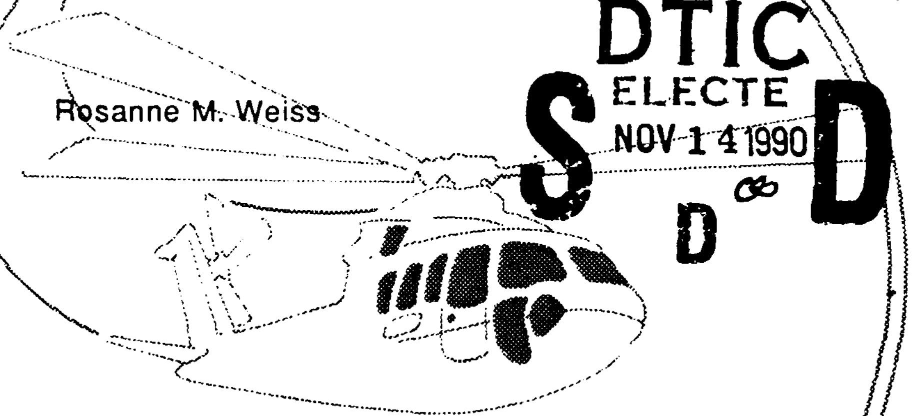
# Analysis of Heliport Environmental Data; Intracoastal City



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July 1990

DOT/FAA/CT-TN89/43

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16. Abstract


During a 2-day period in May 1988, heliport environmental data were collected at Petroleum Helicopter Incorporated's Heliport in Intracoastal City, LA. The purpose of this data collection activity was to gather measurements of rotorwash at a heavy use heliport frequented by larger helicopters with higher gross weights than observed during previous data collection activities. The previous data collection activities are documented in Technical Note DOT/FAA/CT-TN87/54, I, titled, "Analysis of Heliport Environmental Data: Indianapolis Downtown Heliport, Wall Street Heliport, Volume I, Summary." During this operation, ten wind vector transmitters were situated at various locations around the facility in order to gather information to describe the rotorwash induced wind speed and wind direction changes.

This report documents the results of this data collection activity. The data collection and analysis methodology are explained. Graphical presentations of the heliport environment and of rotorwash induced wind speeds and wind speed and direction changes are included. The Concepts Analysis Division Report, ACD-330-89-10, "Analysis of Heliport Environmental Data, Intracoastal City, LA," contains the heliport wind speed and direction plots for each flight.

The results of this study will be considered in future modifications of the Federal Aviation Administration (FAA) Heliport Design Advisory Circular (AC) 150/5390-2.


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TABLE OF CONTENTS

## LIST OF ILLUSTRATIONS

## LIST OF TABLES

# EXECUTIVE SUMMARY

During 2 days in May 1988, heliport environmental data were collected at Petroleum Helicopter Incorporated's Heliport in Intracoastal City, LA. The purpose of this data collection activity was to collect data to obtain unobtrusive operational measures of rotorwash from maneuvering helicopters at a heavy use facility frequented by larger/heavier helicopters than those seen during previous data collection activities at New York's Wall Street Heliport and Indianapolis Downtown Heliport during the summer of 1987 (see Technical Report DOT/FAA/CT-TN87/54, I, "Analysis of Helicopter Environmental Data: Indianapolis Downtown Heliport, Wall Street Heliport Volume I Summary"). The two parameters collected were wind speed and wind direction.

Ten wind vector transmitters were placed strategically around the facility in order to collect data from the most active pads as well as from the normal approach/departure area. The data collection activity was conducted only during daylight hours under visual meteorological conditions. Other observations such as visibility, surface winds, type rotorcraft in operation, type maneuver, estimated hover heights, and path of the aircraft were recorded by the data collection team.

This report documents the results of this activity. The locations of the sensors around the heliport, the heliport environment in terms of wind speed and direction, expert observations, and data collection procedures are described. Data plots of the two parameters as well as for changes in speed and direction due to the operating aircraft are included.

It was determined that, for the larger/heavier helicopters observed during this test period, high wind velocities due to helicopter rotorwash occur a significant percentage of the time at the surface. In addition, it was observed that the winds generated by these helicopters had a greater impact on surface wind direction than on wind speed. The forward movement of the aircraft had a greater impact on wind direction shifts than on velocity shifts.

One aspect not consider in this data collection activity was the effects of multiaircraft operations in close proximity to one another. Therefore, additional wind sensor data collection activities will be planned to study this issue.

# INTRODUCTION

## PURPOSE.

This report examines the emvironmental data, wind speed and direction, collected at a private use heliport at Intracoastal City , Lousiana (LA), in order to more fully explore rotorwash during rotorcraft operations. The "Heliport Parking, Taxiing, and Landing Area Criteria Test Plan," DOT/FAA/CT-TN87/10, addressed issues concerning rotorcraft separation in ground maneuver areas at heliports. One issue discussed in DOT/FAA/CT-TN87/10, involved the measurement of rotorwash due to rotorcraft maneuvering in parking and taxiing areas.

## OBJECTIVE.

The objective of this data collection activity was to obtain unobtrusive operational measures of the heliport environment in terms of wind speed and direction changes due to rotorwash from maneuvering helicopters. The measures will be used to develop characteristic vertical profiles of the rotorcraft induced wind velocities under varying environmental conditions. Other uses of the data include the development of heliport design and construction considerations that take into account rotorwash effects.

## BACKGROUND.

The focus of this data collection activity was the measurement of maneuvering helicopter rotorwash in the heliport environment. Guidelines concerning clearances in the parking areas and in relation to taxi routes are spelled out in the current Federal Aviation Administration (FAA) Heliport Design Advisory Circular (AC 150/5390-2). These guidelines were based on pilot experience, tempered with engineering judgement, with little actual environmental data used to support the decisions made. The guidelines may or may not reflect the clearances actually required for surface operations, or desired by rotorcraft pilots. The issue of rotorwash impact on helicopter control and stability and its effect on required or desired separation criteria was examined by the FAA Technical Center in the summer of 1987. Results of that data collection activity were reported in DOT/FAA/CT-TN87/54, I, "Analysis of Heliport Environmental Data: Indianapolis Downtown Heliport, Wall Street Heliport, Volume I Summary." From preliminary analysis of the Indianapolis and Wall Street data and from further discussions with rotorcraft related organizations, it was determined that subsequent data collection should be conducted at a heavy use facility frequented by larger/heavier helicopters.

# METHODS

## DATA COLLECTION.

LOCATION. Environmental data were collected at Petroleum Helicopters Incorporated's (PHI) Heliport in Intracoastal City, LA, over a 2-day period in May 1988. This location was chosen based on the number and type of operations that occur there everyday.

PROCEDURES. Ten Belfort Instrument Company wind vector transmitters were used to collect wind data during rotorcraft maneuvers at the heliport. These transmitters consist of two major elements: an upper section containing a wind speed generator attached to an airplane rudder shaped vane, and a fixed, vertical support and connector housing. The wind speed generator is housed in a weatherproof housing and is driven by a six-blade propeller. The transmitter senses both wind speed and direction. These measurements are converted into two direct current (dc) voltages, one of which is a sine value and the other a cosine value. From the sine and cosine values, wind speed and wind direction can be calculated. The sensors were connected to an interface system which provided the data to a Zenith personal computer (PC). The data were as collected at 30 hertz (Hz). The PC was programmed to read the sine and cosine sensor values, sensor number, and time in a chronological manner. Photographs of the sensors are presented in appendix A.

The ten sensors were placed strategically around the heliport in order to collect data from the parking pads which experienced the most activity, as well as from the normal approach/departure area. A drawing of the heliport showing the locations of these sensors along with separation distances from each other and from ground facilities is found in figure 1. Two sensors were placed in front of parking pads B-1 and C-1. These two pads are used for heavy helicopter operations. One sensor was placed in front of each of the following pads: C-2, C-3, B-2, and B-3. These four helipads were used for smaller helicopter operations. The wind speed generators were approximately 20 inches above the ground.

The data collection system was operational during daylight hours only. The weather was visual flight rules (VFR) with clear skies and temperatures reaching a high of 90 degrees. The winds were calm during the data collection period.

Measurements were taken of the distances between the helipads as well as the distances each sensor was from its corresponding coverage area. These measurements will aid in analysis of rotorwash dispersion across the surface. Ground photos were taken of the ground facilities to aid in the discussion of sensor placement.

OBSERVATIONS. The observers were responsible for recording the following information for each operation:

Visibility and winds
Type rotorcraft
Type maneuver
Hover/taxi height
Path of the helicopter during the maneuver and lateral displacement
Chronological history for each maneuver

The observers began the data collection before the helicopter began maneuvering and stopped data collection after the helicopter either left the area or shut down. When the helicopter passed near each sensor the observer entered an event mark into a data file on the PC. Aircraft type, hover height, and observed path of the helicopter were noted on the heliport map.

ROTORCRAFT TYPES.

During the 2-day period, data were collected for 100 operations. Many times the surface environment was at or near capacity, with four or five helicopters operating simultaneously. Data were recorded for 11 different rotorcraft types. A breakdown of rotorcraft operations by type is found in table 1.

TABLE 1. TYPE ROTORCRAFT AND NUMBER OF OPERATIONS

| Aircraft Type | Number of Operations |
|---|---|
| Aerospatiale Astar | 19 |
| Aerospatiale Twin Star | 11 |
| Bell 212 | 5 |
| Bell 214ST | 8 |
| Bell 222UT | 2 |
| Bell 412 | 1 |
| Bell Jet Ranger | 13 |
| Bell Long Ranger | 15 |
| Boelkow 105 | 14 |
| Puma | 1 |
| Sikorsky S-76B | 11 |
| Total | 100 |

## DATA PROCESSING AND ANALYSIS

ROTORCRAFT GROUPINGS.

The helicopters were grouped into the same weight classes as used in DOT/FAA/CT-TN87/54, I, which documents the data collection activity conducted at New York's Wall Street Heliport and Indianapolis Downtown Heliport. The breakdown of the aircraft by weight class is found in table 2.

TABLE 2. OBSERVED ROTORCRAFT CLASSIFIED BY GROSS WEIGHT

| 3000-7000 lbs | $\geq$7000 lbs |
|---|---|
| Astar | Bell 212 |
| Boelkow 105 | Bell 214ST |
| Jet Ranger | Bell 222UT |
| Long Ranger | Bell 412 |
| Twin Star | Puma |
| | Sikorsky S-76B |

SENSOR GROUPINGS.

Due to wind and operational conditions the approach and departure patterns flown during the observation period varied. Therefore, for the purposes of data processing and analysis, the sensors were grouped into seven possible configurations based on which sensors were active due to the helicopter's movement. Table 3 lists these configurations.

TABLE 3. SENSOR USAGE FOR DIFFERENT ACTIVITY PATTERNS

| Configuration | Active Sensors | Applicable Activity |
|---|---|---|
| A | 1 - 10 | Both Classes Approaches + Departures |
| B | 5, 6, 9, 10 | 3000-7000 lb Approaches + Departures |
| C | 2 - 10 | Both Weight Classes- Departures |
| D | 1 - 6 | Both Approaches, 3000-7000 lb Departures |
| E | 1 - 4, 7, 8 | >7000 lb Approaches, 3000-7000 lb Departures |
| F | 1, 2, 7, 8 | Both Approaches, >7000 lb Departures |
| G | 1 - 8 | 3000-7000 lb Taxi Operations |

As seen in table 3, configurations A, B, D, E, and F are applicable to both approaches and departures, while C is applicable to departures only and G to taxi operations. The figures in appendix A depict the aircraft's paths for each configuration.

Data analysis procedures also subdivided the configurations into sensor groupings. Table 4 lists these subdivisions with applicable sensor configurations.

TABLE 4. SENSOR GROUPINGS BY CONFIGURATION

| Sensor Grouping | Applicable Configuration |
|---|---|
| 1,2 | A, D, E, F, G |
| 3,4 | D, E, G |
| 5,6 | D, G |
| 7,8 | E, F, G |
| 3,4,7,8 | A, C |
| 5,6,9,10 | A, B, C |
| 2 Only | C |

These groupings represent particular areas of coverage: 1, 2 covered the approach/departure area; 3, 4 the area around pad C1; 5, 6 the area from the edge of pad C2 to the far edge of C3; 7, 8 the area around pad B1; 3, 4, 7, 8 the area of coverage between C1 and B1; 5, 6, 9, 10 the area between C2, C3 and B2, B3; and sensor 2 only for operations to the far right of the approach/departure area. These areas are shown in figure 1.

GRAPHICAL AND TABULAR ANALYSIS.

Plots were produced for this data using a California Computer's Calcomp model 1051 drum plotter using Calcomp 907 software for the Digital Equipment Corporation (DEC) VAX 11/750 minicomputer. The individual plots generated were divided into two types: wind direction with speed and wind direction with order of collection.

The wind direction with wind speed plots show a vector representing wind direction with a numerical value printed at the end of each vector indicating the wind speed in knots. The second type plot shows the wind direction line with the numerical value indicating the order of collection. Examples of each of these plots are found in figures 2 and 3.

The 100-knot change near sensors 5 and 6 was most likely due to the aircraft making a high approach over the initial portion of coverage area and then settling down near pad C3.

For the larger aircraft, the figures for velocity changes ranged from less than 1 percent near the approach area to 5 percent between pads B1 and C1. Actual changes ranged from 76 knots near the approach area and near pad C1, to 86 knots between pads C3 and D3.

During Departures. Plots of the distribution for wind velocity changes during departure operations are found in figures 11 and 12.

Velocity changes were less than 11 knots at least 70 percent of the time for both classes of aircraft with configurations D, E, and F and with configurations A and C for the 3000-7000 lb aircraft. For 7000+ lb aircraft, configurations A and C, and 3000-7000 lb aircraft, configuration B, at least 55 percent of the generated velocity changes were less than 11 knots.

The percentage of higher (>10 kts) velocity changes were observed in the areas covered by sensors 5, 6, 9, and 10 during departures in which these sensors were activated, and between pads B1 and C1 (sensors 3, 4, 7, and 8) during the larger aircraft departures for configuration C.

The maximum changes in velocity for all coverage areas, ranged from 12 to 85 knots across all coverage areas for 3000-7000 lb aircraft, and from 36 to 98 knots for the larger helicopters. The maximum velocity change (98 knots) was seen during departures by the larger aircraft near pad B1.

The percentage of large wind speed changes (> 41 kts) during 3000-7000 lb departures ranged from less than 1 percent near sensors 1 and 2, to 6 percent in the area covered by sensors 5, 6, 9, and 10. For the larger helicopters the percentages ranged from 3 to 11 percent. The highest percentage was seen near sensors 3, 4, 7, and 8.

During Taxi Operations. Plots for the wind velocity changes for taxiing operations are found in figure 13. Taxiing data were collected for only the 3000-7000 lb aircraft. Velocity changes of 11 knots or less were observed at least 86 percent of the time. No more than 2 percent of the observed velocity changes were greater than 41 knots.

Table 6 contains the maximum observed wind speed changes for each area, along with the procedure that produced those velocity changes.

TABLE 6. OBSERVED MAXIMUM WIND SPEED CHANGES BY HELIPORT AREA

| Area | Sensors | Maximum Change | Maneuver/Procedure |
|---|---|---|---|
| T/L | 1,2 | 95.67 | >7000 lb Aircraft Departure |
| P C1 | 3,4 | 89.26 | >7000 lb Aircraft Approach |
| P C2, C3 | 5,6 | 100.44 | 3000-7000 lb Aircraft Approach |
| P B1 | 7,8 | 98.10 | >7000 lb Aircraft Departure |
| P B2, B3 | 9,10 | 83.84 | 3000-7000 lb Aircraft Approach |

Other C calcomp plots were produced showing the percentage of actual observed windspeeds at each 5-knot interval and the percentages of observed wind speed changes by 5-knot intervals. These plots present approach, departure and taxi operations data by helicopter weight class for each applicable sensor pattern. Plots of the percentages of wind direction changes by 10° intervals for each pattern were also produced.

## RESULTS

WIND SENSOR DATA.

All wind sensor plots for these data are included in Concepts Analysis Division Report, ACD-330-89-10, "Analysis of Heliport Environmental Data, Intracoastal City, LA." Appendixes A to E contain the plots showing wind direction with order of collection, while appendixes F to J contain plots with wind direction and wind speed (see figures 2 and 3 for sample plots). For this data collection activity, an operation period is defined as the time period from just prior to the aircraft's initiating a maneuver to the time when the aircraft either touched down or flew out of the area.

As seen in table 2 the aircraft at Intracoastal City were representative of only two of the three weight classes examined in the previous data collection activities in New York and Indianapolis (Technical Note DOT/FAA/CT-TN87/54).

ACTUAL WIND SPEEDS. These data were obtained directly from the sensor measurements.

During Approaches. Figure 4 contains plots of the observed wind speeds during operational periods for 3000-7000 lb aircraft approaches, for the appropriate sensor configurations, while figure 5 contains similar plots for >7000 lb aircraft approaches.

The average time for each approach operation for the 3000-7000 lb aircraft, with configurations A, B, D, and F, lasted from 25.3 to 34 seconds. For the larger weight class the average times of approach operations ranged from 22.9 to 31.7 seconds for applicable configurations A, D, E, and F.

For both weight classes with configuration A, at least 65 percent of the approaches generated less than 11 knots of wind for all sensor coverage areas. With configurations B, D, and E, for both weight classes and with configuration F for the larger aircraft, the percentage of low wind conditions (<11 knots) during approaches occurred 50 to 84 percent of the time. With configuration F for 3000-7000 lb aircraft, the percentage of winds (<11 knots) was at least 72 percent.

For approach configurations A, D, E, and F, regardless of aircraft weight, larger percentages of the high wind conditions (> 20 knots) were observed in the area of coverage between pads C1 and B1. Smaller proportions of high wind conditions were seen in the area covered by sensors 1 and 2 when these sensors were activated by the approach (configurations A, D, E, and F). During the approach for both weight classes, the aircraft was out of ground effect at this area of coverage, with an average height of 20 feet above ground level (AGL), while at the middle area covered by sensors 3, 4, 7, and 8 the aircraft was much lower, 10 to 15 feet AGL; thus, the sensors in this area showed larger winds. However, for approaches in which all ten sensors were activated (configuration A), the percentages and distribution of high wind conditions were similar across all three groupings. The duration of these high wind conditions ranged from 1 to 10 seconds per approach operation. These conditions occurred, at most, 30 percent of the period for smaller helicopters, and, at most, 40 percent for larger helicopters.

The percentages of observed wind speeds greater than 41 knots for 3000-7000 lb class approaches for all sensor configurations ranged from less than 1 percent for the area covered by sensors 1 and 2, to 13 percent for the area covered by sensors 5, 6, 9, and 10. The maximum observed winds during approach operations for each sensor grouping ranged from 90 knots at the area covered by sensors 1 and 2, to 106 knots near sensors 5, 6, 9, and 10. The maximum wind speed observed for the middle area covered by sensors 3, 4, 7, and 8 ranged from 83 to 89 knots.

For approaches by the larger aircraft, the percentages of observed wind velocities >41 knots ranged from 5.5 percent near sensors 1 and 2, to 16 percent near sensors 3 and 4. The actual winds observed ranged from 90 knots in the vicinity of sensors 1 and 2, to 98 knots near sensors 3 and 4. The maximum speed for the larger aircraft in the vicinity of sensors 3, 4, 7, and 8 was as much as 97 knots.

<u>During Departures</u>. Plots of actual wind speeds for 3000-7000 lb helicopter departures, for each applicable sensor configuration, are found in figure 6. Figure 7 contains departure plots of actual wind speed for the larger helicopters. For the 3000-7000 lb aircraft, the average time for a departure ranged from 25 to 34 seconds. The average time for a departure for the larger aircraft ranged from 17 to 34 seconds.

The percentage of occurrences of the higher wind (>20 knots) conditions observed for all departure operations at each measured area were similar or slightly larger than that seen for the approaches. Most of these higher wind observations occurred in the vicinity of pads B2, B3, C2, and C3. The sensors covering these areas included sensors 5, 6, 9, and 10. However, when the aircraft lifted off near pads C1 and B1, in the areas covered by sensors 3 and 4 or 7 and 8, higher wind speeds were also more prevalent. In the vicinity of the liftoff areas, wind speeds as high as 112 knots were seen. The duration of these greater than 20-knot wind conditions during departures lasted as long as 14 seconds, which corresponded to, at most, 34 percent of the period for the 3000-7000 lb helicopters and 36 percent for the larger helicopters. These high wind conditions can be explained by the helicopter having low airspeed (below translational lift) during initial liftoff activity.

The percentage of observed winds greater than 41 knots for the 3000-7000 lb departures for all areas ranged from less than 1 percent for sensors 1 and 2, to 8 percent for the area covered by sensors 5, 6, 9, and 10. The maximum speeds were from 41 knots at sensor 2, to 91 knots at sensors 5, 6, 9, and 10.

These figures were somewhat higher for the larger aircraft (>7000 lbs). The percentage of winds greater than 41 knots increased to as much as 17 percent near sensors 3, 4, 7, and 8. The area around sensors 1 and 2 also showed an increase in higher winds, up to 6 percent when the liftoff occurred at sensors 7 and 8. Maximum speeds reached 112 knots near sensors 7 and 8 during the liftoff period.

During Taxi Operations. Plots of observed wind speeds for taxi operations are found in figure 8. All observed taxi operations were conducted by the 3000-7000 lb aircraft. The average time for each taxi operation was 48 seconds. Over all the sensor groupings, at least 67 percent of the wind observations were less than 11 knots. The maximum observed wind was 86 knots near pad B1 (sensors 5 and 6). High wind conditions (>20 kts), averaged approximately 4 seconds per operation. At most, 3 percent of the observations were greater than 41 knots.

Maximum observed wind speeds for each area, along with the procedure that produced that speed, are reported in table 5.

TABLE 5. OBSERVED MAXIMUM WIND SPEEDS BY HELIPORT AREA

| Area | Sensors | Maximum Speed (knots) | Maneuver/Procedure |
|---|---|---|---|
| TO/LNDG | 1,2 | 97.81 | >7000 lb Aircraft Departure |
| PAD C1 | 3,4 | 97.28 | >7000 lb Aircraft Approach |
| PADS C2, C3 | 5,6 | 105.89 | 3000-7000 lb Aircraft Approach |
| PAD B1 | 7,8 | 112.58 | >7000 lb Aircraft Departure |
| PADS B2, B3 | 9,10 | 90.27 | >7000 lb Aircraft Approach |

CHANGES IN WIND SPEED. Another measure of the effect of rotorwash is the changes in wind speed observed during the operational periods. These changes were generated by comparing each wind speed measurement to the previous measure.

During Approaches. Plots of the distributions of wind velocity changes for approaches are found in figures 9 and 10.

Changes in wind speed were less than 11 knots at least 65 percent of the time for both weight classes with configuration A and F, with configuration D for 3000-7000 lb aircraft, and for the larger helicopters for configuration E. With configuration B for the 3000-7000 lb helicopters and configuration D for the larger helicopters, at least 50 percent of the approaches generated changes less than 11 knots.

The smallest proportion of high wind speed changes were seen in the area covered by sensors 1 and 2. As discussed previously, the aircraft was more likely to be out of ground effect at this area due to high approaches. However, when all sensors were activated by the approach, all areas of coverage showed similar large percentages of small wind speed changes.

The percentage of observed large wind speed changes (>41 kts), for 3000-7000 lb aircraft, for the approach area and between pads C1 and B1 was less than 1 percent. For the area between pads C2, B2 and C3, B3 it was 9 percent.

The maximum observed change for each sensor grouping ranged from 86 knots near the approach area (sensors 1 and 2) to 100 knots between pads C2 and C3 (sensors 5 and 6). For the areas near pads C1, C2, B1, and B2 (sensors 3, 4, 7, and 8), the maximum change observed was 83 knots.

CHANGES IN WIND DIRECTION. Since wind direction influences the amount of lift that can be generated, the changes in wind direction were also examined as a measure of rotorwash effect. These changes were calculated by comparing each measurement of direction to the previous measurement.

Figures 14 and 15 contain plots of the percentages of observed wind direction changes for approaches. Large shifts in wind direction (>30 degrees) were observed 70 percent or more of the time for both weight groupings near the area where the actual approach was made. That is, when the approach occurred near sensors 1 and 2, that area had the largest shifts; when it was made to the area covered by sensors 5, 6, 9, and 10 (between pads B3 and C3), that area had the percent of large direction shifts. At the other data collection locations these large shifts occurred anywhere from 20 to 66 percent of the time. The smallest percent of large direction variations was observed near pad B1 covered by sensors 7 and 8.

Plots of observed wind direction shifts for departures are found in figures 16 and 17. For departures with both weight groupings the large shifts were seen at least 79 percent of the time at the approach/departure area (sensors 1 and 2), when the departure actually took place near those sensors. When the helicopter actually lifted off near sensors 3, 4, 7, and 8, the largest percent of wind direction shifts were observed at that area.

Based on the location where the departure maneuver occurred, the wind shifts ranged from 40° to 180°. The percentage of these observed large wind shifts occurred as much as 89 percent of the period.

For the taxi operations, the largest percent of observed wind shifts greater than 30° (76 percent) was seen near sensors 1 and 2, the approach/departure area. These data are plotted in figure 18. All taxi operations saw wind shifts up to 180° with the percentage of shifts >51° ranging from 23 to 69 percent.

The large shifts near sensors 1 and 2 for all 3 types of operation can be explained by the aircraft's height above ground. Even though the aircraft is out of ground effect, the rotorwash still has a major effect on wind direction at the surface and up to a height of twice the rotor diameter. This effect is directly influenced by the helicopter's power setting.

## CONCLUSIONS

1. Wind velocities in excess of 20 knots occurred as much as 14 seconds per approach/departure operation. This corresponds to, at most, 40 percent of the total operation period. The significance of these wind velocities in relation to other aircraft, however, is dependent upon the weight class and type of aircraft operating in the vicinity.

2. The winds generated by the helicopter have a stronger effect on surface wind direction than on surface wind velocity when the helicopter is maneuvering out of ground effect. Forward movement of the helicopter in the approach or departure areas will have a greater effect on wind direction shifts than on wind velocity changes.

3. Since this data did not account for the effects of other aircraft operating in the vicinity of those being observed, additional data must be collected with aircraft operating nearby.

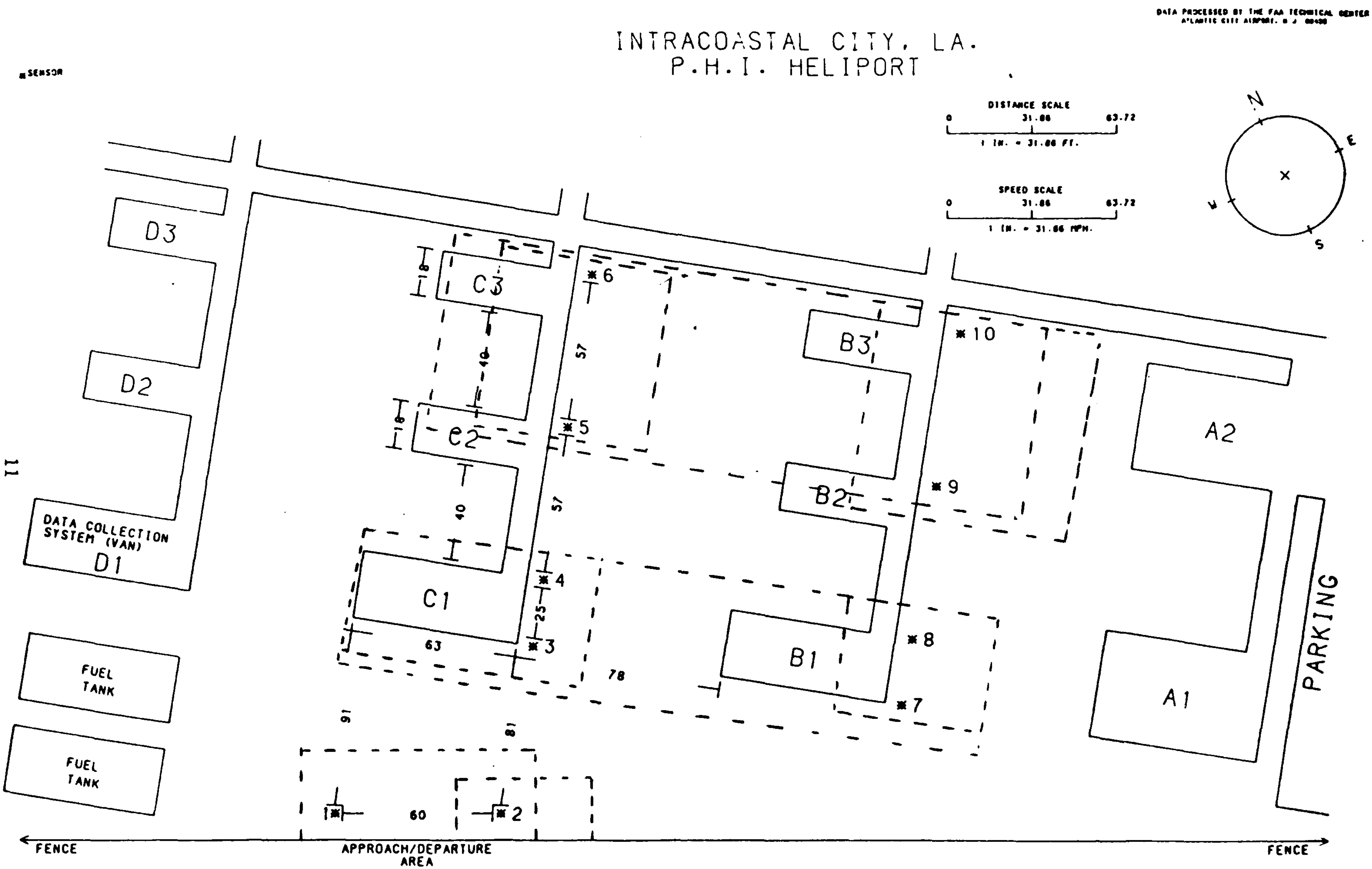



FIGURE 1. HELIPORT DRAWING

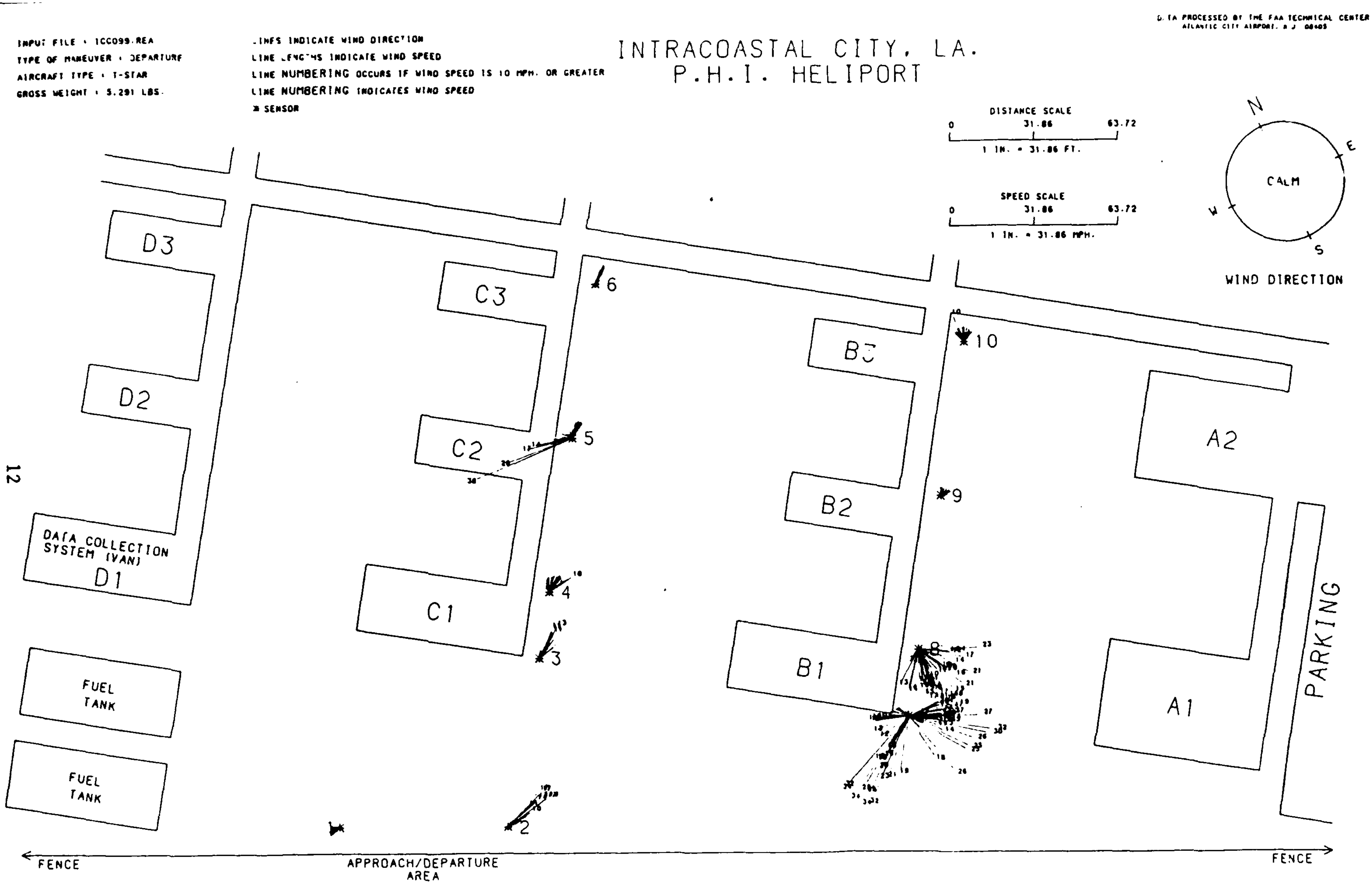



FIGURE 2. SAMPLE WIND DIRECTION/WIND SPEED PLOT

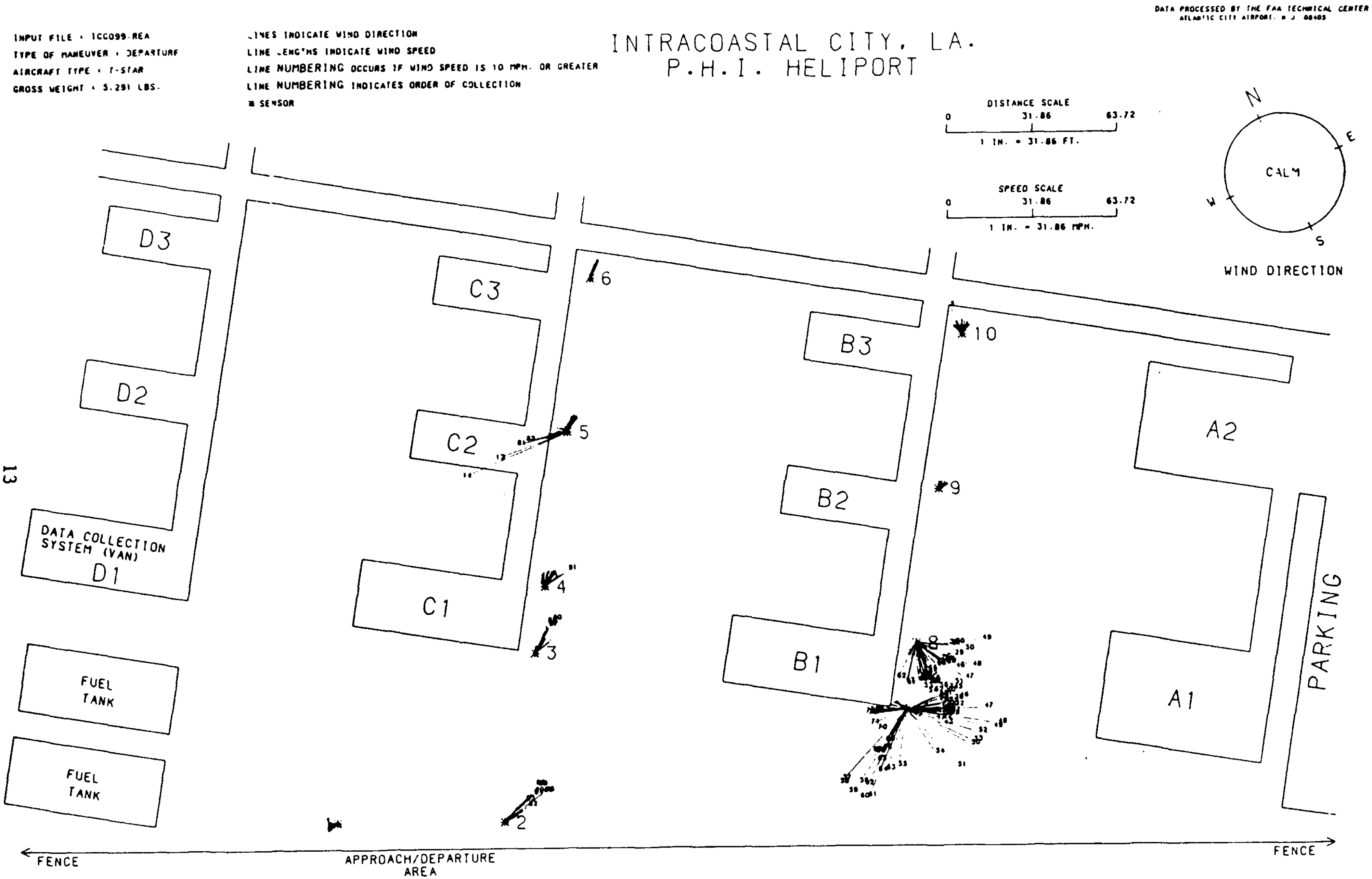



FIGURE 3. SAMPLE WIND DIRECTION/ORDER OF COLLECTION PLOT

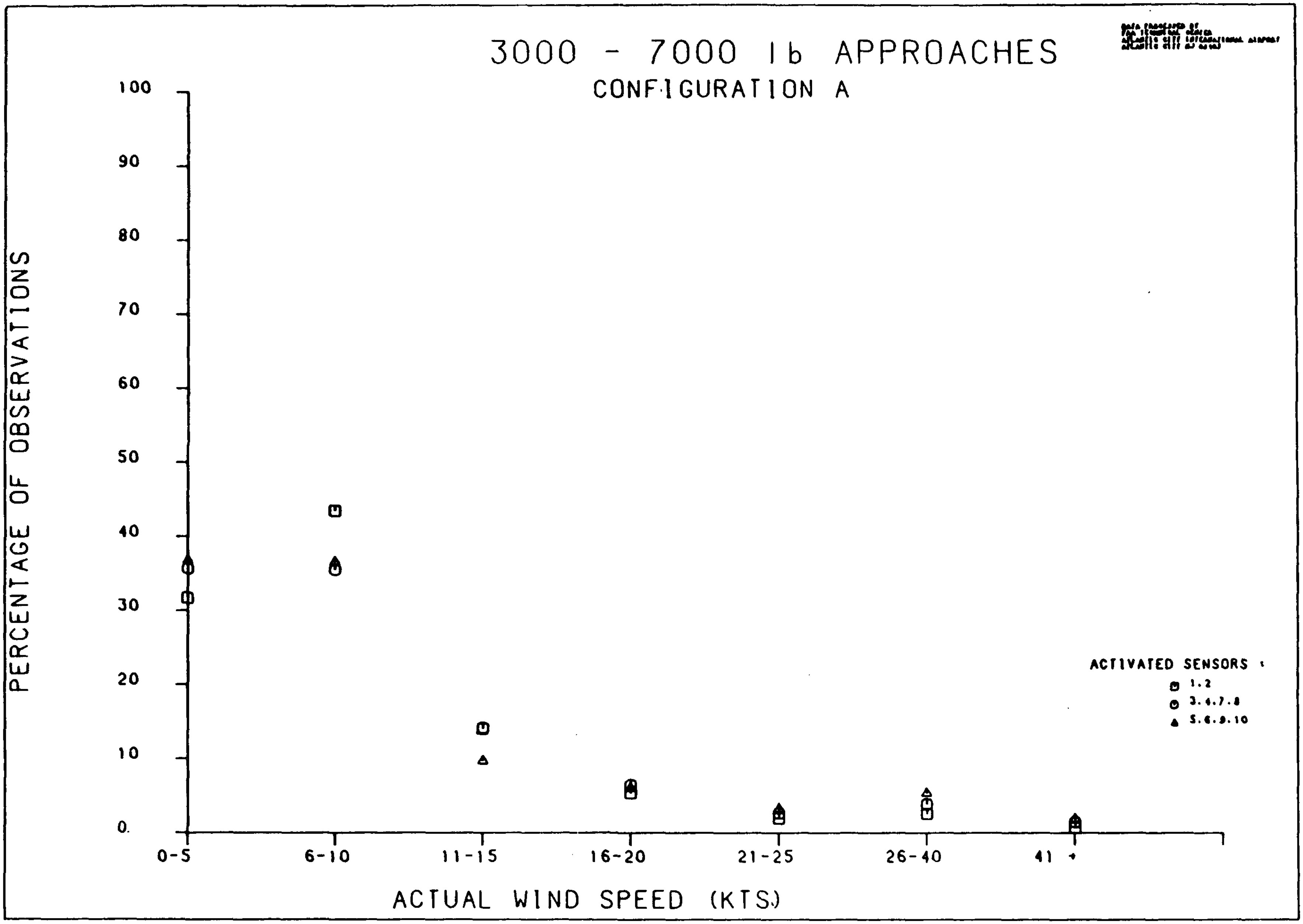



FIGURE 4. PLOTS OF OBSERVED WIND SPEEDS FOR 3000-7000 POUND AIRCRAFT APPROACHES (SHEET 1 OF 4)

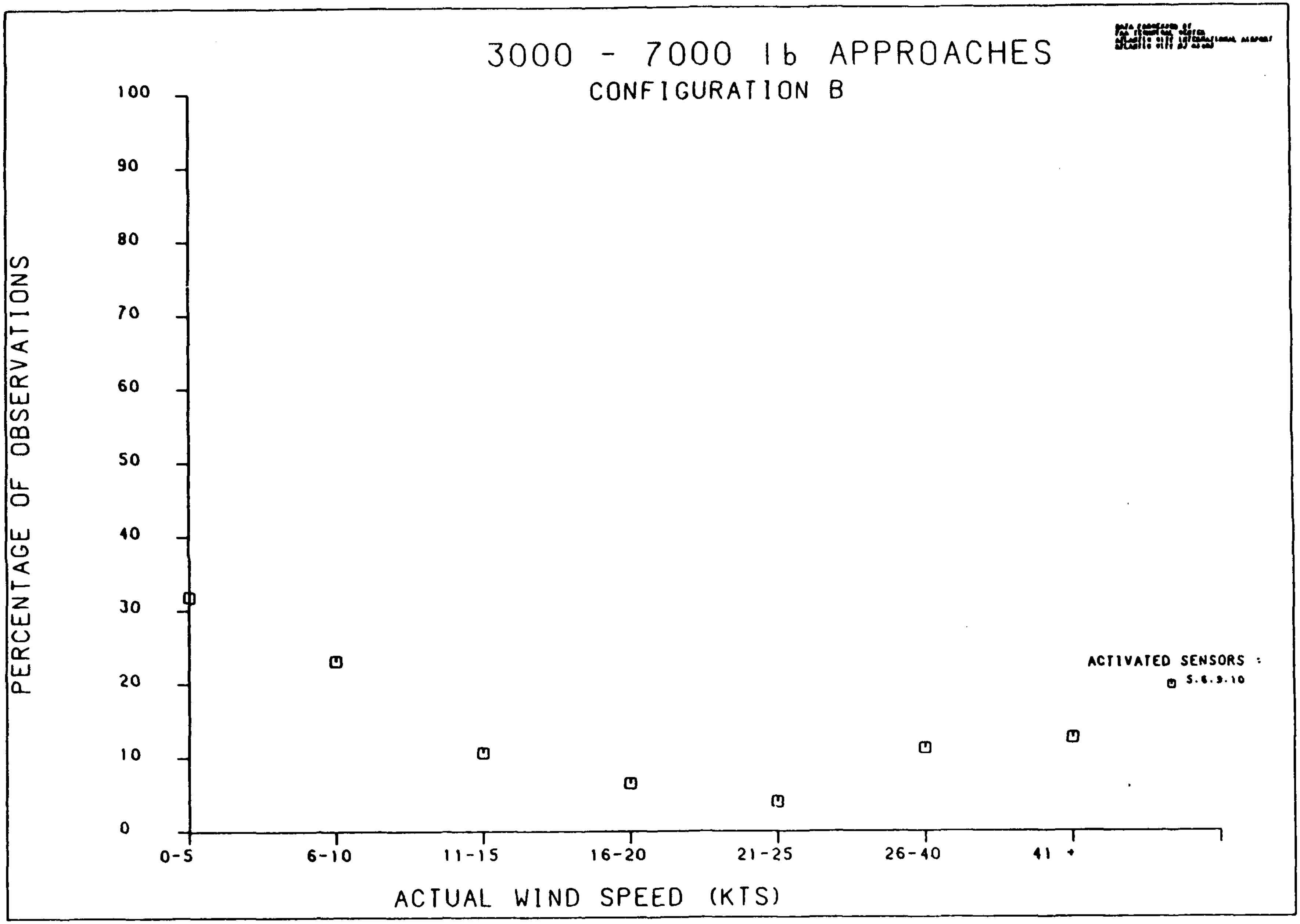



FIGURE 4. PLOTS OF OBSERVED WIND SPEEDS FOR 3000-7000 POUND AIRCRAFT APPROACHES (SHEET 2 OF 4)

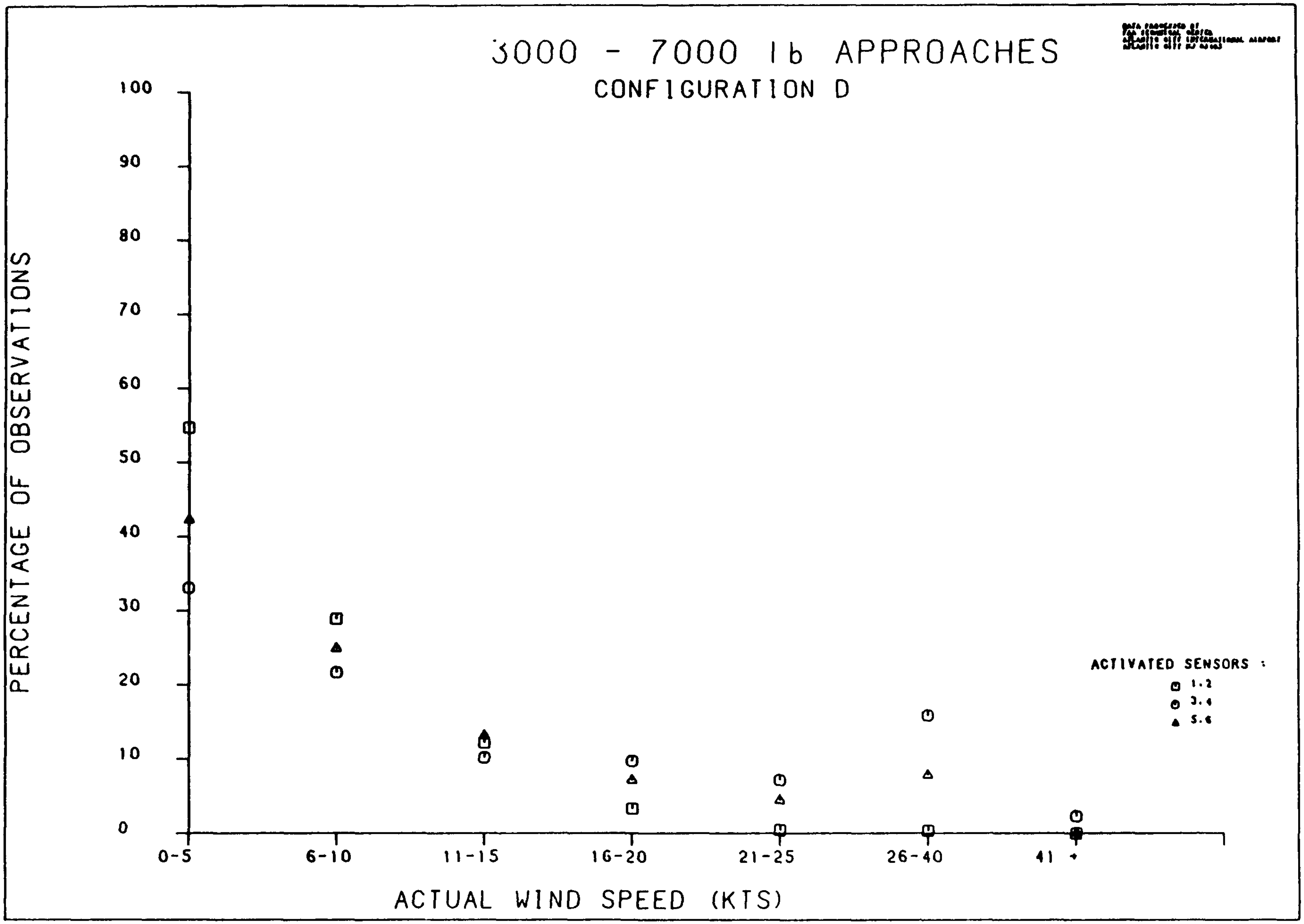



FIGURE 4. PLOTS OF OBSERVED WIND SPEEDS FOR 3000-7000 POUND AIRCRAFT APPROACHES (SHEET 3 OF 4)

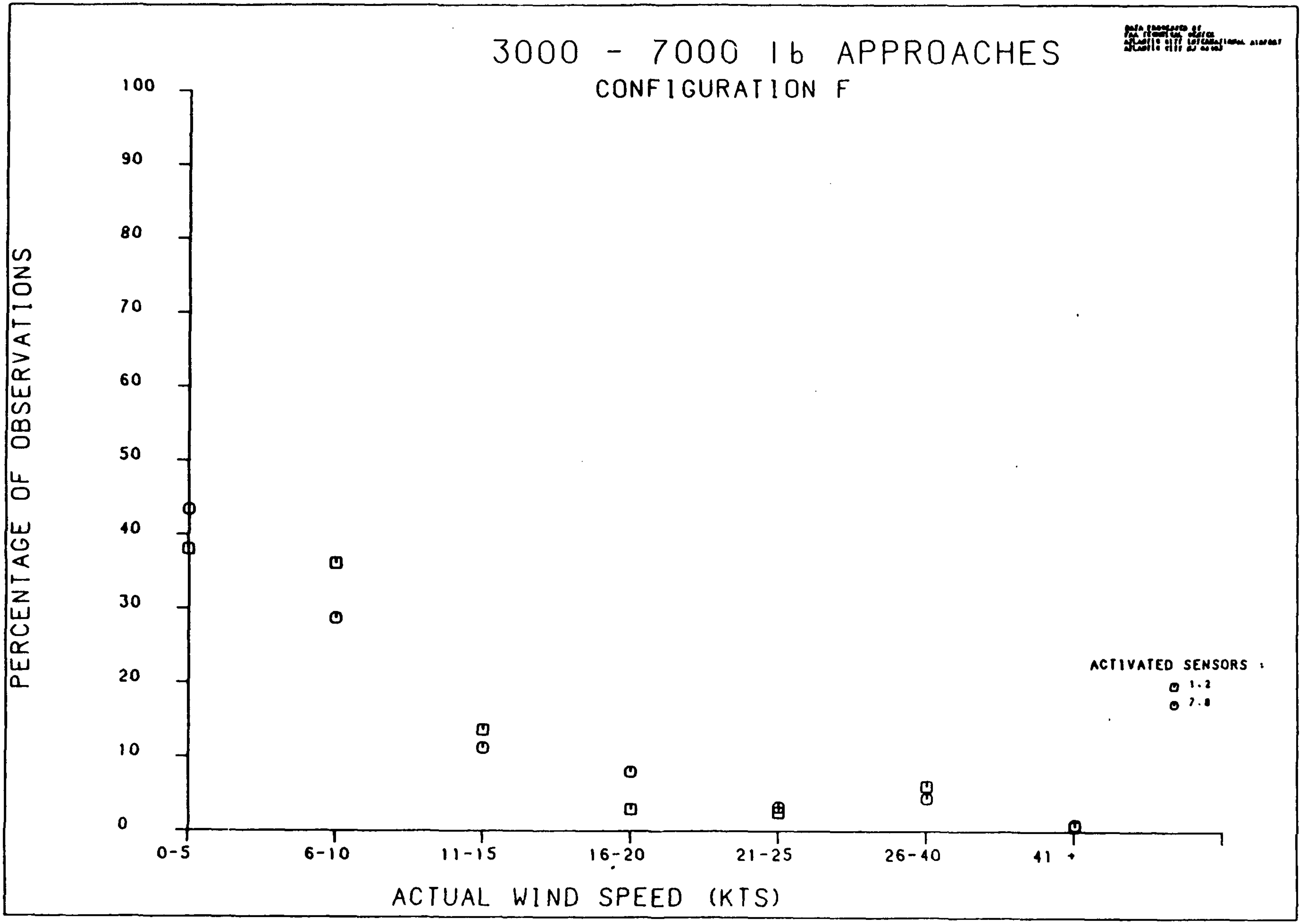



FIGURE 4. PLOTS OF OBSERVED WIND SPEEDS FOR 3000-7000 POUND AIRCRAFT APPROACHES (SHEET 4 OF 4)

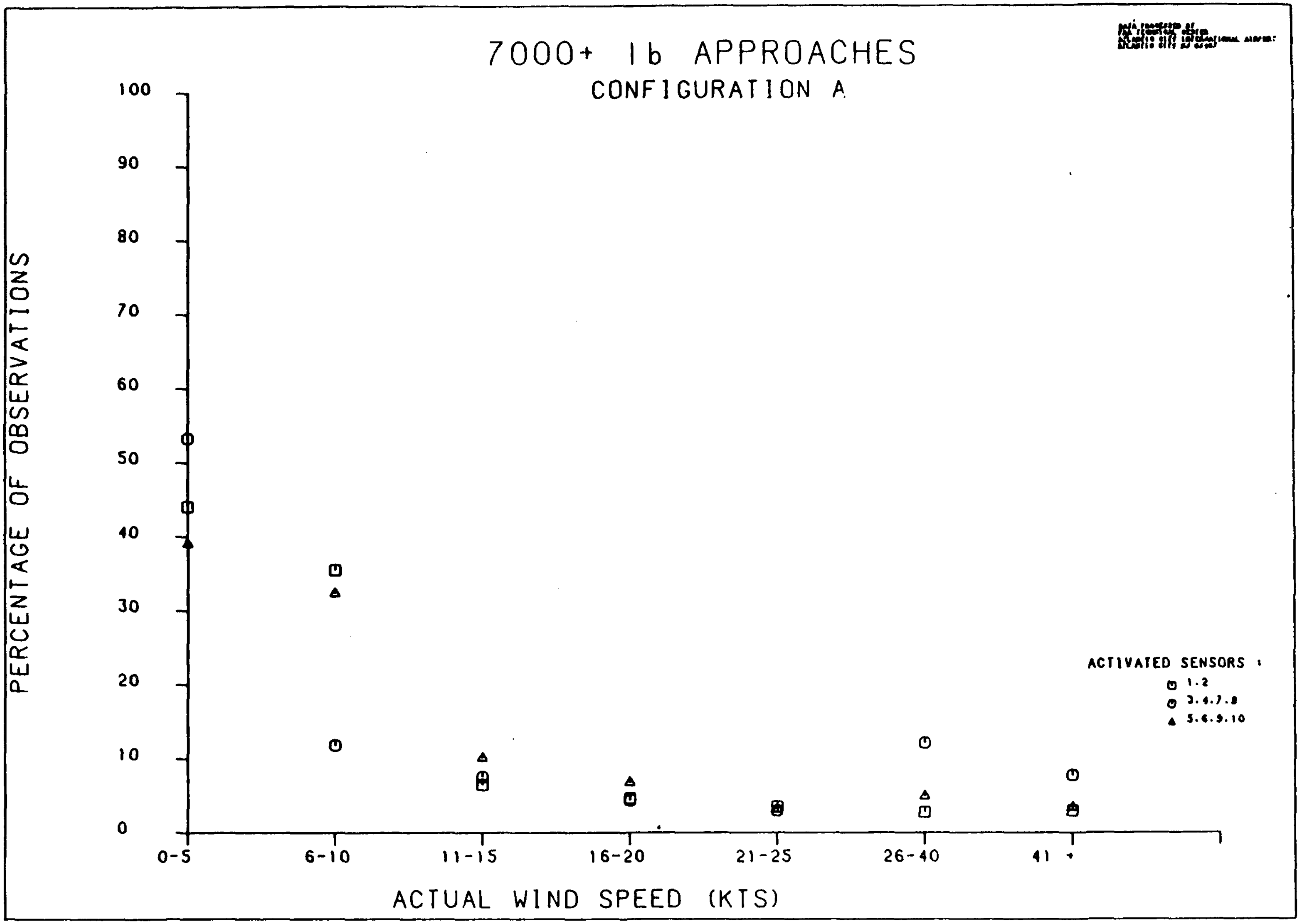



FIGURE 5. PLOTS OF OBSERVED WIND SPEEDS FOR AIRCRAFT GREATER THAN 7000 POUNDS, APPROACHES (SHEET 1 OF 4)

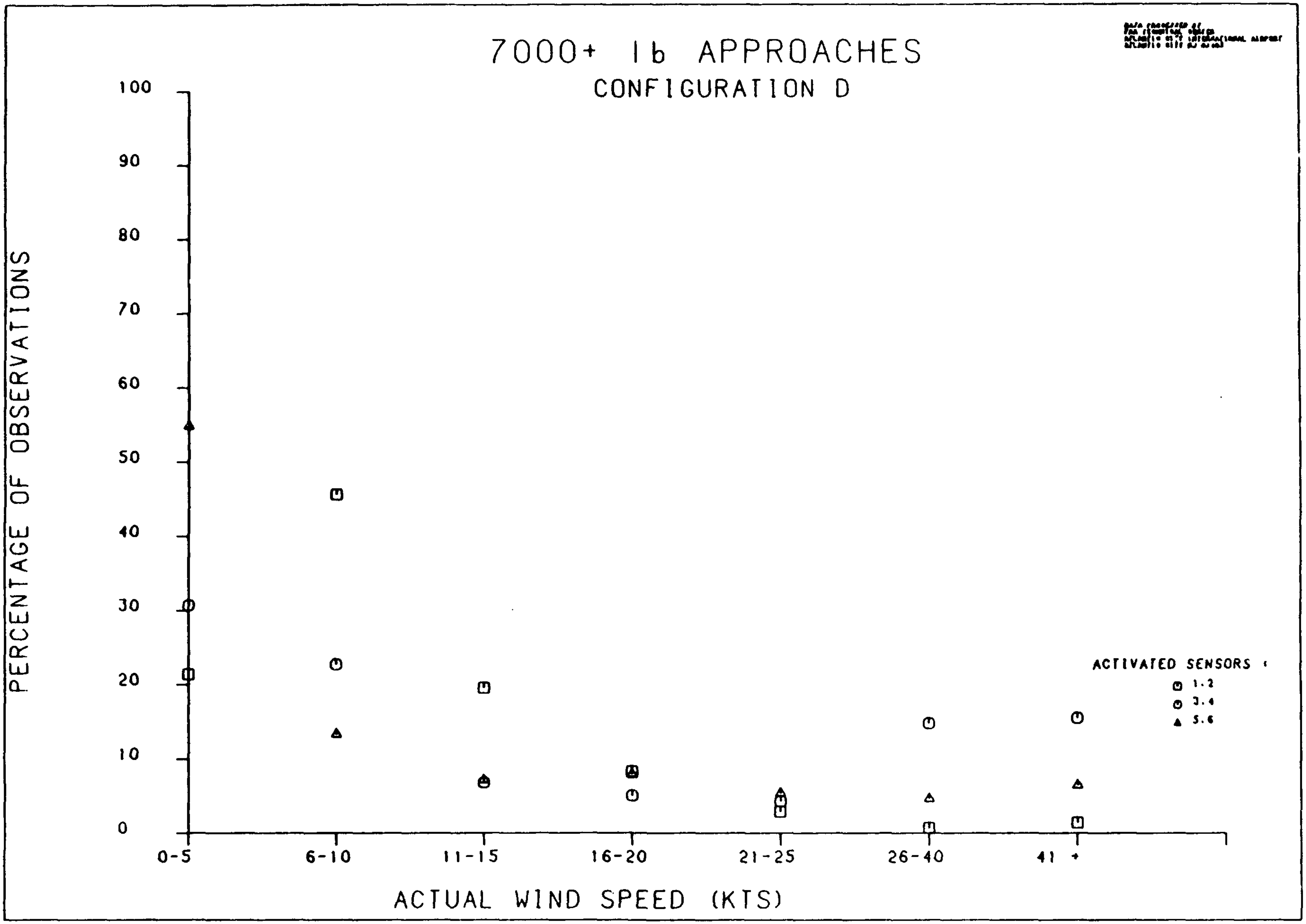



FIGURE 5. PLOTS OF OBSERVED WIND SPEEDS FOR AIRCRAFT GREATER THAN 7000 POUNDS, APPROACHES (SHEET 2 OF 4)

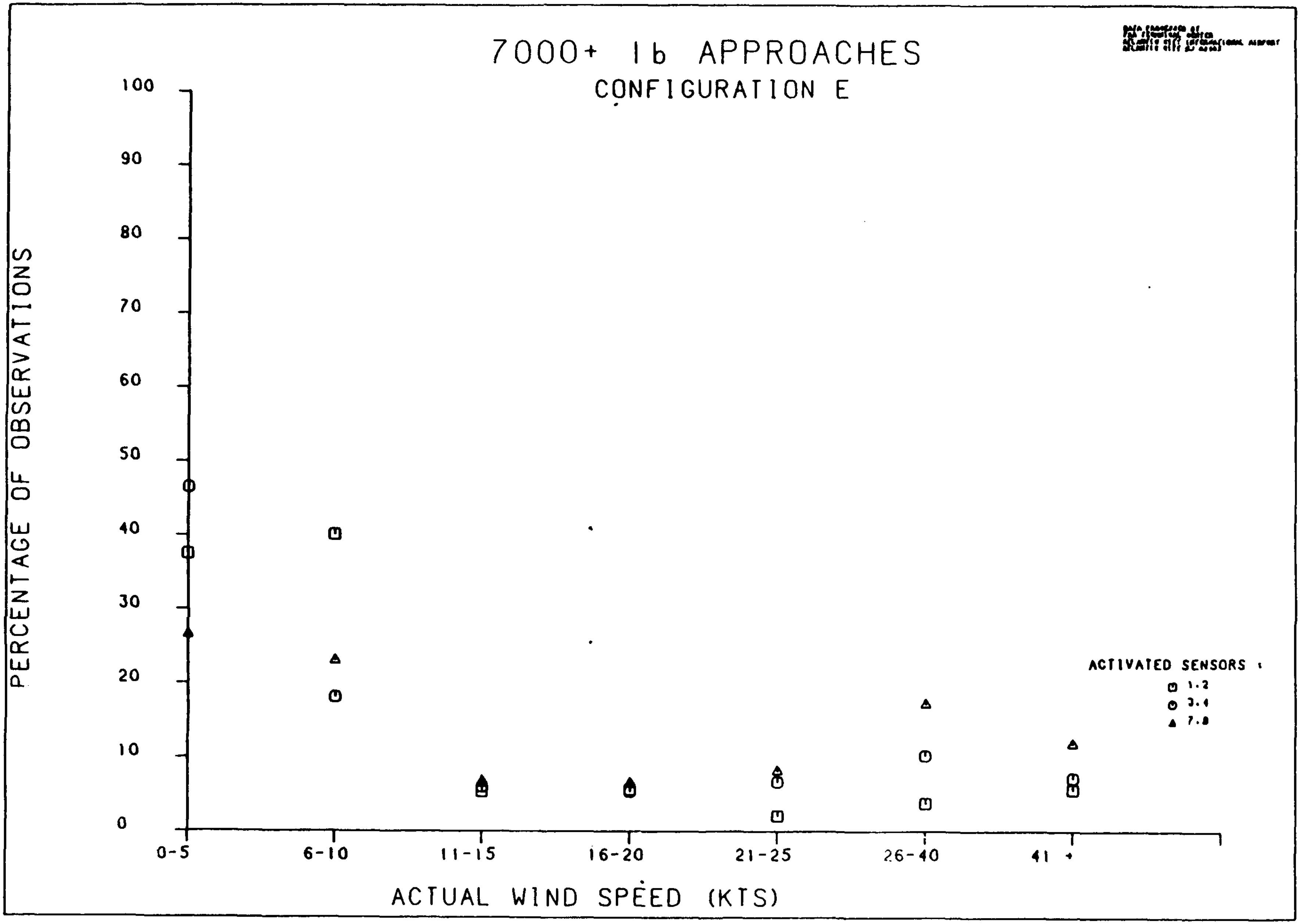



FIGURE 5. PLOTS OF OBSERVED WIND SPEEDS FOR AIRCRAFT GREATER THAN 7000 POUNDS, APPROACHES (SHEET 3 OF 4)

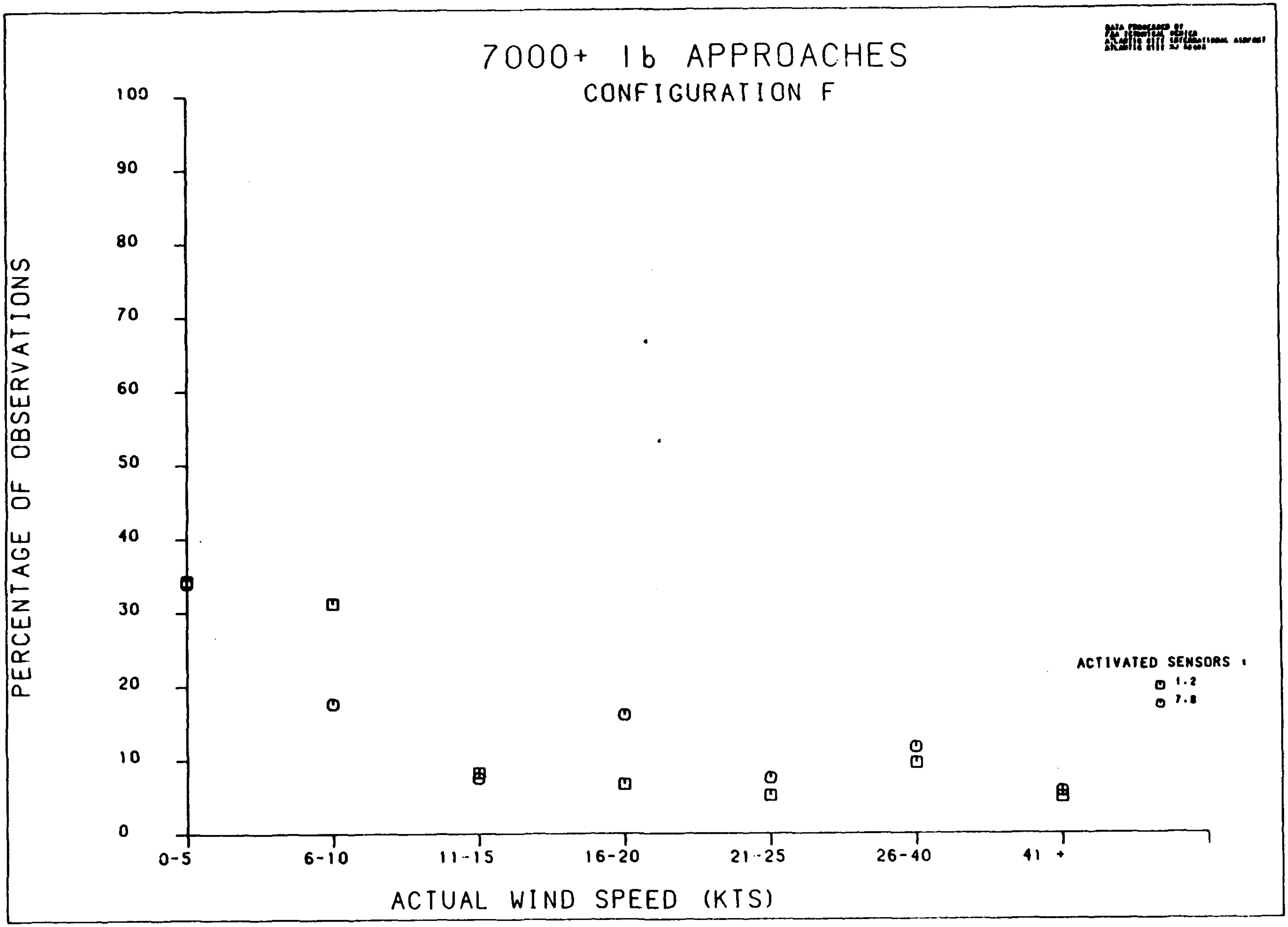



FIGURE 5. PLOTS OF OBSERVED WIND SPEEDS FOR AIRCRAFT GREATER THAN 7000 POUNDS, APPROACHES (SHEET 4 OF 4)

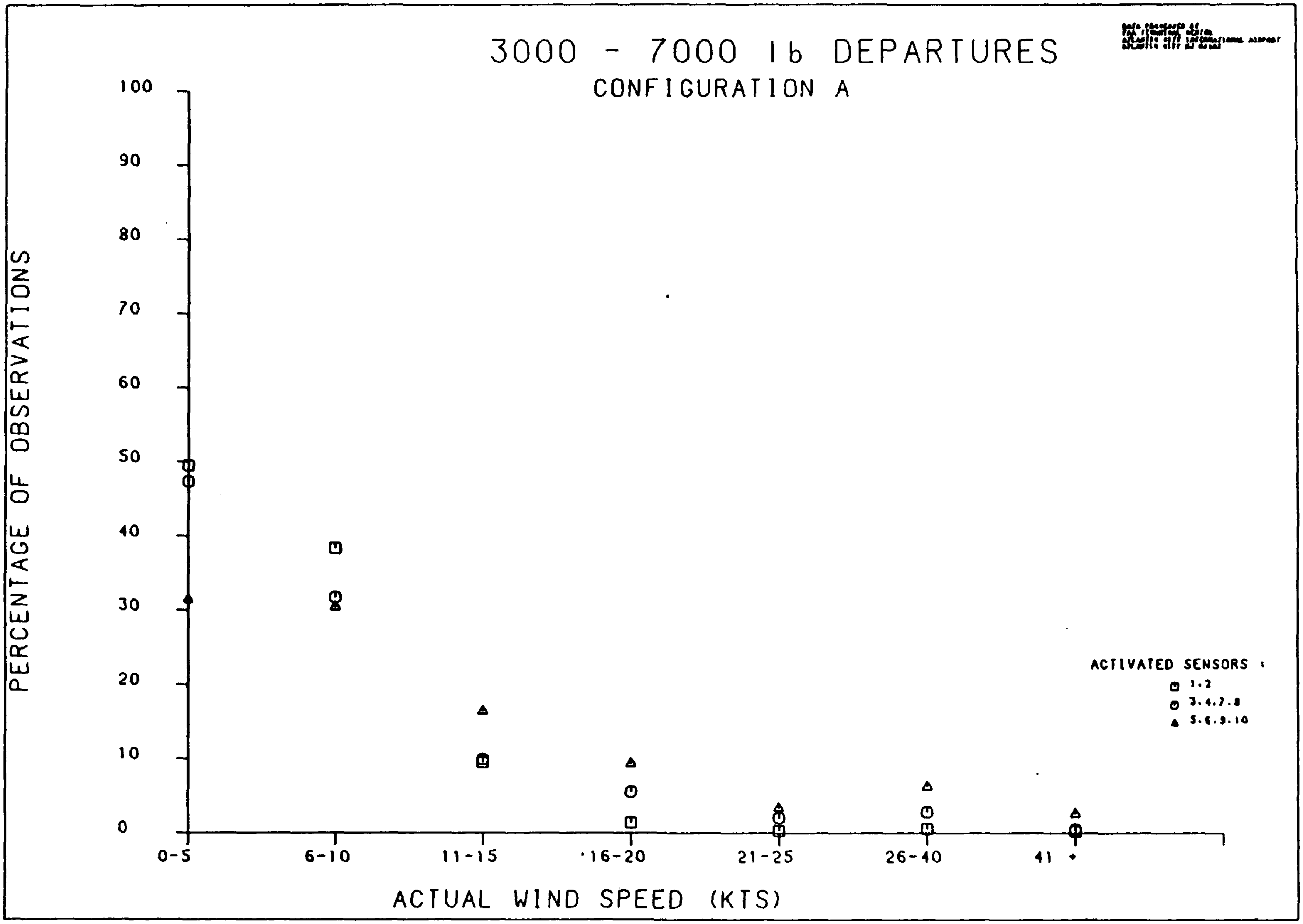



FIGURE 6. PLOTS OF OBSERVED WIND SPEEDS FOR 3000-7000 POUND AIRCRAFT DEPARTURES (SHEET 1 OF 5)

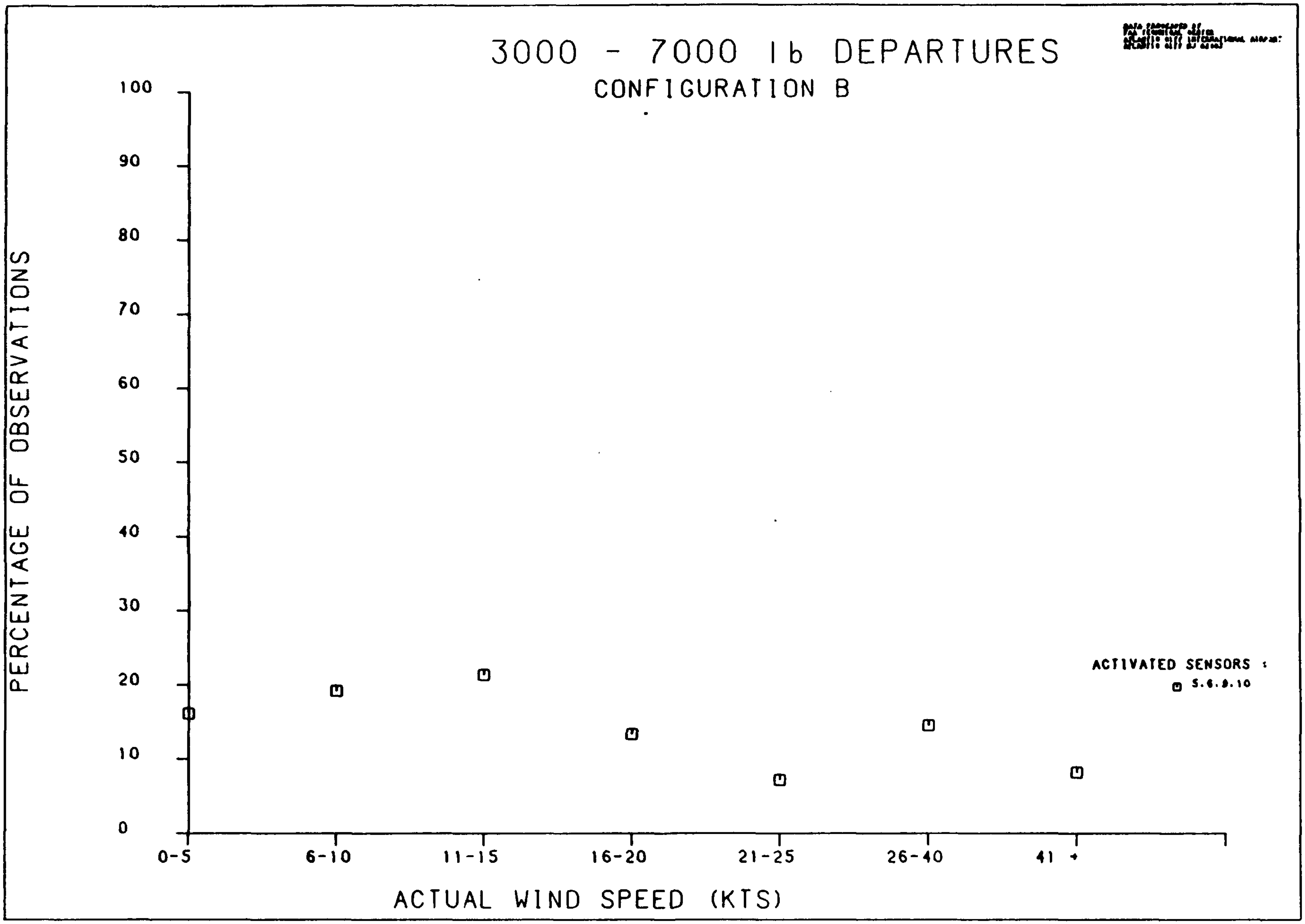



FIGURE 6. PLOTS OF OBSERVED WIND SPEEDS FOR 3000-7000 POUND AIRCRAFT DEPARTURES (SHEET 2 OF 5)

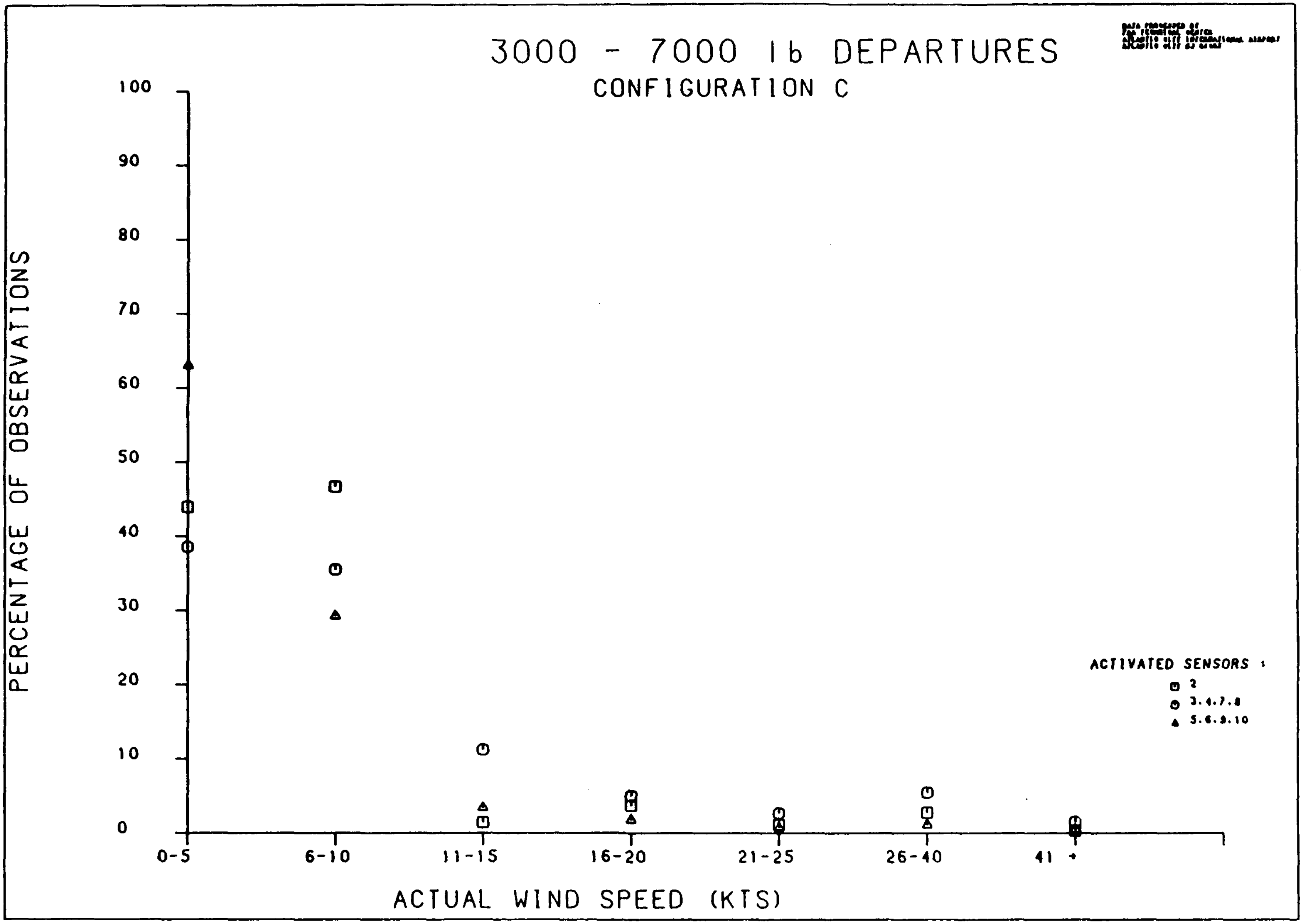



FIGURE 6. PLOTS OF OBSERVED WIND SPEEDS FOR 3000-7000 POUND AIRCRAFT DEPARTURES (SHEET 3 OF 5)

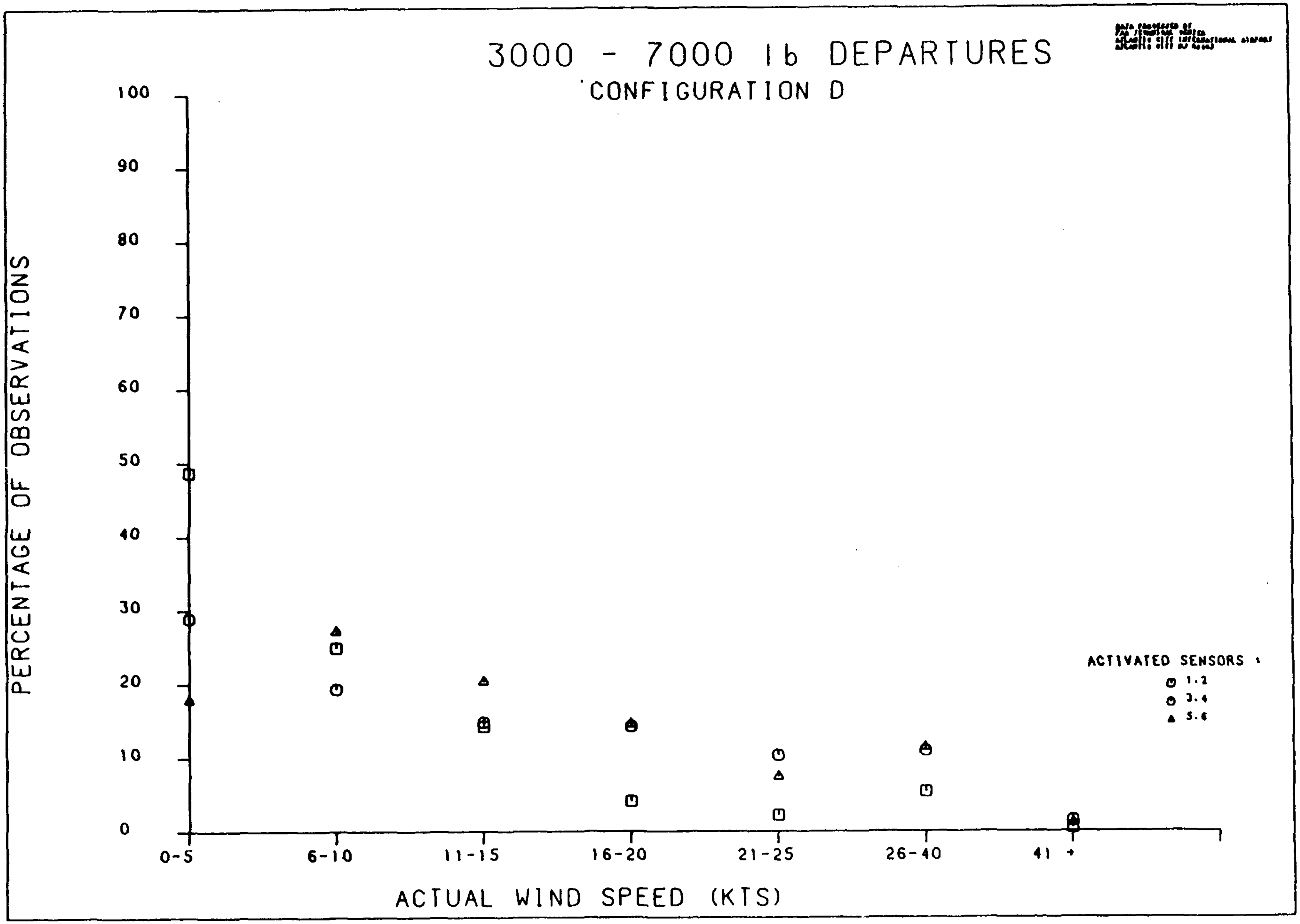



FIGURE 6. PLOTS OF OBSERVED WIND SPEEDS FOR 3000-7000 POUND AIRCRAFT DEPARTURES (SHEET 4 OF 5)

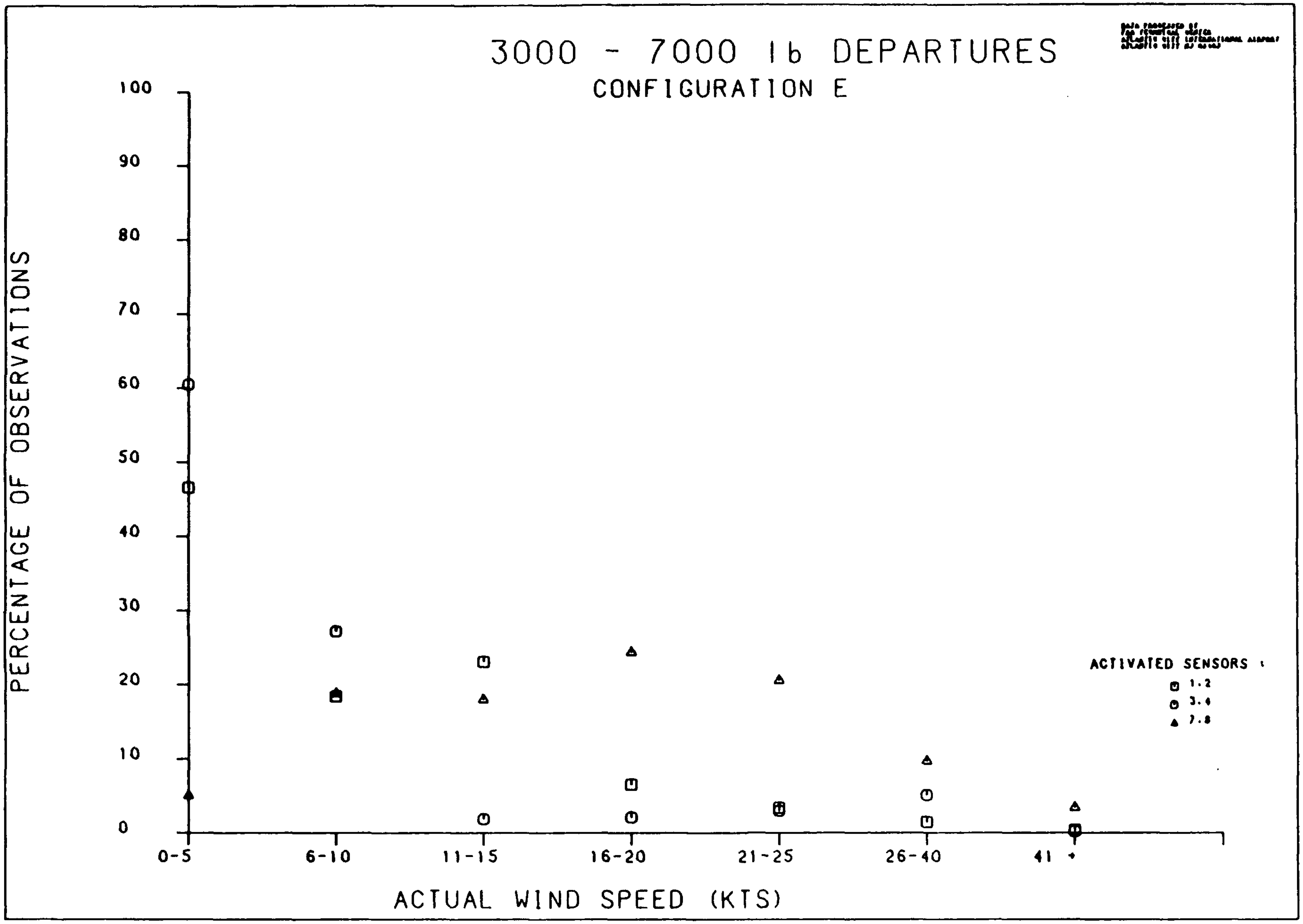



FIGURE 6. PLOTS OF OBSERVED WIND SPEEDS FOR 3000-7000 POUND AIRCRAFT DEPARTURES (SHEET 5 OF 5)

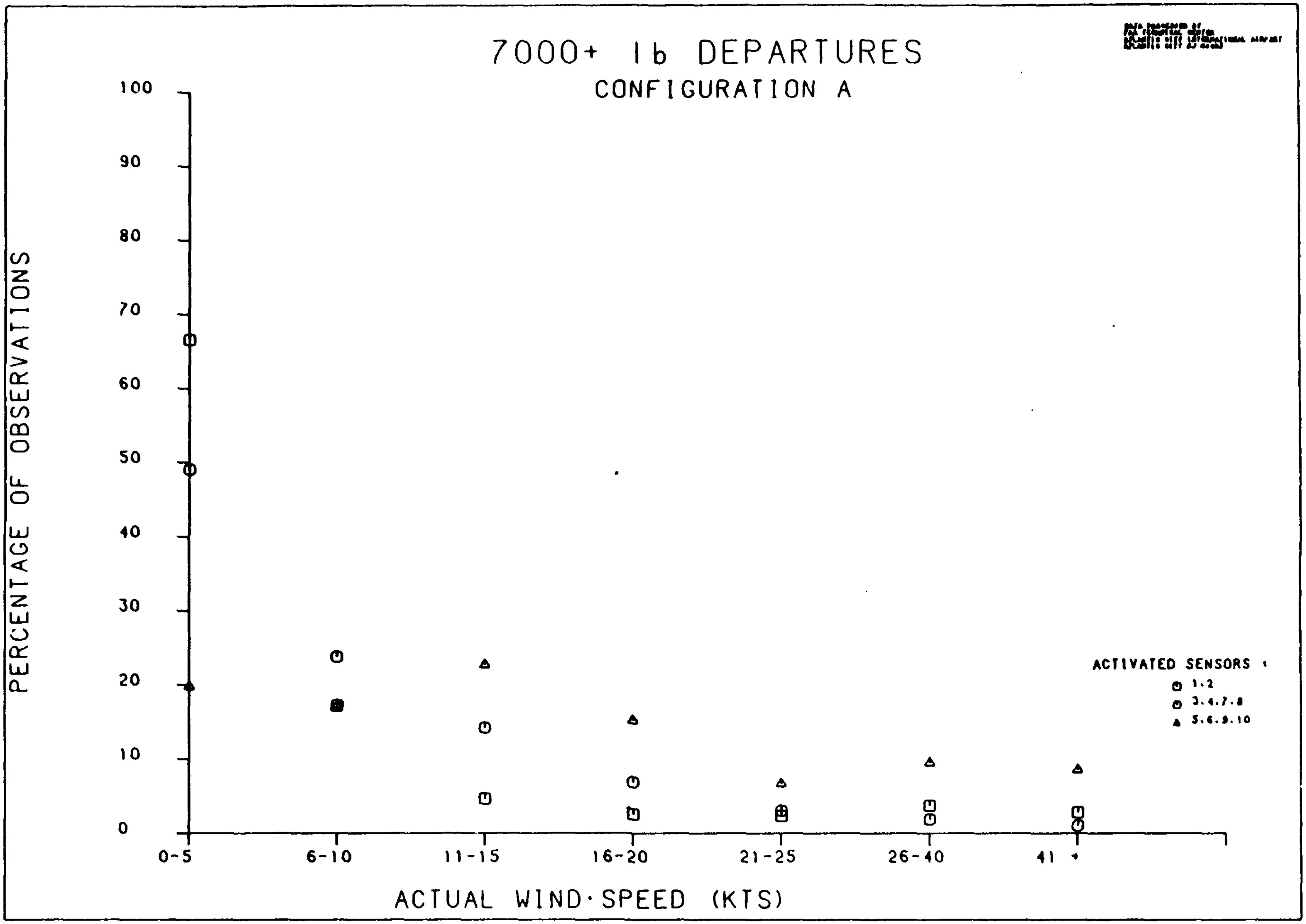



FIGURE 7. PLOTS OF OBSERVED WIND SPEEDS FOR AIRCRAFT GREATER THAN 7000 POUNDS, DEPARTURES (SHEET 1 OF 3)

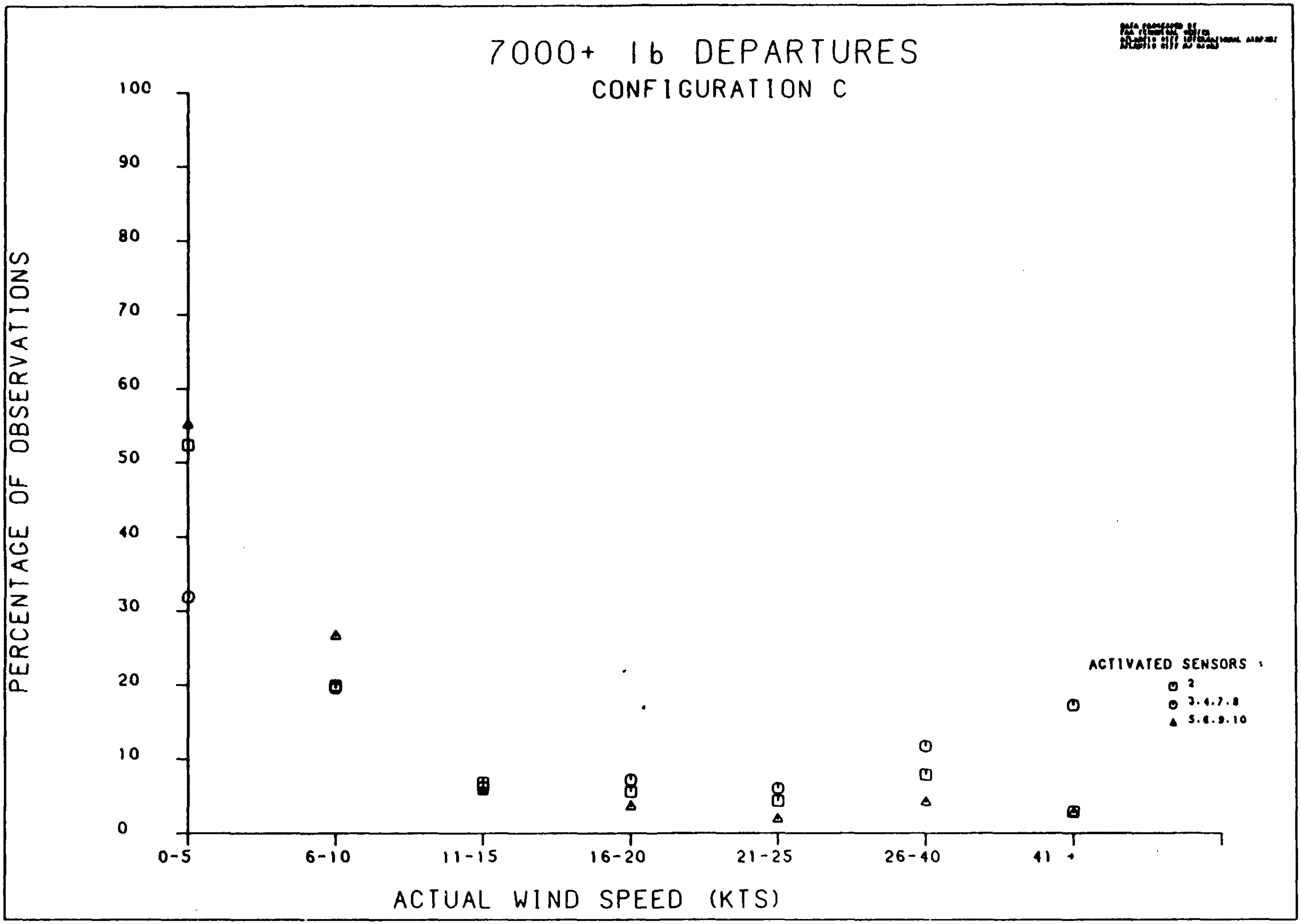



FIGURE 7. PLOTS OF OBSERVED WIND SPEEDS FOR AIRCRAFT GREATER THAN 7000 POUNDS, DEPARTURES (SHEET 2 OF 3)

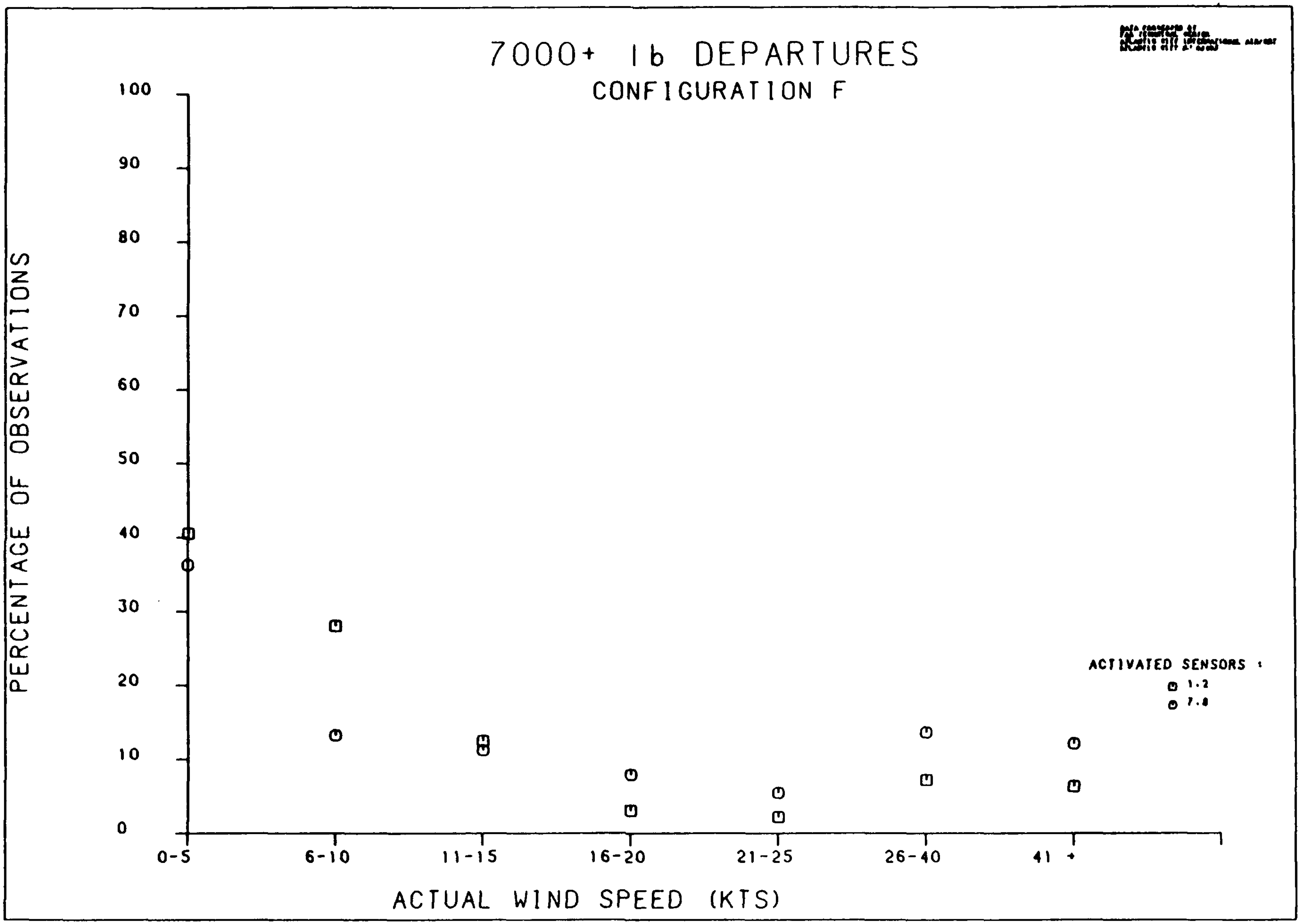



FIGURE 7. PLOTS OF OBSERVED WIND SPEEDS FOR AIRCRAFT GREATER THAN 7000 POUNDS, DEPARTURES (SHEET 3 OF 3)

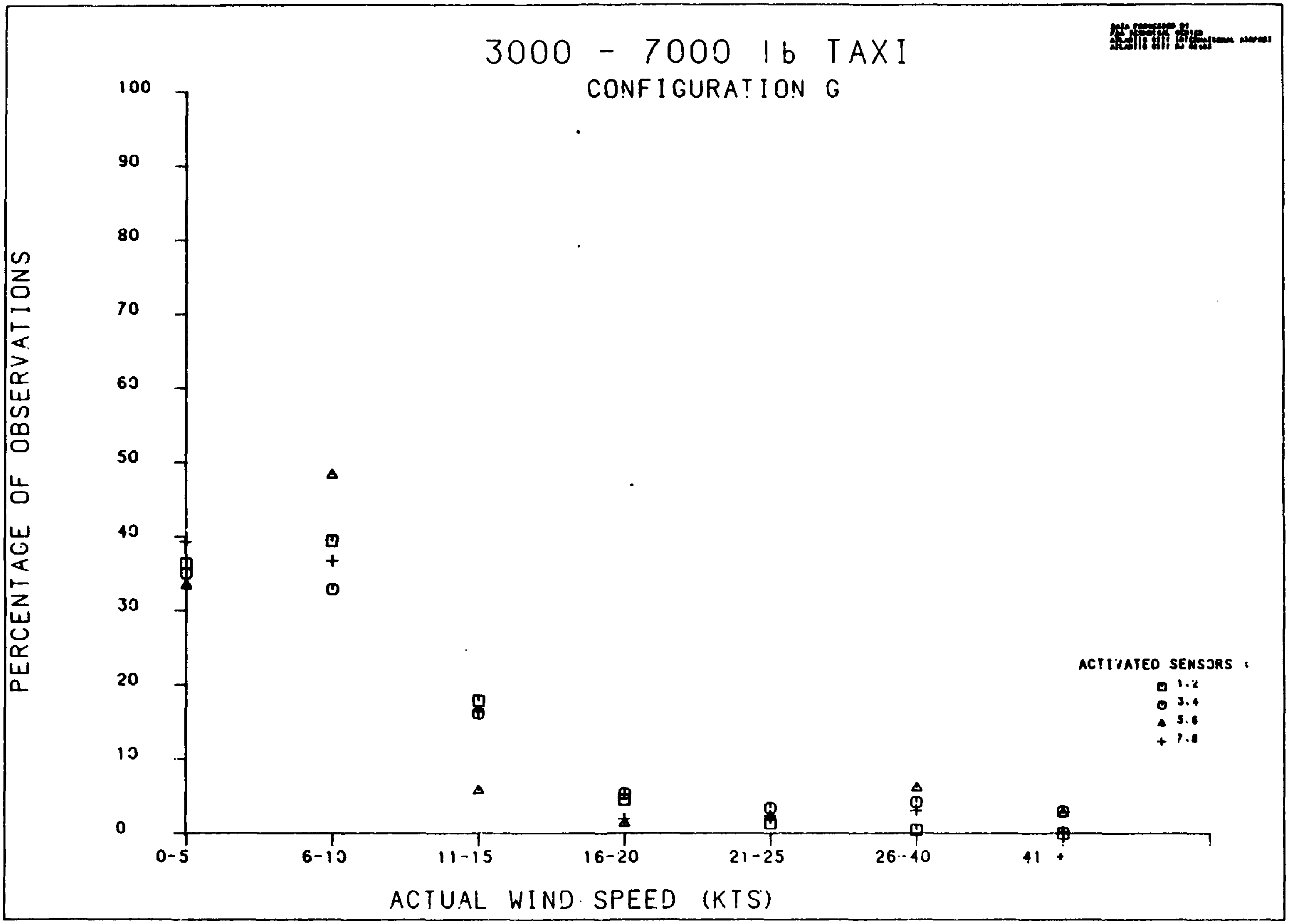



FIGURE 8. PLOT OBSERVED WIND SPEEDS FOR ALL TAXI OPERATIONS

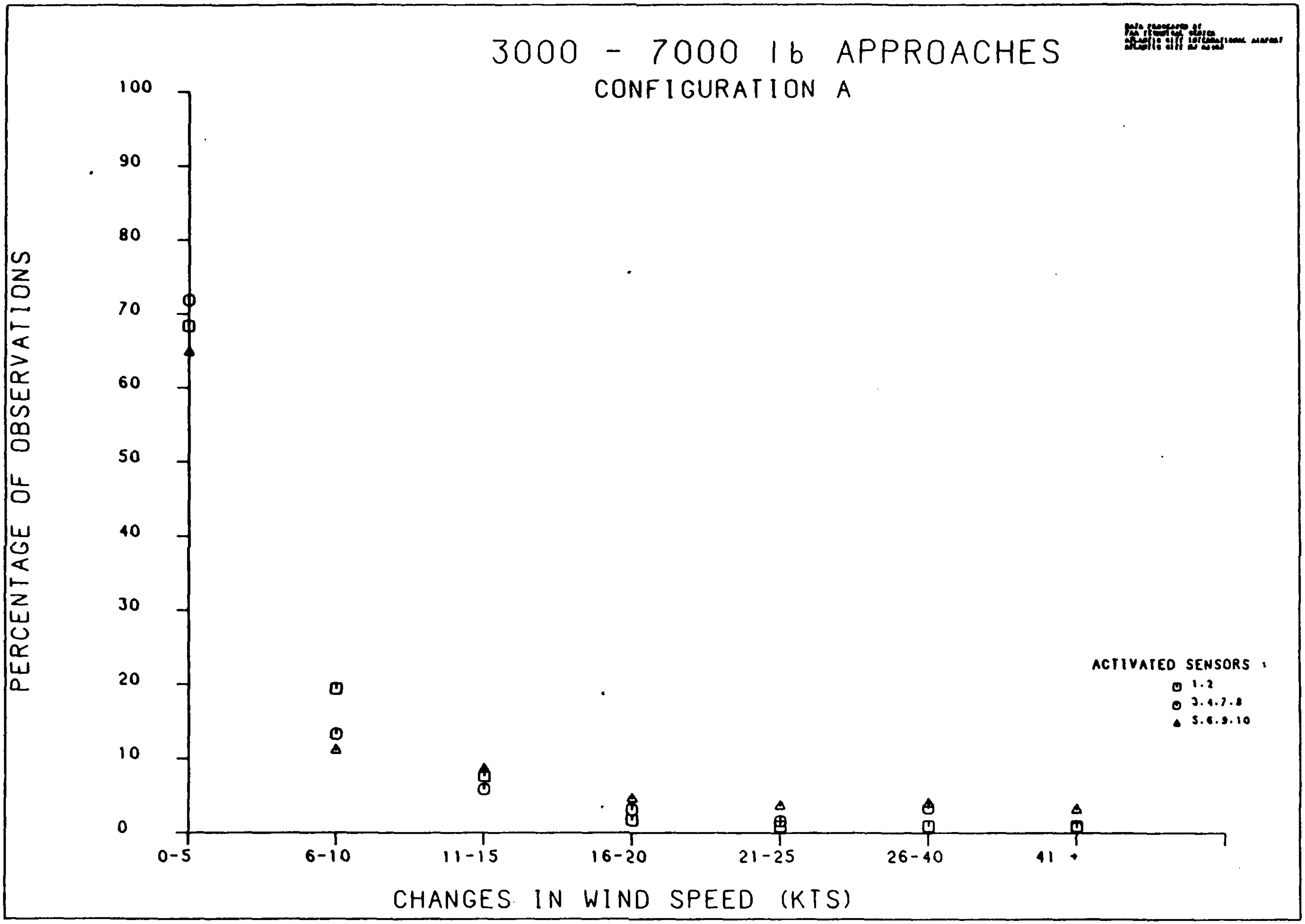



FIGURE 9. PLOTS OF DISTRIBUTIONS FOR VELOCITY CHANGES FOR 3000-7000 POUND AIRCRAFT, APPROACHES (SHEET 1 OF 4)

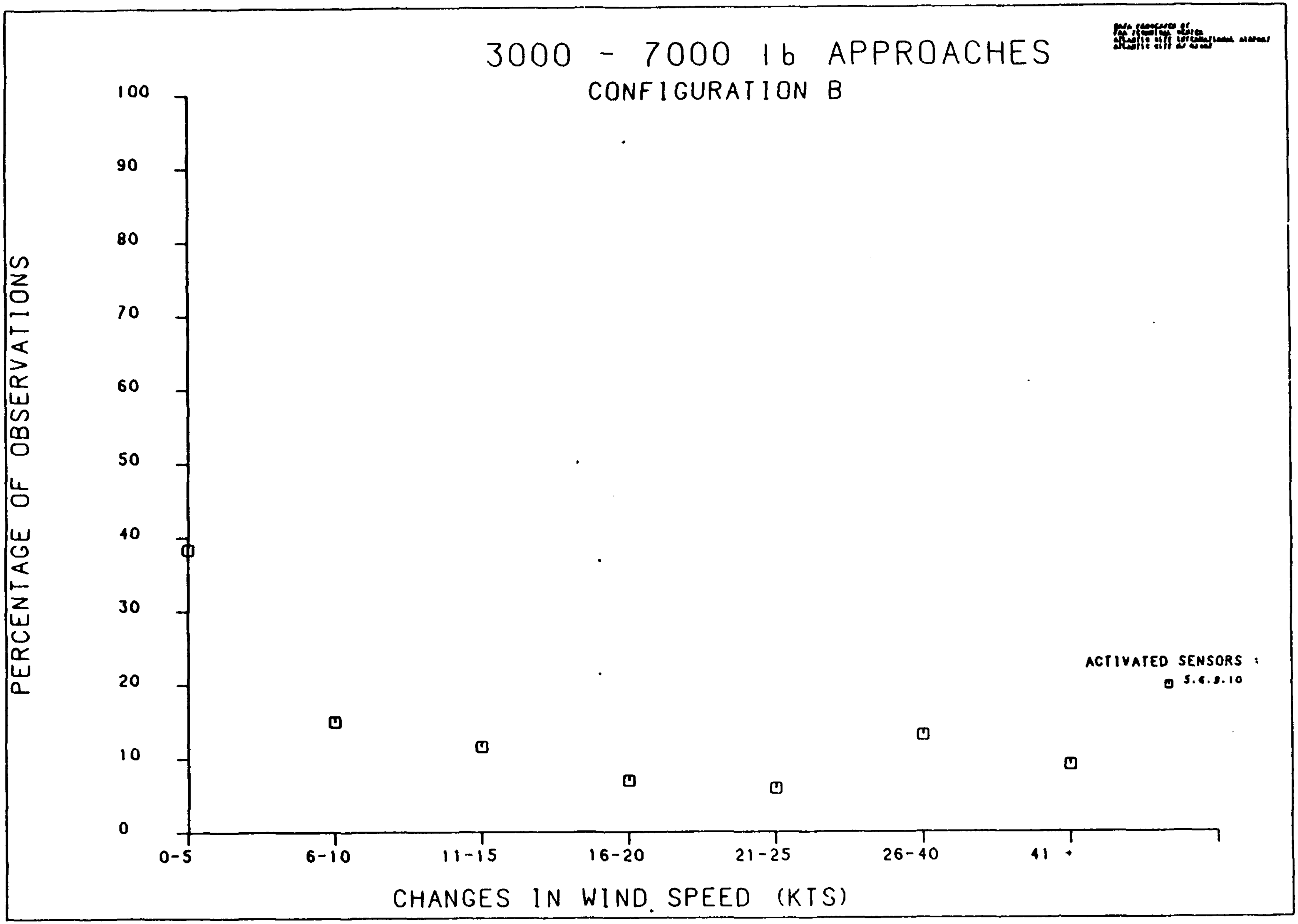



FIGURE 9. PLOTS OF DISTRIBUTIONS FOR VELOCITY CHANGES FOR 3000-7000 POUND AIRCRAFT, APPROACHES (SHEET 2 OF 4)

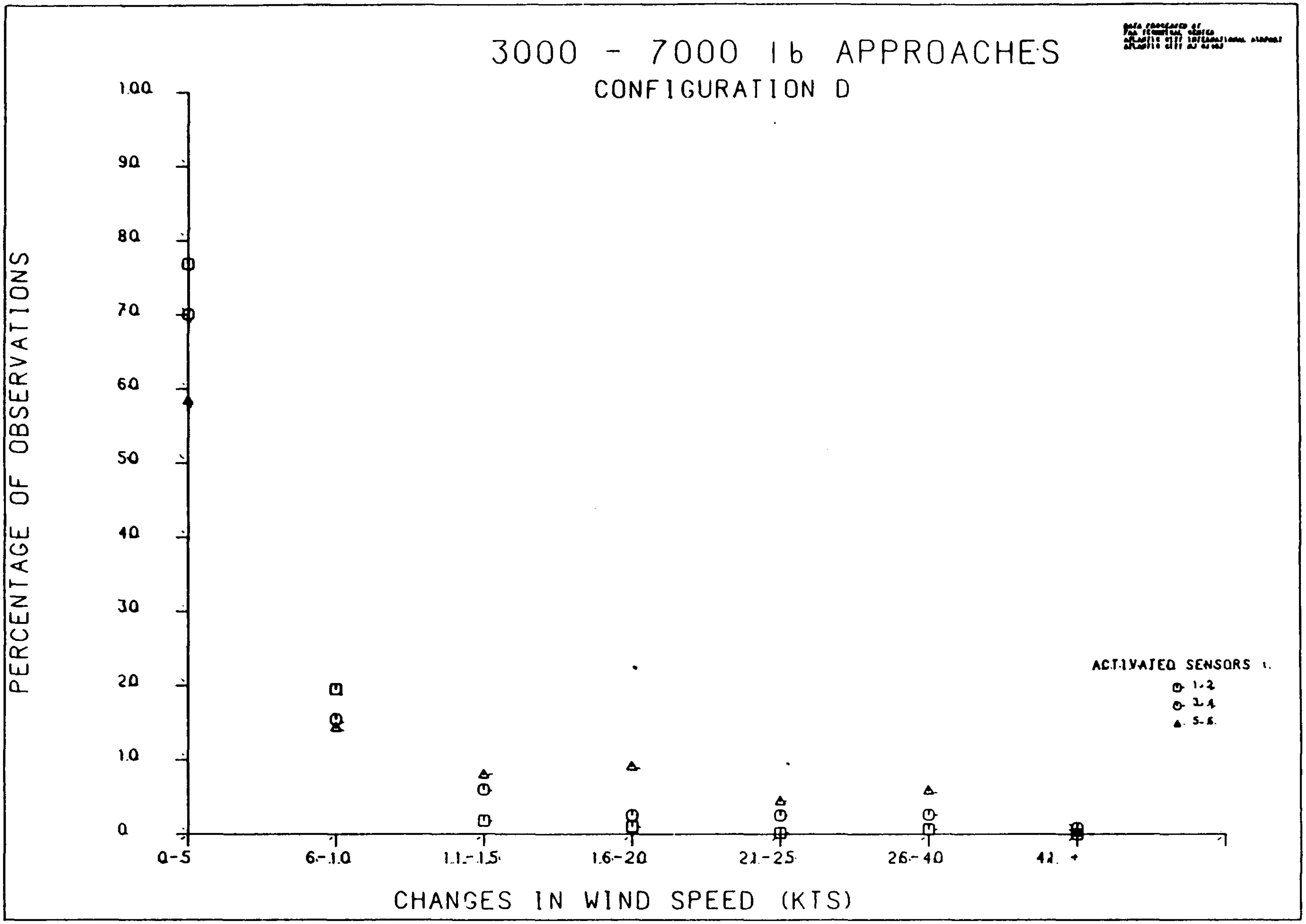



FIGURE 9. PLOTS OF DISTRIBUTIONS FOR VELOCITY CHANGES FOR 3000-7000 POUND AIRCRAFT, APPROACHES (SHEET 3 OF 4)

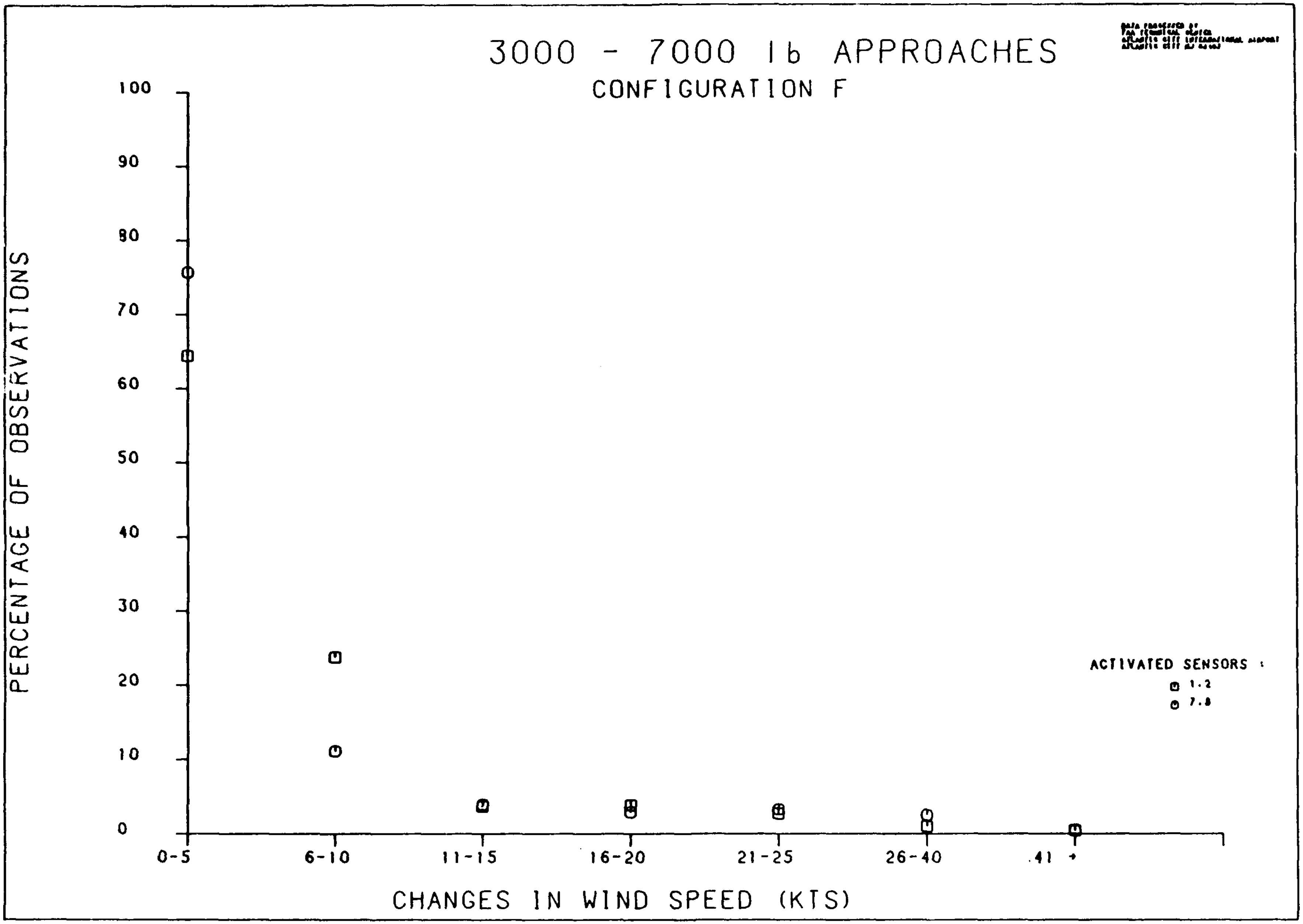



FIGURE 9. PLOTS OF DISTRIBUTIONS FOR VELOCITY CHANGES FOR 3000-7000 POUND AIRCRAFT, APPROACHES (SHEET 4 OF 4)

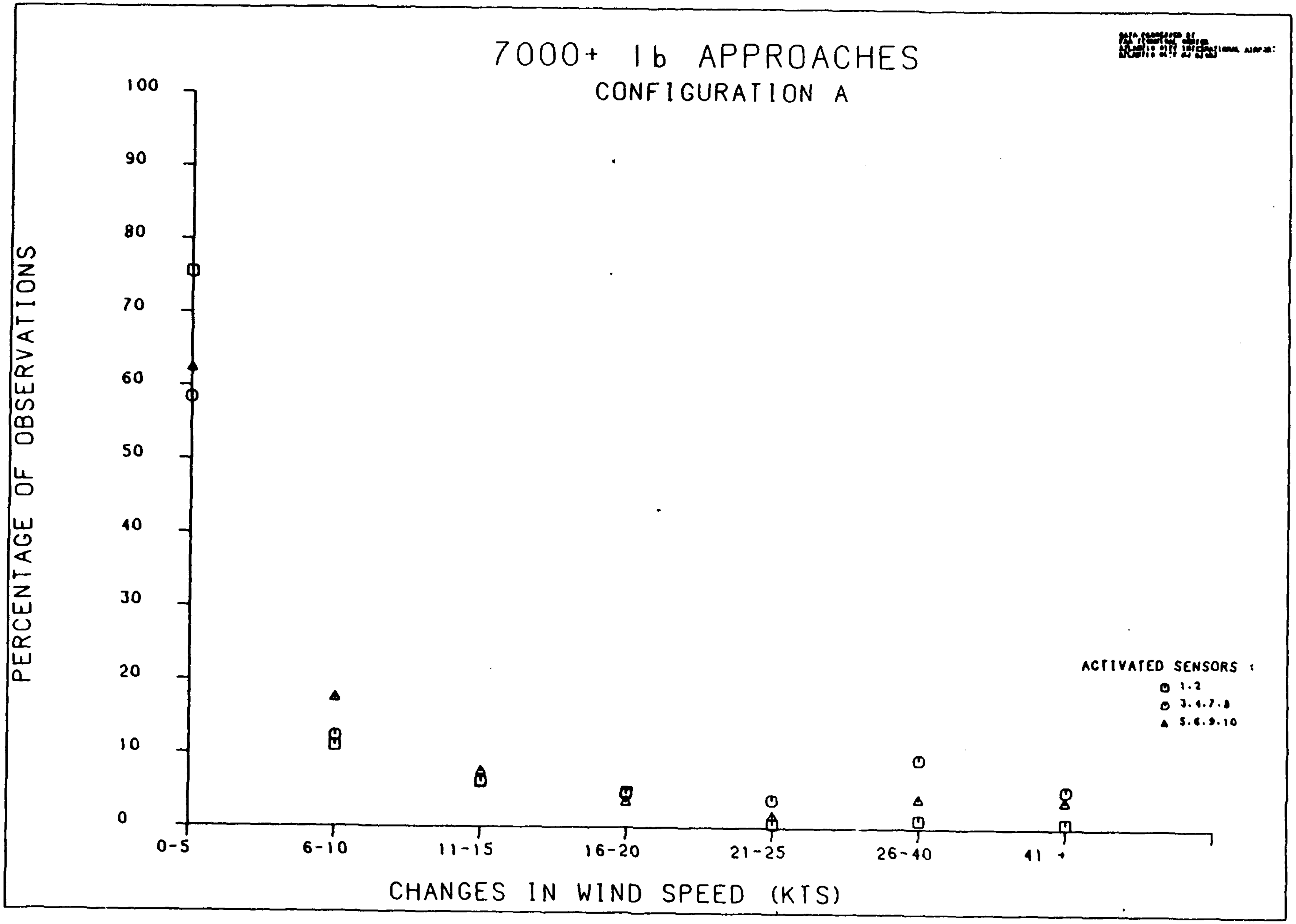



FIGURE 10. PLOTS OF DISTRIBUTIONS FOR VELOCITY CHANGES FOR AIRCRAFT GREATER THAN 7000 POUNDS, APPROACHES (SHEET 1 OF 4)

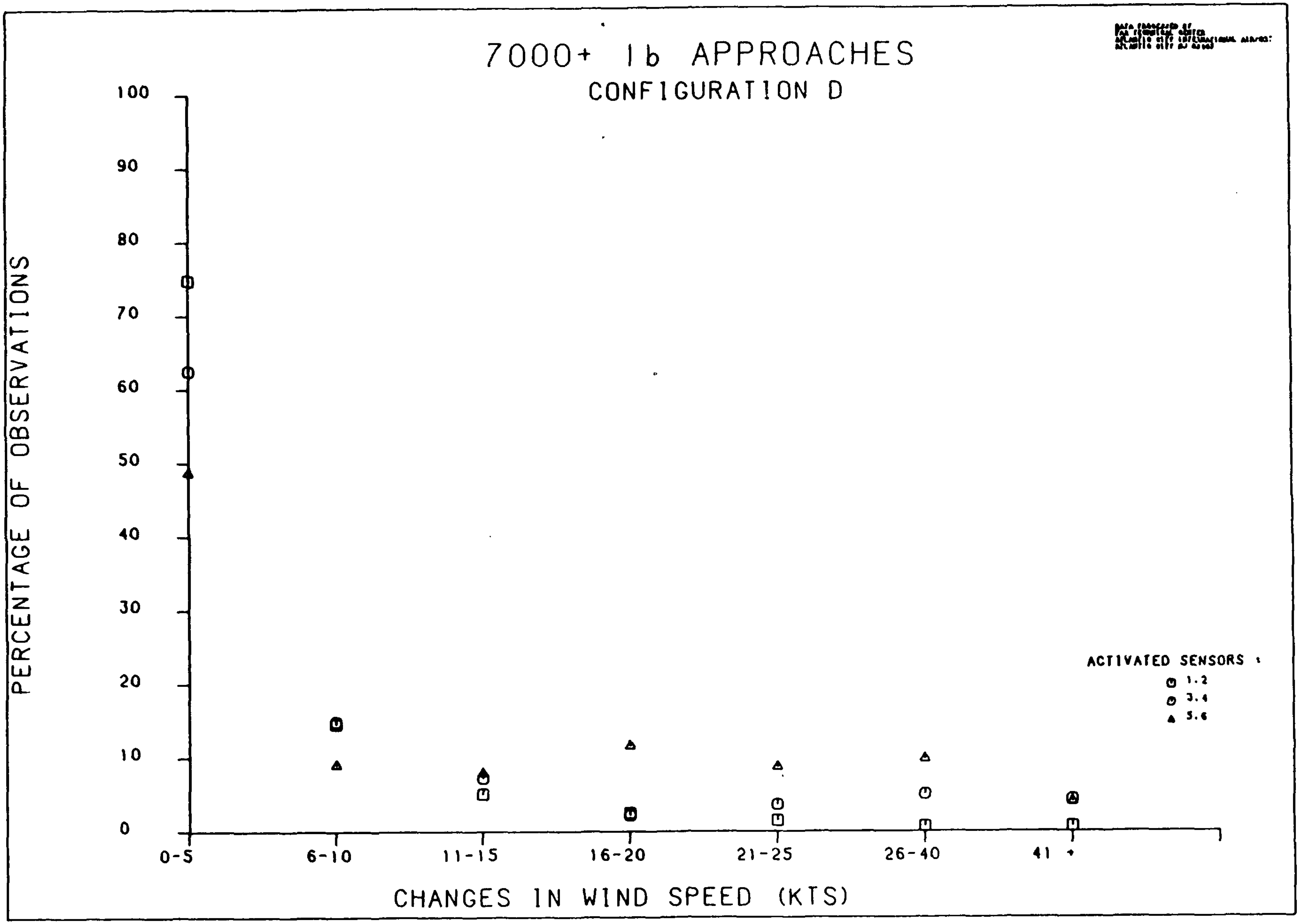



FIGURE 10. PLOTS OF DISTRIBUTIONS FOR VELOCITY CHANGES FOR AIRCRAFT GREATER THAN 7000 POUNDS, APPROACHES (SHEET 2 OF 4)

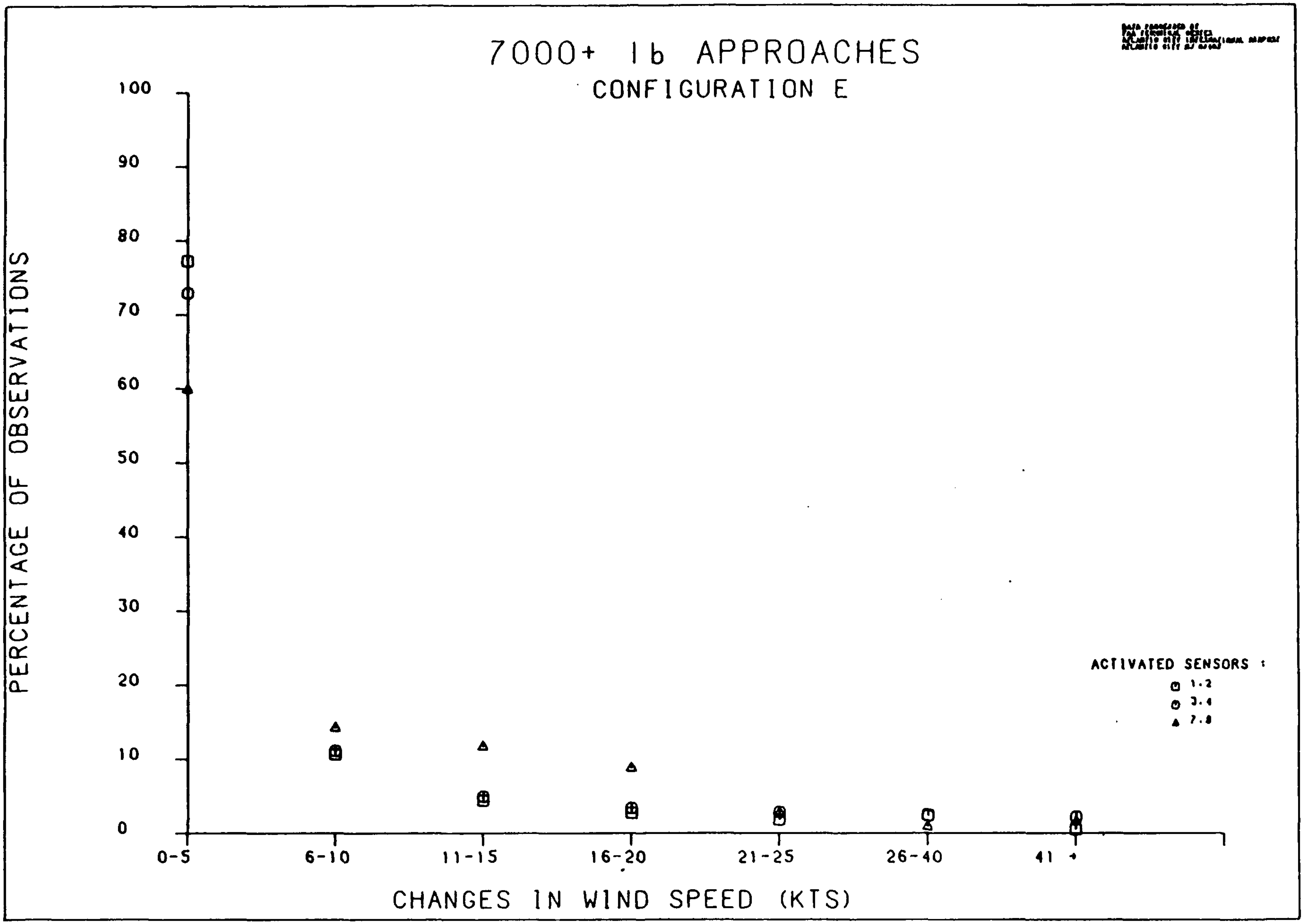



FIGURE 10. PLOTS OF DISTRIBUTIONS FOR VELOCITY CHANGES FOR AIRCRAFT GREATER THAN 7000 POUNDS, APPROAHCES (SHEET 3 OF 4)

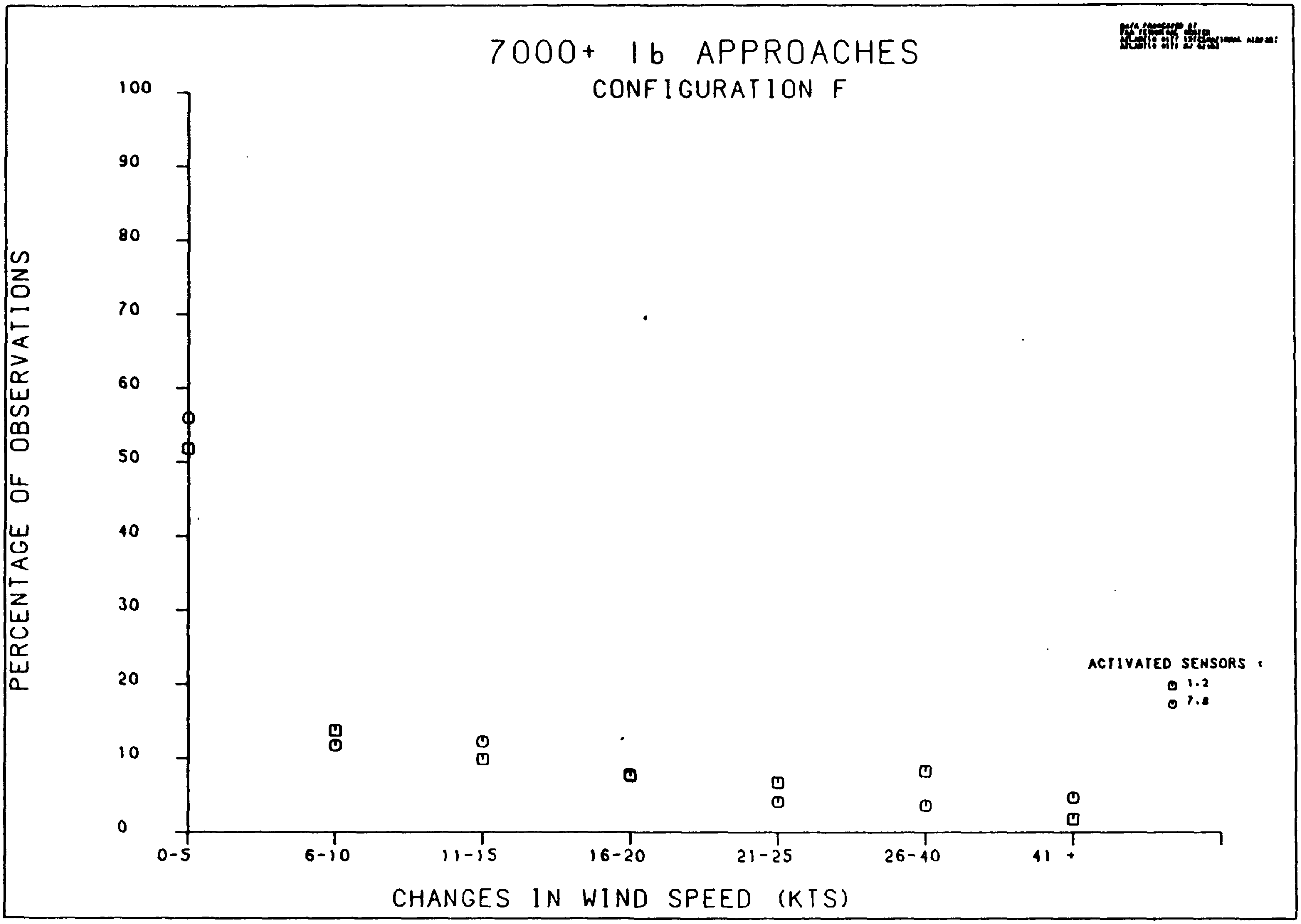



FIGURE 10. PLOTS OF DISTRIBUTIONS FOR VELOCITY CHANGES FOR AIRCRAFT GREATER THAN 7000 POUNDS, APPROACHES (SHEET 4 OF 4)

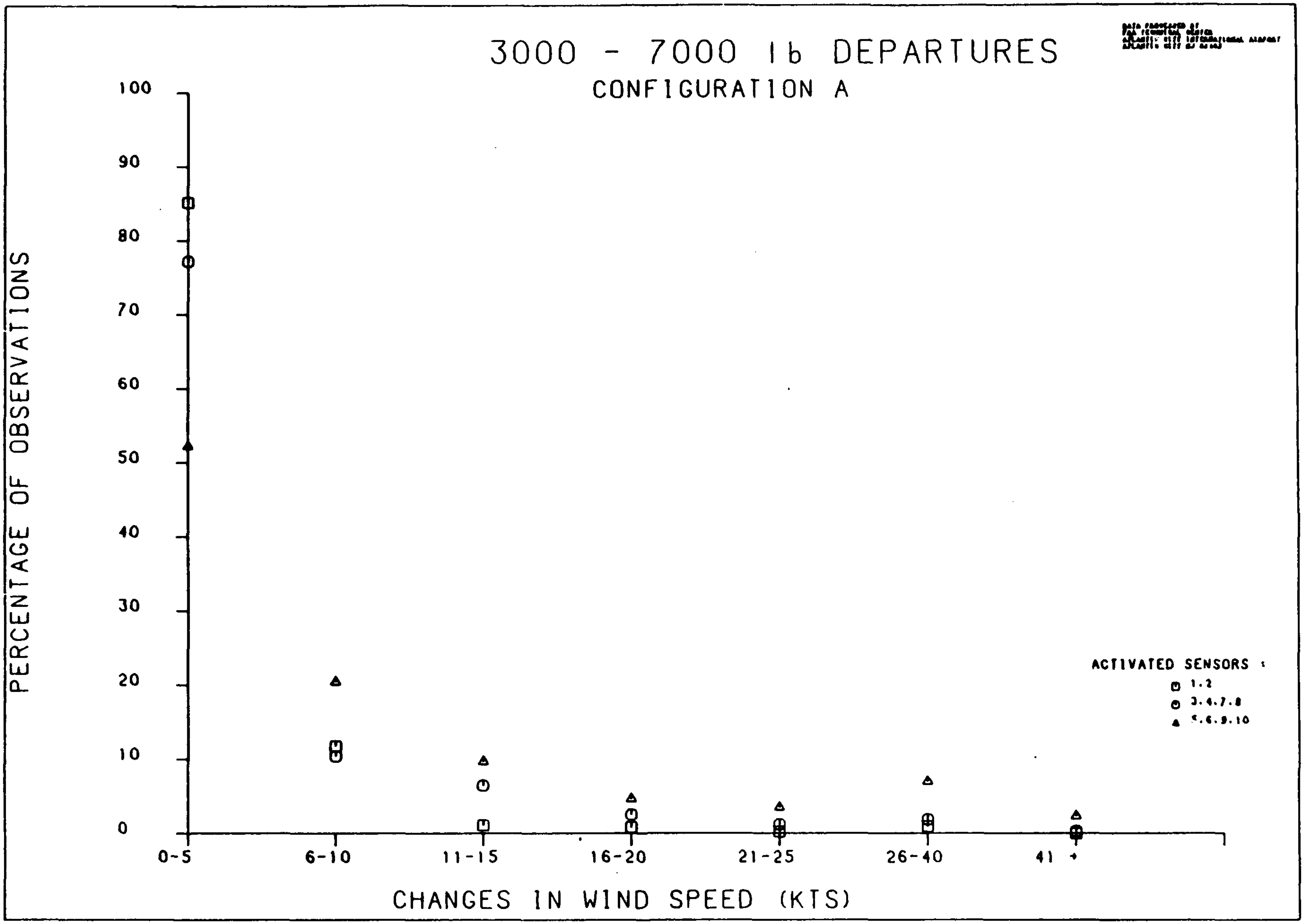



FIGURE 11. PLOTS OF DISTRIBUTIONS FOR VELOCITY CHANGES FOR 3000-7000 POUND AIRCRAFT, DEPARTURES (SHEET 1 OF 5)

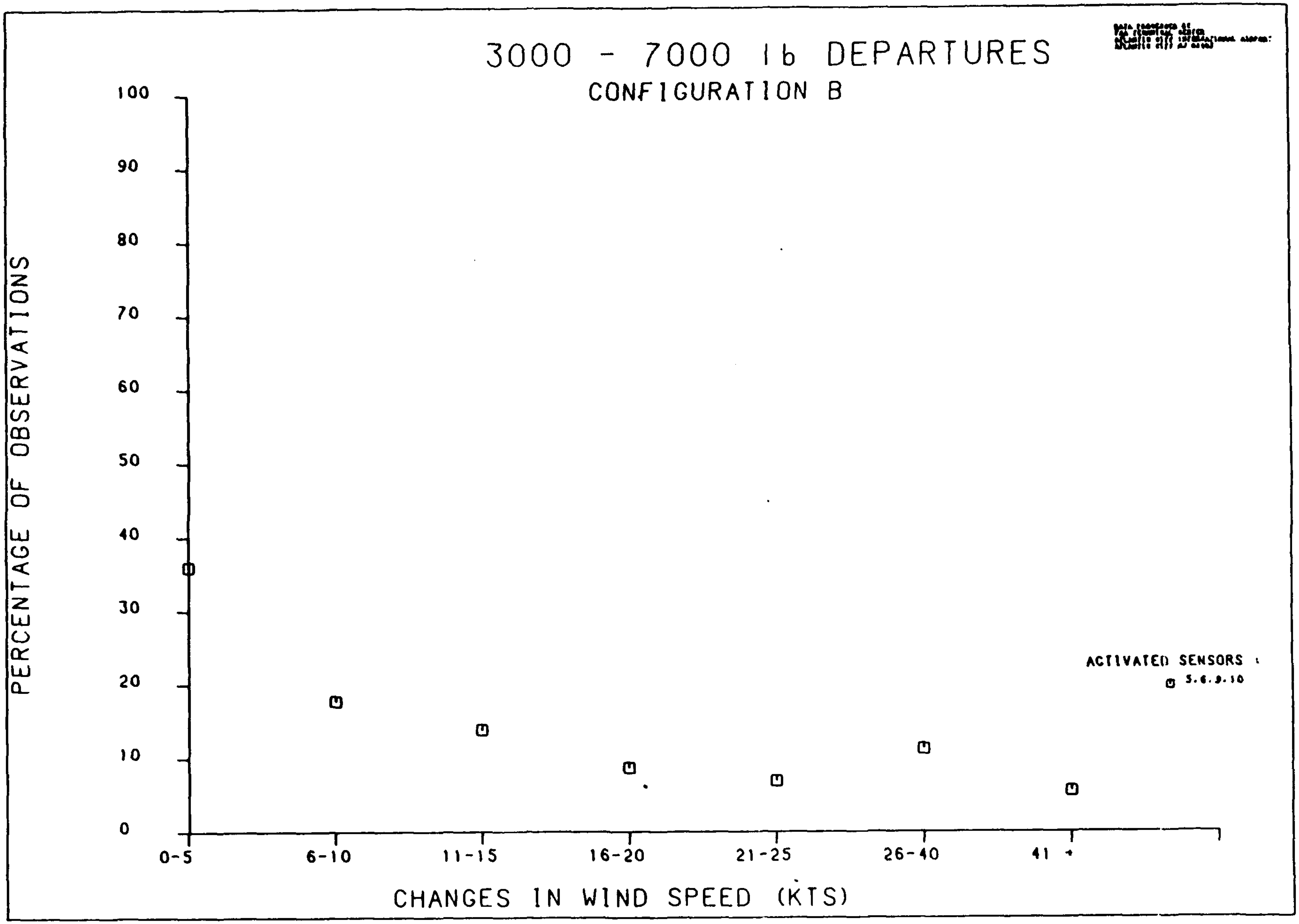



FIGURE 11. PLOTS OF DISTRIBUTIONS FOR VELOCITY CHANGES FOR 3000-7000 POUND AIRCRAFT, DEPARTURES (SHEET 2 OF 5)

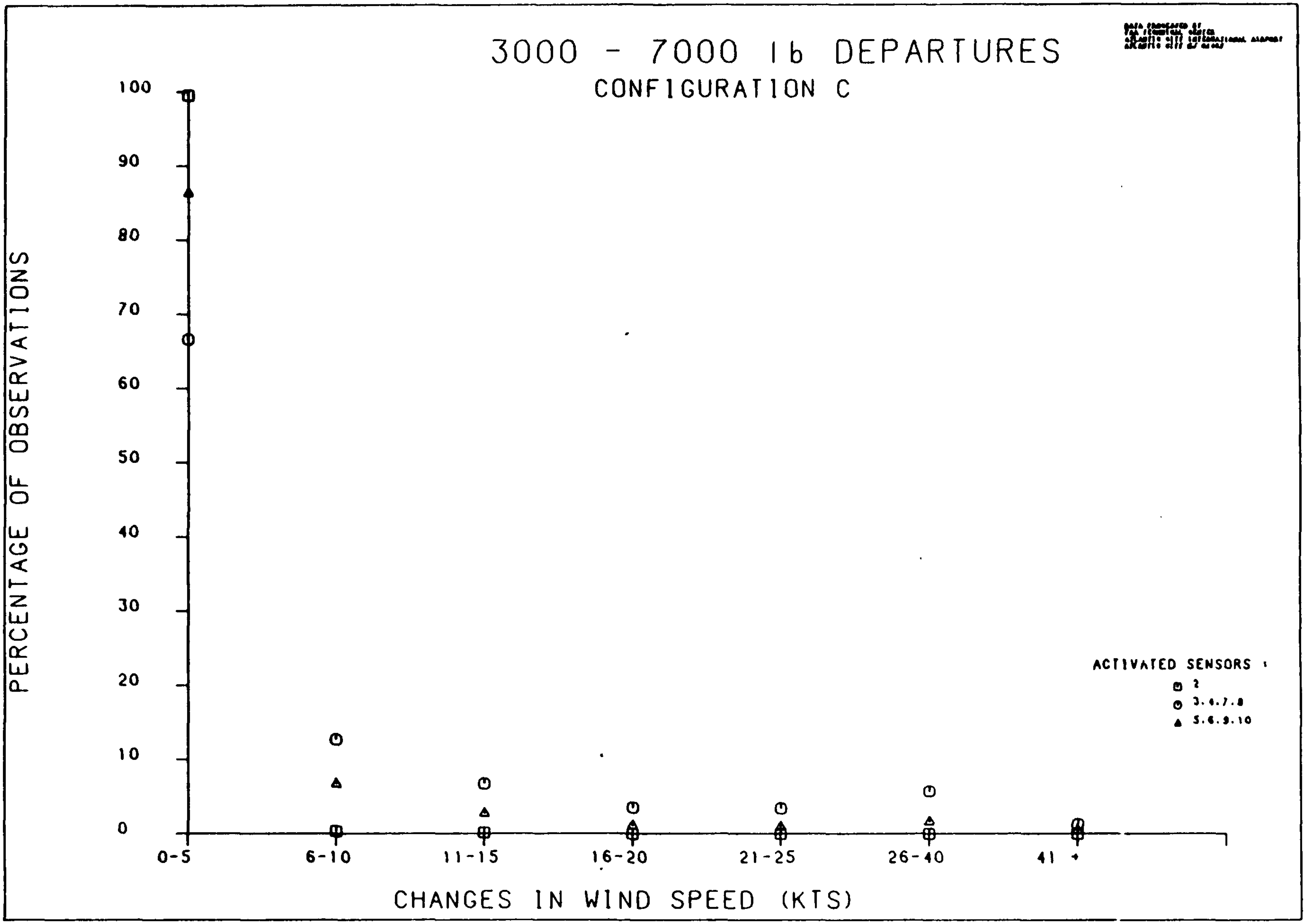



FIGURE 11. PLOTS DISTRIBUTION FOR VELOCITY CHANGES FOR 3000-7000 POUND AIRCRAFT, DEPARTURES (SHEET 3 of 5)

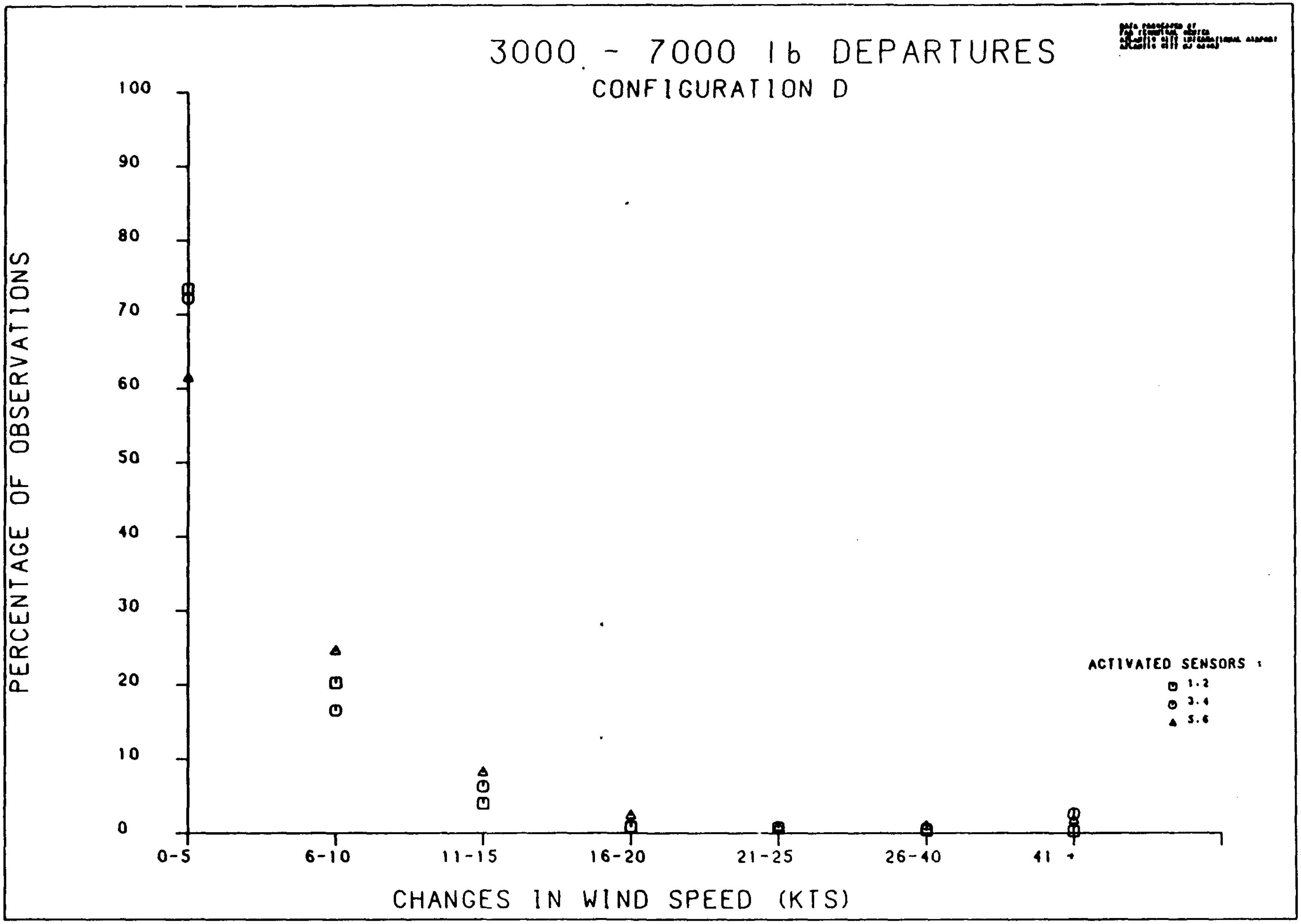



FIGURE 11. PLOTS OF DISTRIBUTIONS FOR VELOCITY CHANGES FOR 3000-7000 POUND AIRCRAFT, DEPARTURES (SHEET 4 OF 5)

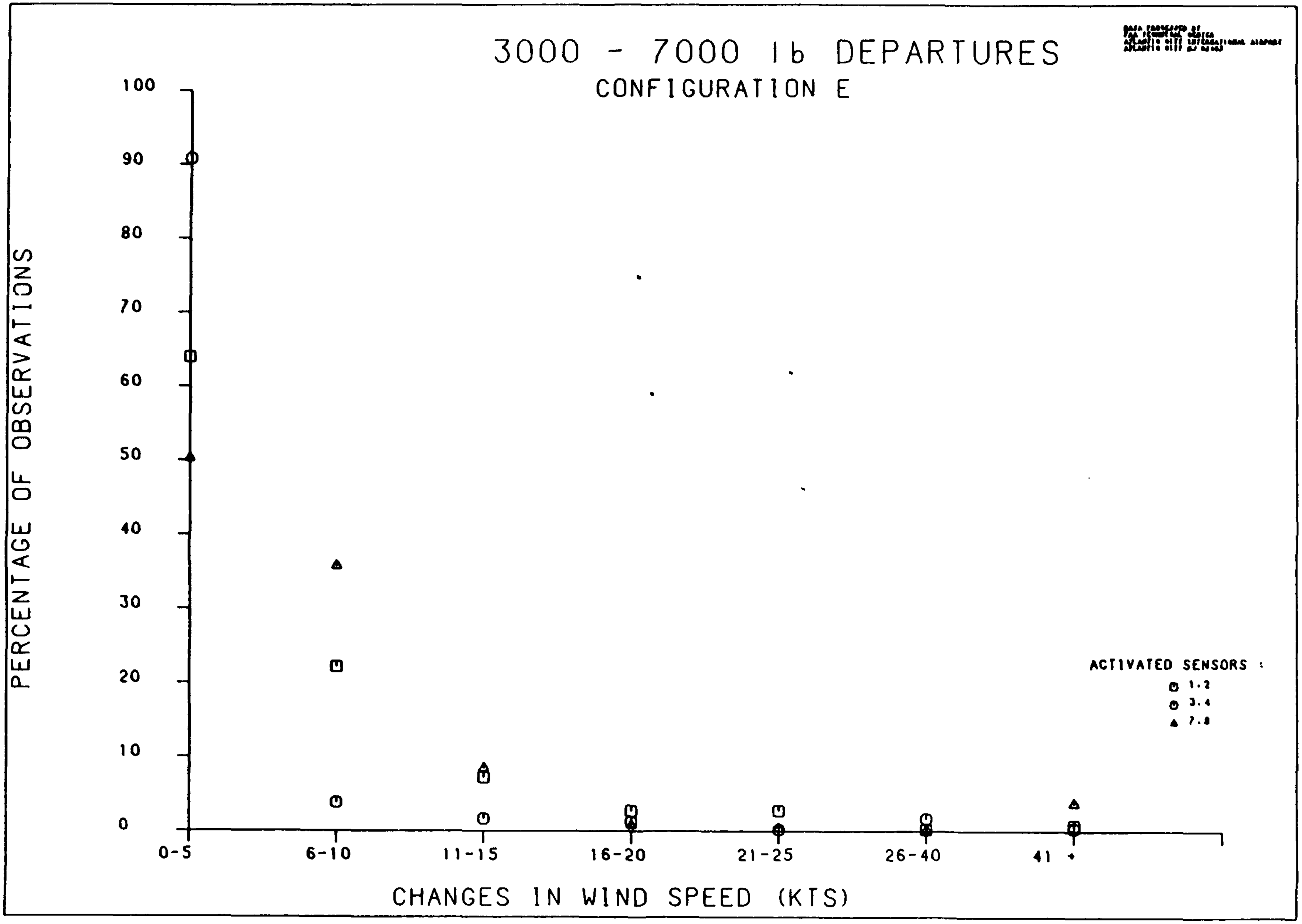



FIGURE 11. PLOTS OF DISTRIBUTIONS FOR VELOCITY CHANGES FOR 3000-7000 POUND AIRCRAFT, DEPARTURES (SHEET 5 OF 5)

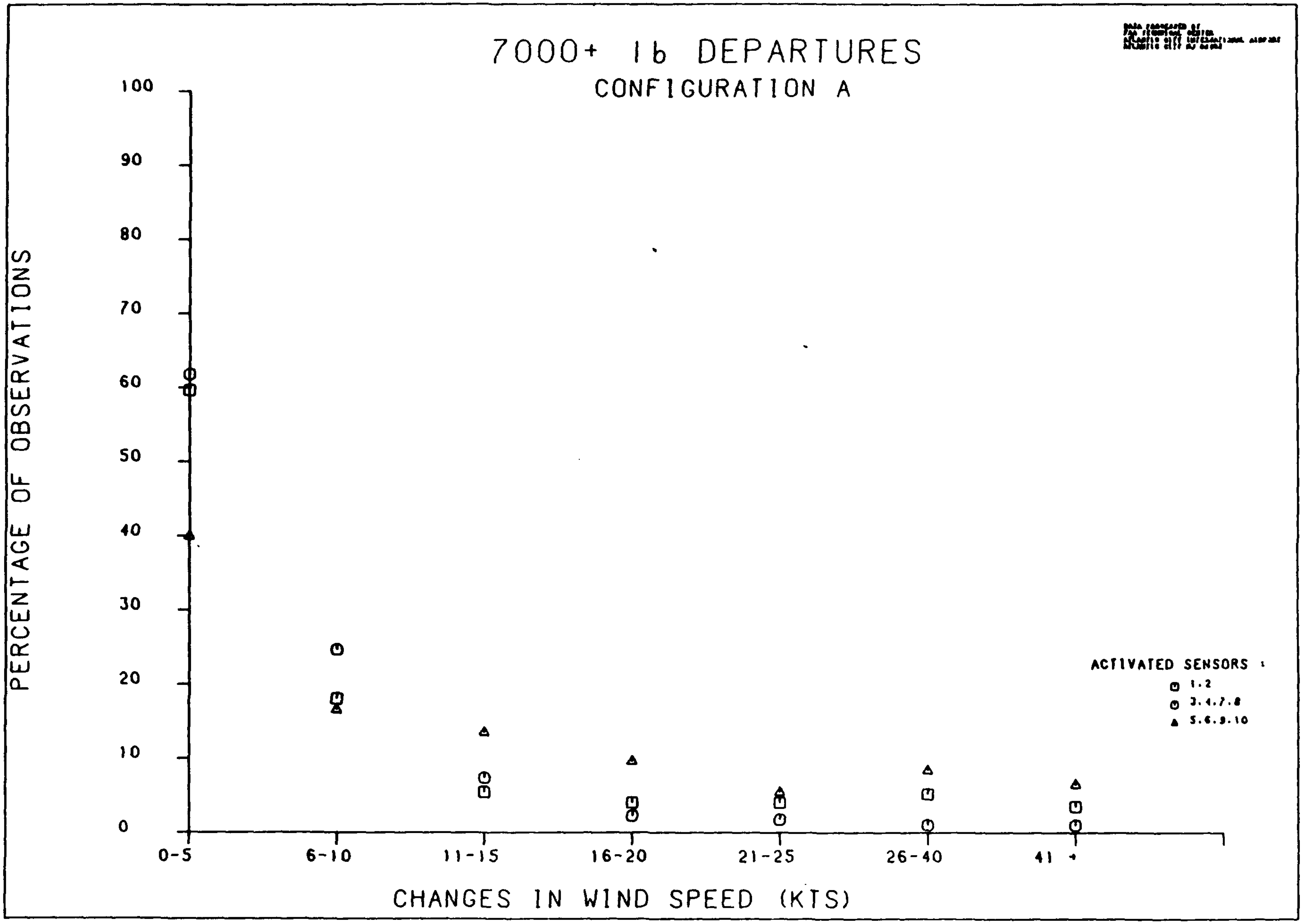



FIGURE 12. PLOTS OF DISTRIBUTIONS FOR VELOCITY CHAGNES FOR AIRCRAFT GREATER THAN 7000 POUNDS, DEPARTURES (SHEET 1 OF 3)

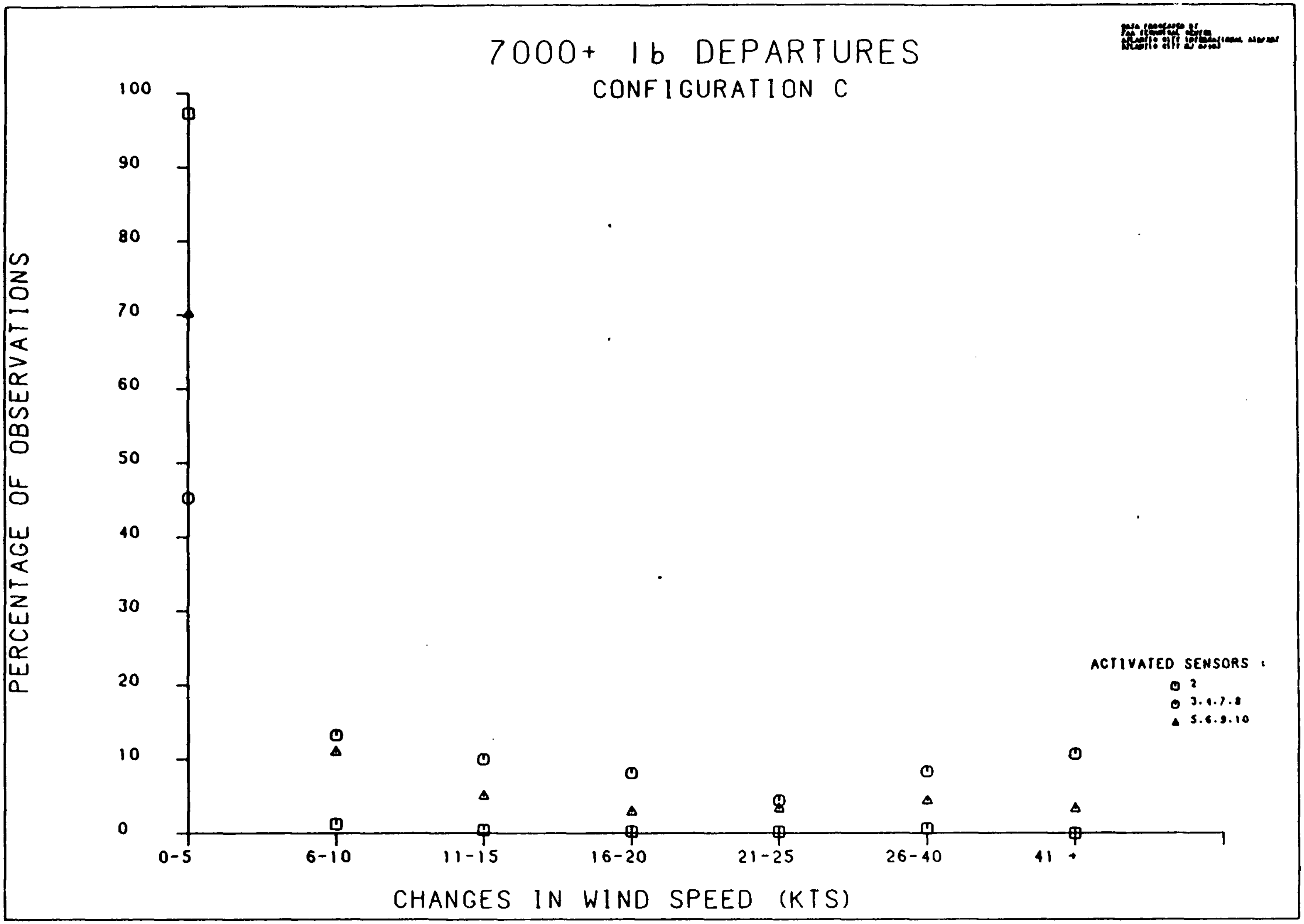



FIGURE 12. PLOTS OF DISTRIBUTIONS FOR VELOCITY CHANGES FOR AIRCRAFT GREATER THAN 7000 POUNDS, DEPARTURES (SHEET 2 OF 3)

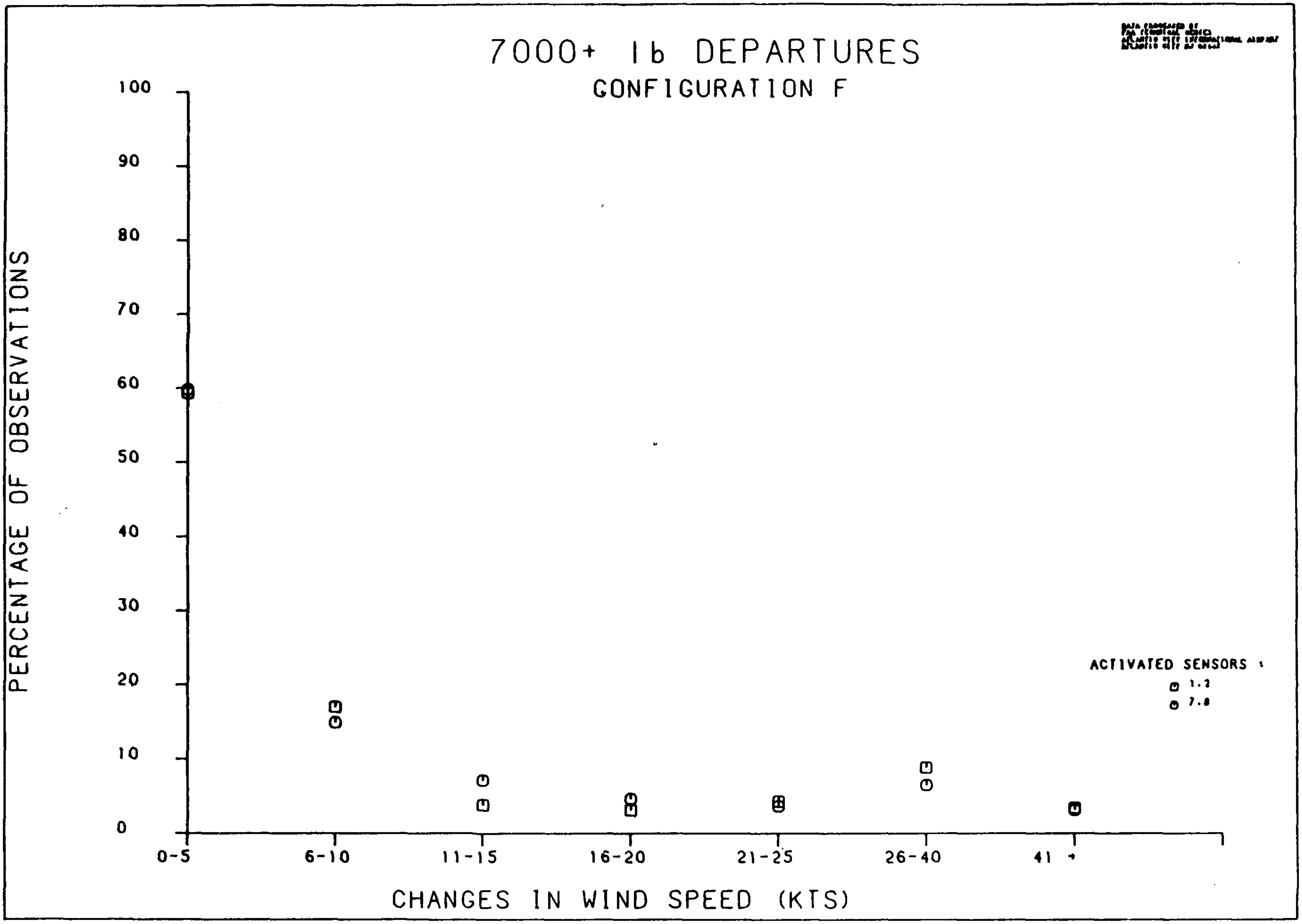



FIGURE 12. PLOTS OF DISTRIBUTIONS FOR VELOCITY CHANGES FOR AIRCRAFT GREATER THAN 7000 POUNDS, DEPARTURES (SHEET 3 OF 3)

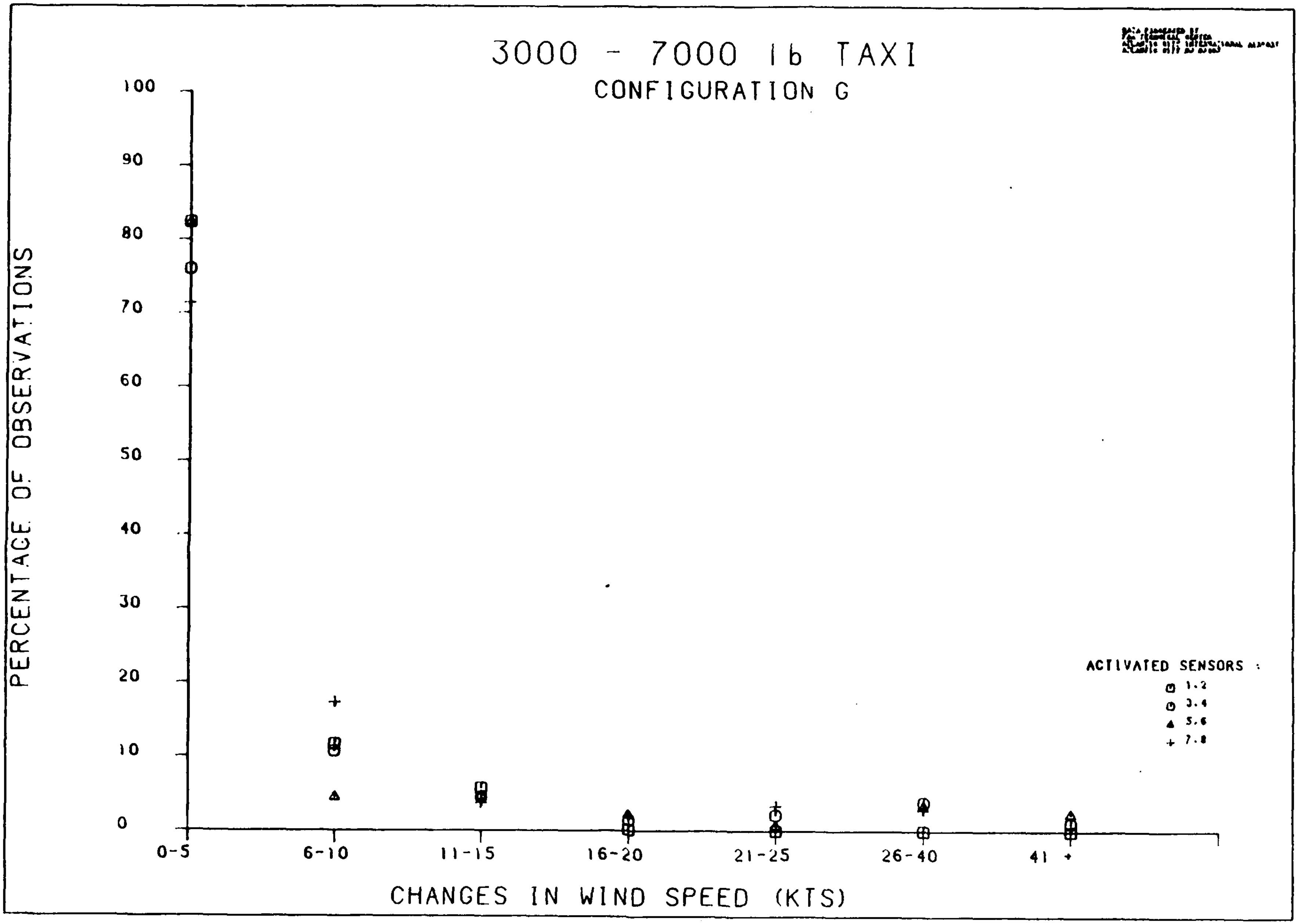



FIGURE 13. PLOT OF DISTRIBUTIONS FOR VELOCITY CHANGES FOR ALL TAXI OPERATIONS

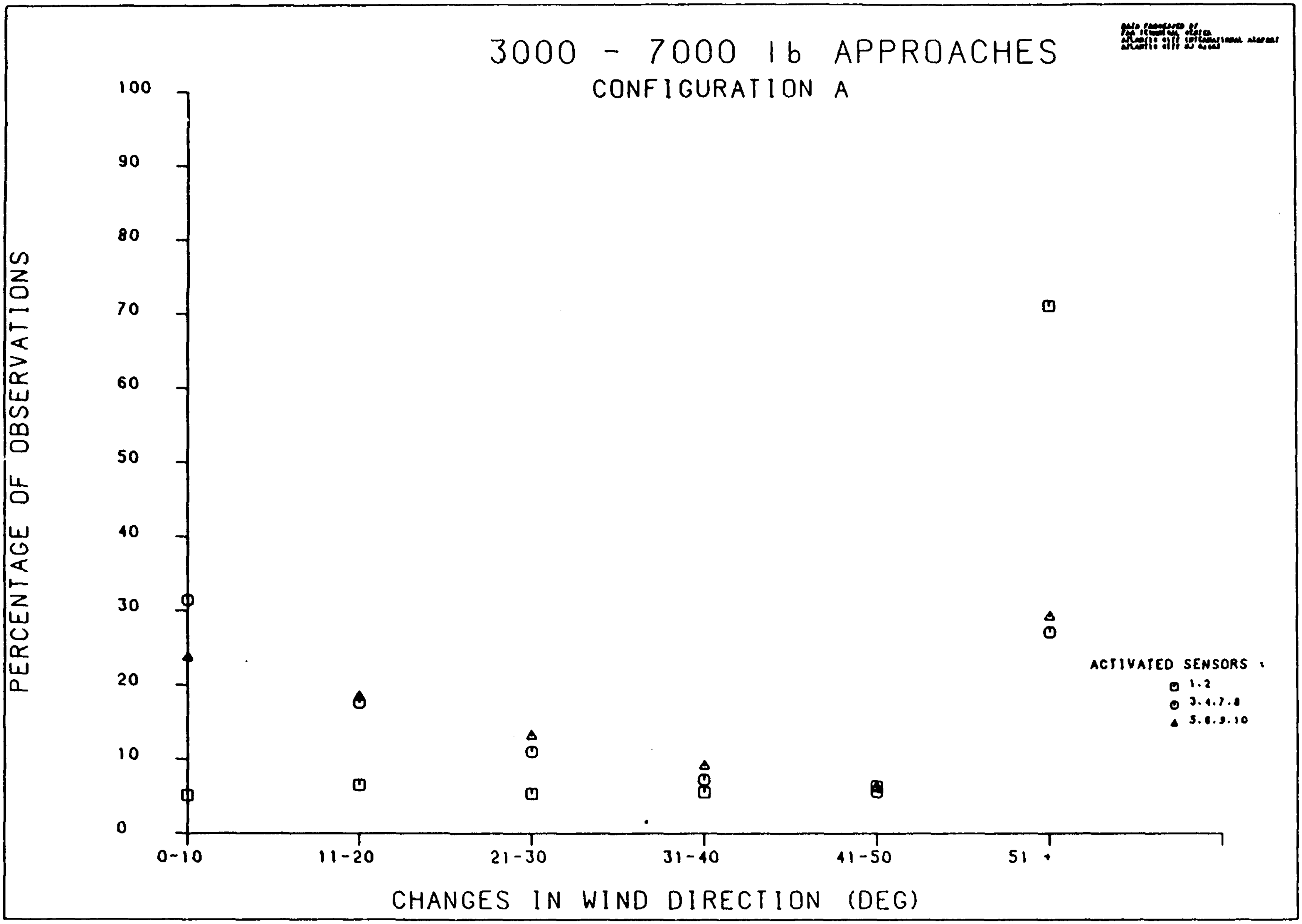



FIGURE 14. PLOTS OF DISTRIBUTIONS FOR WIND DIRECTION CHANGES FOR 3000-7000 POUND AIRCRAFT, APPROACHES (SHEET 1 OF 4)

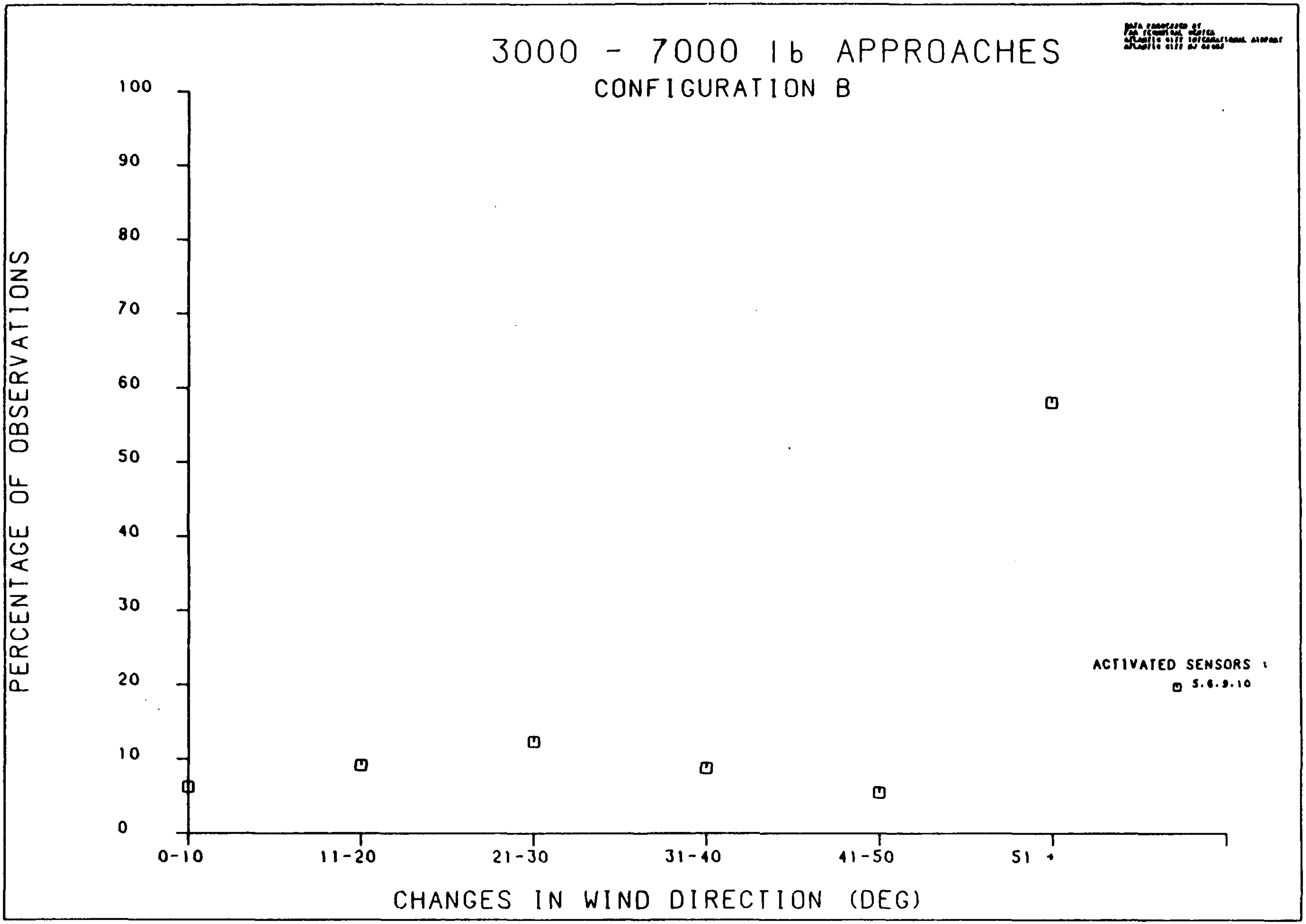



FIGURE 14. PLOTS OF DISTRIBUTIONS FOR WIND DIRECTION CHANGES FOR 3000-7000 POUND AIRCRAFT, APPROACHES (SHEET 2 OF 4)

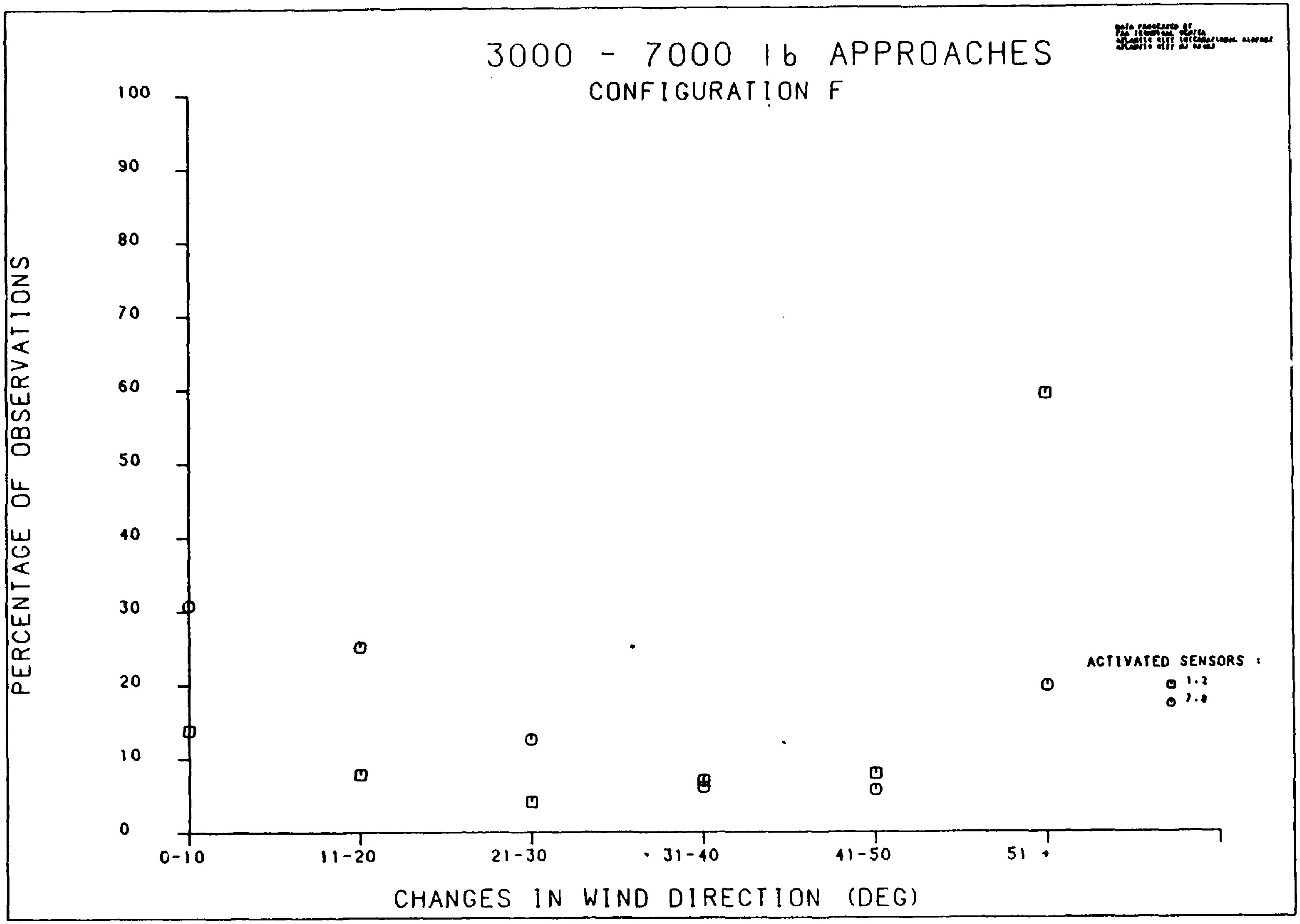



FIGURE 14. PLOTS OF DISTRIBUTIONS FOR WIND DIRECTION CHAGNES FOR 3000-7000 POUND AIRCRAFT, APPROACHES (SHEET 3 OF 4)

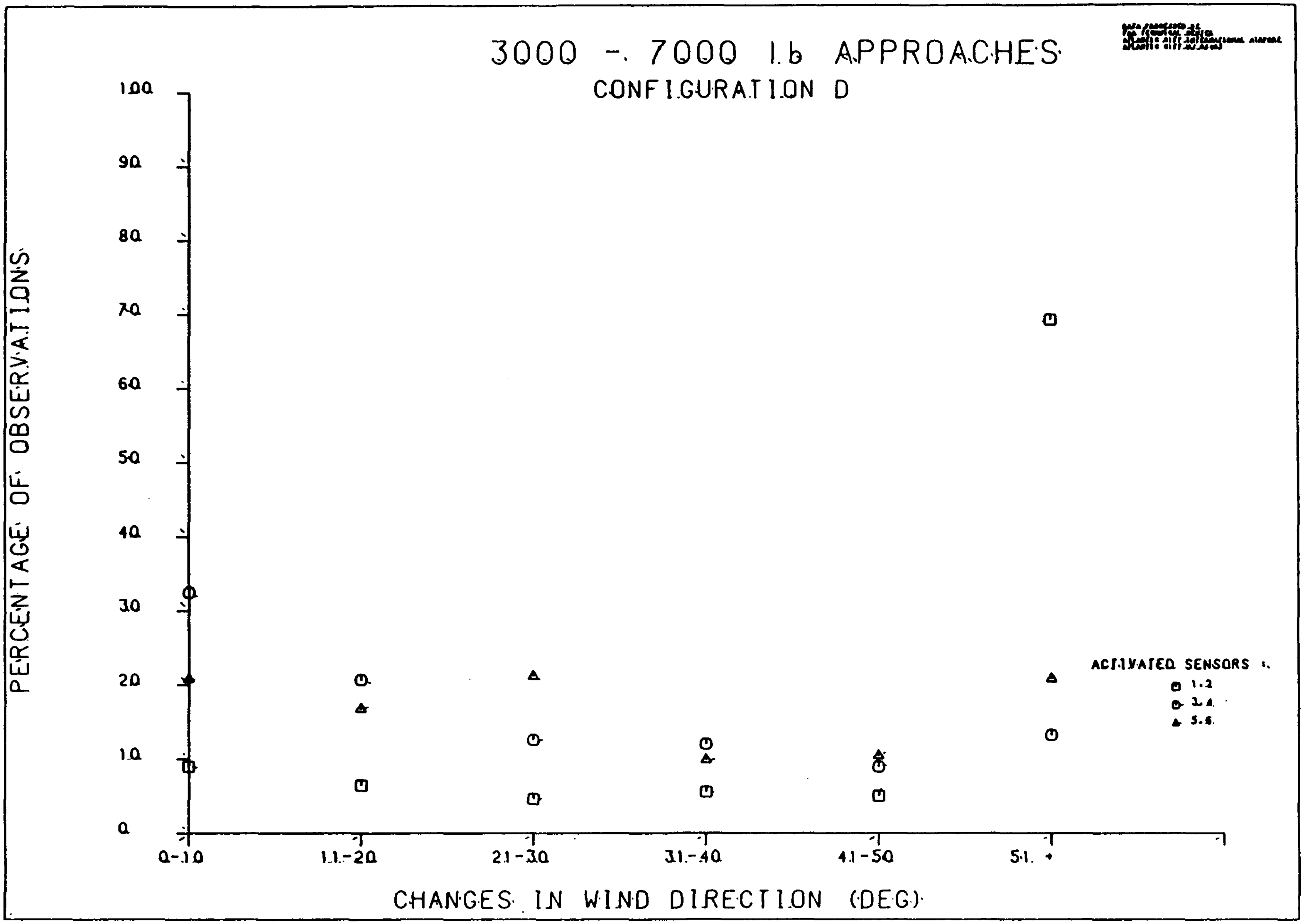



FIGURE 14. PLOTS OF DISTRIBUTIONS FOR WIND DIRECTION CHANGES FOR 3000-7000 POUND AIRCRAFT, APPROACHES (SHEET 4 OF 4)

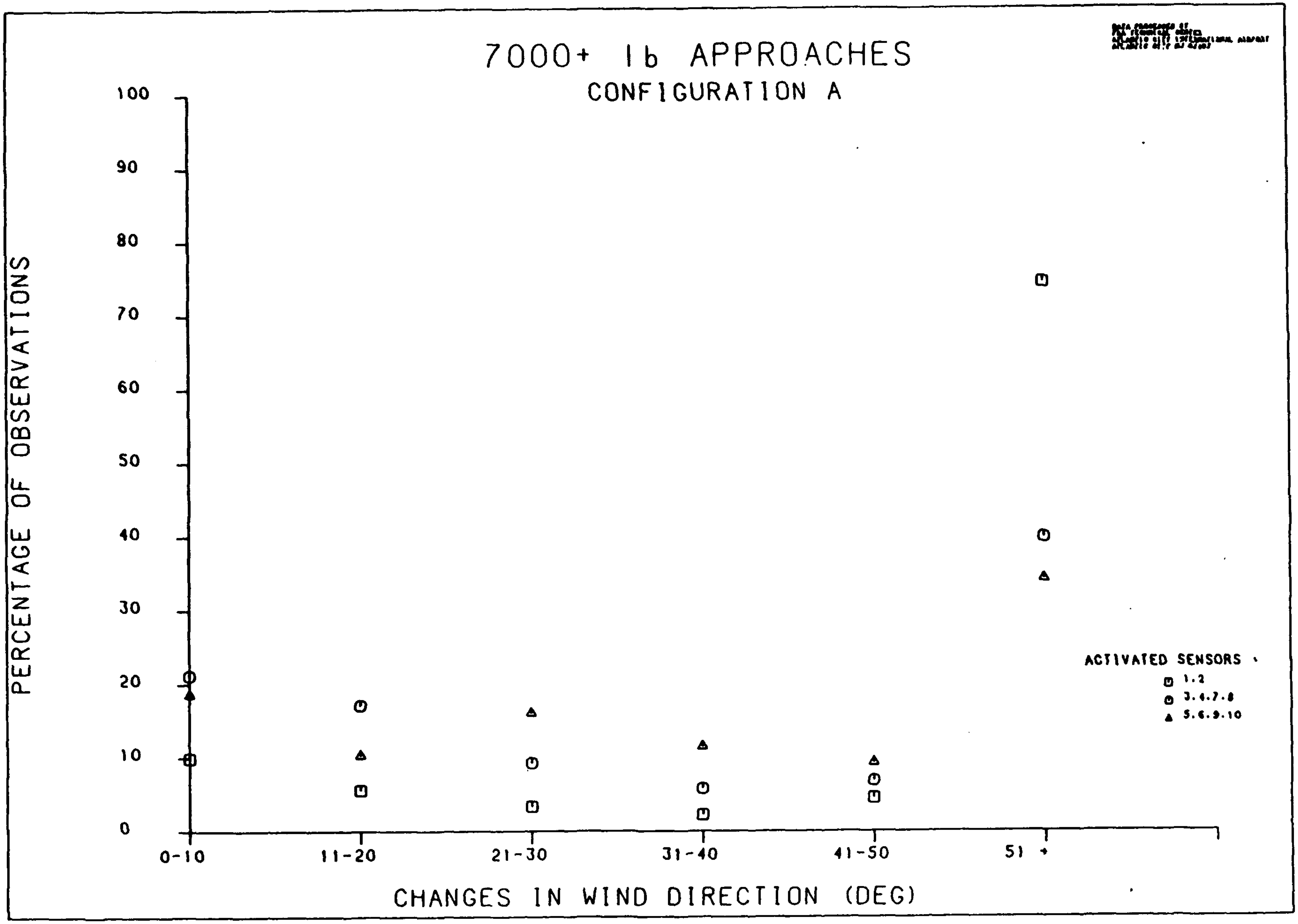



FIGURE 15. PLOTS OF DISTRIBUTIONS FOR WIND DIRECTION CHANGES FOR AIRCRAFT GREATER THAN 7000 POUNDS, APPROACHES (SHEET 1 OF 4)

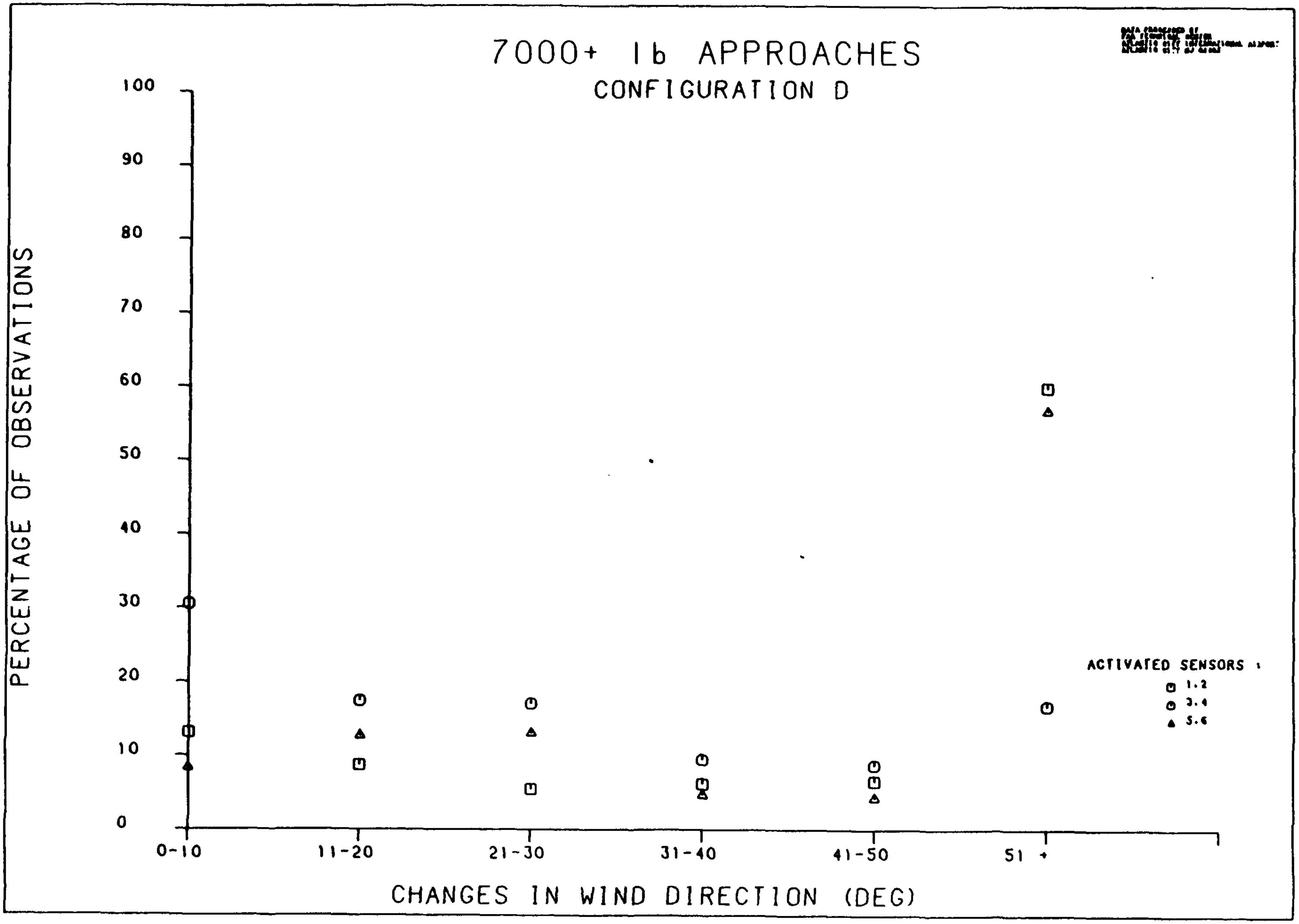



FIGURE 15. PLOTS OF DISTRIBUTIONS FOR WIND DIRECTION CHANGES FOR AIRCRAFT GREATER THAN 7000 POUNDS, APPROACHES (SHEET 2 OF 4)

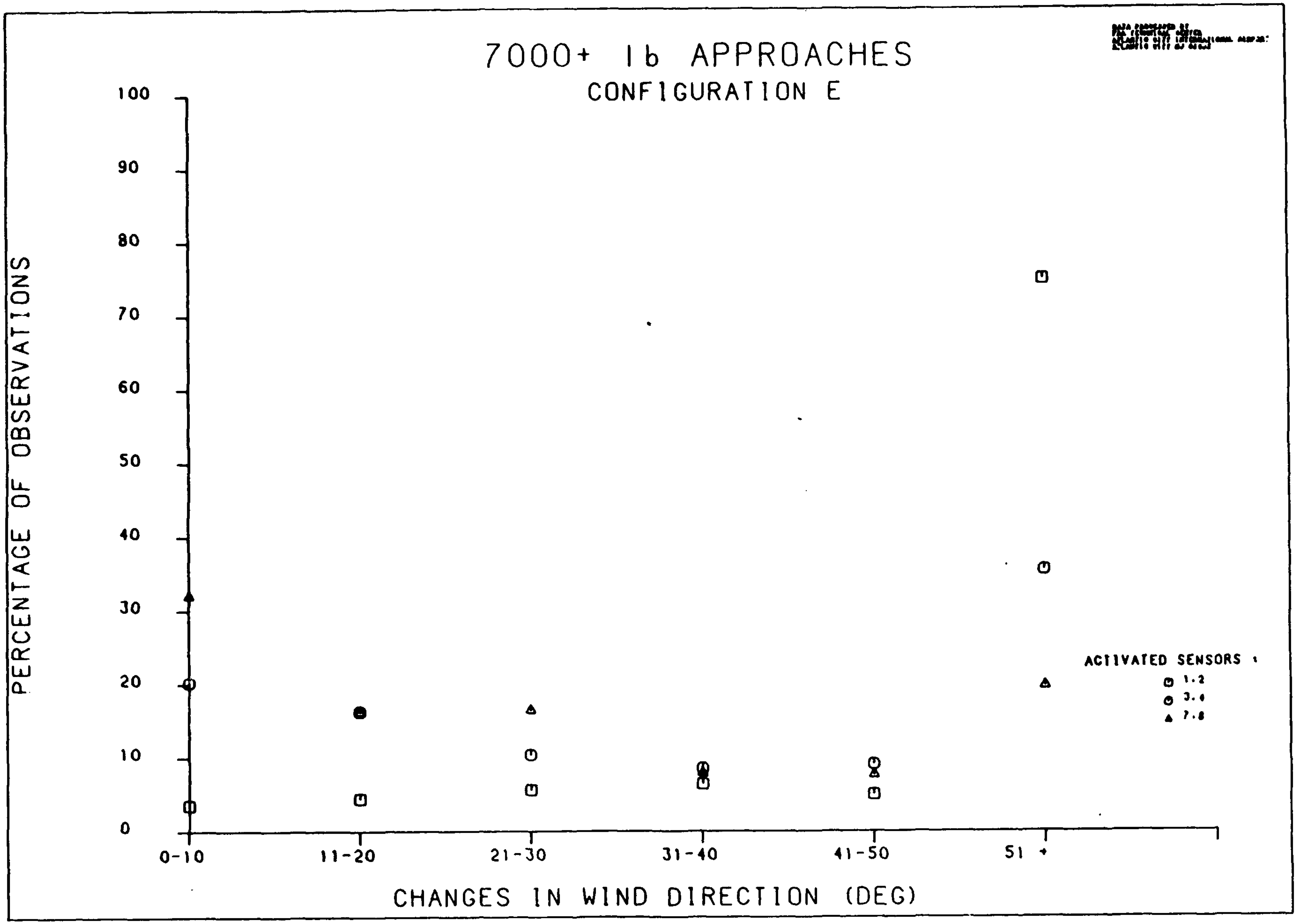



FIGURE 15. PLOTS OF DISTRIBUTIONS FOR WIND DIRECTION CHANGES FOR AIRCRAFT GREATER THAN 7000 POUNDS, APPROACHES (SHEET 3 OF 4)

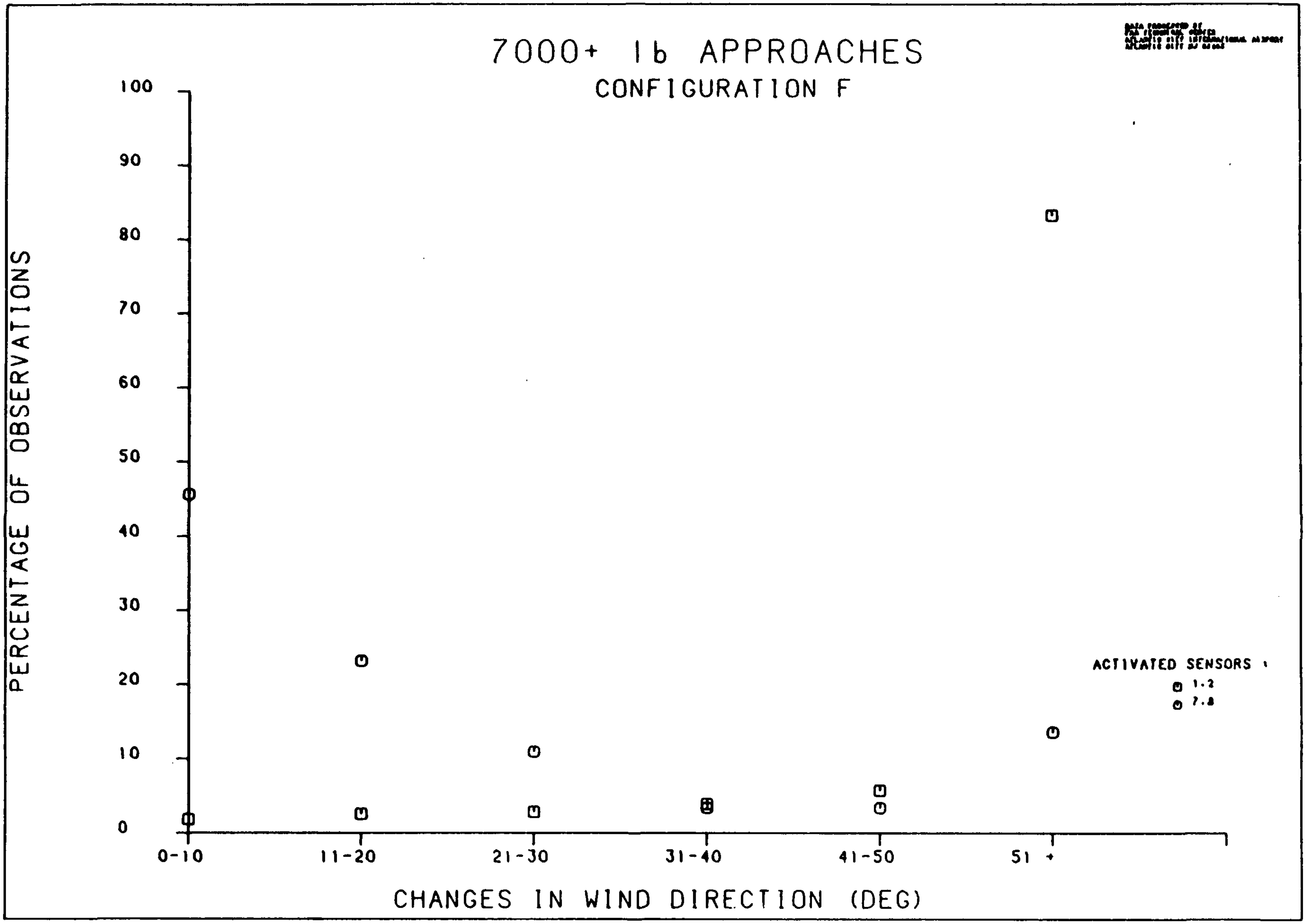



FIGURE 15. PLOTS OF DISTRIBUTIONS FOR WIND DIRECTION CHANGES FOR AIRCRAFT GREATER THAN 7000 POUNDS, APPROACHES (SHEET 4 OF 4)

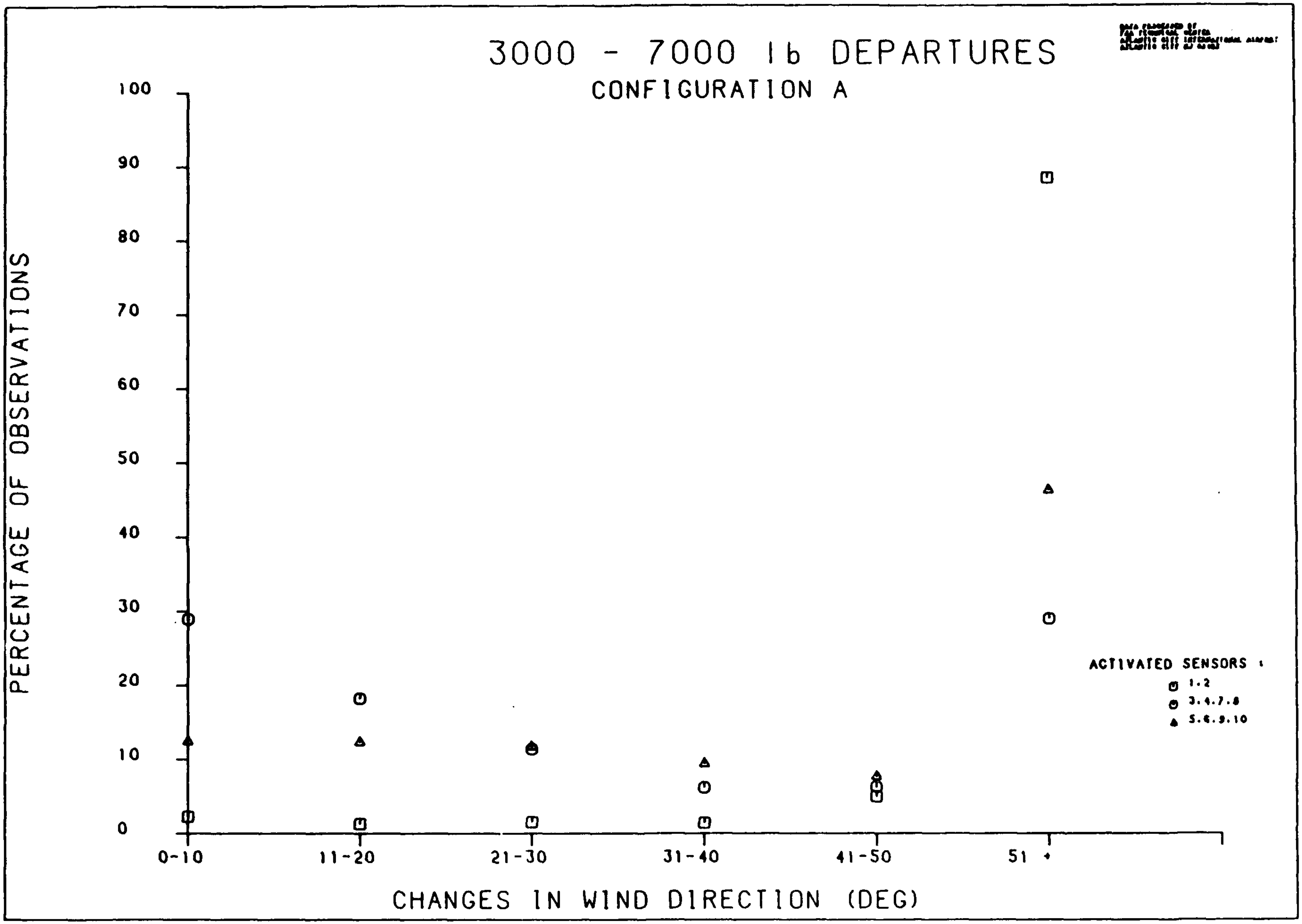



FIGURE 16. PLOTS FOR DISTRIBUTION FOR WIND DIRECTION CHANGES FOR 3000-7000 POUND AIRCRAFT, DEPARTURES (SHEET 1 OF 5)

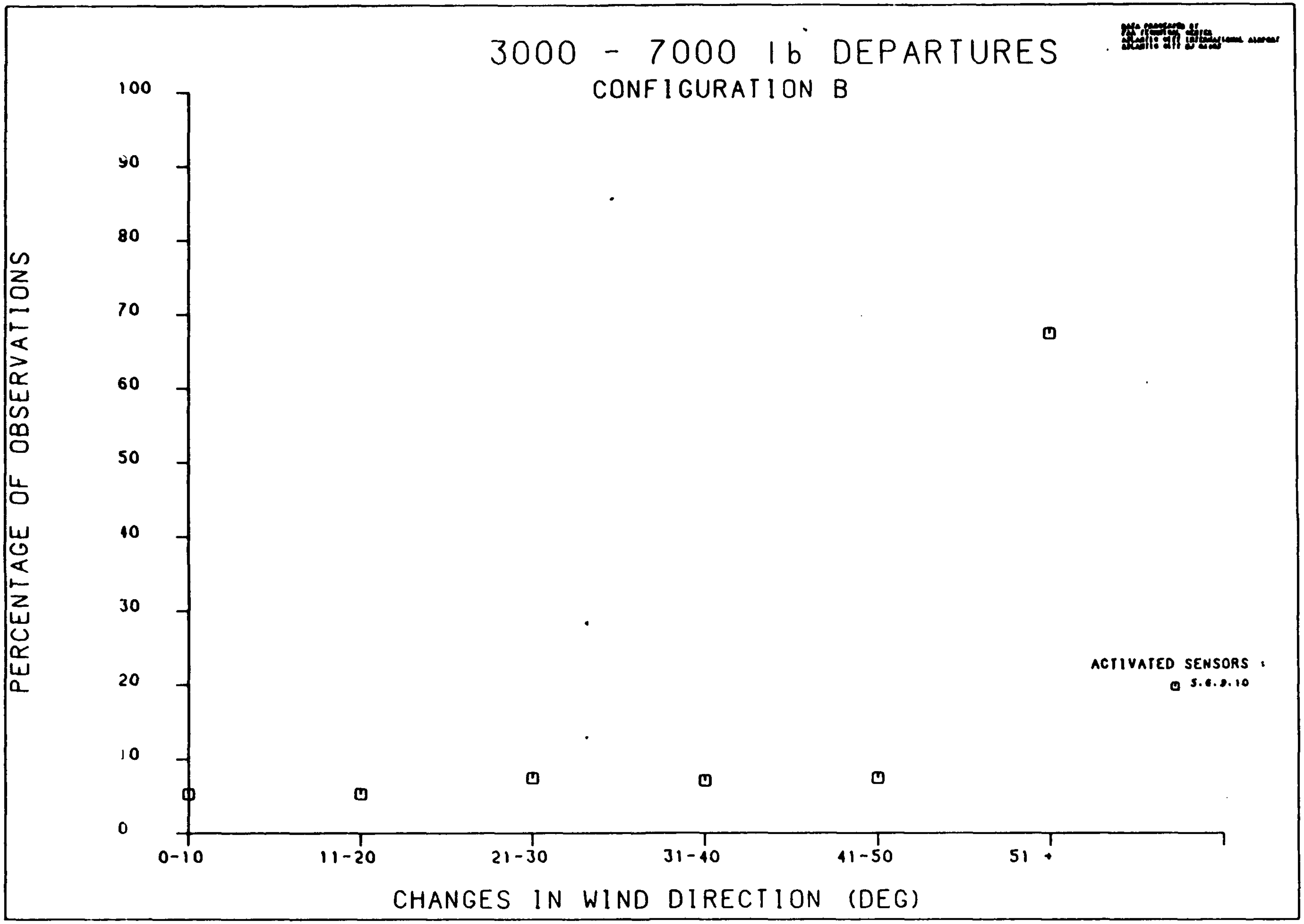



FIGURE 16. PLOTS OF DISTRIBUTIONS FOR WIND DIRECTION CHANGES FOR 3000-7000 POUND AIRCRAFT, DEPARTURES (SHEET 2 OF 5)

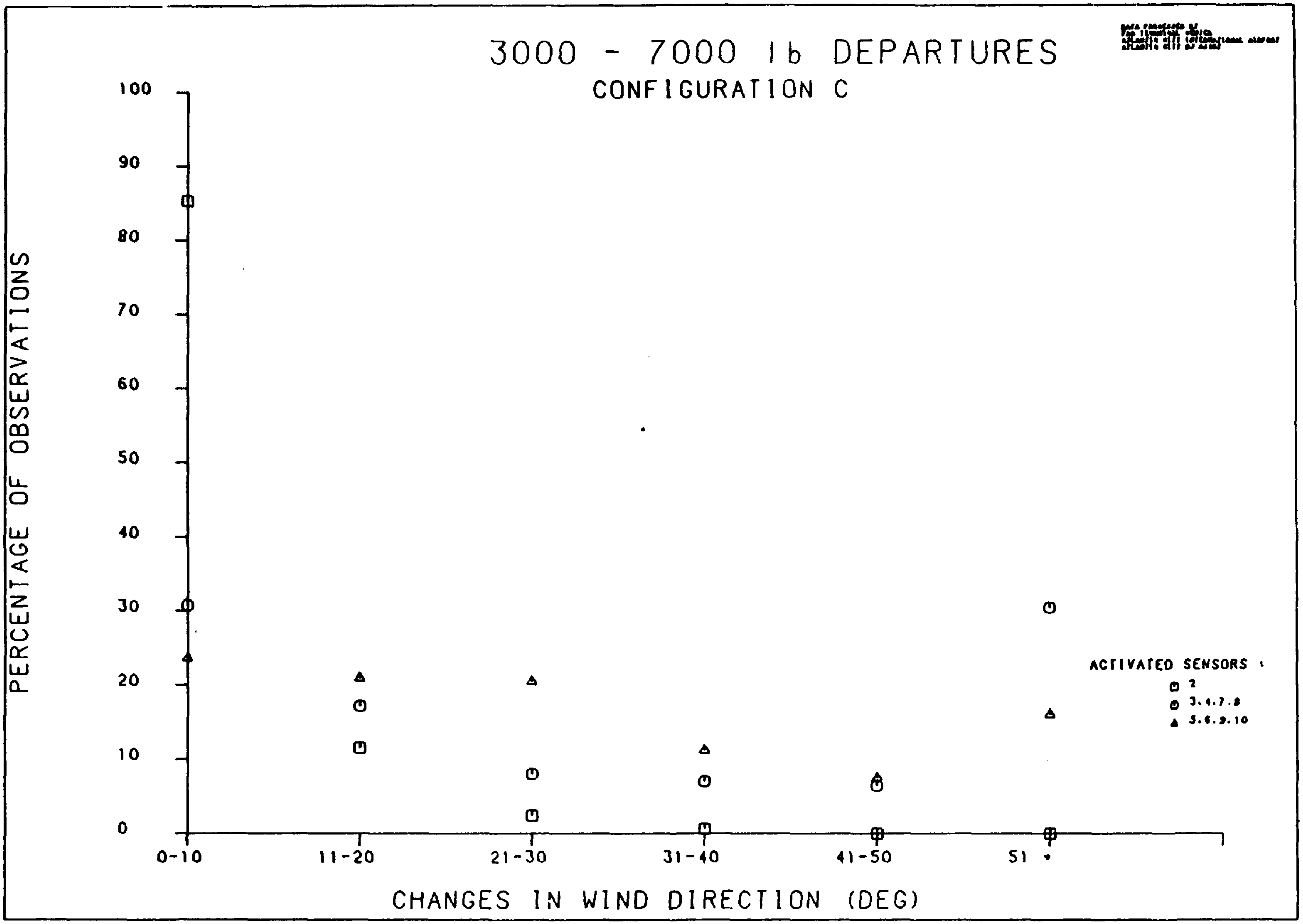



FIGURE 16. PLOTS OF DISTRIBUTIONS FOR WIND DIRECTION CHANGES FOR 3000-7000 POUND AIRCRAFT, DEPARTURES (SHEET 3 OF 5)

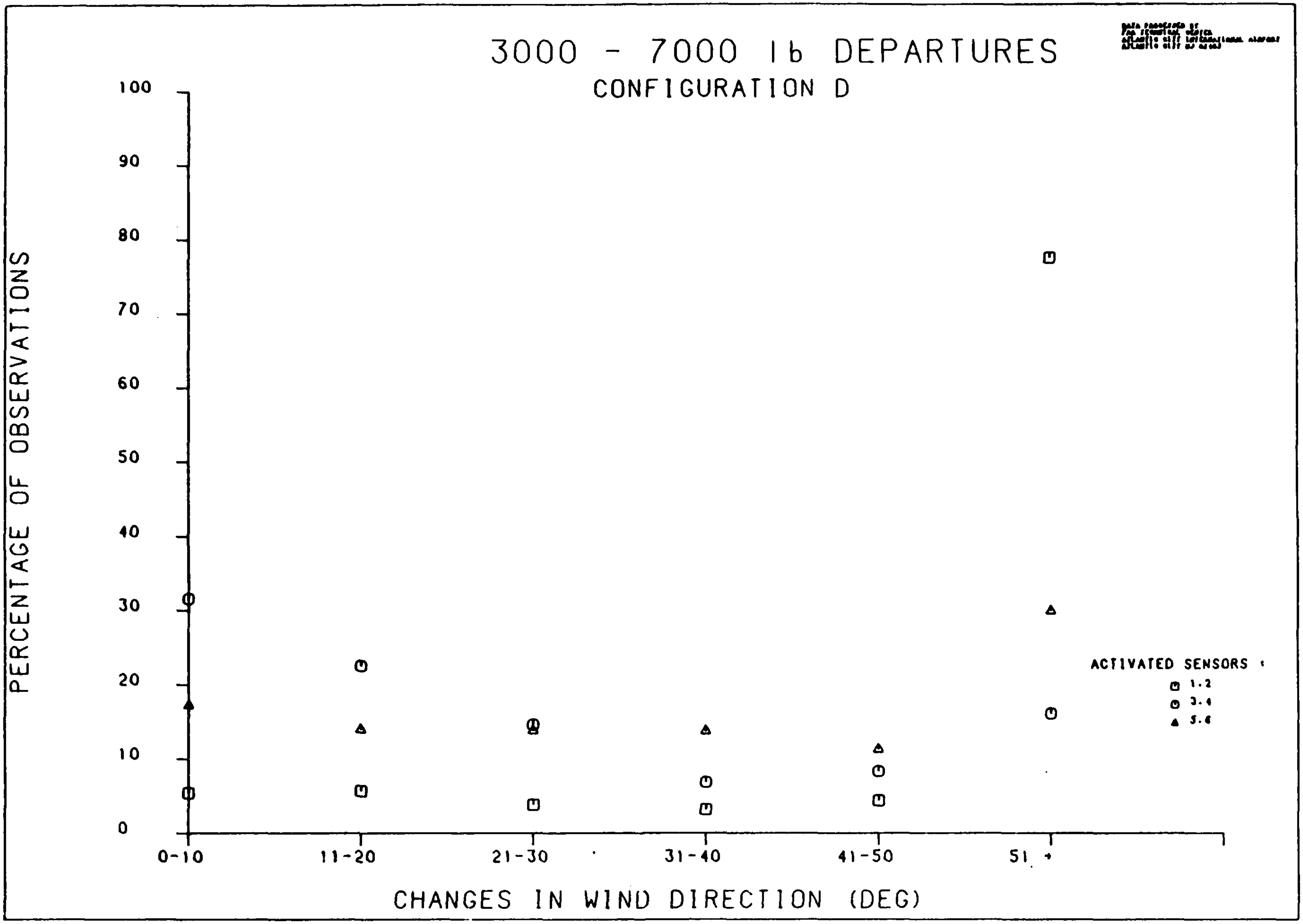



FIGURE 16. PLOTS OF DISTRIBUTIONS FOR WIND DIRECTION CHANGES FOR 3000-7000 POUND AIRCRAFT, DEPARTURES (SHEET 4 OF 5)

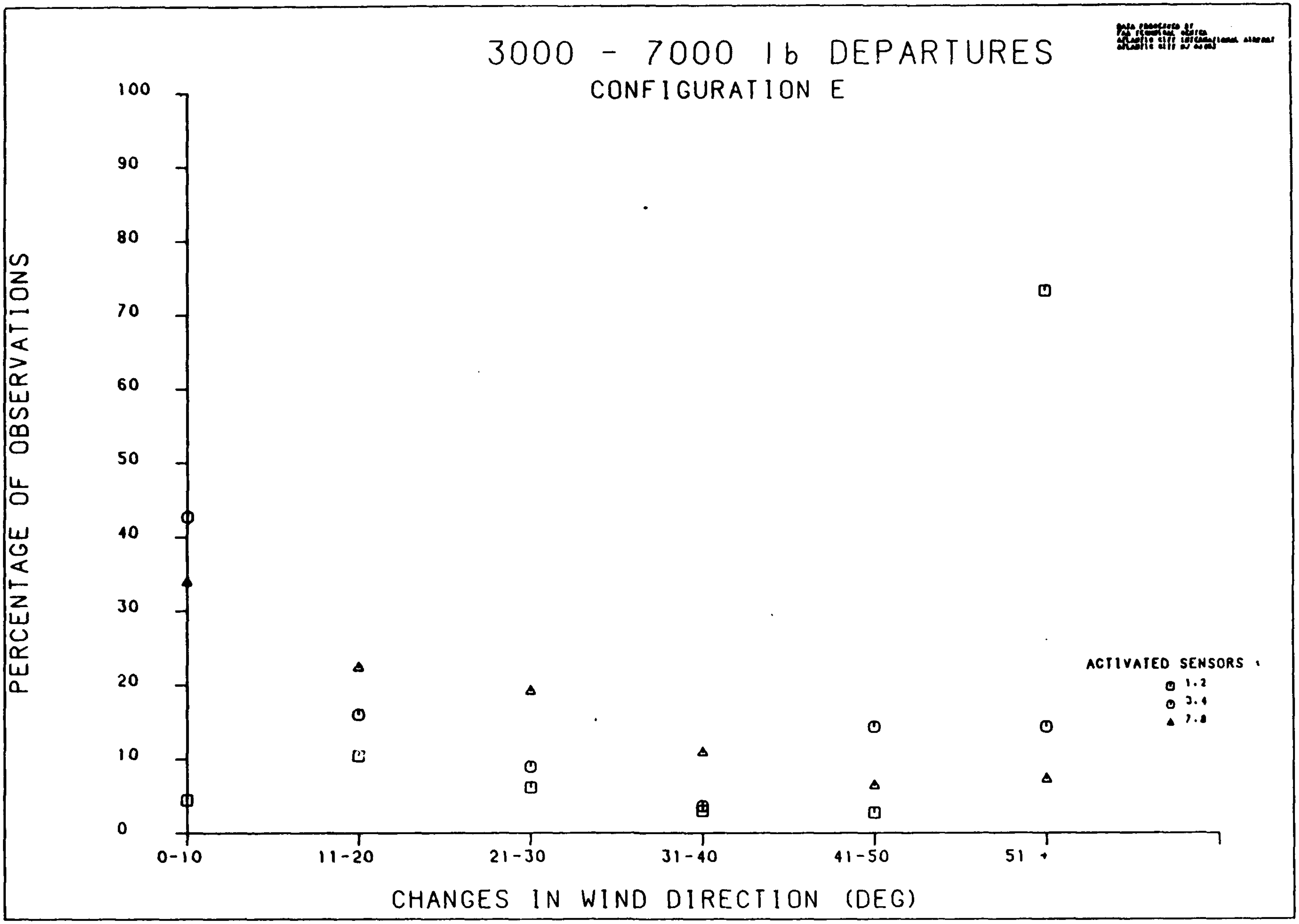



FIGURE 16. PLOTS OF DISTRIBUTIONS FOR WIND DIRECTION CNANGES FOR 3000-7000 POUND AIRCRAFT, DEPARTURES (SHEET 5 OF 5)

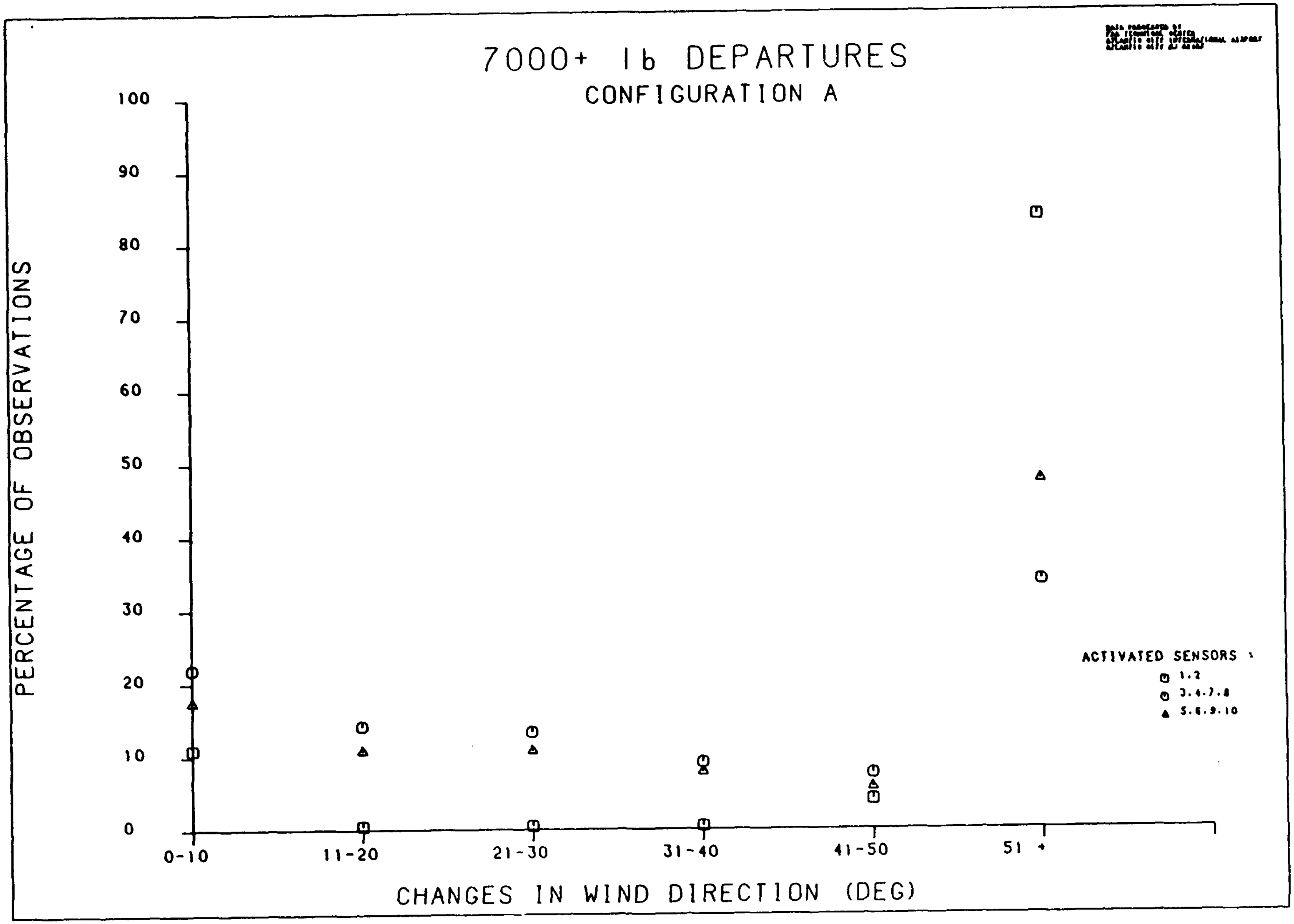



FIGURE 17. PLOTS OF DISTRIBUTIONS FOR WIND DIRECTION CHANGES FOR AIRCRAFT GREATER THAN 7000 POUNDS, DEPARTURES (SHEET 1 OF 3)

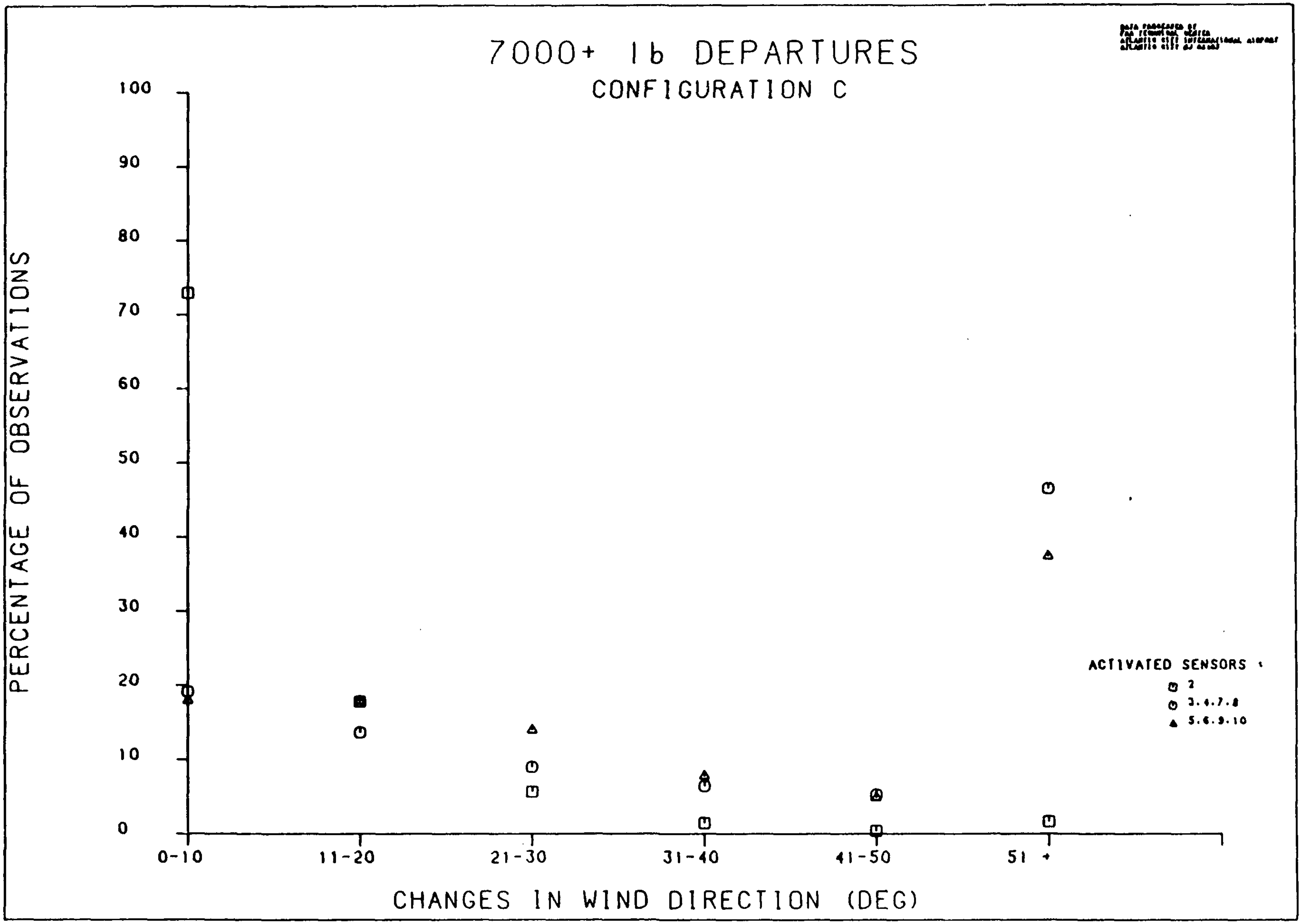
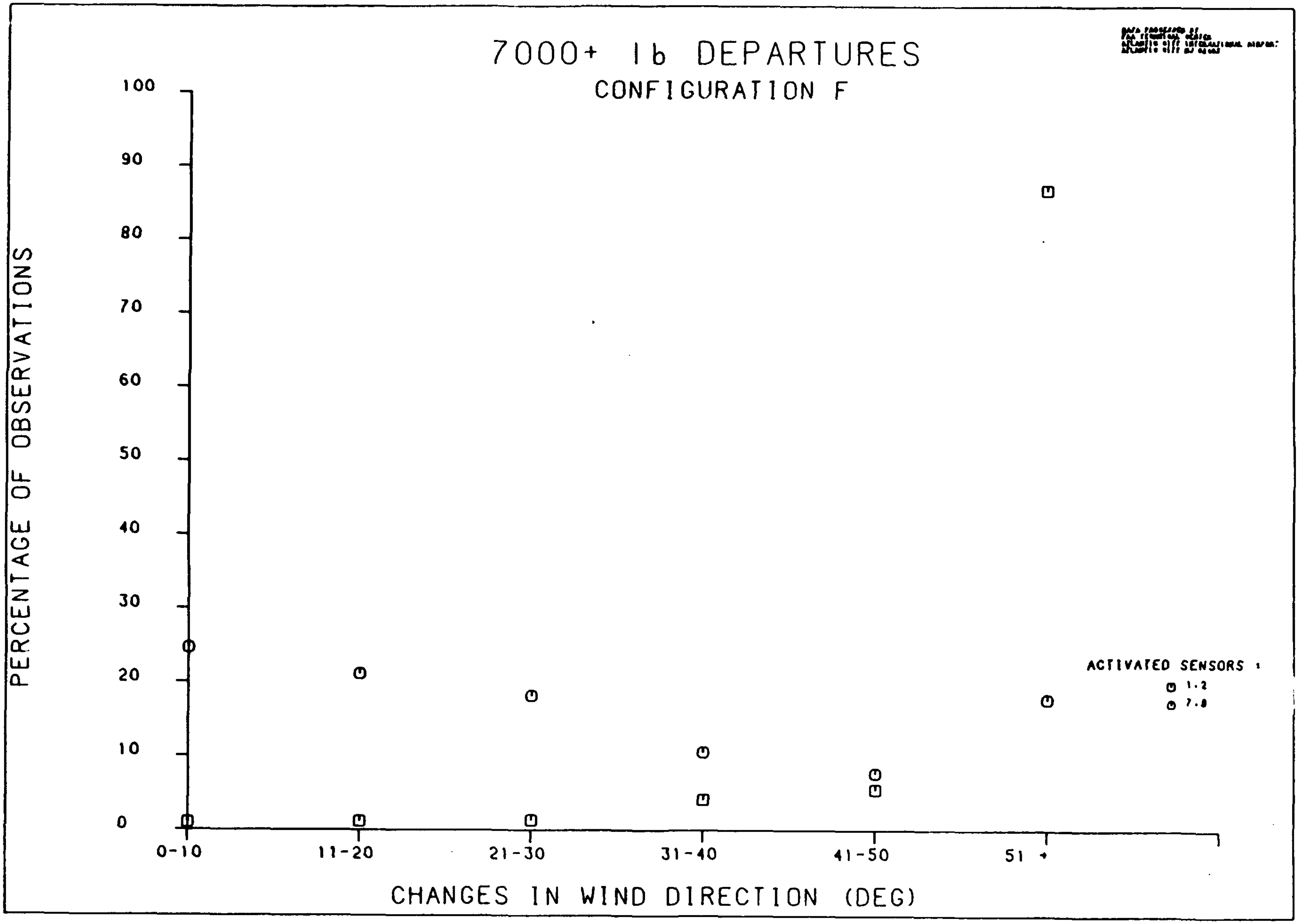



FIGURE 17. PLOTS OF DISTRIBUTIONS FOR WIND DIRECTION CHANGES FOR AIRCRAFT GREATER THAN 7000 POUNDS, DEPARTURES (SHEET 2 OF 3)




FIGRURE 17. PLOTS OF DISTRIBUTIONS FOR WIND DIRECTION CHANGES FOR AIRCRAFT GREATER THAN 7000 POUNDS, DEPARTURES (SHEET 3 OF 3)

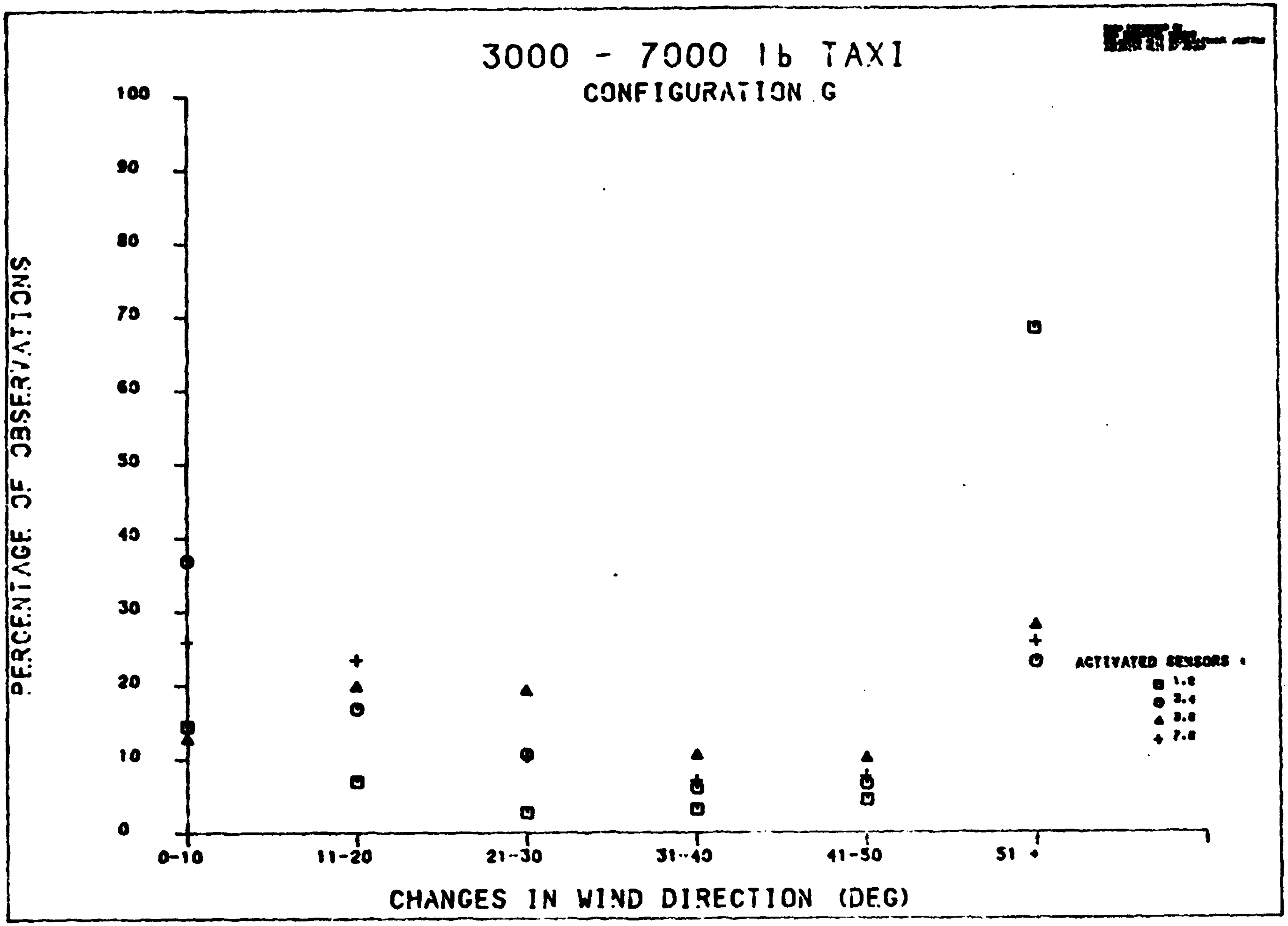



FIGURE 18. PLOT OF DISTRIBUTIONS FOR WIND DIRECTION CHANGES FOR ALL TAXI OPERATIONS

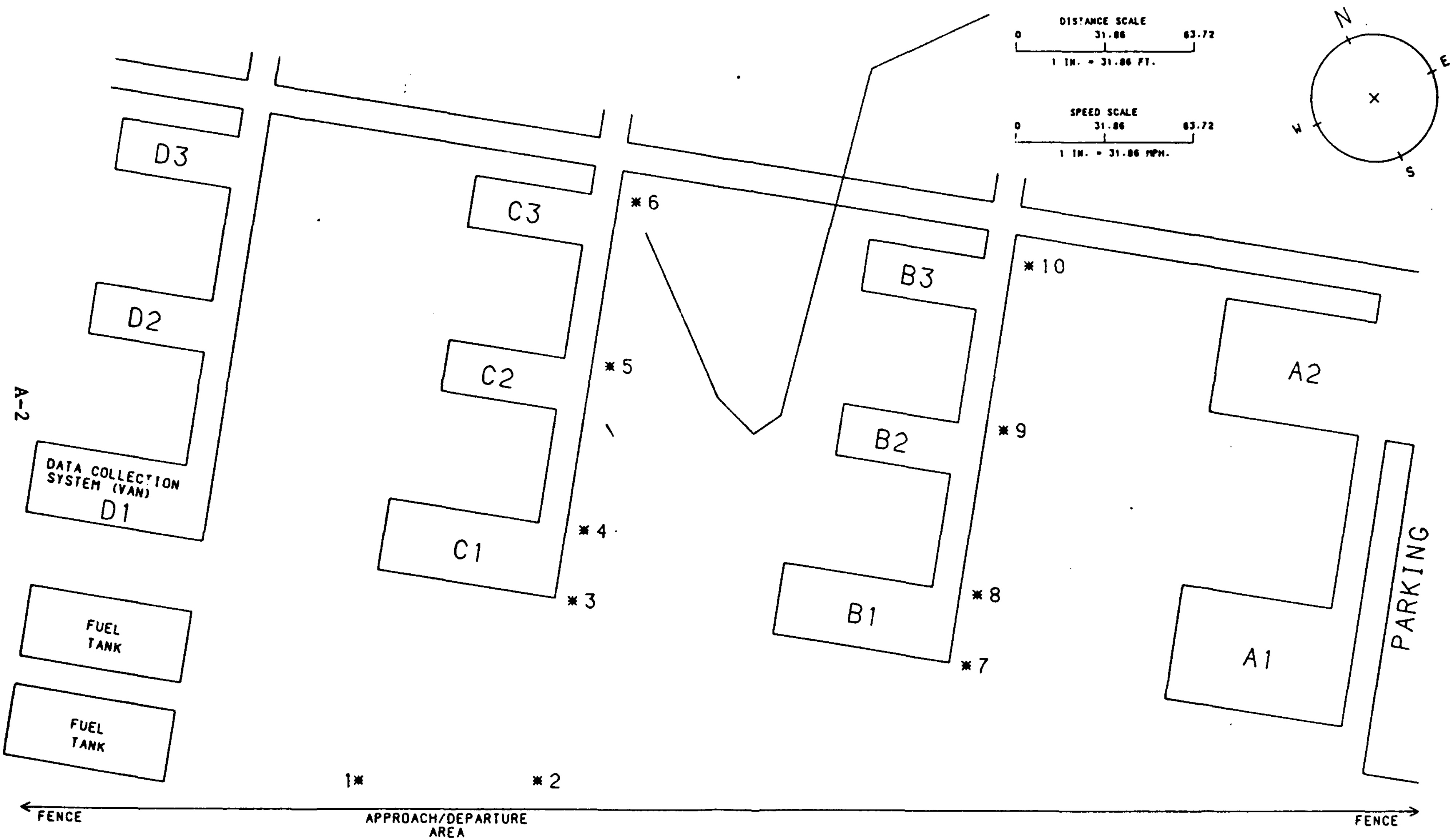
# APPENDIX A

## ILLUSTRATIONS OF FLIGHTPATHS FOR EACH SENSOR CONFIGURATION

FLIGHT PATTERN - 8

DATA PROCESSED BY THE FAA TECHNICAL CENTER
ATLANTIC CITY AIRPORT, N.J. 08405

# INTRACOASTAL CITY, LA.
# P.H.I. HELIPORT

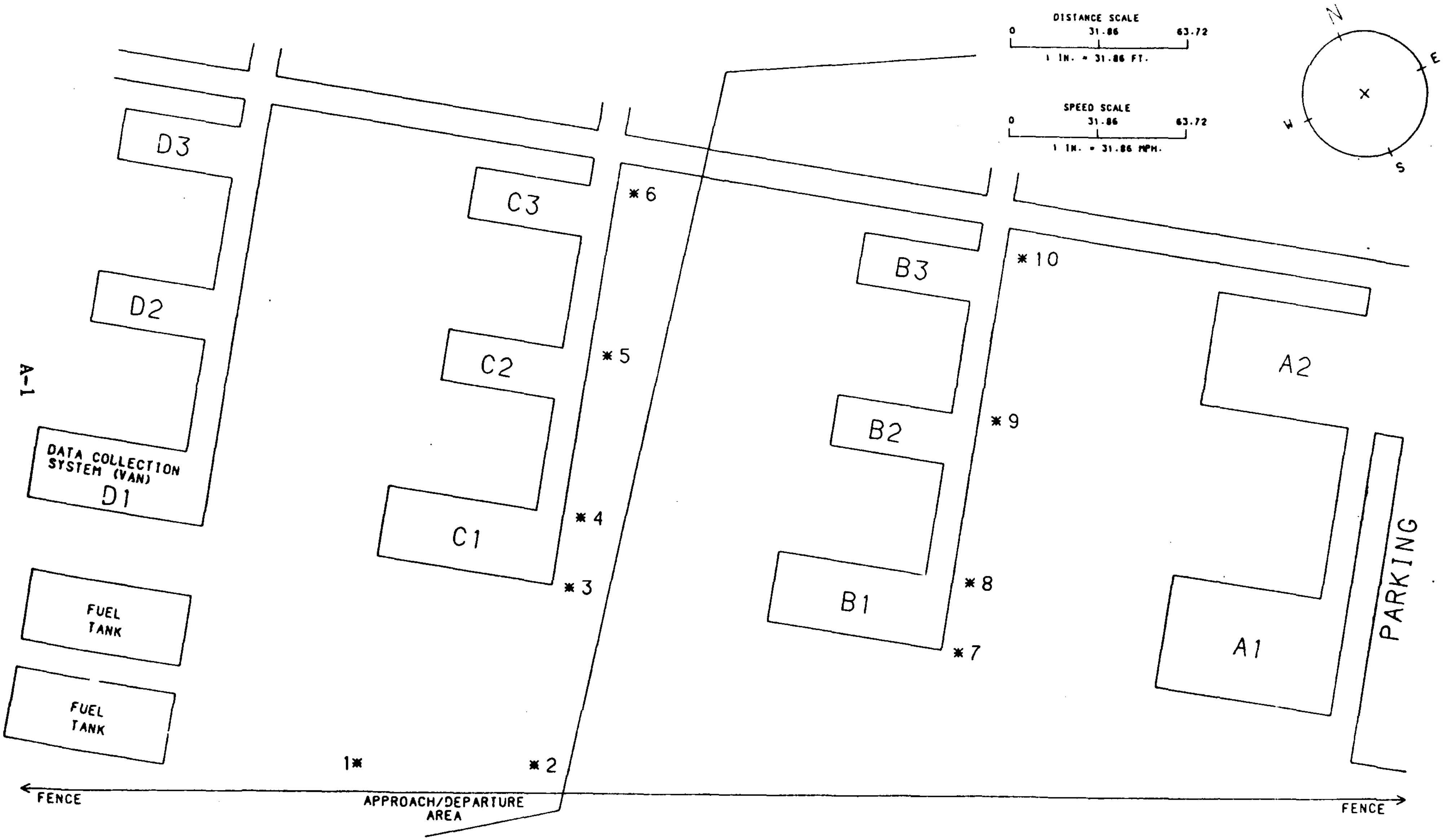


FLIGHT PATTERN : A

* SENSOR

# INTRACOASTAL CITY, LA.
# P.H.I. HELIPORT

DATA PROCESSED BY THE FAA TECHNICAL CENTER
ATLANTIC CITY AIRPORT, N J 08405

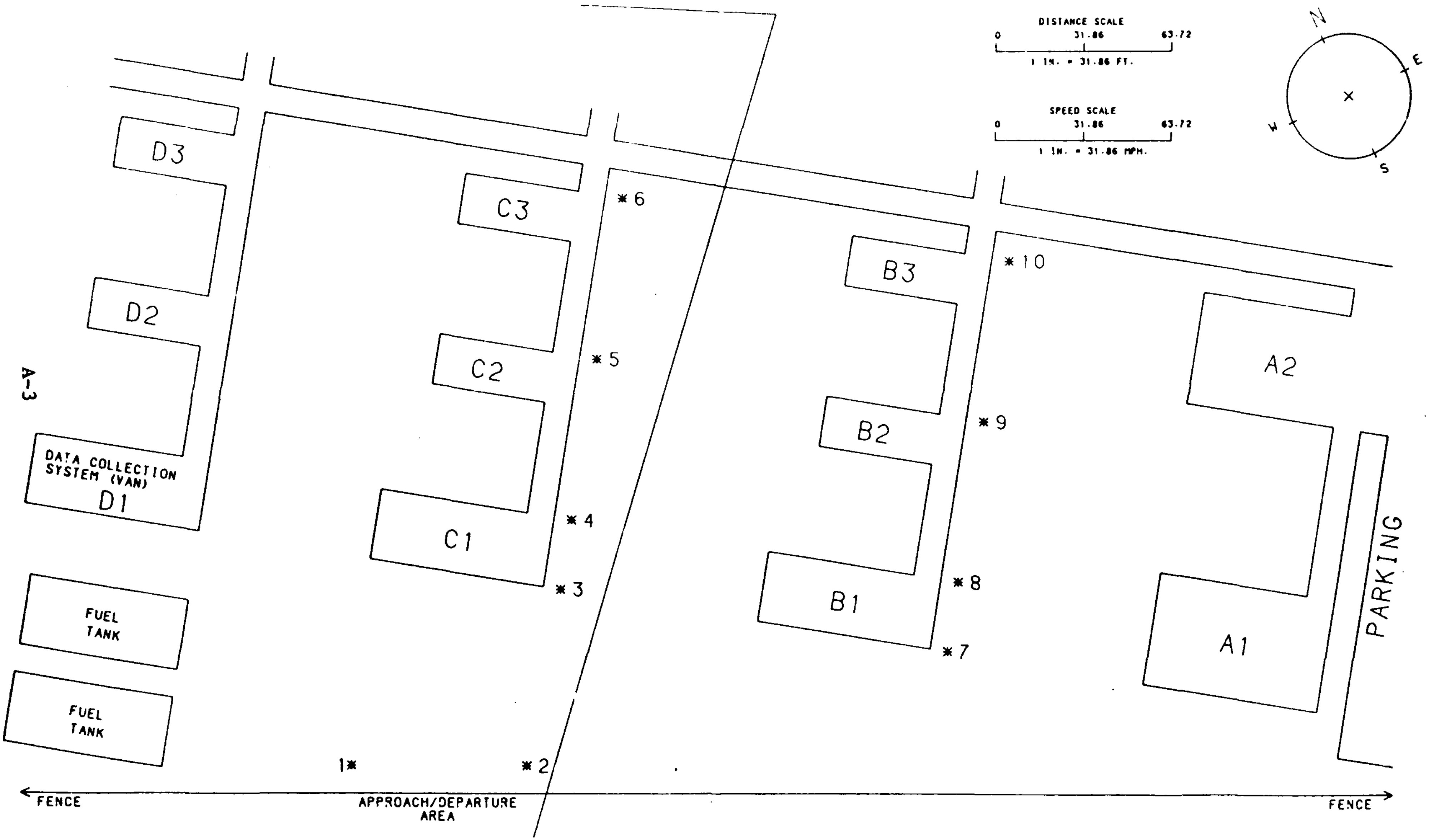


FLIGHT PATTERN - C

* SENSOR

DATA PROCESSED BY THE FAA TECHNICAL CENTER
ATLANTIC CITY AIRPORT, N J 08405

# INTRACOASTAL CITY, LA.
# P.H.I. HELIPORT

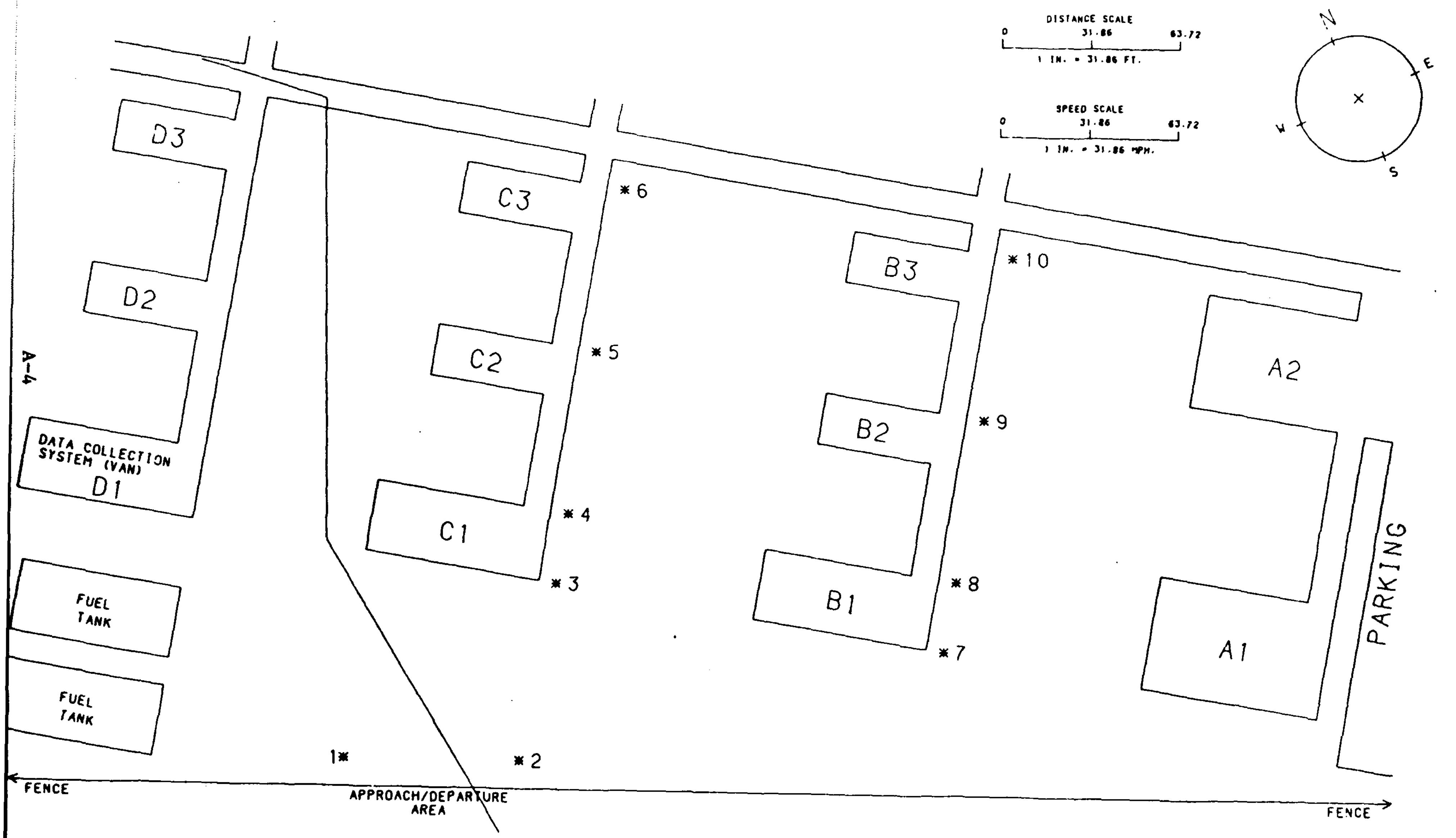


FLIGHT PATTERN - D

▪ SENSOR

# INTRACOASTAL CITY, LA.
# P.H.I. HELIPORT

DATA PROCESSED BY THE FAA TECHNICAL CENTER
ATLANTIC CITY AIRPORT, N.J. 08405

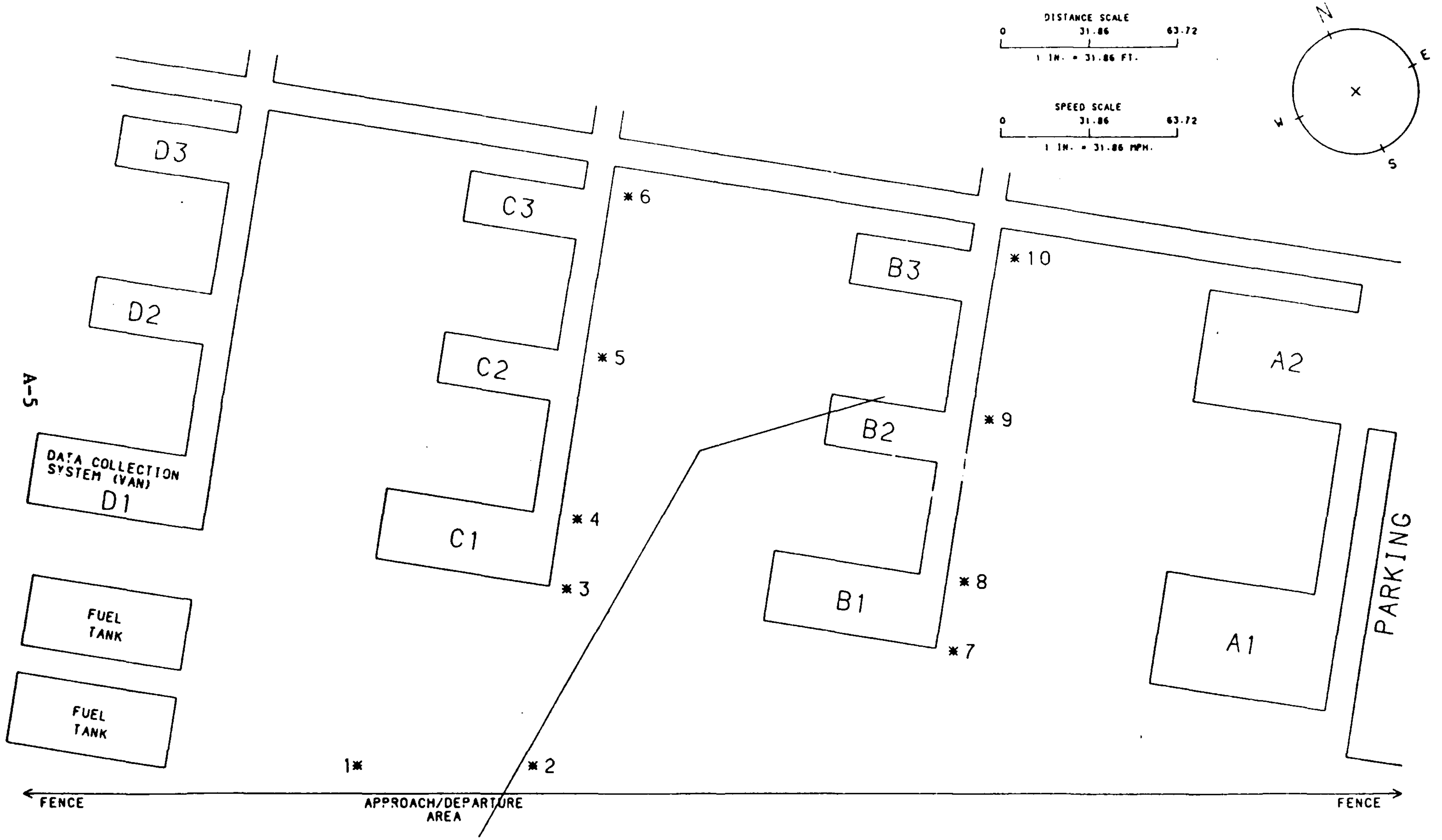


FLIGHT PATTERN - E

■ SENSOR

DATA PROCESSED BY THE FAA TECHNICAL CENTER
ATLANTIC CITY AIRPORT, N.J. 08405

# INTRACOASTAL CITY, LA.
# P.H.I. HELIPORT

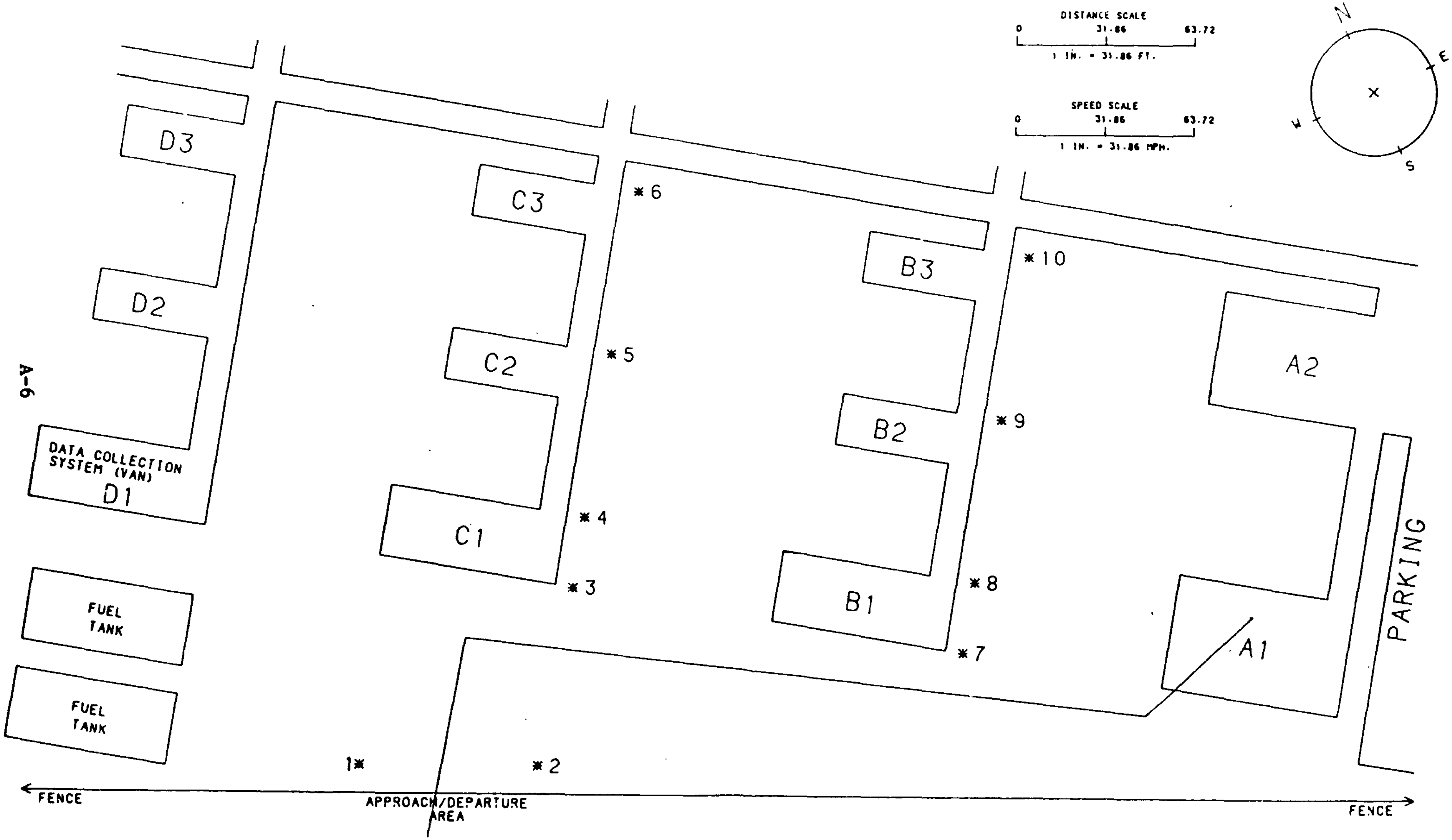


FLIGHT PATTERN : F

*SENSOR

DATA PROCESSED BY THE FAA TECHNICAL CENTER
ATLANTIC CITY AIRPORT, N.J. 08405

INTRACOASTAL CITY, LA.
P.H.I. HELIPORT



FLIGHT PATTERN - G

* SENSOR

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# INTRACOASTAL CITY, LA.
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