Report on:

HEALTH ASPECTS OF SMOKING IN TRANSPORT AIRCRAFT

December 1971

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
HEALTH SERVICES AND MENTAL HEALTH ADMINISTRATION
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

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ACKNOWLEDGMENT

The National Institute for Occupational Safety and Health wishes to thank those who assisted in the design, conduct, and analysis of this study including the Department of the Air Force, the Military Airlift Command, and the Air Transport Association.

HEALTH ASPECTS OF SMOKING IN TRANSPORT AIRCRAFT

ABSTRACT

A study of the health aspects of smoking in transport aircraft was conducted jointly by the Federal Aviation Administration, Department of Transportation, and the Bureau of Occupational Safety and Health, Environmental Control Administration, Public Health Service, Department of Health, Education, and Welfare*. The purpose of the study was to define the levels of certain combustion by-products of tobacco produced by passengers' smoking; to determine passengers' subjective reaction to tobacco smoke; and to obtain passenger opinion on the need for regulatory change regarding the control of smoking in commercial passenger airplanes.

The study involved (1) the collection of samples to determine the environmental exposure levels to carbon monoxide, particulate matter, polynuclear hydrocarbons, ammonia, and ozone, and (2) the use of a questionnaire during twenty Military Airlift Command (MAC) international flights and eight domestic flights.

The results of environmental sampling revealed very low levels of each contaminant measured, much lower than those recommended in occupational and environmental air quality standards.

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*This Bureau is now a part of the National Institute for Occupational Safety and Health, Health Services and Mental Health Administration, Public Health Service, Department of Health, Education, and Welfare.

These combustion products were judged not to represent a hazard to the nonsmoking passengers, based on environmental levels and expected dosage-response relationships of contaminants. However, an evaluation of the results of the questionnaire indicated that a significant proportion of the nonsmokers (over 60%) were bothered by tobacco smoke and suggested that corrective action be taken such as segregation of the smokers. Furthermore, over 70% of the nonsmokers who had history of respiratory conditions expressed annoyance by tobacco smoke.

HEALTH ASPECTS OF SMOKING IN TRANSPORT AIRCRAFT

I. INTRODUCTION

The Problem

The public's concern with air pollution has recently manifested itself in an increasing number of complaints about smoking in aircraft as a potentially harmful source of pollution in confined spaces. That this subject of smoking in aircraft has assumed critical importance is confirmed by the large number of complaints received by the Federal Aviation Administration (FAA), the Public Health Service (PHS), and the airlines. Several of these complaints have been referred to the FAA and the PHS by the White House and by members of Congress.

Passengers have alleged that on some flights the levels of tobacco smoke in aircraft cabins are of such concentrations as to be not only annoying, but also harmful to health. Some aircraft passengers have contended that cabin smoke may even compromise air crew flight performance. In addition to passenger comments, malfunctioning of delicate instrumentation, resulting in more frequent repairs, has been attributed to tobacco smoke, and it has been reported that particulate matter from burning tobacco has caused pressure control valves to malfunction, resulting in decompression of aircraft. The adverse effects of tobacco smoke as an air pollutant, generally, are outlined in an editorial in Science, December 22, 1967.

Possibly contributing to the problem is the increased and extended delays in departure because of the congested air terminal situation as usually passengers are permitted to smoke during this "wait" time.

Background Information

During February 1968, H. L. Reighard, M.D., Acting Federal Air Surgeon, FAA, wrote to William H. Stewart, M.D., Surgeon General, PHS, outlining the problem arising from cigarette smoking on commercial airlines and requesting information regarding the actual or possible threat to the health of nonsmokers from the smoking of others. The Surgeon General requested Daniel Horn, Ph.D., Director, National Clearinghouse for Smoking and Health (NCSH), to reply. Dr. Horn in his reply stated, "We have long known that many nonsmokers are made uncomfortable by tobacco smoke, some to the point of allergic-type reaction and subsequent illness. However, we know of no evidence that such exposure has a direct harmful effect on health in any other way." He concluded, "My own feeling is that a field test of the contamination in the air in such flights is in order, and that consideration should be given to establishing regulations that would minimize the discomfort and the hazard that results from other people's cigarette smoke."

On March 13, 1968, a meeting to discuss the problem was attended by Dr. Daniel Horn and Mr. Robert S. Hutchings of the NCSH, and Dr. Cierebiej, and Mr. Edwin A. Richardson, FAA. It was concluded that no accurate data presently exist as to concentrations in aircraft cabins of toxic materials emanating from burning tobacco. P. V. Siegal, M.D., Federal Air Surgeon, FAA, summarized information from the meeting and provided other information in a letter dated March 25, 1968, (signed by Dr. Reighard) to Senator Magnuson.

On March 27, 1968, Mr. Hutchings, NCSH, in Dr. Horn's absence, submitted a report expanding on the March 26th letter and including recommendations for future action by PHS in regard to cigarette smoking on commercial airlines. The points covered in his report included:

1. Increasing complaints are being received. Congressional interest has been expressed by Senator Magnuson and public interest, by Ralph Nader.
2. Complaints are likely to increase as the proportion of nonsmokers is increasing and larger aircraft are being put in service.
3. The position of the NCSH is that for too long the "rights" of smokers have abridged the rights of nonsmokers.
4. There are, as far as is known, no federal and few State regulations about air quality in public transportation.
5. The FAA believes that no hazard to health exists as a result of cigarette smoke in aircraft; however, it would appreciate PHS assurance on this point.

6. The FAA is concerned about the nuisance and discomfort from cigarette smoke and is particularly concerned in view of the much larger passenger planes in planning or construction stages.

7. The FAA realizes that it has neither the criteria for, nor the knowledge of, air quality encountered in aircraft. The FAA is desirous of cooperating with the PHS to acquire such information, but does not itself possess the personnel nor the sophisticated equipment to monitor the air quality.

It was recommended that a letter from R. A. Prindle, M.D., Director, Bureau of Disease Prevention and Environmental Control (BDPEC), PHS, be sent to Dr. Reighard suggesting a limited program for monitoring air quality presently found on commercial airlines. An offer was submitted to establish a procedure for providing personnel and equipment for a collaborative study.

Early in April 1968, Mr. Clyde B. Eller, Interstate Carrier Section, National Center for Urban and Industrial Health (NCUIH), BDPEC, visited the FAA office and expressed an interest in the matter of smoking in aircraft and the need for field tests for health evaluations.

On September 6, 1968, Dr. Reighard received a call from the Office of the Secretary of Transportation inquiring about the status of the studies to be made on smoking in aircraft.

The entire problem of smoking in aircraft was reviewed at a meeting of PHS and FAA representatives in Cincinnati, Ohio on September 20, 1968. The possible harmful effects on crew members, passengers, and instrumentation were discussed. It was the consensus of the group that tests must be made in aircraft cabins to determine the amount of smoke produced and the toxic contents of such smoke. It was agreed that: (1) the instrumentation and analytical service and the necessary technical and medical staff to conduct the study would be supplied by the PHS; (2) the cost of per diem would be supported by the respective agencies; (3) all air transportation expenses would be absorbed by FAA or the airlines; and (4) since such a study would require the cooperation of the various commercial airlines, such cooperation could best be achieved through arrangement with the industry association, the Air Transport Association (ATA).

II. OBJECTIVE OF THE STUDY

The principal objectives of the study were: (1) to measure the levels of environmental contaminants resulting from tobacco smoking by passengers during flight of commercial transport aircraft and (2) to obtain from the passengers information about their smoking history and their reaction to passenger smoking.

The ultimate goal of the study was to develop a more complete understanding of the contaminant build-up during flight and to ascertain passenger opinion regarding possible action to control or eliminate smoking aboard commercial transport aircraft.

The results of the study are to be used in considering the need for establishing regulations that would minimize passenger discomfort and possible health hazards that may result from tobacco smoking during air-flight.

III. METHODOLOGY

The study was conducted jointly by the Federal Aviation Administration and the Environmental Control Administration, Department of Health, Education, and Welfare (see Appendix A: "Agreement Between Federal Aviation Administration and Department of Health, Education, and Welfare.") It was decided to conduct the initial phase of the study in commercial transport aircraft under contract to the Military Airlift Command (MAC) because of the (1) high passenger density, (2) length of the flights, and (3) possibility of a higher percentage of smokers.

Twenty MAC flights were involved in the initial phase, representing overseas flights to both Europe and Asia. (See Table 1.)

It was originally planned to measure carbon monoxide in the blood and breath of a representative sample of passengers aboard each flight. However, after considerable deliberation, it was decided that this aspect of the study was impractical. Thus, it was eliminated from the protocol on the basis that valid scientific results would not be possible. This was primarily due to the lack of appropriate study design controls that would be required and to the difficulty of obtaining sufficient numbers of passengers willing to contribute blood samples. In order to attribute the measured blood and/or breath carbon monoxide levels to the tobacco smoke inhaled during the flight, it would be necessary to determine the CO levels for each passenger before the flight. Since the MAC passengers were required to report to the airport only about two hours in advance of the flight, it was judged to be logistically not feasible to obtain pre-flight data on a significant number of passengers. Also, these measurements would be practically impossible to accomplish on domestic flights. **For similar logistical reasons, pulmonary function testing of passengers with a history of asthma was not attempted.**

Table 1

Military Airlift Command Flights

Test No.	Aircraft Type	Date	Origin	Destination	Flight Duration Hr:Min.
1	B-707	1/23/70	Travis	Yokota	10:45
2	B-707	1/29/70	Yokoto	Travis	10:15
3	B-707	2/15/70	Travis	Yokota	11:15
4	B-707	2/19/70	Yokota	Travis	11:10
5	DC-8	6/6/70	Travis	Yokota	11:00
6	DC-8	6/13/70	Yokota	Travis	10:50
7	B-707	8/17/70	McGuire	Rhein Main	8:30
8	B-707	8/22/70	Rhein Main	McGuire	9:25
9	DC-8	8/25/70	McGuire	Rhein Main	8:15
10	DC-8	8/30/70	Rhein Main	McGuire	9:00
11	B-707	9/16/70	McGuire	Rhein Main	8:30
12	B-707	9/23/70	Rhein Main	McGuire	9:15
13	DC-8	9/28/70	McGuire	Rhein Main	8:45
14	DC-8	10/3/70	Rhein Main	McGuire	9:20
15	DC-8	11/5/70	McGuire	Lakenheath	7:50
16	B-707	11/11/70	Lakenheath	McGuire	8:40
17	DC-8	11/18/70	McGuire	Lakenheath	8:00
18	DC-8	11/22/70	Lakenheath	McGuire	8:30
19	B-707	12/4/70	McGuire	Torrejon	8:00
20	B-747	12/14/70	Madrid	New York (Commercial Flight)	7:00

McGuire AFB, New Jersey
Travis AFB, California

Lakenheath AFB, England
Rhein Main AFB, Germany
Torrejon AFB, Spain
Yokota AFB, Japan

Eight domestic flights were involved in the second phase, representing flights of various lengths and passenger density (see Tables 2 and 3).

Table 2

Domestic Airline Flights

Test No.	Aircraft Type	Date	Origin	Destination	Flight Duration Hr.:Min.
1-a	737	6/7/71	Washington	Chicago	1:20
1-b	737	6/7/71	Chicago	Des Moines	:45
2-a	737	6/7/71	Des Moines	Chicago	:45
2-b	737	6/7/71	Chicago	Washington	1:25
3-a	727	6/9/71	Cincinnati	New York	1:31
3-b	727	6/9/71	New York	Boston	1:00
4-a	727	6/9/71	Boston	New York	:45
4-b	727	6/9/71	New York	Cincinnati	1:31
5	DC-9	6/11/71	Cincinnati	New York	1:30
6	DC-9	6/11/71	New York	Cincinnati	1:39
7-a	BAC-111	6/15/71	Cincinnati	Washington	1:16
7-b	BAC-111	6/15/71	Washington	Boston	1:01
8-a	727-S	6/15/71	Boston	Washington	1:09
8-b	727-S	6/15/71	Washington	Cincinnati	1:04

Note: a and b numbers indicate intermediate stops with passenger changes.

Table 3

Passenger Density

Test No.*	Aircraft Type	Total Number Seats	Number of Seats Filled	% Capacity
		MAC FLIGHTS		
1 thru	DC-8 (9)**	219	219	100
20	707 (10)**	165	165	100
	747 (1)**	-	-	-
		DOMESTIC FLIGHTS		
1-a	737	88	35	39
1-b	737	88	27	34
2-a	737	88	57	65
2-b	737	88	51	58
3-a	727	93	66	71
3-b	727	93	57	61
4-a	727	93	51	55
4-b	727	93	65	70
5	DC-9	66	40	61
6	DC-9	66	61	92
7-a	BAC-111	63	51	81
7-b	BAC-111	63	39	62
8-a	727 Stretch	128	113	88
8-b	727 Stretch	128	110	86

*Note: a and b numbers indicate intermediate stops with passenger changes.

**Note: Number in parenthesis is number of planes.

Environmental

In the initial FAA/HEW working agreement, it was stated that "Carbon monoxide will be measured with a continuous carbon monoxide indicator and recorder. Polycyclic aromatic hydrocarbon components, aldehydes, and ketones will be sampled using a battery operated pump and appropriate collection devices. In addition, particulates will be sampled for gravimetric analysis on a membrane filter. Oxides of nitrogen and sulfur products may also be collected."

Equipment for the evaluation of airborne contaminants was required to be portable and self-contained. The selection of equipment to measure carbon monoxide concentrations was therefore reduced to three potential units, the infrared analyzer, the carbon monoxide indicator, and carbon monoxide detector tubes.

The infrared analyzer is accurate and sensitive; however, after extensive testing on an FAA aircraft, it was eliminated because of its size, its power requirements, and the effect of vibration on its performance. The carbon monoxide indicator and associated recorder operate continuously, but preliminary use in aircraft in the initial stages of the investigation proved it to be not sensitive enough to measure and record the low ambient concentrations (less than five parts per million). Therefore, carbon monoxide detector tubes, utilizing length-of-stain as the indicator of concentration, were used on all of the flights. Laboratory tests indicated that if samples were collected at a low volume for a long period of time, reproducible results could be obtained. A small battery-operated pump was used to move air being sampled through the tube at a constant uniform flow rate. It was recognized that in using detector tubes, measured concentrations may vary ±25 percent from the true value. Nonetheless, because of the low concentrations encountered, an error of even ±50 percent would not significantly affect the conclusions drawn from the results. In higher concentrations, detector tubes would not be as acceptable.

Hydrocarbons existing in the vapor phase (aromatic hydrocarbons, aldehydes, and ketones) were collected on activated charcoal. The collecting device consisted of a straight glass tube six inches by four millimeters, inside diameter, packed with two one-inch sections of activated charcoal, which are separated from each other and the tube ends by fiber glass plugs. The ends of the glass tubing were flame sealed until used. As with CO, a small battery-operated pump was used to move the air being sampled through the tube at a constant uniform flow rate.

The charcoal tube samples were analyzed utilizing a gas chromatographic technique (see Appendix B). The following hydrocarbons can be detected with this technique.

Aldehydes (except formaldehyde)	Hydrocarbons
Acetaldehyde	Toluene
Propionaldehyde	Butadiene
Acrolein	Pentene
Butyraldehyde	Isoprene
Valericaldehyde	Pentane
Crotonaldehyde	Hexane
	Benzene

Alcohols

Methyl

Esters

Methyl formate
Ethyl formate
Methyl acetate

Miscellaneous

Methyl chloride

Ketones

Acetone
Butanone
Pentanone

Nitriles

Hydrogen cyanide
Acrylonitrile

The thin layer chromatographic technique utilized to analyze particulate samples (see Appendix B) was capable of detecting polynuclear hydrocarbons in less than microgram quantities. The following compounds can be detected with this technique:

Polynuclear hydrocarbons

Benzene
Naphthalene and derivatives
Acenaphthalene
Fluorene
Phenanthrene
Anthracene
Pyrene
Fluoranthene
1, 2-Benzfluorene
2, 3-Benzfluorene
9, 10-Benzphenanthrene
1, 2-Benzanthracene
Chrysene
3, 4-Benzpyrene (benzo-a-pyrene)
1, 2-Benzpyrene
Perylene
2, 3-Benzfluoranthene
1, 12-Benzperylene
Anthanthrene
Cozonene

Immediately preceding the charcoal tubes in the sampling train, a pre-weighed 37-millimeter diameter nonhygroscopic filter was utilized to collect polynuclear hydrocarbons existing as particulates. After sampling and prior to analysis, the filters were reweighed.

On the initial MAC flights, air samples for ammonia were collected by passing air through a bubbler containing 0.1 normal sulphuric acid, utilizing a small battery-operated pump at a flow rate of one liter per minute. Samples were collected for 20-minute periods during the flight, however, results were below the sensitivity of the method (see Appendix B) and the tests were discontinued after four flights.

On two MAC flights, rubber strips were utilized to evaluate ozone concentrations. Strips were exposed for various periods of time at several locations throughout the aircraft and then read using a standard microscopic technique.

Relative humidity measurements were made periodically during several MAC flights utilizing either a sling or battery-operated psychrometer.

1. MAC FLIGHTS

On the flights to be sampled, the planes were made available to the investigators approximately one hour before departure. Sampling packages were assembled, consisting of a battery-operated pump to move an air sample through a carbon monoxide detector tube and a second pump to move another air sample through a membrane filter to collect particulates before passing that air sample through charcoal tubes to collect organic vapors. Charcoal tubes were operated in parallel in order to obtain lower flow resistance. Tips of the indicator and charcoal tubes were broken when mounting, but resealed with caps or tape until sampling commenced. The caps sealing the tubes and filters were removed, and the pumps started as soon after take-off as practical. This generally occurred as soon as the seat belt sign was turned off. The flow rate for the filter and charcoal tubes was set at one liter per minute and for the indicator tube at 0.2 liter per minute. Pumps were calibrated prior to use.

The sampling packages were placed in four locations: (1) flight deck--generally on the navigator's table behind the pilot; (2) front of the passenger cabin--in the overhead rack (either right or left);(3) center of the passenger cabin--in the overhead rack (either right or left); and (4) rear of the passenger cabin--in the overhead rack (either right or left).

The sampling packages in the overhead rack were secured to prevent their movement during the flight with the sample inlet for carbon monoxide, particulate, and vapor projecting over and below the rack at approximately 5½ feet above the floor which is about the breathing zone height for a standing person. The location of the sample inlet was chosen as near as possible to the breathing zone of a seated passenger but outside the turbulance caused by the overseat ventilation system.

The operation of the units was monitored throughout the flight. Sampling was discontinued before landing to preclude sampling ground level pollution. Samples were sealed for submission to the laboratory. Indicator tubes were read and recorded immediately.

2. DOMESTIC FLIGHTS

Sampling was conducted in a manner similar to that described in the preceding section of this report. The differences between domestic and MAC flights were as follows: (1) MAC flights sampled were long range aircraft, i.e., DC-8's and 707's, while domestic flights sampled were intermediate range aircraft, i.e., DC-9's, 727's, and 737's. (2) The seating capacity of the aircraft used for MAC flights was 219 and 165, while the number of seats on domestic flights varied from 66 to 128. (3) One hundred percent of the seats on average MAC flights were filled, while, on the average, only 66 percent of the seats on the domestic flights sampled were filled. (4) Sampling on MAC flights was continuous from 6 to 7 hours in duration, while domestic flights were from one hour 15 minutes to two hours 30 minutes in duration with intermediate stops for passenger changes. (5) There was no passenger segregation in the MAC flights, while the domestic flights had first class and coach compartments. (6) Sampling stations were placed near the front, middle, and rear of the MAC flight passenger compartment as well as on the flight deck whereas sampling stations in the domestic flights were on the flight deck, rear of the first class compartment, and mid-section of the coach compartment. (7) Alcoholic beverages were served on the domestic flights, but not on the MAC flights.

Equipment was set up on the aircraft approximately one hour before passenger loading. The sampling packages consisted of one portable personal sampling pump set at 0.2 liter per minute providing air flow for the carbon monoxide indicator tubes and one portable personal sampling pump set at 1.0 liter per minute providing air flow through a membrane filter to collect particulate, followed by an activated charcoal tube to collect organic vapors. The pumps were calibrated prior to use. The sampling packages were established in three locations: (1) flight deck--generally behind the pilot seat; (2) the first class section--the rear wall (either right or left) at the overhead rack level; (3) the coach section--near the center in the overhead rack (either right or left).

Precautions were used to prevent sample contamination, including recording carbon monoxide tubes immediately after sampling ceased and sealing of filters and tubes before and after sampling period. The sampling period began after the seat belt sign went off and ended after landing instructions were given.

Subjective Response to Smoking--Questionnaire

The study was precipitated largely as a result of expressions of concern from passengers and the general public that smoking aboard aircraft may be harmful to health. It was felt that the environmental results should be accompanied by passengers' subjective response to tobacco smoke in confined spaces and of their opinion of the need for control or regulation of smoking in these situations.

To accomplish this, a confidential questionnaire on the subjective and objective reactions of passengers and crew in aircraft to tobacco smoke was developed. (See Appendix C.) Included were questions related to smoking history, history of upper respiratory condition, response to passenger smoking in aircraft, and to opinions of whether smoking in aircraft should be permitted.

The questionnaire was distributed to each passenger by the flight attendants near the end of the flight. An announcement was made just prior to distributing the questionnaire briefly describing the purpose of the study and requesting the passengers' cooperation in answering the questions.

The individual data from the questionnaires were coded, key punched, and evaluated by automatic data processing equipment. The print-out of these data is included in Appendix D.

IV. RESULTS

Environmental

1. Carbon monoxide--Measurements of carbon monoxide were made in four locations on each of 18 out of 20 MAC flights and on all eight domestic flights. For the MAC flight, the highest concentration measured was five parts per million in one location on one flight. All other concentrations were below 5 ppm. In the total of 72 MAC flight samples, 32 were 2 ppm or less, 25 were 3 ppm, 14 were 4 ppm, and 1 was 5 ppm (see Summary of Environmental Results - Table 4). For the domestic flights, no carbon monoxide concentrations greater than 2 ppm were observed out of 24 samples taken. The low concentrations evidently resulted from the rapid exchange of air in aircraft (see Section on Aircraft Ventilation - Appendix E) and the relatively carbon monoxide-free air entering the aircraft at the cruising altitude (see Figures A-E, Environmental CO Frequency Distribution).

2. Aldehydes and other volatile hydrocarbons--All of the charcoal tube samples for hydrocarbon vapors in both MAC and domestic flights were negative in that no concentration of contaminants could be detected. The methods employed were capable of detecting such compounds in the parts-per-million range for a 10-liter sample. In all MAC flights, sample volumes were above 300 liters. In all domestic flights, sample volumes were above 10 liters. In one set of MAC samples, a compound identified as limonene was detected. The presence of the compound in all four samples of the set in approximately equal quantities indicates contamination after collection.

3. Particulates--The gross airborne concentration of particulates ranged up to 120 micrograms per cubic meter on MAC flights (see Table 4). These concentrations were determined by dividing the change in filter weight before and after sampling by the sample volume. The only polynuclear hydrocarbon identified on the filters was benzo-a-pyrene. Although the maximum concentration observed was only a fraction of a $\mu g/m^3$, the levels were in excess of that reported for typical urban areas in the United States[1]. This factor is presently being investigated. (See Figures F-J, Particulate Comparisons.)

4. Other--Concentrations of ammonia measured on four MAC flights were below the detection level of the method and, therefore, are shown in the results as less than 0.02 parts per million. The limited data on ozone on two MAC flights indicate concentrations of 0.01 and 0.02 parts per million. Relative humidity on the aircraft was low ranging from 10 to 20%. These low humidities result from bringing the extremely low temperature air outside the aircraft into the aircraft and heating it for comfort without associated control of humidity. Written comments of some passengers indicated respiratory irritation which they attributed to the drying effect of the air.

A comparison of results with both industrial hygiene and air quality standards shows that the average levels of each of the contaminants measured (i.e., carbon monoxide, particulates, ammonia, and ozone) are below the recommended standard values. A summary of these comparisons is presented in Appendix G.

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1. National Air Pollution Control Administration Publication No. APTD 69-43.

Table 4

SUMMARY OF ENVIRONMENTAL RESULTS

Test #1--1/23/70

Sampling Location	Carbon Monoxide (ppm)	Total Particulates (mg/m^3)	Ammonia (ppm)	Ozone (ppm)	Relative Humidity (%)
Flight Deck	2	0.05	< 0.02	-	10
Cabin-Front	3	0.12	< 0.02	-	12
Cabin-Center	2	0.09	< 0.02	-	14
Cabin-Rear	2	0.07	< 0.02	-	12

Test #2--1/29/70

Sampling Location	Carbon Monoxide (ppm)	Total Particulates (mg/m^3)	Ammonia (ppm)	Ozone (ppm)	Relative Humidity (%)
Flight Deck	4	0.08	< 0.02	-	12
Cabin-Front	2	0.06	< 0.02	-	16
Cabin-Center	2	0.04	< 0.02	-	14
Cabin-Rear	4	0.05	< 0.02	-	12

Table 4 (Continued)

Test #3--2/15/70

Sampling Location	Carbon Monoxide (ppm)	Total Particulates (mg/m^3)	Ammonia (ppm)	Ozone (ppm)	Relative Humidity (%)
Flight Deck	2	0.04	< 0.06	0.01	10
Cabin-Front	4	0.07	< 0.06	0.01	14
Cabin-Center	2	0.03	< 0.06	0.01	12
Cabin-Rear	2	0.05	< 0.06	0.01	14

Test #4--2/19/70

Sampling Location	Carbon Monoxide (ppm)	Total Particulates (mg/m^3)	Ammonia (ppm)	Ozone (ppm)	Relative Humidity (%)
Flight Deck	3	0.07	< 0.06	0.01	11
Cabin-Front	< 2	0.02	< 0.06	0.02	12
Cabin-Center	4	0.12	< 0.06	0.01	14
Cabin-Rear	2	0.04	< 0.06	0.01	12

Table 4 (Continued)

Test #5--6/6/70

Sampling Location	Carbon Monoxide (ppm)	Total Particulates (mg/m^3)	Ammonia (ppm)	Ozone (ppm)	Relative Humidity (%)
Flight Deck	3	0.09	-	-	12
Cabin-Front	3	0.11	-	-	11
Cabin-Center	4	0.07	-	-	14
Cabin-Rear	5	0.10	-	-	12

Test #6--6/13/70

Sampling Location	Carbon Monoxide (ppm)	Total Particulates (mg/m^3)	Ammonia (ppm)	Ozone (ppm)	Relative Humidity (%)
Flight Deck	< 2	0.02	-	-	10
Cabin-Front	3	0.03	-	-	16
Cabin-Center	4	0.05	-	-	14
Cabin-Rear	2	0.03	-	-	12

Table 4 (Continued)

Test #7--8/17/70

Sampling Location	Carbon Monoxide (ppm)	Total Particulates (mg/m^3)	Ammonia (ppm)	Ozone (ppm)	Relative Humidity (%)
Flight Deck	4	0.07	-	-	-
Cabin-Front	2	0.02	-	-	-
Cabin-Center	3	0.05	-	-	-
Cabin-Rear	3	0.04	-	-	-

Test #8--8/22/70

Sampling Location	Carbon Monoxide (ppm)	Total Particulates (mg/m^3)	Ammonia (ppm)	Ozone (ppm)	Relative Humidity (%)
Flight Deck	3	0.04	-	-	-
Cabin-Front	2	0.05	-	-	-
Cabin-Center	2	0.04	-	-	-
Cabin-Rear	3	0.02	-	-	-

Table 4 (Continued)

Test #9--8/25/70

Sampling Location	Carbon Monoxide (ppm)	Total Particulates (mg/m^3)	Ammonia (ppm)	Ozone (ppm)	Relative Humidity (%)
Flight Deck	< 2	0.01	-	-	-
Cabin-Front	3	0.03	-	-	-
Cabin-Center	3	0.04	-	-	-
Cabin-Rear	4	0.02	-	-	-

Test #10--8/30/70

Sampling Location	Carbon Monoxide (ppm)	Total Particulates (mg/m^3)	Ammonia (ppm)	Ozone (ppm)	Relative Humidity (%)
Flight Deck	2	0.02	-	-	-
Cabin-Front	3	0.04	-	-	-
Cabin-Center	2	0.04	-	-	-
Cabin-Rear	< 2	0.03	-	-	-

Table 4 (Continued)

Test #11--9/16/70

Sampling Location	Carbon Monoxide (ppm)	Total Particulates (mg/m^3)	Ammonia (ppm)	Ozone (ppm)	Relative Humidity (%)
Flight Deck	2	0.03	-	-	10
Cabin-Front	2	0.04	-	-	12
Cabin-Center	< 2	0.04	-	-	11
Cabin-Rear	3	0.05	-	-	14

Test #12--9/23/70

Sampling Location	Carbon Monoxide (ppm)	Total Particulates (mg/m^3)	Ammonia (ppm)	Ozone (ppm)	Relative Humidity (%)
Flight Deck	4	0.02	-	-	12
Cabin-Front	< 2	0.04	-	-	14
Cabin-Center	2	0.04	-	-	11
Cabin-Rear	2	0.02	-	-	12

Table 4 (Continued)

Test #13--9/28/70

Sampling Location	Carbon Monoxide (ppm)	Total Particulates (mg/m^3)	Ammonia (ppm)	Ozone (ppm)	Relative Humidity (%)
Flight Deck	3	0.02	-	-	-
Cabin-Front	4	0.07	-	-	-
Cabin-Center	4	0.05	-	-	-
Cabin-Rear	3	0.05	-	-	-

Test #14--10/3/70

Sampling Location	Carbon Monoxide (ppm)	Total Particulates (mg/m^3)	Ammonia (ppm)	Ozone (ppm)	Relative Humidity (%)
Flight Deck	3	0.03	-	-	-
Cabin-Front	3	N.D.	-	-	-
Cabin-Center	2	0.04	-	-	-
Cabin-Rear	4	0.07	-	-	-

Note: Limonene was detected in all samples collected on this flight. This was judged to be a result of sample contamination and not a substance in the aircraft environment.

Table 4 (Continued)

Sampling Location	Carbon Monoxide (ppm)	Total Particulates (mg/m^3)	Ammonia (ppm)	Ozone (ppm)	Relative Humidity (%)
Test #15--11/5/70					
Flight Deck	2	N.D.	-	-	-
Cabin-Front	3	0.02	-	-	-
Cabin-Center	3	0.03	-	-	-
Cabin-Rear	2	0.02	-	-	-
Test #16--11/11/70		NO SAMPLING--EQUIPMENT PROBLEM			
Test #17--11/18/70					
Flight Deck	3	0.02	-	-	12
Cabin-Front	3	< 0.01	-	-	14
Cabin-Center	4	0.03	-	-	11
Cabin-Rear	2	0.02	-	-	12

Table 4 (Continued)

Test #18--11/22/70

Sampling Location	Carbon Monoxide (ppm)	Total Particulates (mg/m^3)	Ammonia (ppm)	Ozone (ppm)	Relative Humidity (%)
Flight Deck	4	0.03	-	-	14
Cabin-Front	3	0.02	-	-	12
Cabin-Center	3	N.D.	-	-	16
Cabin-Rear	2	< 0.01	-	-	15

Test #19--12/4/70

Sampling Location	Carbon Monoxide (ppm)	Total Particulates (mg/m^3)	Ammonia (ppm)	Ozone (ppm)	Relative Humidity (%)
Flight Deck	3	0.01	-	-	-
Cabin-Front	2	0.03	-	-	-
Cabin-Center	3	0.02	-	-	-
Cabin-Rear	2	0.04	-	-	-

Test #20--12/14/70

NO TEST - RETURNED ON B-747 -- MADRID - NEW YORK

FIGURE A. CARBON MONOXIDE ALL SAMPLING LOCATIONS MAC FLIGHTS

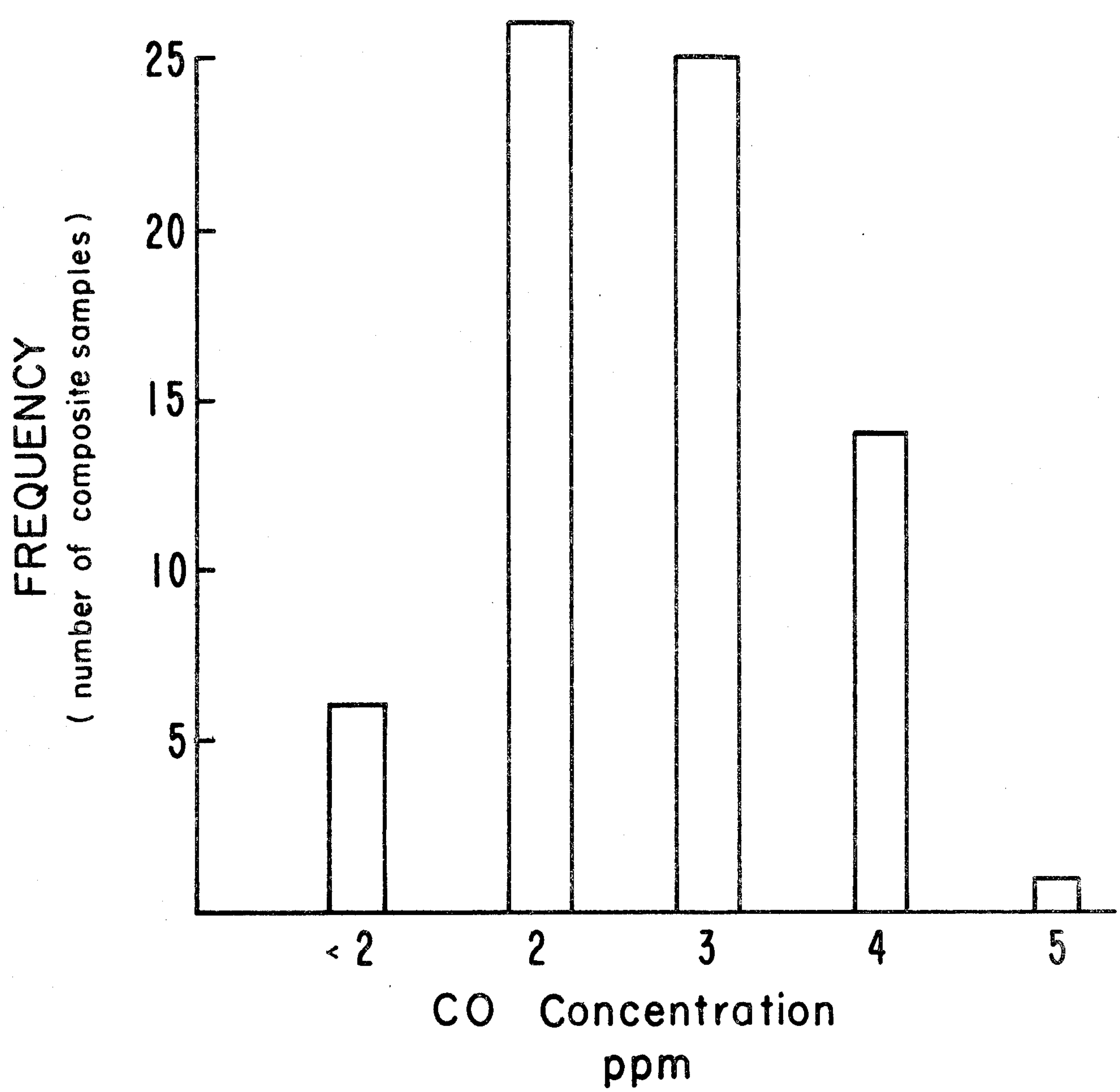


FIGURE B. CARBON MONOXIDE FLIGHT DECK MAC FLIGHTS

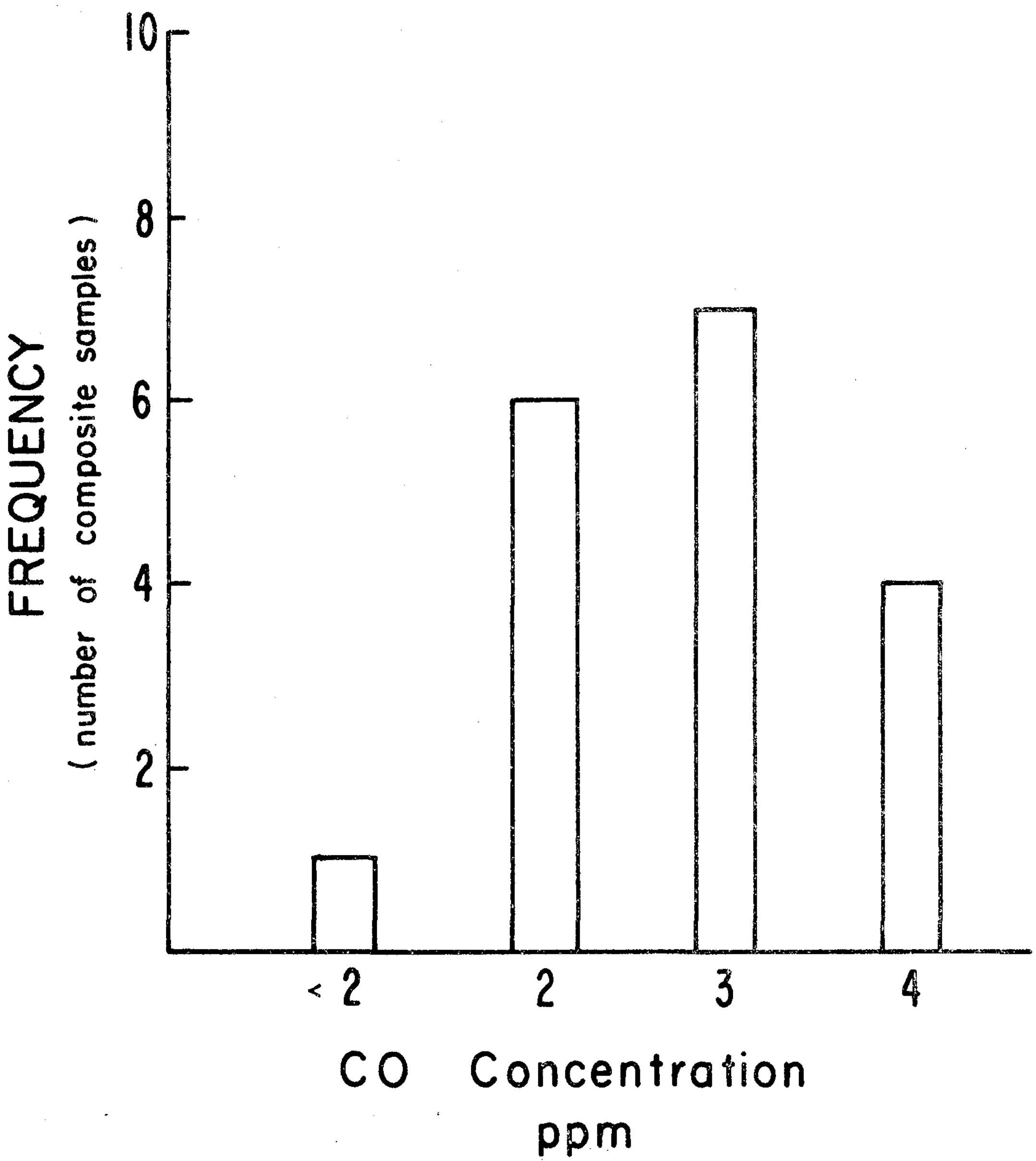


FIGURE C. CARBON MONOXIDE FRONT OF CABIN MAC FLIGHTS

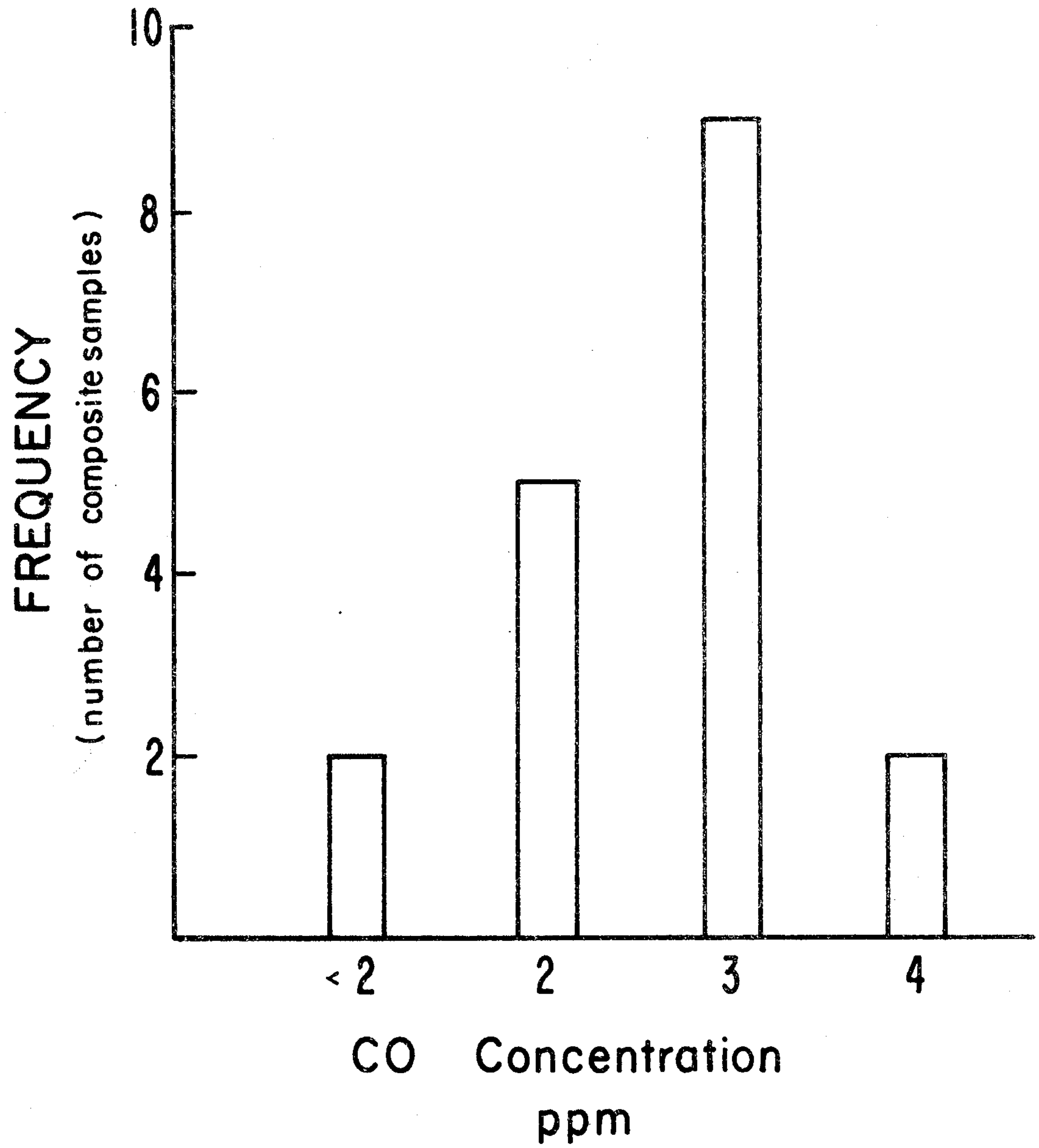


FIGURE D. CARBON MONOXIDE CENTER OF CABIN MAC FLIGHTS

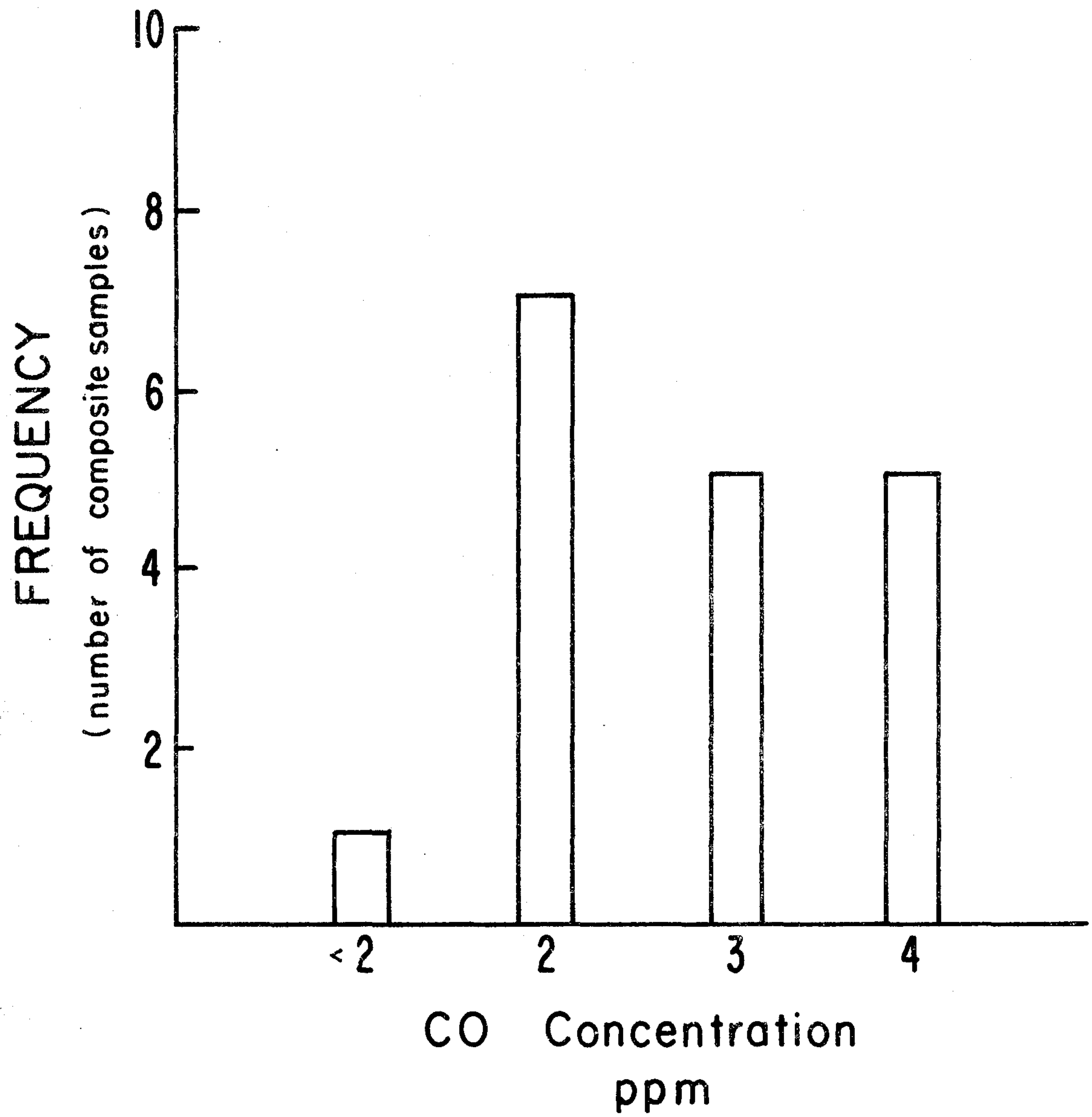


FIGURE E. CARBON MONOXIDE REAR OF CABIN MAC FLIGHTS

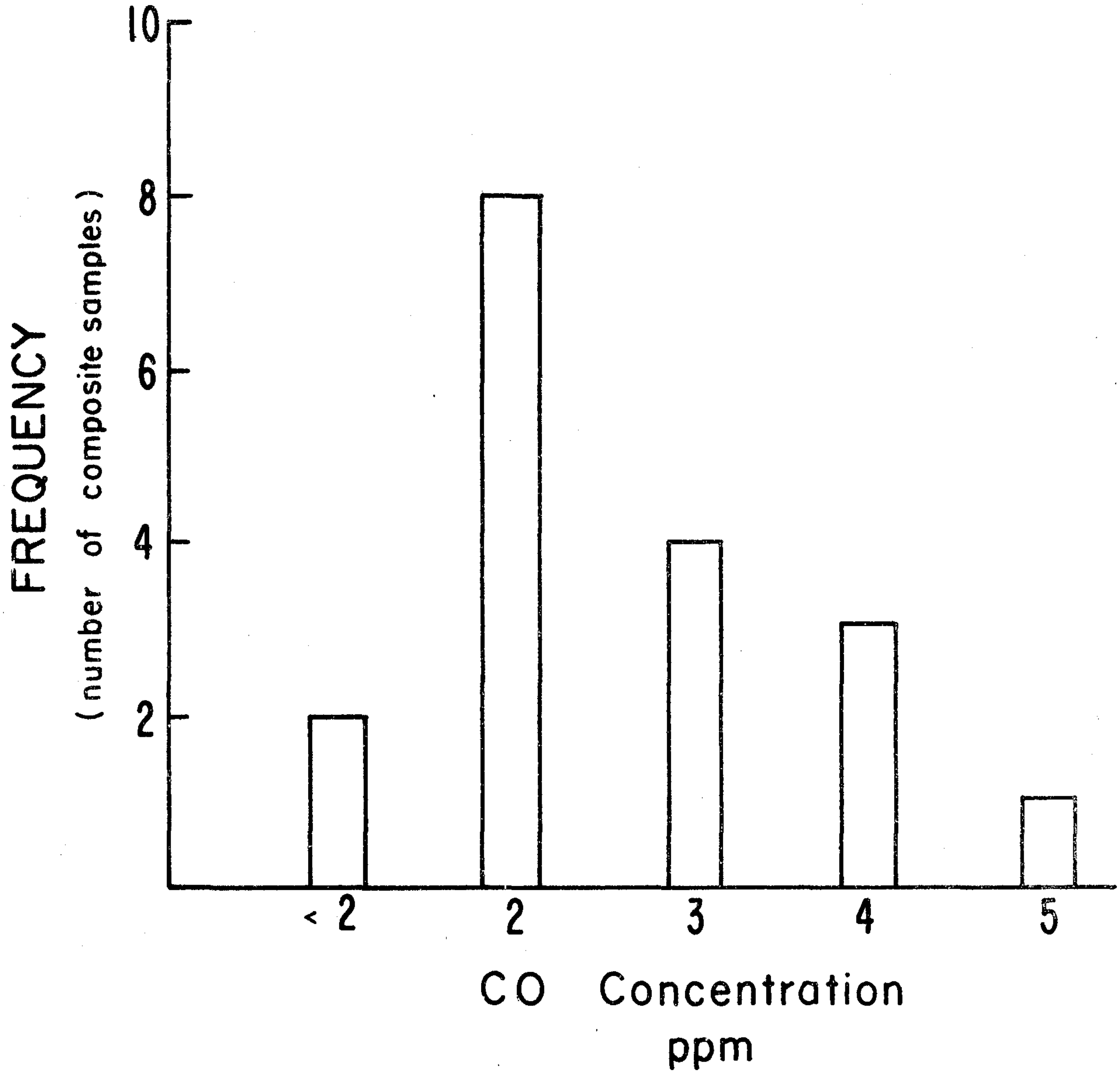


FIGURE F. PARTICULATE CONCENTRATION ALL SAMPLING LOCATIONS MAC FLIGHTS

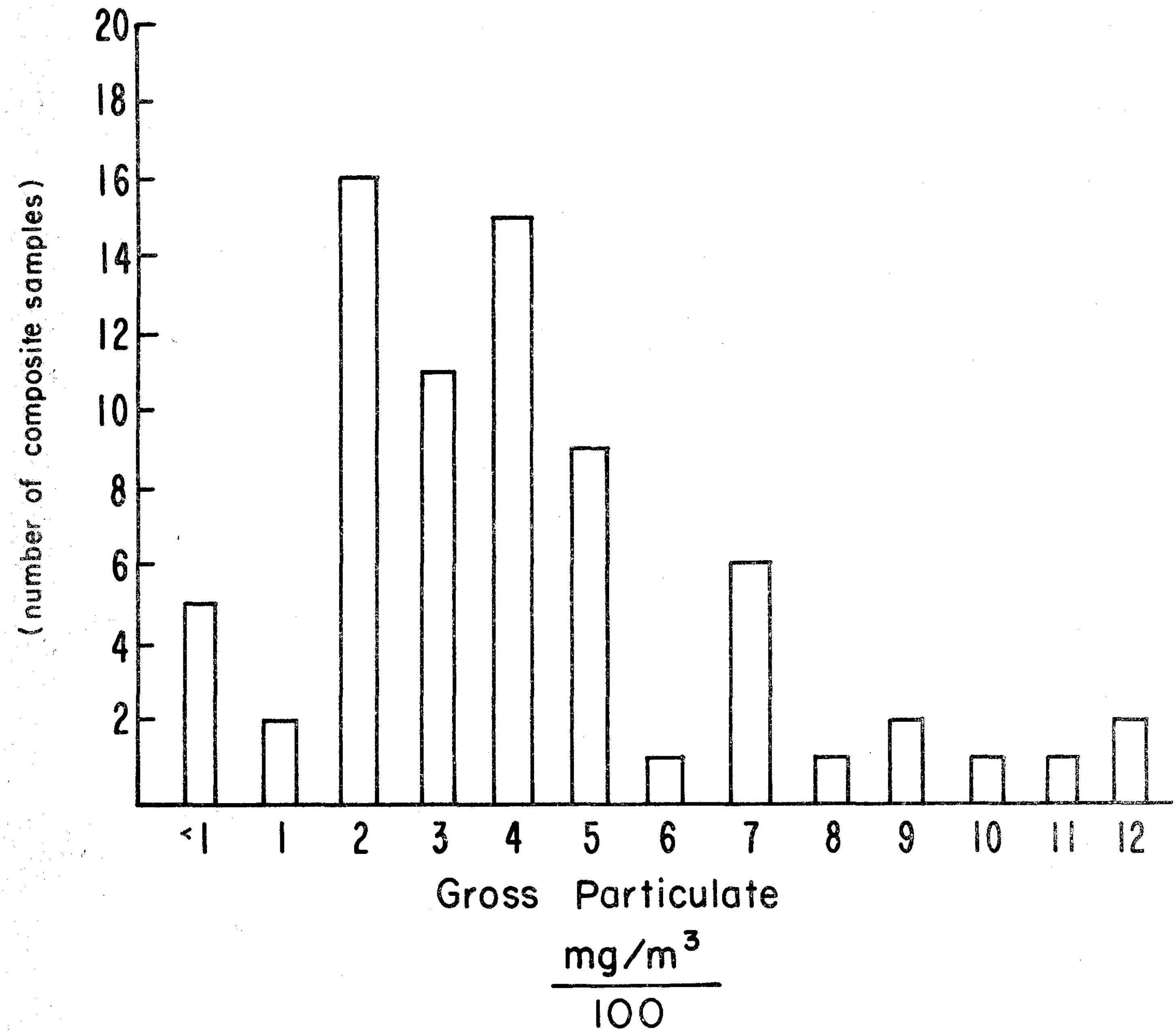


FIGURE G. PARTICULATE CONCENTRATION FLIGHT DECK MAC FLIGHTS

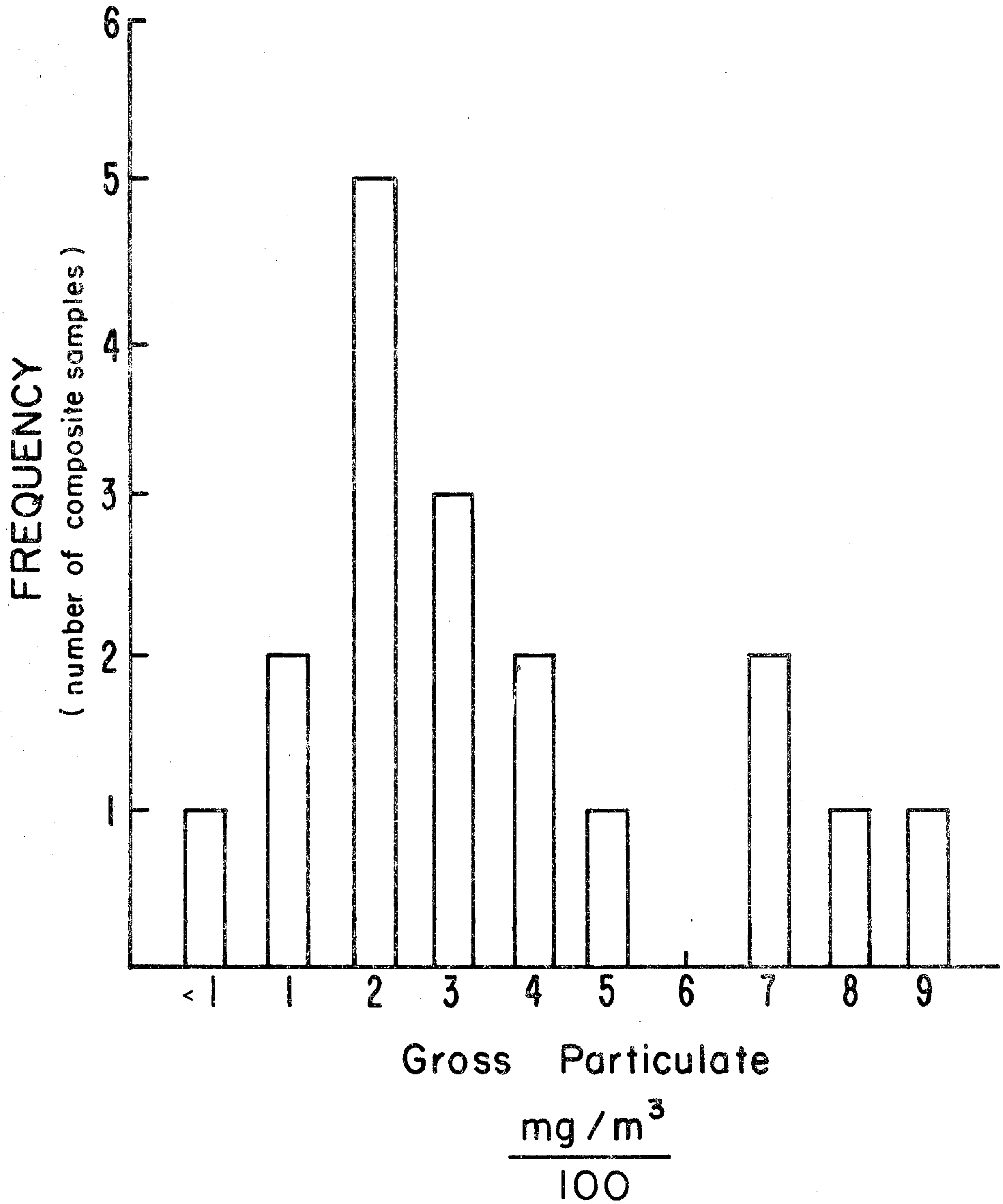


FIGURE H. PARTICULATE CONCENTRATION FRONT OF CABIN MAC FLIGHTS

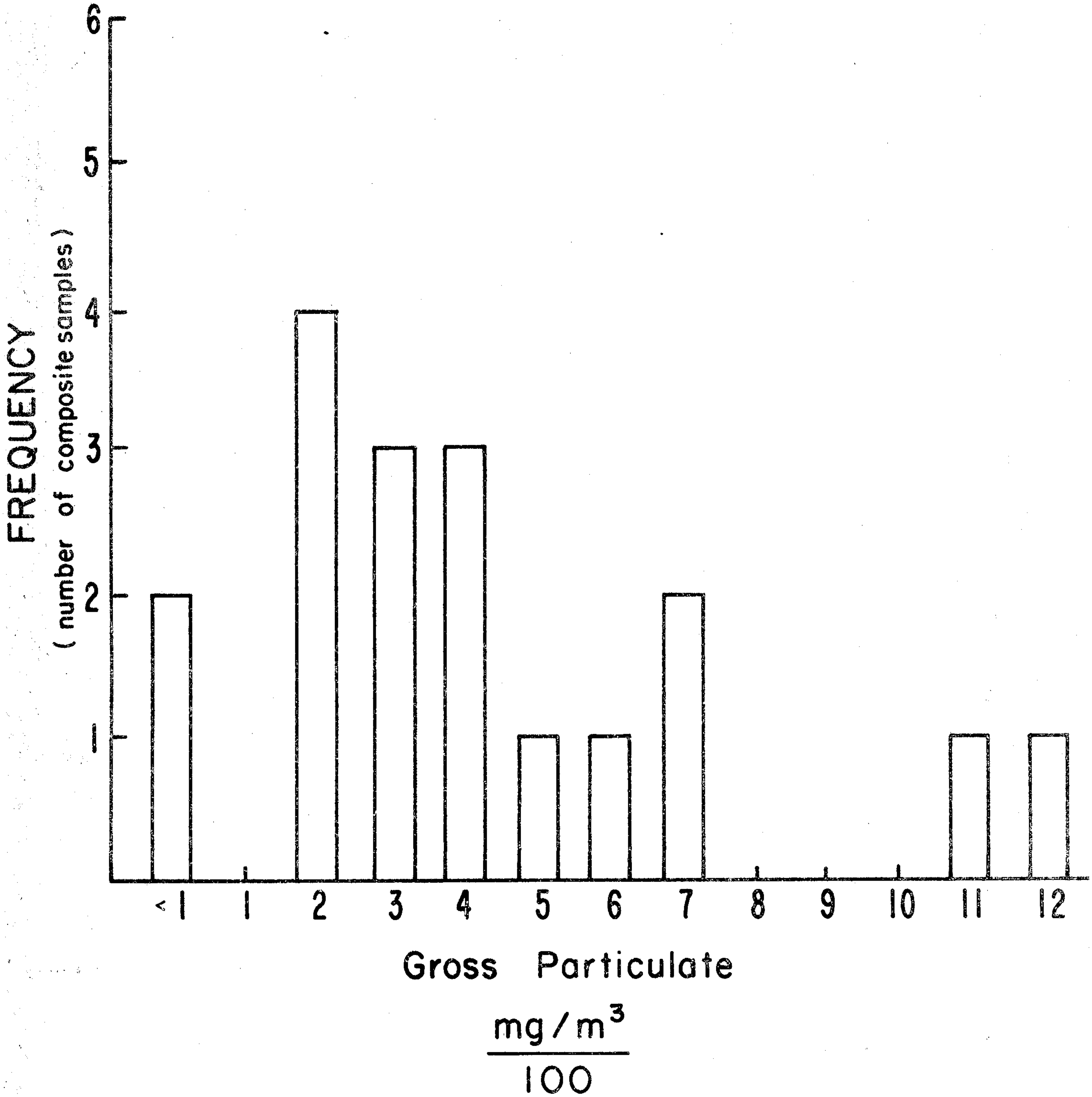


FIGURE I. PARTICULATE CONCENTRATION CENTER OF CABIN MAC FLIGHTS

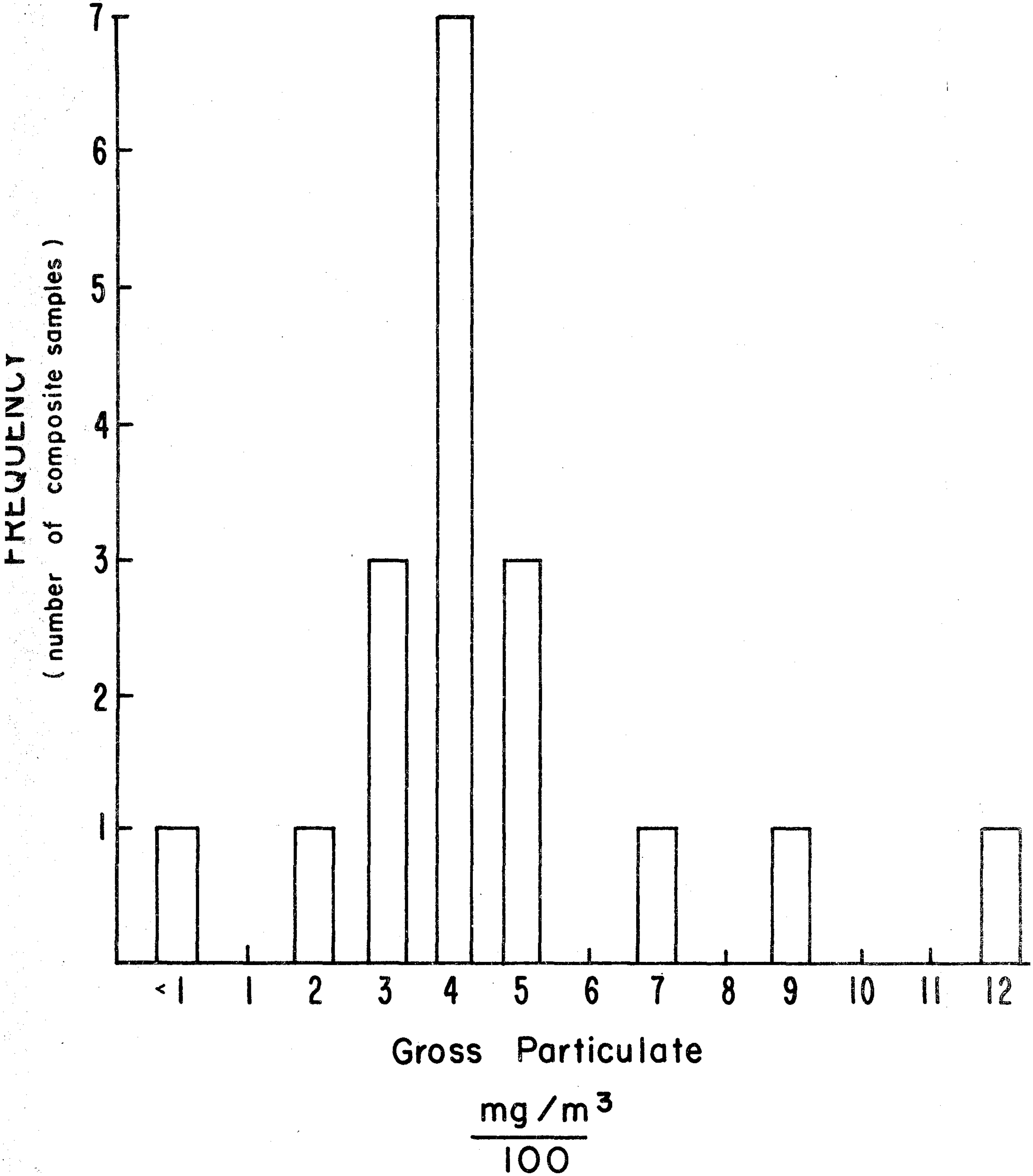
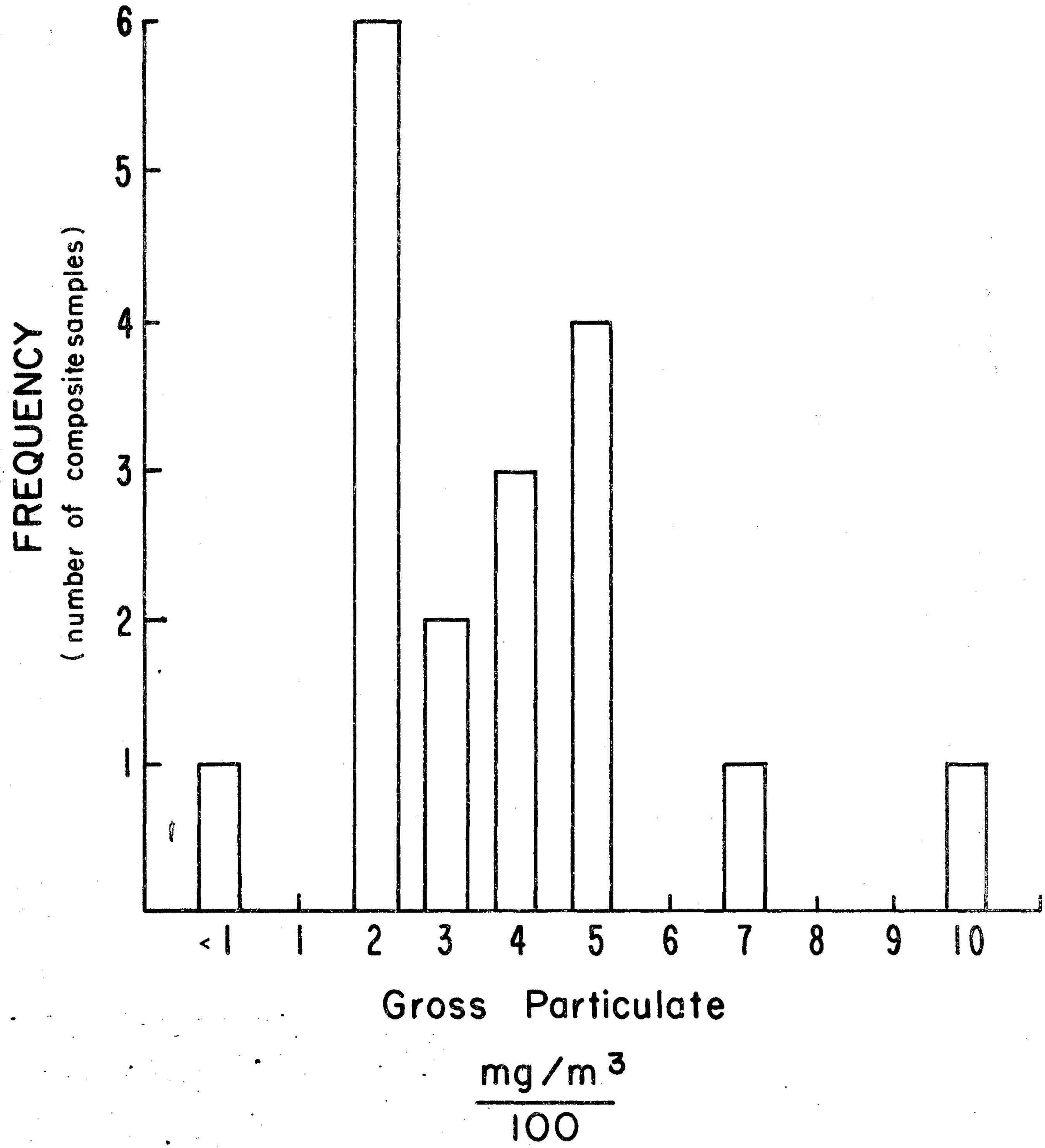


FIGURE J. PARTICULATE CONCENTRATION REAR OF CABIN MAC FLIGHTS



Questionnaire

A copy of the questionnaire and the results obtained by computer are provided in Appendix D. Some of the more interesting and important data are summarized here for easy reference. Not all passengers filled out all the questions on the form and, therefore, some population numbers may appear to be inconsistent, but the individual questions were treated separately where appropriate.

The total population in this survey was 3,296. There were 3,043 on MAC flights and 253 on domestic. Average flight times were about seven and 1½ hours respectively. All MAC flights were filled to capacity, whereas only 66% of the seats were filled on the domestic flights.

Table 5 lists the distribution of the passengers on both the MAC and domestic flights by age and sex.

Table 5

Age and Sex Distribution of Passengers

Age Group (Years)	MAC Male	MAC Female	Domestic Male	Domestic Female
0-19	173	53	7	6
20-40	945	519	78	21
over 40	253	76	109	27
TOTAL	1371	648	194	54

Item 1 on the questionnaire (summarized in Table 6) was designed to obtain the number of passengers who had a history of respiratory conditions. This was considered to be an important parameter which would possibly be associated with passengers' attitude toward smoking.

Table 6

Respiratory Disease History of Passengers

	MAC		Domestic	
	No.	%	No.	%
No respiratory condition	2032	(67)	149	(59)
One or more respiratory conditions	1011	(33)	104	(41)

The smoking habits of individuals on the flights are tabulated in Table 7.

Table 7

Smoking Habits of Passengers

	MAC					
	Male		Female		Total	
	No.	%	No.	%	No.	%
Smokers	1476	(62)	256	(39)	1732	(57)
Nonsmokers	907	(38)	404	(61)	1311	(43)
	DOMESTIC					
Smokers	95	(49)	18	(32)	113	(45)
Nonsmokers	101	(51)	39	(68)	140	(55)

Table 8 summarizes the percent of passengers who are annoyed by smoking in aircraft, designated by smoking habit, sex distribution, and history of respiratory condition.

Table 8

Passengers Annoyed by Smoking Related to Sex, Smoking Habit, and Respiratory History

	MAC % Annoyed	Domestic % Annoyed
1. By smoking habit		
a. male smokers	21	15
b. male nonsmokers	60	65
c. female smokers	20	22
d. female nonsmokers	62	49
2. By respiratory disease history		
a. males with respiratory history	43	45
b. males without respiratory history	34	38
c. females with respiratory history	57	75
d. females without respiratory history	38	22

Table 9 describes passenger annoyance as related to smoking habit, age, and history of respiratory condition.

Table 9

Passengers Annoyed by Smoke, Related to Smoking Habit, Age, and Respiratory History

	% Smokers Annoyed Age Distribution-Years				% Nonsmokers Annoyed Age Distribution-Years			
	0-19	20-39	40+	Total	0-19	20-39	40+	Total
Passengers w/ respiratory history	29	28	18	26	70	73	70	71
Passengers w/o resp. history	13	21	13	18	49	56	49	54

Table 10 lists the percentage of passengers who either feel that smoking should be eliminated or that smokers should be segregated in a separate portion of the aircraft.

Table 10

% Passengers Recommending Remedial Action

	MAC Passengers Suggesting Action	Domestic Passengers Suggesting Action
1. Effect of smoking habit		
(a) smokers	27	39
(b) nonsmokers	62	73
2. Effect of history of respiratory condition		
(a) passengers with history	46	63
(b) passengers without history	39	55

V. DISCUSSION

Environmental

In an air supply system, there are two principal sources of pollutants. One is the outside air and the other is the products given off by, or produced by, people. Tobacco smoke is a major contaminant in this latter category and is believed to be the major contaminant aboard passenger aircraft.

Approximately 23 percent of the gas phase of tobacco smoke is carbon monoxide[1]. Therefore, it was selected as the

1. D. F. Owens, A. T. Rossano, "Design Procedures to Control Cigarette Smoke and Other Air Pollutants." ASHRAE Semi-annual Meeting, Chicago, Illinois, January 27-30, 1969.

compound to be measured aboard aircraft to serve as an indicator of the presence of irritating combustion products of burning tobacco.

The environmental measurements made in the aircraft for carbon monoxide were extremely low, much lower than ambient concentrations in urban environments. All measurements were 5 ppm or less. These low concentrations of carbon monoxide result from the rapid exchange of air aboard the aircraft (the equivalent of one complete airchange each 3-4 minutes) and the relative pollution-free air entering the aircraft at the cruising altitudes of the test flights. This also resulted in low concentrations of both total airborne particulates and polynuclear and other hydrocarbons. The highest particulate concentration was 0.12 milligrams per cubic meter. However, in addition to tobacco smoke particulates, other particulates, either generated or dispersed in the aircraft, were collected. Benzo-a-pyrene was found in only five of the samples and in less than microgram quantities. No other polynuclear hydrocarbons were detected. In only one series of charcoal samples utilized to collect hydrocarbon vapors was any compound detected, and this evidently resulted from sample contamination.

The humidity aboard the aircraft was low, less than 20 percent in all of the tests. This low relative humidity results from the ventilation system utilizing cold outside make up air and heating it without adding moisture to maintain the relative humidity at a higher level. Some passenger alleged that the drying of the respiratory membranes contributed to respiratory irritation.

It should be pointed out that the study was designed to show whether or not levels of air contamination from tobacco smoking on aircraft represent a significant health problem. On the basis of the very low levels of the contaminants measured, it is concluded that inhalation of the by-products from tobacco smoke generated as a result of passengers smoking aboard commercial aircraft does not represent a significant health hazard to nonsmoking passengers. However, these low environmental contaminant levels do not indicate the degree of passenger annoyance from odor or irritation to eyes, nose, and throat from the smoking of other passengers in the aircraft as is indicated by the results of the passenger survey.

Questionnaire

The results from the questionnaire have been evaluated on the basis of the age, sex, respiratory condition, and smoking habits of the passengers. These criteria were compared to the response concerning whether they were: (a) bothered by smoking in aircraft and (b) wanted some corrective measures taken.

Figure K compares the age distribution of the passengers on the MAC and domestic flights. Only 11% of the MAC passengers were above the age of 40' whereas, 55% were in this same group on the domestic flights. There appears to be little relationship between age grouping and those annoyed by smoke in aircraft, as shown in Table 9.

Figure L compares the smoking habits of the passengers on both flight systems by sex. It is evident that the majority of the passengers were men; and that 60% of the males smoked while only 40% of the females were smokers. Although there were slightly more females than males who were annoyed by smoking in aircraft (see Table 8), the difference is not considered to be significant based on the limited number in the study population.

The history of respiratory conditions of the passengers is shown in Figure M. Differences in respiratory disease experienced between the two flight groups are not considered to be significant although there was a slightly higher percent of males on the domestic flights noting one or more respiratory conditions than on the MAC flights. Figures N and O depict the number of persons annoyed by smoke and those suggesting corrective action on both flight systems related to their respiratory history. Those noting a history of hay fever, asthma, sinus trouble, lung disorder, or an allergy, were considered as positive responders for this evaluation. Sixty-three percent of domestic flight passengers versus 46% of MAC passengers, who indicated a history of respiratory disease, wanted some action taken to limit smoking. Fifty-five percent of the domestic passengers and 39% of the MAC passengers who did not indicate respiratory disease history wanted such action taken.

The most significant relationships exist among the smoking habits of the passengers, their annoyance by smoke, and their desire that corrective action be taken. As may be expected, more nonsmokers than smokers were concerned about tobacco smoke in the aircraft (refer to Tables 8, 9, and 10). As shown in Figure L, there was a difference in the smoking habits of the passengers on the MAC and domestic flights. Fifty-seven percent of the MAC passengers and 45% of the domestic passengers were smokers. Statistics also show that 92% and 71% of the smokers, respectively, actually smoked on the flights. Figures P and Q graphically illustrate the response of the smokers and nonsmokers to the questions of "bothered" and the need for corrective action. In both instances, more of the domestic passengers were bothered and wanted some corrective action taken to either separate the smokers or ban smoking. Seventy-three percent of the domestic passengers on the domestic flights and 62% of the MAC passengers who were nonsmokers suggested corrective action. It is significant to note that 58% of the domestic passengers and 41% of the MAC passengers wanted corrective action with an overall average of 43% for both groups. The lower percentage of smokers on the domestic flights undoubtedly accounts for this difference. Approximately 85% of those passengers suggesting that corrective action be taken felt that segregating the smokers from the nonsmokers would be a satisfactory solution. The remaining 15% felt that smoking should be banned.

A significant correlation exists between the respiratory disease history of the passengers and their annoyance by smoke. Figure R shows a greater prevalence of annoyance to tobacco smoke among nonsmokers who gave a respiratory history as contrasted with nonsmokers giving no such history. A similar difference of lesser magnitude was noted among smokers.

If it is presumed that two trends in American society continue, namely that (1) greater emphasis is placed on the health aspects of nonsmoking and (2) the incidence of respiratory symptomatology among the American population is increasing, it can be predicted that more people will be annoyed by tobacco smoke in the future, unless corrective action is taken.

FIGURE K. DISTRIBUTION OF PASSENGERS BY AGE AND SEX

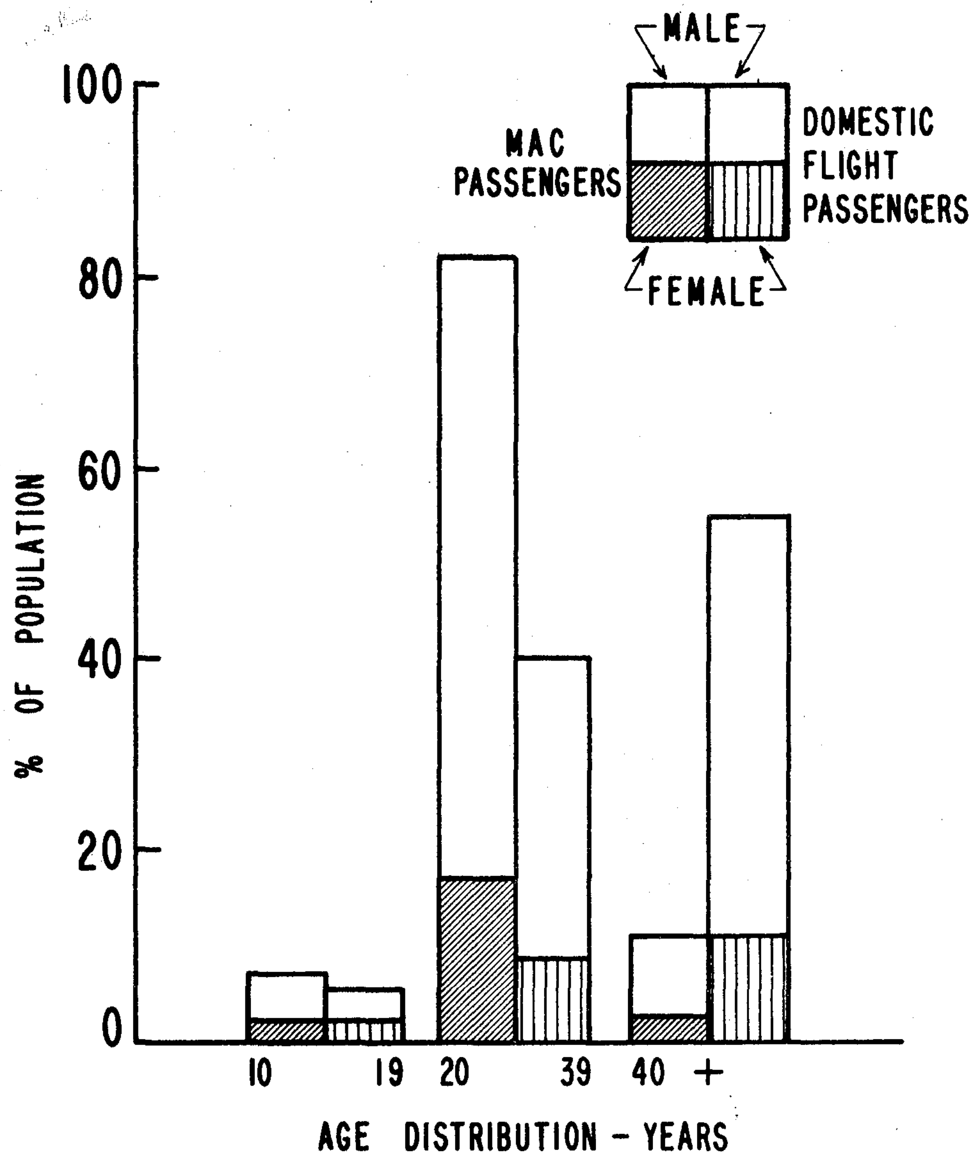


FIGURE L. PASSENGER DISTRIBUTION BY SMOKING HABIT AND SEX

MAC PASSENGERS

	MALES	FEMALES	TOTAL
SMOKERS	1476	256	1732
NON-SMOKERS	907	404	1311
TOTAL	2383	660	3043

DOMESTIC FLIGHT PASSENGERS

	MALES	FEMALES	TOTAL
SMOKERS	95	18	113
NON-SMOKERS	101	39	140
TOTAL	196	57	253

FIGURE M. PASSENGER DISTRIBUTION BY RESPIRATORY DISEASE HISTORY

MAC PASSENGERS

	MALES	FEMALES	TOTAL
RESP. HISTORY	733	272	1005
NO RESP. HISTORY	1650	388	2038
TOTAL	2383	660	3043

DOMESTIC FLIGHT PASSENGERS

	MALES	FEMALES	TOTAL
RESP. HISTORY	80	20	100
NO RESP. HISTORY	116	37	153
TOTAL	196	57	253

FIGURE N. PASSENGERS BOTHERED BY SMOKE RELATED TO RESPIRATORY DISEASE HISTORY

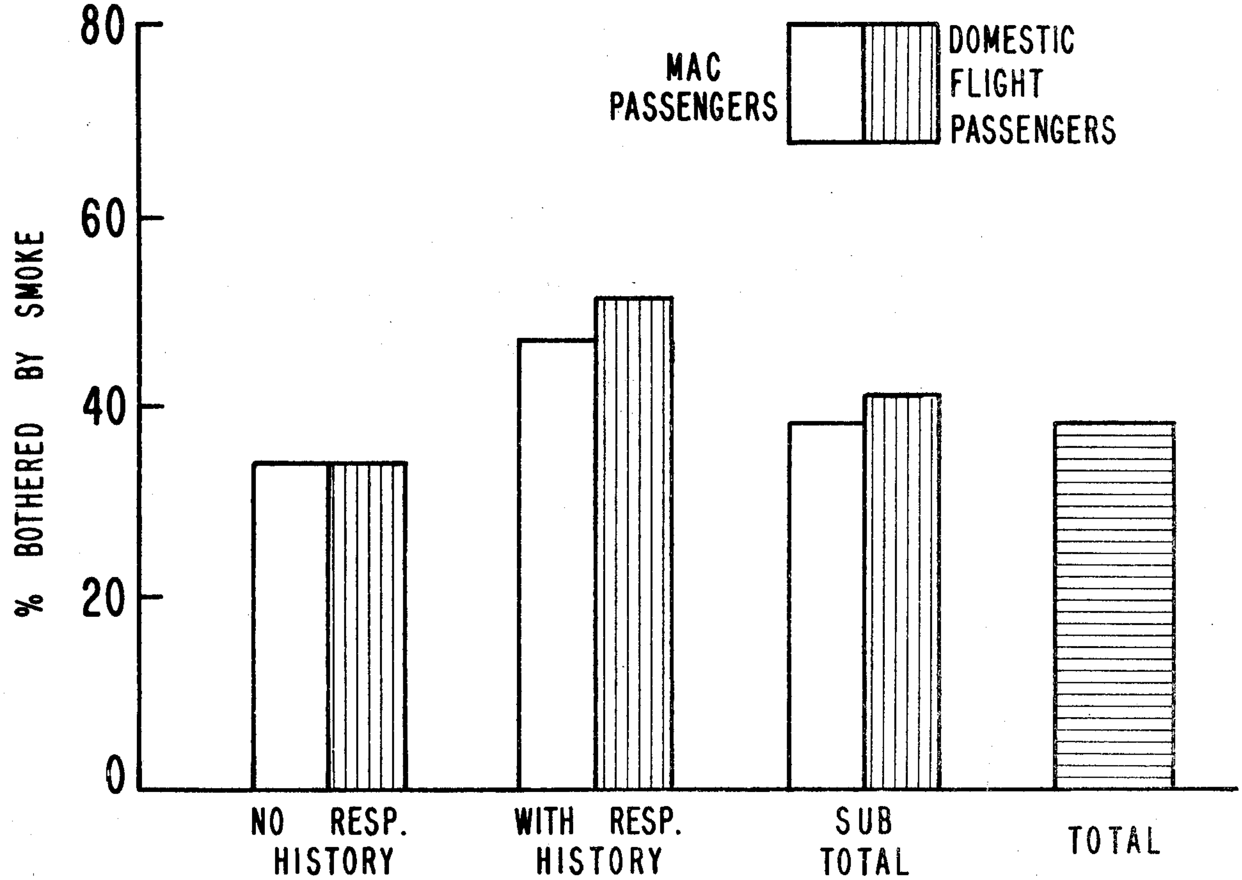


FIGURE O. PASSENGERS SUGGESTING CORRECTIVE ACTION RELATED TO RESPIRATORY DISEASE HISTORY

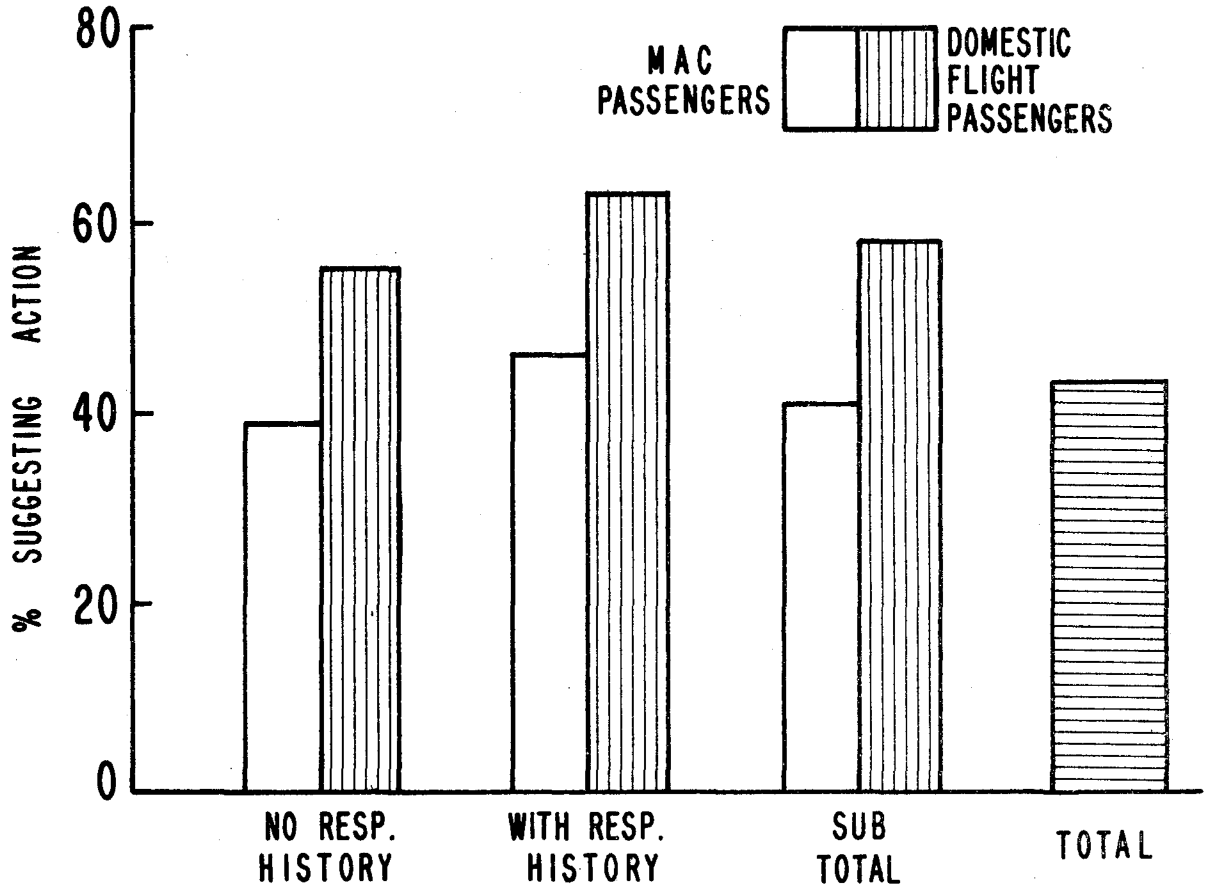


FIGURE P. PASSENGERS BOTHERED BY SMOKE RELATED TO SMOKING HABIT

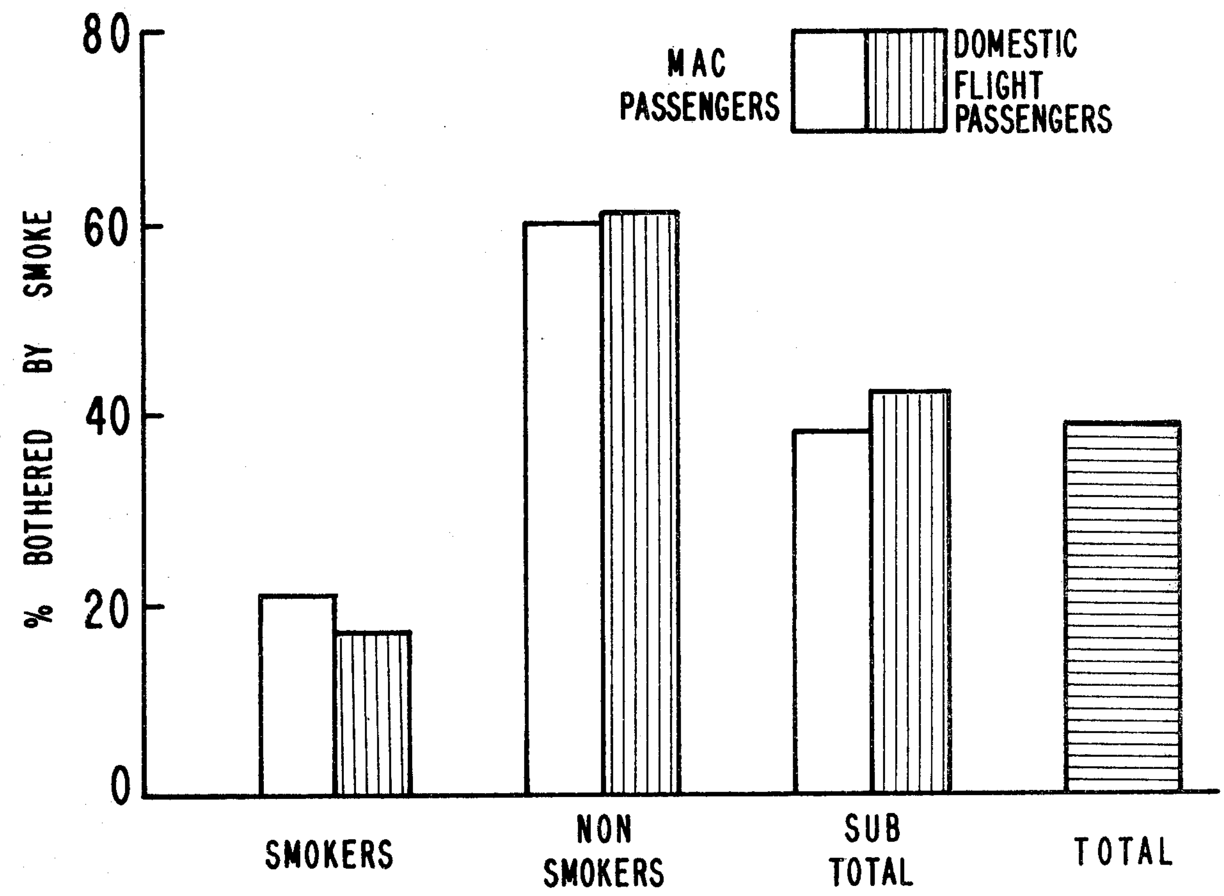


FIGURE Q. PERSONS SUGGESTING CORRECTIVE ACTION RELATED TO SMOKING HABITS

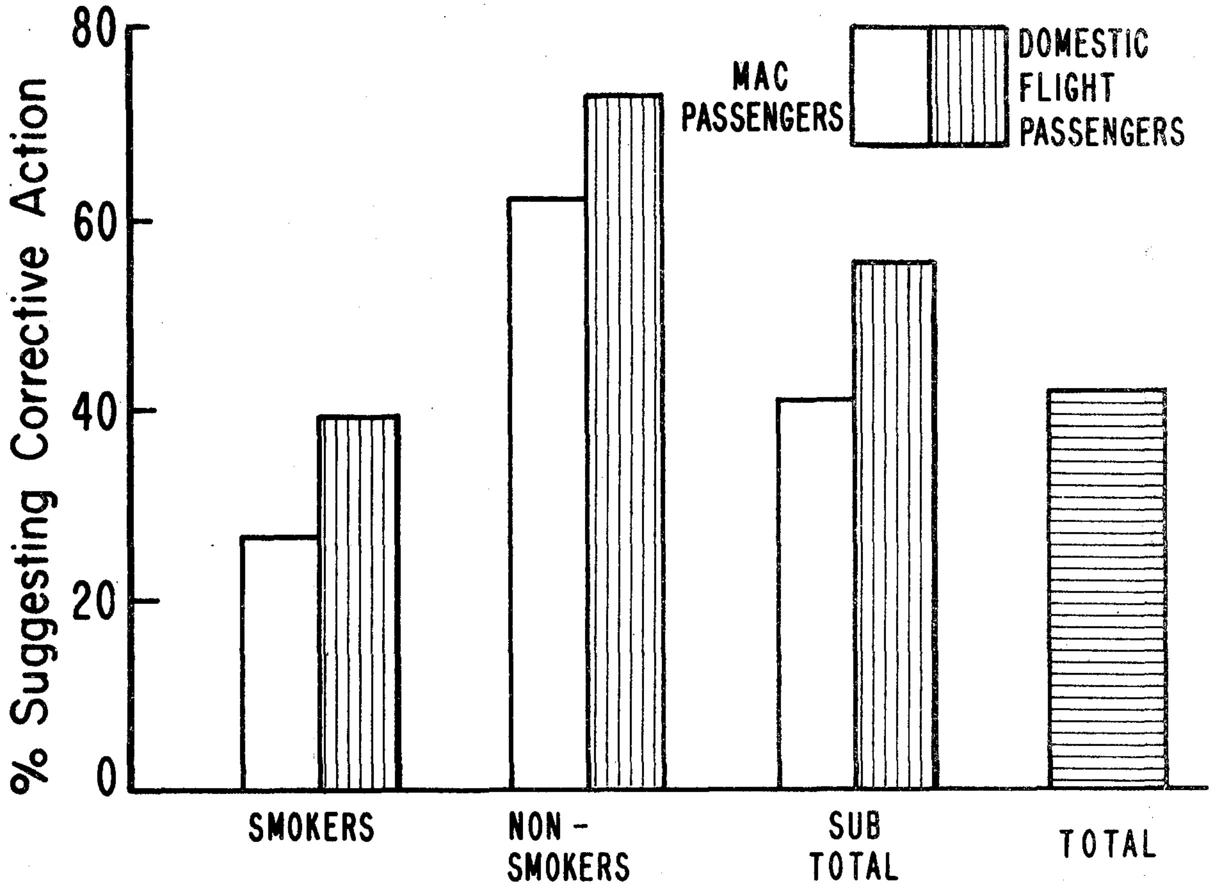
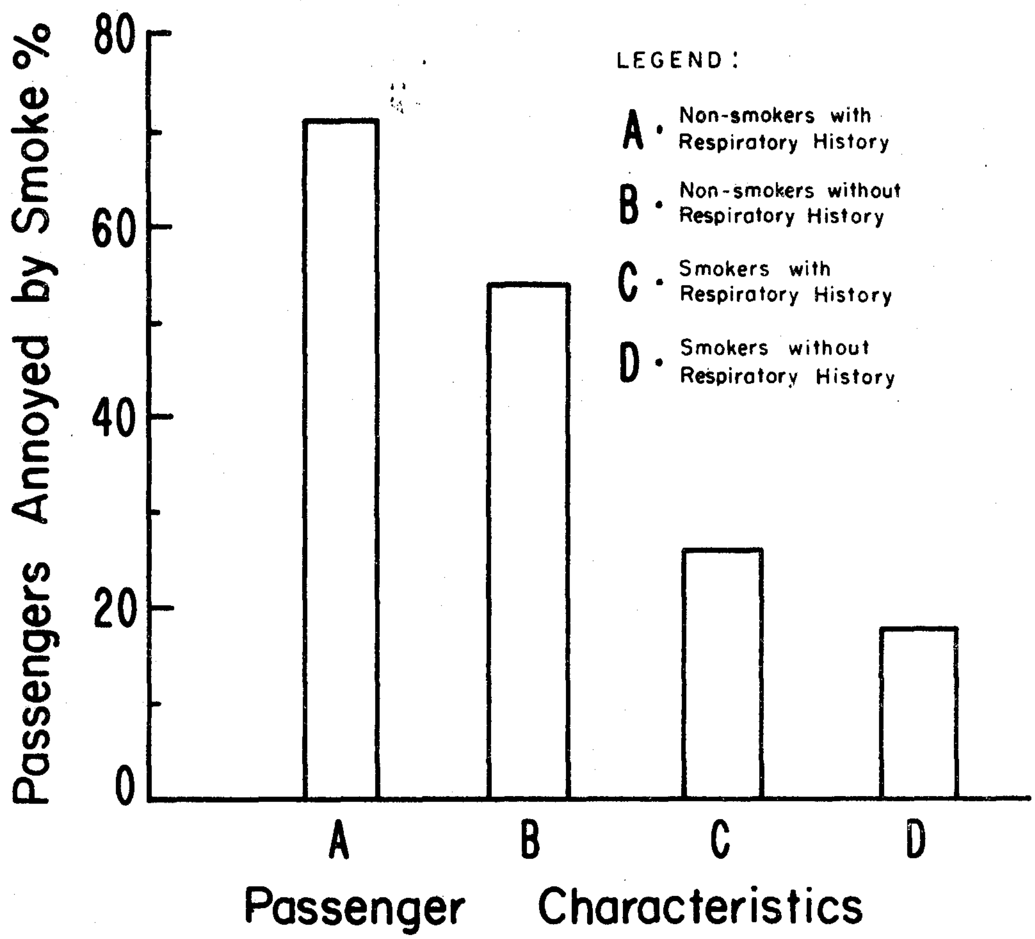


FIGURE R. PASSENGERS ANNOYED BY SMOKE RELATED TO SMOKING HABITS AND RESPIRATORY DISEASE HISTORY



A P P E N D I C E S

APPENDIX A

AGREEMENT BETWEEN FEDERAL AVIATION ADMINISTRATION/ DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Title: Health Aspects of Smoking in Transport Aircraft

I. BACKGROUND

The Federal Aviation Administration is conducting studies of tobacco smoke concentrations and its by-products in air transport aircraft. Several departments of the federal government are participating in instituting this study. It has been alleged that cabin smoke levels on some transport flights are of such concentrations as to be not only annoying but also harmful to health. Some have contended that combustion products resulting from burning tobacco may even compromise aircrew flight performance.

The short and long term effects of breathing the contamination in the air during flights must be comprehensively analyzed. The work to be accomplished by the two agencies under this agreement will serve, in part, to augment the total research effort.

The main thrust of this work will be given to measuring tobacco smoke products in aircraft interiors, including the cockpit and passenger area of the cabin environment. A questionnaire will be distributed requesting information regarding the passengers' personal attitudes toward smoking and their smoking activity during the flight.

II. PURPOSE

The purpose of the agreement between the Federal Aviation Administration (hereinafter referred to as FAA) and the Department of Health, Education and Welfare, Public Health Service, Consumer Protection and Environmental Health Service, Environmental Control Administration, (which will hereinafter be referred to in the agreement as DHEW) is to provide for studies to measure the environmental concentrations of combustion products resulting from tobacco smoking and the response of passengers in transport aircraft.

Consideration will be given to the need for establishing regulations that would minimize the discomfort and the nazard that results from other peoples smoking.

III. SCOPE

The work to be accomplished is as follows:

1. To measure the concentration of environmental contaminants.
2. To obtain smoking history and the subjective response of passengers to smoking

It should be noted that the investigation outlined here must be considered exploratory in nature, serving to define the current levels of known contaminants and to determine passenger reaction to smoking. The ultimate goal of the research will be a more complete understanding of the contaminant build-up in a closed environment, and the consequences of such build-ups. This knowledge can also provide a rational basis for control and foster criteria development aimed at minimizing problems of smoking in confined or closed environments. The subject study may also reveal contaminant levels that may affect the individual's capability for work, his responses or proneness to error and possible mishap. As such, it has a bearing on occupational health and safety matters.

Carbon monoxide will be measured with a continuous carbon monoxide indicator and a recorder. Polycyclic benzopyrene type components, aldehydes, ketones and aromatic hydrocarbons will be sampled with a battery operated pump and appropriate collection devices. In addition, particulates will be sampled for analysis on a membrane filter. Oxides of nitrogen and sulphur products may also be collected. Passengers will be asked to complete a questionnaire to provide information as to their age, sex, history of respiratory problems and to their current and/or past usage (if any) of tobacco. In addition, their personal attitudes toward the smoking of others and their subjective response to the smoking of others will be obtained.

Arrangements have been made for the tests to be conducted in commercial transport aircraft under contract to the Military Airlift Command (MAC). The Department of Defense has assigned the project to the Office of the Air Force Surgeon General. The use of air transport aircraft leased to the MAC was decided upon because of the high passenger density and the length of the flights involved. Approximately 20 flights will be involved in the initial study representing overseas flights to both Europe and Asia.

IV. RESPONSIBILITIES OF EACH PARTY

DHEW will provide the following:

1. The services of a technically qualified person to collect environmental samples.
2. The necessary instrumentation and supplies.
3. The laboratory analysis of data.
4. The statistical analysis of data.
5. Questionnaires.

FAA will provide the following:

1. The services of an industrial hygienist.
2. Aircraft ventilation system specifications.
3. Transportation costs on the aircraft involved in the study.
4. Arrangements for air transportation to and from port of departure.

It is understood that per diem, surface travel and incidental costs incurred by personnel on TDY will be absorbed by their respective agencies.

The FAA will negotiate the necessary arrangements with the Department of Defense to assure their support, cooperation and space on aircraft.

V. COMPLETION

The work called for herein shall be completed within 12 months after date of this agreement.

VI. REPORTS

Unless otherwise agreed, DHEW shall provide the FAA with reports in accordance with the following scheme.

1. Periodic reports (quarterly) on the status of the study.
2. A final scientific report.
3. A draft of a final report will be submitted to FAA for approval suitable for general public information. The FAA will provide comments. The final report incorporating the FAA comments will be delivered 15 months after the date of this agreement.

The final report will be made available to the aerospace industry, the transport industry, the military, and the general public.

VII. FUNDING

This agreement is for one year. FAA costs for FY 70 will be airline costs for the survey team plus the cost of their employees on TDY.

DHEW costs for FY 70 will be per diem and surface transportation of their team members, cost of equipment and supplies, laboratory service, and the statistical analysis of the data.

No funds will be either committed or spent by either agency for the other agency.

VIII. PUBLICITY

The FAA and DHEW will mutually approve any release of publicity relative to these studies and final reports.

IX. Any data collected under this project by DHEW will be available to FAA upon completion of the project. DHEW shall make delivery or disposition of such records as directed by the FAA.

X. The FAA technical representative and coordinator for this agreement shall be Mr. E.A. Richardson, Chief of the Industrial Hygiene Branch of the Office of Aviation Medicine, FAA.

The DHEW coordinator for this agreement shall be Mr. G.W. Sutton, Chief, Technical Assistance Branch, BOSH, ECA, CEPHS, PHS, DHEW.

P V Siegel MD
Federal Aviation Agency

Date 10 Sept. 1969

Peter J Bernard
Office of the Commissioner
Environmental Control Administration

Date SEP 9 1969

APPENDIX B

ANALYTICAL METHODOLOGY

POLYCYCLIC 3,4-BENZOPYRENE TYPE COMPOUNDS

Introduction

There are not any easy methods for the analysis of polycyclic hydrocarbons found in polluted air and tobacco tars. A certain degree of complexity and a considerable amount of labor is inherent in all these methods and the accuracy is not very high. This method is a variation of the result of concerted effort on the part of G. E. Moore, R. S. Thomas, and J. L. Monkman of the Environmental Assessment Unit, Occupational Health Division, Department of National Health and Welfare, Ottawa, Ontario, Canada and D. E. Richards of the Bureau of Occupational Safety and Health, Environmental Control Administration, U.S. Public Health Service, 1014 Broadway, Cincinnati, Ohio.

Collection of Sample

A known volume of air is aspirated through a membrane filter capable of collecting all particulate matter present in polluted air. The hi-vol filter is capped and shielded from light while in transport to the laboratory.

Apparatus and Reagents

1. 300 ml. capacity Soxhlet extractors
2. 1 cm I.D. x 15 cm length liquid chromatographic columns
3. Automatic fraction collector
4. Aminco-Bowman spectrophotofluorometer
5. Activated 30-200 mesh silica gel
6. Activated 100-200 mesh alumnia
7. Fluorometric grade cyclohexane, iso-octane, ethyl ether and benzene
8. Zone refined quality polycyclic hydrocarbons of interest

Procedure

The membrane filter is extracted with cyclohexane using a Soxhlet extractor. After evaporation, a measured portion of the total cyclohexane extract is placed on a column of activated silica gel. Elution of the aliphatic compounds from the column is accomplished with iso-octane. The aromatic fraction left on the silica gel column is then removed with benzene. This aromatic fraction is carefully concentrated and poured onto the alumina column. The column is capped with alumina and elution begun with pure cyclohexane then gradually increasing concentrations of ethyl ether in cyclohexane.

Order of elution:

Benzene
Naphthalene and naphthalene derivatives
Acenaphthalene
Fluorene
Phenanthrene
Anthracene
Pyrene
Fluoranthene
1,2-Benzfluorene
2,3-Benzfluorene
9,10-Benzphenanthrene
1,2-Benzanthracene
Chrysene
3,4-Benzpyrene
1,2-Benzpyrene
Perylene
2,3-Benzfluoranthene
1,12-Benzperylene
Anthanthrene
Coronene

Calculations

An Aminco-Bowman spectrophotofluorometer is used to analyze the fractions as they are collected from the column. The fractions containing any particular polycyclic may be combined and concentrated after which the total concentration can be determined with a single measurement. The resultant sample intensities are then used to calculate the concentrations of the polycyclic hydrocarbons from standard curves.

Atmospheric Solvent Vapor Sampling on Activated Charcoal

Atmospheric solvent vapors can be collected efficiently on activated charcoal and desorbed with carbon disulfide prior to separation and analysis using a gas chromatograph with a flame ionization detector.

1. A straight glass tube 6" x 4 mm I.D. packed with 2 - 1 inch sections (125 mg. each) of activated charcoal separated with a fiber glass plug and retained with fiber glass plugs at either end.

2. Standard sample volume -- 10 liters at 1.0 liter per minute.

3. Each section is analyzed separately with the one nearest the pump being designated as Section B.

4. Each section of activated charcoal is placed in a small stoppered flask. One ml. of carbon disulfide is added to the charcoal and allowed to stand for 30 minutes.

5. A known aliquot is withdrawn from the flask with a microliter syringe and introduced into the gas chromatograph.

6. Peak areas rather than peak heights are measured to calculate the solvent concentration.

7. Calibration curves must be established for each compound identified in the sample.

8. Calibration curves are established by injecting known amounts of the standard material into the gas chromatograph and measuring the areas under the peaks. A curve is established using concentration versus peak area.

Engineering Aspects of Activated Charcoal Solvent Vapor Tubes

1. Break both ends, set up in series with the pump and sample the standard volume of air.

2. After the sampling period, securely cap off both ends of the tube and mark the tube with direction of air flow.

3. Be sure to leave the one tube as a blank. That is, at the time the first sample is taken, break off the ends of the blank tube and securely cap each end immediately in the same manner as the sample tubes.

Ammonia in Air

In high concentrations ammonia can be absorbed in standard acid and the excess of the latter titrated with standard alkali. For general use, determination with Nessler's reagent is more convenient, however.

Collection of Sample

Using a petri bubbler with 25 ml. 0.1 N H_2SO_4, or a midget impinger with 10 ml. of 0.1 N H_2SO_4, sample for 10 to 30 minutes at 1 to 3 lpm.

Analysis

Dilute sample to 50 ml. with water; take 1 ml. and dilute to 50 ml. in a Nessler tube. Add 1 ml. Nessler reagent, and compare after 10 minutes with standards similarly treated.

Calculations

$$\frac{\text{mg } NH_3}{17} \times \frac{25}{\text{liters air}} \times 10^3 = \text{ppm}$$

Sensitivity

0.002 mg NH_3 detectable, corresponding to 0.1 mg in entire sample, or 3 ppm in a 50-liter air sample.

Reagents

H_2SO_4. 0.1 N.

Standard ammonia solution 0.0314 gram NH_4Cl in 1 liter water. 1 ml. contains 0.01 mg NH_3.

Nessler's reagent. 3 grams KI and 1 gram HgCl in 20 ml. water. Add 10 ml. 6 N NaOH, let stand, and decant or filter through glass wool.

Reference: H. B. Elkins, "The Chemistry of Industrial Toxicology", John Wiley and Sons, 1959, pp. 292-293.

Budget Bureau No. 85-S69046
Approval Expires 11/30/70

AIRCRAFT PASSENGER SMOKING QUESTIONNAIRE

Your Age______ Male______ Female______ Seat No.______

	YES	NO
Have you ever been told that you have:		
a. hay fever	___	___
b. asthma	___	___
c. sinus trouble	___	___
d. lung disorder	___	___
e. an allergy	___	___
Have you been bothered by any odors in the aircraft:		
a. before take off	___	___
b. after take off	___	___
Do you smoke?	___	___
If YES, do you regularly smoke:		
a. cigarettes	___	___
b. cigars	___	___
c. pipe	___	___
If you smoke cigarettes, what is your daily consumption: Number of cigarettes ___		
Did you smoke on this flight:	___	___
If YES, did you smoke:		
a. cigarettes	___	___
How many? ___		
b. cigars	___	___
c. pipe	___	___
Have you ever smoked?	___	___
If YES, did you smoke:		
a. cigarettes	___	___
b. cigars	___	___
c. pipe	___	___
Have you ever been bothered by other passengers in an aircraft smoking:		
a. cigarettes	___	___
b. cigars	___	___
c. pipe	___	___

	YES	NO
7. Are you bothered by the tobacco smoking of others in other places:	___	___
8. Have you ever experienced any discomfort of the following sites during a flight:		
a. eyes	___	___
b. ears	___	___
c. nose	___	___
d. throat	___	___
9. If your answer was YES, the duration of such irritation has been:		
a. only during the flight	___	___
b. 1-4 hrs after flight	___	___
c. 5-24 hrs after flight	___	___
d. more than 24 hrs	___	___
10. Does tobacco smoke in the aircraft cabin bother your:		
a. eyes	___	___
b. nose	___	___
c. throat	___	___
d. chest	___	___
11. Does tobacco smoke in other confined places bother your:		
a. eyes	___	___
b. nose	___	___
c. throat	___	___
d. chest	___	___
12. Do you think smoking in an aircraft should be permitted:		
a. only in certain areas	___	___
b. not at all	___	___
c. as at present	___	___

USE OTHER SIDE FOR ANY COMMENTS

CA-102(CIN)
(1-70)

APPENDIX D

Tabulation of Questionnaire Responses From MAC Flight Passengers

TOTAL NUMBER OF PASSENGERS 3073

AGE	0-19		20-29		30-39		40-49		50-59		60-UP		PASSENGERS	
	TOTAL	PCT	TOTAL	PCT	TOTAL	PCT	TOTAL	PCT	TOTAL	PCT	TOTAL	PCT	TOTAL	PCT
MALE	173	.05	1484	.48	461	.15	180	.05	59	.01	14	.00	2383	.77
FEMALE	53	.01	326	.10	193	.06	48	.01	18	.00	10	.00	660	.21
TOTAL	226	.07	1810	.58	654	.21	228	.07	77	.02	24	.00	3073	

PHYSICAL DISORDERS

	YES		NO	
	TOTAL	PCT	TOTAL	PCT
HAY FEVER	348	.11		
ASTHMA	136	.04		
SINUS TROUBLE	625	.20		
LUNG DISORDER	59	.01		
ALLERGY	369	.12		
ONE OR MORE	1011	.32	2062	.67

DISCOMFORT FROM ODORS IN ARCFT

	TOTAL	PCT
BEFORE TAKE-OFF	222	.07
AFTER TAKEOFF	445	.14
ONE OR MORE	558	.18

DO YOU SMOKE

	TOTAL	PCT
YES	1745	.56
NO	1328	.43

	TOTAL	PCT
CIGARETTES	1672	.54
CIGARS	124	.04
PIPE	147	.04

CIGARETTES CONSUMED DAILY

PER SMOKER 21

SMOKE ON THIS FLIGHT

	TOTAL	PCT
YES	1604	.52
NO	1469	.47

SMOKING PREFERENCE ON FLIGHT

	TOTAL	PCT
CIGARETTES	1538	.50
CIGARS	28	.00
PIPE	37	.01

CIGARETTES CONSUMED ON FLIGHT

1-5		6-10		11-15		16-30		31-UP	
TOTAL	PCT	TOTAL	PCT	TOTAL	PCT	TOTAL	PCT	TOTAL	PCT
692	.22	635	.20	145	.04	146	.04	14	.00

AVG NUM CIGARETTES PER PASSGER 4

AVG NUM CIGARETTES PER SMOKER 8

HAVE YOU EVER SMOKED

	TOTAL	PCT
YES	2055	.66
NO	1018	.33

PREFERENCE

	TOTAL	PCT
CIGARETTES	2040	.66
CIGARS	584	.19
PIPE	572	.18

PASS BOTHERED SMOKING IN ARCFT

	TOTAL	PCT
CIGARETTES	808	.26
CIGARS	834	.27
PIPE	436	.14
ONE OR MORE	1220	.39

BOTHERED OTH SMOKING OTH PLACS

	TOTAL	PCT
YES	1145	.37
NO	1928	.62

EXPERNCD DISCOMF DURING A FLGT

	TOTAL	PCT
EYES	672	.28
EARS	915	.29
NOSE	573	.18
THROAT	324	.10
ONE OR MORE	1678	.54

	TOTAL	PCT
ONLY DUR FLGT	1284	.41
1-4 HRS AFTER	301	.09
5-24 HRS AFTER	67	.02
OVER 24 HRS	40	.01

BOTHERED TBCO SMK IN ACFT CABN

	TOTAL	PCT
ONE OR MORE YES	1168	.38
NO	1905	.61

BOTHERED TBCO SMK OTH CONF PLC

	TOTAL	PCT
ONE OR MORE YES	1646	.53
NO	1427	.46

SMOKING PERMITTED IN AIRCRAFT

	TOTAL	PCT
CERTAIN AREAS	990	.32
NOT AT ALL	211	.06
AS AT PRESENT	1706	.55

	ILL		HEALTHY		TOTAL	
	TOTAL	PCT	TOTAL	PCT	TOTAL	PCT
PASSENGERS	1011	.32	2062	.67	3073	
MALE PASSENGERS	733	.23	1650	.53	2383	.77
FEMALE PASSENGERS	272	.08	388	.12	660	.21
FEMALE CIGARETTE SMOKERS	94	.03	162	.05	256	.08
MALE CIGARETTE SMOKERS	454	.14	1022	.33	1476	.48
MALE SMOKERS BOTHERED	119	.03	197	.06	316	.10
MALE NON-SMOKERS BOTHERED	193	.06	346	.11	539	.17
FEMALE SMOKERS BOTHERED	25	.00	26	.00	51	.01
FEMALE NON-SMOKERS BOTHERED	129	.04	120	.03	249	.08
PASS ANS YES TO QUESTION 10A	398	.12	600	.19	998	.32
PASS ANS YES TO QUESTION 10B	262	.08	332	.10	594	.19
PASS ANS YES TO QUESTION 10C	148	.04	138	.04	286	.09
PASS ANS YES TO QUESTION 10D	40	.01	42	.01	82	.02
PASS ANS YES TO QUESTION 11A	576	.18	939	.30	1515	.49
PASS ANS YES TO QUESTION 11B	324	.10	418	.13	742	.24
PASS ANS YES TO QUESTION 11C	173	.05	174	.05	347	.11
PASS ANS YES TO QUESTION 11D	56	.01	57	.01	113	.03
SMOKERS ANS YES TO Q 12A	137	.04	263	.08	400	.13
SMOKERS ANS YES TO Q 12B	15	.00	39	.01	54	.01
SMOKERS ANS YES TO Q 12C	384	.12	856	.27	1240	.40
NON-SMOKERS ANS YES TO Q 12A	230	.07	360	.11	590	.19
NON-SMOKERS ANS YES TO Q 12B	66	.02	91	.02	157	.05
NON-SMOKERS ANS YES TO Q 12C	148	.04	318	.10	466	.15
EX-SMOKERS ANS YES TO Q 12A	115	.03	152	.04	267	.08
EX-SMOKERS ANS YES TO Q 12B	24	.00	41	.01	65	.02
EX-SMOKERS ANS YES TO Q 12C	79	.02	161	.05	240	.07

	ILL		HEALTHY		TOTAL	
	TOTAL	PCT	TOTAL	PCT	TOTAL	PCT
BTHD SMOKERS ANS YES TO Q 12A	68	.02	95	.03	163	.05
BTHD SMOKERS ANS YES TO Q 12B	7	.00	11	.00	18	.00
BTHD SMOKERS ANS YES TO Q 12C	71	.02	125	.04	196	.06
NON-BTHD SMOKERS ANS YES Q 12A	69	.02	168	.05	237	.07
NON-BTHD SMOKERS ANS YES Q 12B	8	.00	28	.00	36	.01
NON-BTHD SMOKERS ANS YES Q 12C	313	.10	731	.23	1044	.33
BTHD NON-SMOKERS ANS YES Q 12A	197	.06	270	.08	467	.15
BTHD NON-SMOKERS ANS YES Q 12B	60	.01	75	.02	135	.04
BTHD NON-SMOKERS ANS YES Q 12C	63	.02	95	.03	158	.05
NON-BTHD NON-SMK ANS YES Q 12A	33	.01	90	.02	123	.04
NON-BTHD NON-SMK ANS YES Q 12B	6	.00	16	.00	22	.00
NON-BTHD NON-SMK ANS YES Q 12C	85	.02	223	.07	308	.10
BTHD EX-SMOKERS ANS YES Q 12A	98	.03	109	.03	207	.06
BTHD EX-SMOKERS ANS YES Q 12B	23	.00	32	.01	55	.01
BTHD EX-SMOKERS ANS YES Q 12C	29	.00	44	.01	73	.02
NON-BTHD EX-SMK ANS YES Q 12A	17	.00	43	.01	60	.01
NON-BTHD EX-SMK ANS YES Q 12B	1	.00	9	.00	10	.00
NON-BTHD EX-SMK ANS YES Q 12C	50	.01	117	.03	167	.05

Appendix E

Tabulation of Questionnaire Responses From Domestic Flight Passengers

TOTAL NUMBER OF PASSENGERS 265

AGE	0-19		20-29		30-39		40-49		50-59		60-UP		PASSENGERS	
	TOTAL	PCT	TOTAL	PCT	TOTAL	PCT	TOTAL	PCT	TOTAL	PCT	TOTAL	PCT	TOTAL	PCT
MALE	7	.02	26	.09	52	.19	63	.23	34	.12	12	.04	196	.73
FEMALE	6	.02	17	.06	4	.01	15	.05	3	.01	9	.03	57	.21
TOTAL	13	.04	43	.16	56	.21	78	.29	37	.13	21	.07	265	

PHYSICAL DISORDERS

	YES		NO	
	TOTAL	PCT	TOTAL	PCT
HAY FEVER	42	.15		
ASTHMA	12	.04		
SINUS TROUBLE	59	.22		
LUNG DISORDER	9	.03		
ALLERGY	47	.17		
ONE OR MORE	104	.39	161	.60

DISCOMFORT FROM ODORS IN ACFT

	TOTAL	PCT
BEFORE TAKE-OFF	50	.18
AFTER TAKEOFF	48	.18
ONE OR MORE	66	.24

DO YOU SMOKE

	TOTAL	PCT
YES	116	.43
NO	149	.56

PREFERENCE OF SMOKERS

	TOTAL	PCT
CIGARETTES	88	.33
CIGARS	22	.08
PIPE	17	.06

CIGARETTES CONSUMED DAILY

PER SMOKER	17

SMOKE ON THIS FLIGHT

	TOTAL	PCT
YES	83	.31
NO	182	.68

SMOKING PREFERENCE ON FLIGHT

	TOTAL	PCT
CIGARETTES	72	.27
CIGARS	1	.00
PIPE	5	.01

CIGARETTES CONSUMED ON FLIGHT

1-5		6-10		11-15		16-30		31-UP	
TOTAL	PCT	TOTAL	PCT	TOTAL	PCT	TOTAL	PCT	TOTAL	PCT
65	.24	4	.01		.00		.00		.00

AVG NUM CIGARETTES PER PASSGER

AVG NUM CIGARETTES PER SMOKER 2

HAVE YOU EVER SMOKED

	TOTAL	PCT
YES	138	.52
NO	127	.47

PREFERENCE

	TOTAL	PCT
CIGARETTES	134	.50
CIGARS	58	.21
PIPE	63	.23

PASS BOTHERED SMOKING IN ARCFT

	TOTAL	PCT
CIGARETTES	82	.30
CIGARS	118	.44
PIPE	63	.23
ONE OR MORE	135	.50

BOTHERED OTH SMOKING OTH PLACS

	TOTAL	PCT
YES	120	.45
NO	145	.54

EXPERNCD DISCOMF DURING A FLCT

	TOTAL	PCT
EYES	57	.21
EARS	112	.42
NOSE	40	.15
THROAT	21	.07
ONE OR MORE	150	.56

DURATION OF DISCOMFORT

	TOTAL	PCT
ONLY DUR FLGT	99	.37
1-4 HRS AFTER	46	.17
5-24 HRS AFTER	6	.02
OVER 24 HRS	6	.02

BOTHERED TBCO SMK IN ACFT CABN

	TOTAL	PCT
ONE OR MORE YES	104	.39
NO	161	.60

BOTHERED TBCO SMK OTH CONF PLC

	TOTAL	PCT
ONE OR MORE YES	144	.54
NO	121	.45

SMOKING PERMITTED IN AIRCRAFT

	TOTAL	PCT
CERTAIN AREAS	105	.39
NOT AT ALL	37	.13
AS AT PRESENT	102	.38

	ILL		HEALTHY		TOTAL	
	TOTAL	PCT	TOTAL	PCT	TOTAL	PCT
PASSENGERS	104	.39	161	.60	265	
MALE PASSENGERS	80	.30	116	.43	196	.73
FEMALE PASSENGERS	20	.07	37	.13	57	.21
FEMALE CIGARETTE SMOKERS	5	.01	13	.04	18	.06
MALE CIGARETTE SMOKERS	39	.14	56	.21	95	.35
MALE SMOKERS BOTHERED	7	.02	7	.02	14	.05
MALE NON-SMOKERS BOTHERED	29	.10	37	.13	66	.24
FEMALE SMOKERS BOTHERED	2	.00	2	.00	4	.01
FEMALE NON-SMOKERS BOTHERED	13	.04	6	.02	19	.07
PASS ANS YES TO QUESTION 10A	42	.15	43	.16	85	.32
PASS ANS YES TO QUESTION 10B	35	.13	31	.11	66	.24
PASS ANS YES TO QUESTION 10C	16	.06	11	.04	27	.10
PASS ANS YES TO QUESTION 10D	7	.02	2	.00	9	.03
PASS ANS YES TO QUESTION 11A	58	.21	63	.23	121	.45
PASS ANS YES TO QUESTION 11B	42	.15	36	.13	78	.29
PASS ANS YES TO QUESTION 11C	14	.05	17	.06	31	.11
PASS ANS YES TO QUESTION 11D	6	.02	3	.01	9	.03
SMOKERS ANS YES TO Q 12A	14	.05	25	.09	39	.14
SMOKERS ANS YES TO Q 12B	1	.00	2	.00	3	.01
SMOKERS ANS YES TO Q 12C	25	.09	40	.15	65	.24
NON-SMOKERS ANS YES TO Q 12A	32	.12	34	.12	66	.24
NON-SMOKERS ANS YES TO Q 12B	15	.05	19	.07	34	.12
NON-SMOKERS ANS YES TO Q 12C	11	.04	26	.09	37	.13
EX-SMOKERS ANS YES TO Q 12A	18	.06	13	.04	31	.11
EX-SMOKERS ANS YES TO Q 12B	5	.01	7	.02	12	.04
EX-SMOKERS ANS YES TO Q 12C	7	.02	12	.04	19	.07

	ILL		HEALTHY		TOTAL	
	TOTAL	PCT	TOTAL	PCT	TOTAL	PCT
BTHD SMOKERS ANS YES TO Q 12A	4	.01	2	.00	6	.02
BTHD SMOKERS ANS YES TO Q 12B	1	.00	2	.00	3	.01
BTHD SMOKERS ANS YES TO Q 12C	4	.01	3	.01	7	.02
NON-BTHD SMOKERS ANS YES Q 12A	10	.03	23	.08	33	.12
NON-BTHD SMOKERS ANS YES Q 12B		.00		.00		.00
NON-BTHD SMOKERS ANS YES Q 12C	21	.07	37	.13	58	.21
BTHD NON-SMOKERS ANS YES Q 12A	26	.09	20	.07	46	.17
BTHD NON-SMOKERS ANS YES Q 12B	14	.05	16	.06	30	.11
BTHD NON-SMOKERS ANS YES Q 12C	4	.01	4	.01	8	.03
NON-BTHD NON-SMK ANS YES Q 12A	6	.02	14	.05	20	.07
NON-BTHD NON-SMK ANS YES Q 12B	1	.00	3	.01	4	.01
NON-BTHD NON-SMK ANS YES Q 12C	7	.02	22	.08	29	.10
BTHD EX-SMOKERS ANS YES Q 12A	15	.05	8	.03	23	.08
BTHD EX-SMOKERS ANS YES Q 12B	4	.01	6	.02	10	.03
BTHD EX-SMOKERS ANS YES Q 12C	3	.01	3	.01	6	.02
NON-BTHD EX-SMK ANS YES Q 12A	3	.01	5	.01	8	.03
NON-BTHD EX-SMK ANS YES Q 12B	1	.00	1	.00	2	.00
NON-BTHD EX-SMK ANS YES Q 12C	4	.01	9	.03	13	.04

APPENDIX F

Ventilation Systems in Jet Aircraft

The following discussion of aircraft ventilation systems pertains specifically to the Boeing 707, 300 series with the JT 3D engine. Ventilation systems are basically the same for all of the Boeing aircraft with some obvious modifications.

The engines are numbered from port to starboard 1, 2, 3, 4 (see Figure 1).

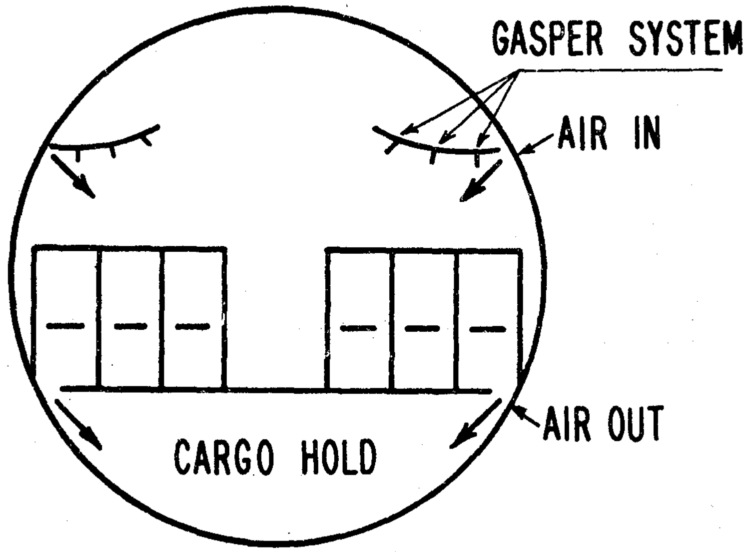
The JT 3D engine has four major components (see Figure 1), the fan, low spool bleed, high spool bleed, and turbine. Air for cabin pressurization and ventilation is obtained from the turbo compressors and/or the low spool bleed. Numbers 2, 3, and 4 engines have both turbo compressor and low spool bleed take-offs. Whereas, engine 1 has only a low spool bleed.

The recommended take-off procedure calls for 2 turbo compressors in operation. At take-off power setting, each turbo compressor can deliver approximately 85 pounds of air per minute. According to the Boeing engineer, there are approximately 12 cubic feet per minute per pound of air. Therefore, there are approximately 1,020 cubic feet per minute per turbo compressor at standard operating conditions. (According to calculations, the density of air at standard conditions is 0.075 pounds per cubic foot. This would yield 1,132 cubic feet per minute per turbo compressor. It is not known how the Boeing engineer derived his approximations). At a flight altitude of 35,000 feet, the flow may be approximately 70 pounds per minute for a total of about 210 pounds per minute from the three turbo compressors. Approximately 10% of the total air goes to the crew cabin, leaving approximately 190 pounds per minute to the passenger cabin. This is based on the assumption that the turbo compressors are new. This amount of air will give an air change in the passenger cabin every 3.4 minutes. All of Boeing's passenger aircraft provide an air change about every 3 to 4 minutes.

The turbo compressor uses only <u>clean</u> air -- no engine air. Any engine with a turbo compressor can also provide air to the cabin from its low spool bleed by the manipulation of valves. Cabin pressurization can be accomplished either through the use of the turbo compressor or the low spool bleed. There are two situations in which ground operation ventilation is accomplished. When the engine is not running, a low pressure ground cart can provide conditioned air to the airplane, or a high pressure ground cart which will duplicate what the engines or auxiliary power units (APU) can do. When the engines are running two turbo compressors are kept on, delivering from 60 to 80 pounds per minute per turbo compressor.

Figure 2 illustrates the cabin pressurization and ventilation system through the turbo compressor. The low pressure manifold gauge is the only indicator of air flow (inches H_2O) in the cabin, regardless of the source of air. This gauge is located on the flight engineer's panel.

Air is distributed in the passenger cabin just beneath the overhead racks and is discharged at floor level adjacent to the bulkheads. The individual air supplies or Gasper system takes air from the same source, but has a separate distribution system. Air from the Gasper system is not heated. The velocity around the passengers' heads is approximately 30 to 50 feet per minute. Air is not recirculated, but is discharged through four "out flow" valves located in the bottom of the airplane (See Figure 3).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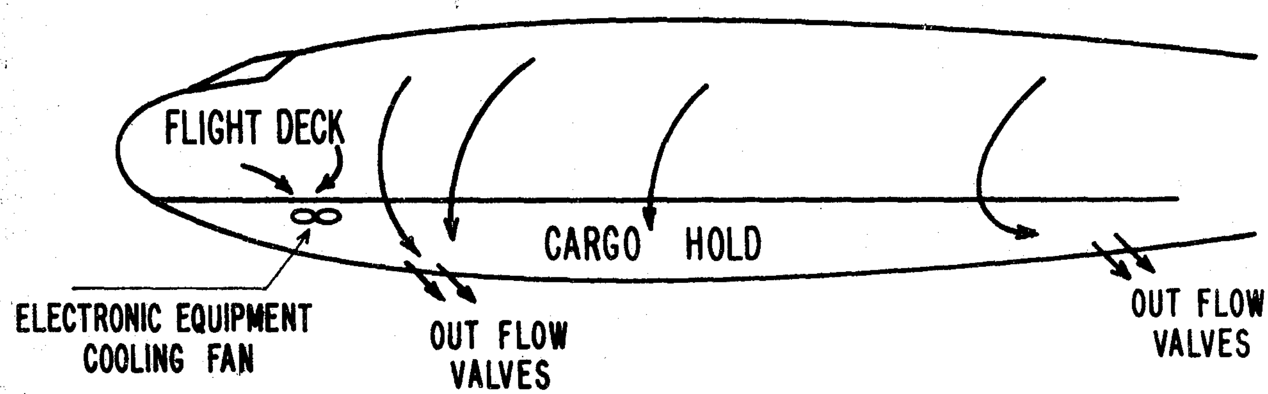
AIR IN
AIR OUT
CARGO HOLD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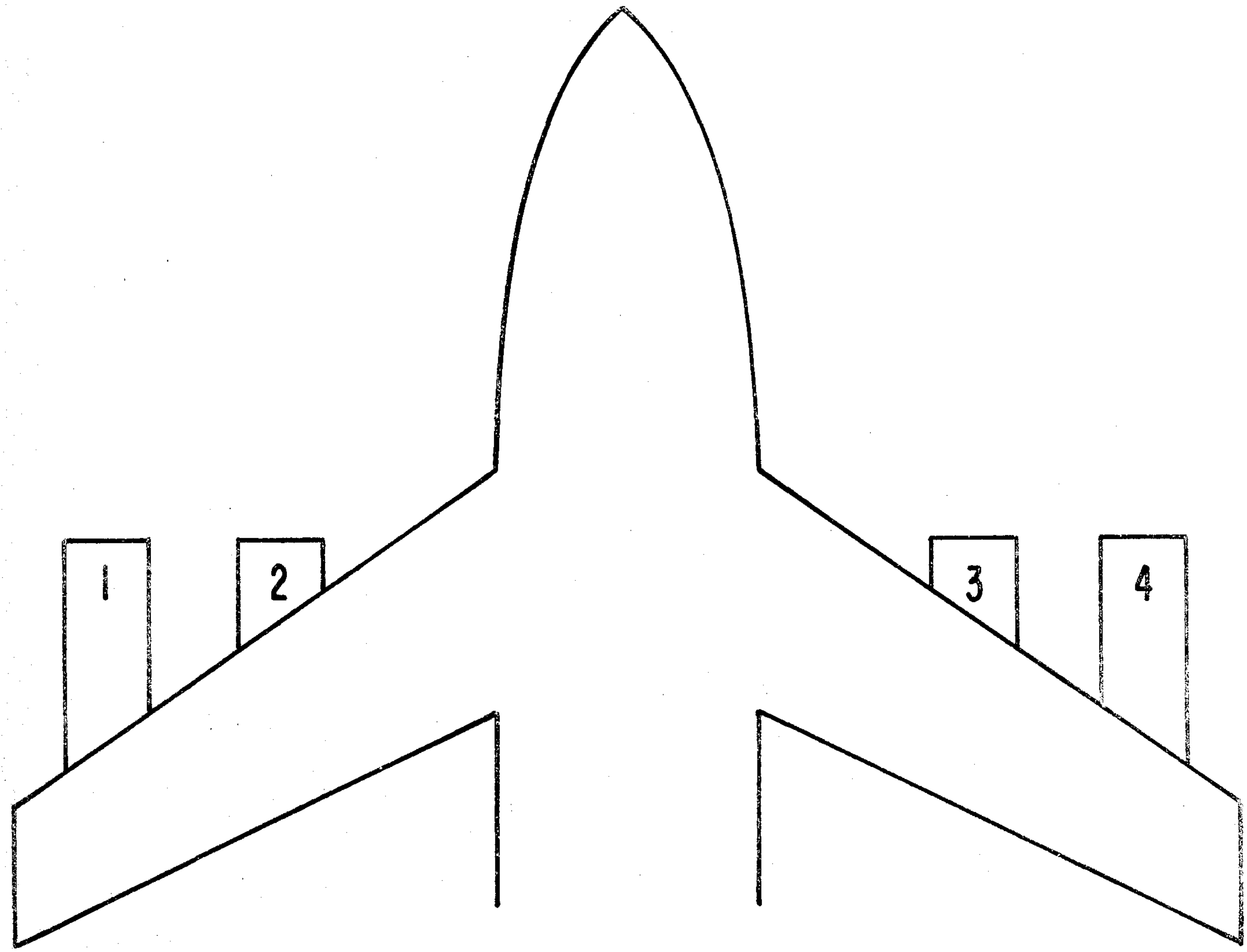
CARGO HOLD
ELECTRONIC EQUIPMENT
COOLING FAN
OUT FLOW
VALVES
OUT FLOW
VALVES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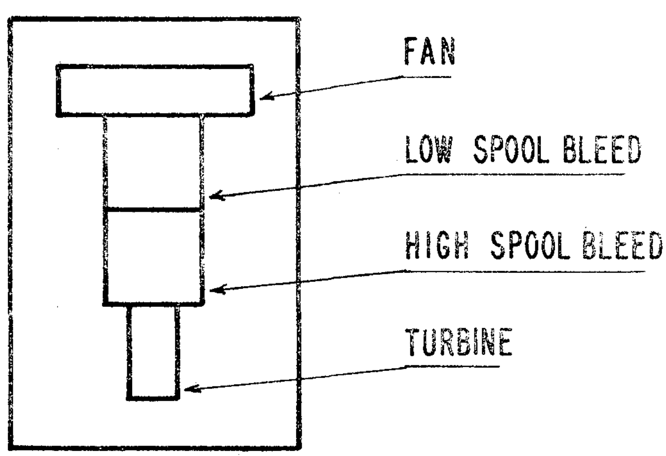
2
3
4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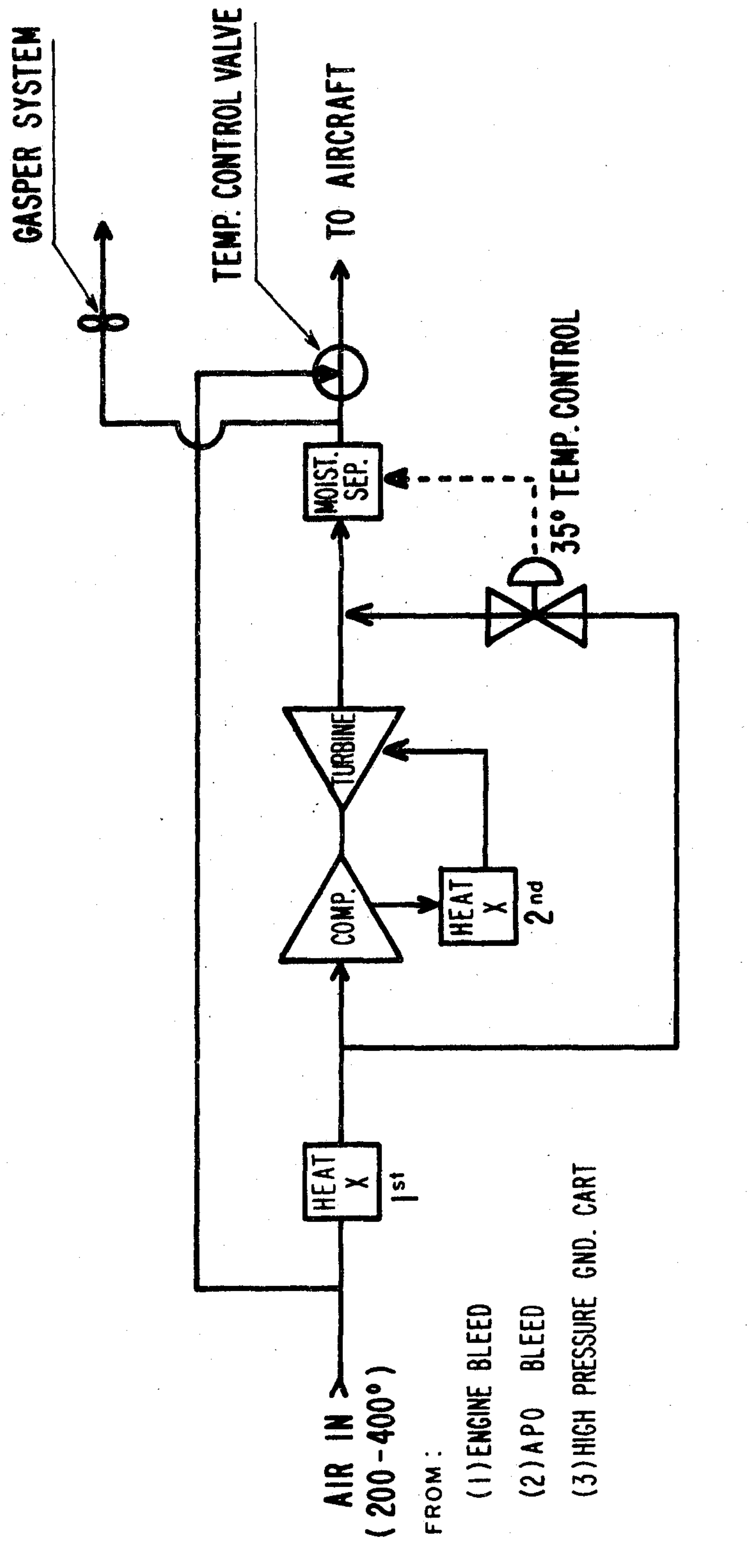
HIGH SPOOL BLEED
TURBINE



AIR CYCLE MACHINE

APPENDIX G

Comparison of average concentration of contaminants found on aircraft with occupational[1] and nonoccupational[2] ambient air standards

	Carbon Monoxide ppm	Ammonia ppm	Total Oxidants (as ozone) ppm	Total Particulates mg/m^3
Average concentration on planes	2.8	<0.02	<0.02	0.04
Occupational-TLV	50	50	0.10	10.0
Nonoccupational standard	9	5[3]	0.08	0.26

1. Threshold Limit Values of Airborne Contaminants, adopted by the American Conference of Governmental Industrial Hygienists, 1971.

2. Ambient Air Quality Standards of the Environmental Protection Agency, March 1970.

3. No standard for ammonia exists in the United States; 5 ppm is the standard adopted in Ontario, Canada.