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AIRLINE PILOT QUESTIONNAIRE STUDY ON COCKPIT VISIBILITY PROBLEMS

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SUMMARY

A questionnaire concerning vision problems from aircraft cockpits was distributed to approximately 6,000 airline pilots as a part of a broad study relating to cockpit visibility About 1,342 of the questionnaires were completed and returned. This questionnaire included specific evaluation of vision characteristics of present aircraft in various maneuvers and directions of sight, and also covered general evaluation of different vision problems The results of the questionnaire show that pilots are concerned about cockpit visibility problems and strongly believe that improvement is needed in most present aircraft

Analysis of the questionnaire data shows that vision cut-off angles for the different directions of sight may be defined in terms of windshield outlines which correspond to pilot ratings of adequate or excellent. In determination of these vision cut-off angles, the attitude of the airplane in various critical maneuvers must be considered Reasonable accuracy appears to be obtained by this method, although knowledge of airplane attitudes in different maneuvers is not precise and could be improved through further investigation

Results of analysis of the questionnaire data are presented in relation to the various specific vision problems, and are combined into a general set of requirements which include vision cut-off angles, post arrangement, and allowable vision distortion The results are not considered to be a final solution to the visibility problem, but offer a useful guide to the amount and quality of vision which will be considered suitable by the pilots

INTRODUCTION

During the past several years, the problem of vision from aircraft cockpits, as determined by window size, type, and location, has been receiving increased attention Such attention has arisen as a result of mid-air collisions in which the pilots involved did not see the colliding aircraft until the instant of impact, and as a result of the apparent large variation in vision characteristics of modern transport aircraft It is evident that entirely different standards of vision have been used in the design of different aircraft models, and vision in some models has been seriously questioned by pilots and regulatory authorities

During 1948 the Technical Development and Evaluation Center of the Civil Aeronautics Administration at Indianapolis commenced an investigation of this problem The purpose of this investigation is to establish, upon some reasonable basis, definite standards of vision which will insure adequate visibility for safe operation of aircraft In this broad investigation several different lines of approach to the final objective are being tried The pilot questionnaire study covered by this report represents one such line of approach, and is considered as supplying contributory data and not as a final solution to the problem

In this pilot questionnaire study it was desired to utilize average estimation of a large group of transport pilots to evaluate detailed vision characteristics of transport aircraft now in use, and also to secure average pilot opinion on specific vision problems It is recognized that in any type of questionnaire study the results may be difficult to interpret and that unconscious bias in portions of the group being investigated may influence the data in an undetermined manner It was felt, however, that any definite conclusions which could be obtained from such a study would have great value, and that most conclusions eventually could be checked by other means

Supplementary data on airplane vision cut-off angles and airplane attitudes in specific maneuvers were previously secured from aircraft manufacturers These data, which are necessary for interpretation of the pilot opinions, were found to be inaccurate and incomplete Some of the airplane data were corrected by direct measurements upon aircraft It appears that when more complete and accurate data are available, some of the conclusions of this report may be modified slightly, and that some of the correlations probably can be improved

PROCEDURE

After original formulation of the questionnaire, numerous discussions were carried out with interested groups in the government and industry As a result of these discussions, changes were made in most of the questions A prestudy procedure was then conducted This involved completion of the revised questionnaire by 20 airline pilots picked at random, with each question being discussed, through interview, after each questionnaire was completed The questionnaire was then again revised as a result of this prestudy, and its final form as it was distributed to the entire group of pilots, is given in the Appendix

Distribution of the questionnaire was made by mail, utilizing the membership list and addressing machines of the Air Line Pilots Association An addressed return envelope was included for mailing the completed questionnaire directly to the CAA Technical Development and Evaluation Center at Indianapolis A total number of 6,061 questionnaire forms was distributed in this manner During the week of February 9, 1949, questionnaires were sent to the entire membership of the ALPA (approximately 99 per cent of all airline pilots), rather than to a smaller random sample, in order to simplify follow-up procedures

After receipt of 1,270 completed questionnaires, when return of the questionnaires had slowed to a low rate, a follow-up letter was sent to the entire membership of the ALPA urging return of additional completed questionnaires The follow-up letter had little effect in accelerating return of questionnaires, but 109 more completed forms were returned

The data contained on the questionnaires were transferred to punch cards, and tabulation, classification, and totalization of the data were carried out with punch-card machines

The total return of 1,342 completed questionnaires represents 22 1 per cent of the questionnaires distributed Additional questionnaire forms were distributed through the Air Transport Association and the Aircraft Industries Association to special pilot and engineering personnel of the airline operators and aircraft manufacturers The completed questionnaires received from these sources are not included in the present report

GENERAL PRESENTATION AND LIMITATIONS OF BASIC DATA

Questionnaire Data

The total number of pilots in each airplane and experience group who returned a completed questionnaire is shown in Table I

Large differences exist in the size of the different pilot groups shown in Table I The pilot group associated with the Douglas

TABLE I

Pilot Replies Broken Down by Experience and Type of Airplane

Airplane Type	Pilots Reporting 0 - 4,749 Hours	Pilots Reporting 4,750 - 99,999 Hours	Total Pilots Reporting 0 - 99,999 Hours
Douglas DC-3	345	203	548
Douglas DC-4	136	180	316
Douglas DC-6	49	96	145
Lockheed Constellation	99	82	181
Convair 240	31	76	107
Martin 202	7	19	26
Boeing 307	3	2	5
Other	10	4	14
TOTAL	680	662	1 342

DC-3 airplane is the largest in number, and a majority of this group have experience less than the approximate median value of 4,750 hours obtained for the entire pilot group Only 26 questionnaires were obtained from Martin 202 pilots This group is too small to provide desirable accuracy, but the data obtained from the Martin 202 pilots were included in analysis of questions where division was made by airplane group to provide additional guidance, and reasonably consistent results were obtained

No data were secured from Boeing 377 pilots as this airplane was just entering airline service at the time the questionnaire data were being secured

It is seen from Table I that average values of estimation utilized in analysis of some questions are determined largely by opinion of Douglas DC-3 pilots because of the large size of this group Average estimation values relating only to the Douglas DC-6, the Convair 240, and the Martin 202 airplanes are determined principally by pilots in the high-experience group, whereas opinion of Douglas DC-3 pilots is influenced most strongly by pilots in the low-experience group If significant difference in opinion should exist between various experience or airplane pilot groups, then bias would be introduced in varying amount in different questions and would be difficult or impossible to correct

In general, no significant difference or bias was observed in the data secured from the different pilot groups The only apparent bias which might be suspected from analysis of the data is the possible tendency for pilot groups which have a general high regard for the airplane they are flying and which rate its visibility characteristics high, to overrate all individual vision characteristics of that airplane This might be suspected in connection with the Convair 240 pilot group Measurements show that vision cut-off angles are good in this airplane, and, in many directions, are better than in any of the other airplanes considered It appears, however, that the average evaluations made by this pilot group concerning the Convair 240 may be higher than are justly warranted A similar but reverse bias possibly exists in the case of an airplane which consistently receives low-visibility rating in the questionnaire, such as occurs for the Lockheed Constellation

The data obtained for the various questions are presented in terms of the proportional percentage of all pilots, or of each group of pilots, answering in each manner where fixed choices were presented in the question Where a free numerical estimate was made, the mean value and the median value of estimation both are shown

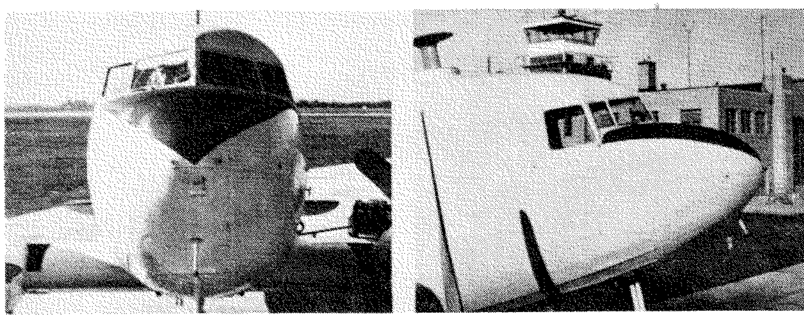
In Questions 7 and 8, the pilots were given a choice of three fixed classifications (Classes 1, 2, and 3) relating to adequacy of vision In the presentation of the data for these questions, the per cent of pilots answering in each manner is shown, but in the analysis of the data for curve-plotting purpose, the three percentage figures for each portion of the question are combined into one mean rating value The mean rating value falls somewhere in the interval from 1 00 to 3 00, depending upon the percentage of pilots choosing each class of 1, 2, and 3

Aircraft Data

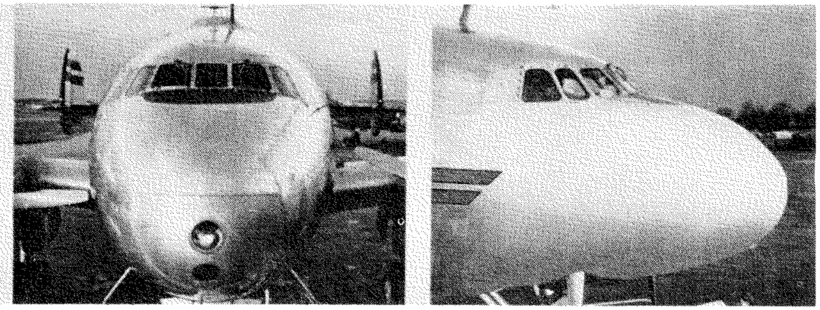
Front and profile photographs of the different airplane cockpits included in this study are shown in Fig 1

The data used in the report which describe or are related to the existing vision characteristics of the different airplane models are shown in Table II These data are based principally upon information obtained from the aircraft manufacturers, but have been revised in certain cases where it was apparent that use of the airplane in actual practice does not correspond to the manufacturers' figures Revision is particularly required where location of the pilot eye position is critical and where the attitude of the airplane in specific maneuvers is important

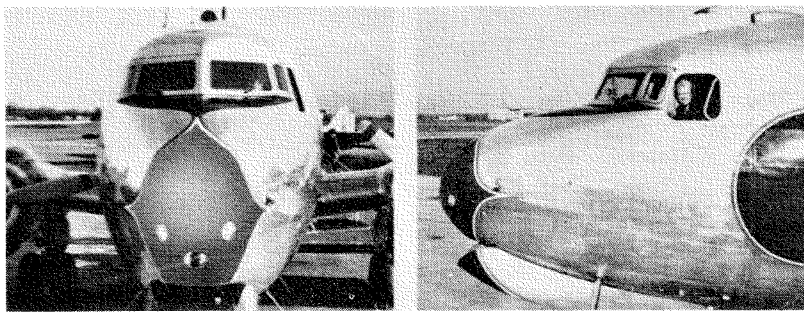
The eye position in the cockpit will vary with each individual pilot, depending upon his height and seat adjustment It had been assumed, in preparation for this study, that such variation would cause a spread in the results obtained from various questions, but the average result still would be significant if the average eye position were known approximately However, it appears that the average eye position is not necessarily at the average position shown on the manufacturers' diagrams For example, it was found that in the Douglas DC-3 airplane, where height of eye level is particularly important during landing and taxiing, the pilots tend to adjust



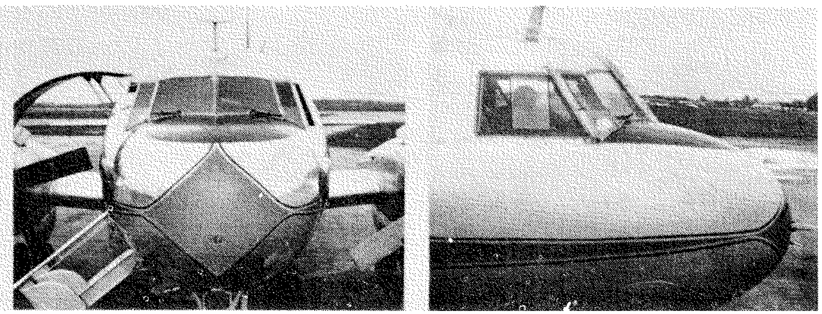
DOUGLAS DC-3



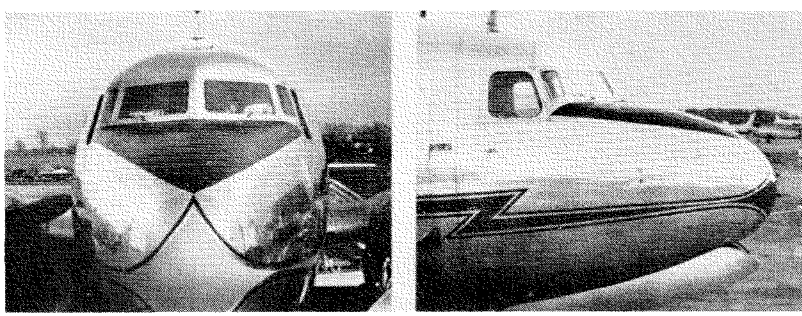
LOCKHEED CONSTELLATION



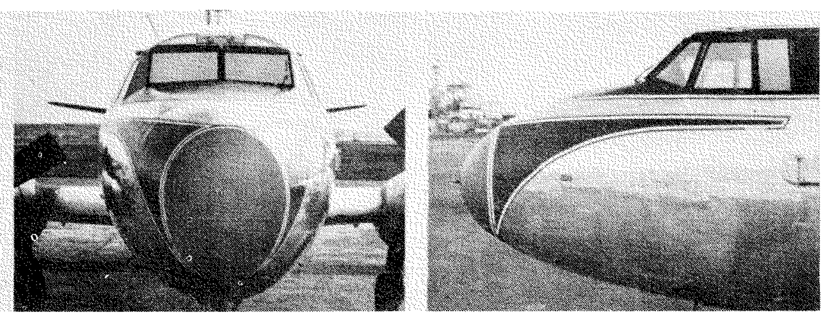
DOUGLAS DC-4



CONVAIR 240



DOUGLAS DC-6



MARTIN 202

Fig. 1 Photographs of Airplanes Considered in This Study

TABLE II

General Data Relating To Airplanes Considered In This Study

	Douglas DC-3	Douglas DC-4	Douglas DC-6	Lockheed Constel-lation	Convair 240	Martin 202
Total Steradians	2 0414	1 478	1 310	1 632	1 972	1 328
Per Cent of Total Steradians in Sphere	16 25	11 76	10 4	12 4	15 7	10 6
Steradians Entire Window 90° Right Side	0 9027	0 088	0 081	2 Windows 0.068	0 143	2 Windows 0 117
Degrees Up and For-ward Cut-off Angle	11 0	14 0	14 0	12 0	17 0	20 0
Degrees Down and Forward Cut-off Angle	13 0	10 0	10 0	10 0	12 0	16 0
Degrees Left Side Azimuth Angle Cut-off	135 0	90 0	90 0	117 0	117 0	123 0
Degrees Right Side Azimuth Angle Cut-off	103 0	91 0	91 0	96 0	97 0	102 0
Degrees Left Side Upper 90° Edge Cut-off	23 0	19 0	19 0	14 0	18 0	7 0
Degrees Left Side Lower Edge Cut-off 90°	33 0	33 0	33 0	25 0	32 0	37 0
Degrees Right Side Upper Edge Cut-off 90°	4 0	4 0	4 0	3 0	2 0	1 0
Degrees Right Side Lower Edge Cut-off 90°	16 0	11 0	11 0	10 0	14 0	13 0
Attitude During Straight Climb (Degrees)	5 5	5 5	6 5	4 5	5 0	5 0
Attitude at Touchdown (Degrees)	5 0	4 5	2 0	4 0	0 5	5 0
Attitude in Taxi Condition (Degrees)	11 5	1 5	1 6	2 5	0 0	3 0
Type of Landing Gear	Tail Wheel	Nose Wheel	Nose Wheel	Nose Wheel	Nose Wheel	Nose Wheel
Vertical Distance of Pilot Eye Above Ground in Taxi Condition (Inches)	175 0	175 0	175 0	195 0	150 0	160 0

the seat so that their eye level is considerably lower than the position indicated by the manufacturer as being the desirable height

Another factor which influences eye position is head movement It is apparent that the pilot will rotate his head in utilizing vision through the left-hand window This head rotation, which brings the eyes closer to the left-hand window, will permit greater angles of vision, particularly in an upward direction, than if the eyes remain at one central location such as is assumed in most visibility measurements The increase in vision permitted by this movement varies in an inverse manner with distance between the side window and the head, and is an important factor in some cockpits where this distance is small Additional moderate movement of the head toward the left provides even more increase in vision over that shown by normal visibility measurements These factors are not shown by manufacturers' data, but are important in determining vision characteristics of different aircraft for use in the questionnaire analysis

Another airplane characteristic which

influences vision, and about which insufficient information is available, is the attitude of the airplane in particular maneuvers In actual practice, airplane attitudes during such maneuvers as gliding turns, climb, and approach, vary considerably from the attitudes specified by the manufacturer, and it appears possible that variations from the normal condition may strongly influence the pilot evaluation of vision adequacy

In attempting to correct the original values used in Table II, photographs were taken of airline airplanes in different maneuvers to determine aircraft attitudes, measurements were obtained in cockpits of distances from normal eye positions to the various window edges, a limited number of airline pilots were interviewed regarding manners in which they operate airplanes in certain maneuvers, and some measurements were obtained of actual seat positions and eye levels used in the Douglas DC-3 airplane The values given in Table II, therefore, are partially manufacturers' data and partially data secured by direct measurement

It is recognized that the data of Table II still are not as accurate as is desirable, even after corrections have been applied, and that various correlations shown in this report probably can be improved when more accurate data are secured However, it is believed that the data of Table II are of sufficient accuracy to permit definite correlations and conclusions to be established

PRESENTATION AND DISCUSSION OF DETAILED DATA

Question 1 - Pilot Experience

At the time the questionnaire was prepared, it was believed that obtaining years of flight experience from the pilots might prove helpful in analysis, but no use has been made of the information secured in Question 1(a) and these data have not been presented Question 1(b) was used as a control question to obtain experience ratings of the pilots in hours of flight time Most of the results of subsequent questions have been analyzed to determine if the amount of experience of the pilot results in a difference in the manner in which the question is answered

The median value of pilot experience for the entire pilot group is approximately 4,750 hours, therefore, two major experience classifications were made, one from zero to 4,749 hours, and the other from 4,750 to 99,999 hours Differences in opinion found as a result of this breakdown will be discussed with each question where a significant difference was noted

Question 2 - Pilot Classification

This question was included as a control question for the purpose of further breaking down the pilot replies to determine if the type of pilot classification influences the manner in which the questions are answered However, it was found that 98 per cent of the pilots were included in the principal main classification, which covered Captain, Reserve Captain, and First Officer, so that this main division was not possible Breakdown into smaller groups was not considered practical or important

Question 3 - Minimum Forward Ground Distance Visible During Landing and Taxiing

The results obtained from part (a) of this question, relating to minimum forward ground distance visible during landing, are shown in Fig 2 The vertical line on this chart indicates the geometric mean value of minimum ground distance in front of the airplane that all pilots estimated to be necessary to see at the instant of touchdown during a landing The white horizontal bars indicate the approximate nearest distance that a pilot actually can see the ground directly ahead of the airplane at the instant of touchdown during landing in the airplane models specified. These distances generally were calculated by using the forward and downward cut-off angles of visibility supplied by the airplane manufacturer, and by correcting for airplane attitude at the instant of touchdown Measurements were made of airplane attitude during the touchdown condition for most of the aircraft considered The solid horizontal bars indicate the geometric mean distances of ground vision which the pilots consider necessary during touchdown attitude in the airplanes listed

A distribution curve was plotted and it was found that the geometric mean value fell very near the peak of the curve The geometric mean value being 75 3 feet is very

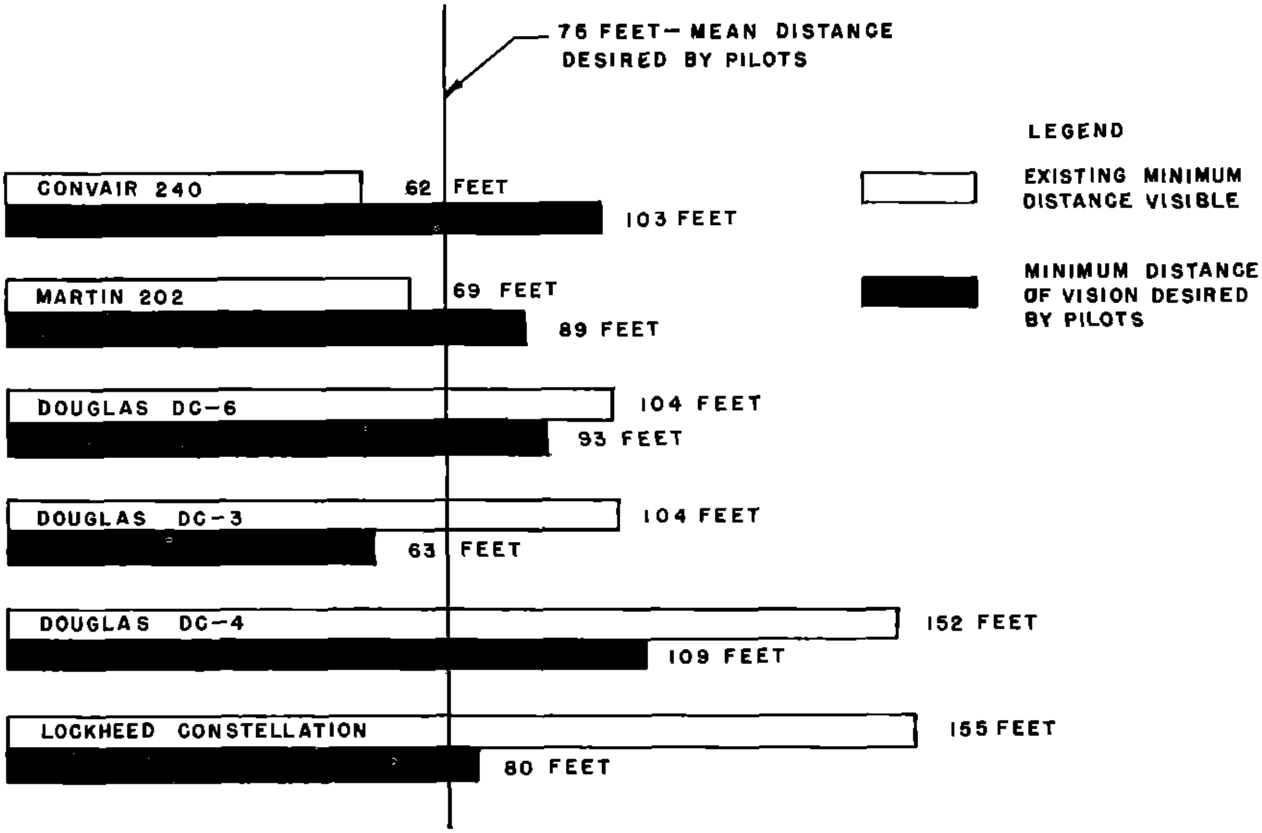


Fig 2 Existing and Desired Minimum Forward Ground Distance Visible at Touchdown as Restricted by Lower Edge of Windshield or Nose

close to the median value of 75 feet and varies a considerable amount from the arithmetic mean value of 184 feet If the arithmetic mean value is considered to be the most significant, all of the airplane models included in the chart are seen to have better vision than that specified as minimum adequate vision by the pilots However, if the geometric mean or median value is accepted, less than one-half of the pilots would be satisfied Acceptance of the geometric mean and median value of 75 feet would result in the conclusion that all of the aircraft considered except the Convair 240 and the Martin 202 are unsatisfactory in this respect

A similar situation is shown in Fig 3, where data are plotted identically for the taxi condition The geometric mean value of estimation of 32 4 feet for the minimum forward ground distance visible is shown The median value is 30 feet and the arithmetic mean value is 60 feet For this condition, however, it would be concluded that all of the aircraft are unsatisfactory if the median or geometric mean value is used, and all aircraft except the Convair 240 and Martin 202 are unsatisfactory if the arithmetic mean value is used

It is believed that complete analysis and interpretation of the results of this question cannot be secured until comparison is made with the results obtained from other related questions Such comparison is made later in this report in the general discussion

A further breakdown of the results from this question was made upon the basis of pilot experience, and it was found that pilots with less than 4,750 hours flying experience answered the question identically to pilots having more than 4,750 hours experience

Fig 3 shows the geometric mean values of minimum forward distance for the taxi condition selected by pilots in the different groups associated with the airplane they are flying It is interesting to note that in the case of the Constellation airplane, which has the least forward and downward visibility

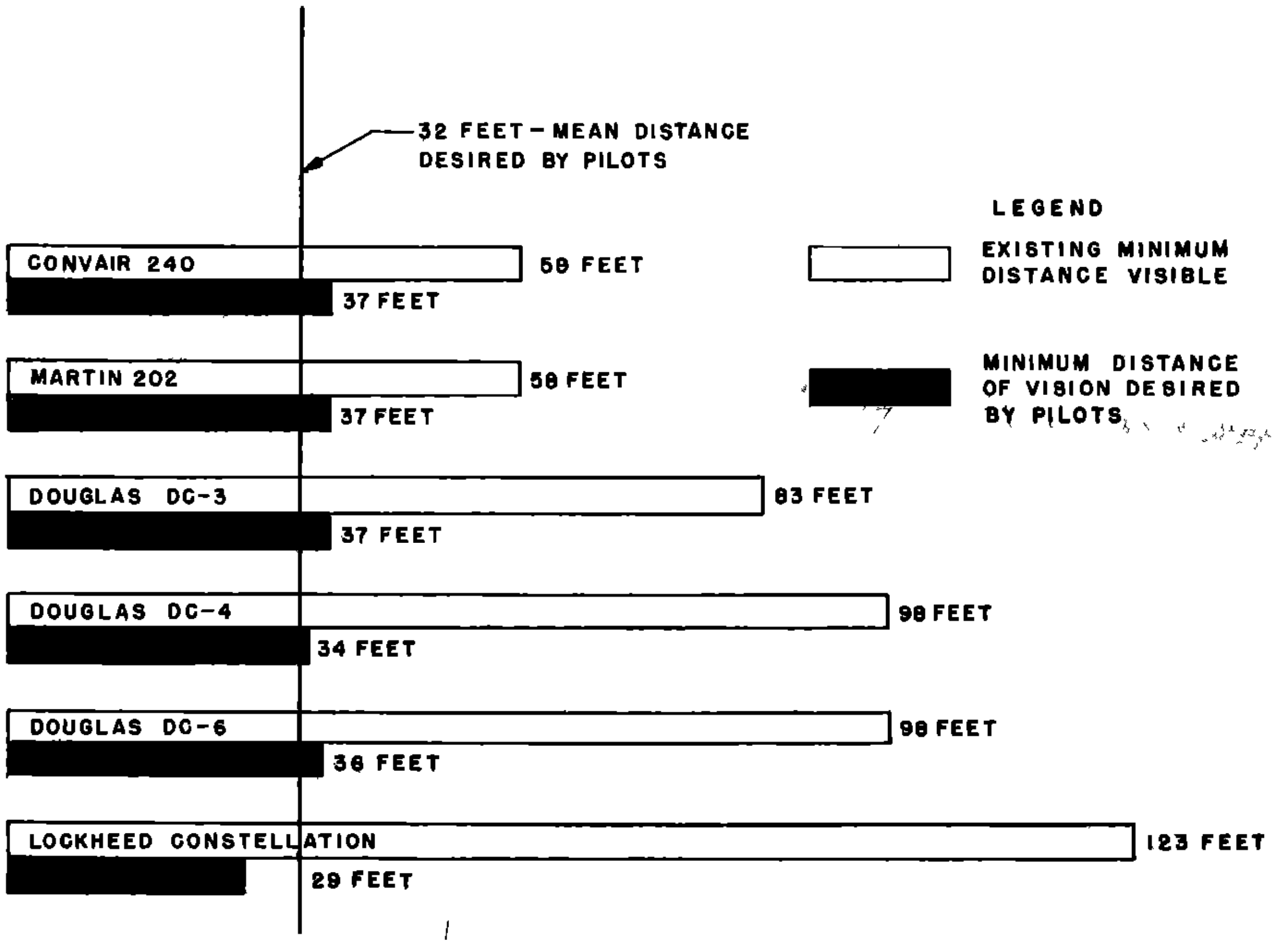


Fig 3 Existing and Desired Minimum Forward Ground Distance Visible in Taxi Attitude as Restricted by Lower Edge of Windshield or Nose

during taxiing, the pilots specified a very small distance, indicating they wanted to see the runway at a much closer point than the airplane provides and closer than that specified by any other pilot group In contrast to this, the pilot group associated with the Convair 240 airplane, which has relatively good downward visibility characteristics during taxiing, specified a large distance, indicating they would be satisfied to see the runway only at a more distant point than the airplane provides

Question 4 - External Portions of Aircraft Visible from Cockpit

The results of this question show that 96 per cent of the pilots answering the questionnaire express a desire to see some external portion of the airplane The detailed results obtained from this question are shown in Fig 4 It is demonstrated that the large majority of pilots consider it necessary to see wing tips, engine nacelles and propellers by moderate movement of the head and shoulders It also is shown that 92 per cent of the pilots feel that it is necessary to see the wing tips through either moderate or maximum head and body movement, 97 per cent feel it is necessary to see the engine nacelles and propellers under similar conditions, and 66 per cent feel it is necessary to see the main landing gear

The other five locations on the aircraft shown in this figure are specified by a relatively small number of pilots This may not mean that these locations are relatively unimportant, when compared to the first three

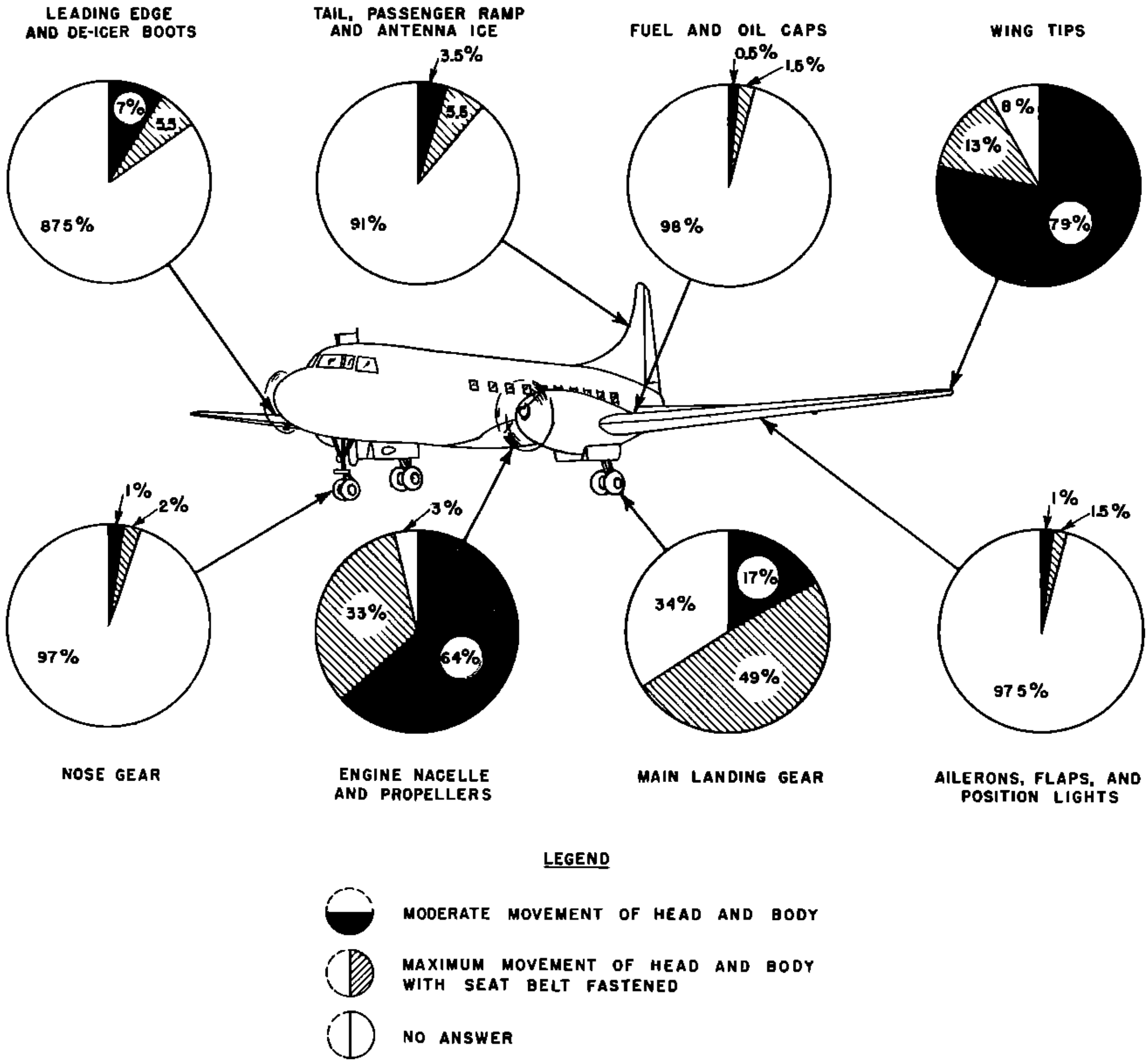


Fig 4 Percentages of Pilots Desiring to See External Portions of the Airplane

locations, as the comparable percentage figures indicate The first three locations that were shown to be of maximum importance for inclusion in vision were listed on the questionnaire form, and merely needed a check mark to answer, whereas the other five locations were suggested spontaneously by the pilots

Question 5 - Maneuvers for Which Maximum Visibility is Required

The data obtained from this question are presented in Fig 5 It can be seen that the pilots believe that the maneuver in which good visibility is most urgently required is the final approach The gliding-turn maneuver is their next choice, with taxiing placing third in their preference

Question 6 - Vision Cut-Off Angles in Douglas DC-3 Airplane

The Douglas DC-3 airplane was selected for use in this question because most airline pilots have had experience in it, and the airplane is generally available if a pilot should desire to evaluate its vision characteristics

The results obtained from this question are shown in Table III in terms of the geomet-

TABLE III

Desired Improvements of
Visibility In Douglas DC-3

	Increase in Window Opening in Inches Mean Value
Upper and forward edge of windshield	2 39
Upper edge of left side window	2 29
Lower and forward edge of windshield	1 22
Lower edge of left side window	0 50
Aft edge of left side window	1 69

ric mean value of linear increase of windshield dimensions specified by the pilots The data of Table III also are plotted in Fig 6 in terms of the angular increase in vision cut-off limits corresponding to the mean values for the linear dimensions given in the table Fig 6 is based upon direct measurement in the cockpit of a Douglas DC-3 airplane, and includes the effect of head rotation in the various azimuth angle directions The eye level was based upon the eye level chosen by three experienced pilots, all of whom showed close agreement

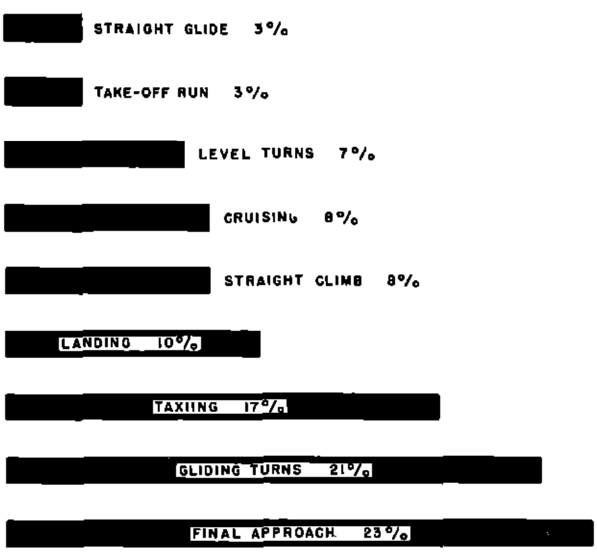


Fig 5 Relative Importance of Visibility During Common Maneuvers Shown in Percentage of Total Replies From Pilots

The mean values of pilot estimation shown in Table III and Fig 6 indicate that more visibility is considered necessary than is provided by the DC-3 airplane The amount of increase varies with each window The pilots considered a 7° increase in the forward-upward vision to be necessary, and a 3° increase necessary in forward-downward vision

The question specifically instructed the pilot not to consider airplane structure in answering this question In the DC-3 airplane the nose reduces the forward-downward visibility by approximately 3° Therefore, the 3° increase in forward and downward visibility that the pilots requested must be added to the 3° obstruction caused by the nose to obtain a true picture of the pilots' desire for increased visibility from the DC-3 airplane

The mean values of pilot estimation further indicate that an approximate 7° increase in vision to the left side and upward is necessary, and a 3° increase to the left and downward is required Further, a 10° increase in vision to the extreme aft edge of the left-hand window in the cockpit is desired

Question 7 - Evaluation of Specific
Aircraft Being Flown by Pilot

It was found that the individual pilot's flying time in the airplane now being flown varied from 3 hours to 14,000 hours The average values for each airplane pilot group are shown in Table IV.

TABLE IV

Average Flight Experience of Pilots
In The Airplane They Are Now Flying

Airplane Type	Flight Experience of Pilots in Hours
Douglas DC-3	1811
Douglas DC-4	1659
Douglas DC-6	535
Lockheed Constellation	916
Convair 240	284
Martin 202	459
Boeing 307	674
Other	187

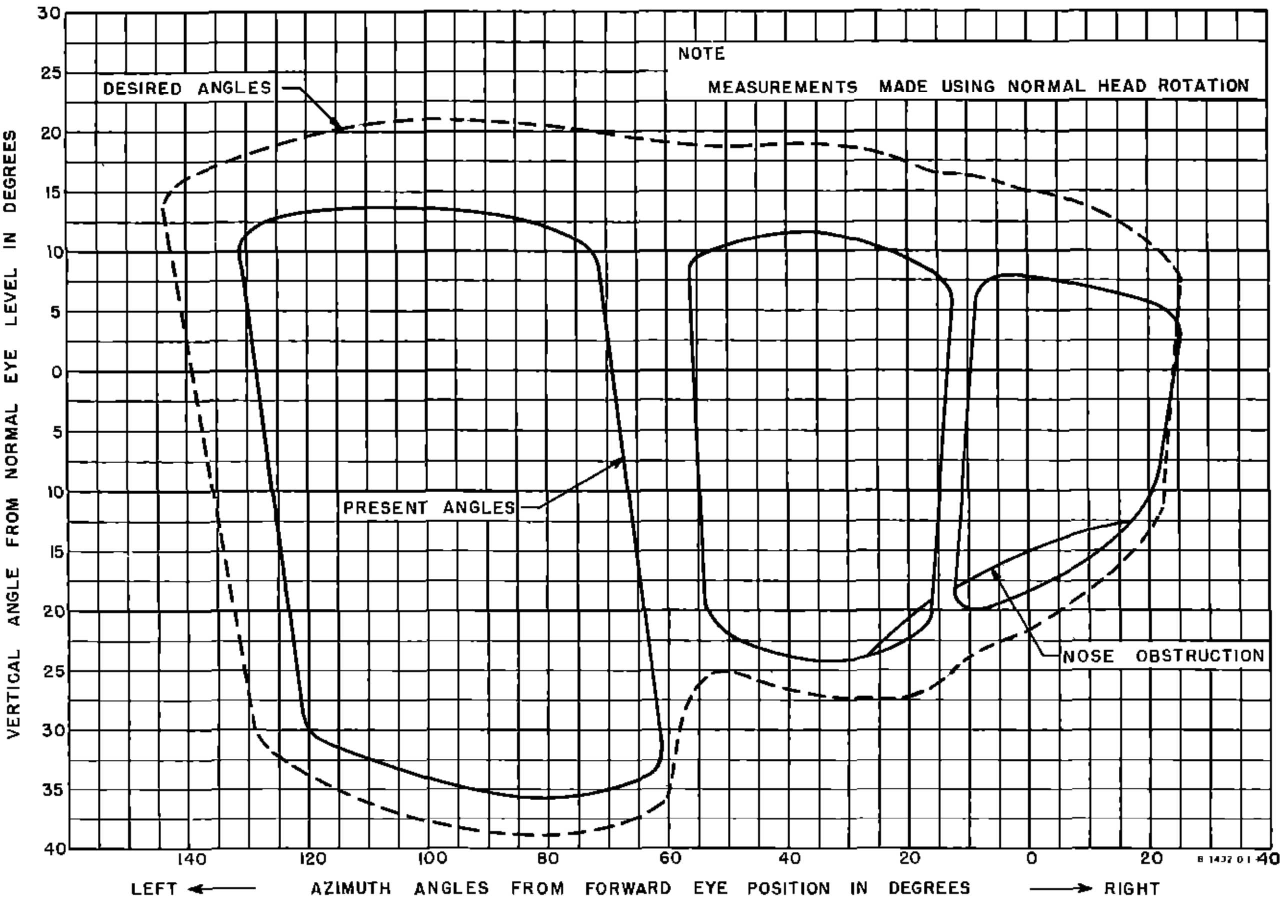


Fig 6 Present and Desired Vision Cut Off Angles in the Douglas DC-3 Airplane

The percentage of pilots of each airplane group answering the various portions of Question 7 in each of the three possible manners is shown in Table V As specified in the question, Class 1 signifies excellent vision, Class 2 signifies adequate vision, and Class 3 signifies inadequate vision There also is shown in Table V the mean estimation value for each portion of the question, which is the mean value for the three numerical ratings weighted by the percentage of pilots specifying each rating These mean values can vary from 1 00 to 3 00 A mean value of 2 00 would be assumed to correspond to minimum adequate vision, and the amount of variation of the mean value from 2 00 corresponds to the degree of superiority or inferiority of vision compared to this minimum adequate condition

It is shown in Table V that with each airplane model the lowest rating for visibility upward to the front and visibility sideward to both left and right is obtained for the gliding-turn maneuver The lowest rating for visibility downward to the front is obtained with most aircraft models for the straight climb maneuver In further analysis of the results of this question, one of these two maneuvers generally was used for evaluation of vision in the different directions In the case of visibility downward to the front the results obtained in Question 7 for the taxiing and landing maneuvers also were utilized

The arithmetic mean estimation values obtained for each of the six aircraft in Question 7 for forward and downward vision in straight climb are shown in Table VI There are shown also in the same table the approximate forward and downward cut-off angles below the horizon during climb These angles were determined partially from manufacturers data and partially from photographic records of airplane attitude during climb procedure

These data are plotted in Fig 7 It

TABLE V

Percentage Of Pilots And Ratings Of Different Aircraft For Different Conditions

Visibility Upward To Front

	DC-3				DC-4				DC-6				Constellation				Convair 240				Martin 202			
Maneuver	1	2	3	M	1	2	3	M	1	2	3	M	1	2	3	M	1	2	3	M	1	2	3	M
Taxiing	60	37	3	1 43	63	32	5	1 42	68	28	4	1 36	44	46	10	1 66	93	7	0	1 07	72	28	0	1 28
Take-off Run	51	40	9	1 58	59	36	5	1 46	67	27	6	1 39	42	42	16	1 74	90	9	1	1 11	56	40	4	1 48
Straight Climb	37	45	18	1 81	46	38	16	1 70	50	31	19	1 69	24	50	26	2 02	78	16	6	1 28	52	40	8	1 56
Cruising	30	51	19	1 89	42	46	12	1 70	49	36	15	1 66	27	50	23	1 96	81	18	1	1 20	56	40	4	1,48
Level Turns	22	45	33	2 11	29	48	23	1 94	40	31	29	1 89	18	39	43	2 25	74	25	1	1 27	32	60	8	1,76
Straight Glide	29	50	21	1 92	34	44	22	1 88	43	34	23	1 80	24	45	31	2 07	82	16	2	1 20	32	44	24	1 92
Gliding Turns	16	44	40	2 24	24	43	33	2 09	32	35	33	2 01	17	34	49	2 32	69	27	4	1 35	28	36	36	2 08
Final Approach	30	47	23	1 93	36	46	18	1 82	47	36	17	1 70	27	41	32	2 05	85	14	1	1 16	24	44	32	2 08
Landing	51	40	9	1 58	56	38	6	1 50	66	27	7	1 41	41	44	15	1 74	87	13	0	1 13	52	40	8	1 56
Average	36	44	20	1 84	43	41	16	1 73	51	32	17	1 66	29	44	27	1 98	82	16	2	1 20	45	41	14	1 69

Visibility Downward To Front

	DC-3				DC-4				DC-6				Constellation				Convair 240				Martin 202			
Maneuver	1	2	3	M	1	2	3	M	1	2	3	M	1	2	3	M	1	2	3	M	1	2	3	M
Taxiing	15	49	36	2 21	27	54	19	1 92	34	50	16	1 82	21	58	21	2 00	83	16	1	1 18	48	44	8	1 60
Take-off Run	56	38	6	1 50	42	48	10	1 68	62	30	8	1 46	40	43	17	1 77	84	15	1	1 17	60	32	8	1 48
Straight Climb	23	55	22	1 99	16	43	41	2 25	16	43	41	2 25	18	45	37	2 19	34	44	22	1 88	40	40	20	1 80
Cruising	37	53	10	1 73	31	50	19	1 88	38	44	18	1 80	26	47	27	2 01	76	22	2	1 26	52	48	0	1 48
Level Turns	37	50	13	1 76	33	46	21	1 88	39	39	22	1.83	22	48	30	2 08	78	21	1	1 23	52	44	4	1 52
Straight Glide	42	44	14	1 72	41	44	15	1 74	49	34	17	1 68	29	45	26	1 97	84	14	2	1 18	64	28	8	1 44
Gliding Turns	36	45	19	1 83	38	42	20	1 82	47	30	23	1 76	27	40	33	2 06	77	21	2	1 27	60	24	16	1 56
Final Approach	43	43	14	1 71	42	45	13	1 71	56	27	17	1 61	30	46	24	1 94	83	16	1	1 18	56	32	12	1 56
Landing	33	44	23	1 90	26	44	30	2 04	41	41	18	1 77	26	42	32	2 06	75	23	2	1 27	40	48	12	1 72
Average	36	47	17	1 81	33	36	21	1 68	42	38	20	1 78	27	45	28	2 01	75	21	4	1 29	52	38	10	1 58

TABLE V (CONTINUED)

Percentage Of Pilots And Ratings Of Different Aircraft For Different Conditions

Visibility Sideward To Left

	DC-3				DC-4				DC-6				Constellation				Convair 240				Martin 202			
Maneuver	1	2	3	M	1	2	3	M	1	2	3	M	1	2	3	M	1	2	3	M	1	2	3	M
Taxiing	53	41	6	1 53	65	32	3	1 38	68	30	2	1 34	28	57	15	1 87	80	18	2	1 22	71	29	0	1 29
Take-off Run	61	36	3	1 42	67	30	3	1 36	75	24	1	1 26	37	51	12	1 75	90	10	0	1 10	75	25	0	1 25
Straight Climb	51	43	6	1 57	58	37	5	1 47	64	31	5	1 41	28	53	19	1 91	82	18	0	1 18	75	21	4	1,29
Cruising	53	41	6	1 53	61	35	4	1 43	64	32	4	1 40	29	59	17	1 98	83	16	1	1 18	75	25	0	1 25
Level Turns	34	44	22	1 88	45	41	14	1 69	48	37	15	1 67	18	48	34	2 16	73	23	4	1 31	62	25	13	1 51
Straight Glide	51	42	7	1 56	59	37	4	1 45	62	34	4	1 42	29	54	17	1 88	84	15	1	1 17	71	25	4	1 33
Gliding Turns	32	43	25	1 93	42	42	16	1 74	49	35	16	1 67	16	46	38	2 22	69	25	6	1 37	48	28	24	1 76
Final Approach	49	43	8	1 59	59	38	3	1 44	61	32	7	1 46	27	50	23	1 96	85	14	1	1 16	58	33	9	1 51
Landing	56	38	6	1 50	64	32	4	1 40	66	30	4	1 38	34	48	18	1 84	87	13	0	1 30	71	29	0	1 29
Average	49	41	10	1 61	58	36	6	1 48	62	32	6	1 44	27	51	22	1 95	81	17	2	1 21	67	27	6	1 39

Visibility Sideward To Right

	DC-3				DC-4				DC-6				Constellation				Convair 240				Martin 202			
Maneuver	1	2	3	M	1	2	3	M	1	2	3	M	1	2	3	M	1	2	3	M	1	2	3	M
Taxiing	12	45	43	2 31	15	42	43	2 28	21	52	27	2 06	12	27	61	2 49	43	48	9	1 66	29	63	8	1 79
Take-off Run	34	48	18	1 84	29	46	25	1 96	47	38	15	1 68	24	38	38	2 14	76	21	3	1 27	54	46	0	1.46
Straight Climb	21	53	26	2 05	21	44	35	2 14	27	48	25	1 98	14	35	51	2 37	63	30	7	1 44	46	46	8	1 62
Cruising	23	52	25	2 02	27	48	25	1 98	33	51	16	1 83	14	41	45	2 31	69	27	4	1 35	50	50	0	1 50
Level Turns	10	42	48	2 38	10	41	49	2 39	19	41	40	2 21	6	33	61	2 55	48	40	12	1 64	21	54	25	2 04
Straight Glide	21	52	27	2 06	23	45	32	2 07	31	48	21	1 90	14	40	46	2 32	67	29	4	1 37	42	54	4	1 62
Gliding Turns	8	39	53	2 45	11	36	53	2 42	19	38	43	2 24	6	26	68	2 62	41	45	14	1 73	8	56	36	2 28
Final Approach	22	49	29	2 07	23	35	32	1 89	32	43	25	1 93	13	37	50	2 37	70	25	5	1 35	29	58	13	1 84
Landing	29	48	23	1 94	29	45	26	1 97	42	40	18	1 76	20	36	44	2 24	75	21	4	1 29	50	50	0	1 50
Average	20	47	33	2 13	21	43	36	2 15	30	44	26	1 96	14	35	51	2 37	61	32	7	1 46	36	53	11	1 75

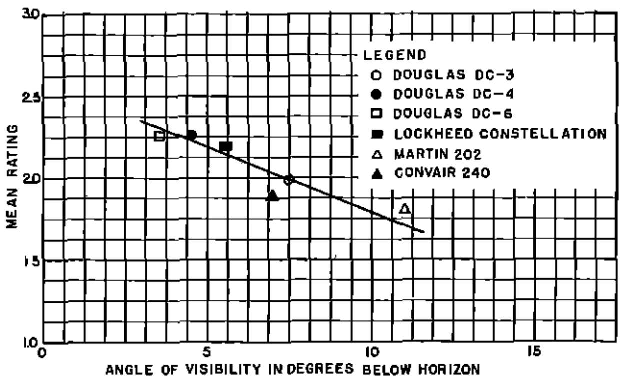


Fig 7 Adequacy of Forward and Downward Vision During Straight Climb in Different Aircraft

appears from the plotted curve that if the average pilot can see about 8° below the horizon during climb, he will consider the forward and downward vision just adequate From approximate extrapolation of the curve, it might be concluded that if the limit of vision extends 15° to 20° below the horizon during the climb, the resulting vision would be considered excellent

The mean estimation values plotted in Fig 7 might also be plotted directly against forward and downward cut-off angle relative to the longitudinal axis of the airplane, or relative to the flight path of the airplane during climb However, the type of plotting shown, using the horizon as a reference, appears to provide the best correlation

It may be assumed that the basis of pilot estimation for forward and downward vision during climb is the sighting of other aircraft to avoid collision No necessity can be seen for the amount of vision desired from the standpoint of visual judgments unless the pilots were considering the possibility of surveying the terrain below flight path in the event of an emergency landing In addition to this consideration it is recognized that the forward and downward direction during climb in the vicinity of airports does represent a dangerous area from the collision standpoint

It is noted that the estimation value for the Convair 240 airplane for this condition, although better than a value corresponding to minimum adequate vision and slightly inconsistent with the values for the other airplanes, is the lowest rating given by the Convair 240 pilot group for vision in any direction in any maneuver This relatively low rating appears associated with the attitude of the airplane during climb

There are shown in Table VII the arithmetic mean estimation values for the landing and taxiing condition for forward and downward vision for all airplanes and the corresponding approximate ground distances in front of the airplanes which can be seen in landing and taxiing attitudes The latter distances were obtained partially from manufacturers' data and partially from photographic records of aircraft during landing touchdown and taxi These data are plotted in Fig 8

The average curve drawn through the plotted points in Fig 8 crosses the estimation value corresponding to minimum adequate vision when the vision ground distance is about 130 feet It may be concluded that if a ground distance less than 130 feet in front of the airplane can be seen during both taxiing and landing, the average pilot will consider vision

TABLE VI

Mean Values And Cut-Off Angles For Forward And Downward Vision In Straight Climb For Different Aircraft

Airplane	Mean Value Of Pilot Estimation	Forward and Downward Cut-Off Angles Below Horizon In Degrees
Douglas DC-3	1 99	7 5
Douglas DC-4	2 25	4 5
Douglas DC-6	2 25	3 5
Lockheed Constellation	2 19	5 5
Convair 240	1 88	7 0
Martin 202	1 80	11 0

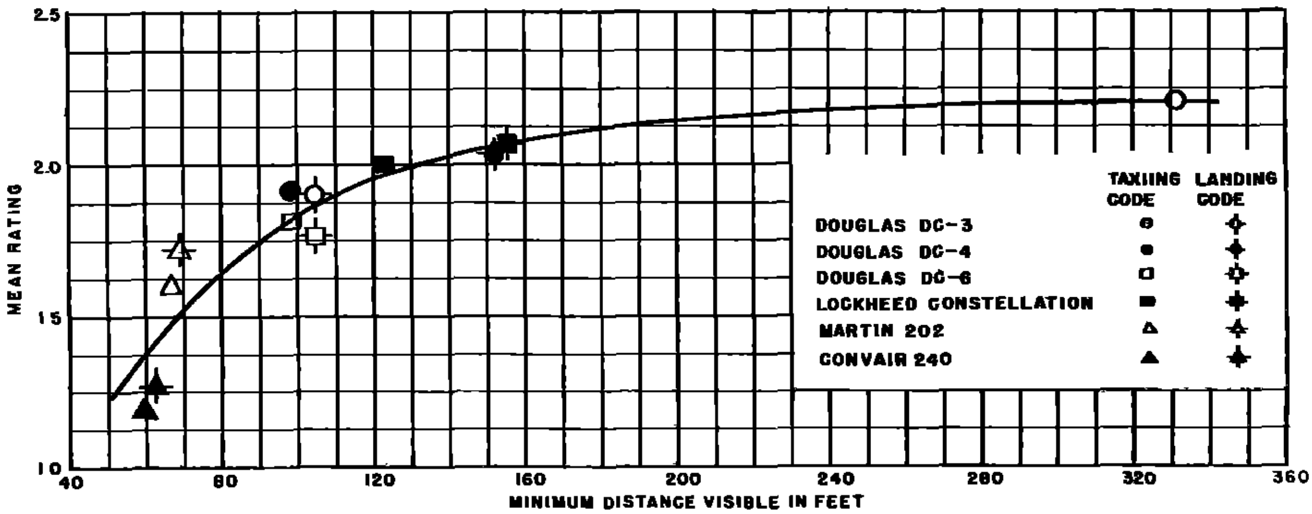


Fig 8 Adequacy of Forward and Downward Vision During Taxiing and Landing in Different Aircraft

to be adequate, and if a forward ground distance of about 60 feet can be seen, the pilot will consider vision to be excellent.

From the small slope of the average curve it appears that forward and downward vision probably would not be rated definitely poor under these conditions unless the forward and downward cut-off limit is about at the horizon.

The fact that a single curve is obtained for both the landing and taxiing condition is significant Although it is reasonably certain that short-distance vision is not used for basic judgments during landings, the results of this question appear to imply that short-distance vision equivalent to that needed for taxiing also is desired in the landing attitude, either for secondary judgments or for seeing obstacles.

In reviewing the mean values shown in Table V, the pilots selected gliding turns as the most critical maneuver when evaluating visibility upward and to the front. For vision in this direction the average of the arithmetic mean values for the gliding-turn maneuver for all pilots and aircraft is 2.05, which represents vision slightly worse than minimum adequate vision. The best rating for this condition was 1 35, and was given to the Convair 240 airplane, which affords the pilot the greatest forward and upward vision of any of the airplanes under consideration. The poorest rating was 2.32, and was given to the

TABLE VII

Forward And Downward Visibility Estimations During Landing And Taxiing Condition In Different Aircraft

Airplane	Landing Condition: Estimated Mean Values	Landing Condition: Corresponding Ground Distance In Feet	Taxiing Condition: Estimated Mean Values	Taxiing Condition: Corresponding Ground Distance in Feet
Douglas DC-3	1 90	104	2 21	331
Douglas DC-4	2 04	152	1.92	98
Douglas DC-6	1 77	104	1 82	98
Lockheed Constellation	2 06	155	2 00	123
Convair 240	1 27	62	1 18	59
Martin 202	1 72	69	1.60	66

TABLE VIII

Mean Estimated Values And Vision Cut-Off Angles Of Upper Edge Of Edge Of Left Window In Gliding-Turn Condition

Airplane	Mean Estimated Values	Vision Cut-Off Angle, Upper Edge Left Side Window In Degrees
Douglas DC-3	1 90	22
Douglas DC-4	1 74	27
Douglas DC-6	1 67	27
Lockheed Constellation	2 22	19
Convair 240	1 37	26
Martin 202	1 76	22

Constellation airplane, which affords the pilot the smallest forward and upward vision of any of the airplanes under consideration

In spite of the general consistency of results shown above, it was not found possible to establish a reasonably precise relationship between the forward and upward cut-off angles and the pilot ratings which would hold for all of the types of aircraft under consideration This absence of correlation probably is associated with the small angular difference in upward vision between the various airplanes, and to lack of knowledge of the flight attitudes of the different airplanes in the gliding-turn maneuver

The mean values of evaluation obtained in Question 7 for vision upward to the left for all airplanes in a gliding-turn condition are shown in Table VIII, with the approximate corresponding vision cut-off angle of the upper edge of the side window The cut-off angles are for the condition where the head is turned directly sideward from its normal position These values are plotted in Fig 9

It may be concluded from Fig 9 that vision upward and to the left is considered barely satisfactory if the cut-off angle is about 21° with the head turned sideward This eye position is arbitrary, but is considered to closely represent the actual conditions

The increase in upward vision cut-off angle with head movement also may be an important factor If the data of Fig 9 were replotted for a 5-inch side head movement, still including head rotation, the cut-off angle for the Constellation airplane would increase to about 37° and the cut-off angle for the Douglas DC-4 and DC-6 airplanes would increase to about 49° The minimum satisfactory angle in this case would be about 44° However, it is not apparent from the data that such head movement was considered in evaluation of vision in this direction

These results indicate that upward vision through the left window is desired at least up to the horizon in a 21° bank with sideward head rotation, and in a 44° bank with a 5-inch sideward head movement

The data obtained for each airplane in Question 7 for vision to the right side in gliding turns are plotted in Fig 10 against the total solid angle of vision provided by the right-hand window or windows as seen from the left-hand seat A general trend is shown for the degree of pilot satisfaction to increase with increase in solid angle of vision

An attempt was made to correlate these

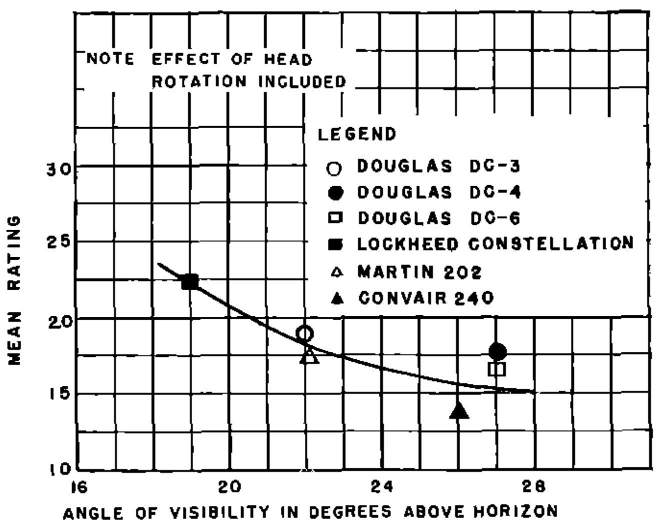


Fig 9 Adequacy of Upward Vision at 90° to the Left During a Gliding Turn in Different Aircraft

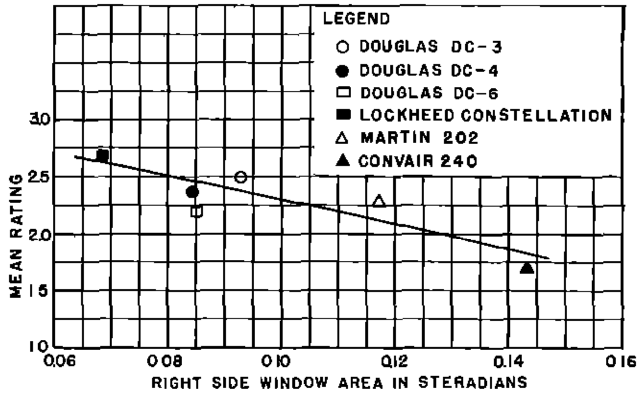


Fig 10 Adequacy of Sideward to Right Vision During Gliding Turn in Different Aircraft

data with vision cut-off angles of the right-hand window upper edge, lower edge, and rear edge, but no relationship could be found The correlation with total solid angle of vision is the only one which shows a definite trend, although this correlation also is not completely satisfactory

The curve shown in Fig 10 indicates that, if the total solid angle of vision to the right side as seen from the left-hand seat is greater than about 0 13 steradians, the average pilot will consider the right-hand vision to be an adequate but minimum amount In view of the low slope of this curve and the apparent general tendency of the Convair 240 pilot group to slightly overrate visibility in that airplane, it might be estimated that the minimum solid angle should be slightly greater than the value given, or about 0 14 to 0 15 steradians Approximate extrapolation of the curve indicates that right-hand vision with a solid angle of 0 18 to 0 20 steradians would be classified as excellent by all pilot groups

In a symmetrical cockpit with side-by-side seating, there obviously is a close relationship between vision to the left side and vision to the right side This is shown by the close parallelism of ratings given to each airplane for vision in the two directions for the gliding-turn condition The cockpit width undoubtedly is an important factor in connection with right-hand vision, but the airplanes considered do not vary widely in cockpit width, and this factor apparently influences both left- and right-hand vision in a similar manner

Question 8 - Distortion and Obstruction of Vision

The results obtained with Question 8(a) are shown in Table IX, which gives the arithmetic mean value of numerical rating for each azimuth segment angle specified in the question. Mean values are shown for the entire pilot group, and separately for the two pilot groups with experience from zero to 4,749 hours and 4, 750 plus hours, respectively

There also are shown the mean values obtained from the pilots associated with each airplane type These latter values cover pilots of both experience groups

It is seen that a small difference exists between the ratings of pilots in the two experience groups, with the more experienced pilots generally specifying slightly higher quality of vision for the side segments and slightly lower quality for the forward segments A greater variation exists between the pilot groups for the different airplanes The Douglas DC-6 pilots generally specify the lowest quality and the Convair 240 pilots specify the highest quality No reason is apparent for this difference between the pilots associated with each airplane, and it appears that the difference cannot be explained by amount of experience alone

The over-all mean values obtained for all pilots are influenced most strongly by the Douglas DC-3 pilots because of the larger sample obtained of these pilots The DC-3 pilots also are preponderantly in the low-experience group The standard deviation from the over-all mean value of the individual mean values obtained with the ten different experience and airplane groups was 0 11 for the 120°-90° L segment The standard deviation for this segment was a maximum, and represents a deviation of 5 5 per cent of the range of possible values

The over-all mean values given in Table IX are converted into a quality per cent rating These values also are shown and represent the difference between each mean value and the low-quality value of 3 00, expressed in per cent of the total possible variation from 3 00 to 1 00 Thus, a mean value of 1 00 represents 100 per cent and a mean value of 3 00 represents zero per cent It is recognized that the quality scale is not necessarily linear, as this procedure assumes, but it is

TABLE IX

Variation Of Quality Of Vision With Azimuth Angle For Different Airplanes

Azimuth Angle (Degrees)	Mean Value - Quality Rating Pilots 0 - 4749 Hours	Pilots 4750+ Hours	All Pilots	Quality Per Cent Rating
120 - 90 L	2.20	2 13	2 16	42
90 - 60 L	1.68	1 64	1 65	67
60 - 30 L	1 12	1 16	1 15	92
30 - 0 L	1 03	1 01	1 01	99
0 - 30 R	1 02	1 03	1.03	98
30 - 60 R	1.14	1 17	1.15	92
60 - 90 R	1 71	1 65	1 68	66
90 - 120 R	2.22	2 14	2 18	41

Azimuth Angle (Degrees)	Mean Value - Quality Rating Douglas DC-3 Pilots	Douglas DC-4 Pilots	Douglas DC-6 Pilots	Lockheed Constellation Pilots	Convair 240 Pilots
120 - 90 L	2 12	2 22	2 29	2 21	1 98
90 - 60 L	1 59	1 72	1 82	1 67	1 54
60 - 30 L	1 09	1 23	1 21	1 18	1 08
30 - 0 L	1 01	1 02	1 03	1 02	1 00
0 - 30 R	1 01	1 03	1 04	1 03	1 00
30 - 60 R	1 08	1 23	1 18	1 21	1 11
60 - 90 R	1 60	1 74	1 85	1 71	1 56
90 - 120 R	2 12	2 24	2 29	2 24	2 01

believed that a reasonably accurate estimate is secured

The quality per cent rating for the different angular segments, as given in Table IX, are plotted in Fig 11 A curve is drawn through the midpoints of each segment value to indicate a continuous variation

It is desired to estimate from this curve the azimuth angles over which the various classes of vision quality are desired If it is assumed that quality of 75 per cent or greater corresponds to the high quality Type (1) vision specified in the question, that quality between 25 and 75 per cent corresponds to Type (2) vision, and that values less than 25 per cent correspond to Type (3) vision, then definite conclusions can be drawn

Upon this basis, it is seen that the high quality Type (1) vision is desired over a range of azimuth angles extending from about 70° left to 65° right of the forward axis Beyond these limits, and to the limit of 120° left and right, Type (2) vision is desired At no point in this total range of azimuth angles is Type (3) vision desired

There is shown also in Fig 11 a curve defined by the equation

$$Q = 50 \ (1 - \sqrt{\text{Cos} \ [\theta - \pi]})$$

where Q is the quality per cent factor already used and θ is a positive azimuth angle measured from the forward axis A close agreement exists between this curve and the experimental curve for azimuth angles between 90° left and 90° right This mathematical expression might be utilized for estimation of vision quality in this angular range

The estimations made by pilots answering this question were based solely upon quality of vision desired It is obvious, however, that estimation of quality of vision desired is related closely to estimation of relative importance of accurate vision at different azimuth angles In this sense the vertical scale of Fig 11 may be considered a scale

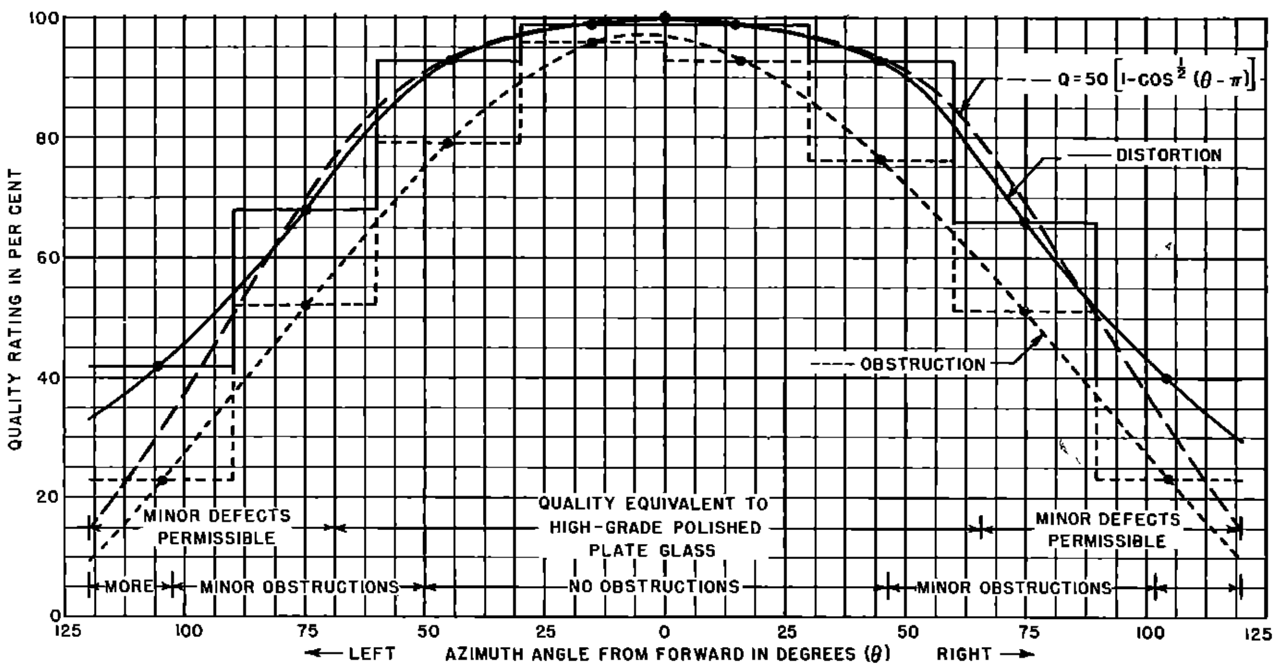


Fig 11 Variation of Obstruction and Distortion Ratings with Azimuth Angles

of importance of vision, and the experimental curve shows the manner in which importance of vision varies with azimuth angle

It is of interest to compare the curve, interpreted in this sense, with a similar relationship given by Gray and Scott and shown by McFarland[1] They define a weighting factor W_f, which is proportional to the usefulness of vision at any given azimuth during the landing maneuver, and conclude that W_f = 1 00 from 0° to 20° left, and $W_f = \sqrt{\cos 2(\theta - 20^\circ)}$ from 20° left to 65° At 65° the value of $W_f = 0$, and at azimuth angles greater than about 30° the values of W_f are much less than the corresponding relative values shown by the present curve The large increase in relative importance of the side angles, as indicated by the present curve, probably is associated with the use of such areas in turns and in maneuvers other than landing

In formulation of the question to be presented to the pilots, it was necessary to define the different quality levels of vision in broad terms which could be interpreted and applied by the pilot In actuality, the quality of vision may be determined by measurement of deviation and distortion introduced by the glass The principal factors are the amount of deviation of line of sight through the glass, and the rate of change of such deviation across the pane Quality of vision is influenced by both of these factors, which in turn are influenced strongly by the angle of sight with respect to the glass surface Quantitative specification of vision quality, therefore, is complex However, the three categories of vision quality used in the question may be defined approximately in terms of distortion as zero to two minutes per inch rate of change of arc deviation for Type (1) quality, two to four minutes per inch rate of change of arc deviation for Type (2) quality, and greater than four minutes per inch rate of change of arc deviation for Type (3) quality

If strict adherence were made to the quality requirements indicated by the results of this question, it probably would be necessary to utilize flat, glass panes in the azimuth angles from 0° forward to at least 70° right and left, and to place the panes so that the line of sight is as close as possible to 90° with respect to the glass surface

The data obtained from answers of Ques-

[1]Ross A McFarland, "Human Factors in Air Transport Design," 1st Ed , p 443, McGraw Hill Book Co , Inc , New York and London, 1946

TABLE X

Variation Of Obstruction To Vision With Azimuth Angle For Different Aircraft

Azimuth Angle (Degrees)	Mean Value - Obstruction Rating Pilots 0 - 4750 Hours	Mean Value - Obstruction Rating Pilots 4750+ Hours	Mean Value - Obstruction Rating All Pilots	Obstruction Per Cent Rating
120 - 90 L	2 53	2 54	2 54	23
90 - 60 L	1 94	1 97	1 96	52
60 - 30 L	1 43	1 45	1 44	78
30 - 0 L	1 06	1 07	1 07	96
0 - 30 R	1 14	1 16	1 15	92
30 - 60 R	1 46	1 49	1 47	76
60 - 90 R	1 96	2 00	1 98	51
90 - 120 R	2 54	2 56	2 55	22

Azimuth Angle (Degrees)	Mean Value - Obstruction Rating Douglas DC-3 Pilots	Douglas DC-4 Pilots	Douglas DC-6 Pilots	Lockheed Constellation Pilots	Convair 240 Pilots
120 - 90 L	2 48	2 54	2 54	2 66	2 53
90 - 60 L	1 92	1 94	1 99	2 04	1 96
60 - 30 L	1 36	1 44	1 49	1 56	1 50
30 - 0 L	1 06	1 05	1 07	1 11	1 08
0 - 30 R	1 15	1 16	1 16	1 16	1 21
30 - 60 R	1 40	1 47	1 50	1 59	1 57
60 - 90 R	1 93	1 96	2 04	2 07	2 00
90 - 120 R	2 48	2 56	2 58	2 67	2 53

tion 8(b) are given in Table X, expressed as the mean value obtained for each segment angle, as estimated by the two pilot experience groups, and also as estimated by the pilot groups associated with each of the five airplanes The over-all mean values and the corresponding per cent ratings also are shown

Close agreement is obtained between the results secured from the two experience groups, although in the evaluation of permissible obstructions in each segment angle the pilots of less experience consistently give slightly lower numerical rating values

The data showing variations in evaluation made by the pilot groups associated with the individual aircraft again show definite and consistent differences, as in the case of Question 8(a) In this portion of the question, the pilots associated with the Constellation airplane give a consistently higher numerical evaluation, and the Douglas DC-3 pilots give the lowest numerical evaluation Again, no explanation is obvious for this variation or for the different alignment in the two parts of the question of the pilot groups associated with the specific aircraft.

The obstruction per cent rating derived from the mean values obtained for the entire pilot groups are plotted in Fig 11 The resultant curve is similar in shape to the curve found in Question 8(a) for quality of vision, but the obstruction per cent rating is lower in value for all azimuth angles than the previous quality per cent rating

If it is assumed that an obstruction per cent rating greater than 75 per cent corresponds to Condition (1) on the rating scale, then it may be concluded that it is desired that no obstruction be present in the windshield over a range of azimuth angles extending from 50° left to 49° right Similarly, the angular segments in which minor obstruction is permissible, corresponding to ratings of 25 to 75 per cent, extend between 50° and 100° left and 49° and 100° right From 100° to 120° on both sides, greater obstruction is permissible A slight decrease in importance

TABLE XI

Mean Estimated Values For Minimum Width Of Slot
In Inches Necessary To Operate Airplane

	Mean Value For Width Of Vertical Slot (Inches)						
	Douglas DC-3 Pilots	Douglas DC-4 Pilots	Douglas DC-6 Pilots	Lockheed Constellation Pilots	Convair 240 Pilots	Other Pilots	All Airplanes
0 - 4749 Hours	6 70	7 56	9 13	7 10	7 85	8 73	7 08
4750+ Hours	6 96	7 49	6 80	8 03	5 54	7 91	7 05
All Experience	6 80	7 52	7 54	7 50	5 69	7 71	7 06

of obstruction is noted for the right-hand side, as compared to the left-hand side

In the original question, a minor obstruction was defined as a thin post less than 1 1/2 inches in width A post of this size will not completely obstruct binocular vision because of the approximate 2 1/2-inch eye spacing However, the edges of windshield panes generally produce distortion, and the width of posts may increase at an oblique angle of sight because of thickness, so that if a post width is increased appreciably beyond 1 1/2 inches, a definite loss in vision may be expected even with binocular vision

It may be concluded that binocular vision without appreciable obstruction is desired for all azimuth angles over which simple head movement is possible, or over an angular range slightly greater than the forward semicircle The particularly critical angular directions from the standpoint of obstructions cover a total range of about 100°, centered about the forward direction

Question 9 - Width of Forward Vision Area Necessary for Landing Judgments

The results of this question are given in Table XI, which lists the geometric mean value of the slot width in inches specified by each pilot group, and also shows the over-all geometric mean value of 7 06 inches obtained A median value of 7 inches and an arithmetic mean value of 8 61 inches was found for the entire pilot group

Individual answers to this question varied over a range from 1 inch to 36 inches, but the mean values given by each group appear reasonably consistent Only a slight difference is shown between the over-all values for the two experience groups, and this difference does not appear to be significant More difference is found between the pilot groups associated with the different airplanes, but even in this case no consistent trend is observed which might be explained by particular airplane characteristics

The geometric mean value of slot width of 7 06 inches, when converted into an angular measurement, corresponds to a total angle of about 23° over which binocular vision is secured Monocular vision would be obtained somewhat beyond this limit, and slight head movements, which were not mentioned in the question but which may have influenced the pilot estimation, would increase the limit further If monocular vision is assumed for the maximum angles, together with a 5-inch sideward head movement, then the total angle over which vision may be obtained is 78° However, it appears that the angle of 23° over which unobstructed binocular vision is obtained with a 7 06-inch slot width is probably the most significant figure

It may be concluded that, in average pilot opinion, the essential visual judgments which are made while landing an airplane are made through a portion of the windshield contained within at least 13° on both sides of a line directly forward of his head position

Question 10 - Forward and Upward Vision During Landing Approach

The answers to this question, as obtained from all pilots of both experience groups, and flying all airplane models, give the following results

(1) 19 per cent said that it was necessary

TABLE XII

Evaluation Of Forward And Upward Visibility Needed During Final Approach In Percentage Of Total Pilot Replies

Limiting Vision	Douglas DC-3 Pilots	Douglas DC-4 Pilots	Douglas DC-6 Pilots	Lockheed Constellation Pilots	Convair 240 Pilots	Other Pilots	All Airplanes Experience Under 4750 Hours	All Airplanes Experience 4750 Hours And Over	All Pilots
Midpoint Runway	20 0	19.0	22.0	12.0	25 0	18 0	17 0	22.0	19 0
Far End Runway	17 0	20.0	15 0	19.0	13 0	16 0	20 0	15 0	18.0
Horizon	32 0	32.0	31 0	40 0	31 0	36 0	34 0	32 0	33.0
Above Horizon	31.0	29 0	32.0	29 0	31 0	30.0	29 0	31 0	30 0
Degrees Above Horizon	17.2	15 9	15 6	19 7	17 5	13.9	18 4	15 4	16 8

to see approximately the first half of the runway, and not beyond the midpoint.

(2) 18 per cent said it was necessary to see only to the far end of the runway.

(3) 33 per cent said it was necessary to see all of the runway and up to the horizon.

(4) 30 per cent said it was necessary to see above the horizon, and estimated an arithmetic mean value of 21° and a geometric mean value of 16 8° above the horizon as being required.

This question basically does not require angular estimations, but rather an estimation of objects outside of the airplane which should be seen during final approach in order to avoid obstruction and to make necessary visual judgments. Actually, the vertical angular difference between the first and third choices for the condition stated is only about 4°

The complete results obtained for this question are given in Table XII In these data no significant difference is seen between the results for the various airplane pilot groups or experience groups The only noticeable difference is the variation between the first and second choices, although the total for the two choices remains reasonably uniform except in the case of the Constellation pilot group. For this group the total of the first two choices, representing a limit of upward vision which is below the horizon, is 31 per cent as compared to 37 per cent for the entire pilot group. It might appear that the difference between the first two choices is not sufficiently important to produce a consistent trend, and that the total of the first two choices is more significant.

Upon this basis, it is seen that 37 per cent of the pilots feel that minimum vision for routine safe landings exists, from the standpoint of making visual judgments and seeing obstructions, if the runway is in sight but not the horizon. A total of 70 per cent are satisfied in this respect if the horizon also is in sight.

It may be concluded that the upper edge of the windshield should be located so that vision is retained at least up to the horizon in an approach where the airplane is normally in a nose-down attitude. This conclusion relates only to vision necessary for making judgments and seeing obstacles, and not for seeing other aircraft to avoid possible collision.

In one sense, the answers obtained with this question are inclusive In framing the question it was considered possible that need for forward and upward vision in an approach, particularly from the standpoint of making judgments, might be consciously associated with sight of particular standard objects outside of the airplane such as some part of the runway or horizon. Although this possibility still may exist, at least with regard to the horizon, the answers do not demonstrate this in a conclusive manner The proportional division of 37, 33, and 30 for limiting vision below the horizon, at the horizon, and above the horizon, respectively, is too equal a distribution to permit selection of a definite nodal point, although it is true that 63 per cent of the pilots include the horizon in their estimate.

From this viewpoint, it also is not clear why the 30 per cent of the pilots who specified minimum vision to extend above the horizon should choose a geometric mean value as great as 17° above the horizon

Analysis of answers to this question may be made also from the standpoint of angular estimation alone On this basis the mean value of estimation by all pilots is approximately 7° above the horizon for the minimum vision cut-off point It is not clear that this method of analysis is correct, but the result obtained is in close agreement with the previous considerations

In spite of these uncertainties in complete evaluation of the answers obtained, it appears to be definitely established that forward and upward vision extending slightly above the horizon will provide at least minimum necessary vision in the opinion of the large portion of the pilots

Question 11 - Frequency of Accidents and Near-Accidents Associated with Lack of Visibility

The results obtained from Question 11 show that approximately 25 per cent of the pilots answering the questionnaire were involved in a near-accident associated with inadequate visibility from the cockpit The per cent figure corresponds to a total of 344 pilots reporting a near-accident of this type An additional 0 8 per cent of the entire pilot group were involved in an actual taxi accident, and another 0 5 per cent had a collision in the air with another aircraft or struck an object during landing or take-off

While interviewing pilots during the pre-study phase of the investigation, it was indicated that the near-accidents which were reported, principally involved sudden, extremely close proximity to another aircraft in the air, the presence of which was not previously known and which required rapid and violent maneuvering to avoid collision

The results of this question indicate that about one-quarter of the pilots experience at least one near-accident of this general nature, although the number of actual air collisions reported is very small In this instance, the number of near-accidents is considered to be more significant than the number of actual accidents, as the normal extreme severity of the latter already is well known and as pilots involved generally do not survive It is considered significant and important that one pilot out of every four reports a near-accident of this type

Question 12 - Pilot Comment upon Miscellaneous Visibility Problems

A total of 911 pilot comments were received in answer to this question This number represents 68 per cent of all pilots who answered the questionnaire Most of these comments obviously represent considerable thought by the pilots Because of the large number of comments, however, it is not possible to present the complete information available from them at this time

Most of the comments secured deal with specific details of particular aircraft and are not presented, although general conclusions can be obtained from them The following comments include only a small portion of the total comments, and are not necessarily considered to be the most important, but represent those remarks which were repeated a sufficient number of times by different pilots to become significant in this respect alone

The comments are classified under general headings according to content, and the number of pilots making each comment is shown

Increase of Amount of Vision

Bubble observation windows were suggested by seven pilots as a method for increasing vision from the cockpit, particularly to the top and rear

Mirrors to aid the pilot in seeing upward and to the rear were suggested by seven pilots

Relocation of the magnetic compass was suggested by 54 pilots

It also was mentioned by many of these pilots that de-frosting and de-icing equipment obscure important vision in many aircraft

There were 37 comments regarding the distance that the pilots eyes should be located from the forward windshield It was mentioned specifically that the pilot is too far away from the windshield in the Douglas DC-4 and DC-6 airplanes The pilots generally desire to have their eyes close to the windshield during precipitation or low-visibility conditions There was general agreement that the Douglas DC-3 airplane is good in this respect Some pilots commented that windshield de-icing temperature causes the eyes to dry out and become tired if the pilot is too close to the heated windshield

Visibility limitation by the glare shield, due to the steep angle of climb which is possible in pressurized aircraft, was mentioned by seven pilots

Large improvement in upward vision was specifically suggested by 20 pilots Seven of these 20 pilots suggested some type of overhead window

Improvement of Quality of Vision

The necessity for elimination of distortion caused by curved panes and corner windows was mentioned by eight pilots

The annoyance and hazard of multiple images now present in double-pane windshield installations were listed by 13 pilots It was mentioned that this condition is especially critical when the insides of the windows are dirty

A need for a simplified method for windshield cleaning, especially double-pane windshields, was suggested by 13 pilots

Improvement of Cockpit Components

Inadequate de-icing and de-fogging of the windshield and windows was pointed out by 19 pilots as being a critical problem

Reduction of sun glare by installation of colored, transparent, flexible sun visors was suggested by 16 pilots

Glare and reflections on the windshield from various other sources, such as inside lights, outside lights, and water surfaces, were mentioned as being objectionable by 18 pilots

Six pilots desired better forward visibility by removal of the clear-vision window where adequate windshield de-icing equipment was installed on the airplane

Eight pilots felt that it was necessary to have a window that could be opened in the event of icing to allow sufficient vision for landing the airplane

Inadequate seat adjustment was mentioned by 20 pilots Some of these pilots stated that their present seat adjustment would not allow pilots of different size to locate themselves so that they would have the proper vision angles and still be comfortable

Improvement in windshield wipers was suggested by 40 pilots In general, they desired better clearing in heavy rains, bug removal with water or alcohol, and more positive positioning of blade when not in use

Improvement in cockpit lighting was suggested by ten pilots Several suggested simpler flight forms that would require minimum use of dome light

Improvement of External Lighting

Improvement of airport lighting was considered desirable by four pilots Several stated that the green runway threshold lights cause an objectionable glare in the cockpit

Improvement of navigation or identification lights on aircraft was suggested by ten pilots Flashing lights and more powerful lights on all aircraft flying at night were generally desired It was stated that present navigation lights are not adequate during the taxiing maneuver

General Discussion

Three of the questions relate wholly or partially to forward and downward vision Question 3 concerns forward and downward vision during landing and taxiing, Question 6 concerns forward and downward vision during the most critical maneuvers, which appear to be taxiing and straight climb, and Question 7 concerns forward and downward vision during all common maneuvers

The mean value of estimation of adequacy of forward and downward vision for taxiing, as given in Question 7 for each airplane, is shown in Table VII, together with the corresponding minimum distance in front of each airplane which actually is visible during taxiing These values are plotted in Fig 8 The resultant curve, which is reasonably consistent, is seen to reach the value of 2 00 on the vertical scale at a distance of about 130 feet It might be concluded that a minimum distance of vision of about 130 feet during taxiing is the maximum distance which is considered adequate by the pilots

The value of 130 feet determined in this manner is not in agreement with the results of Question 3(b), wherein the mean value for this distance when estimated directly is 32 feet

No means can be seen for reconciling the results of these two questions if the answers to Question 3(b) are considered to represent minimum necessary vision conditions For example, the Constellation pilots separately estimated in Question 3(b) as shown in Fig 3, that forward and downward vision during taxiing should extend to within a ground distance of about 29 feet This same group of pilots gave a mean rating of 2 00 (or barely satisfactory) in Question 7 for forward and downward vision during taxiing for the Constellation airplane in which the minimum ground distance visible is about 123 feet This apparent inconsistency is present also with the other airplane pilot groups in different degree

This discrepancy may be explained if it is assumed that the answers to Question 3(b) represent, not minimum suitable vision conditions, but an amount of vision which would be classified as being excellent The mean value of 32 feet obtained from all pilots in Question 3(b) shows that the pilots demanded more vision than the actual vision in the Convair 240 and Martin 202 airplanes, both of which received relatively high rating in this portion of Question 7

In Question 6, it was found that the pilots as a group estimated that the lower edge of the Douglas DC-3 windshield should be lowered 1 22 inches This linear value corresponds to a 3° total angular increase In this question, an estimate of minimum adequate vision was requested for any maneuver which might be considered critical, which in the DC-3 airplane appears to be the taxi condition for vision in this direction

If this angular value is taken in addition to the normal lower-edge cut-off angle, and fuselage nose interference is neglected, then the minimum ground distance visible in front of the airplane decreases from 128 to 50 feet The 50-foot ground distance determined in this manner from Question 6 is in disagreement with the 130-foot distance determined in Question 7 for the minimum vision condition However, it is in good agreement with the 32-foot distance determined in Question 3 It is indicated that in a question of the type of Questions 3 and 6, wherein the pilot is asked what he desires, there is a tendency to ask for an amount of vision which would be rated as excellent, even though the question may specifically ask for evaluation upon a basis of minimum adequate vision In a question of the type of Question 7, wherein the pilot evaluates existing vision which he now uses, there is an apparent tendency to give a more conservative evaluation, probably more truly representing minimum adequate vision conditions

It may be concluded from these considerations, with respect to ground vision in front of the airplane during taxiing, that if the pilot can see a point about 130 feet ahead, he will consider the vision to be adequate but minimum, and if he can see a point about 40 to 50 feet ahead, he will consider the vision desirable and excellent

Questions 3 and 7 both relate partially to the landing condition It was shown in discussion of Question 7 that the average pilot desires to see within a forward distance of about 130 feet during landing if he is to classify the forward and downward vision as being barely adequate In Question 3, it was shown that the mean value directly evaluated for this distance is 75 feet No ready explanation for this discrepancy can be seen, if the difference is to be considered a discrepancy and not simply within the limits of accuracy of distance judgment

In previous discussion, it was shown that the comparable distance estimated in Question 3 for taxiing probably represents an amount of vision which the pilots consider excellent The same is true in the case of the landing condition where the distance estimated in Question 3 is less than that found in Question 7 as being barely adequate

It may be concluded that forward and downward vision to within a ground distance of 130 feet is considered barely adequate, and to within 32 feet is considered excellent for both the landing and taxi attitudes

In summary of the problem of vision in a forward and downward direction, it is apparent that the position of the lower edge of the windshield and the attitude of the airplane during taxiing, landing, and climbing are the controlling factors In aircraft with relatively high rate of climb, and with tricycle landing gear which permits relatively level landing and taxiing attitudes, the climbing maneuver becomes critical for forward and downward vision In climbing attitude, it is desired by the pilot to see a minimum of about 8° below the horizon, or 15° to 20° below the horizon for excellent vision

The relative importance and necessity for vision at different azimuth angles is a direct or indirect factor in several of the questions Consideration of these questions together is necessary in order to secure a complete answer

It was indicated from the results of Question 9 that the windshield area which is utilized for making critical judgments during landing, which probably is the maneuver requiring the most accurate judgments, extends over an angular range approximately 12° on each side of the forward direction In Question 8, it was indicated that in the windshield area within approximately 60° on each side of the forward direction the vision is critical when all maneuvers are considered The results of the question show that vision in the first 30° from the forward direction is particularly critical, and that vision in the 30° to 60° azimuth range is of less but still great importance

With regard to the limit of rearward vision, it is shown in Question 6 that it is desirable to extend the rear edge of the side window of the Douglas DC-3 airplane backward about two inches to provide minimum suitable vision If this were done, a rearward cut-off angle of about 135° would be obtained, as measured from the forward direction

This rearward limit of about 135° as defined for the Douglas DC-3 airplane may not apply exactly to other aircraft An additional factor which should be considered is the distance of the seat from the side window and the resulting ability of the pilot to look rearward by moving his head closer to the window In an aircraft with a greater distance between the seat and the side window, the rearward cut-off angle of 135° would have to be increased to provide the same effective rearward vision

In a cockpit of normal design, with the pilot and copilot sitting side by side, it is obviously impossible to secure symmetrical vision from one seat If only a forward area and one side of the cockpit are considered for each pilot, then the following general vision zones might be defined

Zone 1 - A 60° forward azimuth section directly in front of the pilot on both sides of the forward direction is of first importance, and should have high-quality vision and no obstructions

Zone 2 - A 30° segment extending from 30° to 60° from the forward line on one side is of second importance, but still, in pilot opinion, should have high-quality vision and no obstructions It might be assumed that some compromise would be acceptable in this zone

Zone 3 - A 50° segment extending from 60° to 110° from the forward line on one side is of third importance In this segment, slight distortion and thin obstructions are permissible

Zone 4 - A 25° segment extending from 100° to 135° from the forward line on one side is of fourth importance In this segment, slight distortion and thick obstructions are permissible

The definitions for such zones are intended to relate only to general importance of vision, in so far as it can be limited to azimuth angle alone and disregard vertical extension of vision It is apparent that vertical extension of vision also is important, but this has been considered separately

The practical problem of providing good vision to the right-hand side for a pilot sitting in the left-hand seat is a difficult one It might be assumed, if a pilot were provided with adequate vision in the four zones already defined, extending from 30° right to 135° left, that considerably more than 50 per cent of necessary vision has been provided and that the remaining segment to the right has less importance In partial corroboration of this assumption, it was shown by the results of Question 7 that, although vision to the right is considered inadequate in most of the present aircraft, in the case of the Convair 240 vision to the right from the left-hand seat is considered adequate for all maneuvers, even though the amount of right-hand vision is considerably less than the amount of left-hand vision This partially contradicts the results of Question 8, where it was shown that almost equal quality of vision and lack of obstruction is desired on both sides

This apparent contradiction might be explained by the presence of recognition and acceptance of practical limitations in answers to Question 7, and by the more abstract nature of Question 8

It may be concluded generally, with regard to vision to the right from the left-hand seat, that such vision is considered basically to be of almost equal importance to corresponding left-hand vision, but willingness exists to accept partial compromise

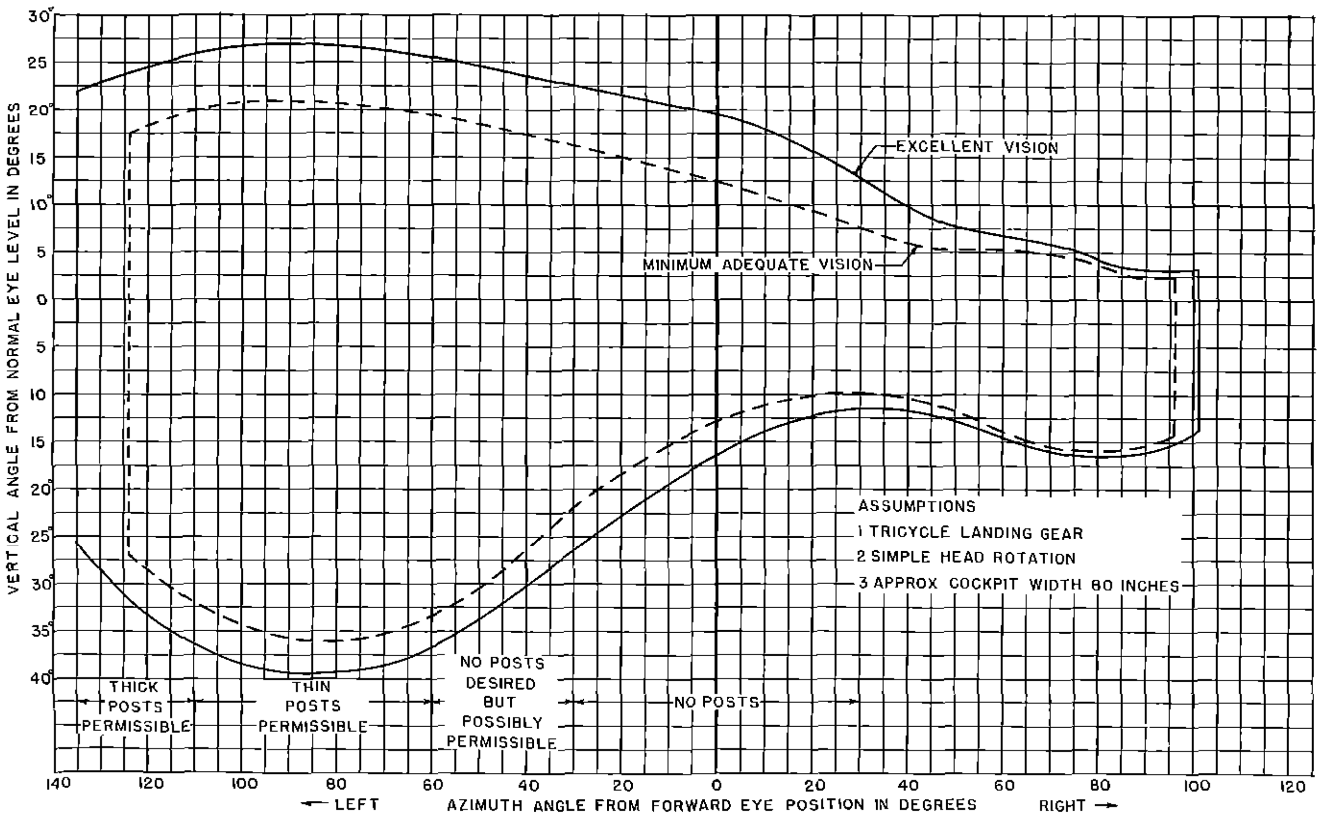


Fig 12 Example of Combined Visual Requirements Showing Vision Limits Corresponding to Pilot Ratings of Adequate and Excellent in Transport Aircraft

COMBINED VISION REQUIREMENTS

The estimates made by pilots in the different questions for vision in various directions of sight may be combined into one general and coordinated set of requirements An attempt has been made to do this in Fig 12 Disagreement exists between the results of various questions so that some degree of arbitrary judgment and compromise was necessary in determination of the various angles of limiting vision Also, assumptions were required regarding cockpit dimensions and airplane attitude in different maneuvers These factors introduce variables for which allowance must be made in application of the results to any specific aircraft arrangement

In the derivation of Fig 12 it was assumed that the principal cockpit dimensions and airplane attitudes are similar to those of the Convair 240 airplane The cruise and taxi attitudes, therefore, are closely identical The vision cut-off limits shown are based upon head rotation through the various azimuth angles with the eyes fixed relative to the head This system of measurement results in more apparent vision through the left-hand side window, and is used in place of angular measurement from one fixed point because it is believed to correspond more closely to true conditions and because some of the questionnaire results are interpreted in this manner

The cut-off angles shown in Fig 12 are determined principally from the results of Questions 6 and 7 However, the results of Questions 3 and 10 also were utilized

Two outlines are shown in Fig 12, one of which corresponds to the approximate condition of minimum but adequate vision The other outline corresponds to the minimum amount of vision which would be classified by the pilots as being excellent It is recognized that these classifications are not precise, and that some degree of arbitrary judgment must enter in the interpretation and reconciliation of the results of the different questions, but it is believed that the outlines shown in Fig 12 fairly represent the opinions of the pilots as expressed in the questionnaire The Convair 240 cockpit window arrangement, when plotted in a similar manner for comparison, shows an outline which falls closely within the outlines for the excellent condition, in Fig 12, for all vision to the left side and in a forward and upward direction The outline for the Convair 240 falls slightly within the outline for minimum but adequate vision in the forward and downward direction and for vision through the right-hand side window The pilot rating for this airplane generally was very high, and was definitely higher than for any of the other aircraft considered, but was a minimum in the forward and downward direction and for vision to the right-hand side

If the outlines shown in Fig 12 are to be considered from a practical standpoint, the problem of vertical post location must be introduced There are shown, in conjunction with the two outlines, the ranges of azimuth angles of sight in which obstruction due to posts is permissible, as determined from Question 8

In practical design the elimination of posts in the azimuth angle sector from 0° to 30° left might be accomplished only by elimination of the usual clear-vision window, which has been done in some aircraft It would appear difficult to eliminate posts in the azimuth sector from 30° to 60° left in a conventional type of design As mentioned in previous discussion, although the results of Question 8 show that no posts are desired in this region, it was indicated further that this sector has less importance than the sector from 0° to 30° left At azimuth angles greater than 60° left, posts of different thickness are permissible and the post problem is simplified

The conclusions of Question 8 relating to quality of vision through the glass also should be considered in the present general application It was shown by the results of Question 8 that high-quality vision is desired between the forward direction and a side azimuth angle of 75° At azimuth angles greater than 75° minor distortion is permissible Accomplishment of this objective in practical design probably would involve the use of high-grade glass panes which are mounted in a position to avoid acute angle of sight through them in the azimuth sector from 0° to 75°

Some question might arise whether the vision characteristics shown in Fig 12 could be secured in practice, where consideration must be given to many other practical factors relating to cockpit arrangement Although in such circumstances compromise of all factors commonly is necessary, it is noted that in several modern aircraft designs, most of the important requirements shown in Fig 12 have been closely met, and that further improvement might have been obtained with minor change in the original design

The requirements illustrated in Fig 12, and covered in the previous discussion, are not considered in any sense a final answer to the cockpit visibility problem The questionnaire method of investigation has basic weaknesses which lead to lack of precision and need for arbitrary interpretation This method also cannot reveal basic principles which are necessary for complete understanding of the vision problem, as, for example, the actual visual cues unconsciously used by the pilot in performance of various maneuvers However, it is believed that the results of the questionnaire have strong provisional validity, and, in particular, that an aircraft cockpit window arrangement, in agreement with the outline for the condition of excellence shown in Fig 12, would be classified as providing completely satisfactory and excellent vision by the average airline pilot

CONCLUSIONS

1 The data secured from the 1,342 completed questionnaires obtained from airline pilots are reasonably consistent, and definite conclusions can be derived Small disagreement exists between pilots with different amounts of experience More disagreement on general problems is found between pilots flying different aircraft models, and such difference of opinion probably is associated with vision characteristics of the airplane model to which the pilot is accustomed

2 The importance of vision from the quality standpoint decreases with increase of azimuth angle measured from the forward direction The azimuth angle sector from 0° to 30° each side of the forward direction is considered most important by the pilots, and the sector from 30° to 60° is considered of second importance In both of these sectors high-quality vision, without post or other ob-

struction, is considered desirable

3 Vision in a forward and downward direction is rated of minimum but adequate amount if the pilot can see the ground to within 130 feet forward of the airplane during landing and taxiing, and if vision extends about 8° below the horizon during straight climb Corresponding values for an excellent rating are approximately 32 feet and 15° respectively

4 Vision in a forward and upward direction is critical during gliding-turn and landing-approach maneuvers The results obtained for this condition are indecisive, but it is indicated that the vision cut-off angle of the upper edge of the windshield should have a minimum value of about 13° to be considered adequate During landing approach it is desired by pilots to see at least up to the horizon, from the standpoints of visual judgments and seeing ground obstructions

5 Vision in a left-hand upward direction is most important during gliding turns The vision cut-off angle in this direction should have a minimum value of about 21°, with the head rotated to the left, to receive a pilot rating of minimum but adequate The effect of distance between the seat and side window, and the effect of additional head and body movement, appear to be particularly important for vision to the left side

6 Adequacy of vision to the right side from the left-hand seat apparently is related to the total solid angle of vision available in that direction A minimum value of about 0 14 steradians appears to be required for a rating of adequate, and a value of about 0 20 steradians is required for a rating of excellent

7 Vision in a left-hand rearward direction should extend to an azimuth angle of about 135° from the forward direction to be considered excellent This amount of vision should be obtained with head rotation but without extensive body movement

8 A majority of pilots desire to see the wing tips, propellers, and engine nacelles with only moderate head and body movement, and to see the main landing gear with maximum limiting movement of the head and body

9 The final approach, gliding turn, and taxi maneuvers are considered most critical from the standpoint of vision requirements by the largest number of pilots

10 The results obtained from the questionnaire are not considered a complete solution to the problem of vision requirements However, application of these results should permit reasonable prediction of pilot evaluation of cockpit vision characteristics, and such evaluation probably is closely related to true adequacy of vision from the safety standpoint

ACKNOWLEDGMENT

Acknowledgment is made to the Air Line Pilots Association for extensive assistance in the distribution of the questionnaire, to the Air Transport Association for similar assistance, and to the Aero Medical Laboratory of the Department of the Air Force and the Special Devices Center of the Department of the Navy for aid in preparation of the questionnaire

APPENDIX I

Budget Bureau #41-4890
Approval Expires 9-1-1949

DEPARTMENT OF COMMERCE
CIVIL AERONAUTICS ADMINISTRATION
Technical Development
Experimental Station
P.O. Box 5767
Indianapolis 21, Indiana

January 1949

PILOT QUESTIONNAIRE ON COCKPIT VISIBILITY IN TRANSPORT AIRCRAFT

The Office of Technical Development of CAA is conducting a project for the improvement of cockpit visibility in transport aircraft. The ultimate objective of the project is to establish standards of cockpit visibility which will be consistent with adequate operating safety.

The principal factor influencing cockpit visibility is considered to be the directions of the angles of sight or field of vision through windshield panels and cockpit windows from the normal pilot eye position, with consideration of the airplane in different maneuvers. Another important factor is the obstructions and distortion allowable at different angles of sight.

One of the most important aspects of the program consists of evaluating the ideas of the operating pilots concerning these visibility problems. Since it is obvious that the best judges of the quality of visibility in cockpits are the pilots themselves, we are calling upon you to supply us with the necessary basic information on which an analysis can be made. Such an analysis will permit a quantitative evaluation of the present designs and the possible establishment of quantitative standards for future designs.

The success of this cockpit visibility study is dependent upon your returning this questionnaire as soon as possible with all the questions completed.

The Air Line Pilots Association and the airline companies have given their approval to this project and urge that you fill in the questionnaire. They, as well as the CAA, are interested in improving the safety standards of commercial flying.

Your response will be strictly confidential, and will be used only for analytical purposes by the CAA. No one else is authorized to see your answers or to use the information for any other purposes. Your signature is not necessary.

NOTE: IT IS RECOMMENDED THAT YOU READ THE QUESTIONNAIRE OVER THOROUGHLY, FLY A "TRIP" WITH THE QUESTIONNAIRE IN MIND, AND THEN FILL IN THE ANSWERS.

1. (a) How many years have you been flying in civil transport aircraft of the type not older than the Douglas DC-3? (Do not include military experience.)

Number of years (civil) ☐

(b) How many hours (civil) have you flown aircraft of such type?

Number of hours ☐

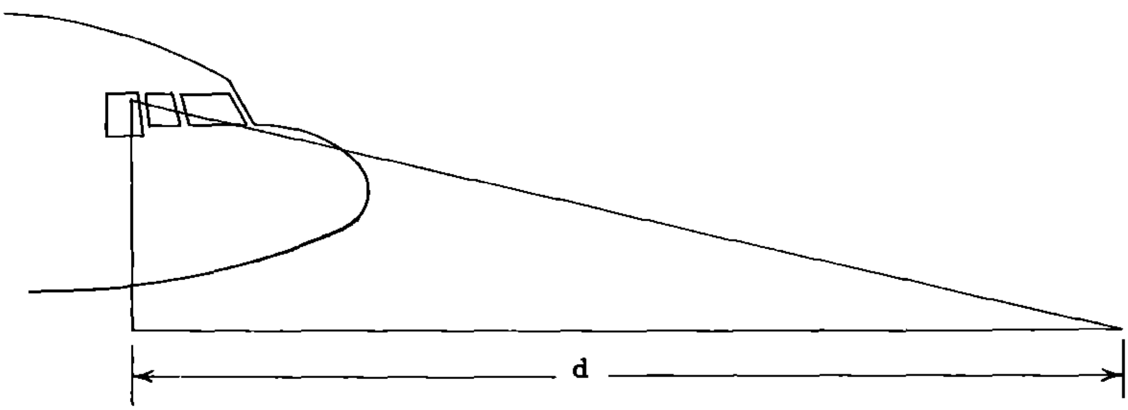
2. What is your present classification?

1	☐	Captain	1	☐	Instructor Pilot
2	☐	Reserve Captain	2	☐	Check Pilot
3	☐	First Officer	3	☐	Supervisor of Flight Personnel (Including Chief Pilots & Ass'ts.)
			4	☐	Engineering Pilots & Test Pilots

3. How close a distance in front of the airplane (distance "d" in diagram) should a pilot be able to see the ground under the following conditions?

(a) During landing at instant of touchdown, ______________ feet.

(b) During taxiing, ____________ feet.



DISTANCE TO BE JUDGED

4. (a) Do you consider it necessary from an overall safety standpoint to be able to see any external portion of the aircraft from the cockpit?

1 [ ] Yes

2 [ ] No

(b) If your answer was "yes" to part (a), check the boxes below, indicating the portions of the airplane which you feel must be seen and the amount of head and body movement which is permissible in each case.

		Moderate Movement of Head and Body			Maximum Possible Movement with Seat Belt Fastened
Wing Tips	1	[ ]	or	2	[ ]
Engine Nacelle & Propeller	1	[ ]	or	2	[ ]
Main Landing Gear	1	[ ]	or	2	[ ]
Other (Specify)__________	1	[ ]	or	2	[ ]

5. Place a check mark in <u>one</u> of the boxes below indicating the particular maneuver for which you feel maximum visibility from the cockpit is most urgently required. Do <u>not</u> consider limited visibility due to atmospheric conditions.

[ ] 1 Taxiing

[ ] 2 Take-Off Run

[ ] 3 Straight Climb

[ ] 4 Cruising

[ ] 5 Level Turns

[ ] 6 Straight Glide

[ ] 7 Gliding Turns

[ ] 8 Final Approach

[ ] 9 Landing

6. **In order to evaluate the adequacy of visibility of a Douglas DC-3 airplane with regard to the minimum visibility that is required for safe operation of the aircraft, a sketch of a Douglas DC-3 cockpit is shown below. Five edges of the window and windshield that restrict vision on one side of the cockpit are labeled for identification purposes.**

   First, evaluate edge A, considering only the particular maneuver during which visibility limited by this edge is most critical. Place a figure in the box near side A to indicate the movement, in inches, of this edge which you consider will permit adequate, but minimum, visibility in this direction for the critical maneuver considered.

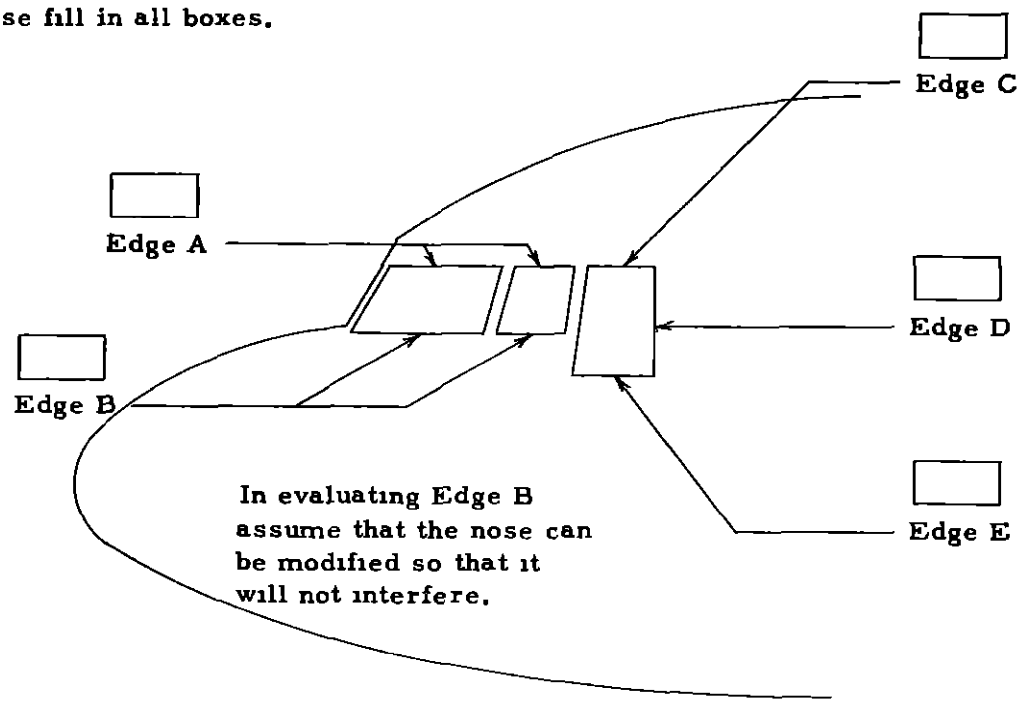
   If you believe the window opening at edge A should be increased to provide adequate, but minimum, visibility, write the number of inches in the box preceded by a plus (+) sign.

   If you believe the window opening at edge A does, at present, provide adequate, but minimum, visibility, write zero (0) in the box.

   If you believe the window opening at edge A could be decreased and still provide adequate, but minimum, visibility, write the number of inches in the box preceded by a minus (-) sign.

   Then, evaluate edges B, C, D, and E in the same manner as you did edge A.

   Please fill in all boxes.



SIDE VIEW OF DC-3 COCKPIT

7. (a) In what model aircraft are you now doing most, or all, of your flying?

1	☐	DC-3	5	☐	Convair 240
2	☐	DC-4	6	☐	Martin 202
3	☐	DC-6	7	☐	Boeing 307
4	☐	Constellation	8	☐	Other (Specify) ____________

(b) How many hours have you flown in this aircraft? ☐ hours

(c) For the model you have indicated above, please classify the visibility for the maneuvers and directions shown in the following table. This classification should be made on the basis of adequacy of windshield area and angles of sight from the left-hand seat in the cockpit

The numbers of classification to be used are

1 - Visibility excellent, no improvement desired.
2 - Visibility adequate, some improvement desirable, but not mandatory.
3 - Visibility not adequate, improvement strongly desired.

Fill in every space in the table below with the number you think classifies the visibility of this aircraft for each maneuver and direction indicated.

MANEUVER	VISIBILITY UPWARD TO FRONT	VISIBILITY DOWNWARD TO FRONT	VISIBILITY SIDEWARD (From left seat)	
			To Left	To Right
Taxiing				
Take-Off Run				
Straight Climb				
Cruising				
Level Turns				
Straight Glide				
Gliding Turns				
Final Approach				
Landing				

7. (d) If you indicated in 7 (a) that you now do most of your flying in a Douglas DC-3, omit the rest of question 7 and go on to question 8.

If you now primarily fly a model other than a DC-3, please answer the remaining parts of this question

(e) How many hours have you flown in a DC-3?

Number of hours [ ]

(f) The table below is similar to that shown in (c), but pertains to the DC-3 only. Fill in every space with the above numbers classifying the visibility for the DC-3.

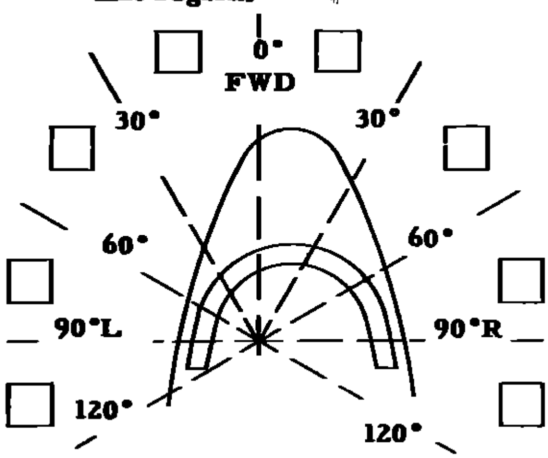
MANEUVER	VISIBILITY UPWARD TO FRONT	VISIBILITY DOWNWARD TO FRONT	VISIBILITY SIDEWARD (From left seat)	
			To Left	To Right
Taxiing				
Take-Off Run				
Straight Climb				
Cruising				
Level Turns				
Straight Glide				
Gliding Turns				
Final Approach				
Landing				

8. There are given below two charts (A and B) to be used for estimating the quality of vision at different lateral directions of sight which you feel is necessary for safe operation of the aircraft during all maneuvers. Chart A is concerned with windshield and window distortion and Chart B is concerned with obstructions in the cockpit.

Two diagrams of cockpits are shown with radial lines emitting every 30° from the left-hand pilot's position. Between each radial line is a box in which your evaluation of that region should be entered. Rating scales to be used for your evaluations are shown for each chart.

(a) <u>Chart A -- Windshield and Window Distortion</u>

Enter in each box between the radial lines the number in the "Distortion Rating Scale" which describes best the quality of vision you consider necessary in that region.



<u>Distortion Rating Scale</u>

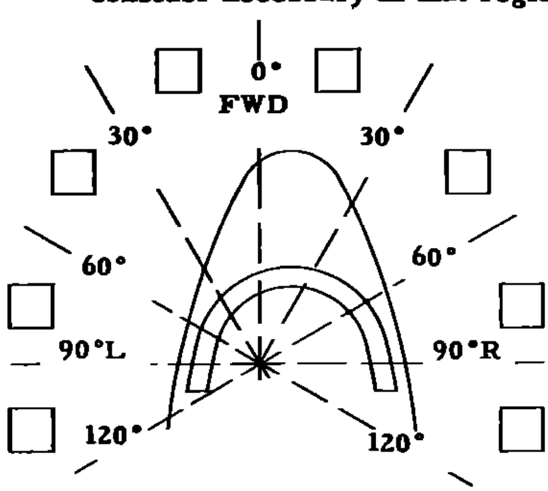
1 — Quality of vision required such as that provided by high-grade, polished plate glass.

2 — Quality of vision suitable such as that provided by polished plate glass but with minor defects or distortion.

3 — Quality of vision suitable such as that provided by plastic or curved panels.

(b) <u>Chart B -- Obstructions in the Cockpit</u>

Enter in each box between the radial lines the number in the "Obstruction Rating Scale" which best describes the vision you consider necessary in that region.



<u>Obstruction Rating Scale</u>

1 — No obstructions permissible.

2 — Minor obstructions permissible, such as thin posts, (1-1/2" wide or smaller) etc.

3 — More obstructions permissible, such as wide posts, (greater than 1-1/2") etc.

9. Imagine yourself in the cockpit of an airplane whose windshield is 12 inches from your eyes. The windshield and windows are entirely blacked out except for a vertical slot or cleared space on the windshield directly ahead of you. You are on final approach for landing. What minimum width do you believe that the slot or cleared space must be for you to see a sufficient amount of terrain to make the necessary accurate judgment needed for routine safe landings?

   Do not consider angles of vision required for searching the sky for other aircraft.

   Minimum width of slot [inches]

10. In order to evaluate the forward and upward angle of visibility needed to make accurate judgments and see obstructions during the final approach phase of a landing at approximately 400 feet altitude, four statements are made below. Enter a check mark in one box opposite the statement you feel most accurately states the minimum upward visibility requirements consistent with normal safe operation of the aircraft. Check only one.

    1 [ ] (a) It is necessary to see only approximately the first half of the runway, and not beyond the midpoint, during the final approach.

    2 [ ] (b) It is necessary to see only to the far end of runway during the final approach.

    3 [ ] (c) It is necessary to see all of the runway and up to the horizon of the earth (assuming terrain is level) during the final approach.

    4 [ ] (d) It is necessary to see above the horizon of the earth during the final approach.

    If you have checked (d), indicate in the following box the number of degrees visibility above the horizon that you feel is necessary.

    [degrees]

11. During your service as an airline pilot, has inadequate cockpit visibility ever, in your opinion, been the whole or partial cause of any accident, or near accident, that you have experienced? If so, please describe each experience briefly below. Use back of this page, if necessary.

If answer to question 11 is "no" please check here. ☐

12. Do you have any additional general comments, or other factors to suggest, which influence the problem of cockpit visibility?

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