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# AIRPLANE LANDING BEHAVIORS CONTROLLED BY MAN-PILOTS

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**Abstract**

Over the region of about 1,000 meters airplanes side from the touch down points the landing behaviors of airplane, mainly altitude, attitude angle and decent velocity are observed for about 90 airplanes of many kinds at Haneda (now, Tokyo Domestic Airport) and Komaki (Nagoya Airport) Airfields. The dispersions, mainly of touchdown points were also observed.

Thus the landing behaviors of the large size jet-engine airliners, medium size turbo-prop airliners and also small size piston engine airplanes were observed and studied. It is pointed out as an important observation that among only about one hundred observations one very dangerous landing which might be an amateur happed.

## CONTENTS

## 1. Introduction

Recently we have known a very miserable aircraft accident —JAL Boeing 747 collided against a mountain edge in Tochigi Prefecture—. The motivation of this report does not depend upon it, however aircraft accidents, generally speaking, often happen near and in airfields. Therefore our observations of 13 years ago may well, as yet, be expected to give some aids to pilots or our passengers when considering accidents.

We often look at airplanes landing scenes in televisions or movies, however nobody has the clear images of landing traces because there is nothing left after the airplanes have safely finished their landing actions.

Here we are to present many such landing traces and are expecting pilots to control their planes make the most appropriate landing traces.

The reasons of delay of reporting is that the research is, I think, very interesting and total data are not few with several different kinds airplane, but the data with one type airplane are not enough even to induce the statistical conclusion. If one more day of observation in airfield could be added under the research appropriation, all the matter might be better.

Now I have only about 200 days before retiring Nagoya University and there is a custom here which gives one chance to write a report to a professor reaching the age limit. Then I decided to leave the observation records which had not always enough data.

## 2. Motivation of the research

At those days an instrument landing systems had already been constructed in the first class airfields in Japan. However they, at least in Haneda (at the days, the Tokyo International) and Komaki (Nagoya) Airports, had not fully been used. The reasons have not been clear for me, but now I think that many Japanese Airfields rather have almost always good visual ranges and the pilots might feel to be unnecessary to depend on them or might be tempted to test their own activities of landing.

In 1970 my working place in Nagoya University, Faculty of Engineering, was changed from the Automatic Control Laboratory to the Aeronautical Engineering Department. And I wanted to have experimental experiences concerning to airplane dynamical studies. The many problems had been left not to be studied in above stated region at those days.

I thought that the advanced studies of the automatic landing problems had been most interesting and might been most valuable to be researched. These had been true and the antena systems for one type of the automatic landing systems had already been constructed in almost all Japanese first class airfields. These system has not been altered hereafter. In spite of the facts stated above the systems had not fully been utilized at those days. These circumstances has been, I think, continued today through I did not confirm them with the concerned of airfields.

Many kinds of electric waves are transmitted in airfields. As the so-called "glide slope" is made as the intersection of the electric waves, the studies of improving the finding method of glide slope have to be constantly continued for advance. Concerning these problems I have been able to find only one technical note of NASA of the days[1].

At those days I had believed that man-pilots could control airplanes ideally, therefore the flight traces were ideal especially in the stage after entering the landing maneuvers. Therefore observations of them could give us an ideal landing paths informations.

These expectations induced us the observations travels to airfields and the results obtained really are to be reported here.

Komaki Airfield is very near our university, therefore it was expected to give us enough informations of landing there at first. But it gave rather small size airplane data much more than large size airplane ones. These results made us to go to Haneda Airfield.

## 3. Methods of observation

We can obtain the data of airplane, altitude, attitude angle etc. from the movie films. But in order to use this technique, it has to be utilizable that very fine camera angles data were to be recorded on each film, but this is not realizable. Therefore we distributed 13 observers —this number was maximum in Haneda Airfield, less observers worked in Komaki Airfield—. Fig. 1 shows observation region and observers distribution in Komaki Airfield. In this airfield 2 times observations were done and number of observers decreased few at the second observation (Feb. 20, 1972).

Fig. 2 shows the same one at Haneda Airfield as Fig. 1. Here No. 1 and No. 2 observers occupied the same position as shown in the figure, but one of them (No. 1) takes photo directing his camera to the see side at about 35 degrees shown in the figure and another obthever (No. 2) takes photo in front of him like the other 8 men and also oders to start each observer his stop-watch excepting No. 1. No. 1 starts his stop-watch at the chance of clicking his shutter and stops it when No. 2 gives his signal. Each observer was handed personally an electric interphone and could communicate each other.

The best shutter chance is an instant when photo can be taken like $\varepsilon=0$ in Fig. 3. This is an instant when the airplane passes just in front of him.

At the stage of data consideration, it was found that the films photographed at the best instant were scarce, but almost all (90%) ones have small $\varepsilon$ and did not need readjustment. One regret at the data consideration stage was the fact that we did not endeavor to collect 10 same type cameras. No high price cameras were necessary, therefore the collection of 10 same cheap cameras was a very easy thing. Table 1 show 10 used cameras with their focus lengths etc. And many troublesome works were needed later.

The cameraman positions in Fig. 1 and 2 show that they take photographs of side view of airplanes. The front views are also impotant and in order to take this we employed a professional movie-cameraman and took movie at the another edge of the runway in Haneda Airport by using 16 mm film. In this case one more person was made to follow him and correspond to a connecting person of the group of Fig. 2 by using wireless telephonic apparatus. This machine was, however, given way soon and could not use for correspondence. This unexpected break made the relation between side and front views of landing phenomena lost. Then the front movies had become difficult to be considered for data adjustment but it is interesting and has been kept until now though it was disturbed by very strong haze and not a good picture.

Fig. 4 shows the indicators of position and direction of camera setting. Each camera was so set on the tripods that the film surfaces were coinsided with the line marked ont he board of Fig. 4 by using a conical weight with string. The top of the weight was directed to P point of Fig. 4.

Position number marked on the board was photographed by each observer every time of film change in order to be recongnizable to the position number of the film.

Fig. 3 is a sham figure of a photographed plane and shows main quantities of observation, $h$ and $\theta$. $h$ is height and $\theta$ is attitude angle and $\varepsilon$ is a deflection of shutter chance. If $\varepsilon$ is zero, it is such an ideal shuttering that an airplane passes just in front of the observer. The case of small $\varepsilon$ can be treated as it were ideal, but when it is a little large, then some cariburations have to be introduced.

Total number of photographed airplanes is about one hundred and among them 78 photographs were really used as available data. In Table 2, the type names of airplane and their number photographed and also the number used really in this study are shown.

## 4. Treatment of data

The main data obtained are written in data sheets which record the instants when all the planes pass No. 1 (at the Komaki) or No. 2 (at the Haneda) point*, durations needed to each observer for coming in front of him and his taken photographs. The time data contains the errors of the instants when each observer starts and stops his stop-watch. But these errors were tested for all the observers and were known rather small to each observer and therefore were neglected due to the facts that the large effort had to be payed for the small merit though the results about velocities were very much fluctuated. Each observer records, if possible, the type name of the objective plane in the reference column.

The shutter chance error $\varepsilon$ were almost all small and neglected but the photo of No. 1 cameraman at the Haneda is not a side view; therefore the quantity corresponding to $\varepsilon$ does not exist, and rather complicated calibulations are needed, but its process omitted. Each photograph, in fact, needed the different kinds calibulation resulting from the differences of focus length of 10 cameras as shown in Table 1.

Therefore we had to attribute camera factors $f_i$ ($i=1, 2, \ldots, 10$) to each camera corresponding to $f_2=1$ at Haneda Airport ($f_5=1$ at Komaki Airport).

$f_{is}$ were obtained as a mean value of the same position length of 6 YS-11's.

* This recorded instant for each airplane is common to all the observers and used for counting durations needed and therefore it is an another name of the plane, for example, 16:30 is the first Boeing 747.

In this processing they were assumed to be equal distance apart from each observer. This assumption may be permitten as some time before touch down instant they fly generally over the center line of the runway. $f_{is}$ values thus obtained were examined by photographs of the same line written on the board in the experimental room.

The real height $H$ is expressed as follows, but this does not contain No. 1 observer's one at Haneda Airport.

$$H=h_i \times \frac{2.88}{Lf_i} \qquad \text{(A)}$$

here $h_i$ is the length of height measured from the photo of $i$th observer and $h_i$ measuring was usually done by definitely magnifying by means of projector because of rendering the errors small, however definitely magnified photos were often used because of easiness of treatments. And 2.88 meter is the definite position length of YS-11 and $L$ is its mean length of 6 times measuring for the standard camera (No. 2 at the Haneda and No. 5 at the Komaki).

Thus $H$ means the altitude of objective airplane photographed by No. 2 (at the Haneda, No. 5 at the Komaki) camera at the $i$th observer potition. The values of $f_{is}$ at the Komaki are, of course, different from ones at the Haneda because of difference of the standard camera etc.

No. 33 $R$ and $L$ runway at the Haneda are constructed on the reclaimed ground from the sea and the former used landing only, the latter taking off only. As already stated and shown in Fig. 2, No. 1 and No. 2 observers occupies the same position but the former directed his camera to the sea side and the latter directed it in fron of him.

We decided intuitionally to direct No. 1 camera at about 35 degrees toward the sea. This made No. 1 camera take photo of plane at about 223 meters apart from the edge wall of the airfield reclaimed ground. Thus the photos taken by No. 1 observers were different from the others and needed some conversion of measured quantities from No. 1 photos. This conversion method is somewhat complicated but not essential of this study, therefore its description might well be neglected.

## 5. Results obtained

Touch down points were scattered as shown later, therefore one person had to observe these only. This observer is No. 11 and he carried the same observing apparatuses as the others without a camera. The instant of touch down was considered to be unnecessary to be photographed but needed to be recorded the duration shown by his stop-watch until the main gear spreaded a cloud of sand on the runway. The position of touching down was also not measured. The recorded time can show the position if the horizontal speed were assumed to be kept constant. The speed could be estimated as a mean value near the touch down point as shown later.

Photo 1 shows one example of landing airplane photos taken by from No. 1 to No. 10 observers. This airplane is a Boeing-747 and the enlarged size of each photo is adjusted by using their camera factors $f_i(i=1, \ldots, 10)$ as to be able to be compared each other. The corresponding altitude versus distance curve is lower one in Fig. 5, (1). The descent velocity versus distance curve is upper one in Fig. 6, (1) and the attitude angle versus distance curve is longer one in Fig. 7, (1).

Another Boeing 747 shows larger descent velocity (in Fig. 5, (1) upper, in Fig. 6, (1) lower) and No. 10 observer's photo (this is not shown in the report) shows that this plane touched and went upper once. But the assistant lady hesitated to extend the attitude versus distance curve in order to show the singular (at least for her) phenomenon.

The distance origins were always fixed as the first touch down point reported by the touch down point observer.

The next example is a DC-8, Supper 61 case shown in Photo 2. This flight trace is the lowest one in Fig. 5, (5). The landing was felt the most dangerous for us among the Haneda Airfield observations of the 15 th March, 1972.

Photo 2-(2) is the one above the edge wall of the Airfield. Here its main gear center height was about 6.0 meters and it took about 5.5 seconds and 350 meters distance from here for touch down. In Fig. 5, (4) we find very low altitude flights of Boeing 737. However these were all in Komaki Airfield and there were nothing dangerous considered from the touch down points.

From Fig. 5, (1) to (11) show the landing traces which are drawn as skiding at the same touch down points for many airplane varieties without distinction of airports.

What do exist outward direction from runway edge are important for landing. Whether there are private houses or sea water does not alte the danger. Therefore very low altitude flight outside airfield is not permitted. Among about 90 airplanes landings observed by us only one airplane DC-8, S61 above mentioned was felt dangerous.

Fig. 5, (7) shows that jet fighters landings are rather low altitudes and small entry angles. The reasons were not clear, but somebody having experiences of controlling such planes said that they might be in some special training.

Photo 3 is an example of landing of medium size airplane YS-11 and Photo 4 is an example of small size one, Cessna 172. These two examples were ones at Komki Airfield.

In from the Fig. 5, (1) to (11), from Fig. 6, (1) to (11) and from Fig. 7, (1) to (11) are shown the altitude, descent velocity and attitude angle versus distance relation curves. As already mentioned the decent velocities curves must be considered less trustable than the others due to time measuring errors.

No. (12)'s of Fig. 5, 6 and 7 show the averaged curves. However the significance of averaging process may not be clear and the dispersing curves themselves may be meaningful. It is also not interesting that all these curves are drawn as if they touched down at the utterly same point. In Fig. 12, (1) $\sim$ (6) the landing characteristics of representative planes are shown for the facility of comparison.

## 6. Dispersion of Data

In this section the dispersion of above stated three quantities and newly added touch down points are written. For this we may divide obtained data at the Haneda and Komaki because the dispersion may depend upon their geographic environments.

As total observed airplanes were not many, the each plane dispersion may have little meaning. Therefore the airplanes were grouped by considering the size of airplanes and then dispersion study was made to the groups.

Concerning the altitude, attitude angle and decent velocity at Komaki Airfield, No. 1 observing point is considered, and No. 2 point at Haneda Airfield. These dispersion diagram are shown from Fig. 10 to Fig. 14 and there the diagrams of the two airfields are separated. At the Komaki smaller size airplanes were observed many more than at the Haneda. Then the circumstances of the two fields were felt somehow differently to us and the separation was tried in the dispersion diagrams.

We assumed that for the origins of measuring distance was taken No. 1 at the Komaki and No. 2 at the Haneda. First this assumption may be investigated by the dispersion diagrams. Table 3 shows the statistical values of the two points, and clearly indicates that the two points are a little different as the origins of measuring distance. No. 2 at the Haneda is near the mean touch down point than at the Komaki. Howevr the decision of the origins had been made under only our feelings, therefore hereafter all the results obtained must be treated under consideration of this fact.

However the curve above shown written with common touch down points etc. are not affected by the difference, however the scale on the axis of absissa of touch down points may be affected little.

At first the dispersions of touch down point will be investigated by using the figures from 13, (1) to (5). The problem of the origin from which measuring distance has already been considered. The difference about 4.5 meters is 1 percent of mean distance of touch down point. Therefore we can consider the total distribution including both the fields.

The total distribution diagram is Fig. 12 with the mean value 542.7 meters and standard deviation 109 meters.

The touch down points are spreaded from about 300 meters to 800 meters and the runway portions near about 550 meters from the origins above stated most frequently used. Therefore these portions of runway may be most severely worn down. Whether this is true or not must be confirmed by the participators of airfield.

## 7. Consideration and Discussion

At first several things found in our observation will be brought to a conclusion. The most dangerous cases felt by us were ones of DC-8, S 61 and the rapid decent Boeing 747 which touched and went. The jet fighters had small entry angles and flied at low altitude.

The dispersion of altitude curves is small for Friendship but attitude angle ones are rather large as in Fig. 5, (8) and Fig. 7, (8). On the contrary the dispersion of altitude curves of YS-11 is large but the attitude ones are rather small. The entry angles of small size airplanes are large as in Fig. 5, (11) or Fig. 7 (11). This may be due to their small circular turning ability.

Large ently angles airplanes often showed so called "touch and go" actions as in Boeing 747 case above stated and Cessna 172.

The average behaviors of altitude-distance can be said almost the same characters from Cessna 172 to Boeing 747. And attitude angle curves figures show that almost all the airplanes carried out flare out actions. The smaller the airplane size becomes, the more often the actions can be seen as shown from Fig. 7, (11) to (12). However compared to YS-11 with Friendship the both planes are nearly equal size, but almost all the former show to practise the flare out but the latter do not always practise. Japanese pilots may be more methodical than foreign pilots.

Generally the airplanes run in a prone position in taxing stage. This attitude may be settled by their main gear radius and front or tail gear ones. One of YS-11's did not behave like this. By the reexamination of its photo this (this in the Haneda) was recognized. The reason was not clear for us and the pilot might forget his nose-down for some seconds after touch down, we think.

Among DC-8, S 61s one always continued nose-down attitude. This reason could not be found either, but if in rather ealier stage of landing maneuver its flaps might happen to be down with larger angle, then such an attitude might have to be necessary.

As already often told, averaging process does not have clear significance, though numer of taking means was different from airplane types, the mean curves in Fig. 5 (12), Fig. 6, (12) and Fig. 7, (12) show that the rough structures of landing behaviors can be said all resemble.

Though the decent velocity-distance curves contain rather large measuring errors like often said above, total average of Fig. 6, (12) might well be considered as the errors have the tendence of decreasing by increased averaging process. Fig. 6, (12) shows that the decent velocities become the larger by aparting the longer distance from the touch down point. This means the landing process itself. —in Fig. 8 the origin is taken as the distance measuring origin at each airfield.—

Fig. 8 shows that the averaged values of horizontal velocities for many representative planes. These points can not combined by smooth curves and can by broken lines. However we can see here that there are three groups, these are jet engine large airplanes, turbo-prop medium size propelar airplanes and piston engine small airplanes groups. Those averaged velocities are 60 meters per second (m/sec) $\sim$ 50m/sec, 40m/sec $\sim$ 30m/sec aud 30m/sec $\sim$ 20m/sec. In Fig. 9, (1) $\sim$ (6) the behaviors of representative airplanes can be compared.

## 8. From Front Movie (at the Haneda only) Observation

This project taking movie of landing airplane fron views at about 3500 meters distance by a telephoto lens may have nothing troublesome. It was very fine and the sunshine made very strong heat haze to fill over the airfield in spite of winter day. At the instant when looking in camera finder, the flickering image obstructed us to find the existence of any structure on the field.

The professional cameraman had predicted the disturbance of the heat haze and said us that the clear pictures were not able to expect but the ones useful for our study purpose could be obtained. We understood him soon but found another unexpected behaviors of airplanes. As shown in the compliment section, the lateral wind existed and the airplanes could not come down on the straight extension of the runway.

As the next trouble soon occurred as already told, the connection between groups of lateral side observers was intermitted. Thus about 10 airplanes front view movies were took only as reference materials.

About 6 airplanes front views could always be seen as one standing behind another on staircase with naked eye. As the north wind of averaged about 13.5 meters per second had always been blowing, all the airplanes had been descending at about 30 degrees with the 33 R runway and had changed their heads to the runway a little before touched down points and almost all airplanes could be considered to be flying just over the center line of the runway at some points between No. 2 and No. 3 observing points under the conditions of mean touch down point and horizontal velocities. At Komaki Airport no problems like these might be needed considered due to the wind directions and velocities shown in Table 4.

## 9. Conclusion and Acknowledgement

This research presents all the data observed and adjusted at the two airfields. When some cases happen these data can be expected to have a role under the fine examination of the records.

Despite of the fact that all the pilots fully recognize the dangers of landing and accumulate his cares, the dispersions of traces or attitude angles were not small. When some pilots investigate these data they may think that all the landings were very much free from danger. And therefore the accidents in airfields may scarcely happen even near the fields.

First the author would like to thank Mr. Y. Sato and Mr. Dosho (the chief of Tokyo International Airport and the chief of Nagoya Airport at those days) and all the participants of both the fields.

Next the author would like to thank the following 18 gentlemen and one lady. The names of them would like to be permitted to be written in alphabetical order and in parenthesis his observation fields and times, for instance, K-2, H-1 means that he observed 2 times at the Komaki, one time at the Haneda and also his working place at present by abbreviated expression. Mr. J. Aoyama (NEC. H-1), M. Hayase (Tokyo Univ. at Agriculture and Technology, K-2), M. Honda (Nissan Motor Co., H-1, K-1), M. Ito (N. U., H-1, K-2), M. Kawabata (Nippon IBM, KK., H-1, K-2), H. Kawasaki (NTT Corporation, H-1), M. Kishi (MHI. KK., H-1), M. Kobayashi (MHI. KK., K-1), M. Kohno (Tokyo Mercantile Marine Coll., H-1, K-2), T. Mori (Toyoda Inst. Tech., H-1, K-2), T. Naruse (N. U., H-1, K-2), S. Niwa (N. U., H-1, K-2), M. Nonaka (Sumitomo Precision Ind. KK., H-1), H. Ohta (N. U., H-1, K-1), H. Sasai (Yokohama National Univ., K-1), M. Suzuki (N. U., H-1, K-2), T. Teramoto (Nippon Steel Tube KK., K-2), Y. Yamamoto (Tottori Univ., K-1), NEC=Nippon Electric Co., N. U.=Nagoya Univ., MHI=Mitsubishi Heavy Industry Co. And one lady was Mrs. Yamamoto and at that days Miss F. Sakabe, she adjusted all the data presented here alone with cooperation of Mr. Naruse and Mr. Ito. It has passed 13 years from her data adjustment, however, I had felt no improprieties for writing this report. I have no words to express my gratitude for her precise work. Once again I would like to say "thank you very much" for all the observaers in cold airfields.

## 10. Compliment

The atomospheric phenomena must be added because th flight conditions are very much influenced by the condition. The airfield weather bureaux always records the atomospheric conditions there. At the three times observation their records copies were given us by the weather bureaux. Each one is the continuous records of the flow charts, some necessary portions only were picked up and summarized in Table 4. They are hoped to by some references.

## Reference

1) J. W. Stickel, "An investigation of landing-contact conditions for two large turbojet transports and a turboprop transport during routine daylight operation"', NASA Technical Note D-899, May 1961.

Table 1. Used camers and their focus lengths and camera factors.

| Jan. 28, '72 at Komaki Airport | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Observing Point | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Camera | M | A | A | N | NM | N | A | M | — | — |
| Focus Length (mm) | 55 | 50 | 55 | 50 | 50 | 50 | 50 | 55 | — | — |
| Camera Factor $f_i$ | 1.11 | 1.01 | 1.10 | 1.04 | 1.00 | 1.03 | 1.00 | 1.08 | — | — |
| **Feb. 20, '72 at Komaki Airport** | | | | | | | | | | |
| Observing Point | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Camera | M | A | A | M | NM | NM | N | N | — | — |
| Focus Length (mm) | 55 | 50 | 55 | 55 | 50 | 50 | 50 | 50 | — | — |
| Camera Factor $f_i$ | 1.09 | 1.02 | 1.13 | 1.11 | 1.00 | 1.02 | 1.02 | 1.04 | — | — |
| **March 15, '72 at Haneda Airport** | | | | | | | | | | |
| Observing Point | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Camera | M | A | M | M | M | N | N | A | N | M |
| Focus Length (mm) | 55 | 55 | 35 | 55 | 55 | 50 | 50 | 55 | 50 | 55 |
| Camera Factor $f_i$ | | 1.00 | 0.59 | 1.01 | 0.98 | 0.91 | 0.91 | 0.97 | 0.88 | 0.93 |

M: Minolt A: Asahi-pentax NM: Nikomat N: Nikon

Table 2. Observed Airplanes and Numbers Photographed and Used for Measuring.

| Airplane | No. of Photos | No. of Measured ones |
|---|---|---|
| B-747 | 2 | 2 |
| B-707 | 7 | 7 |
| B-727 | 11 | 10 |
| B-737 | 8 | 7 |
| DC-8 | 6 | 6 |
| DC-8 (S-61) | 6 | 6 |
| F-86 | 4 | 4 |
| YS-11 | 13 | 13 |
| F. S. | 10 | 9 |
| Cessna | 17 | 9 |
| Piper (PA-28) | 5 | 5 |
| Total | 89 | 78 |

Table 3. Comparison of Flight Data at the Origin Point of Measuring Distance of Both the Fields.

| Airfield (No. of airplane) | Komaki (34) No. 1 Point | Haneda (47) No. 2 Point |
|---|---|---|
| Altitude mean value | 19.75m | 14.11m |
| Altitude standard deviation | 4.41m | 3.69m |
| Attitude angle mean value | −0.62deg. | −0.29deg. |
| Attitude angle standard deviation | 2.72deg. | 2.15deg. |

Table 4. Atomospheric Condition.

| Observation Time O'clock | Wind Direction | Wind Velocity (m/sec) | Atmospheric Pressure (mb) | Temperature (℃) |
|---|---|---|---|---|
| Jan. 28, 1972 at Komaki Airport | | | | |
| 11 | WNW | 5.15 | 1021.3 | 9.0 |
| 12 | WNW | 4.12 | 1020.6 | 9.0 |
| 13 | WNW | 6.18 | 1020.1 | 8.5 |
| 14 | WNW | 6.18 | 1020.1 | 9.6 |
| 15 | NW | 8.24 | 1020.5 | 8.0 |
| 16 | WNW | 7.72 | 1021.0 | 8.0 |
| 17 | NWN | 7.72 | 1021.8 | 7.0 |
| Feb. 20, 1972 at Komaki Airport | | | | |
| 11 | NW | 8.23 | 1013.4 | 5.6 |
| 12 | WNW | 6.69 | 1012.3 | 5.8 |
| 13 | WNW | 7.72 | 1011.5 | 5.7 |
| 14 | WNW | 8.24 | 1010.9 | 7.2 |
| 15 | WNW | 8.75 | 1010.8 | 6.4 |
| 16 | WNW | 8.75 | 1011.3 | 5.3 |
| 17 | W | 5.66 | 1011.4 | 4.4 |
| March 15, 1972 at Haneda Airport | | | | |
| 11 | NNW | 10.29 | 1022.0 | 9.5 |
| 12 | NNW | 11.32 | 1021.0 | 10.0 |
| 13 | NNW | 12.87 | 1020.3 | 11.0 |
| 14 | NNW | 15.44 | 1019.5 | 11.8 |
| 15 | NNW | 15.44 | 1019.8 | 11.5 |
| 16 | N | 14.41 | 1019.9 | 10.7 |
| 17 | N | 15.44 | 1020.4 | 8.8 |

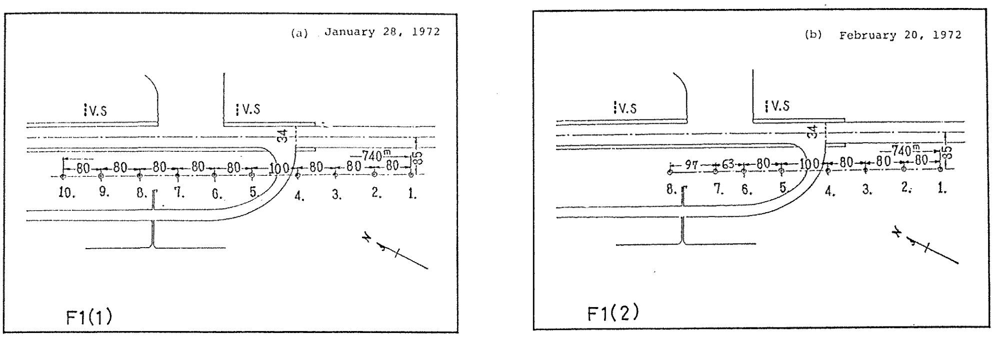



Fig. 1. Observers distribution at Komaki Airport.

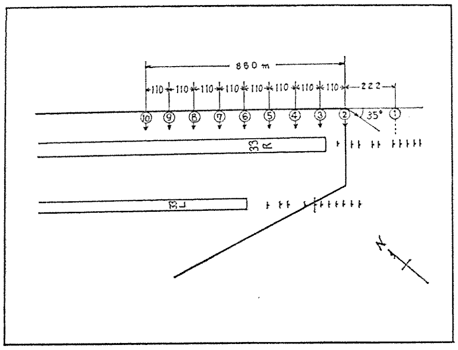



Fig. 2. Observers distribution at Haneda Airport, March 3, 1972.

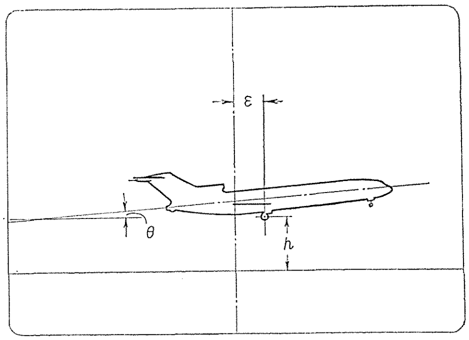



Fig. 3. Instruction of observed quantities.

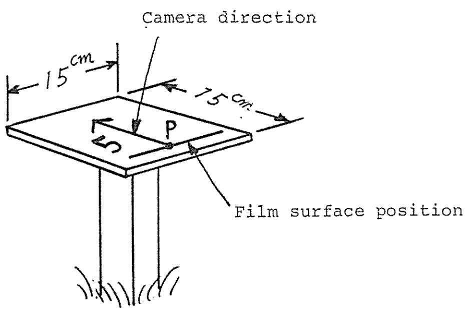
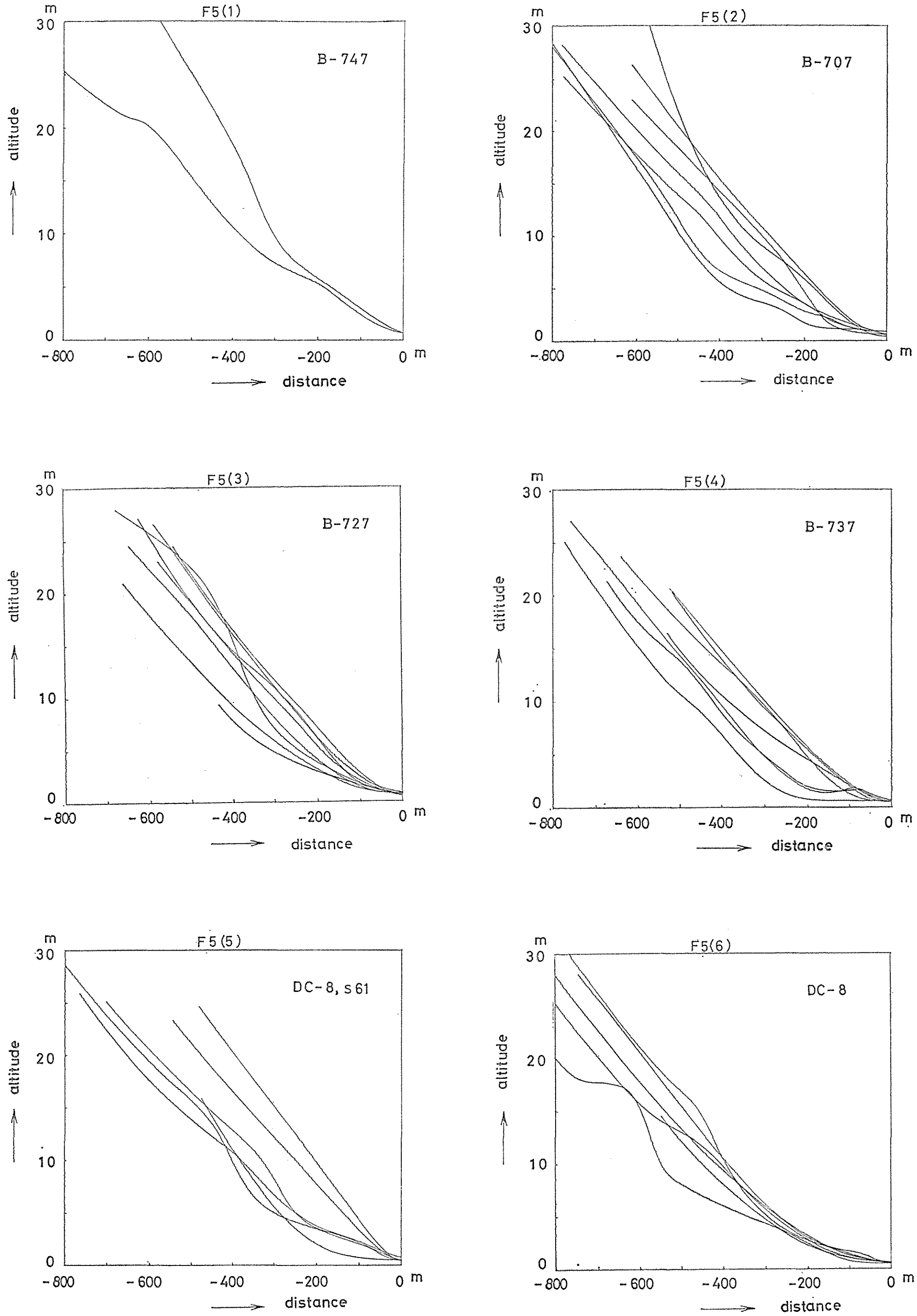



Fig. 4. Indicator of ofserver position and camera direction and film surface position.


F5(1)
B-747
F5(2)
B-707
F5(3)
B-727
F5(4)
B-737
F5(5)
DC-8, S 61
F5(6)
DC-8
m
30
20
10
0
altitude
-800
-600
-400
-200
0 m
distance

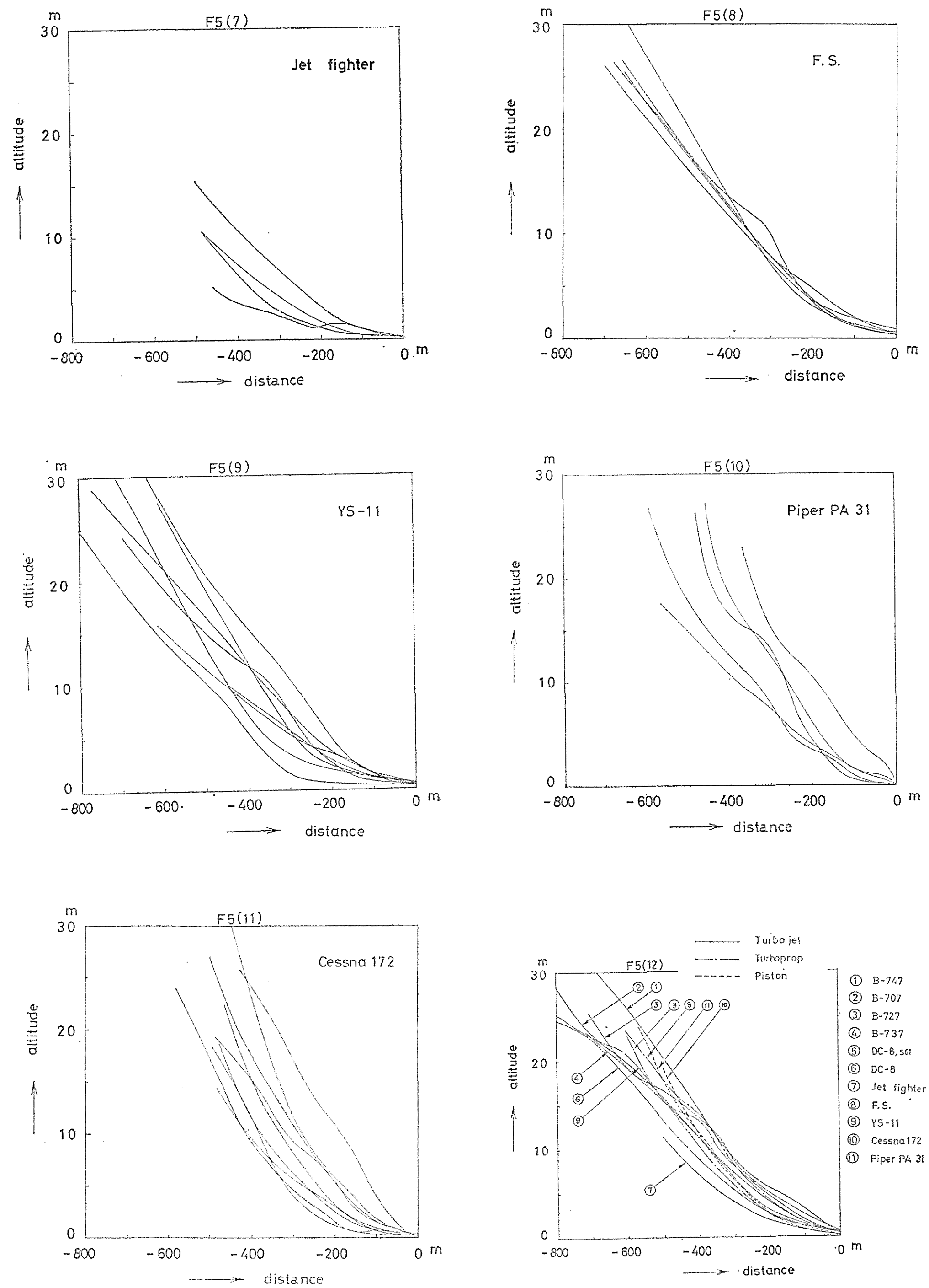
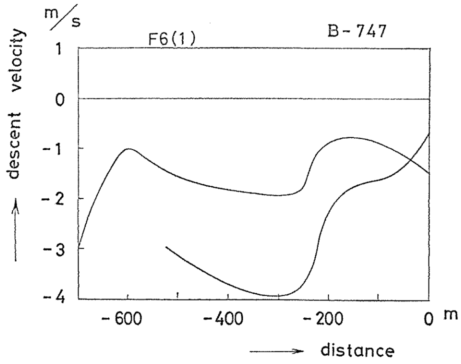
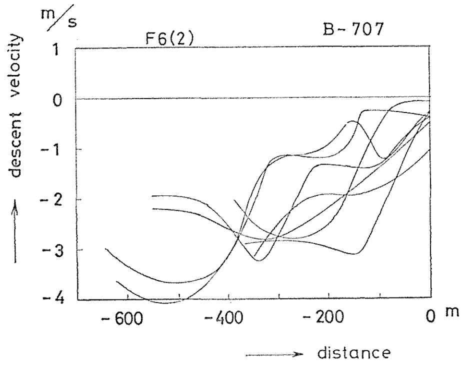
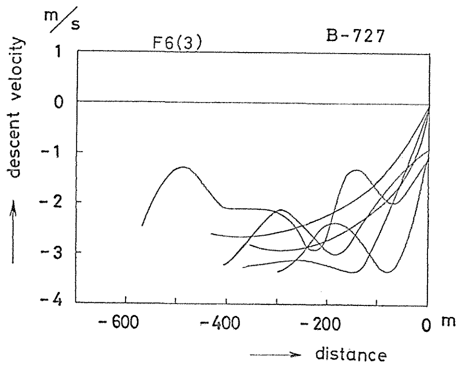
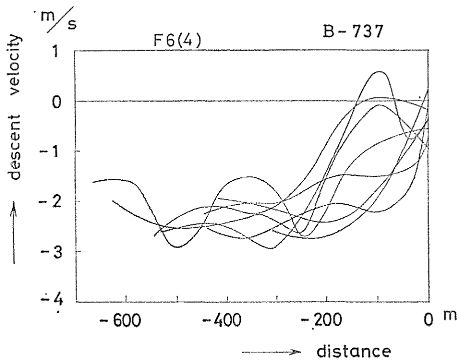


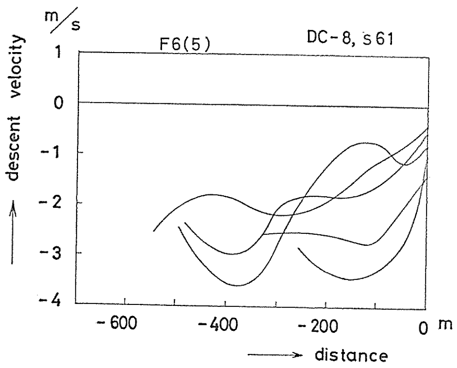

Fig. 5. Altitude and distance relations —landing traces— for many kinds airplanes, (12) averaged behaviors.

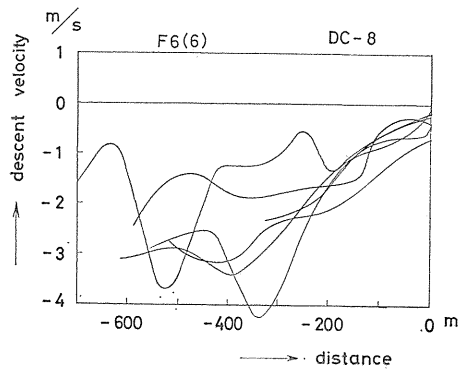

F6(1)
B-747
m/s
descent velocity
distance
m


F6(2)
B-707
m/s
descent velocity
distance
m


F6(3)
B-727
m/s
descent velocity
distance
m


F6(4)
B-737
m/s
descent velocity
distance
m


F6(5)
DC-8, S61
m/s
descent velocity
distance
m


F6(6)
DC-8
m/s
descent velocity
distance
m

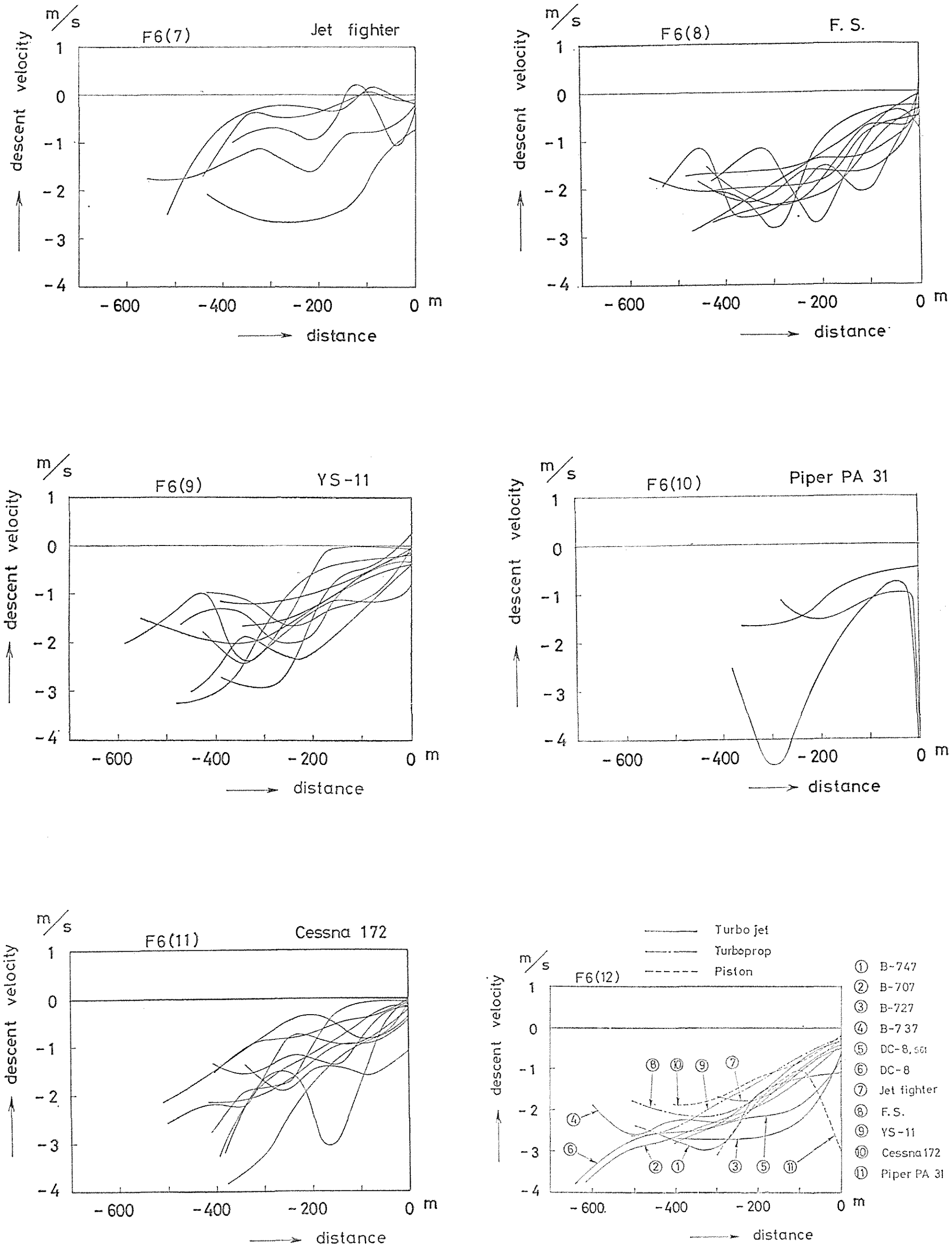
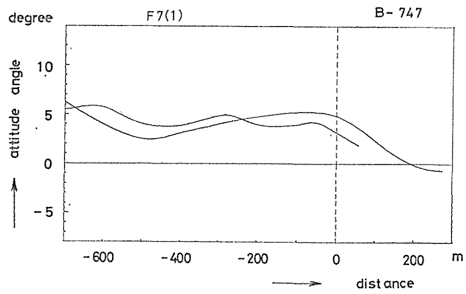
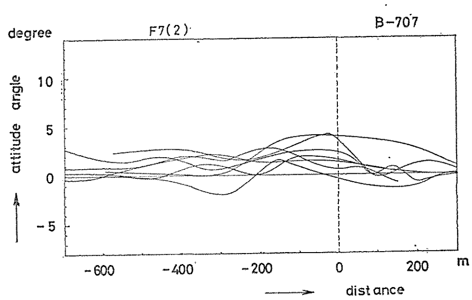
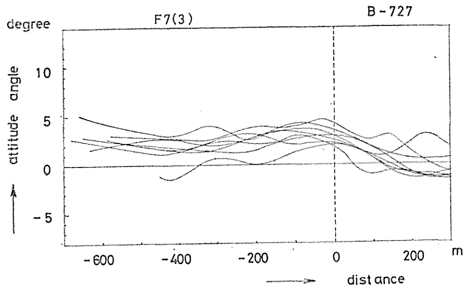
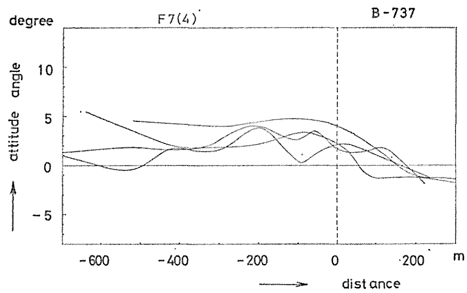


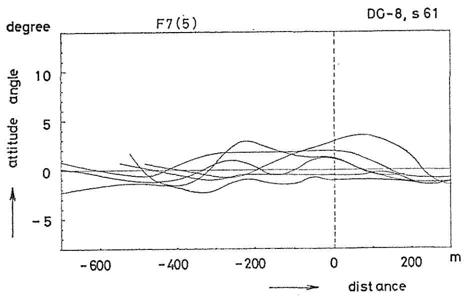

Fig. 6. Descent velocity and distance relation, (12) averaged behaviors.

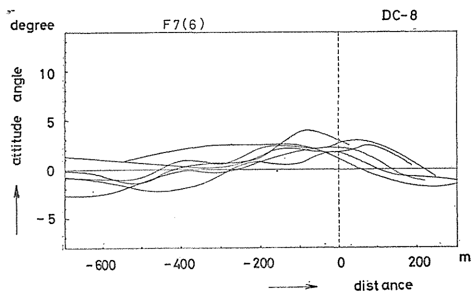

F7(1)
B- 747
degree
attitude angle
10
5
0
-5
-600
-400
-200
0
200
m
distance


F7(2)
B-707
degree
attitude angle
10
5
0
-5
-600
-400
-200
0
200
m
distance


F7(3)
B-727
degree
attitude angle
10
5
0
-5
-600
-400
-200
0
200
m
distance


F7(4)
B-737
degree
attitude angle
10
5
0
-5
-600
-400
-200
0
200
m
distance


F7(5)
DC-8, s 61
degree
attitude angle
10
5
0
-5
-600
-400
-200
0
200
m
distance


F7(6)
DC-8
degree
attitude angle
10
5
0
-5
-600
-400
-200
0
200
m
distance

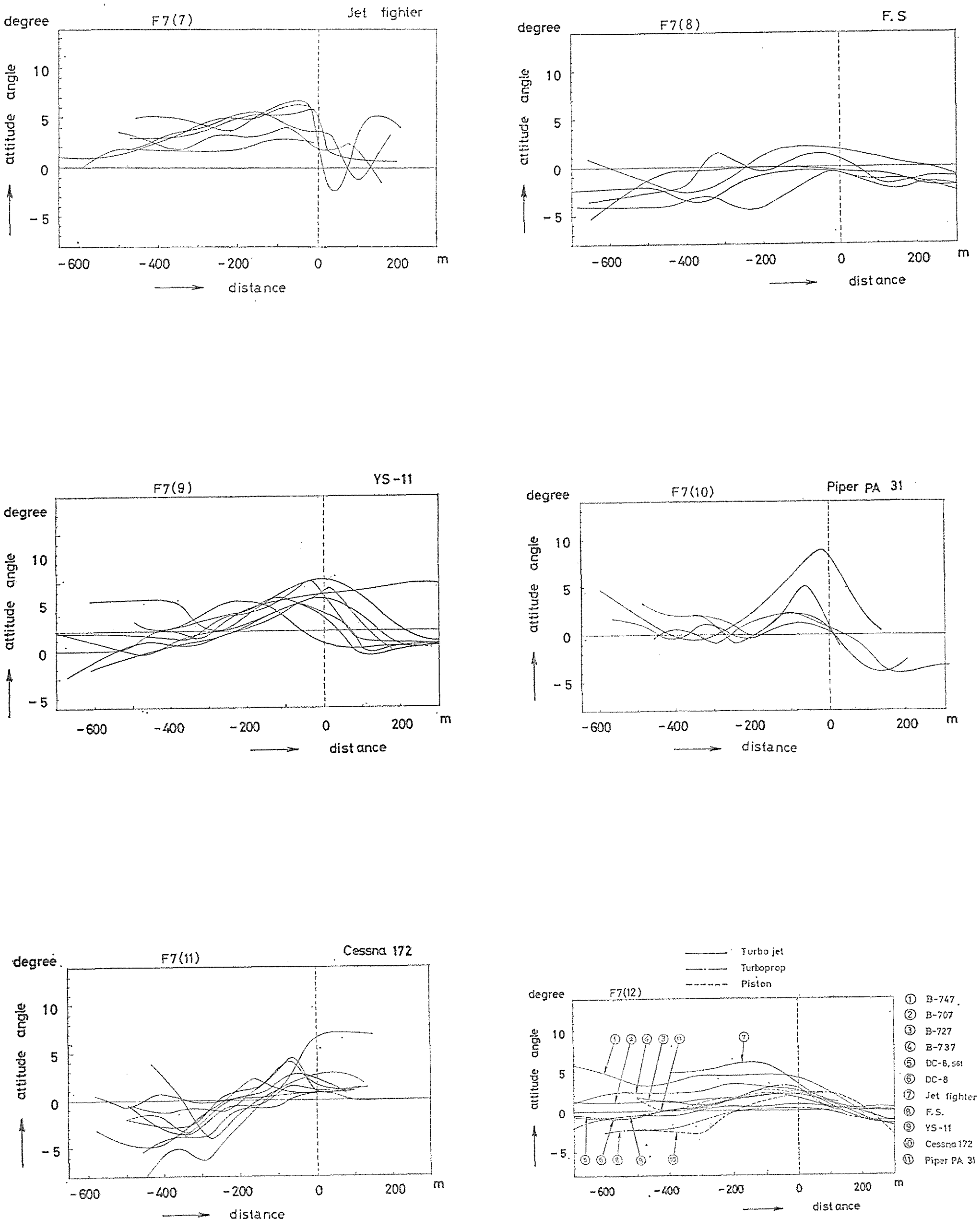



Fig. 7. Attitude angle and distance relation, (12) averaged behaviors.

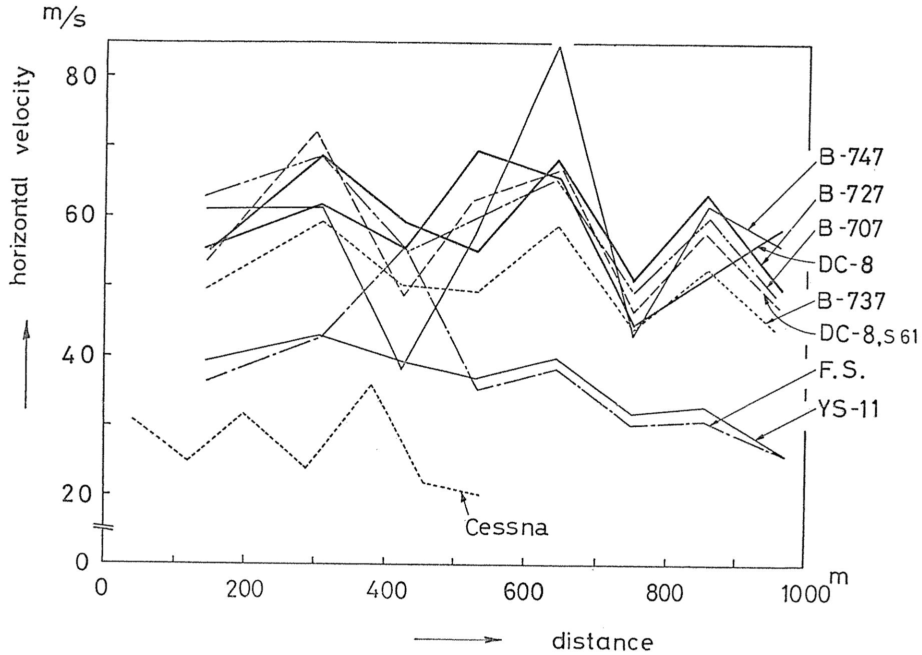
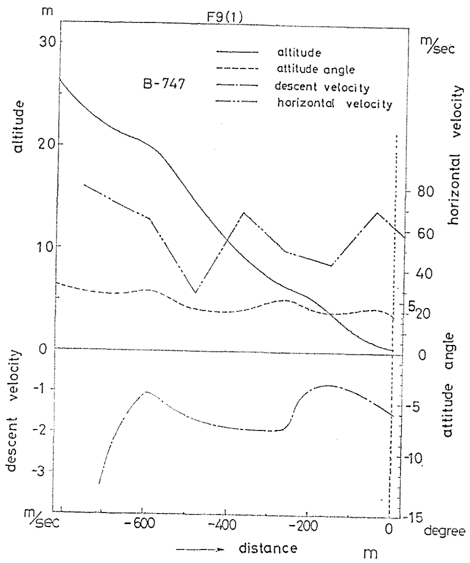
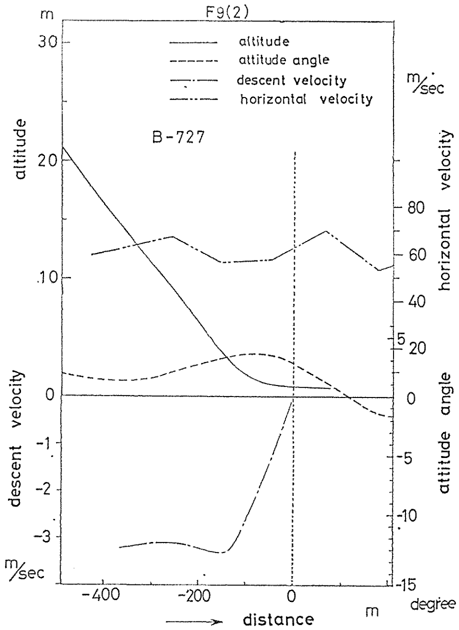



Fig. 8. Horizontal velocity and distance relation.



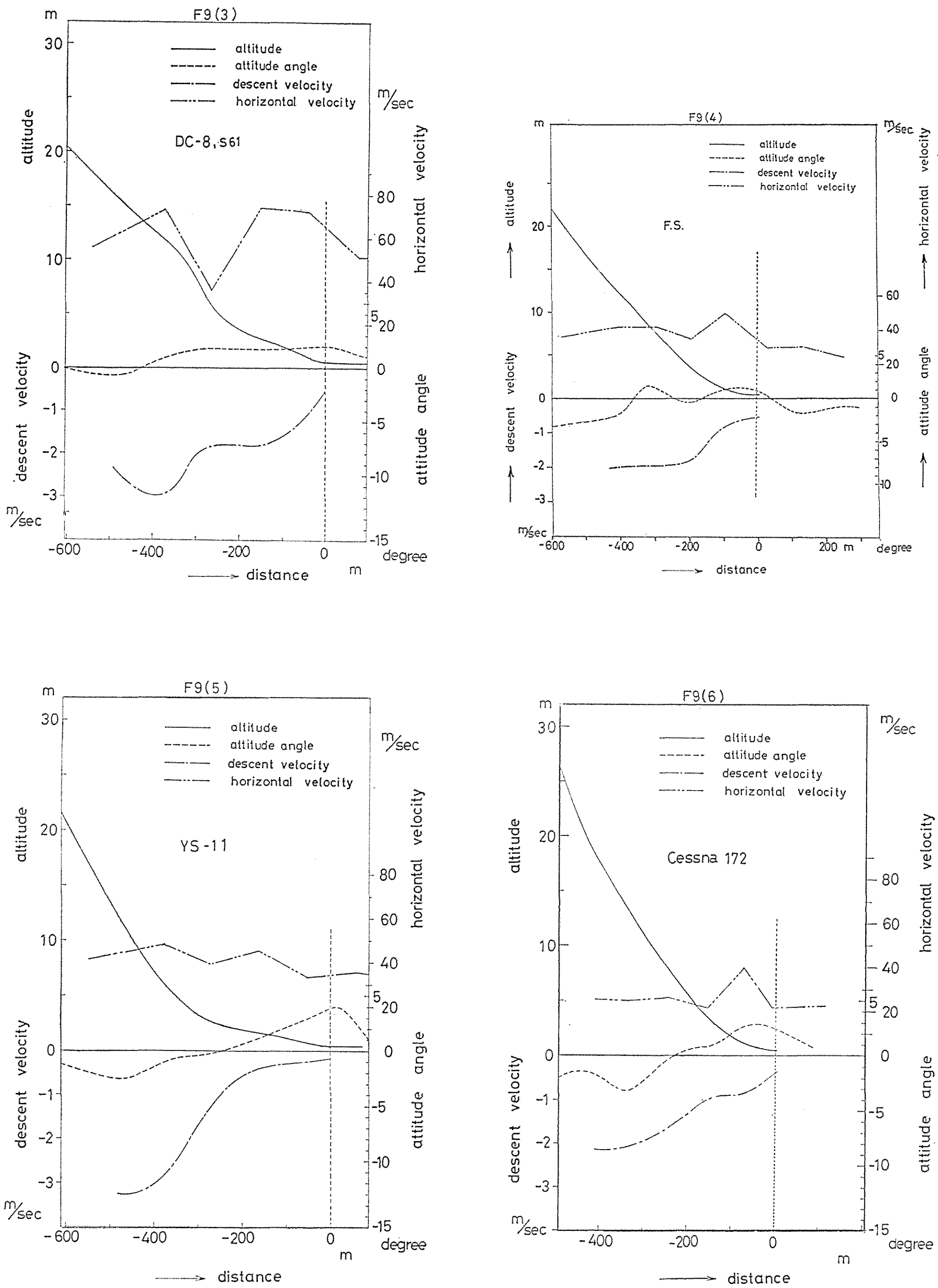



Fig. 9. Landing behaviors of representative airplanes.

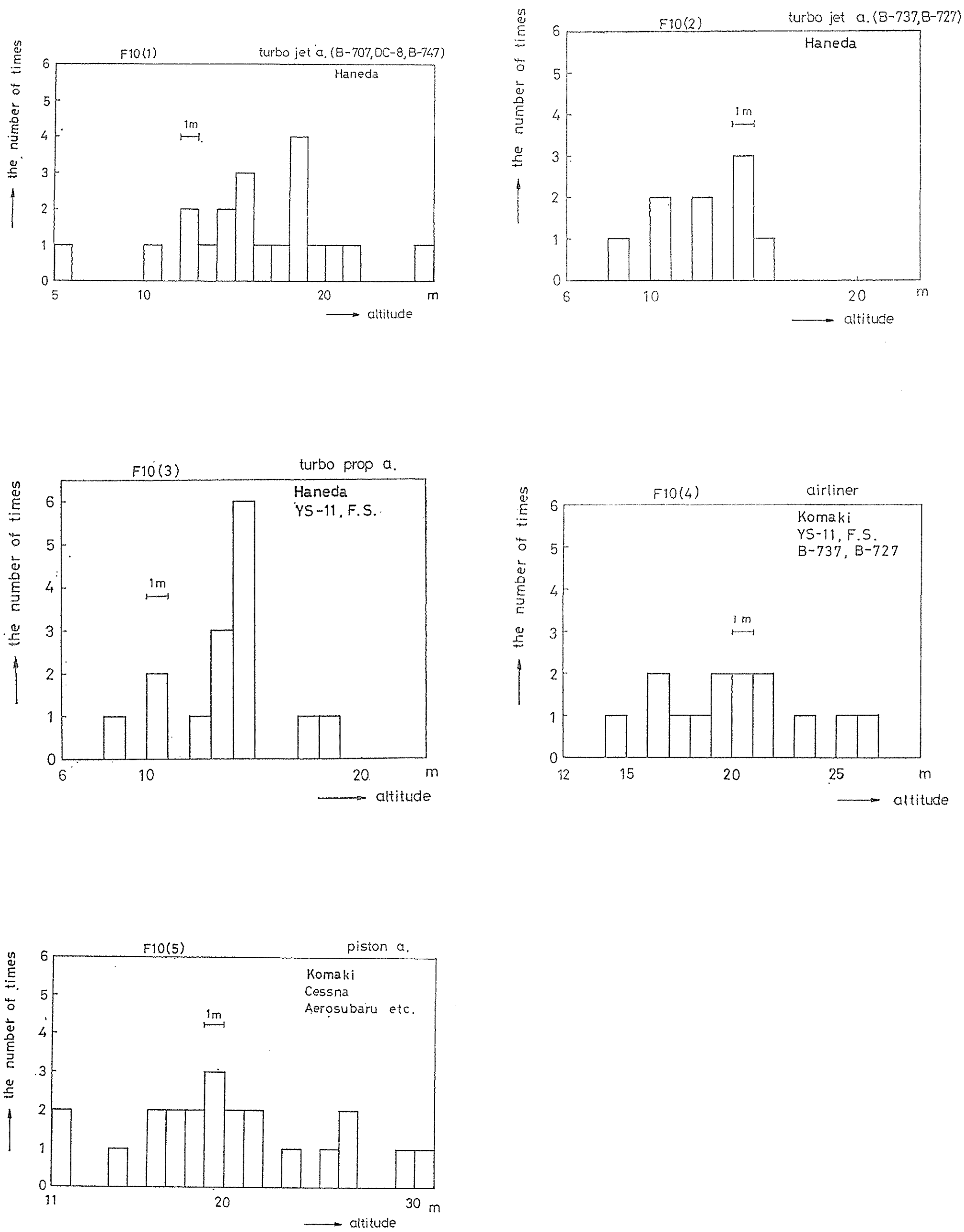



Fig. 10. Altitude dispersion at No. 1 point of the Komaki and No. 2 point of the Haneda.

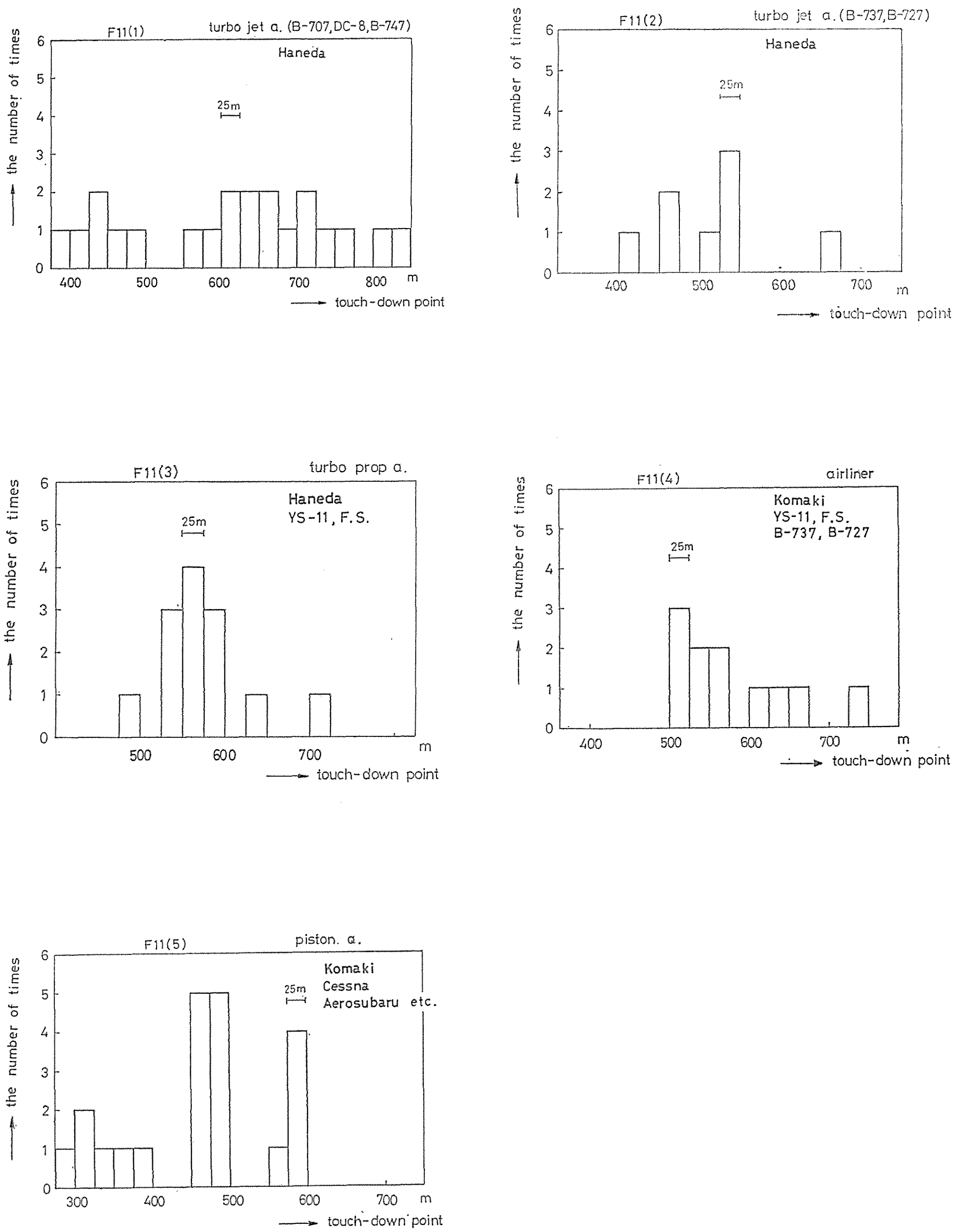



Fig. 11. Touch-down point dispersion at No. 1 point of the Komaki and No. 2 point of the Haneda.

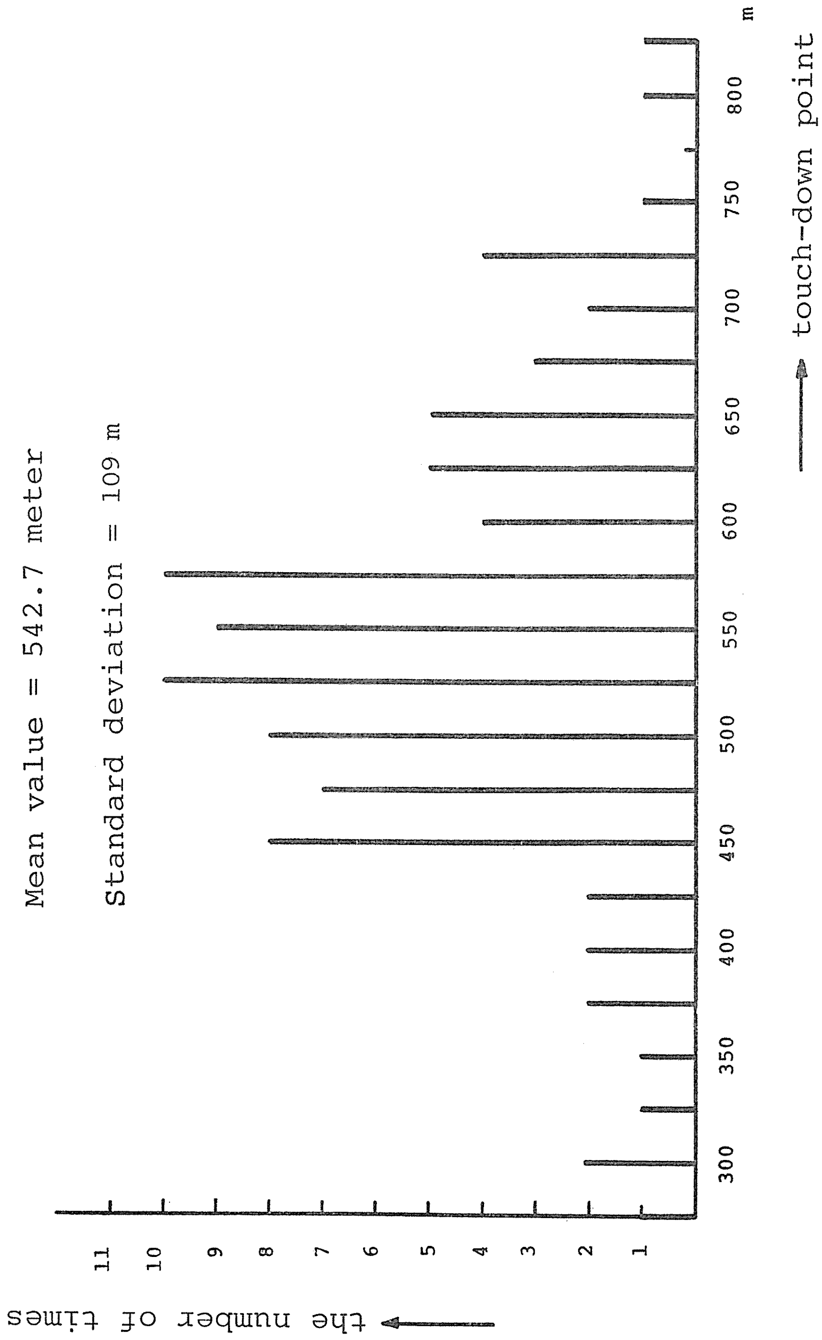



Fig. 12. Total toucg-down point dispersion of both the fields.

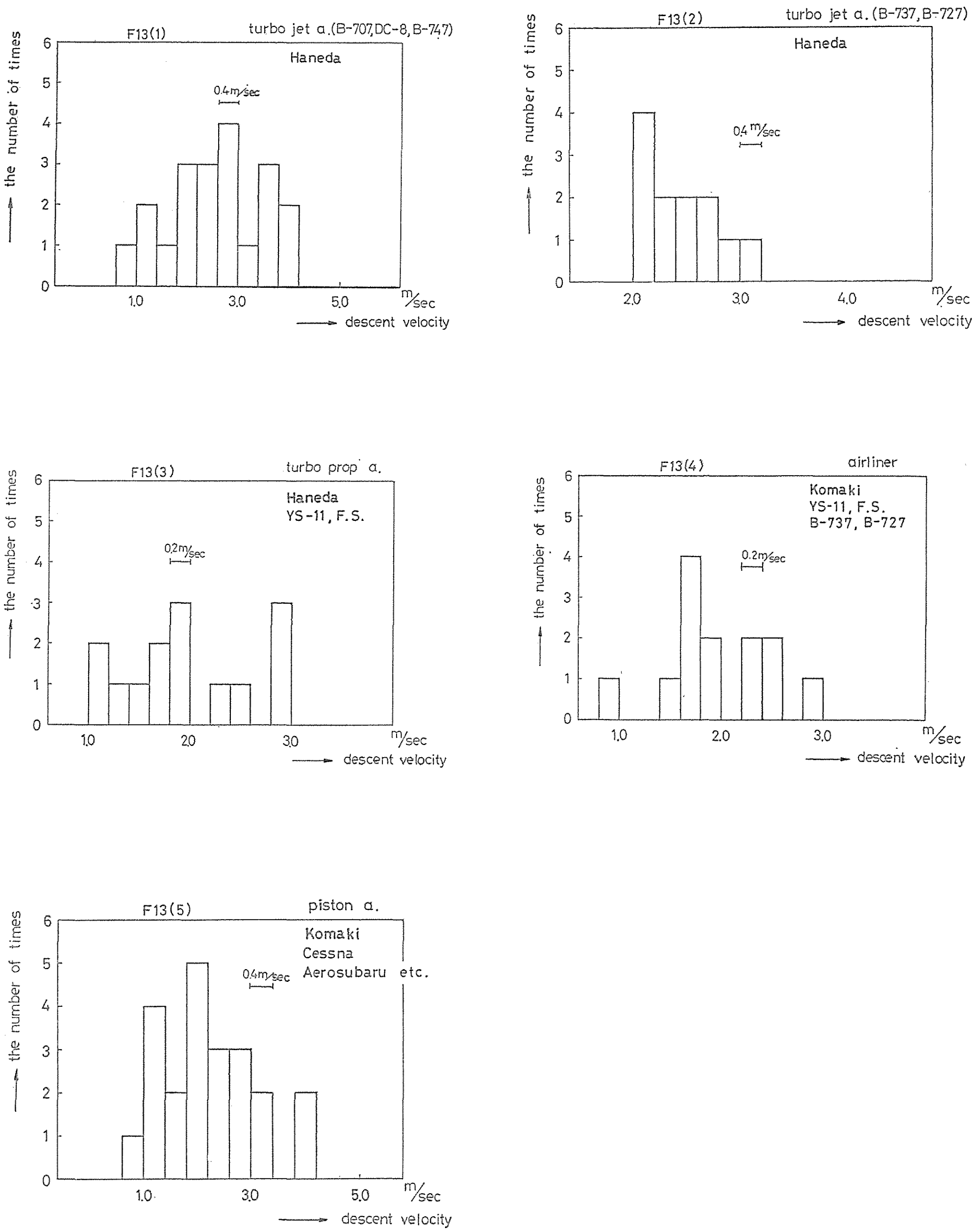



Fig. 13. Descent velocity dispersions at No. 1 point of the Komaki and No. 2 point of the Haneda.

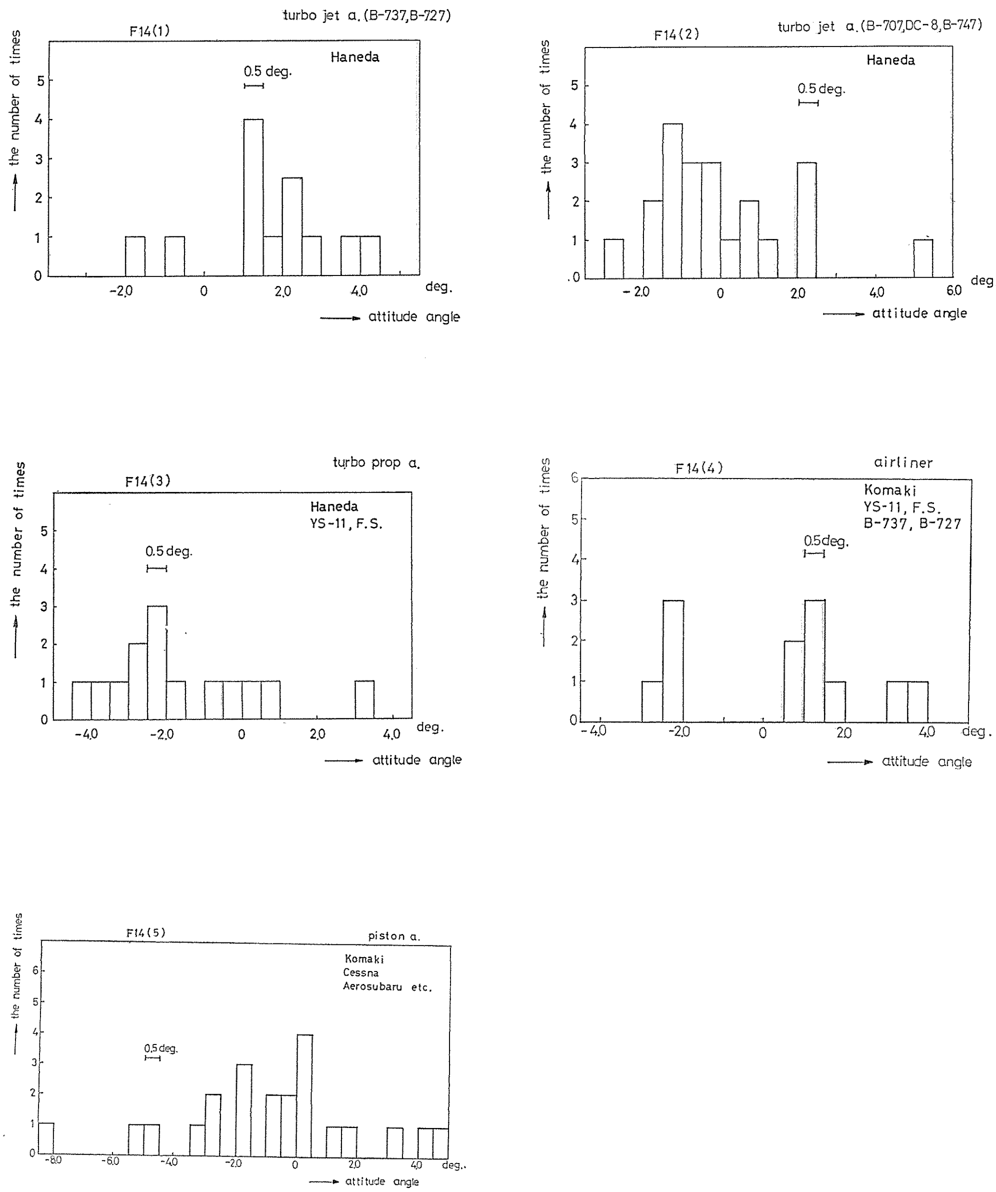



Fig. 14. Attitude angle dispersions at No. 1 point ofthe Komaki and No. 2 point of the Haneda.


1

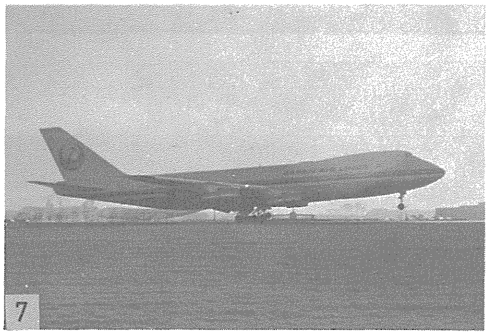

2


3


4


5


6


7


8

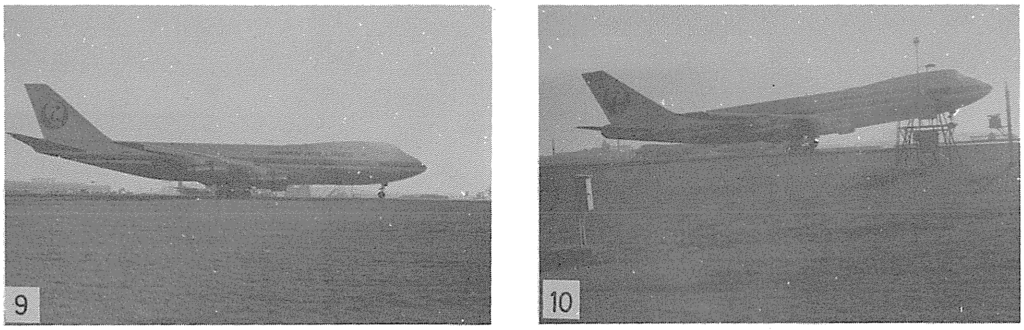


Photo. 1. Boeing 747 landing at Haneda Airfield.

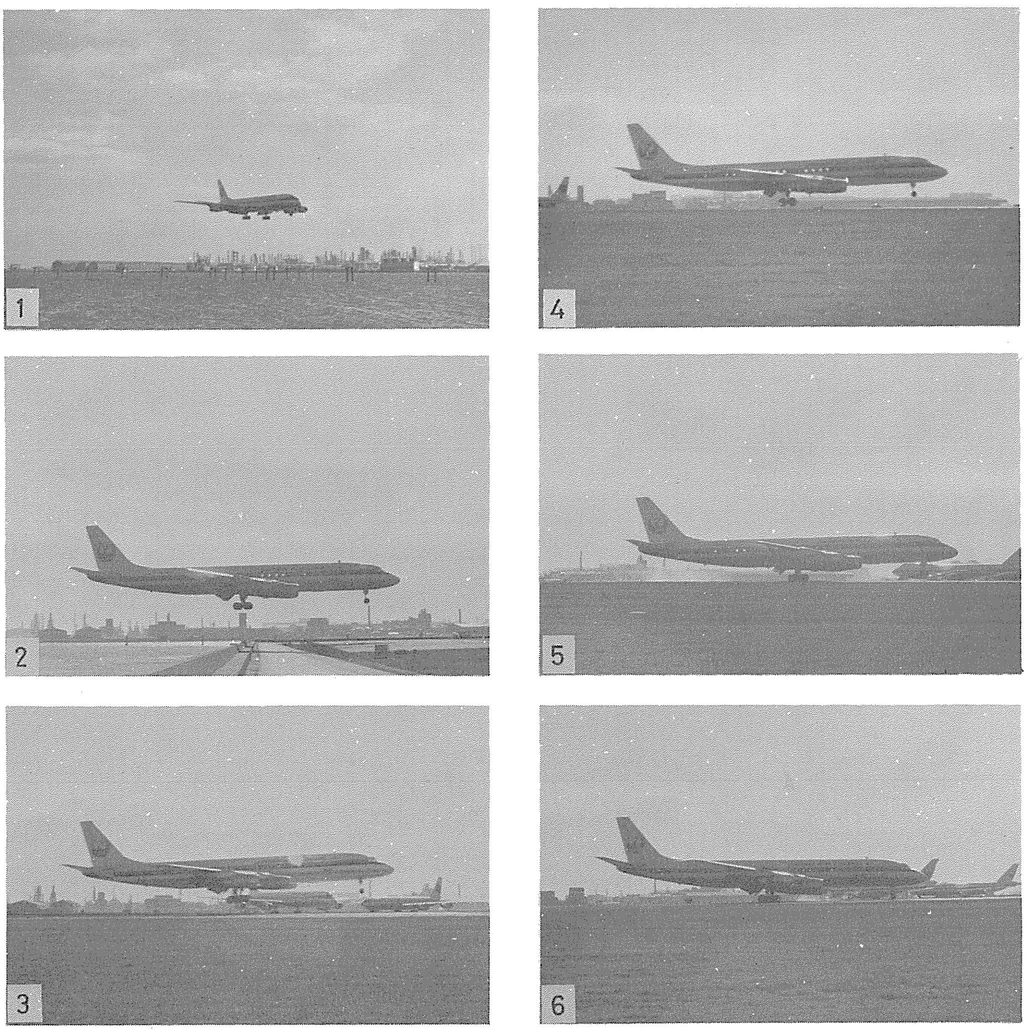


Photo. 2. DC-8, Super 61 landing at Haneda Airfield.

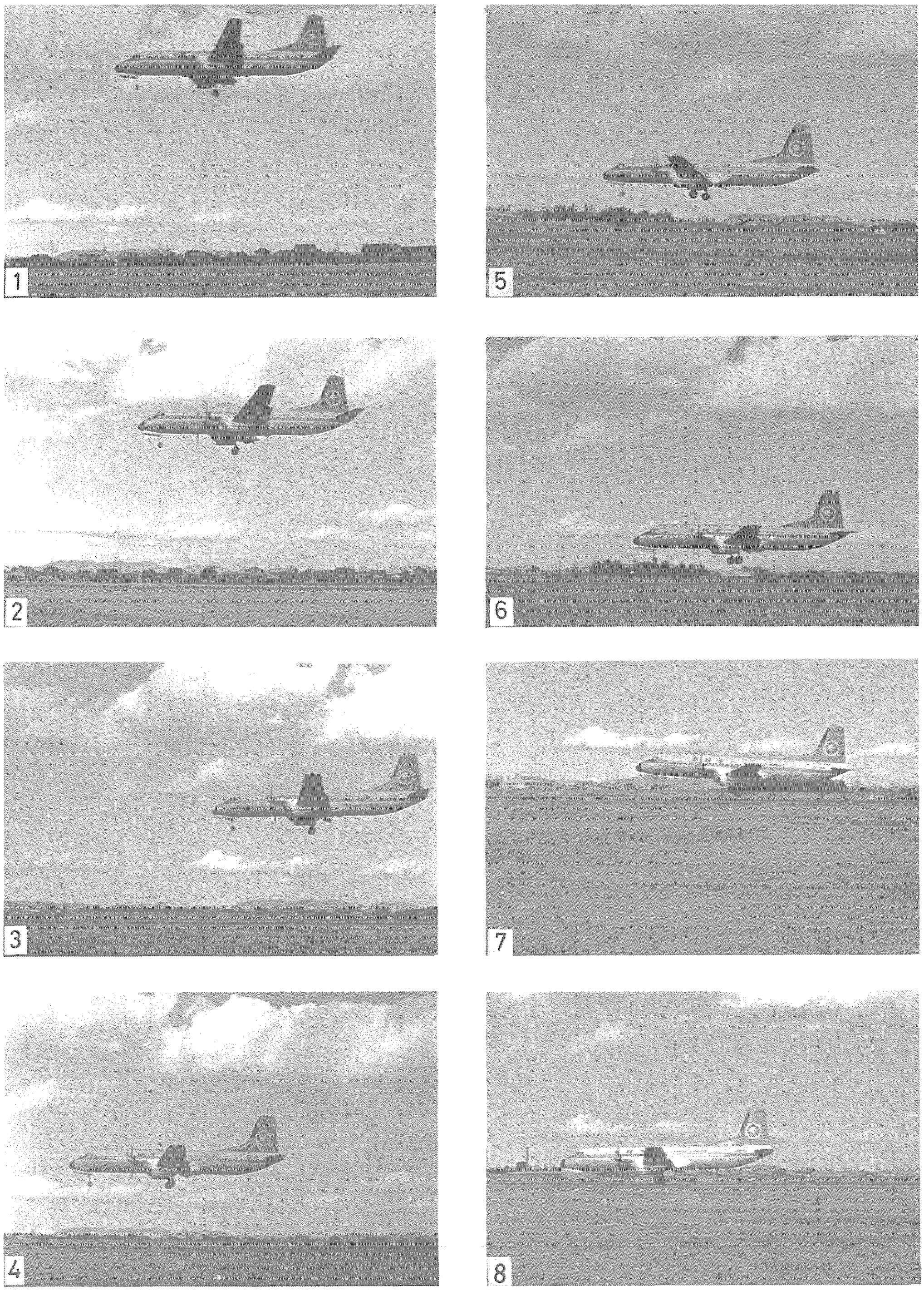



Photo. 3. YS-11 landing at Komaki Airfield.


Photo. 4. Cessna 172 landing at Komaki Airfield.