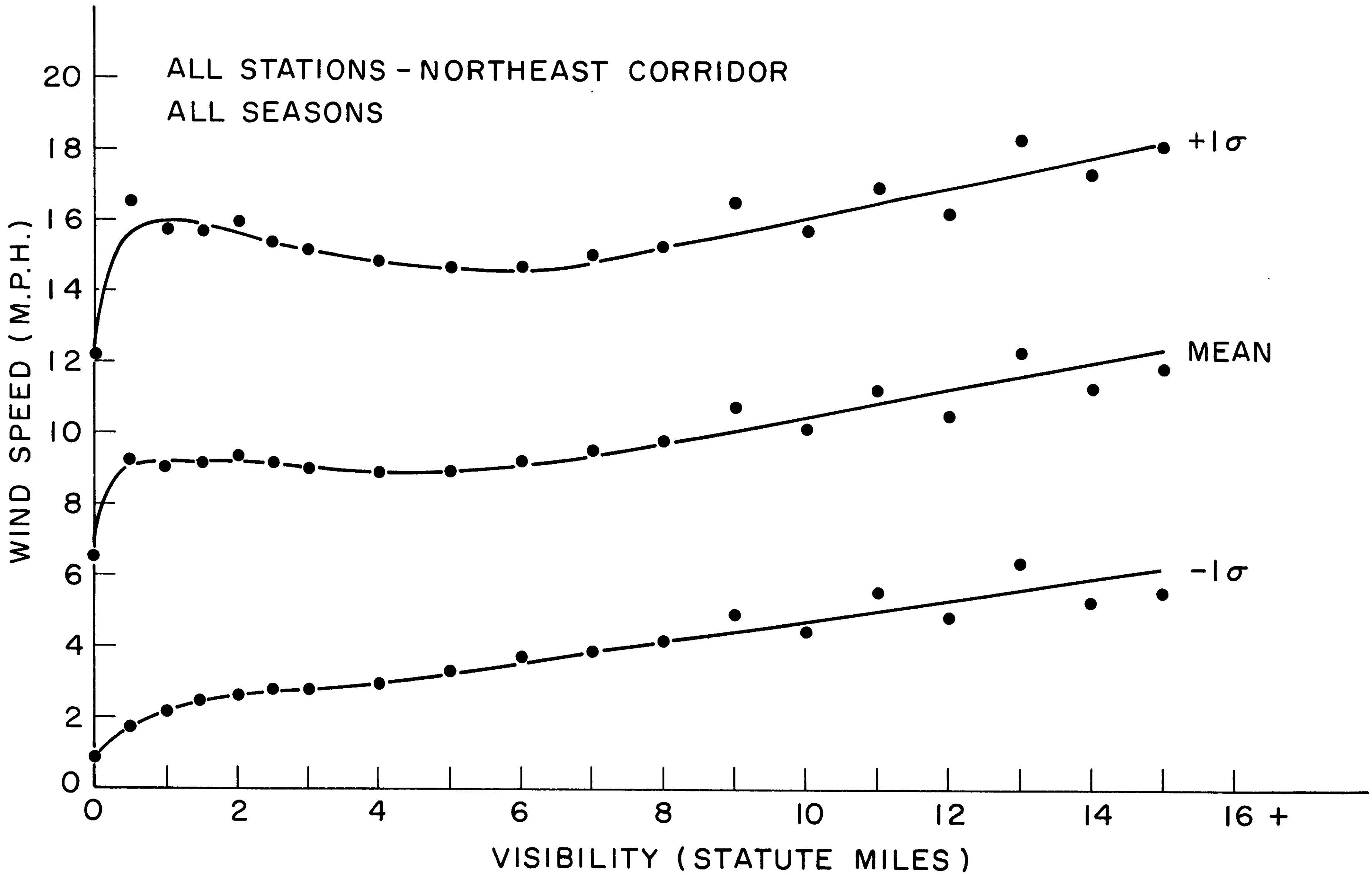


FIGURE 6 WIND SPEED VS VISIBILITY

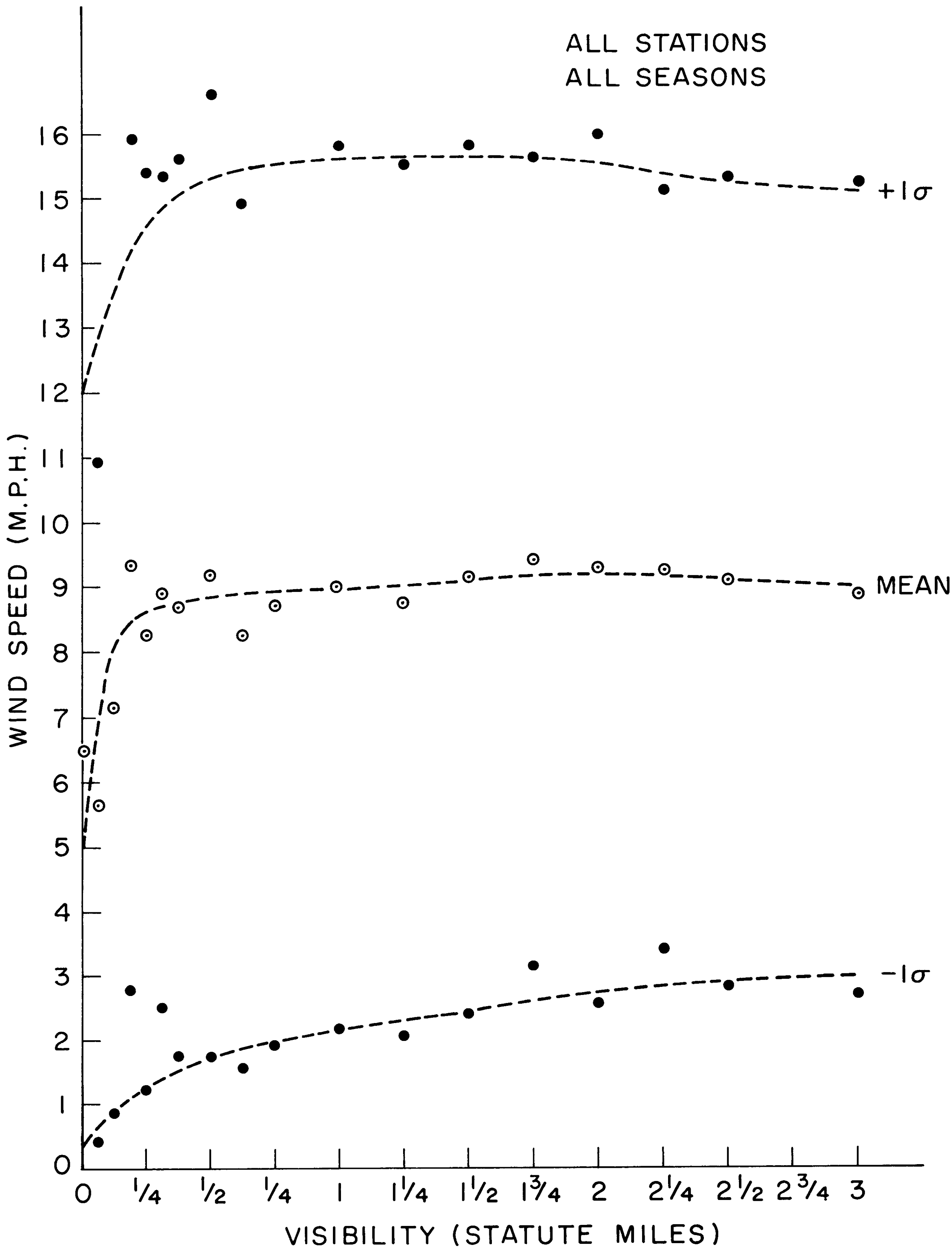


FIGURE 7 WIND SPEED VS LOW VISIBILITY

## f) Percentage IFR Operations at Northeast Corridor Airports

Statistics were gathered to obtain the percentage of time that the NE Corridor would have weather requiring IFR (instrument flight rules) operations. The average is 12.15%, and the variation throughout the year is shown in Figure 8. The summer months are best with July-August having only 8.8% IFR weather. January-February are the worst months having 16.1% IFR weather. This indicates that VFR operations are legal more than 87% of the time, averaging over the year and over the Northeast Corridor.

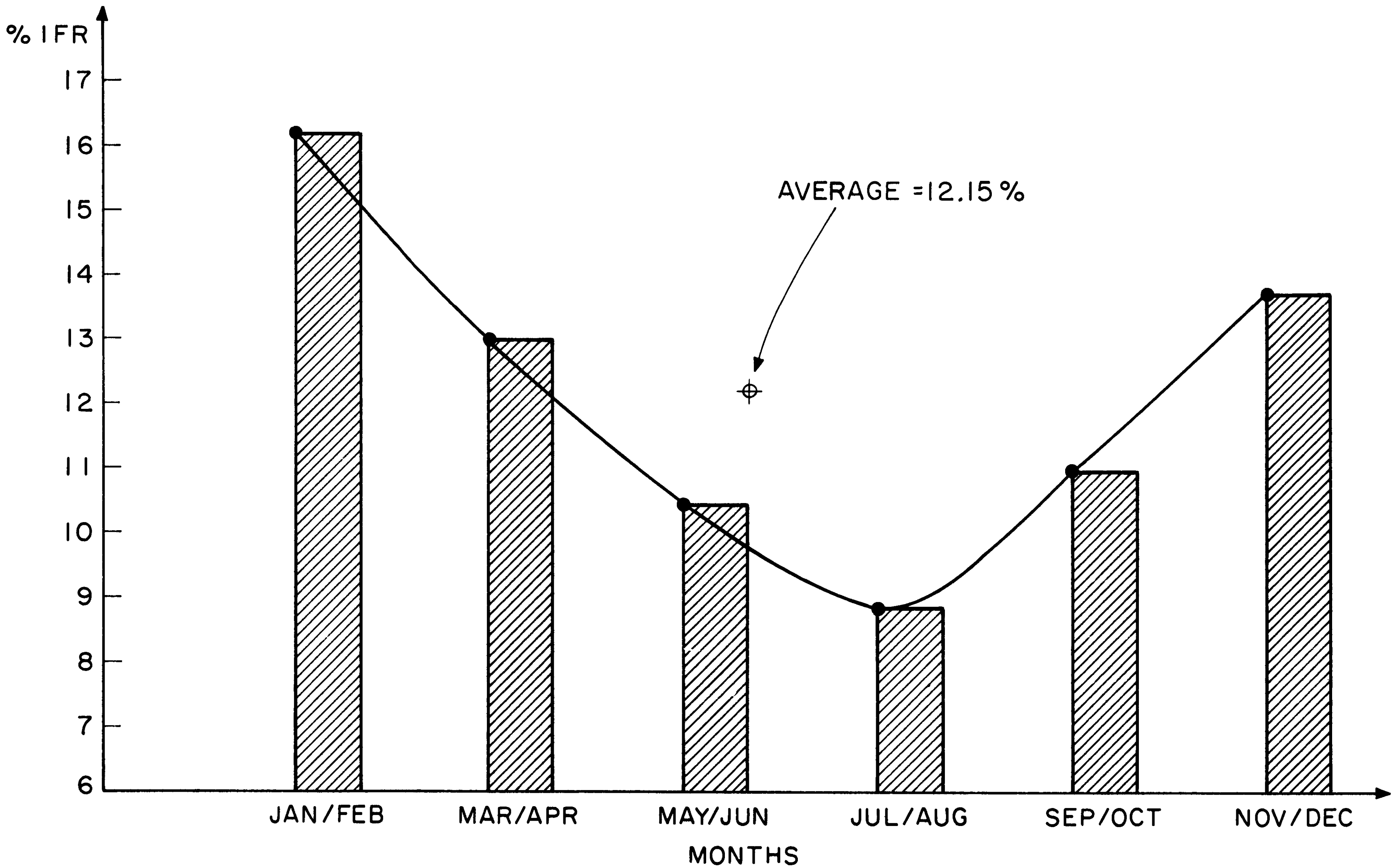


FIGURE 8 % IFR VS MONTHS (ALL STATIONS)

g) Occurrence of Low Ceiling and Visibility

The joint probabilities of the occurrence of a given ceiling and visibility were obtained for the whole Northeast Corridor and selected major stations in the Corridor. Figures 9 through 18 show this information on a matrix of ceiling versus visibility. Each cell in the matrix has two entries: N, the number of weather observations corresponding to the cell which were made in the ten year period; RF, the relative frequency, or the fraction of total observations which this cell represents.

As well, various areas of the matrix have been grouped together to correspond approximately with the international categories of all weather operations. The assignment of cells to each category is summarized below.

| Category | Ceilings (feet) | Visibilities (st.miles) |
|---|---|---|
| I | greater than 200 | greater than ½ |
| II | greater than 100 | greater than ¼(less Cat. I) |
| IIIa | greater than zero | greater than 1/8 (less Cat. I and Cat. II) |
| IIIb | all ceilings | between 1/16 and 1/8 |
| IIIc | all ceilings | between zero and 1/16 |

These areas are indicated on each matrix. They do not correspond exactly to the present definitions of Category III operations which are defined in terms of RVR (runway visual range) which is a different measurement of visibility from that reported by the weather observer. However, over a ten year period, the relative frequency of occurrence of low runway visual ranges is adequately represented by the relative frequency of weather observations of low visibility.

The results for all stations in the Northeast Corridor are given by Figure 9. For example, the zero-zero cell shows 4027 reports out of a total of 1.58 million, or a relative frequency of .0025, or one quarter of one percent. By adding cells for a given category, one gets the absolute number of reports and the relative frequency corresponding to each category. Figure 10 shows similar information recorded during the worst two month period of the year. For all stations in the Corridor, it is January-February, but may vary with individual stations. Figures 11 to 18 show similar ceiling-visibility matrices for Boston (Logan Airport), New York (JFK, Laguardia and Newark combined), Washington (National Airport), and Philadelphia. Results are given for the whole ten year period, and the worst two months throughout the ten year period.

Figure 19 summarizes the frequency of occurrence of the all weather landing categories at these stations. For all stations, it can be seen that Category III weather occurs about 0.9% of the time, although this percentage is much lower at the major stations. New York, for example, has about half as much Category III weather. The smaller stations in the Corridor must have worse conditions of ceiling and visibility than the major stations selected for study. Similar information is given in Figure 20 for the worst two months of the year.

By examining these weather conditions, one can determine the Airbus system reliability with regard to landing and take-off operations, at least as far as low ceiling and visibility. If one selects 100 feet as a ceiling limit, and 1/16 miles or 350 feet as a visual range limit, then the percentages given in Table III will represent the average operational reliability as affected by weather.

In the worst months of the year, the data of Table III indicates reliabilities of less than 99.5% which is the system goal. Figure 2 has shown that ceilings of the order of 75 feet should be chosen to ensure 99.5% operations for all stations during January - February. This was obtained by extrapolating ceiling data since no observations less than 100 foot ceilings are recorded. The all stations average value should be properly weighted to reflect schedule frequencies at these stations in order to reflect the schedule reliability. Thus, if the major stations are better than the all stations value, the schedule reliability will be better. However, by reducing the ceiling to 75 feet, we raise weather reliabilities above 99.5% for all stations during the worst two months. This ensures 99.5% weather reliability for the whole year, and since the major stations are better, the schedule reliability would be higher yet.

The Airbus system weather operational limits are thus selected as 75 feet for ceiling, and 350 feet for visibility.

## TABLE III

## ALL-WEATHER RELIABILITY

| Station | Complete Year | Worst Months |
|---|---|---|
| All stations | 99.46% | 99.21% (Jan-Feb) |
| Boston | 99.94% | 99.84% (Jan-Feb) |
| New York | 99.76% | 99.48% (Jan-Feb) |
| Washington | 99.97% | 99.95% (Nov-Dec) |
| Philadelphia | 99.75% | 99.36% (Jan-Feb) |

Weather limits - Ceiling 100 feet

- Visibility 350 feet or 1/16 st. miles

## REFERENCES

1. National Weather Records Center, ESSA, Frequency of Selected Weather Conditions for 23 Stations, January 1949 - December 1958, for MIT Flight Transportation Laboratory, November 1966.

2. FAA, Climatic Studies for Proposed Landing System for JFK International Airport, SRDS, June 1964.

# BIBLIOGRAPHY


1. MIT Flight Transportation Laboratory, A Systems Analysis of Short Haul Air Transportation, Department of Commerce, Federal Clearinghouse, Arlington, Va. PB-169-521.

2. MIT Flight Transportation Laboratory, Analysis of VSTOL Aircraft Configurations for Short Haul Air Transportation Systems, Report FT-66-1, November 1966.

3. MIT Flight Transportation Laboratory, Maintenance Cost Studies of Present Aircraft Subsystems, Report FT-66-2, November, 1966.

4. MIT Flight Transportation Laboratory, Computerized Schedule Construction for an Airline Transportation System, Report FT-66-3, December 1966.

# NUMBER & RELATIVE FREQUENCY OF LOW CEILING AND VISIBILITY
## 1949-1958 (0600-2400)
## ALL STATIONS

| ALL WEATHER LANDING CATEGORIES | | IIIc | IIIb | IIIa | | II | | | I | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CEILING (Feet) 400+ | RF | 0.0001 | 0.0003 | 0.0004 | 0.0001 | 0.0009 | 0.0000 | 0.0003 | 0.0025 | 0.0004 | 0.0043 | 0.9644 | 0.9737 | CAT I |
| | N | 159 | 428 | 696 | 147 | 1410 | 42 | 544 | 3945 | 635 | 6793 | 1530103 | 1544902 | |
| 300 | RF | 0.0000 | 0.0000 | 0.0002 | 0.0001 | 0.0004 | 0.0000 | 0.0002 | 0.0009 | 0.0001 | 0.0013 | 0.0061 | 0.0093 | |
| | N | 14 | 70 | 230 | 84 | 664 | 19 | 262 | 1465 | 194 | 1994 | 9693 | 14689 | |
| 200 | RF | 0.0000 | 0.0002 | 0.0004 | 0.0001 | 0.0008 | 0.0000 | 0.0003 | 0.0012 | 0.0001 | 0.0010 | 0.0025 | 0.0068 | |
| | N | 41 | 245 | 699 | 200 | 1307 | 61 | 433 | 1941 | 223 | 1651 | 3922 | 10723 | |
| 100 | RF | 0.0001 | 0.0006 | 0.0011 | 0.0003 | 0.0012 | 0.0000 | 0.0003 | 0.0008 | 0.0000 | 0.0003 | 0.0004 | 0.0051 | CAT II |
| | N | 101 | 950 | 1726 | 546 | 1884 | 52 | 415 | 1249 | 70 | 506 | 616 | 8115 | |
| 0 | RF | 0.0025 | 0.0009 | 0.0010 | 0.0001 | 0.0004 | 0.0000 | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0051 | CAT IIIa |
| | N | 4027 | 1469 | 1654 | 126 | 609 | 9 | 73 | 137 | 5 | 29 | 60 | 8198 | |
| | | 0 | 1/16 | 1/8 | 3/16 | 1/4 | 5/16 | 3/8 | 1/2 | 5/8 | 3/4 | 1+ | ALL | |

**VISIBILITY (MILES)**

FIGURE 9

# ALL STATIONS (JAN. - FEB.)

| ALL WEATHER LANDING CATEGORIES | | IIIc | IIIb | IIIa | | II | | | I | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CEILING (Feet) 400+ | RF | 0.0002 | | | | | | | | | | | | | CAT I |
| | N | 38 | 73 | 131 | 28 | 357 | 19 | 187 | 1264 | 248 | 2298 | 243235 | 247878 | | |
| 300 | RF | 0.0000 | | | | | | | | | | | | | |
| | N | 3 | 21 | 77 | 28 | 226 | 8 | 85 | 451 | 66 | 526 | 1998 | 3489 | | |
| 200 | RF | 0.0001 | | | | | | | | | | | | | |
| | N | 13 | 65 | 221 | 41 | 371 | 15 | 101 | 472 | 47 | 370 | 791 | 2507 | | |
| 100 | RF | 0.0001 | | | | | | | | | | | | | CAT II |
| | N | 23 | 239 | 411 | 81 | 436 | 11 | 90 | 264 | 17 | 108 | 124 | 1804 | | |
| 0 | RF | 0.0004 | 0.0014 | 0.0014 | 0.0001 | 0.0005 | 0.0000 | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0076 | | CAT IIIa |
| | N | 1030 | 353 | 351 | 32 | 135 | 3 | 9 | 28 | 2 | 4 | 7 | 1954 | | |
| | | 0 | 1/16 | 1/8 | 3/16 | 1/4 | 5/16 | 3/8 | 1/2 | 5/8 | 3/4 | 1+ | ALL | | |

**VISIBILITY (MILES)**

FIGURE 10

# NUMBER & RELATIVE FREQUENCY OF LOW CEILING AND VISIBILITY
## 1949-1958 (0600-2400)
## BOSTON

| ALL WEATHER LANDING CATEGORIES | | IIIc | IIIb | IIIa | | II | | | I | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CEILING (Feet)** 400+ | RF | 0.0000 | 0.0002 | 0.0002 | 0.0000 | 0.0005 | 0.0000 | 0.0001 | 0.0021 | 0.0002 | 0.0030 | 0.9732 | 0.9796 | |
| | N | 2 | 11 | 13 | 1 | 35 | 0.0000 | 10 | 148 | 15 | 210 | 67527 | 67972 | |
| 300 | RF | 0.0000 | 0.0001 | 0.0001 | 0.0000 | 0.0007 | 0.0000 | 0.0001 | 0.0010 | 0.0000 | 0.0017 | 0.0077 | 0.0113 | CAT I |
| | N | 1 | 5 | 4 | 1 | 47 | 0.0000 | 8 | 67 | 2 | 116 | 533 | 784 | |
| 200 | RF | 0.0001 | 0.0002 | 0.0006 | 0.0000 | 0.0011 | 0.0000 | 0.0002 | 0.0016 | 0.0001 | 0.0008 | 0.0021 | 0.0067 | |
| | N | 6 | 14 | 43 | 0 | 74 | 0 | 14 | 112 | 8 | 52 | 144 | 467 | |
| 100 | RF | 0.0002 | 0.0003 | 0.0005 | 0.0000 | 0.0007 | 0.0000 | 0.0001 | 0.0003 | 0.0000 | 0.0001 | 0.0001 | 0.0021 | CAT II |
| | N | 15 | 17 | 34 | 0 | 47 | 0 | 5 | 18 | 0 | 6 | 5 | 147 | |
| 0 | RF | 0.0001 | 0.0000 | 0.00000 | 0 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0002 | CAT IIIa |
| | N | 5 | 2 | 3 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 1 | 15 | |
| | | 0 | 1/16 | 1/8 | 3/16 | 1/4 | 5/16 | 3/8 | 1/2 | 5/8 | 3/4 | 1+ | ALL | |

**VISIBILITY (MILES)**

FIGURE 11

# BOSTON (JAN. - FEB.)

| ALL WEATHER LANDING CATEGORIES | | IIIc | IIIb | IIIa | | II | | | I | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CEILING (Feet) 400+ | RF | 0.0002 | | | | | | | | | | | | CAT I |
| | N | 2 | 1 | 3 | 1 | 7 | 0 | 4 | 58 | 10 | 110 | 10801 | 10997 | |
| 300 | RF | 0.0000 | | | | | | | | | | | | |
| | N | 0 | 3 | 1 | 0 | 9 | 0 | 1 | 11 | 1 | 22 | 82 | 130 | |
| 200 | RF | 0.0004 | | | | | | | | | | | | |
| | N | 4 | 6 | 14 | 0 | 20 | 0 | 3 | 18 | 1 | 5 | 23 | 94 | |
| 100 | RF | 0.0007 | | | | | | | | | | | | CAT II |
| | N | 8 | 6 | 4 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 1 | 22 | |
| 0 | RF | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0003 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0001 | 0.0004 | CAT IIIa |
| | N | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | |
| | | 0 | 1/16 | 1/8 | 3/16 | 1/4 | 5/16 | 3/8 | 1/2 | 5/8 | 3/4 | 1+ | ALL | |

**VISIBILITY (MILES)**

FIGURE 12

# NUMBER & RELATIVE FREQUENCY OF LOW CEILING AND VISIBILITY
# 1949-1958 (0600-2400)
# WASHINGTON

| ALL WEATHER LANDING CATEGORIES | | IIIc | IIIb | IIIa | | II | | | I | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CEILING (Feet)** | | | | | | | | | | | | | | |
| 400+ | RF | 0.0000 | 0.0001 | 0.0001 | 0.0001 | 0.0003 | 0.0000 | 0.0002 | 0.0008 | 0.0003 | 0.0015 | 0.9875 | 0.9908 | CAT I |
| | N | 0 | 4 | 4 | 5 | 18 | 2 | 14 | 52 | 21 | 105 | 68503 | 68728 | |
| 300 | RF | 0.0000 | 0.0000 | 0.0000 | 0.0001 | 0.0002 | 0.0000 | 0.0002 | 0.0003 | 0.0001 | 0.0004 | 0.0034 | 0.0049 | |
| | N | 0 | 0 | 2 | 7 | 15 | 3 | 14 | 21 | 10 | 30 | 236 | 338 | |
| 200 | RF | 0.0000 | 0.0000 | 0.0003 | 0.0003 | 0.0004 | 0.0001 | 0.0001 | 0.0003 | 0.0001 | 0.0002 | 0.0005 | 0.0023 | |
| | N | 0 | 3 | 18 | 17 | 26 | 10 | 10 | 17 | 6 | 16 | 35 | 158 | |
| 100 | RF | 0.0000 | 0.0003 | 0.0006 | 0.0004 | 0.0002 | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0019 | CAT II |
| | N | 0 | 23 | 43 | 28 | 13 | 3 | 9 | 3 | 1 | 3 | 3 | 129 | |
| 0 | RF | 0.0000 | 0.0001 | 0.0000 | 0.00000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0002 | CAT IIIa |
| | N | 3 | 6 | 3 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 1 | 16 | |
| | | 0 | 1/16 | 1/8 | 3/16 | 1/4 | 5/16 | 3/8 | 1/2 | 5/8 | 3/4 | 1+ | ALL | |

**VISIBILITY (MILES)**

FIGURE 13

# WASHINGTON (NATION) - (NOV. - DEC.)

| ALL WEATHER LANDING CATEGORIES | | IIIc | IIIb | IIIa | | II | | | I | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CEILING (Feet) 400+ | RF | 0.0000 | | | | | | | | | | | | CAT I |
| | N | 0 | 3 | 2 | 2 | 4 | 0 | 6 | 21 | 9 | 40 | 11278 | 11365 | |
| 300 | RF | 0.0000 | | | | | | | | | | | | |
| | N | 0 | 0 | 1 | 3 | 5 | 1 | 3 | 7 | 5 | 9 | 48 | 82 | |
| 200 | RF | 0.0000 | | | | | | | | | | | | |
| | N | 0 | 0 | 11 | 13 | 10 | 4 | 2 | 8 | 2 | 9 | 11 | 70 | |
| 100 | RF | 0.0000 | | | | | | | | | | | | CAT II |
| | N | 0 | 11 | 20 | 14 | 5 | 2 | 4 | 1 | 1 | 1 | 2 | 61 | |
| 0 | RF | 0.0001 | 0.0004 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0005 | CAT IIIa |
| | N | 1 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | |
| | | 0 | 1/16 | 1/8 | 3/16 | 1/4 | 5/16 | 3/8 | 1/2 | 5/8 | 3/4 | 1+ | ALL | |

**VISIBILITY (MILES)**

FIGURE 14

# NUMBER & RELATIVE FREQUENCY OF LOW CEILING AND VISIBILITY
## 1949-1958 (0600-2400)
## NEW YORK

| ALL WEATHER LANDING CATEGORIES | | IIIc | IIIb | IIIa | | II | | | I | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CEILING (Feet)** | | | | | | | | | | | | | | |
| 400+ | RF | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0005 | 0.0001 | 0.0004 | 0.0023 | 0.0006 | 0.0047 | 0.9724 | 0.9813 | CAT I |
| | N | 22 | 21 | 28 | 12 | 106 | 16 | 80 | 463 | 117 | 981 | 202184 | 204030 | |
| 300 | RF | 0.0000 | 0.0001 | 0.0001 | 0.0001 | 0.0003 | 0.0000 | 0.0001 | 0.0005 | 0.0001 | 0.0010 | 0.0054 | 0.0076 | |
| | N | 3 | 11 | 12 | 23 | 60 | 9 | 25 | 96 | 29 | 198 | 1120 | 1586 | |
| 200 | RF | 0.0001 | 0.0001 | 0.0003 | 0.0002 | 0.0002 | 0.0001 | 0.0004 | 0.0008 | 0.0002 | 0.0009 | 0.0023 | 0.0057 | |
| | N | 14 | 26 | 71 | 31 | 100 | 13 | 73 | 160 | 42 | 181 | 483 | 1194 | |
| 100 | RF | 0.0001 | 0.0003 | 0.0005 | 0.0002 | 0.0006 | 0.0001 | 0.0005 | 0.0005 | 0.0001 | 0.0003 | 0.0003 | 0.0035 | CAT II |
| | N | 30 | 53 | 108 | 49 | 131 | 15 | 94 | 98 | 19 | 52 | 72 | 721 | |
| 0 | RF | 0.0006 | 0.0004 | 0.0005 | 0.0001 | 0.0002 | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0019 | CAT IIIa |
| | N | 134 | 81 | 94 | 16 | 36 | 5 | 11 | 5 | 1 | 2 | 8 | 393 | |
| | | 0 | 1/16 | 1/8 | 3/16 | 1/4 | 5/16 | 3/8 | 1/2 | 5/8 | 3/4 | 1+ | ALL | |

**VISIBILITY (MILES)**

FIGURE 15

# NEW YORK (JAN. - FEB.)

| ALL WEATHER LANDING CATEGORIES | | IIIc | IIIb | IIIa | | II | | | I | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CEILING (Feet) 400+ | RF | 0.0003 | | | | | | | | | | | | CAT I |
| | N | 9 | 6 | 9 | 7 | 45 | 8 | 30 | 134 | 37 | 303 | 32074 | 32662 | |
| 300 | RF | 0.0001 | | | | | | | | | | | | |
| | N | 2 | 4 | 5 | 9 | 19 | 3 | 10 | 27 | 12 | 62 | 237 | 390 | |
| 200 | RF | 0.0002 | | | | | | | | | | | | |
| | N | 5 | 5 | 23 | 10 | 22 | 1 | 16 | 46 | 11 | 44 | 105 | 288 | |
| 100 | RF | 0.0004 | | | | | | | | | | | | CAT II |
| | N | 12 | 24 | 34 | 18 | 38 | 4 | 27 | 25 | 4 | 6 | 14 | 206 | |
| 0 | RF | 0.0019 | 0.0011 | 0.0008 | 0.0001 | 0.0002 | 0.0001 | 0.0001 | 0.0001 | 0.0000 | 0.0000 | 0.0001 | 0.0043 | CAT IIIa |
| | N | 65 | 37 | 27 | 3 | 6 | 2 | 2 | 2 | 0 | 0 | 2 | 146 | |
| | | 0 | 1/16 | 1/8 | 3/16 | 1/4 | 5/16 | 3/8 | 1/2 | 5/8 | 3/4 | 1+ | ALL | |

**VISIBILITY (MILES)**

FIGURE 16

# PHILADELPHIA - ALL SEASONS

| ALL WEATHER LANDING CATEGORIES | | IIIc | IIIb | IIIa | | II | | | I | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CEILING (Feet) 400+ | RF | 0.0001 | 0.0004 | 0.0004 | 0.0001 | 0.0007 | 0.0000 | 0.0003 | 0.0022 | 0.0003 | 0.0005 | 0.9769 | 0.9860 | CAT I |
| | N | 6 | 27 | 28 | 9 | 46 | 2 | 19 | 151 | 18 | 328 | 67773 | 68407 | |
| 300 | RF | 0.0000 | 0.0001 | 0.0001 | 0.0000 | 0.0004 | 0.0000 | 0.0001 | 0.0001 | 0.0001 | 0.0012 | 0.0028 | 0.0058 | |
| | N | 0 | 5 | 10 | 1 | 26 | 1 | 9 | 66 | 7 | 86 | 191 | 402 | |
| 200 | RF | 0.0000 | 0.0002 | 0.0005 | 0.0001 | 0.0006 | 0.0000 | 0.0001 | 0.0007 | 0.0000 | 0.0006 | 0.0009 | 0.0036 | |
| | N | 0 | 11 | 32 | 6 | 38 | 1 | 10 | 48 | 3 | 40 | 60 | 249 | |
| 100 | RF | 0.0000 | 0.0005 | 0.0006 | 0.0001 | 0.0004 | 0.0000 | 0.0001 | 0.0004 | 0.0000 | 0.0000 | 0.0001 | 0.0022 | CAT II |
| | N | 1 | 34 | 42 | 9 | 25 | 0 | 9 | 26 | 0 | 3 | 6 | 155 | |
| 0 | RF | 0.0009 | 0.0006 | 0.0005 | 0.0001 | 0.0002 | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0024 | CAT IIIa |
| | N | 60 | 41 | 35 | 5 | 16 | 0 | 5 | 2 | 0 | 0 | 0 | 164 | |
| | | 0 | 1/16 | 1/8 | 3/16 | 1/4 | 5/16 | 3/8 | 1/2 | 5/8 | 3/4 | 1+ | ALL | |

**VISIBILITY (MILES)**

FIGURE 17

# PHILADELPHIA - (NOV. - DEC.)

| ALL WEATHER LANDING CATEGORIES | | IIIc | IIIb | IIIa | | II | | | I | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CEILING (Feet) 400+ | RF | 0.0000 | | | | | | | | | | | | |
| | N | 4 | 11 | 13 | 1 | 19 | 0 | 5 | 49 | 7 | 106 | 11134 | 11349 | |
| 300 | RF | 0.0000 | | | | | | | | | | | | CAT I |
| | N | 0 | 2 | 2 | 0 | 4 | 0 | 3 | 15 | 4 | 26 | 31 | 87 | |
| 200 | RF | 0.0000 | | | | | | | | | | | | |
| | N | 0 | 5 | 6 | 0 | 11 | 1 | 5 | 12 | 1 | 11 | 8 | 60 | |
| 100 | RF | 0.0000 | | | | | | | | | | | | CAT II |
| | N | 0 | 16 | 12 | 3 | 3 | 0 | 2 | 7 | 0 | 0 | 0 | 43 | |
| 0 | RF | 0.0025 | 0.0006 | 0.0004 | 0.0001 | 0.0004 | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0041 | CAT IIIa |
| | N | 29 | 7 | 5 | 1 | 5 | 0 | 1 | 0 | 0 | 0 | 0 | 48 | |
| | | 0 | 1/16 | 1/8 | 3/16 | 1/4 | 5/16 | 3/8 | 1/2 | 5/8 | 3/4 | 1+ | ALL | |

**VISIBILITY (MILES)**

FIGURE 18

# OCCURRENCE OF ALL WEATHER LANDING CATEGORIES OF WEATHER
# 1949-1958 (0600-2400)
# N. E. CORRIDOR

| | BOSTON | | WASHINGTON | | NEW YORK – 3 | | PHILADELPHIA | | NE CORRIDOR ALL STATIONS | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. | % | No. | % | No. | % | No. | % | No. | % |
| Total Observations | 69385 | 100. | 69369 | 100. | 207924 | 100. | 69377 | 100. | 1586627 | 100. |
| | | | | | | | | | | |
| Total Cat I | 68934 | 99.35 | 69052 | 99.543 | 206054 | 99.101 | 69173 | 99.705 | 1562558 | 98.484 |
| | | | | | | | | | | |
| Total Cat II | 269 | 0.390 | 147 | 0.212 | 963 | 0.463 | 221 | 0.318 | 9535 | 0.601 |
| | | | | | | | | | | |
| Total Cat IIIa | 104 | 0.151 | 131 | 0.189 | 512 | 0.246 | 200 | 0.288 | 7030 | 0.443 |
| IIIb | 49 | 0.0711 | 36 | 0.052 | 192 | 0.0925 | 118 | 0.170 | 3162 | 0.199 |
| IIIc | 29 | 0.042 | 3 | 0.004 | 203 | 0.0975 | 67 | 0.096 | 4342 | 0.273 |
| | | | | | | | | | | |
| Total Cat III | 182 | 0.264 | 170 | 0.245 | 907 | 0.436 | 385 | 0.554 | 14534 | 0.915 |

FIGURE 19

# OCCURRENCE OF ALL WEATHER LANDING CATEGORIES OF WEATHER
# 1949-1958 (0600-2400)
# N.E. CORRIDOR

| | NEW YORK | | WASHINGTON NATIONAL | | PHILADELPHIA | | BOSTON | | ALL STATIONS | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. | % | No. | % | No. | % | No. | % | No. | % |
| Total Observations | 33692 | 100. | 11584 | 100. | 11587 | 100. | 11247 | 100. | 257632 | 100. |
| Cat I | 33092 | 98.219 | 11447 | 98.817 | 11404 | 98.420 | 11142 | 99.066 | 251766 | 97.723 |
| Cat II | 272 | 0.807 | 51 | 0.440 | 60 | 0.518 | 48 | 0.427 | 2419 | 0.939 |
| Cat IIIa | 159 | 0.472 | 67 | 0.578 | 49 | 0.423 | 27 | 0.240 | 1589 | 0.617 |
| IIIb | 76 | 0.226 | 18 | 0.155 | 39 | 0.337 | 16 | 0.142 | 751 | 0.292 |
| IIIc | 93 | 0.276 | 1 | 0.009 | 33 | 0.285 | 14 | 0.124 | 1070 | 0.415 |
| Total Cat III | 328 | 0.974 | 86 | 0.742 | 121 | 1.044 | 57 | 0.507 | 3410 | 1.324 |

## - WORST TWO MONTHS -

FIGURE 20