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THE ANNOYANCE CAUSED BY NOISE AROUND AIRPORTS

FINAL REPORT

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16. Abstract
This is a comprehensive study of noise around selected airports in France.

By use of questionnaires, the degree of annoyance caused by aircraft noise is determined.

Twenty-four figures, two photographs, eleven Appendices are included in the 113 pages.

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NASA-HQ

THE ANNOYANCE CAUSED BY NOISE AROUND AIRPORTS*)

Final Report

PREAMBLE /1**

The research agreement No. 63 - FR - 138 completed by clauses A_1 and A_2 between the Delegation Generale a la Recherche Scientifique and Technique et le Centre Scientifique et Technique du Batiment, has the purpose of studying acoustical problems of living using three different approaches:

1. Analytical study on the influence of noise on sleep

Under the responsibility of Professor Metz, this study was carried out at the Centre d'Etudes Bioclimatiques de Strasbourg.

2. Sociological study on the satisfaction of occupants of buildings which conform to laws which are supposed to guarantee sufficient comfort.

Under the responsibility of Mr. Josse, Chief Engineer of the Acoustics Division of the C.S.T.B. This study was carried out by the Acoustics Division of C.S.T.B. (meteorological part) and by the Applied Anthropology Association (inquiry part).

3. Statistical study of correlations between external noises and psychological and pathological disturbances in residences.

This sociological study was also under the direction of

*March 1, 1968. Centre Scientifique et Technique du Batiment 4, Avenue du Recteur Poincare, Paris (16e). Study carried out within the research agreement D.G.R.S.T./C.S.T.B. No. 63, FR, 138 A_1 and A_2: Acoustic stresses in inhabited areas. This study was carried out in collaboration with l'Association d'Anthropologie Appliquee. D.S. No. 15, 2/19/68.

**Numbers in the margin indicate pagination in original foreign text.

Mr. Josse, who was assisted by the same personnel as mentioned in section 2 above. The study described in the present report is part of the general study. The persons who participated were the following:

C.S.T.B: Messrs. Gilbert and Drouin for acoustic measurements; /2

A.A.A. : Dr. Coblentz, Mr. Alexandre and Miss Xydias for the inquiry and the processing of results.

The details of this study can be found in:

- report by Mr. Gilbert concerning acoustic measurements around airports;
- enquiry on noise around airports by the Applied Anthropology Association, Vol. No. 5.

These two reports can be reviewed at the C.S.T.B. library.

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0. INTRODUCTION

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We are very much aware as to how important air transportation has become since the end of World War II.

The extravagant development of this means of transportation translates into extending existing airfields, the creation of new ones, putting into service a new breed of extremely powerful and noisy aircraft and a considerable growth in air traffic.

This explosive development has its drawbacks, however, for dwellers near airports, for which such a neighborhood becomes more and more unbearable. These inconveniences create individual and collective complaints which become more numerous with time.

Those individual and collective complaints are brought about by the psycho-physiological reaction to this noise.

The situation for those dwellers within close proximity of airports is getting worse. We are speaking here of a large population, since airports are often situated in densely populated areas. This problem is closely linked to the extension of air traffic and the use of more and more powerful aircraft. Modifications of dwellings for the improvement of soundproofing seem to be unthinkable, like the London experience.*)

So little can be done at this point for those airport dwellers /8 in the area that the Administration has decided to halt any new construction in such areas where aircraft noise could be a potential menace to the existing population. In order to come up with such decision, it is absolutely necessary for the Administration to have in its possession rules dealing with medical, psychological, sociological and economical guidelines.

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*) cf. Aircraft Noise, Report of an international conference on the reduction of noise and disturbance caused by civil aircraft. London, Her Majesty's stationery office, 1967.

The study described below is the result of cooperation between medical doctors, psychologists and engineers which would constitute a valuable source of information toward the establishment of such rules.

The object of this study was to:

- Estimate the effects of noise on the activities and the sleep of airport residents around airports;
- Determine the degree of noise tolerance of those residents;
- Determine the characteristics of aircraft noise considered disturbing;
- Define the interaction of disturbance with sound levels and their variations.

Two American and one British study were undertaken on the same topic:

- In 1952, by Mr. Paul Borsky of "National Opinion Research Center" at the University of Chicago.

- In 1955-57, by Mr. Paul Borsky for the United States Air Force.

- In 1961, by Mr. A. C. McKennell, on the investigation of the Wilson Committee on the Problem of Noise.

This research conducted around the London Airport, in a heavily /9 populated area, is similar to our situation. Under those conditions, it appears hopeful to conduct our investigation in such a way that the results can be compared to those of the British researchers.

1. CHOICE OF METHODOLOGY

The main purpose of this study being concerned with the correlation between the physical characteristics of aircraft noise (level, frequency, etc.) and the annoyance which affects the population, we had to find an appropriate location with a large enough population subjected to a variety of noises so that our investigation would be meaningful.

Referring to the results of the British study*) on the same topic, we have decided, first of all, to categorize aircraft noise at a given point by means of two parameters:

- The average number of aircraft N for which noise is perceived, per day, at the considered level (average reached during the year);

- The average peak level $\bar{L}$ is defined as the level of the quadratic average of maximum acoustic pressure produced by different aircraft appearing at the points under consideration.

$$\bar{L} = 10 \log_{10} \left[\frac{I}{N} \sum_{n=I}^{n=N} 10^{L_n/10} \right]$$

L_n is the level for maximum acoustic pressure produced at a /10
point beyond any obstacle by the time the n^{th} aircraft passes by. In order to take into account the psychophysiological reactions to different sounds according to the frequencies of those sounds, the noise levels are expressed in PNdB**) (abbreviation for perceived noise decibel), an accepted unit for aircraft noise.

To have the largest possible mix of noise conditions, the locations for the investigation would have to differ either by average peak level of noise or by number of daily flights. Therefore, it was decided to interview groups of residents subjected to aircraft

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*) Social Survey in the vicinity of London Airport - Noise final Report London - Her Majesty's Stationery Office - 1963.

**) For a definition of PNdB, consult the project of norm AFNOR P ± S 31 - 008.

noise whose characteristics correspond to each category in the following table:

Traffic (Number of daily flights)	Average peak level (PNdB)			
	93 to 97 82	98 to 102 87	103 to 107 92	108 to 112 97
Less than 15				
from 15 to 50				
More than 50				

Later, in the chapter entitled "Data," we shall see how we /11
partly succeeded in filling in the preceding table.

Once the investigation had been carried on, the disturbance caused by aircraft noise was evaluated, based on answers provided by about one hundred inhabitants of the area in question. The evaluation of this disturbance was determined by using a disturbance scale covering a whole network of points, comparable to those used in Great Britain during the study previously mentioned.

To establish the correlation between the characteristics of noise and disturbance, it was necessary to reduce that data to one factor in order to compare two factors: that of noise and that of disturbance.

The English study lead to the definition of factor NNI (noise number index):

$$NNI = \bar{L} + 15 \log_{10} N - 80$$

Nevertheless, this factor was not the only one in use, since prior to this investigation similar factors were in use in the United States and France, but in which 15 log N is replaced by 10 log N.

Thus, the factor used in France,*) known as R, is defined by

$$R = L + 10 \log N - 34$$

The reasons which lead to the British use of 15 log N rather than 10 log N was not very convincing to us. We decided to keep both factors until further study would determine which would be most preferable for our purpose.

2. DETERMINATION OF NOISE CHARACTERISTICS /12

2.1. The method

In order to find proper testing locations where the noise characteristics correspond to those used in the table above, two alternatives had to be considered:

- On a map of the airport and vicinity, draw theoretical contours of equal maximum noise level (isophones) for every kind of aircraft considered and for every trajectory used. At every point, determine the average peak amplitude. The noise data concerning the air traffic could be furnished by the airport authorities.

Such a procedure assumes that on the basis of noise data pertaining to every type of aircraft, we should be able to determine in an accurate fashion the noise level produced by those aircraft at any one point. This method also assumes that the trajectories

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*) According to recommendations offered by the Commission d'Etude du Bruit du Ministere des Affaires Sociales.

used would be perfectly defined.

However, neither the theoretical method of noise evaluation nor the knowledge of trajectories is accurate enough, and their accuracies are not known. For those reasons, we had to resort to the following method:

- At certain observation points of known location, record acoustic data in order to accurately determine noise level and frequency of passes.

This means that at a given point we determine the maximum /13 noise level for each plane pass and determine the number of planes observed.

The noise level is relatively easy to determine: a sound meter positioned at the proper location records the noise level in dB (A), the maximum noise level value for every plane pass. A correction factor based on spectral analysis of the point in question would allow the determination of corresponding values expressed in PNdB.

Theoretically, the determination of the average amplitude would require to record data at a given point throughout the year. However, since this is not technically possible, we are compelled to reduce the observation time using some hypotheses. This time period is retroactive to one, two or three weeks, depending on the situation. In order for such data to be reliable, it is necessary that during the noise measurement, the weather condition (especially wind) and the flying conditions correspond closely to the existing average during the year. This is only possible if:

A) we took care to investigate only airports with relatively regular traffic, excluding military airfields, since their schedule is very irregular, at least as seen by an outside observer;

B) the traffic distribution, by aircraft type, is more or less uniform during the study throughout the year. This is the case of civilian airports.

Under those considerations, we narrowed down our choice to the airports of Orly, Bourget, Lyon-Bron and Marseille-Marignane.

In order to reach our first goal, we have picked observation /14 points located below those trajectories mostly used during the greater part of the year during those flights. That is how we recorded our data under those principal trajectories of Orly and Bourget for the Paris area (for trajectories with a SW bearing) and for those of Marseille and Lyon-Bron for the provinces (trajectories bearing North).

2.2. Acoustic measurements

The data was collected by a team from the acoustic division of C.S.T.B. with their sophisticated equipment.

At every observation point most likely to be important, noise level measurements and the determination of the frequency of passes were made in a consistent fashion by means of a sonometer connected to a paper-tape recorder. The microphone to the sonometer was most often set at about five feet from the roof of a building, in full view of airplanes, while the equipment was kept safely indoors.

The paper recording made it possible for us to get a constant reading of the data which is then processed.

The use of several recording channels made it possible for us to determine the characteristics of sound at several points simultaneously, with only one technician on hand to monitor the system.

Every recording data channel (photographic) is made up of: /15

- an electrodynamic microphone, surrounded by a protective screen (against rain, wind, snow),

- a coaxial cable of variable length,
- a transformer with a ratio of 40 (voltage gain 32 dB),
- a General Radio type sonometer 1551 B used in a recording network (A),
- a recorder made by Bruel and Kjaer type 2305, used for quadratic detection, 50 dB potentiometer, recording pen speed 64 mm/sec or 64 dB/sec. / /

The recording chart speeds are 0.03 mm/sec (for recording station subjected to frequent noises) and 0.01 mmsec (for less frequent noise).

The different recording channels were standardized before the recording stations were set up.

During each visit of the measuring location we performed electrical calibration using the internal source of the General Radio sonometer.

We proceeded, as often as possible, especially at the beginning and end of a recording series at a given point, at an acoustic calibration.

Despite the initial theoretical approach, the determination of the location of observation points for the study was made by trial and error. We ended up making observations at more points than was necessary for the study. Some points were used twice. /16

The acoustic measurements were recorded between May 20, 1965, to April 6, 1966.

In order to obtain an average value for the amplitude as reliable as possible, the measurements were extended over a period of several days, or even several weeks.

Appendix 1 gives details on the chronology of the data as well as the exact location of the various observation points.

2.3. Results from the measurements

2.31 - Daily results

The results recorded on paper tape from recorders set up at various monitoring points were digitized for convenience.

Every day, a table was compiled giving the number of aircraft noises within the following limits, on an hourly basis, for a given point:

80 to 84 dB (A), 85 to 89 dB (A), ... 115 to 119 dB (A).

During the process, we found that two noise points L_1 dB (A) and L_2 dB (A) only amounted to a single point L_1 dB (A) if the two points were produced at times t_1 and t_2 such that $(t_1 - t_2) \leq 45$ seconds, assuming that $L_2 \leq L_1$. Frequently, it happens that the noise of an aircraft is very variable, and that it lasts between 30 and 40 seconds with an intensity at least equal to $L_1 - 30$ dB. /17

In addition, the tables also give the following:

- meteorological data,
- data about the hourly air traffic according to information provided by the airport.

Appendix 2 gives an example of such a table.

2.32 - Raw global results

From the daily results for a measurement point, we established a summary table for this point which gives the average number of aircraft detected every day by hour and by noise level interval.

For example, if the measurements took place on five consecutive days and if the number of points found for the 8 to 9 hour time interval and the 80-84 dB (A) noise level interval was in succession: 10, 12, 5, 16, 13, we plotted the following number in the summary table, the number 56/5 = 11.2.

This measurement summary was always made after eliminating measurement results which corresponded to nonrepresentative flight conditions compared with yearly averages.

Thus, at Bourget, on at least 150 days, the flight traffic takes place for the most part along a preferential axis P, which is runway 25 at Bourget. This happens on 300 days at Orly and corresponds to runway 26 at Orly (year 1965), for the residents along these axes, flights along other axes do not count much. /18

Appendix 3 gives the procedure for eliminating certain flights.

2.33. Corrected global results

Without corrections, the preceding results would only be representative for the measurement period, i.e., over a few days or over two to three weeks at the most. Therefore, it was important to correct them so that they would be representative for the entire year.

We made two hypotheses in order to transfer from our measurement results to the average annual results:

A) The peak average level established from measurements which last for one year is the same as the one established from our measurements, with a shorter duration.

This hypothesis is valid more, the less the distribution of traffic varies among various type of aircraft over a year, and the more uniform the meteorological and flight conditions over the measurement period.

B) The number N of aircraft perceived every day at the given point on average over the year (total number of aircraft perceived over the year divided by 365) is equal to the number N' of aircraft perceived daily, on the average for the measuring period, multiplied by a correction factor equal to the ratio of the number of aircraft which take off daily averaged over the year from the runway under consideration and the number qm of aircraft which have taken off under the same conditions on a daily average, averaged over the measurement duration. This amounts to using the following equation: /19

$$N = N' \times \frac{qa}{qm}$$

The quantities qa and qm are data supplied by airports.

This hypothesis implies that it is primarily the aircraft which take off from the runway under consideration which are perceived at the point under consideration, and that the runway is utilized in the same way for the most part of the year. This hypothesis is very valid when the measurements are made for main takeoff trajectories, as was done in our case.

In the preceding discussion, by "perceived aircraft" we mean aircraft whose maximum measured level is equal to or greater than 80 dB (A). Below this value it is often difficult to differentiate between noise from aircraft and noise from other sources.

It was therefore possible to obtain the two parameters which essentially characterize the aviation traffic noise at each point, which was our goal:

-- the number of acoustic level points caused by aviation traffic,
-- the average peak noise level corresponding to the above.

By knowing these two fundamental parameters, we were able to easily calculate the following: /20

- the isopsophic index R defined by the Noise Commission of the Social Affairs Ministry,
- the noise index and the noise repetition index NNI (Noise Number Index) used in Great Britain.

These indices were calculated by either considering the entire collection of noise points (24 hours) or only the noise points which were produced at night (21 hrs. - 7 hrs.). The corresponding indices are called "day" and "night."

The following tables give raw global results and corrected global results for 41 measurement points.

In the preceding tables for "day" results we have also added the following: /25

- the number of noise points recorded, exceeding 80 dB (A) and which allowed the determination of the noise characteristics;
- the average quadratic deviation in decibels between the various acoustic levels perceived at the same point.

In many cases we found that the distribution of the noise levels is close to a Gaussian distribution. However, this is not always the case. In particular, at points very close to the airports, the noises produced during taxiing and the noise from fixed points are added to the takeoff noise and then this modifies the noise level distribution.

The measurement results are only valid for the point where the measurement took place. Around each point there is a zone for which the noise characteristics (intensity and distribution) are essentially the same:
- same number of perceived aircraft,
- average peak level is the same two within about 2 decibels.

Average peak level dB(A)	Average quadratic deviation	Number of daily noise points (not corrected)	Location	Average peak level (PNdB)	Daily number of noise points (yearly average)	Noise index and repetition index NNI during the day	Isopsophic index R during the day	Total number of recorded noise points
84	4	2,3	ST-REMY (Domaine de St-Paul)	93	2,3	19	62,5	23
87	5	16	GIF S/YVETTE (C.N.R.S.)	97	15	34	74,5	127
88	4	13	ST-MICHEL SUR ORGE (Gare)	97,5	13	34	74,5	93
88,5	5	19	VILLIERS SUR ORGE	98	1[illegible]	37	76,5	123
92	6	14	RUNGIS (Parc)	101	13	38	78	137
86	6	36	MASSY (Rue Gabriel Péri)	96	33	39	77	290
90	5	28	ORSAY (Faculté)	100	25	41	80	133
93	4	36	ORSAY (Avenue St-Laurent)	103	33	45,5	84	193
90	8	43	WISSOUS (Val la Croix)	100	35	43,5	81,5	118
92	5	40	PALAISEAU (Rue Blaise Pascal)	103	36	47	85	90
95	6	40	VILLEBON (limite d'Orsay)	105	36	49	87	122
91	7	60	LONGJUMEAU (Quartier Croix Breton	102	55	48	85,5	534
91	5	90	LONGJUMEAU (Quartier St-Eloy)	102	85	51	87	815
91	4	130	ORLY (Gare SNCF)	102	120	54	89	450
93	6	140	MORANGIS (Collège)	105	115	56	91	1336
95,5	7	155	CHILLY-MAZARIN (Limite de Wissous)	107	130	59	94	2170
99	7,5	225	PARAY VIEILLE POSTE (Le Contin) Avenue Guyemer	111	200	66	100	1627

Average peak level dB(A)	Average quadratic deviation	Number of daily noise points (not corrected)	Location	Average peak level (PNdB)	Daily number of noise points (yearly average)	Noise index and repetition index NNI during the day	Isopsophic index R during the day	Total number of recorded noise points
86,5	5	3,5	ASNIERES (Rue des Champs)	96	4	25	68	18
89	6	8	EPINAY (Cité Montgerbaud)	98,5	10	33,5	74,5	32
91	6	5	ASNIERES (Courtilles)	100	8	34	75	42
89	5	11	ARGENTEUIL (Gare)	98	13	35	75,5	126
86,5	6	17	STAINS (Limite de Sarcelles)	97	17	36	75,5	186
88	4	21	GARGES (Dame Blanche)	98	18	37	76,5	35
89	6	25	SAINT DENIS (Rue Paul Eluard)	98	28	40	78,5	89
93	7	24	SAINT DENIS (Joncherolles)	104	28	45,5	84	182
93	5	32	STAINS (Rue Victor Renelle)	104	30	46	84,5	207
95	6	40	STAINS (Grignetières Hucailles)	105	30	47	85,5	200
97	10	56	STAINS (Moulin Neuf)	108	44	52,5	90,5	175
100	10	50	STAINS (Prêtresse)	111	40	55	93	335
88	7	10	VITROLLES LE ROUCAS	97	11	33	73,5	85
88	6	9	BERRE L'ETANG	98	9	33	74	135
90,5	5	33	MARIGNANE Ville (moyenne de 2 emplacements	101,5	33	44,5	83	1000
98	10	35	SAINT VICTORET (moyenne de 2 emplacements)	109	35	53	90,5	1200

Average peak level db(A)	Average quadratic deviation	Number of daily noise points (not corrected)	Location	Average peak level (PNdB)	Daily number of noise points (yearly average)	Noise index and repetition index NNI during the day	Isopsophic index R during the day	Total number of recorded noise points
84	very much	2	MEYZIEUX	93	3	20	63	15
89	5	3,3	RILLIEUX	99	5	29	72	45
89	5	12	VAULX EN VELIN (Rue André Chénier)	100	19	39,5	78,5	200
89	7	13	SAINT PRIEST (La Cordière)*	100	20	40	79	160
92	8	10	DECINNES (Stade)	102	16	40	60	80
91	6	11	VAULX EN VELIN (13, Av. G. Rougé)	102	18	41	81	150
103	not defined	14	VAULX EN VELIN (Rue Wilson** "Coupe Gorge")	115	22	56	95	200
95		17	BRON (Grange Perdue près usine CTA)	107	22	48	87	240

* Assuming that 70% of takeoffs are to the North, 30% of takeoffs are to the South.

** Numbers given as an indication, because the distribution of noise points and amplitude is very irregular.

Location	Quadratic average (night-time) PNdB	Daily number of noise points (night-time)	NNI night	R night (21 hr. 7 hr)
SAINT-REMY	- CANNOT BE DETERMINED			
MASSY	92	5	23	65
RUNGIS	100	1	20	66
ORSAY (Fac)	97	5	28	70
ORSAY (Av.St-Laurent)	99	7	32	73,5
VILLEBON	98	4	27	70
LONGJUMEAU (Croix Breton)	101	9	35,5	76
LONGJUMEAU (Est)	101	14	38	78,5
CHILLY MAZARIN	105	32	48	86
PARAY (Contin)	111	40	55	93
ASNIERES (Courtilles)	103	2	27	72
STAINS (Limite de Sarcelles)	97	3	24	67
STAINS (Grignetières)	104	11	40	80
STAINS (Rue Renelle)	106	3,5	34,5	77,5
SAINT DENIS (Joncherolles)	105	4,5	35	76
STAINS (Prêtresse)	114	11	50	90
VITROLLES LE ROUCAS	93	1	13	59
MARIGNANE (Ville)	100,5	5	31	73,5
SAINT VICTORET	101	4	30	73
MEYZIEU, RILLIEUX	- CANNOT BE DETERMINED			
VAULX EN VELIN (13, Av.G.Rouge)	98	3	25	69
BRON (Usine C.T.A.)	102,5	5	33	75

For each of the points retained for the survey, the size of the zone was determined from theoretical analyses while taking into account the experimental results. This zone has a size of only a few hundred meters for points located very close to the airports. However, it can be several kilometers in size for large distances from the airports.

3. EVALUATION OF THE ATTITUDE OF THE RESIDENTS /26

3.1. Organization of the survey

The survey as well as its analysis were carried out by the Applied Anthropology Association.

For each airport, Paris-Orly, Paris-Le Bourget, Lyon-Bron and Marseille-Marignane, the acoustic scientists carefully limited the study zones.

The survey was made using questionnaires and this was carried out within well-established perimeters, 100 in each zone.

A total of 2,000 surveys were made, distributed as follows:

- Orly	8 zones	800 surveys
- Le Bourget	5 zones	500 surveys
- Lyon	4 zones	400 surveys
- Marseille	3 zones	300 surveys
	20 zones	2,000 surveys

The unequal number of zones for the various airports can be justified that the traffic conditions are very different. This meant that it was not possible to find zones having the same acoustic characteristics as in the theoretical model for each case.

In the following table, we find the towns where surveys were carried out, classified as a function of the number of aircraft perceived and the corresponding acoustic level. The survey zones only cover a small part of the territory of each of these towns, for most towns.

3.2. The questionnaire and its use /28

The complete text of the questionnaire, shown in Appendix 4, includes 30 questions which resulted in 62 pieces of coded information.

After questions about the identification of the persons surveyed (age, sex, profession, etc.), there are a number of questions about the various characteristics of the neighborhood (question 7 to 15). Then there are more detailed questions about noise from aircraft.

We presented this study to the residents in the form of a sociological study about their neighborhood, so as not to polarize the answers about aircraft noise.

Since the sample was not predetermined,*) the surveyors were instructed to interrogate adults (more than 20 years old) living within the zones which had been established. The head of the survey requested that in each zone about 25% of the people would be living in villas (single-family residences) and 75% in apartment houses. In the apartment houses, half of the surveys were made in the lower stories and half were made in the upper stories. The questionnaires were filled out around the day the survey ended, and 100 questionnaires were correctly filled out within each zone.

The questionnaires were circulated between November and December of 1965 around the airports of Orly and Bourget. In February 1966, they were completed around Marseille, and in April 1966 around Lyon.

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*) The sampling description can be found in the report of the Applied Anthropological Association.

Number of noise points, daily (yearly average) \ Average peak level in PNdB	93 - 97	98 - 102	103 - 107	108 - 112
Less than 15	St-Rémy (Orly) Meyzieu (Lyon) Vitrolles (Marseille)	Rungis (Orly) Asnières (Bourget) Rillieux (Lyon)		
15 to 50	Massy (Orly) Stains-Sarcelles (Bourget)	Marignane (Marseille) Vaulx-en-Velin (Lyon)	Orsay (Orly) Villebon (Orly) Stains-Renelle (Bourget) Stains-Guignetière (Bourget) Bron (Lyon)	Stains Prêtresse (Bourget) St-Victoret (Marseille)
More than 50		Longjumeau (Orly)	Chilly-Mazarin (Orly)	Paray-Vieille-Poste (Orly)

.../...

Fifteen surveyors were required in Paris, six at Lyon, five at Marseille. They were recruited by the survey head, and he also distributed them among the various zones. Each zone was surveyed by at least four surveyors in order to eliminate the personal "surveyor" factor in the responses as much as possible. The survey chief received and verified the questionnaires. He personally did follow-up work on the work, if necessary. He made checks on the work of the surveyors, and in some instances made a second survey. /29

The refusal to respond was very rare, somewhat greater around Paris than in the provinces.

3.3. Data reduction

The documents were prepared as follows:

- analysis of the open questions in order to determine the classes of responses which could be coded;
- definitive coding of all the questions;
- establishment of two attitude scales:
  - annoyance scale caused by aircraft noise,
  - general satisfaction scale about the neighborhood.

Each subject was classified according to these two scales (1).

- After the coded responses were reported, annoyance and satisfaction indices, as well as corresponding acoustic indices within the survey zone, were established and written down on individual sheets. /30

The calculations were made using a mecanographic service. Three types of data reduction were planned:

- Responses to each of the questions expressed in percentages for each survey zone, airport, noise class for the overall group.

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(1) See paragraph 3.4 of this chapter.

- Calculation of the averages and the standard deviations of the annoyance indices and of the satisfaction indices for various subgroups.

- Calculation of the correlation indices between the annoyance indices and the acoustic level indices.

After these calculations had been done, an important problem had to be solved: Would this have to be done with respect to all of the parameters and indices, or was it sufficient to retain a single index, in the case where it was the best possible one?

For this purpose, we calculated the correlations between the individual annoyance average indices (average for each of the 20 survey zones) and the corresponding noise characteristics. We obtained the following results:

	24 hr	Night
- Number of points	+ .67	.76
- PNdB	+ .82	.76
- R	+ .93	.85
- NNI	+ .91	.85

These results led us to the decision to enlarge the number of points and the PNdB. /31

In addition, the indices calculated for nighttime alone did not seem to be of interest, because this had to do with general questions. They are only considered for the study of questions which specifically referred to nighttime.

It remained to decide whether one should adapt the index R or the index NNI.

The correlation coefficients were essentially the same for the two indices. By graphically plotting the variations of the annoyance index as a function of R or NNI, we attempted to find a difference so as to decide among one of the two indices. Apparently, there is nothing that favors either index. We decided to keep index R instead of NNI, only due to the reason that it is used in urban projects within France.

The survey zones were distributed as follows:

/32

R	Orly	Le Bourget	Lyon	Marseille
$\leq$ 71	St-Rémy		Meyzieu	
72 to 77	Massy	Asnières Stains (Sarcelles)	Rillieux	Vitrolles
78 to 83	Rungis		Vaulx-en-Velin	Marignane
84 to 89	Orsay Longjumeau Villebon	Stains (Renelle) Stains (Guignetière)	Bron	
90 to 95	Chilly-Mazarin	Stains (Prêtresse)		St-Victoret
$\geq$ 96	Paray			

We performed the analysis of information collected during the sociological survey as a function of these noise classes. /33

We were interested in comparing the results obtained for the different reasons; but in order to do this it was necessary to have population samples which are as comparable as possible as regards their noise exposure, for each of the four airports.

For this purpose, we selected several survey zones which satisfied this requirement:

R	Orly	Le Bourget	Lyon	Marseille
72 to 77	Massy (77)	Stains (Sarcelles) (75)	Rillieux (72)	Vitrolles (73)
78 to 84	Rungis (78)	Stains (Renelle) (84)	Vaulx-en-Velin (81)	Marignane (83)
86 to 90	Villebon (87)	Stains (Guignetière) (86)	Bron (87)	St-Victoret (90)

Everytime we compared airports, we compared results obtained for this sampling. /34

In the following chapters, we analyzed the data by studying the following in order:

- the general evaluation of the annoyance provoked by aircraft noise,

- the effects of aircraft noise on activities and sleep.

When we have comparable data, we are required to present results in a form similar to that adapted by the English scientists, so that this study can be compared with theirs. It seemed to us that by proceeding this way, this would lead to generalizations in every case where constants can be separated.

In order to correctly interpret the percentages mentioned above, it is important to recall their degree of confidence, which on the one hand depends on the factors and also on their actual value.

The table shown in Appendix 5 allows one to evaluate the limits within which the percentages are located with a probability of nine chances in 10 ($\pm$ 1.65 σ).

The difference between two percentages for nine chances within 10 becomes significant when there is no overlapping of the confidence intervals.

Nonsignificant differences in the adapted threshold will then indicate the "trends" which we often considered useful to indicate. /35

3.4. Attitude scales

The attitude scales were developed using the Guttman hierarchial analysis method.

Theoretically, the questions adapted are those which allow a classification such that any subject which responds positively to a given question will also have to have responded positively to every question preceding it, according to the following scheme:

Subjects	Questions				
	a	b	c	d	e
1	x	x	x	x	x
2	x		x	x	
3	x	x	x		
4	x	x			

In practice, we can never construct perfect scales. Certain subjects will commit "errors": for example, in the preceding diagram, subject No. 2 responded negatively to question b, but he should have responded positively. /36

The scale characteristics are characterized by indices, the most important of which is the read producibility coefficient:

$$CR = 1 - \frac{\text{Number of errors}}{\text{Number of questions x number of subjects.}}$$

In general, we assumed that the CR must be greater than .90 so that the scale be valid.

3.41 - Attitude scale with respect to aircraft noise or "annoyance scale"

Five questions can be adapted (1). We will give them in the hierarchial order. The first question is the one which most often resulted in a positive response: /37

Q.17 -	Does aircraft noise annoy you?	1 point, regardless whether the response is: a little, quite a lot or a lot
Q.18c-	Does it happen that aircraft noise disturbs you when you are listening to the radio or watching television?	1 point, regardless of whether the response is: sometimes or quite frequently.
Q.18f-	Annoyance during conversations?	(the same)
Q.18b-	Do you sleep?	(the same)
Q.18g-	Does it disturb you or annoy you at other times or in another way?	(the same)

For more security, the reproducibility coefficients were calculated separately for each airport, using subject samples taken at random (100 for Orly, 50 for each of the other three airports).

(1) In the English survey of 1961, an annoyance scale involving 6 questions was established. Our scale includes the same questions except for one, which had to be separated out because it was not adapted to the hierarchial classification "Did the aircraft noise make the house vibrate?" (Q. 18 d).

	CR
Orly	.94
Le Bourget	.94
Lyon	.93
Marseille	.96

We can see that there is a remarkable consistency. /38

For the overall group, we have CR = .94.

The response percentages which were positive for the five questions extend from 9% to 70% for the sample of 250 subjects mentioned above.

Each survey was classified according to this annoyance scale (0 to 5).

Averages of annoyance indices were calculated for various subgroups; they will be mentioned in the following chapters.

The standard deviations are always large. Personal factors play an important role in the individual responses (see Chapter IV). But the subgroups always include a large number of surveys. The personal factors are therefore "compensated for" and the main trends seem to indicate faithfully the characteristic traits of the subgroups, as we will see later on.

3.42. Attitude scale with respect to various living conditions of the neighborhood or "satisfaction scale"

Eight questions were adapted:

Q.7 - Do you like the neighborhood?	1 point for YES
Q.8 - Are there things you don't like or which are not proper here?	1 point for NO
Q.11 - Are you satisfied about the following: 1 - the merchants?	1 point for YES
2 - public transportation?	(the same)
3 - proximity to your workplace?	(the same)
4 - distractions? (entertainment)	(the same)
5 - noise?	(the same)
Q.13 - Do you like it here more or less than when you arrived here?	1 point for MORE

/39

We have here a "quasi-scale" because the reproducibility coefficient is only equal to .83.

Each survey was indexed from 0 to 8.

Just like for the annoyance indices, the average numbers were calculated; they will be mentioned during the analysis of the various questions.

4. ANNOYANCE CAUSED BY AIRCRAFT NOISE /40

4.1. Annoyance indices and general impressions

As explained above, we expressed the annoyance by an index between 0 and 5, associated with 5 questions.

For each of the acoustic classes adapted and for the collection at airports, we calculated the average of the annoyance index.

Using a figure (Fig. 2), we can then examine the variation of the annoyance index as a function of the noise index. We find a clear increase in the index with sonic level, with a slight inflection between the acoustic classes (78-83) and (84-89).

The correlation between the averages of the annoyance indices and the values R of the 20 locations is + 93 (1) (see Fig. 3).

The correlations (significant to 0.01) calculated from the individual indices of annoyance are:

	r (24 hrs.)
Total group (N = 2000).	+ .53
Orly (N = 800)	+ .57
Le Bourget (N = 500)	+ .41
Lyon (N = 400)	+ .54
Marseille (N = 300)	+ .39

The dispersion of the results is given in a figure in Appendix 6 (distribution of annoyance indices with respect to acoustic levels). /41

The results concerning the annoyance index should be compared with results to the general question 17, which is part of the annoyance scale:

(1) The correlation between the average annoyance indices and the NNI values of the 20 locations is + 91.

- Does aircraft noise bother you a lot - quite a lot - slightly - not at all?

When we calculate the average annoyance indices for the subgroups, we obtain:

	Annoyance index
- No annoyance at all	0.43
- Slight annoyance	2.26
- Substantial annoyance	3.12
- Very much annoyance	3.61

We find the following:

A) The responses to the question are closely related to the global annoyance index.

B) Among those which state they are not annoyed at all, some are annoyed in some activities, because the annoyance of the group is not equal to zero. Among those which state they are very much annoyed, all of them are not greatly annoyed in all activities, because the annoyance index is only 3.61 with a maximum of 5.

C) The deviations between the annoyance notes annoyance is reduced to between "no annoyance at all" to "very much."

D) The responses are closely related to the noise indices, as can be seen from Fig. 4. /42

If we observe the responses "a lot," we find a very substantial increase in the degree of annoyance after the acoustic class (84-89).

Figure 2 gives the variation of the annoyance index. For this acoustic class (84-89), we see an accentuation of the increase in the annoyance index.

Therefore, we can compare this with the results of answers to question 16:

- Which noise annoys you the most?
  - road traffic?
  - aircraft:
  - noises within the house?

This is the first question in which aircraft noise is mentioned. This serves as a transition between the first part of the questionnaire about general living conditions in the neighborhood, and the second part which is specifically tailored to aircraft noise. This uncovers the importance of aircraft noise with respect to other noise sources for residents.

<u>Overall group</u>:

Road traffic	13%
Aircraft	51%
House noises	17%
No responses (1)	19%

The differences between <u>airports</u> are <u>minimal</u>: /43

	% "aircraft"
Marseille	51 %
Le Bourget.	46 %
Orly)	44 %
Lyon)	

If we consider the acoustic levels, the response percentages about aircraft noise increase greatly with them (Fig. 5).

A more refined graphical presentation (Fig. 6), representing

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(1) No responses are given by those who are not annoyed by any noise and those who cannot distinguish among the three.

each locality, shows the degree of coherence of the responses.

If we relate the responses to this question and the average of the annoyance indices for each survey zone, we find a very large correlation: + .95

We asked ourselves whether it would not be useful to include this question in the annoyance scale. But a study made afterwards about sampling, which was used for the development of this scale, showed that the addition of question 16 does not improve the situation. In effect, the reproducibility coefficient goes from 94 to 92. Therefore, we have no regrets about this subject.

4.2. Factors on which annoyance depends

4.21. The noise characteristics

At the end of the study about the surroundings of Heathrow Airport, the English demonstrated that the noise felt by the residents /44 depends both on the average noise intensity to which they are subjected and the number of aircraft passes.

As we have seen, our study confirmed this result, because the correlation between noise indices (NNI or R) and the average of individual annoyance indices (average within the 20 survey zones) is very high (greater than 0.90).

On the other hand, we saw (paragraph 3) that the indices R and NNI, even though they take into account the number of aircraft passes differently (10 log N for R and 15 log N for NNI), are both valid because of the strong dispersion of individual reactions in the same noise zone.

We found that if the calculation of the indices R and NNI we express the noise level in dB (A) instead of PNdB, the correlation between the index and the annoyance index is just as high. This means that we can use the decibel A or the PNdB for evaluating the annoyance near airports without any difference.

4.22. Personal factors

Upon examining the results of the survey, we find that the annoyance attributed to aircraft only depends on noise characteristics to which the persons surveyed are subjected. We find that there are large reaction differences to the noise within each zone. Sometimes the noise is identical for all of them. We can even find large variations in the annoyance within the same building. Certain persons state they are very much annoyed and their neighbors next to them say they are not annoyed.

The dispersion of the annoyance indices is always very large, whether we are dealing with distributions by acoustic class or with distributions concerning a particular question (standard deviations on the order of 1.2). /45

Therefore, it appears that the noise index does not alone explain the annoyance level. Even though within a zone noise exposure of all of the apartments is not identical, beyond this it is necessary to find physical noise characteristics to explain the large dispersion of results. Certainly there are factors, which we will call "personal factors," which induce subjects to react more or less favorably to a situation which is objectively the same for the group. These factors can be physiological, psychological or sociological. They then disturb the direct connection between the intensity or frequency of aircraft noise and the annoyance which it produces. It would therefore be interesting to identify and find their influence on the formation of the annoyance sentiment.

a) Accustomization to aircraft noise

From question No. 19 (Does aircraft noise bother you more this year than last year?), we can see that among the persons most annoyed (annoyance index equal to 4 or 5), 40% estimate they are annoyed more this year than in the past. Among those annoyed less, less than 20% estimate that they are annoyed more than in the past (Fig. 7).

Therefore, we find a relationship between the annoyance and the accustomization to noise.

We can therefore say the following: /46

- those who do not get used to the noise have a tendency to be annoyed by it;
- that one accustoms less to the noise, the greater the aircraft noise intensity becomes. Except for individual differences, there is a remarkable relationship between the annoyance indices and the real acoustic levels.

Considering the increase in traffic over the last few years, and considering the progressive replacement of propeller aircraft with jet aircraft, we do not doubt that the noise itself increases from one year to another in both frequency and intensity. Therefore, it is difficult to determine how adaptation and objective observation influence the results and interfere or determine responses. We do believe, however, that hypotheses about the influence of a personal factor "accustomization to noise" must not be dropped.

b) <u>Susceptibility to noise in general</u>

Persons annoyed more than their neighbors by aircraft noise are also more annoyed by noise in general, no matter what its origin is.

We find a very clear connection between dissatisfaction caused by noise (in general) and the annoyance indices (aircraft noise) (Fig. 8). We can say, in general, that those who are more susceptible to noise in general seem to be also annoyed more by aircraft noise.

Therefore, we believe that there is a personal factor which has a certain influence on the intensity of the perceived annoyance. However, we must make one reservation: There is a good chance that the subjects themselves often integrated the aircraft noise in their responses to questions about noise in general. Therefore, we can conclude that this personal factor is not the only one involved in the results observed. /47

c) Number of "things" which displeased the subject in the neighborhood

We can find no relationship between these annoyance sources and the annoyance index (Fig. 9).

d) Moving date:

The elapsed time since the subjects moved in does not influence the annoyance index, in either direction.

e) Sex:

We did not find a significant difference between the average annoyance indices of men or women, no more than between the average satisfaction indices.

f) Age of subjects:

This factor neither influences the annoyance indices nor the satisfaction indices.

g) Number of children living in the building of the subject:

This factor also does not influence annoyance.

h) Profession: /48

The percentages for various professions remain constant for all annoyance levels (see Appendix 7) and the average annoyance indices practically do not vary from one profession to another.

4.23. Drawbacks of the neighborhood

No matter what neighborhood they live in, residents always have a reason for being dissatisfied. We can hardly imagine a neighborhood in which all living conditions are such that no part of the population would have any objections.

Therefore, any resident location has drawbacks which are sensed more or less by various residents. We were interested in establishing the position of aircraft noise among the drawbacks of the neighborhood, and their effect on the degree of dissatisfaction. This is why the sociological survey started with a number of questions about the various aspects of the environment. The subjects were asked whether they liked their neighborhood, whether there were things they did not like, and which were not proper, and they were asked to identify them. They were asked whether they were satisfied with the merchants, transportation, entertainment, noise, etc., and whether they had thought of moving (1).

The survey was made among residents in the form of a survey of living conditions in the neighborhood. The aircraft noise had not yet been mentioned at this step of the questionnaire.

The number of times where the subjects spontaneously mentioned aircraft noise among the other drawbacks, or as a major drawback, allows one to establish the degree of competence in that subject. /49

By studying the responses as a function of acoustic levels to which the subjects are exposed, we can relate the aircraft noise problem with respect to other problems. In this way we can progressively follow the annoyance caused by this noise source, for places with the least exposure, where the annoyance is a minimum, up to

(1) See Appendix 4 for the sociological questionnaire.

localities with the greatest exposure, where this annoyance predominates.

- Questions 7 - 8 and 9 -

- Do you like the neighborhood?

At the locality level, the YES responses varied between 51% and 81%, but there are no differences among airports. The results are remarkably constant:

Orly	67%
Le Bourget (	
Marseille)	66%
Lyon)	

There are also no differences between the percentages of YES responses for the various acoustic classes. We find that the intensity of aircraft noise does not influence the degree of attachment the residents have to their neighborhood.

- Are there things which you do not like or which are not proper here? What are they ?.

The percentages of YES answers (dissatisfied persons) vary according to locality in a more substantial way than for question 7:

33% at Stains-Guignetiere,
84% at Chilly-Mazarin.

The airports also show differences: /50

Orly	71% of dissatisfied persons
Lyon	57% " " "
Marseille	50% " " "
Le Bourget	46% " " "

Orly is quite different from the others.

The causes of dissatisfaction mentioned spontaneously are very different: They are divided into 12 response classes. Detailed information about this point is given in Appendix No. 8.

In order to analyze the percentages as a function of acoustic levels, we grouped the responses to "aircraft noise" and "unspecified noise," as well as with respect to all other types of dissatisfaction.

The "aircraft noise" and "noise" responses without specification cannot be separated. Later on we will see that the subjects very often meant "aircraft" when they responded with "the noise." Let us remember that the surveyor did not intervene and was only writing down the responses given spontaneously.

We can clearly see (Fig. 10):

- the causes of dissatisfaction other than the noise are not related to acoustic levels;
- the percentages of persons who complain about noise before other factors increase with acoustic level, but in a moderate way.

In addition, if we isolate the responses to "aircraft noise," we can see that it is not explicitly mentioned except after class R 84/89 (1%). Also, there is a clear discontinuity at class R 90/95, a level above which the percentages to responses "aircraft noise" increase very rapidly. /51

- Questions 10, 11 and 12

- Are you satisfied with living in this neighborhood?

Out of the entire sample, 84% of the subjects are satisfied with living in their neighborhood. There are no substantial differences between the results for each airport, for the survey location or by noise level.

The average of annoyance indices of the subjects who state they are dissatisfied is only slightly higher than the one for the satisfied residents (2.30 compared with 2.07). No conclusion can be drawn from this difference.

The average satisfaction indices are closely related to the responses to this question:

- Satisfied with living in this neighborhood : 4.7
- Not satisfied with living in this neighborhood : 2.6

This question is part of the satisfaction scale. It influences the average index (for a maximum of 1/8). We can see that this general question very nicely takes into account the satisfaction about the various elements within the neighborhood. The deviation between the two indices is equal to the maximum deviation observed among the survey zones.

- Are you satisfied concerning the following: the merchants, public transportation, proximity of your work-place, entertainment, neighbors, noise? /52

Important differences appear among the survey zones:

- There is a great amount of dissatisfaction about the merchants at Chilly-Mazarin and at Orsay;
- Public transportation is objectionable at Rungis and at Vaulx-en-Velin;
- Three-fourths of the subjects at Rungis are dissatisfied with entertainment available in the neighborhood;
- As far as noise is concerned, there are complaints especially at Paray, Orsay and Saint-Victoret, but less than 15% of subjects are complaining at Saint-Remy and Vitrolles.

If we compare responses obtained around the four airports, we find several differences; around Orly and Lyon, there is less satisfaction about merchants, public transportation and entertainment than around Bourget and Marseille.

On the other hand, there is more satisfaction about the proximity of the work-place around Marseille than around the three other airports.

As Fig. 11 shows, only the dissatisfaction about noise increases as a function of acoustic level: from 27% for $R \leq 71$ to 78% for $R \geq 96$. Even though we are dealing with noise of unknown origin, it appears clearly that the subjects integrate the aircraft noise and do not project their dissatisfaction about noise to other factors they disapprove of in their neighborhood. /53

- <u>If you could change one of the topics I have mentioned, which yould you change?</u>

The response percentages as a function of noise indices vary only slightly in a random manner, except for the response about noise, whose curve increases strongly (Fig. 12): up to R = 78/83, the complaints about noise hardly differ from complaints expressed for other inconveniences (about 20%). For R between 84 and 95, they are much more frequent (close to 40%). For $R \geq 96$, they exceed 70%. We can also show that at higher acoustic levels, only a few of the subjects wished to change anything in their neighborhood except the noise. In effect, all of the responses for the sonic levels were equal to 100%, if the noise is found to be the essential object of complaints. The other causes of dissatisfaction are reduced greatly.

- <u>Questions 13, 14 and 15</u>

- <u>Do you like it here as much as you did at the beginning?</u>

We did not encounter notable differences between the survey areas, the airports or the acoustic levels.

- Have you ever thought of moving? Why?

62% of subjects declared that they had never thought of moving; 3% thought of moving because of the noise; 35% for other reasons.

If we consider only those which thought of moving, we can see that the responses are distributed as follows (Fig. 13): /54

8% want to move because of the noise;

50% want to move in order to obtain a better apartment (34%) or a single house (16%);

The remaining 42% want to move for family reasons, because of isolation or because they want to move their residence from urban centers or because they do not like the neighborhood.

We can see that noise occupies a singular place among reasons mentioned. Also, noise is the first thing they wish to change. In fact, the desire for moving is primarily influenced by deficiencies in lodging (not enough space, decay, rent) or for personal reasons more than for the living conditions in the neighborhood (including noise).

The items of discontent because of lodging are one of the most important reasons, except for the noisiest zone. Among the external lodging factors, noise plays a modest role up to rather high acoustic levels, but beyond this it suddenly takes on the most important place above a certain threshold which seems to be located around R 96.

Satisfaction index

We have seen (Sec. 3.4) that from questions 7, 8, 11 and 13, we established a satisfaction scale which allows one to measure the global degree of satisfaction of the residents.

The average satisfaction index for the total group is 4.36 with a σ of 1.69.

The airports are classified in the following order:

	Satisfaction index	
	All zones	Reduced sample
Marseille	4.94	4.94
Le Bourget.	4.53	4.62
Lyon	4.40	4.29
Orly	4.02	3.95

If we compare the satisfaction indices to the annoyance indices, we find a certain relationship. We have to recall that one question (Q. 11f) is included in the satisfaction scale and that the subjects seem to have, for the most part, integrated the noise of aircraft in their responses to this question. If this is excluded from the scale, the relationship with the annoyance indices no longer appears at all.

We therefore see that the subjects do not at all project their annoyance about satisfaction with the neighborhood, nor vice versa. On the other hand, over the entire sample, the correlation between the satisfaction indices and the annoyance indices is -.24, i.e., it can be considered to be zero.

In addition, if we analyze the distributions of the satisfaction indices at each sonic level, one can see that they are almot "normal" (see Appendix No. 9). The mode is always located at index 4 or 5, and this mode is not shifted as a function of acoustic level. Finally, the average indices of satisfaction by acoustic level vary only slightly and are not related to them.

Therefore, we can conclude in this study about satisfaction regarding the living conditions in the neighborhood that in spite of several differences among airports, zones of survey, or subject categories (higher cadres), the persons interrogated discriminated /56 between aircraft noise and other sources of dissatisfaction in a good way.

4.24. The seasons

To questions 27 and 28:

- Do aircraft bother you more at any time of the year? If yes, when?

The reaction of the inhabitants was the following:

67% of the sample collection are disturbed equally or are not disturbed at all;

25% are more annoyed at a given time of the year;

6% had lived there an insufficient amount of time in order to answer this question; and

2% did not know the answer to give.

In certain locations, on the other hand, the percentage of persons annoyed at a given time of the year greatly exceeds the yearly average. This is always in very noisy zones (Paray, Chilly-Mazarin, Saint-Victoret).

As far as the four airports are concerned, Lyon differs slightly from the others. Very few subjects (13%) are annoyed more at any given time of the year. The traffic at Lyon undoubtedly increases less during vacation time than at Paris or Marseille. But if we /57 consider the acoustic levels, we find that the more the subjects live in a noisy neighborhood, the more sensitive they are to differences in traffic.

The period of the year considered the most annoying is summer. It is mentioned by 84% of the people who detect differences for various seasons. This is not surprising, because windows are open more often during this period and people are outside more.

5. EFFECT OF AIRCRAFT NOISE ON ACTIVITIES AND SLEEP /58

5.1. The disturbance to certain activities

The disturbance to certain activities, even though they are considered in the annoyance index, can be demonstrated by the responses to questions 18 and 24.

- Question 18

  - Does it happen that the noise from aircraft does the following:

    a)- Keeps you from sleeping?
    b)- Wakes you up?
    c)- Disturbs you when you listen to the radio or look at television?
    d)- Makes the house shake?
    e)- Makes you jump?
    f)- Impedes conversation?
    g)- Disturbs you and annoys you even at other times or in another manner?

    no - sometimes - quite often -

Each of these classifications is classified "subject annoyed" if they have responded "sometimes" or "quite often."

In the following graph (Fig. 14) we also show curves for the different classifications as well as the responses to question 17 (general annoyance impression).

In order to eliminate the possible influence of special features of certain zones in the extreme acoustic classes which includes only a few subjects (200 and 100 subjects, respectively), we regrouped two acoustic classes at each of the extremities. We /59 should note that for all of the subquestions to this question, including the one concerning sleep, we kept the index R over 24 hours.

We can see that the responses to questions by the subjects are always related to the acoustic level.

Curves c, d and f, corresponding to the subquestions mentioned most often, as well as the general impression, have steep slopes after R = 78/83.

Curves a, b, e and g, corresponding to the subquestions mentioned the least, increase less rapidly, except for curve b, whose slope increases after R = 84/89.

- Question 24

- During the day, when are you the most annoyed and what are you doing?

a) listening to the radio, television,
b) conversation,
c) reading,
d) study, intellectual work,
e) rest,
f) other,
g) not disturbed at all.

The percentages of "yes" to the preceding questions for the total group are the following: /60

Listening to the radio, television	38 %
Rest	11 %
Conversations	10 %
Other	6 %
Study	2 %
Reading	1 %

Not disturbed . . . . 32 %

The average of the annoyance indices (for the subgroups) distinguished by their option for this question are the following:

	Annoyance index
Reading	1.65
Other	2.22
Listening to radio, television. . . .	2.76
Conversations	3.11
Study, intellectual work	3.14

The percentages of responses as a function of acoustic levels are shown in Fig. 15. We can see that only the selections "radio-television" and "conversation" are related to acoustic level.

At the conclusion of the study of responses to questions 18 and 24, it appears that:

- Radio-television is the activity which is the easiest and the most frequently disturbed by noise. This explains why this disturbance is selected as the second degree of this annoyance scale, after the general impression of annoyance, which makes up the first level. 50% of the inhabitants are annoyed when they are listening /61 to these, when the noise index is between 78 and 83.

- The disturbance to conversations is the third echelon of the annoyance scale. It may appear surprising that this disturbance is not the second echelon, because the radio and television sets can be set so as to produce an acoustic level which is much greater than the level of conversation. In a conversation, one can stop talking while an aircraft is passing overhead, and one is then sure that no information will be lost. On the other hand, the radio and television continue to speak while an aircraft is passing overhead and, in general, the information is lost.

For the same noise level as the one mentioned above (R between

78 and 83) about 25% of the residents are annoyed during conversations.

5.2. Disturbance to sleep

The disturbance to sleep was analyzed from responses to questions 18,a and b:

Does the following happen when there is aircraft noise:

a) it stops you from sleeping?
b) it wakes you up?

The correlation between the responses to these questions and the index R calculated only for nighttime flights (21 hrs.- 7 hrs) is practically zero (Fig. 16). /62

It is remarkable to see that the correlation with the index R calculated for the entire 24 hours is quite a bit larger (Fig. 17).

The result is surprising. It is likely that the relatively small number of flights during the nights the recordings were made is not representative for the average number over the year. The correlation found seems to show that the average number is directly related to the total number of takeoffs every day.

For annoyance at night, we could be tempted to utilize either the peak average level $\bar{L}$ or the number N (nighttime) of aircraft passes as the parameter which represents the noise.

Figures 18 and 19 show that these parameters (at night) are not better than the index R (24 hrs.).

The results found for night flights are therefore less encouraging than those for day flights.

The lack of regularity in these flights, as well as the number of their trajectories could be the reason for this.

Responses to question 23:

"At what time are you annoyed the most by aircraft - daytime or nighttime?

allowed one to determine that most of the subjects are annoyed more during the day than at night: /63

- 56% of the subject group are disturbed more during the day,
- 20% are disturbed more at night,
- 24% are equally disturbed, day and night, or are not disturbed at all.

It is known that nighttime traffic is much less than daytime traffic. In spite of this, 1/5 of the total group stated that they were annoyed more at night (Fig. 20).

For the same traffic, it seems that the nighttime noise would appear much more annoying than daytime noise. Here one finds a non-negligible portion of persons who complain when the number of aircraft taking off or landing at night is very small.

But the data from this survey do not allow one to determine the traffic threshold for nocturnal annoyance, for which it then exceeds or is equal to the daytime annoyance. Also, the intolerable threshold cannot be determined.

5.3. Effect on children

Analysis of the effects on children results from the the responses to questions 25 and 26:

(25) - Are your children annoyed by aircraft noise?

(26) - Do they become more nervous because of aircraft noise? /64

There are slight differences among the zones only. It is apparently in the noisiest areas where one finds most often that the children are annoyed by noise and that they are more nervous because of aircraft noise.

Whether one considers the entire sample, the various survey zones or the various airports between which there was no difference, the subjects always noted that their children are annoyed instead of saying that they became more nervous.

This annoyance and this nervousness of the children increases with acoustic level, as shown by Fig. 21.

The average of the annoyance indices are quite different depending on whether the subjects responded that noise did or did not have an effect on their children.

		Annoyance index
Question 25:	Disturbed children.	3.17
	Not disturbed	1.83
Question 26:	Children more nervous	3.28
	Not more nervous.	1.91

5.4. Defense reactions

Except for concerted actions for reducing the activity and the development of airports and moving to a quieter location, in practice the only measure that remains for the resident is to close the windows of his apartment in order to defend himself against aircraft noise. /65

If the windows are not specially designed to reduce noise, which was the case for apartments visited by the surveyors, closing them only reduced the global noise level by about 15 dB. Even though this is modest, this reduction is translated into dividing the sonic level by three (the physiological impression related to noise intensity), which is appreciable.

Unfortunately, in the case of the apartments visited, this means of protection cannot be used during all seasons. Because there are no mechanical ventilation systems or other air conditioning facilities, this requires that the windows be open for several hours per day during the summer for apartments exposed to the sun in order to reduce the heat due to the solar radiation and to eliminate undesirable odors. Under these conditions, the noise enters the apartment without being reduced.

During spring and fall and even in the winter, a central heating system which cannot be controlled by the occupant (very frequent in the case of stage heating) or one which is poorly regulated can lead to the same results.

The residents of noisy areas only have the choice of living in an overheated area with bad odors or living in more ventilated areas but which are much more noisy. Each one will decide among the annoyances depending on his sensitivities. The percentage of residents who close their windows because of noise can be derived from the responses to question 29 (Fig. 22). /66

- Do you close your windows in order to not hear aircraft?

26% of the subjects stated that they close their windows in order not to hear the aircraft.

The proportion of subjects who closed their windows varies within the following limits:
- at Paray (R = 100), 84% of the subjects closed their windows;
- at Saint Remy (R = 62) and Vitrolles (R = 73) and Meyzieu (R = 63) and at Rillieux (R = 72) 3 to 5% only closed their windows.

It is interesting to note that around Lyon and Marseille, windows are closed the least because of aircraft. It is possible that the annoyance due to heat is less than the one due to noise.

The higher the acoustic levels, the more often one will close the windows: from 4% for $R \leq 71$ to 84% for $R \geq 96$.

It seems that the subjects only have recourse to this method of noise isolation when the annoyance really becomes large. The average annoyance indices are the following for the subgroups: /67

Close their windows	3.20
Do not close them	1.72.

This is one of the rare questions which determines a pronounced difference among the average annoyance indices.

This question is complemented by question 30:

- Do you like your apartment to be air conditioned in order to no longer hear aircraft?

Among the subjects, 32% would like to have their apartment air conditioned. Major differences appear depending on airports:

	Want air conditioning
Le Bourget (. . . . . Marseille)	37%
Orly	30%
Lyon	13%

Here we cannot discuss the differences of opinion. We can only note them.

The variations depending on the survey location are of the same order as the variations found for the preceding question. /68

As a function of acoustic level (Fig. 22), the percentage of positive responses also vary approximately the same as for the preceding question and with the same proportions:

4% for $R \leq 71$ and 70% for $R \geq 96$.

6. CONSEQUENCES

/69

6.1. Limiting acceptable noise levels

The study described in the preceding chapters confirmed that the annoyance felt by residents close to airports is greatly related to the noise intensity and the number of aircraft, just like the English demonstrated by their survey around Heathrow Airport.

The best way of taking into account these two parameters is to group them in an index, like the index R defined by the Noise Study Commission of the Ministry of Social Affairs:

$$R = \bar{L} + 10 \log N - 34$$

or the one proposed by the English:

$$NNI = \bar{L} + 15 \log N - 80$$

$\bar{L}$ is the average peak noise level expressed in PNdB.

N is the number of aircraft for which noise is perceived.

Even though they are different in the manner of taking into account the repetition factor (10 log N or 15 log N), these two indices are of equal value as regards the dispersion of the individual reactions for a single noise area. The use of the index R amounts to assuming that the annoyance felt by the inhabitants is related to the total noise energy which they receive over the day (average over the year).

The study showed that by knowing the value of such an index, we can predict with a high accuracy the average annoyance which is felt by a group of individuals (100 persons or less, living at a specific location). On the other hand, the individual reactions vary so much that it is impossible to predict them. /70

The annoyance is expressed using an annoyance index which can vary between zero and 5 and which condenses the responses to five questions.

Figure 23 shows the relation found between the index R of noise and the average annoyance index. Essentially, this relationship is:

Annoyance index = 0.06 R - 2.95 for $R < 86$
Annoyance index = 0.064 R - 2.76 for $R > 86$

We can see that the annoyance index increases in a linear manner with R for the range studied ($63 < R < 100$), except for the region around $R = 86$. At this point it makes a jump of about 0.8 units, from 2 to 2.8.

The annoyance index has the advantage of taking into account the responses to several questions, but has the disadvantage of not "speaking." In order to see what it corresponds to, it seemed useful to us to consider the various echelons of the annoyance scale (Fig. 23) as well as the general impression of annoyance from the responses to question 17.

The jump in the annoyance index observed around R = 86 corresponds to the fact that the response "yes" to question 18,f "Does aircraft noise bother conversations?" occurs when the index exceeds /71 a relatively exact value. We can observe this by examining Fig. 24. This is not surprising, because in contrast to the annoyance sensation which involves psychological phenomena, the masking of a conversation only depends on the relationship between the noise intensity and the conversation intensity. The conversation intensity is well defined.

If we consider the tables in paragraph 2.3, we can see that the points in Fig. 23 located in the discontinuity zone (around R = 86) corresponds to peak levels which vary between 101 and 107 PNdB [92 to 98 dB (A)] with the number of passes between 20 and 80.

The level above which the "yes" answer is given to the questions of the annoyance scale other than 18,f are much more diffuse. This is why the increase in the annoyance index with noise index is relatively linear outside of the discontinuity zone.

The noise class 84 - 89 which contains the limit beyond which the conversations are disturbed seems to play a more general role.

If we consider Fig. 11, we can see that the noise is a cause of dissatisfaction which emerges from the other causes of dissatisfaction (markets, transportation) when the index reaches class 84 - 89. In addition, to the question "What would you like to change?" (Fig. 12), the response "the noise" is given most often, more often than any other item when the index reaches class 84 - 89. For this class, the residents estimate that they are "slightly or rather heavily annoyed."

The convergence of these observations allows us to consider /72
that starting at the class R = 84/89, to which an annoyance index greater than 2 corresponds, the noise of aircraft is quite annoying for the residents.

Consequently, it seems that any apartment not specially protected should not be located in an area where R exceeds 84. This conclusion is reached with the conclusions of the Wilson Committee which was made after the English survey. In it, it was found that the maximum acceptable noise index was located between 50 and 60 NNI.

(An NNI index of 50 corresponds to a peak level of 100 PNdB for 80 aircraft passes, i.e., for a R index of about 85.)

The good agreement between these conclusions leads us to believe that the recommendations of the Noise Study Commission at the Social Affairs Ministry, which specified R = 89 as the maximum tolerable limit which should not be exceeded for unprotected apartments, are not sufficiently severe.

Because of the nature of the questions which make it up. the annoyance index takes into account both the annoyance during the day and the annoyance at night. For the noise class R = 84/89, which corresponds to annoyance indices between 2 and 3, the night annoyance only is involved relatively rarely because the night annoyance (waking up) corresponds to indices 4 and 5.

We have established that the dispersion in the individual sensitivity to noise at night is great, and this is true for any noise index used (index R, number of aircraft passes, noise level in PNdB) /73 in order to characterize the various zones. Thus, for class R = 84/89, 26% of the subjects stated that they were awakened at night by the noise of aircraft (Fig. 24). Even for this relatively low noise class, there is a mixing of the effects of day and night for the annoyance level.

The study did not allow us to investigate how this annoyance varies when the noise conditions at night are aggravated.

The poor correlation found between the noise index calculated for nighttime (21 hrs. - 7 hrs.) and the percentage of persons awakened does not allow one to conclude that the noise index concept (R) is not valid in this case. The absence of correlation could be due in part because the noise measurement results are not significant at nighttime, related to a large fluctuation in nighttime traffic for different days of the year.

Using young people in a laboratory in good health, Professor Metz and his collaborators (Bioclimatic Study Center of Strasbourg) established that jet aircraft noise which does not exceed a level (in the bedroom) of 75 dB (A) does not disturb sleep in a significant manner.

On the other hand, noise levels which reach 90 dB (A) do seriously disturb sleep. If this were the general rule, we would derive from this that in the boundary area defined previously (R = 84), people will sleep with closed windows and would then not have their sleep disturbed by the noise (assuming a reduction in sound of 20 dB between the outside and the inside of their room). On the other hand, those sleeping with open windows would have disturbances to their sleep (assuming, for isolated houses, that the aircraft are visible from the window; this condition is not necessarily true in an urban setting). /74

This finding is important. It shows that if we consider the laboratory results, that it is not sufficient to establish a limit (84) to the calculated R over 24 hours in order to assure tranquility for the residents. In addition, it is necessary to limit the nighttime flights to a minimum. If this were not the case, the boundary area would have to be determined by taking into account nighttime flights, independent of the daytime flights. We are expecting results of additional studies, and it could be that the criterion to be adapted for the nighttime flights could be the one which results from the work of Professor Metz: the noise level at night in a bedroom must not exceed 75 dB (A).

6.2. Noise exposure and ventilation

In order to limit the daytime annoyance to an acceptable value, we have seen that it is desirable to not construct buildings which are not specially protected against noise, in locations where R is equal or greater than 84.

It is probable that living conditions could be acceptable at locations which are slightly noisier, under the condition that the residents live in apartments designed to attenuate the noises, compared with the outside.

The problems of reducing external noise are intimately related to the problems of ventilation and heating.

In the usual apartments, residents have to open windows, especially during the off-season and in summer, in order to provide pure air and an acceptable thermal environment.

As far as air purity is concerned, opening the windows often compensates for ventilation insufficiencies. Of course, this is subject to noncontrollable variations in wind and heating input conditions.

As far as the thermal comfort is concerned, comfort in summer requires that windows are almost constantly open or half open. /75
The movement of air which results goes from the facade in the shade to the facade in the sun. This, in part, allows compensation for external solar input. We can consult the study published in Document No. 608 (delivery 72) for this subject.

Often it is necessary to open windows during the heating periods of the intermediate seasons in order to avoid overheating due to insufficient control or due to an installation which is too inert. Also, sometimes the occupants wish to sleep with fresh air.

Even though we do not have the results of studies on this subject, we can assume that opening windows in a usual apartment occurs

-- for on the order of one hour per day in the winter,
-- for several hours per day in the mid-season,
-- almost continuously during the summer days.

Therefore, we have seen that windows play a very important part for ventilation. They also play an important part for acoustic insulation. It is known that in apartments made of traditional materials (brick), noise penetrates into the apartments essentially through the windows, even if they are closed or well insulated.*)

*) This is not true in the case of individual houses with a light ceiling.

Under these conditions, if the resident is exposed simultaneously to thermal and acoustic constraints, he will open and close his windows in order to select the best possible combination of the two annoyances. /7

During our survey, we found that the percentage of people closing their windows because of noise increases as the noise level increases. This percentage is 20% for R = 78/83 and 30% for R = 84/89.

Therefore, even in the zone where one estimates that the annoyance is acceptable ($R < 84$), a nonnegligible percentage of people close their windows due to noise.

If one examines Appendix No. 10, we can see that on the average, the traditional apartment (3 mm window panes with normal sealing), closed windows provides a protection on the order of 25 dB (A), or what amounts to the same thing, on the order of 25 PNdB, against external noise. On the other hand, wide-open windows provide protection which varies between 0 and 5 decibels. Half-open windows provide a protection on the order of 10 decibels.

It seems reasonable to require builders to provide acoustic insulation (closed windows) which exceeds 25 dB when the noise index exceeds 84, if the construction of apartments in zones where R equals or exceeds 84 is authorized.

The problems of suppressing external noises are closely related to the problems of ventilation and heating. /77

*) ...

*) Translator's note: French text repeats four paragraphs translated on page 74.

For example, if the house is constructed at a location where R = 90, the insulation of the apartments must be at least *) dB. /78

Considering the very large number of days during which ventilation is indispensable, it seems necessary to require acoustic insulation and also artificial ventilation, so that windows do not have to be opened, and which does not reduce the protection against external noise. Appendix 11 gives the conditions which the ventilation system has to satisfy.

The previous requirements could be softened for special cases: single houses, where only one side is subjected to the noise, while being entirely subjected to solar radiation. In the case where a single runway is used with an East-West orientation, this would involve long single buildings parallel to the runway, located perpendicular to this runway to the North of this runway. In such a case, the North face of the building is relatively protected against noise (reduction of 20 dB) and protected from the sun. It is then possible to open the windows along this side in order to obtain ventilation without being annoyed by the noise. In this case, we can assume that the special ventilation is not indispensable and the acoustic insulation is only required for the South-facing side of the building. If possible, the main room should be located in the North.

This reduction in the rules is only valid if the building is really isolated. If other buildings are in the vicinity, such as in an urban setting, no building front will be protected because of noise reflection from adjacent buildings.

For buildings which do not conform to these special conditions, we can see that the solution can be found by using the following types of windows, referring to Appendix 10:

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*) Illegible in French text.

Extreme indices which define the noise zone	Kind of windows
R < 84	Conventional windows
84 - 89	Windows equipped with thick glass, 5.5 mm thick, with improved sealing.
90 - 94	Double windows with glass between 2.9 and 5.5 mm thick, separated by at least 10 cm, with improved sealing.
94 - 99	The same, with spacing at least 15 cm.

/79

We would like to note that in certain cases, the special ventilation will not be necessary for economy. The expense for increasing the insulation of the fronts will not be advantageous except for 30% of the persons involved, if R is between 84 and 89. This is because the other people will prefer to endure the noise and have the ventilation (Fig. 22).

/81

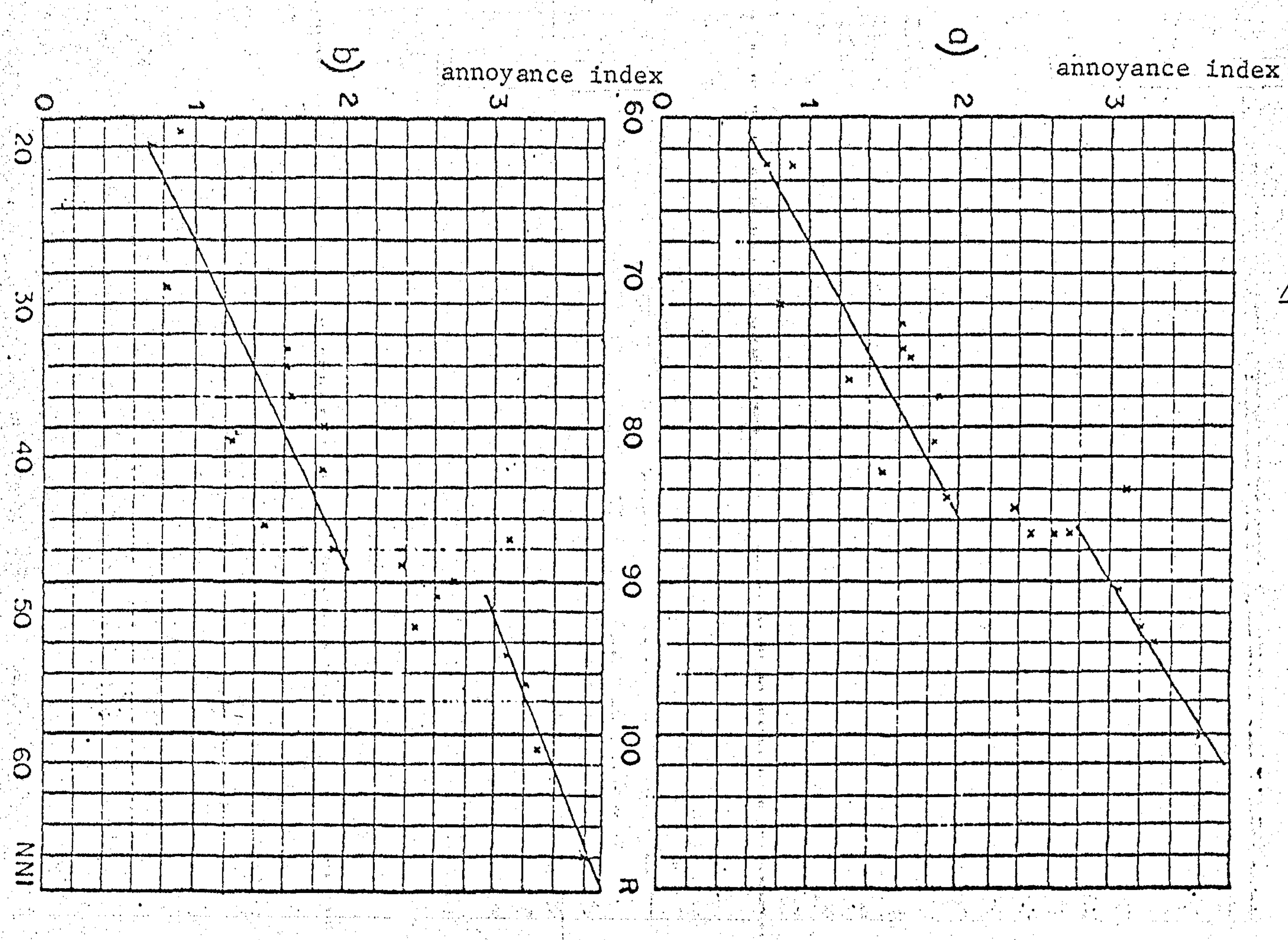

Fig. 1. Variation of the annoyance index with index R and index NNI.

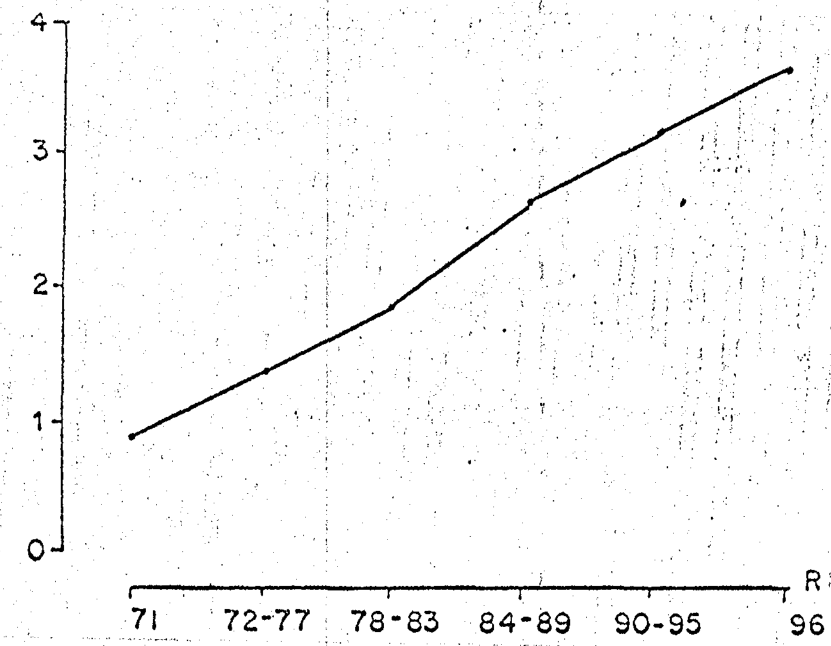

Fig. 2. Variation of the annoyance index as a function of acoustic classes.

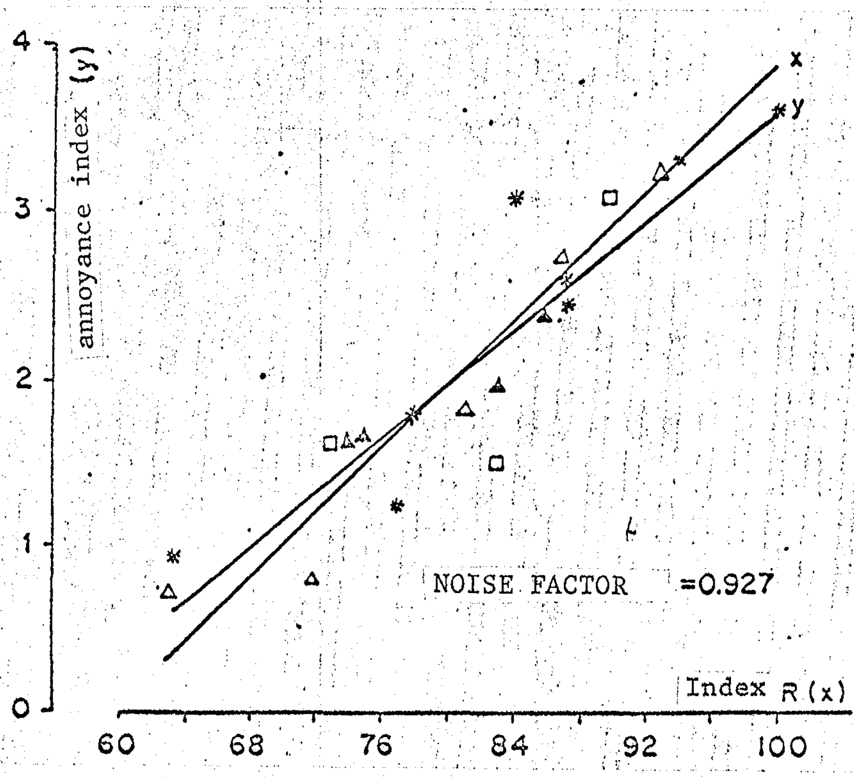

Fig. 3. Variation of the annoyance index as a function of the index R (by locality).

/83

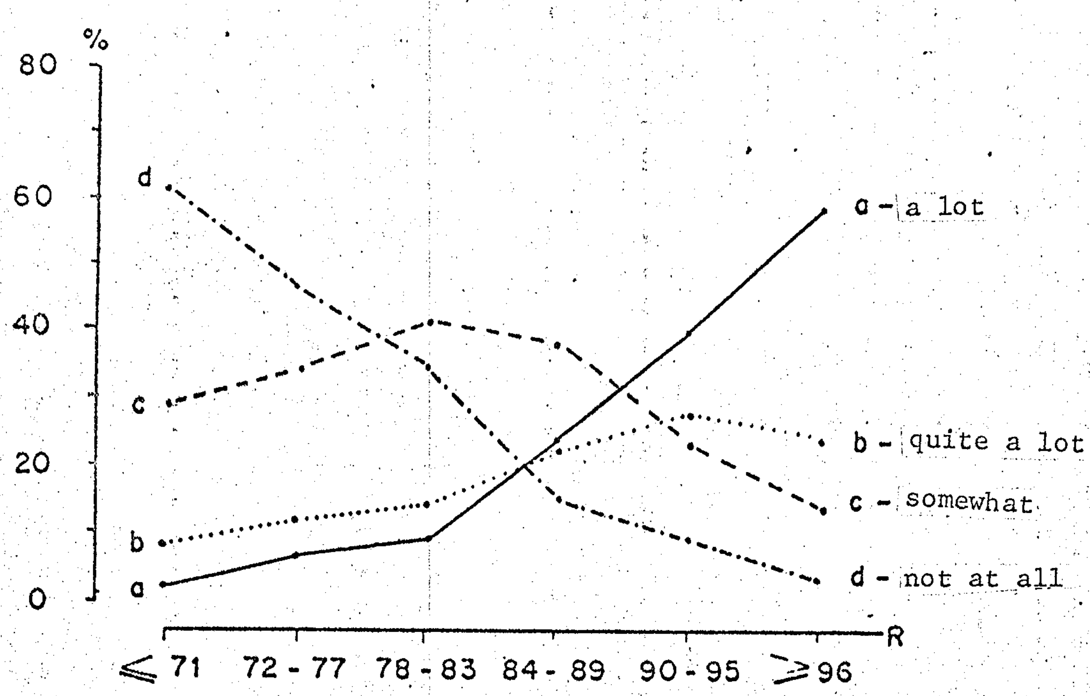

Fig. 4. Does aircraft noise bother you?

/84

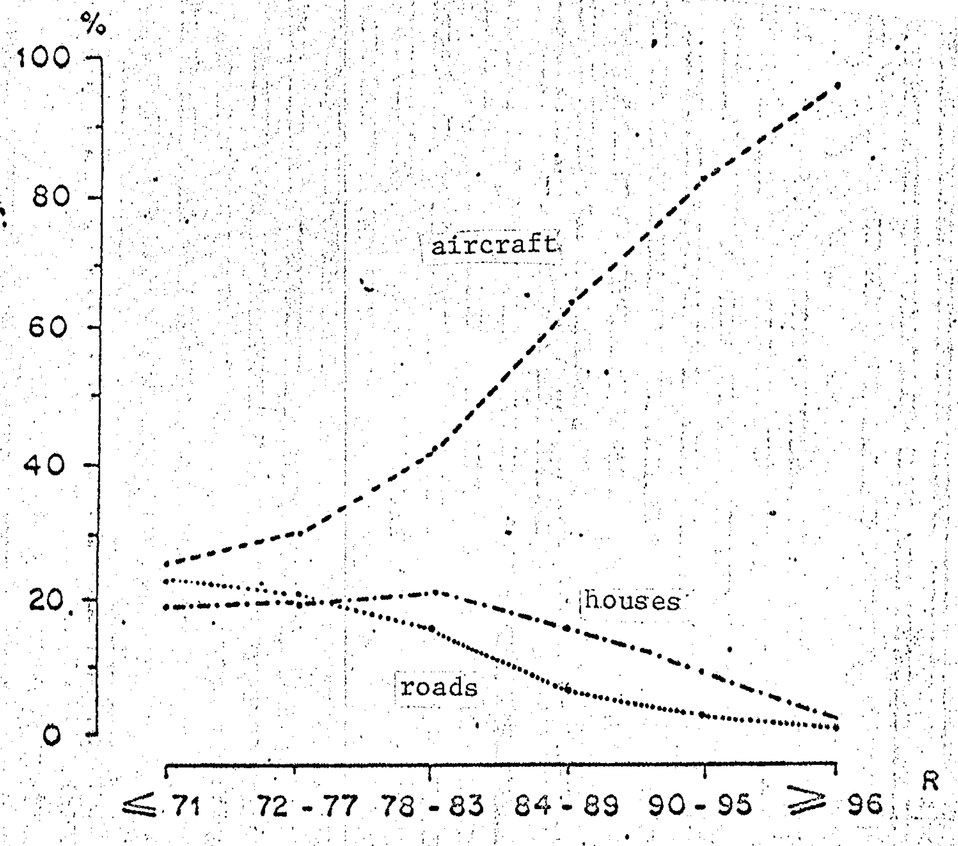

Fig. 5. Which kind of noise bothers you the most?

Note: Each point represents the percentage of "aircraft" responses for a locality.

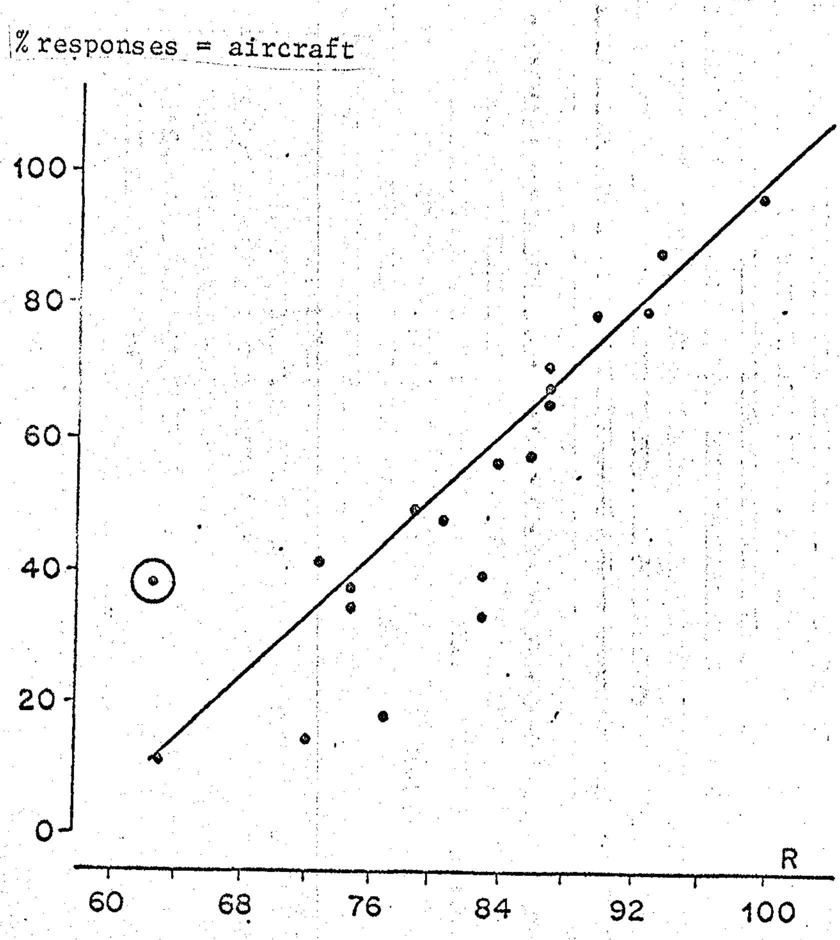

Fig. 6. Which kind of noise bothers you the most?

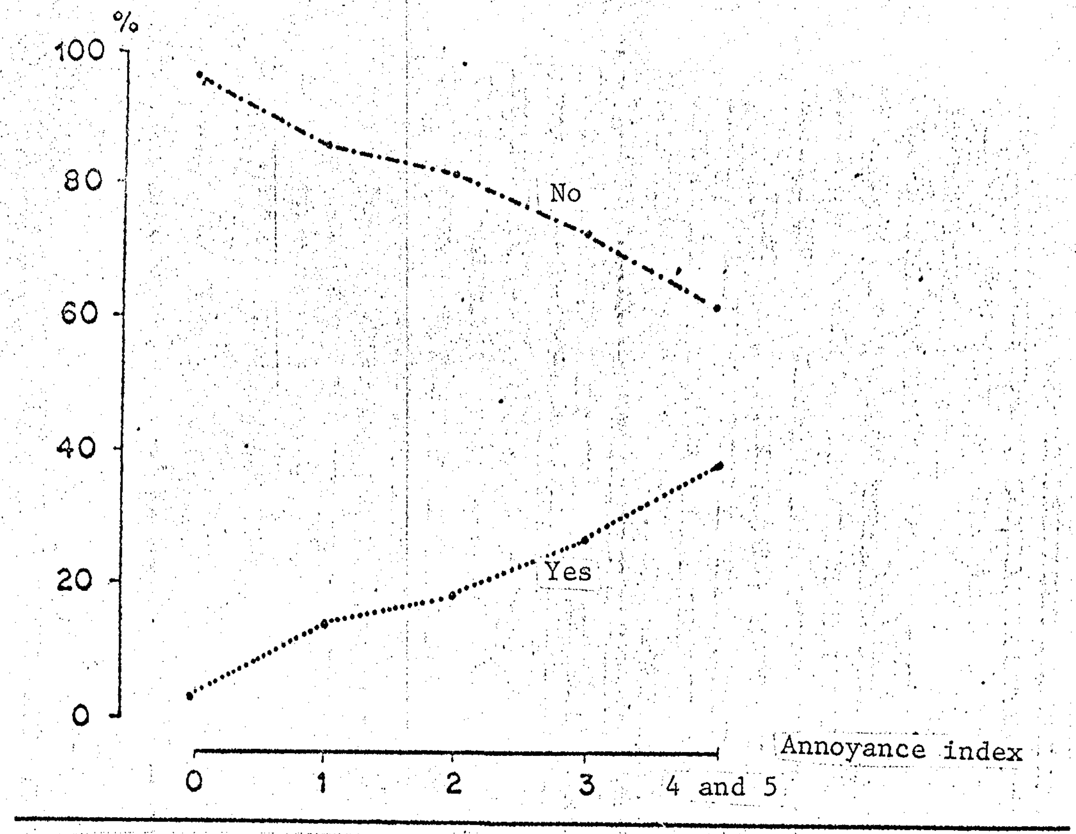

Fig. 7. Adaptation to aircraft noise.

Has aircraft noise bothered you more this year than in the past?

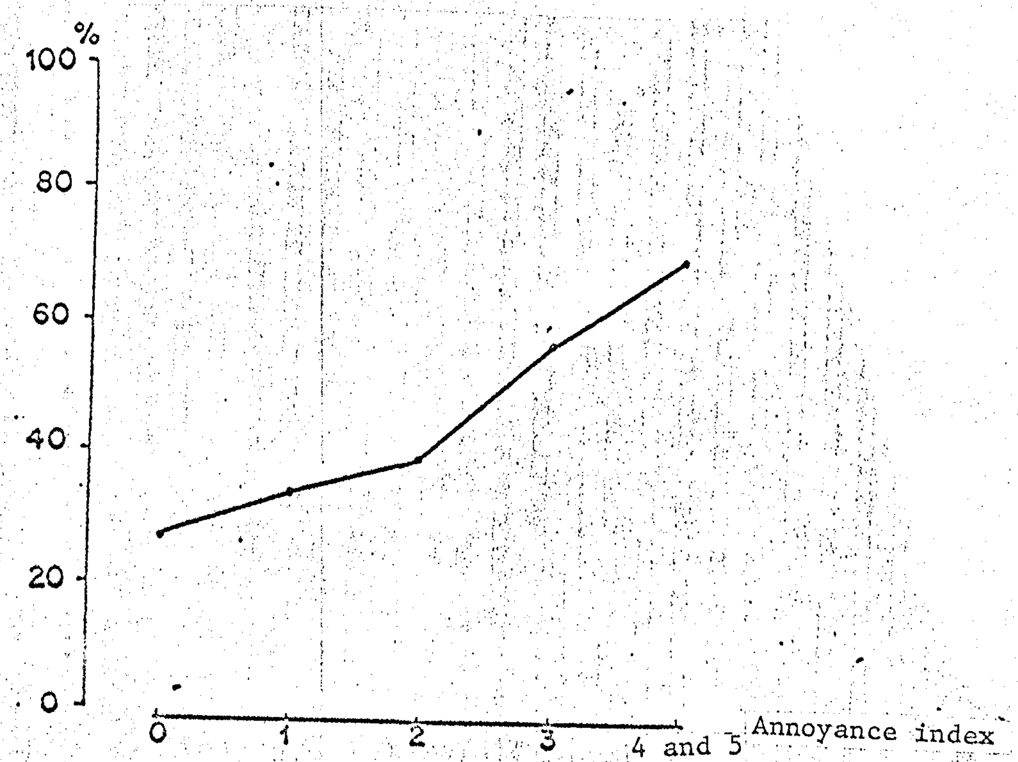

Fig. 8. Dissatisfaction regarding noise in general.

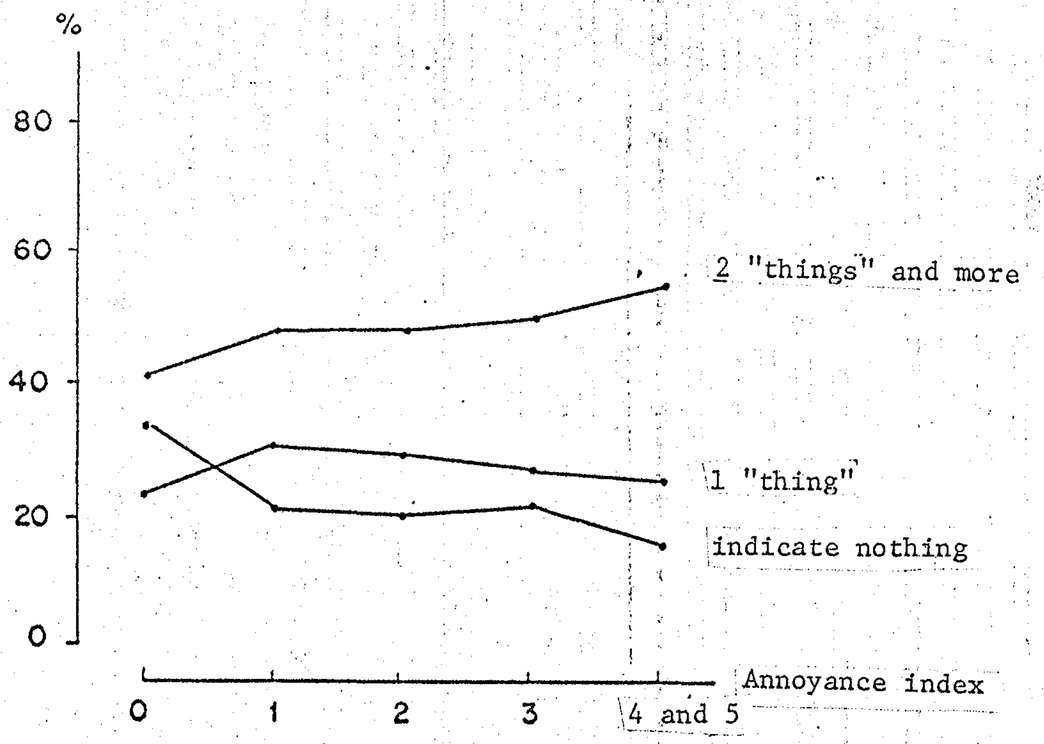

Fig. 9. Number of "things" which are unpleasant in the neighborhood.

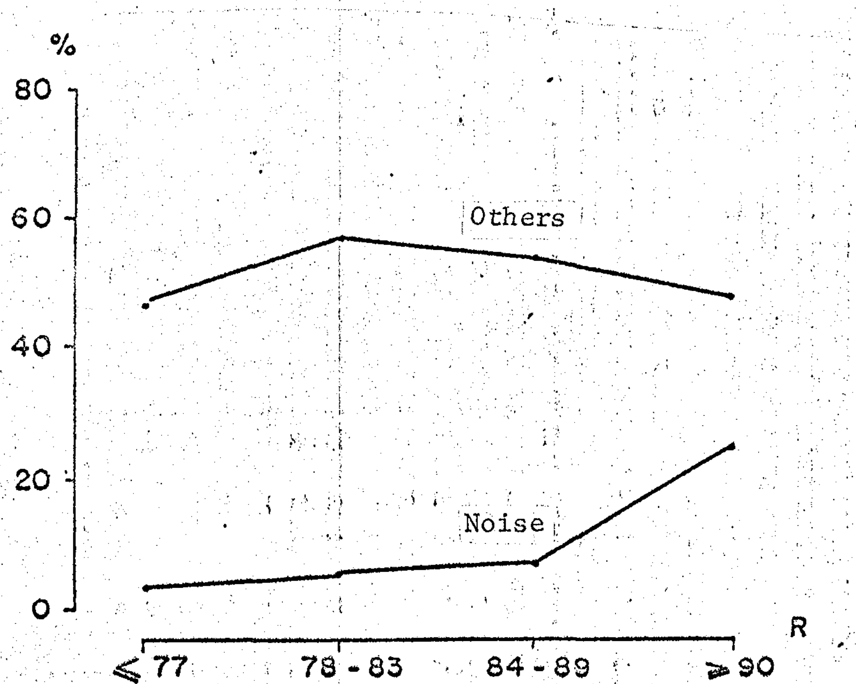

Fig. 10. Are there things you do not like here?

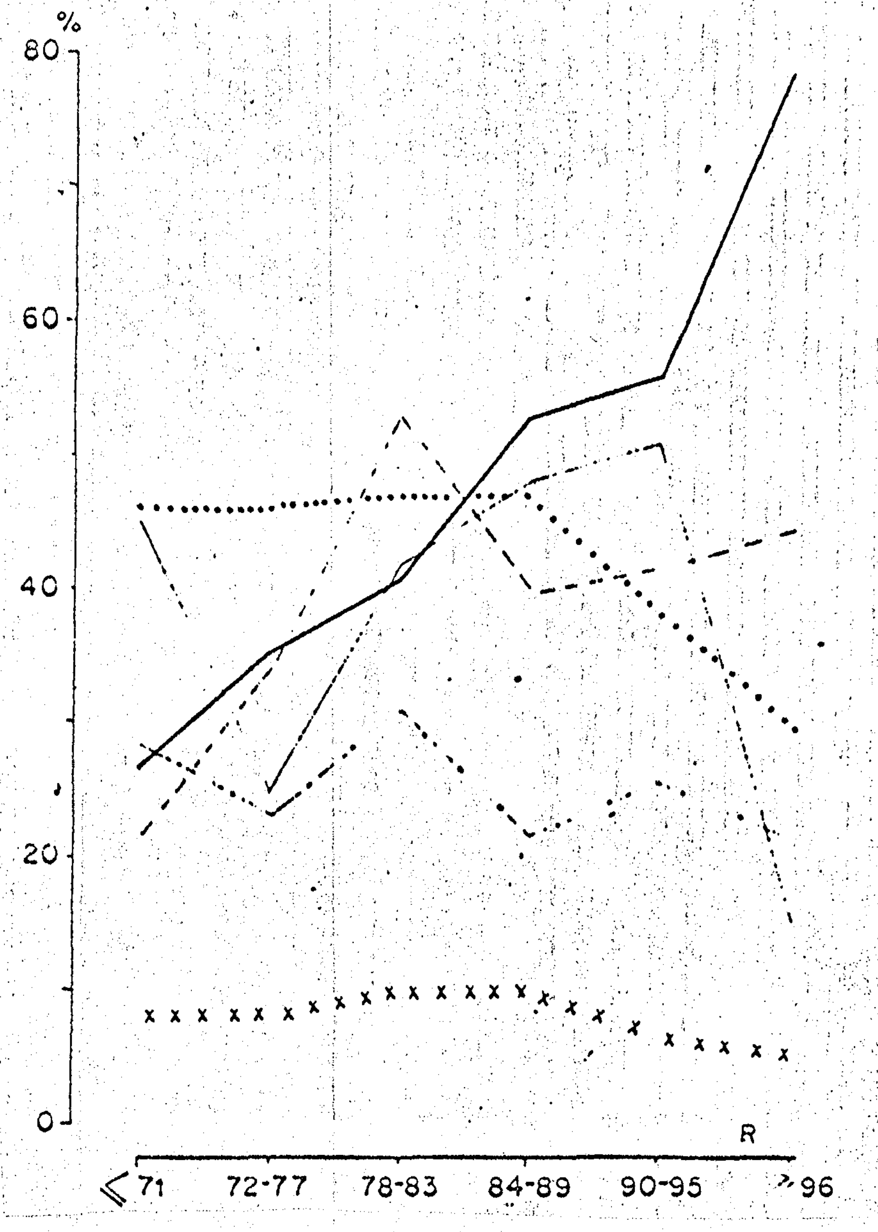

Fig. 11. Dissatisfaction because of
________ Merchants
-------- Public transportation
___ . ___ Proximity to work-place
.... Entertainment
x x x x Neighbors
________ Noise

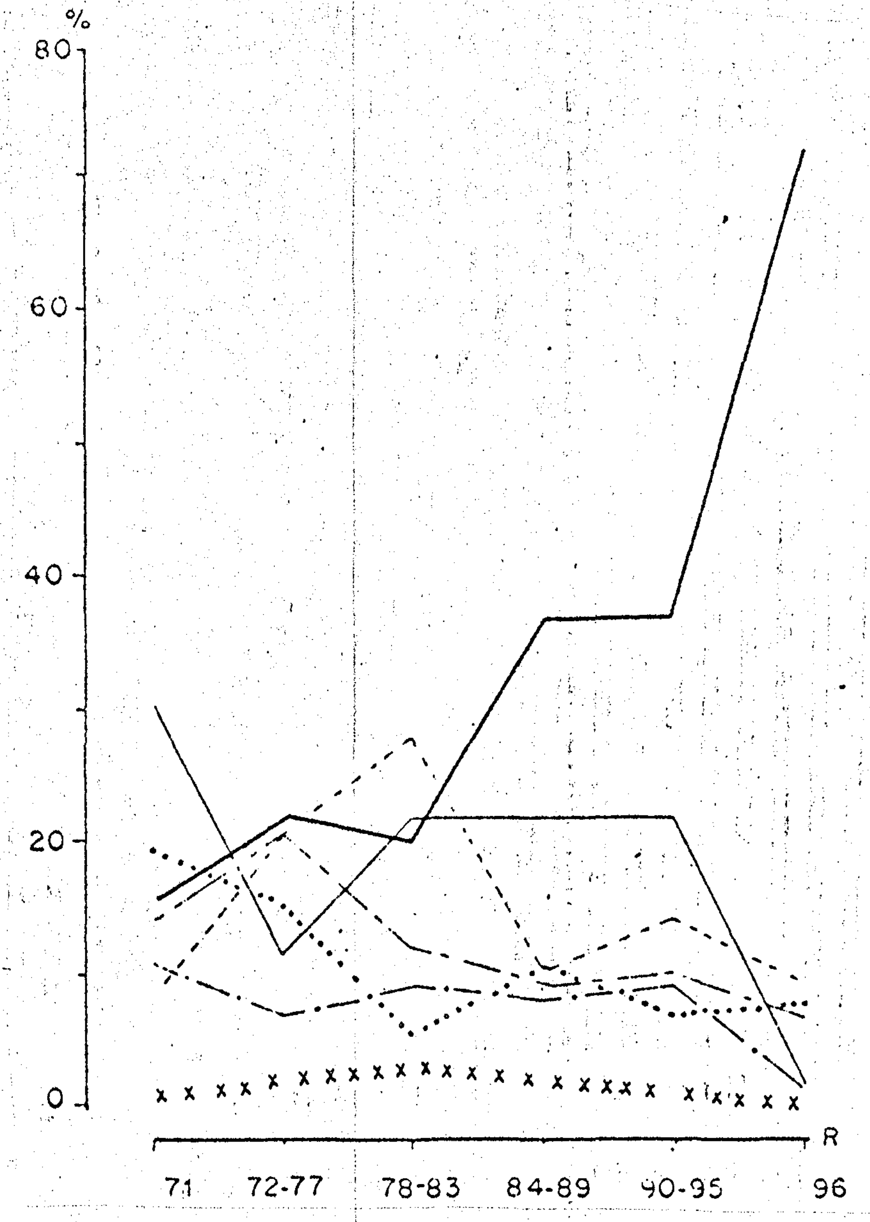

Fig. 12. What would you like to change?

________	Merchants	x x x x x	Neighbors
--------	Public transportation	________	Noise
___ . ___	Proximity to work-place	___ . ___	No response
....	Entertainment		

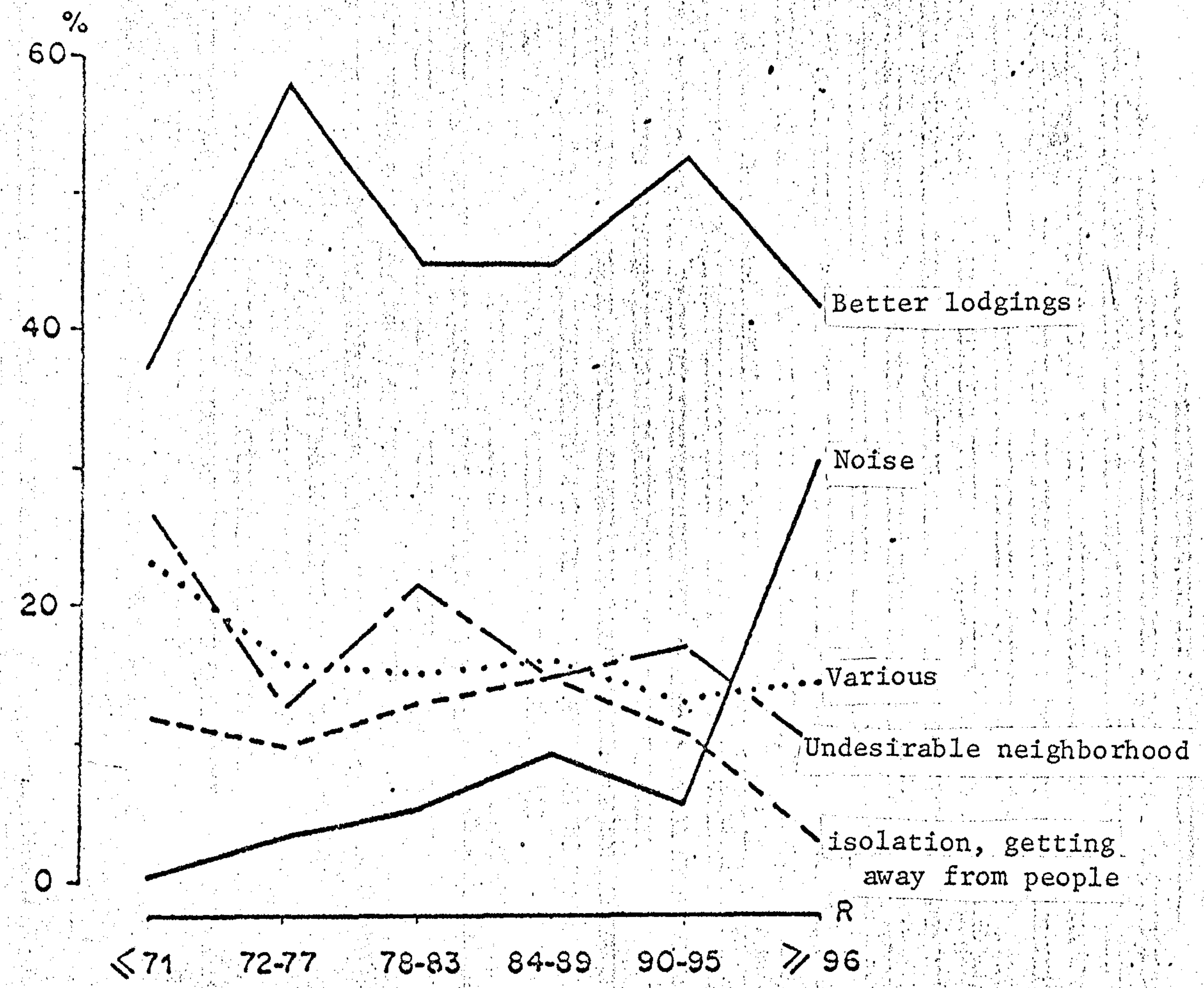

Fig. 13. Why would you want to move?

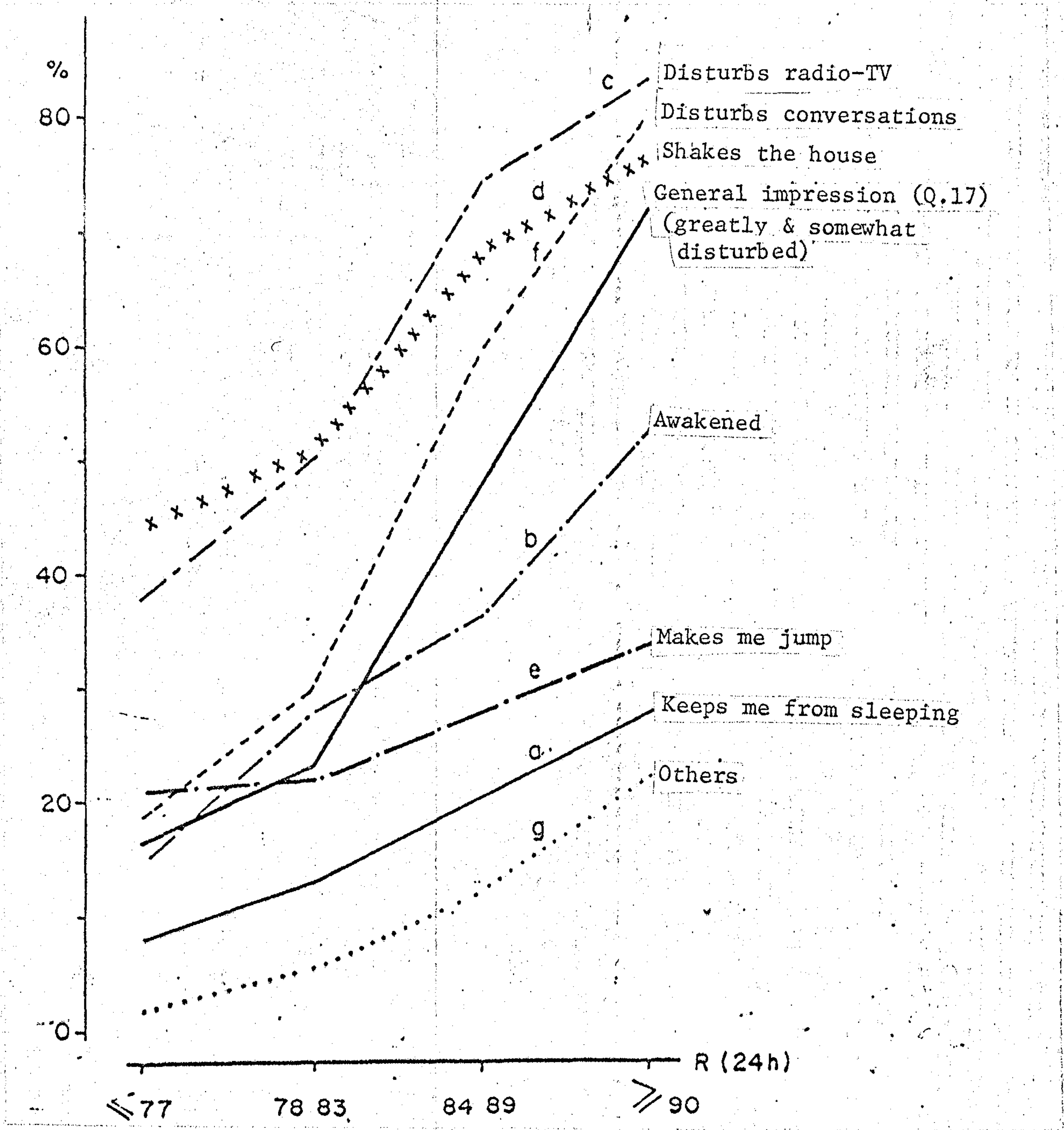

Fig. 14. Percentage of subjects which were disturbed (by acoustic class) (responses: sometimes - quite often).

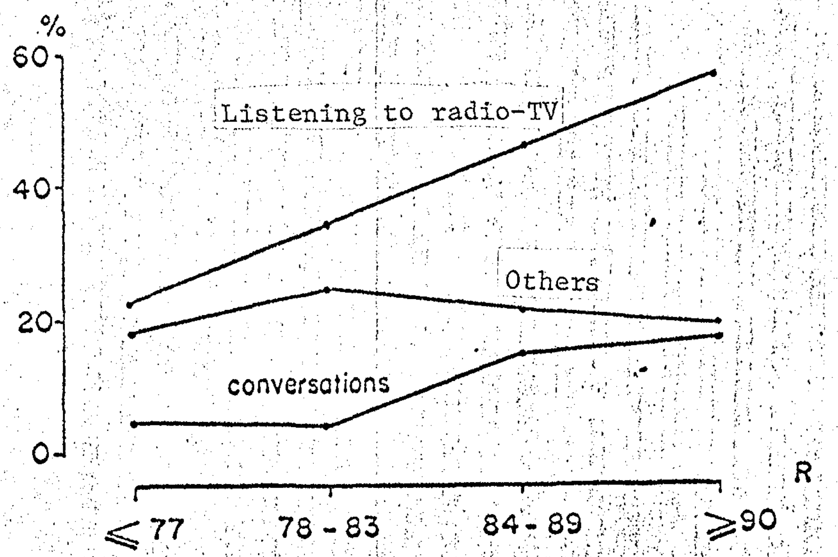

Fig. 15. The activity disturbed the most.

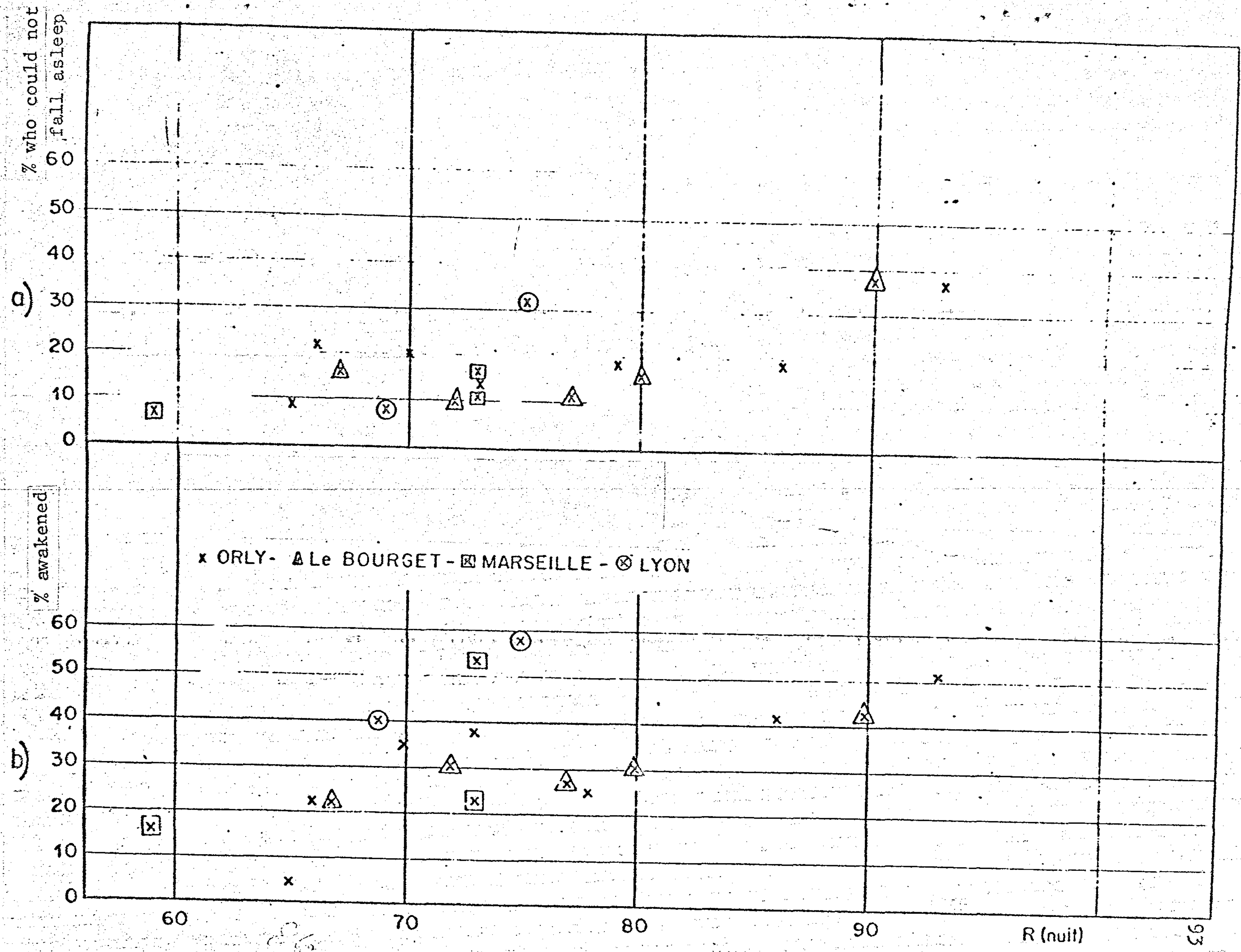

Fig. 16. Percentage of persons who could not fall asleep (a) or who were awakened because of aircraft noise (b).

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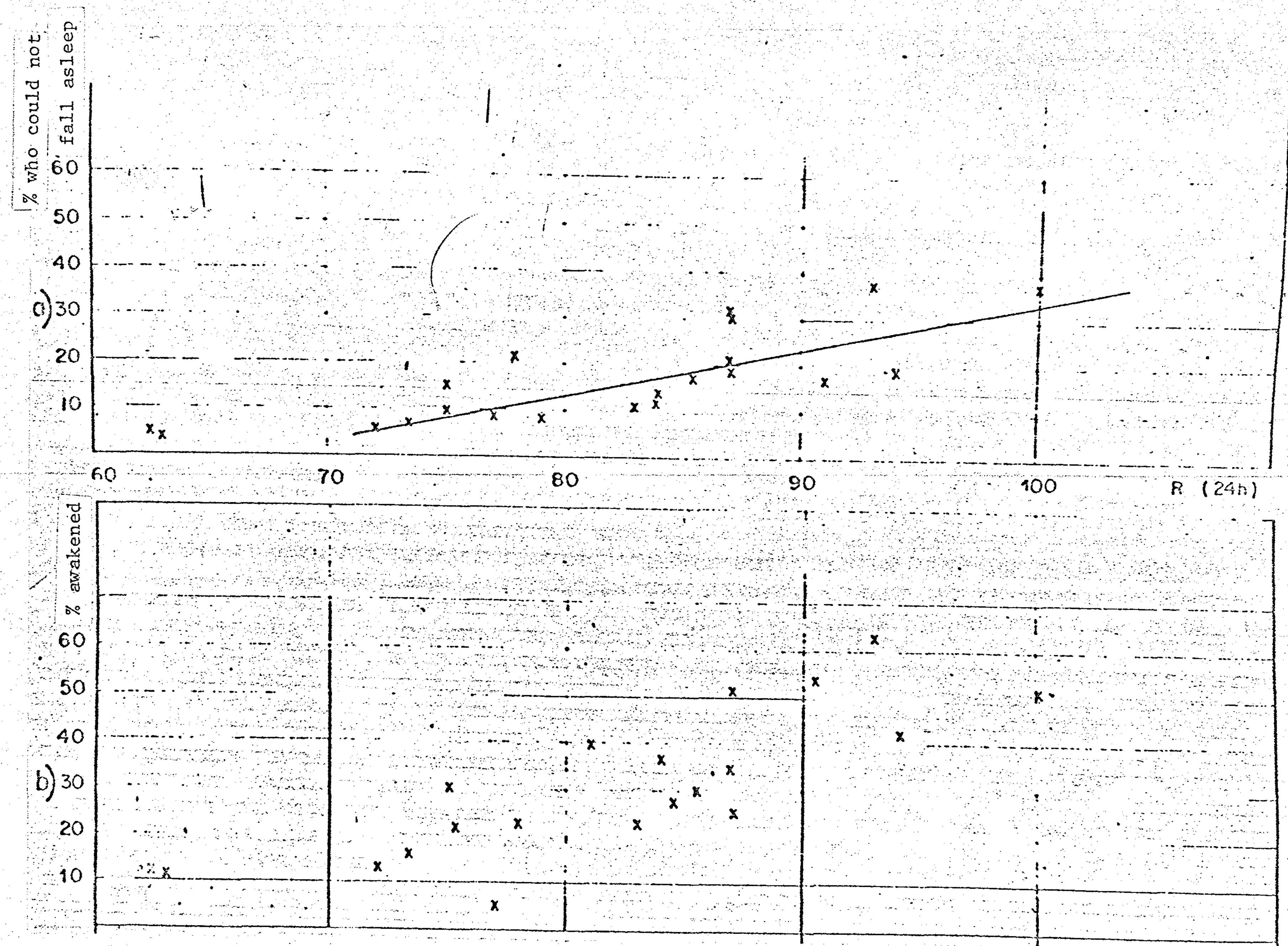


Fig. 17. Percentage of persons who could not fall asleep or wake up (illegible)

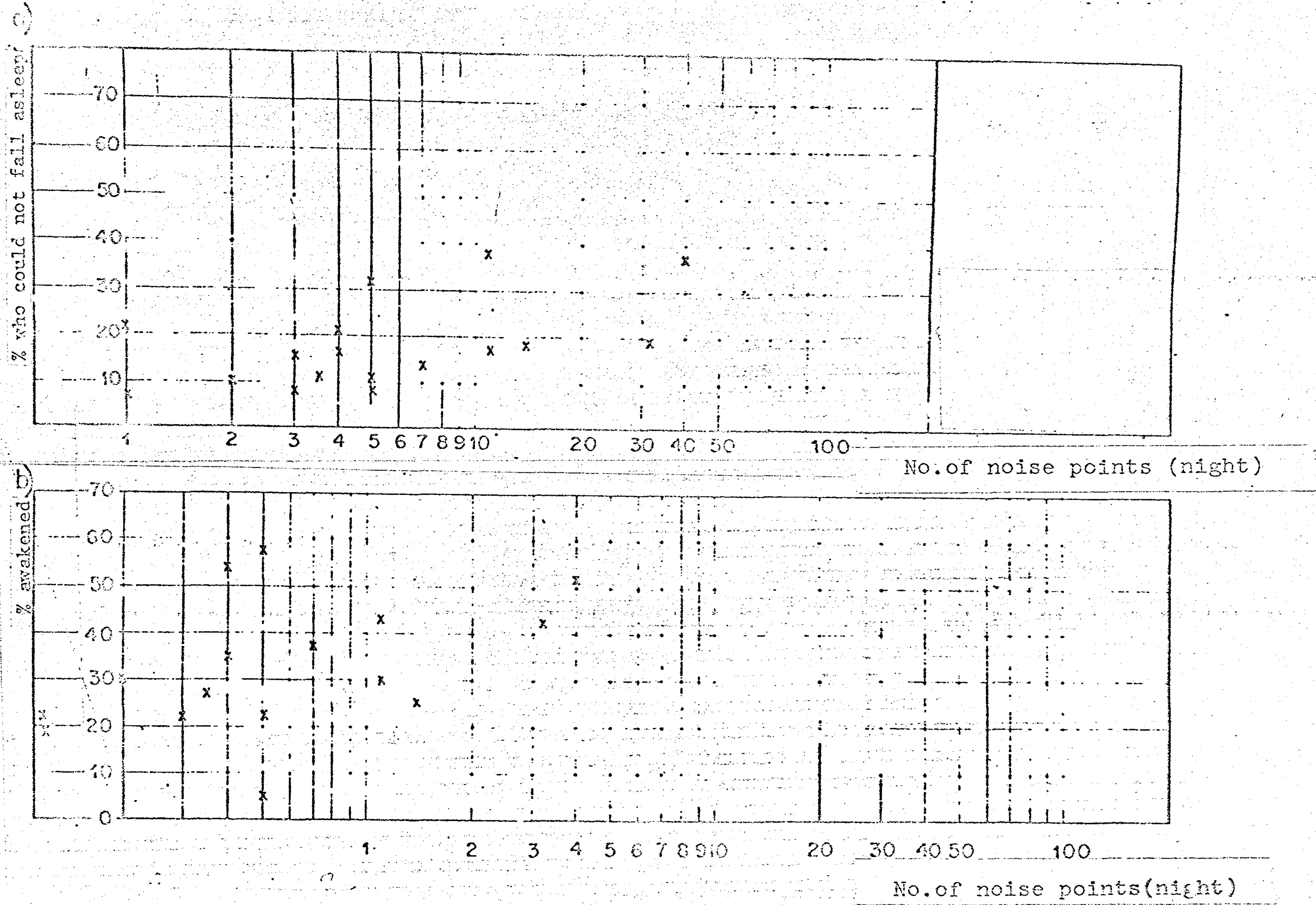


Fig. 18. Percentage of persons who could not fall asleep (a) or who were awakened because of aircraft noise (b).

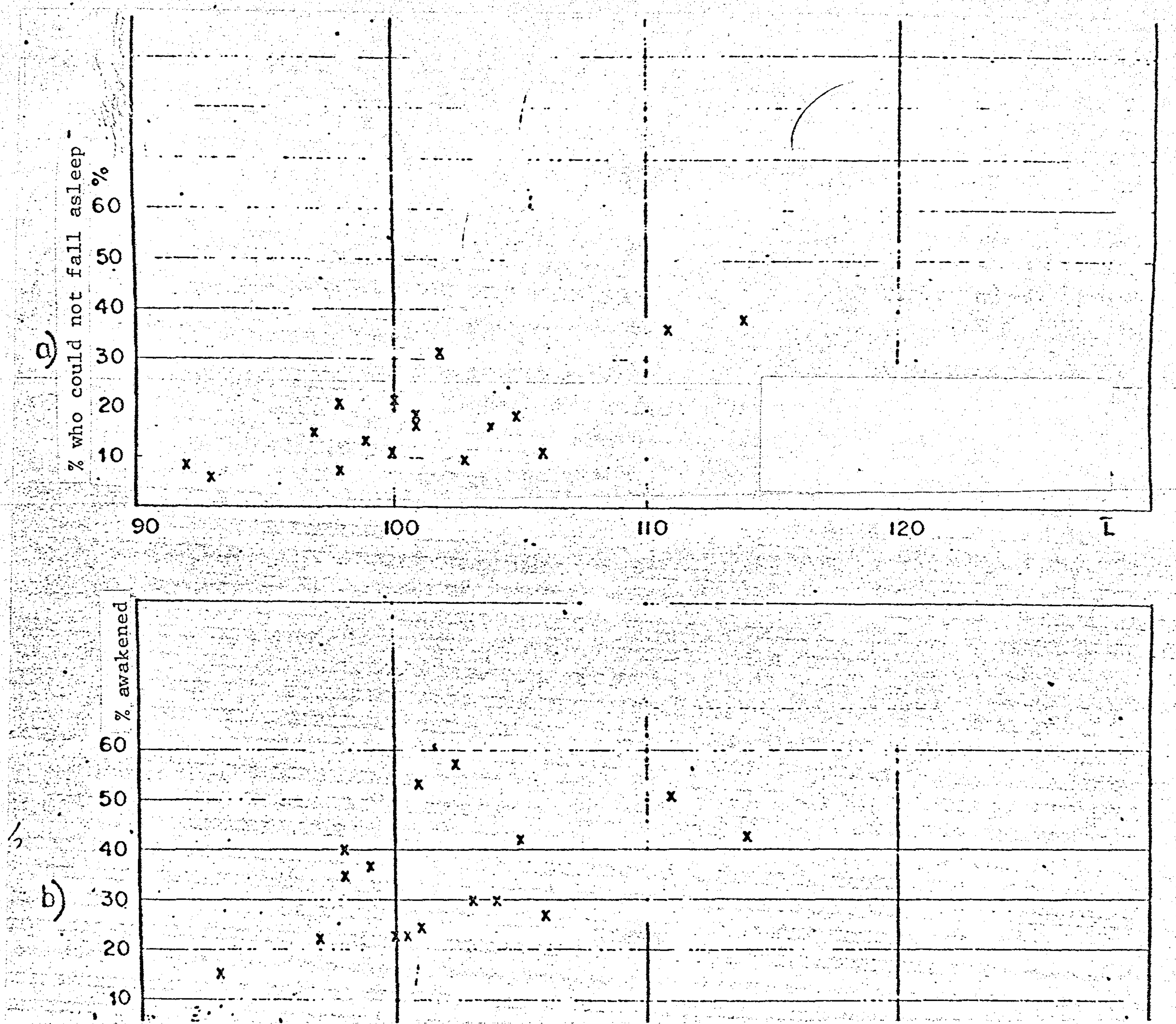


Fig. 19. Percentage of persons who could not fall asleep(a) or who were awakened because of aircraft noise (b).

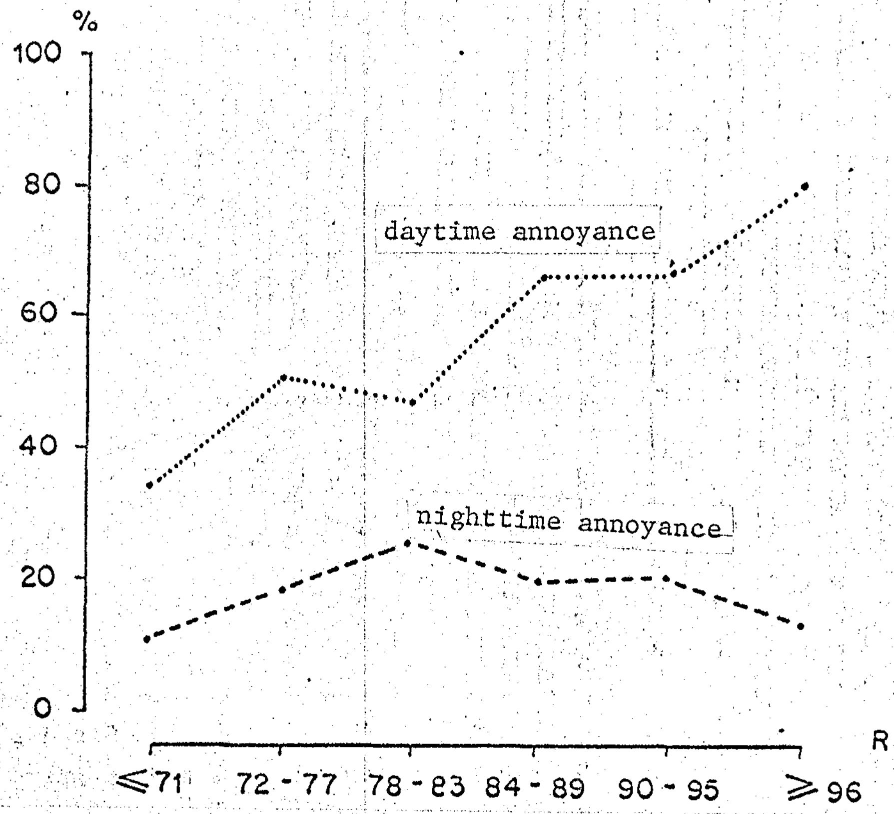


Fig. 20. Daytime and nighttime annoyance.

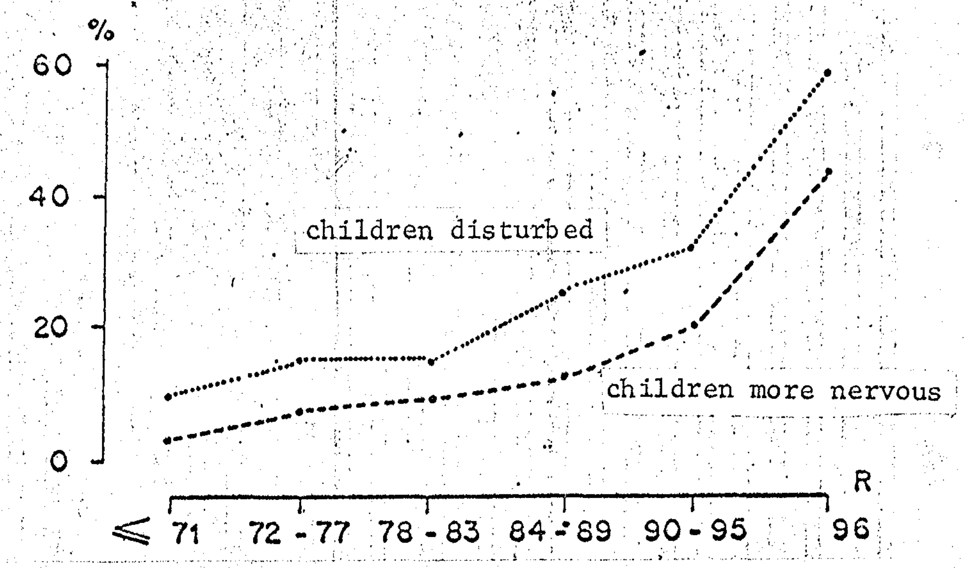


Fig. 21. Influence of noise on children.

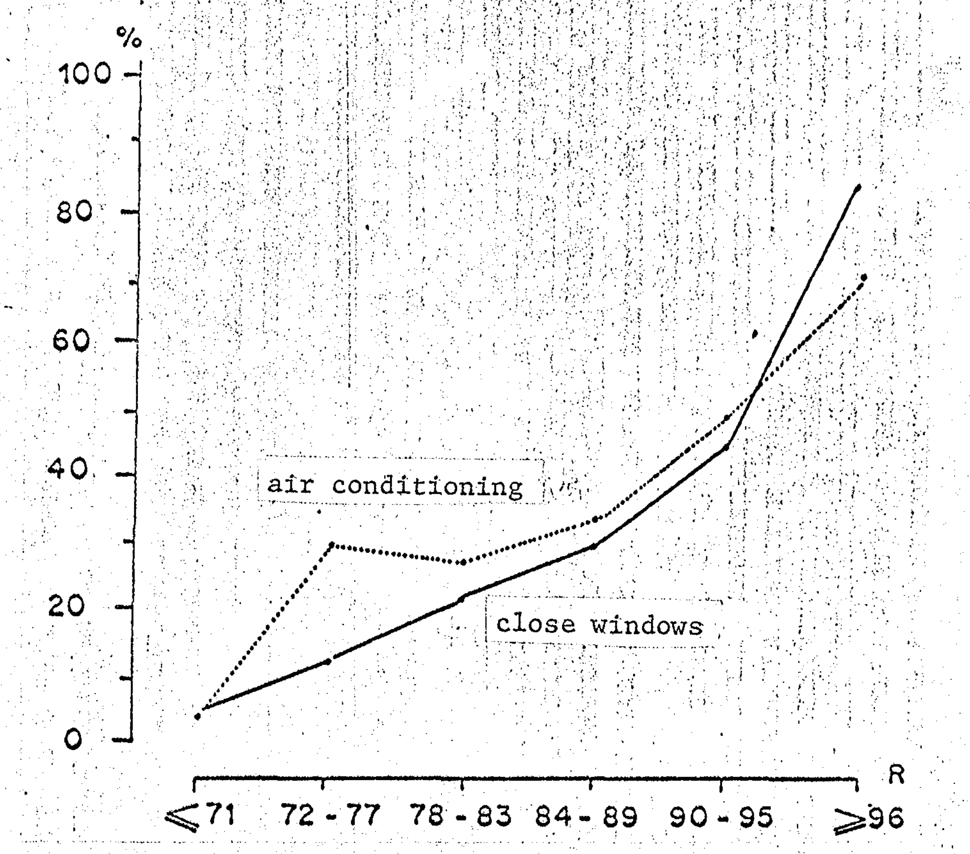


Fig. 22. Closing of windows. Air conditioning.

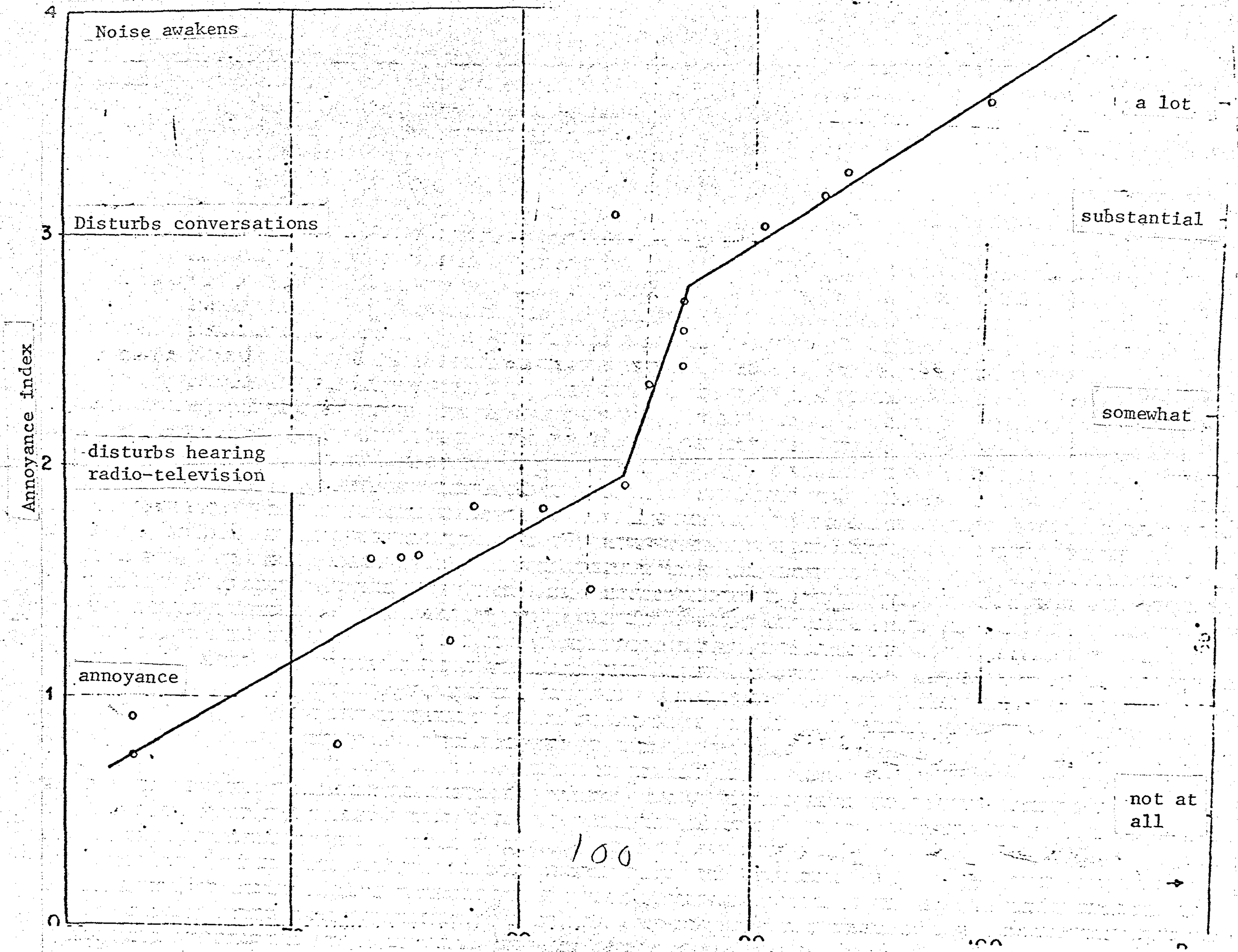
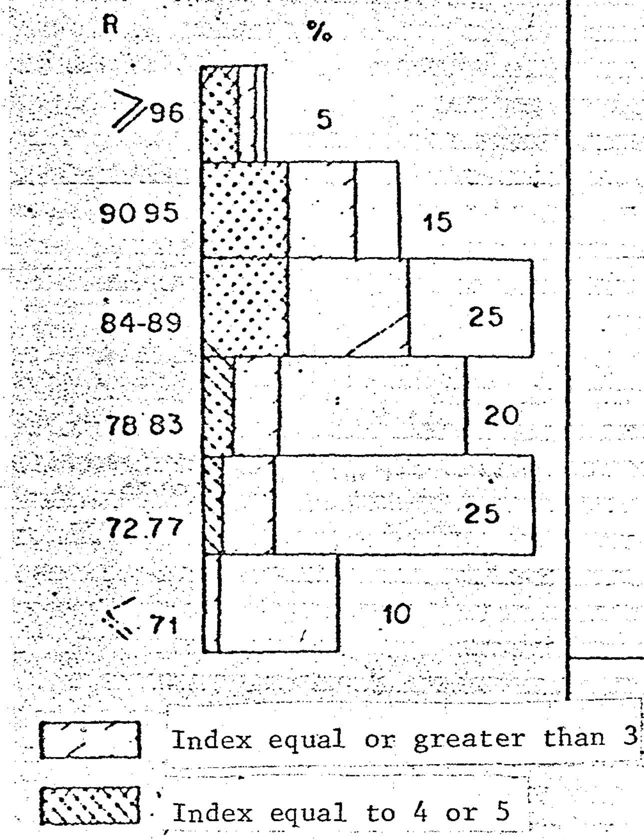


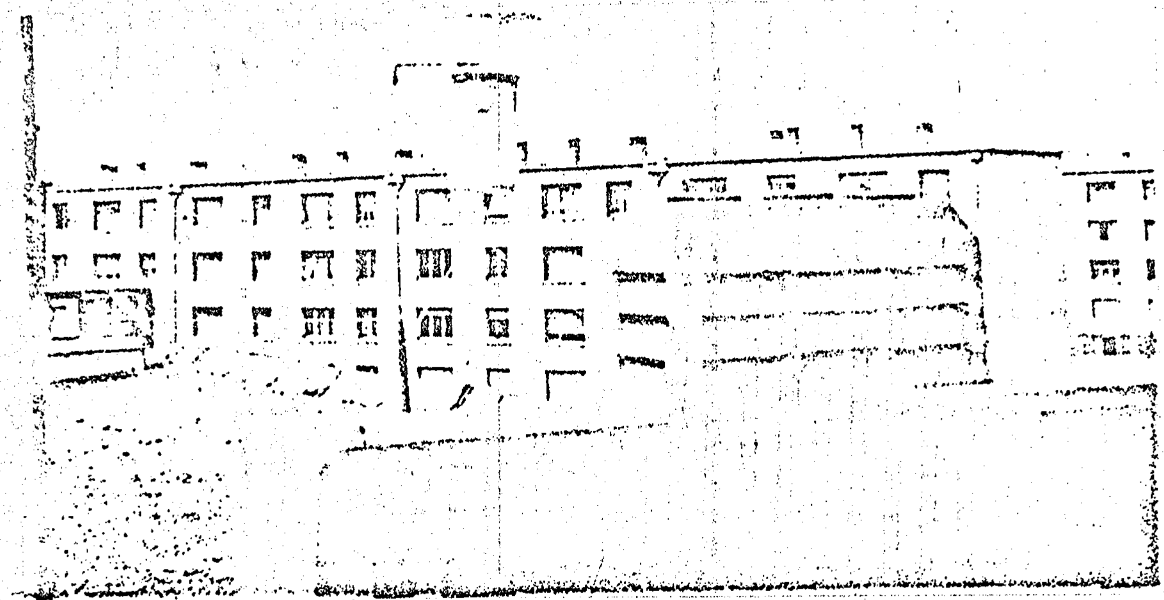
Fig. 23. Variation of annoyance with noise index. Q.17 - Does aircraft noise bother you?



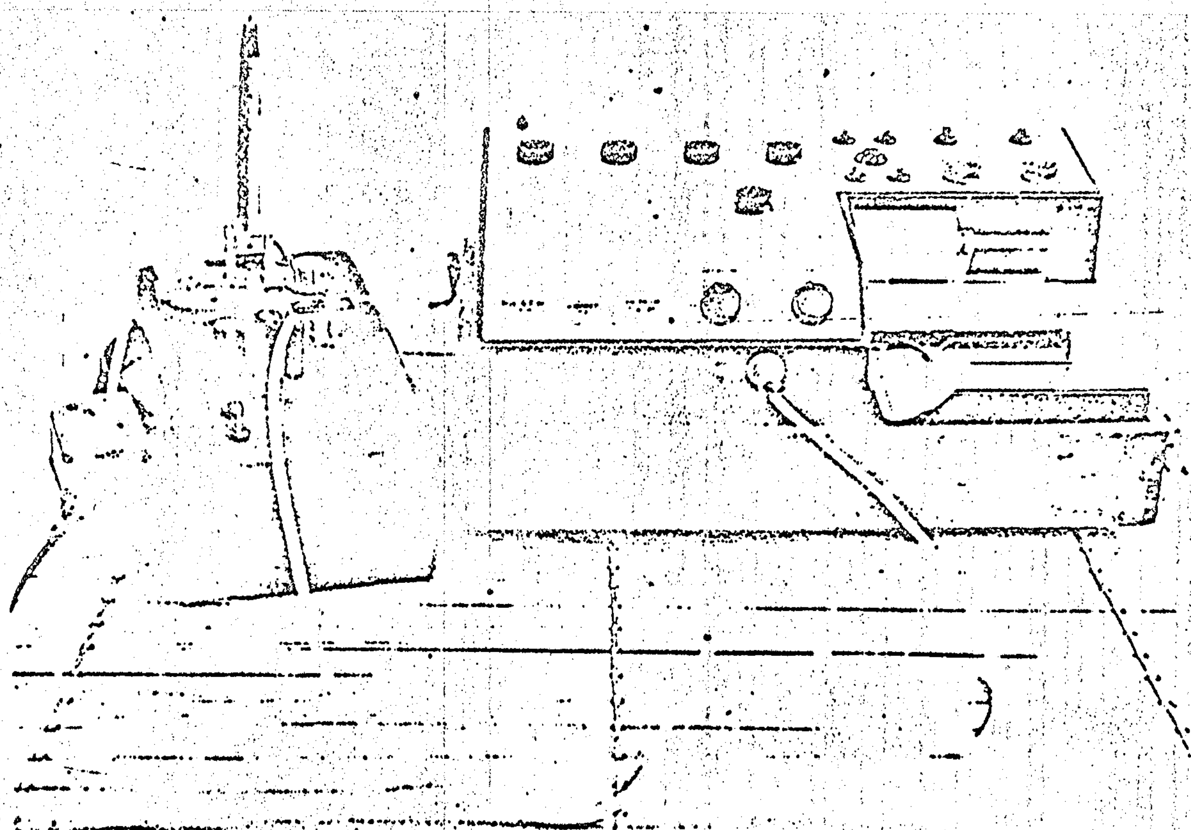
R	% of subjects by acoustic level with respect to total sample	% of indices ≥ 3 by noise class	% of indices ≥ 3 of noise class with respect to total sample	% of indices 4 by noise class	% of indices 4 of noise class with respect to total sample
≥ 96	5	90	5	53	3
90-95	15	78	12	44	7
84-89	25	62	16	26	7
78-83	20	28	6	12	2
72-77	25	21	5	5	1
≤ 71	10	8	1	1,5	0,15
	100 %		45 %		20,15 %

Fig. 24. Distribution of sampling and annoyance indices 3 and 4 as a function of acoustic classes.

/101



/102



Measurement chain:
Sonometer with recorder

APPENDIX NO. 1

SEQUENCE OF MEASUREMENTS

Paris suburbs

Year 1965 - Dates	Town	Address or name of location	Number of stories in buildings on which measurements were made
May 24 and 25*	Garges les Gonesse	Dame blanche	5
June 8 to 11	Stains	Moulin Neuf	5
June 14 to July 5	Chilly-Mazarin	La Voie de Launay (limite de Wissous)	5
June 18 to 28	Morangis	Collège Route de Savigny	1 bâtiment à 3 niveaux à proximité
June 28 to July 5	Paray Vieille Poste (Le Contin)	Avenue Guynemer	4
July 6 to 10	Stains	Les Grignetières (Square Jules Guesde)	5
July 6 to 12	Stains	La Prêtresse	2
July 12 to 21	Longjumeau	Quartier Croix Breton	4
July 12 to 21	Longjumeau	Quartier St-Eloy	5
July 21 to 25	Orsay	Faculté des Sciences	3
July 21 to 25	Orsay	31, Av. St-Laurent	5
July 26 to 29	Villebon	Résidence de Villebon	4
July 27 to 29	Palaiseau	Rue Blaise Pascal	4
Sept. 2 to 10	Massy	Rue Gabriel Péri (route de Chilly Mazarin)	13
Sept. 2 to 10 **	Wissous	Val la Croix	4
Sept. 10 to 20	St-Rémy les Chevreuse	Domaine de St-Paul	3
Sept. 10 to 20	Rungis	Parc	7
Sept. 20 to 27	Villiers s/Orge	Rue Pasteur	4

* Not counting several days where the wind was not the wind which prevails over the year.

** Including several days where the measurement chain did not operate.

APPENDIX NO. 1
(Continuation)

Year 1965 - Dates	Town	Address or name of location	Number of stories in buildings on which measurements were made
Sept. 20 to 27	ST-Michel s/Orge	Près Gare - Limite de Ste-Geneviève	4
Sept. 28 to Oct. 2	Orly	Près Gare S.N.C.F.	11
Sept. 28 to Oct. 5	Gif sur Yvette	(C.N.R.S.)	2
Oct. 6 to 13	Stains	15, rue Victor Ronelle	5
Oct. 6 to 13	Stains	Limite de Sarcelles	15
Oct. 27 to Nov. 2*	Saint Denis	Les Joncherelles (Cité Delaune)	15
Oct. 27 to Nov. 2*	Saint Denis	Rue Paul Eluard	10
Nov. 2 to 10	Asnières	Rue des Champs	4
Nov. 2 to 12	Asnières	Courtilles	5
Nov. 16 to 23**	Epinay s.Seine	Quartier Montgerbaud	10
Nov. 24 to Dec. 5	Argenteuil	Près Gare	4

*Not including several days when the wind was not the wind which dominates over the year.

**Including several days when the measurement chain did not operate.

APPENDIX NO. 1
(Continuation)

MARIGNANE REGION ***

DATES	Towns	Address or name of location	Number of stories in buildings on which measurements were made
Dec. 16 to 30, 1965	Marignane	Parc Camoin	5
Dec. 16 to Jan. 5, 1966	Marignane	Clos St-Pierre	5
Year 1966			
Jan. 5 to 14	Vitrolles le Roucas	H.L.M.	4
Jan. 1 to 20	Saint Victoret	Groupe Cilof près Collège	2
Jan. 18 to Feb. 7	Berre L'Etang	Cabrianne	4
Jan. 20 to Feb. 7	St-Victoret	Clocher	4 équivalent
LYON SUBURBS***			
Feb. 8 to 18	Decinnes	Stade	5
Feb. 8 to 23	Vaulx en Velin	13, Av.Georges Rougé	4
Feb. 22 to Mar. 7	St-Priest	La Cordière	5
Feb. 23 to Mar. 14	Vaulx en Velin	Rue André Chénier	5
Mar. 7 to 21	Vaulx en Velin (coupe Gorge)	Rue Wilson	2
Mar. 14 to 28	Vaulx en Velin (grange perdue)	Usine C.T.A.	2 équivalent
Mar. 21 to April 5	Rillieux	Z.U.P.	16
Mar. 28 to April 6	Meyzieux	Les Plantes	5

***Including the days when the wind was not the dominating wind.

EXAMPLE OF MEASUREMENT TABLE

APPENDIX NO. 2

Time interval	Intervals of acoustic level dB (A) 80/84	85/89	90/94	95/99	100/104	105/109	Number of takeoffs on runway 26 [illegible] reaction	[illegible]	on runway 08 Jet aircraft
0h - 1h				1			1M		
1h - 2h			1					1	
2h - 3h	1	1						2	
3h - 4h									
4h - 5h									
5h - 6h									
6h - 7h	2			2			2M	1	
7h - 8h	2		4	3			2L 5M	1	
8h - 9h	2		4	6			1L 10M	1	
9h - 10h		1	3	5	1		3L 6M	4	
10h - 11h	4	1	2	4		1	3L 4M	4	
11h - 12h	3	1	2	3	1		2L 6M	4	
12h - 13h	2		3	3	1	1	3L 5M	1	
13h - 14h			5	5	1		2L 5M	2	1M
14h - 15h	2	1	3	2	1			1	5L 5M
15h - 16h	1		3	1	1			2	2L 4M
16h - 17h	1		4	1		1		2	3L 3M
17h - 18h	3			2					4L 8M
18h - 19h	2								5M
19h - 20h	3								6M
20h - 21h	3								3M
21h - 22h	2								5M
22h - 23h	6								2L 2M
23h - 24h	3	1							1L 4M

L = long distance
N = medium distance

CHILLY MAZARIN
LES AULNES

27 June 1965

Wind:
North Northeast

No noise point greater than 109 dB (A)

APPENDIX NO. 3 /107

PROCEDURE FOR ELIMINATING OVERFLIGHTS WHICH DO NOT OCCUR ALONG THE PREFERRED AXIS

The procedure for elimination was the following:

a) Paris airport (Le Bourget and Orly)

- If, over a certain number of hours of the day, a rather strong wind prevailed so that aircraft takeoffs could not be made along the preferential axis P, the results recorded during this period were not taken into account. Sometimes the wind changes and takeoffs occur along various runways over the day. In this case, the entire day is eliminated if the number of takeoffs in the nonpreferential direction is equal or greater than 1/3 of the total number of takeoffs.

- If this fraction is not achieved, only the takeoffs not along the preferred axis P are eliminated. Two exceptions were allowed to this rule, in the particular case of measurement carried out at Asnieres and at Epinay.

At ASNIERES- over the measurement period which coincided with a wind period from the North which was rather strong and persistent. The corresponding results for takeoffs to the West were retained, even though the number of flights to the West did not reach 2/3 of the total number of takeoffs. The town of ASNIERES is hardly ever overflown except by long distance aircraft going to Africa, and have to take off from a longer runway (25), that is, to the West.

At EPINAY-, we established that the noise level was at least as large during takeoffs with the wind from the North, using runway 03, as during takeoffs into the wind in the direction West. Therefore, no measurements were eliminated.

b) Marignane Airport /108

The elimination procedure for Berre l'Etang on less representative days compared with the yearly averages the same as before, except for the dominant wind direction, which is the Northwest.

The preferential axis is therefore the Southeast/Northwest direction (runway 32), which is used by about 70% of the aircraft over the year.

It happens very often that takeoffs occur along the axis 32 and landings along runway 14 (even towards the Southeast) on days when the wind is weak, which tends to reduce the annoyance from aircraft noise around Marignane.

The exception to this rule is Saint-Victoret (2 measurement points) where the perceived noises on the one hand are:

- extended noise from the dominant wind (North), i.e., noises from takeoff to the North, the noise from overflights (training on Boeing 707) and landing noise in the North direction (except when the wind is nonexistent).

This occurs 250 days per year, approximately.

- Also, the noise which is extended to the South by the wind, for about 115 days per year, i.e., the takeoff noise and the Saint Victoret (CILOF) overflight noise. We combined the average of 19 measurement days (10% of wind from the South only) with the average of the days when takeoffs to the South were recorded.

At Saint Victoret (church), it was sufficient to take the average of 18 measurement days (1/3 wind to the South).

In the two cases, we find a quadratic mean of 98 dB (A), but /109
with a slightly different number of passes.

For the localities Marignane City (2 measurement points) and Vitrolles le Roucas, we made no eliminations at all. The extended noise level and its frequency did not depend on the wind direction.

c) Lyon Bron Airport

The same elimination procedure was used as for Berre L'Etang (dominant wind from the North), except for St- Priest (Isere).

The extended noises at St-Priest are:

- the landing noises to the North, the training overflight noise for Boeing 707s, and also the takeoffs to the North, when the Wind is weak or coming from the North (about 250 days per year).

The noise is characterized by a quadratic mean (of peaks) of 86 dB (A), with 11 points per day.

- On the other hand, for about 115 days per year, the takeoff noise is to the South and aircraft passes. The noise is characterized by a quadratic mean of the peaks of 91 dB (A) with 15 points per day.

The combination of the quadratic energies gives 89 dB (A) with 12 points per day.

APPENDIX NO. 4 /110

MODEL OF THE QUESTIONNAIRE WHICH WAS USED BY THE APPLIED ANTHROPOLOGY RESEARCH AND STUDY CENTER

SOCIOLOGICAL STUDY ABOUT LIVING CONDITIONS IN THE NEIGHBORHOOD

1 - Address:

....	1	....	6
....	2	....	7
....	3	....	8
....	4	....	9
....	5	....	10

Building: Stairs:

Door Floor:

2 - Sex: Man .... 1 Woman 2

3 - Age:

20 to 24	1	45 to 49	6
25 to 29	2	50 to 54	7
30 to 34	3	55 to 59	8
35 to 39	4	60 to 64	9
40 to 44	5	65 and over	10

4 - Profession of the subjects (or the head of the family) /111

Farmer	1	Businessman	6
Manual labor	2	Employee	7
Qualified worker	3	Lower echelon	8
Technician	4	Higher echelon	9
Craftsman	5	Liberal professions	10

5 - Number of children living in the apartment?
- Less than 5 years
- 5 to 10 years
- 11 to 15 years
- 16 to 20 years

6 - How long have you been living here:
- Less than 6 months 1
- 6 mon. to 2 years 2
- More than 2 years 3

7 - Do you like this neighborhood?

Yes........... 1 Moderately ...... 2 No 3

8 - Are there things you do not like here or which are not proper here?

Yes....... 1 No....... 2

9. If yes, what are they?

10 - Are you satisfied with living in this neighborhood? /112

Yes........... 1 No.......... 2

11 - Are you satisfied about the following:

(Yes - No)

- the merchants.................. 1
- public transportation......... 2
- proximity to work-place....... 3
- entertainment.................. 4
- neighbors...................... 5
- noise.......................... 6

12 - If you could change one of the things you have mentioned, which one would you change? (same numbering as in Q.11)

13 - Do you like it here as much as in the beginning:

More..... 1 The same..... 2 Less..... 3

14 - Have you ever thought of moving?

Yes....... 1 No....... 2

15 - Why?

16 - Which noise is noisier than most?

- road traffic 1
- aircraft......................... 2
- noises inside the building..... 3

17 - Does aircraft noise bother you? /113

A lot........... 1 Somewhat........... 3

Quite a lot..... 2 Not at all......... 4

18 - Does aircraft noise do the following to you:

(No.... 1 Sometimes.....2 Quite often.....3)

a) stops you from falling asleep

b) wakes you up

c) disturbs you when you listen to the radio or look at television

d) makes the house shake

e) makes you jump

f) disturb your conversations

g) disturbs you at other times and in other ways

19 - Does aircraft noise bother you more this year than last year?

Yes...... 1 No........ 2

20 - Do you sometimes escape to certain rooms in order to get away from aircraft noise?

Yes...... 1 No........ 2

21 - If yes, into which room?

Living room......... 1 Patio room 3

Kitchen............. 2 Street room.......... 4

Other................ 5

22 - How many aircraft do you hear over 24 hours? /114

More than 5........ 1 41 to 79............. 4

6 to 15............ 2 80 or more........... 5

16 to 40........... 3

23 - At what times are you disturbed the most by aircraft:

Daytime .... 1 Night 2

(Night: from the time one extinguishes the light until the time one gets out of bed)

24 - Over the day, you are disturbed more and more when you do one of the following?

Listen to radio, TV...	1	Study, intellectual work...............	4
Conversation..........	2	Rest.................	5
Reading...............	3	Other................	6

25 - Are your children disturbed by aircraft noise?

Yes.......... 1 No........... 2

26 - Do they become more nervous because of aircraft noise?

Yes.......... 1 No........... 2

27 - Does aircraft noise disturb you more during any particular part of the year?

Yes.......... 1 No........... 2

28 - If yes, when?

Spring.......	1	Autumn.......	3
Summer.......	2	Winter.......	4

29 - Do you sometimes close the windows in order not to hear aircraft?

Yes......... 1 No.......... 2

30 - Would you like to have your apartment air conditioned so as to not hear aircraft?
(windows permanently closed, but the same pure air as though they were open)

Yes......... 1 No......... 2

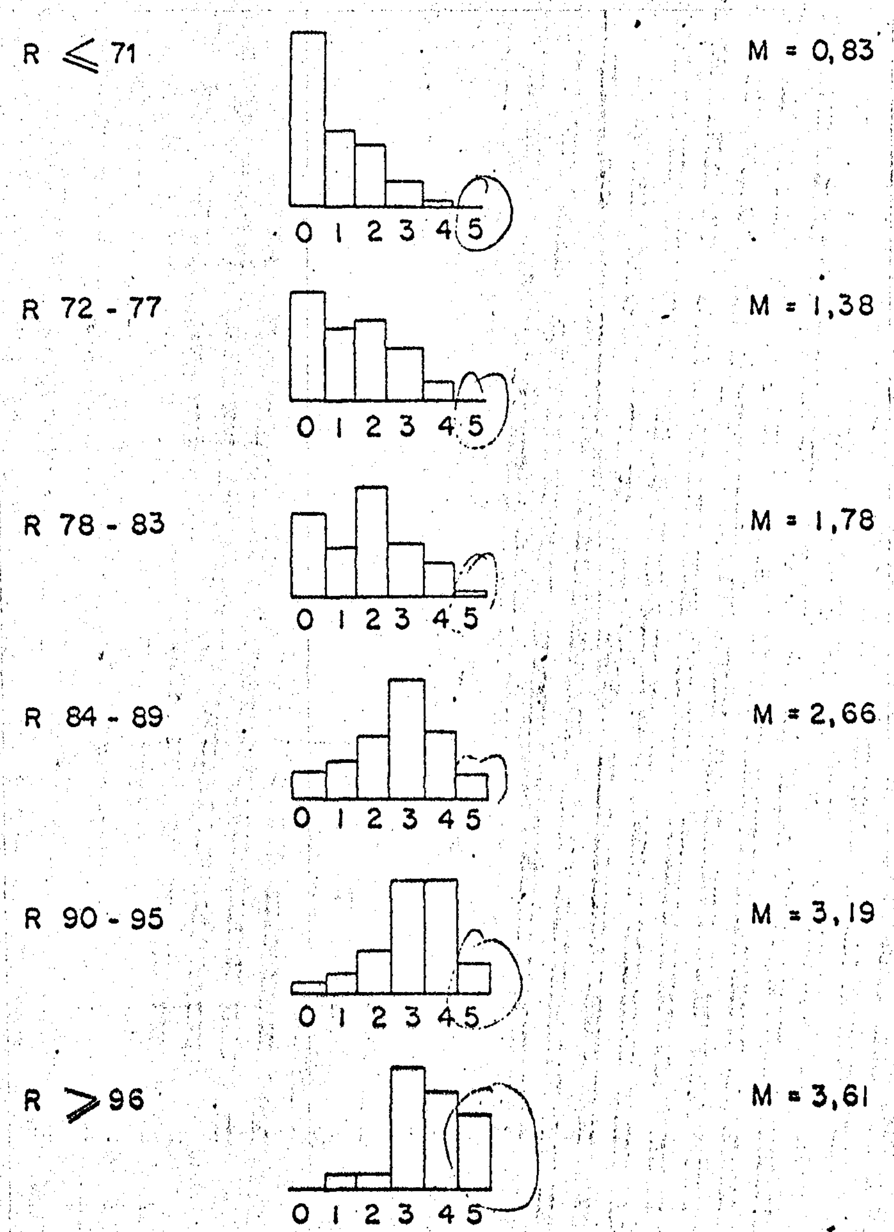
APPENDIX NO. 5

CONFIDENCE INTERVALS (+ 1.65 σ)
(upper and lower limits, in round numbers which have 9 chances in 10 of not being exceeded).

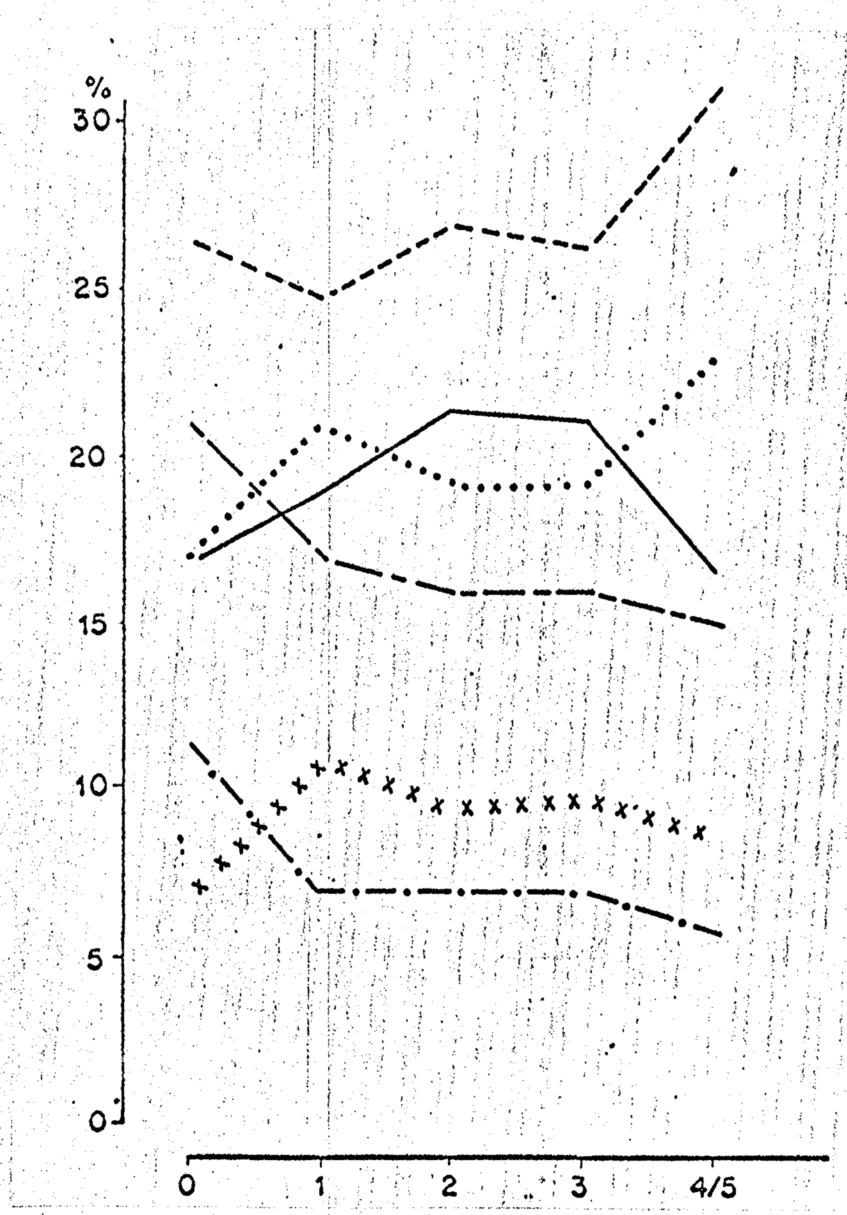
EFFECTIVENESS	PERCENTAGES										
	5	10	20	30	40	50	60	70	80	90	95
100	2	6	14	23	32	42	52	63	74	86	92
	8	14	26	37	48	58	68	77	86	94	98
200	3	7	16	25	35	45	55	65	76	87	93
	7	13	24	35	45	55	65	75	84	93	97
300	3	8	17	26	36	46	56	66	77	88	93
	7	12	23	34	44	54	64	74	83	92	97
400	4	8	17	27	36	46	56	67	77	88	94
	6	12	23	33	44	54	64	73	83	92	96
500	4	8	18	27	37	47	57	67	78	88	94
	6	12	22	33	43	53	63	73	82	92	96
600	4	8	18	27	37	47	57	67	78	88	94
	6	12	22	33	43	53	63	73	82	92	96
700	4	9	18	28	37	47	57	68	78	89	94
	6	11	22	32	43	53	63	72	82	91	96
800	4	9	18	28	38	48	58	68	78	89	94
	6	11	22	32	42	52	62	72	82	91	96
2000	5	9	19	29	39	49	59	69	79	89	95
		11	21	31	41	51	61	71	81	91	

APPENDIX NO. 6

DISTRIBUTIONS OF ANNOYANCE INDICES BY ACOUSTIC CLASSES



ANNOYANCE INDEX BY PROFESSION



____ . ____ Specialized workmen tasks ___.___ Craftsmen, businessmen
---------- Qualified workers ________ Employees
.... Technicians, medium level x x x x Higher level professionals

APPENDIX NO. 8

WHAT DISPLEASES YOU IN THE NEIGHBORHOOD (Q.9)

The responses were highly varied and were grouped into 12 classes:

1 - Commercial (expensive, far away ...)

2 - Transportation (poor)

3 - Amenities of the neighborhood (paths, to my satisfaction, trimmed trees, external lighting, electrical outages, poorly-maintained roads, no sidewalks, garbage disposal, unsightly terrain, one-way roads, red lights, playgrounds, squares, gardens, telephone).

4 - Buildings (responses about the building itself : parking spaces, expensive rent, condition of the building, etc.).

5 - Aircraft (noise from aircraft and helicopters).

6 - Noise in general (internal noise, road noise, train noise and undefined noise).

7 - Proximity (people in the surroundings, crying children, mentality of neighbors, shanty towns, dirty people, life in general, dirty block of houses).

8 - Isolation (far away from everything: work, merchants, police, post office, except for schools).

9 - Entertainment (dancing, movies, sports, social facilities).

10- Schools (no lunchroom, no high school, no child care, far away from the schools).

11 - Not a pleasant area (monotonous, too many people, too quiet, not pretty, life is not gay). /120

12 - Various factors (kerosene odor, dust, car and heavy truck traffic, no work for women, hills to climb, wind, humidity, new construction closing in, expensive living costs).

These responses came from 59% of the subjects, 41% complained about nothing.

40% mentioned a single item of discontentment,
16% mentioned two causes of discontentment,
3% mentioned three causes of discontentment.

The figure shown in the report was established for the first cause of displeasure mentioned (see the following page giving the table of percentages of responses).

PERCENTAGE OF RESPONSES (first cause mentioned)

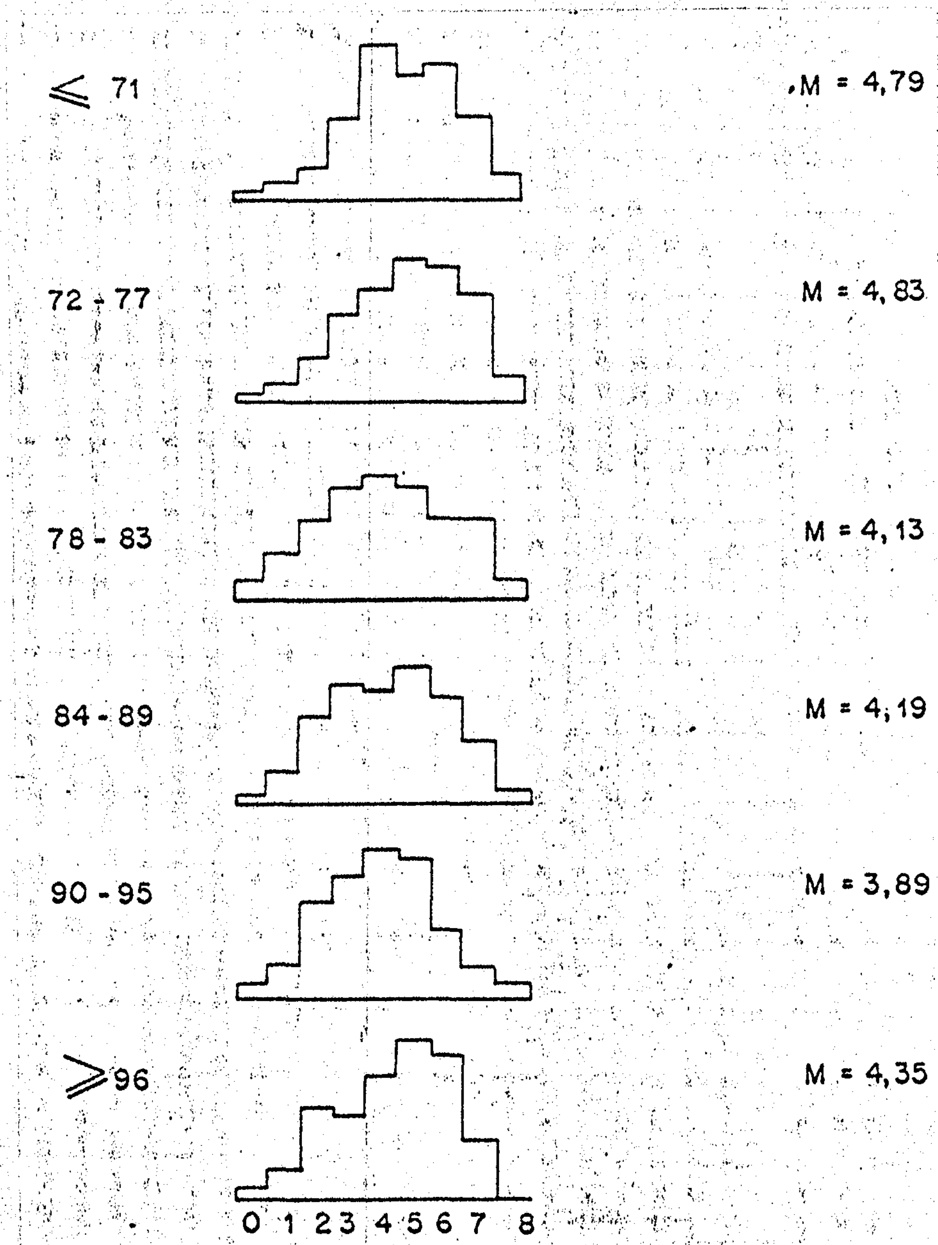
FOR THE ENTIRE GROUP AND BY AIRPORT (all zones)

Cause of displeasure	Total group	Orly	Le Bourget	Marseille	Lyon
Merchants	17	22	13	8.5	17
Transportation	11	13	11	4	9
Neighborhood facilities	6	6	4	8	7
Building	5	5	9	2	5
Aircraft noise	4	7	1	8.5	0.5
Noise (undefined)	4	4	5	5	3.5
Vicinity	3	2	4	4	4
Isolation	3	3	2	4	5
Entertainment	1	1	0	1	1
Schools	1	1	1	2	1
Area	1	2	0	1	0.5
Various	2	1	1	2	1.5
No responses	42 (1)	33	49	50	45

(1) - 1% of the subjects responded "YES" to question 8: "Are there things you do not like here?" and were not able to mention any specific thing.

APPENDIX NO. 9

Distribution of satisfaction indices by acoustic class



APPENDIX NO. 10 /123

ACOUSTIC ISOLATION

I) Definition

1) In the following we will call the acoustic isolation D of an inhabited building with respect to aircraft noise the difference between the noise level which would be measured outside in free space (with the exception of the ground) and the noise level measured inside when an aircraft of the Caravelle type passes in the symmetry plane of the facade (after reduction) and is viewed at an angle of about 45^{o} (with the horizontal).

The noise levels are always expressed in PNdB or in dB (A). The building is assumed to have the following:

- a volume of 34 m^3
- a reverberation period of 0.5 seconds
- a traditional brick facade with a 2 m^2 window.

The noise is assumed to only pass through the facade.

2) By "window with improved air sealing," we mean a window such that when there is a 100 Pascal pressure between the outside and the room, the air flow rate is larger or equal to 12 m^3/h m^2.

The "windows with normal air sealing" are defined in the same way, and the limiting flow rate is 60 m^3/h m2

II) Examples of acoustic isolations /124

Taking into account the studies mentioned at the end of the

Appendix as well as those now in progress at the C.S.T.B. laboratory, we established, on the average, that the acoustic isolation of inhabited apartments is the following:

1) Room for which the window is half open (a pane is open by about 10 cm).

D = 10 dB

2) Opening window equipped with 2.9 to 4.8 mm thick panes.

improved sealing	D = 27 dB
normal sealing	D = 25 dB

3) Opening window equipped with thick glass (eligible) 5.5 mm thick.

improved sealing	D = 29 dB
normal sealing	D = 25 dB

4) Sealed windows with panes 10 to 12 mm thick.

D = 29 dB

5) Opening window with double glass (2.9 to 5.5 mm thick panes spaced by 10 mm of air)

improved sealing D = 25 dB

6) Double windows which open, with 2.9 to 5.5 mm thick panes with a spacing of 10 cm between the panes.

improved sealing D = 38 dB

7) Double windows which open, with 2.9 to 5.5 mm thick panes, with a spacing of 20 cm between panes. /125

improved sealing D = 48 dB

Remark 1

Since the characteristics of the facade and the room differ from those indicated in paragraph I, there is reason to introduce a correction using the general laws of acoustics.

Remark 2

The preceding data can be modified as a function of the results now in progress at C.S.T.B.

III) The origins of the preceding examples

The isolations were determined from measurement results contained in the following:

1) Sound insulation measurements on windows and cavity brick walls by G. H. Aston.

Report of the 1948 summer symposium of the acoustics group.

2) Sound insulation of windows by R. M. Woolley

Current papers No. 64 B.R.S.

3) The sound attenuation of glasses and glass coverings by A. Eisenberg.

1st part, single panes, which appeared in glastechnische Berichte No. 297, Aug. 1958. /126

2nd part, double pane windows, which appeared in glastechniche Berichte No. 544, Nov. 1961.

4) C.S.T.B. (measurements in progress, not published).

IV) Other studies concerning the transmission of noise by windows:

1. J. von den Eijk and M. L. Kasteleyn

   IS measurements of noise transmission by windows which appeared in Technisch Physische Dienst T.N.O. at T.H. No. 35, March 1952.

2. Blocking action of glass windows which appeared in glasforum No. 3 - 1967.

APPENDIX NO. 11 /127

REQUIREMENTS PROPOSED FOR VENTILATION AND THERMAL COMFORT

In order to enhance the sonic protection of windows, it is now necessary to close them. In order to satisfy the requirements for pure air and thermal comfort, it is appropriate to take all or some of the following precautions, depending on how serious the problem is.

1) - Solar protection of glass enclosed areas

In all cases, it is appropriate to provide for external solar protection, with a solar factor equal to at least 0.15 (see the definition of this characteristic in the paper of C.S.T.B. No. 608, delivery 72).

2) - Flexibility of heating

In order to avoid that the occupant has to open windows in order to relieve overheating conditions during the intermediate season, the following is appropriate:

- to always reject installations with a large inertia /128
  and especially those where the total heating capacity is provided by the concrete floor;

- if possible, have an installation which allows a regulation using the facade;

- in extreme cases, to provide for a very flexible installation with the possibility of regulation for each room.

3) - Supply of ventilation air

The direct air intake in the facade is prohibited.

In most cases it is appropriate to provide for a mechanical supply of air:

- the air inlets will be located in the main rooms and living room;

- the air will be supplied mechanically using conduits, from one or several air external intakes not situated along the sun-exposed facade;

- the flow rate will be controllable between one times the volume of the room (normal flow rate in order to provide air purity) and four times the volume approximately (flow rate required for providing comfort in summer) in only the sun-exposed rooms;

In less serious cases, one can do the following:

- provide mechanical air supply in only one part of the main rooms, those which have the poorest acoustic exposure and thermal exposure (West and South);

- provide a natural equivalent system if the plan allows it.

4) - Extraction of ventilation air /129

It will always be good, but not absolutely necessary, to provide mechanical removal of polluted air from service rooms: kitchen, laboratory, toilet.

5) - Inertia of the construction design

The comfort in summer will become more difficult to provide for, the smaller the inertia of the building. Therefore, it is more important to follow the precautions given above, the lower this inertia is. In document No. 608 of the C.S.T.B., series 82, we find information about this concept of inertia.

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NAME	DATE	MS
Jerry Pierce	10/30/92 12/17/92	

NASA Langley (Rev. Dec. 1991) RIAD N-75