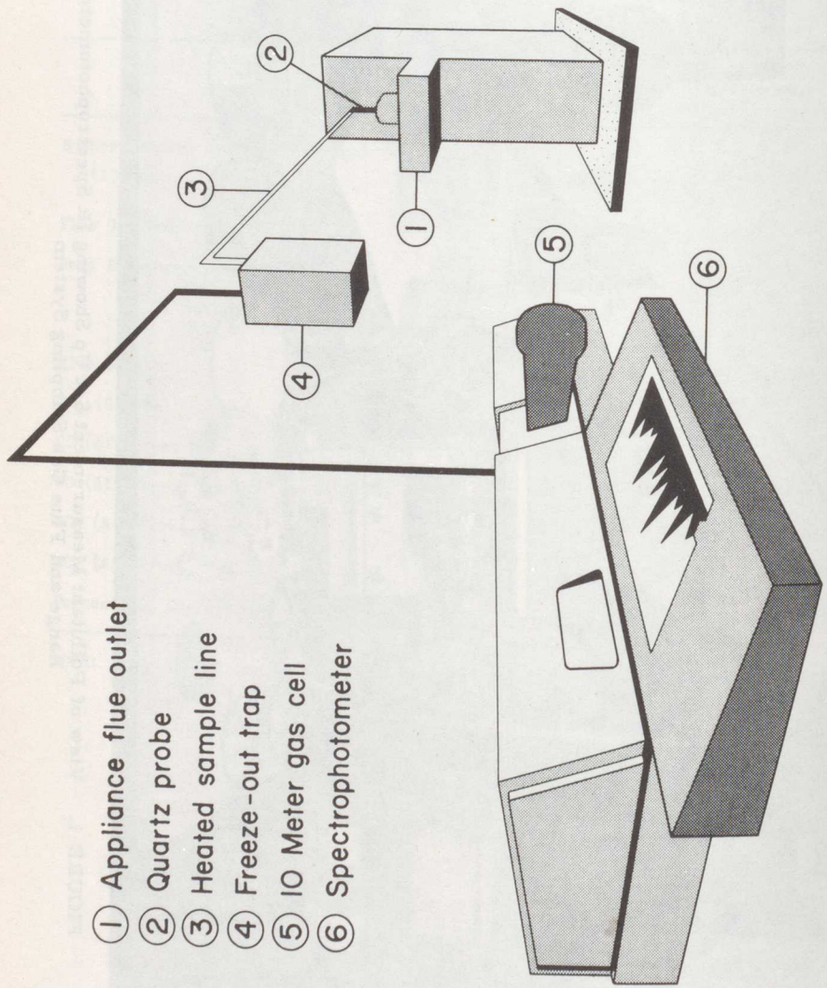

FIGURE 2. Sample Train Used With Gas-Fired Appliances

SURVEY OF THE INCIDENCE OF RESPIRATORY DISEASE IN HOUSEHOLDS USING GAS AND ELECTRIC COOKERY

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ABSTRACT

A study was undertaken to determine the incidence of respiratory disease in households in a midwestern suburban middle-class community, in a relatively unpolluted area. The sample included 441 families, divided into two groups; those utilizing gas cookery and those utilizing electric cookery. Family health and demographic data were obtained from the participants. The period of the study was one year. Reports of acute respiratory illness were obtained through bi-weekly telephone calls to each of the households. The respondents were asked to report respiratory illness in any member of the household, and to indicate the presence or absence of a set of signs and symptoms. Ambient air was analyzed, indoors and outdoors, in a sample of the households, and pulmonary function tests were conducted on a 42 percent sample of the participants, representing both types of household.

The results of the study are presented with regard to reported incidence of respiratory illness in the two types of household. AID analysis and multiple regression were carried out to determine the best set of independent variables as predictors of respiratory disease incidence. This is the first in a series of studies. Subsequent studies will follow-up the reported respiratory illness to ascertain objective signs of illness and obtain bacterial cultures. Similar studies are also contemplated in areas in which the ambient air is more heavily polluted.

SURVEY OF THE INCIDENCE OF RESPIRATORY DISEASE IN HOUSEHOLDS USING GAS AND ELECTRIC COOKERY

INTRODUCTION

In the combustion of fossil fuels many substances are produced that are toxic at certain concentrations. A substance of particular interest is NO_2. Although it is known that NO_2 may be fatal to persons exposed to high concentrations, such as 500 ppm that may be encountered in silos, very little is known about long-term exposure to low levels of concentration. Recent studies in Chattanooga (1,2,3) indicated that persons living in areas with elevated levels of ambient NO_2, reported a high incidence of respiratory illness. This caused some concern regarding the possible effects of NO_2 on the incidence of respiratory illness. It is known that the open flame in gas ranges can produce short-term elevation of NO_2 concentration in the cooking area. However, the possible effects on the respiratory health of members of such households have not been assessed adequately. Accordingly, the present study was initiated to acquire data for making such assessments.

In the Chattanooga area, it was found that in addition to the NO_2 there were other pollutants such as nitric acid, suspended nitrates, and particulates at unusually high levels of concentration. In order to eliminate such factors, it was felt to be of value to study areas with low ambient air pollution levels.

DESIGN

The area chosen for the present study is the City of Upper Arlington, a middle class suburb on the periphery of Columbus, Ohio. In June, 1972, questionnaires were distributed through the elementary schools in Upper Arlington. The questionnaires were developed by the Environmental Protection Agency for the Community Health and Environmental Surveillance System (CHESS) (4) and included questions regarding demographic variables, smoking habits, and a variety of health problems. The completed questionnaires were separated into two groups; households with gas ranges; and households with electric ranges. Families that expected to move within 12 months were excluded from the sample. Among over 1,000 completed questionnaires, 17.5 percent of the households had gas ranges. In order to augment the number of gas-cooking households, additional households were visited and a second appeal was made through the schools. The final sample included 441 households, 232 of which used electricity for cooking, and 209 of which used gas. The final sample included only the families expressing willingness to participate in the program. Table 1 presents the population sample, whose respiratory disease experience is reported in the present paper.

Table 1 UPPER ARLINGTON STUDY POPULATION

	Electric	Gas
Households	232	209
Mothers	230	207
Fathers	222	197
Children, 0-12 Yrs.	407	356

Table 2 presents the overall age and sex distributions of the entire study sample.

Table 2 UPPER ARLINGTON STUDY POPULATION

Ages	Male	Female
0-5	69	59
6-10	176	173
11-15	213	208
16-20	77	90
21-40	215	289
41-60	212	158
61-Up	6	7
Total	968	984

The program was initiated in November, 1972. Participants were contacted by telephone every two weeks to obtain reports on respiratory illness among members of the household during that period. A special calendar was supplied to each household for record keeping. The information obtained was recorded on two sets of records. A master card was maintained for each family in case the working mark-sense card was lost or unreadable. The master card contained all the information obtained by the telephone interviewer. The survey continued for 26 periods to yield one full year of data.

The study population was invited to have pulmonary function screening tests for the detection of chronic respiratory impairment. Also, in order to determine the levels of NO_2 and NO, a sample of the gas and electric households were monitored for these substances.

Pulmonary Function Testing:

Measures of Forced Vital Capacity and 0.75 Second Forced Expiratory Volume were made using a 10 liter dry rolling-seal spirometer. Prior to testing, each subject was instructed regarding the proper method of performing the forced vital capacity maneuver. Care was taken to insure that each subject inspired to maximum capacity and kept the back reasonably straight during forced expiration. The test was repeated a number of times until the results obtained were reproduceable ($\pm$ 5%). A minimum of three trials were obtained with each subject, and the best value for each of the variables was recorded.

Monitoring for NO_x:

Since the study was concerned with the possible relationship between the incidence of respiratory disease and exposure to oxides of nitrogen, it was necessary to measure this substance in a sample of the households. A total of 83 homes with gas cooking modes and 50 homes with electric cooking modes were monitored for NO_2 and NO over periods of 24 hours, using the modified Jacobs-Hochheiser (J-H) method (5). In addition, 53 outdoor samples were taken with the (J-H) units in the areas of the indoor monitoring. Continuous

chemiluminescence measurements were also made for three-day periods in 46 homes to evaluate the instantaneous variation in indoor NO_2 and NO levels.

Peak NO_2 levels in gas cooking mode households, during cooking periods, were generally eight times higher than the 24-hour average. In several households, these peak values exceeded 100 pphm. No peak values of this type were noticed in electric cooking mode households, other than a rise in NO levels during periods of high traffic, in the homes near thoroughfares. Measurements were made in the period of January through April, 1973. Table 3 presents a summary of the NO_2 and NO data:

Table 3

Type	NO_x Monitoring			
	Range (pphm)		Average (pphm)	
	NO_2	NO	NO_2	NO
Gas homes	0.5-11	1-41	5	11
Electric homes	0- 6	0-34	2	7
Outdoors	1.5- 5	0.5-22	3	4

Statistical Method:

The present study seeks to examine the relationship of a large number of variables to the incidence of respiratory illness in the study population. In this type of study the combined effects and interactions of these variables are as important as the individual or main effects of each independent variable. Traditional analytical methods are typically bound by rather stringent assumptions concerning distributions and linearity, and frequently neglect interaction. In nearly all studies like the present one, these assumptions are known to be unwarranted, or they are incapable of being validated by examination of the data. The Automatic Interaction Detector method (AID) of Sonquist and Morgan (6), utilized in the present study, provides a multivariate approach to analysis relatively free of these restrictions. The AID program is based on a sequential analysis of variance. It selects the best set of predictive or explanatory variables with respect to the dependent variable, in this case reported incidence of respiratory disease. It also simultaneously seeks out relationships and interactions among these variables and indicates the significance of the relationship of independent to dependent variables, in terms of the portion of the variance (differential occurrence of respiratory illness) that is explained.

AID was used for analysis of the incidence of respiratory disease in the samples of mothers and of fathers. Multiple regression was used for the analysis of the incidence in children, as will be explained in the section on Results. Table 4 presents the predictive or explanatory variables used in the AID and multiple regression methods.

TABLE 4

Mothers and Fathers - Columbus

Explanatory Variables
- Age (year of birth)
- Group (Gas/Electric)
- Cough - 3 months a year
- Cough - day or night
- Cough - day or night - 3 months a year
- Phlegm in morning
- Phlegm 3 months a year
- Phlegm day or night
- Cough or phlegm 3 weeks
- Shortness of breath
- Current cigaret smoker
- Smoked 5 packs or more in life
- Number of cigarets per day
- Age started smoking
- Age quit smoking
- Number of years smoked
- Number of years since quit smoking
- Exposed to irritant on job

Dependent Variables
1. All respiratory illness (mothers and fathers)
2. Lower respiratory illness (mothers)

Children - Columbus

Explanatory Variables
- Age (year of birth)
- Group (Gas/Electric)
- Sex
- Size of house (number of rooms)
- Numbers of years family lived in community
- Fathers' educational level
- Chronic heart disease
- Chronic lung disease
- Chronic asthma
- Pneumonia
- Croup
- Bronchitis
- Other chest infections
- Hospitalized

Dependent Variable
- All respiratory illness

Mothers - Long Island

Explanatory Variables
- Age
- Group (Gas/Electric)
- Cough or phlegm 3 months a year
- Current cigaret smoker
- Cough in morning
- Cough day or night
- Cough day or night 3 months a year
- Phlegm in morning
- Phlegm day or night
- Phlegm 3 months a year
- Shortness of breath
- Ever smoked
- Number of cigarets per day
- Exposed to irritants on job
- Duration of exposure to irritants
- Kind of irritants
- Where lived as a child (up to age 20)
- Where lived from age 20-30
- Where lived after age 30
- Family size

Dependent Variables
1. All respiratory illness
2. Lower respiratory illness

RESULTS

Figure 1 presents a comparison of the annual incidence of all reported respiratory illness, per hundred persons, in the subject categories indicated. In all cases the rates were higher in households utilizing electricity for cooking. In general, rates were highest in children under 12, and higher in mothers than in fathers. An additional comparison is presented for reported lower respiratory disease ("chest colds") among the mothers. This will be related in the Discussion to data from another study.

Figure 2 presents the AID analysis for all reported respiratory illnesses among the mothers in the Arlington sample. The overall rate for the entire population of mothers was 234 illnesses per hundred mothers per year; mothers cooking with electricity reporting an incidence of 243, while those cooking with gas reporting 222. These are the figures presented above in the bar graph in Figure 1. The AID analysis further indicated a higher incidence among younger mothers, who indicated in the household questionnaire that they usually bring up phlegm. Younger mothers, in general, reported higher incidence than older mothers, even when they did not initially report bringing up phlegm. Beyond this none of the explanatory variables contributed significantly to explaining the differences in incidence. In fact, the AID analysis indicated that whether or not the mothers cooked with gas or electricity explained virtually none of the variance. Figure 2 is the only AID diagram included in the present report to illustrate the method. None of the AID results proved effective in explaining differences in incidence.

AID analysis was also carried out on reports of lower respiratory illness among the mothers. The overall population of mothers had an incidence of 151 per hundred per year. As shown in the bar graph of Figure 1 the mothers cooking with electricity had an incidence of 159 as compared with an incidence of 143 among mothers cooking with gas. However, this difference was of such low significance that it could explain only 1/50 of one percent of the variance. In fact, in this case, all of the explanatory variables together could predict only one percent of the variance, leaving 99 percent unexplained.

AID analysis was carried out for all reported respiratory illness among the fathers. The overall incidence in the population of fathers was 166 per hundred per year. The fathers in households with electric cookery reported an incidence of 172, as compared with 159 in the gas household sample. However, once again the differences between the gas and the electric samples explained only 1/100 of one percent of the variance, and all of the explanatory variables together explained less than one percent. Trends were noted indicating that younger fathers reported more respiratory illness. The only other variable that may be related is smoking, those who smoked more for more years or quit more recently reported more illness than non-smokers or those who quit long ago. However, it must be emphasized that none of these variables significantly explain the incidence of respiratory disease. The AID analysis does not even select the variable of gas or electric cookery for inclusion, since this has so little relation to differences in the occurrence of illness in the two groups.

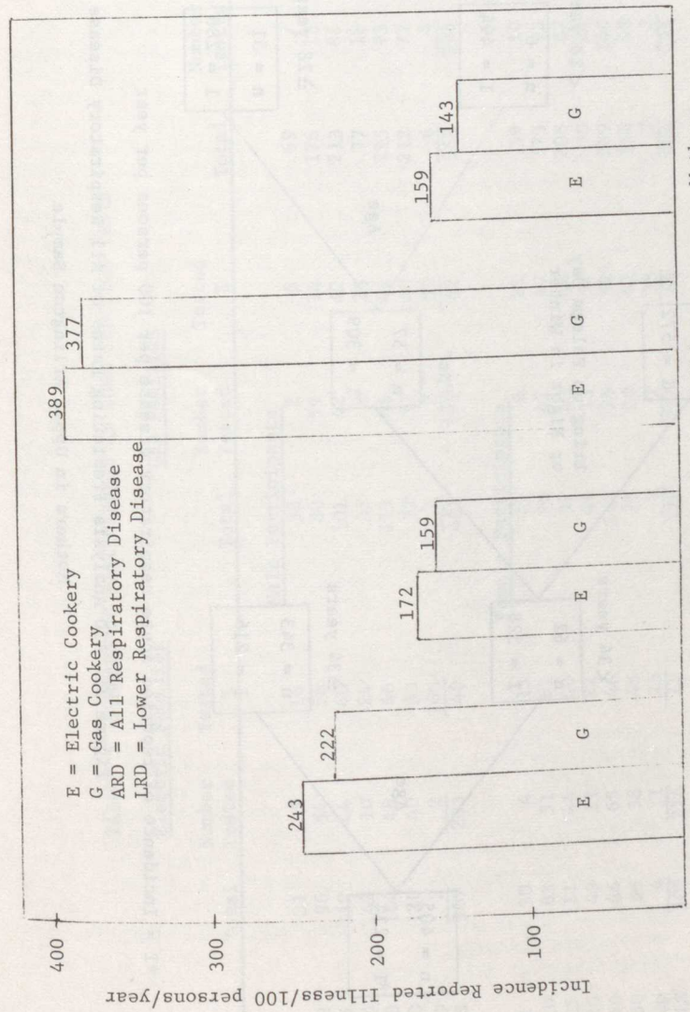
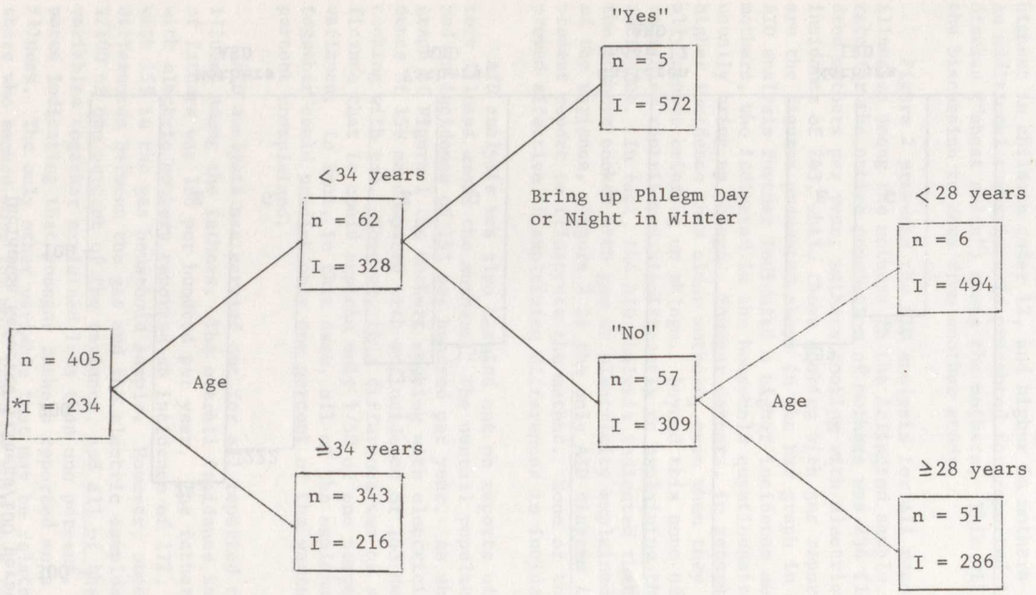


FIGURE 1. UPPER ARLINGTON STUDY - ANNUAL INCIDENCE OF RESPIRATORY ILLNESS



*I = Incidence of reported acute respiratory disease per 100 persons per year

Figure 2: AID Analysis Predicting Rates of All Respiratory Disease Mothers in Upper Arlington Sample

TABLE 5 SUMMARY OF PARTICIPANTS IN LUNG FUNCTION TESTS

Age Group	Electric Families Total	Number Tested	Tested %	Gas Families Total	Number Tested	Tested %	Total	Number Tested	Tested %
				Male Participants					
0-5	31	5	16	38	2	5	69	7	10
6-10	96	54	56	80	59	74	176	113	64
11-15	112	44	40	101	42	42	213	86	40
16-20	42	10	24	35	8	23	77	18	23
21-40	104	48	46	111	45	41	215	93	43
41-60	120	40	33	92	37	40	212	77	36
61-Up	2	2	100	4	2	50	6	4	66
TOTALS	507	203	40	461	195	42	968	398	41
				Female Participants					
0-5	30	4	13	29	6	21	59	10	17
6-10	83	51	61	90	42	47	173	93	54
11-15	111	44	40	97	43	44	208	87	42
16-20	49	11	22	41	13	32	90	24	27
21-40	146	65	46	143	75	52	289	140	48
41-60	85	38	45	73	30	41	158	68	43
61-Up	4	1	25	3	1	33	7	2	29
TOTALS	508	214	42	476	210	44	984	424	43

The incidence of illness among children from birth to 12 years was analyzed by multiple regression. Since in earlier analyses all of the explanatory variables, and in particular the variable of gas or electric cookery, contributed little to explaining incidence of illness, the expense of AID analysis was not warranted for this group, and multiple regression was deemed sufficient to answer the questions posed. The overall incidence for this population of children rent was 384 per hundred per year. The rate was higher among children than among the mothers or the fathers. Children in the electric cooking homes had an incidence of 389 as compared with 377 in the gas cooking sample. However, once again the method indicated no predictive power.

Lung Function Tests:

The entire population of the sample was invited to have lung function examinations. The tests were conducted in the manner indicated in the section on Design. Table 5 presents the age, sex and group (gas or electricity) of the sample tested. Overall, approximately 42 percent of the study population were tested. Chi square (X^2) analysis indicated no significant differences between the gas and electric household participants, in terms of age and sex representation. Table 6 presents the analysis of variance of the results of Forced Vital Capacity and the 0.75 Second Forced Expiratory Volume. There were no significant differences between the groups with respect to the Total Forced Vital Capacity, and a small but significant difference appeared with regard to the 0.75 Second Volume. The participants from the gas cooking households had slightly better lung function measurements on the average. However, the differences explained only an extremely small portion of the variance in pulmonary function, approximately one half of one percent. These tests were carried out in order to detect the possible presence of a large number of individuals with pulmonary impairment in one or the other group, since this might bias the results with regard to the reported incidence of respiratory illness. These data do not indicate such bias.

Table 6 Analysis of Variance
Pulmonary Function Tests

	Group 1 (Electric)	Group 2 (Gas)
	416	405
Mean Age	24.2	23.8
Mean Height	61.5	61.6
Mean Weight	118	116
Mean FVC	3.02*	3.04*
Mean FEV-75	2.32*	2.39*

F Test for FVC (1,816 df) = 0.647
F Test for FEV-75 (1, 816 df) = 4.455**

*Adjusted values on basis of age, sex, and height by co-variate analysis.
**Significant at Alpha 0.05

Discussion:

The overall outcome of the analyses employed in the present study indicate no significant difference in reported respiratory illness between the members of households cooking with gas and those cooking with electricity. This was evident in the comparison of incidence rates among mothers, fathers, and children from birth to 12 years of age.

Additional analyses were carried out with regard to the reported lower respiratory disease among mothers, in order to allow comparison of the present study results with those obtained in an epidemiologic study conducted by the Environmental Protection Agency in a suburban community in Long Island, N.Y. The latter study involved 146 households, 59 of which cooked with electricity and 87 with gas. The study was similar to the present one in Upper Arlington, and was conducted over a period of 30 weeks. Inquiries were made regarding the incidence of respiratory illness every two weeks. Through the courtesy of the Environmental Protection Agency, computer tapes containing the data of the Long Island Study were made available to the authors, so that they could be subjected to AID analysis in the same way as the Upper Arlington data. Table 7 presents a comparison of the two studies with regard to all reported respiratory illness, and lower respiratory illness ("chest colds") only. The data of the Long Island Study were extrapolated to a period of one year, so that incidence rates could be directly compared with those of the Upper Arlington study. It is realized, that this may introduce some error, since seasonal variation may be associated with changes in respiratory disease incidence. However, the basic hypothesis being tested involves comparison of incidence rates among the gas cooking and the electric cooking households in each study area. In Long Island, as in Upper Arlington, the incidence of all respiratory disease was higher among mothers cooking with electricity. In the Long Island Study the overall incidence was 302 respiratory illnesses per hundred mothers per year; those with electric cookery reporting 322, as compared with 289 in the gas cooking households. However, as in the Upper Arlington sample, these differences were insignificant. All of the explanatory variables together were only able to account for 4 percent of the variance in the Long Island Study. While this was somewhat higher than Upper Arlington, it still left 96 percent of the variance in illness unexplained.

The Long Island sample mothers, in general, presented less lower respiratory disease ("chest colds"). The population incidence was 120 per hundred per year, with the mothers in the electric group reporting 99, and the mothers in the gas group reporting 133. However, again the differences were not significant, with only a minute fraction of the occurrence of illness explained. All of the predictor variables in the Long Island Study together explained only 5 percent of the incidence.

Table 7

Respiratory Disease Reported by Sample of Mothers

		N	Rates of Illness* All Resp. Disease	Lower Resp. Disease**
Long Island	Electric	59	322	99
	Gas	87	289	133
	Total	146	302	120
Upper Arlington	Electric	230	243	159
	Gas	207	222	143
	Total	437	234	151

*Reported illnesses per 100 persons per year
** "Chest Colds"

The data presented do not demonstrate sufficient differences to reject the null hypothesis, namely, no difference between the incidence of respiratory illnesses among mothers in the electric and gas cooking households. In both the Upper Arlington and the Long Island studies, insofar as the latter has been analyzed, it would appear that populations living in relatively unpolluted areas do not differ significantly with respect to reported respiratory illness in relation to mode of cookery. The underlying assumption of the present study was that exposure to NO_2 generated by gas cookery might have some effect upon the incidence of respiratory disease. If this were so, it would be reasonable to conclude that either the concentration or the length of the exposure were not sufficient to cause differences in the type of acute illness reported. It may be possible that certain other noxious agents in the general environment, as mentioned by Warner and Stevens (7), might be required to bring out the incidence described in other studies.

There may be an inherent weakness in all of the studies that have been considered, due to the inability of the household respondent to convey accurate information regarding the incidence of respiratory infection in all members of the household. There may be sufficient differences between respondents to introduce error that may seriously affect the outcome of studies with relatively small samples. Certainly, it would be difficult to feel secure about the differentiation of upper and lower respiratory disease by the respondents. Such distinctions are difficult to make, and may vary greatly with the experience and perceptiveness of the respondent.

Further analysis of the specific symptoms that were reported in the present study will be presented in another paper. A second study is now in progress in which a nurse-epidemiologist will examine individuals reporting respiratory illnesses and take nasopharyngeal cultures. At the same time, examination will be made of "well" members of the same household and of members of control households in the study population. By this means it will be possible to obtain more rigorous information regarding the meaning of a reported illness, in terms of objective physical findings and bacterial culture.

Session V
Paper 4

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