U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
CENTER FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
CINCINNATI, OHIO 45226

HEALTH HAZARD EVALUATION DETERMINATION
REPORT NO. 75-11-403

PORT OF DULUTH-SUPERIOR GRAIN ELEVATORS
DULUTH, MINNESOTA & SUPERIOR, WISCONSIN

JUNE 1977

I. TOXICITY DETERMINATION

The National Institute for Occupational Safety and Health (NIOSH) conducted a health hazard evaluation of grain handling activities at grain elevators in the Port of Duluth-Superior in 1975-76. Based upon the results of the NIOSH environmental/medical investigations the following determinations are made.

1. Elevator workers breathing zone exposures (approximately 90 workers monitored) to chemical fumigants were nearly non-existent. Only trace concentrations of carbon tetrachloride were detected at five of the eight elevators surveyed. Other suspect fumigants sampled for but not detected during this period of relatively high level of grain handling particularly incoming by rail cars and trucks included phosphine, methyl bromide, carbon disulfide, ethylene bromide and ethylene chloride. No in-house fumigation of grain had occurred for at least a number of months at any of the elevator facilities, nor had the receipt of "suspect" incoming shipments been reported frequently during this season compared to previous years

2. Some elevator workers were exposed to airborne total grain dust at levels exceeding the OSHA nuisance dust standard (no standard exists for grain dusts per se).

3. Symptoms of eye irritation were reported by a few workers presumably due to the exposure to excessive dust levels during the NIOSH survey. Similar and, in addition, flu-like symptoms were experienced by some NIOSH surveyors during the period.

An extensive medical evaluation of the approximately 300 Port elevator workers was conducted in late 1974 by the University of Wisconsin's Department of Preventive Medicine.[2] Based upon the results of this study, it is concluded that:

4. The working environment in the grain elevators has caused acute respiratory, eye and nasal symptoms as determined by history from workers and personal observation. Durum wheat, barley and rye were the worst offenders.

5. Long-term effects were also noted by history (cough, expectoration, recurrent wheezing) and pulmonary function testing (evidence of airways obstruction). There was some correlation with smoking habits, smokers being more affected than non-smokers, but non-smokers also had a higher incidence of problems than would be expected in the general population.

6. A high frequency of skin reactivity to intradermal injection of insect and flax antigen was found among workers; significant correlations with wheezing upon exposure to grain dust and pulmonary function abnormalities was found.

Recommendations to provide for worker protection, surveillance, and health maintenance in these facilities are offered in Section V of this Report. NIOSH is conducting on-going research which will lead to the generation of a recommended standard for grain handlers throughout the industry.

II. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this Determination Report are currently available upon request from NIOSH, Division of Technical Services, Information and Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days the report will be available through the National Technical Information Service (NTIS), Springfield, Virginia. Information regarding its availability through NTIS can be obtained from NIOSH, Publications Office at the Cincinnati address. Copies have been sent to:

(1) Archer Daniel Midland
(2) Globe Elevator Company
(3) Farmers Union GTA
(4) Continental Grain
(5) M & O Elevator Company
(6) Capitol Elevator Company
(7) Cargill, Incorporated
(8) General Mills, Inc.
(9) AFGM, Local 118
(10) David R. Obey, U.S. House of Representatives
(11) U.S. Department of Labor, OSHA - Region V and Headquarters
(12) NIOSH - Region V and Headquarters

For the purposes of informing the approximately 300 affected employees of the determination, the employer shall upon its receipt post a copy of the Determination Report for a period of 30 calendar days at or near the work place(s) of affected employees. The employer shall take steps to insure that the posted determination is not altered, defaced, or covered by other material during such period.

III. INTRODUCTION

Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6), authorizes the Secretary of Health, Education, and Welfare, following a written request by an employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

A joint request for a NIOSH health hazard evaluation was submitted in February 1975 by an authorized representative of Local 118, American Federation of Grain Millers (AFGM) servicing the Duluth, Minnesota-Superior, Wisconsin grain elevator plants and by Honorable David R. Obey, U.S. House of Representatives. The AFGM request alledged illnesses and complaints from a large number of their membership in the past several years due to chemicals and high dust levels.

A listing of grain elevator plants in the Port was supplied as follows: Archer-Daniels-Midland, Globe Elevator Company, Farmers Union GTA, Continental Grain, M & O Elevator Company, Capitol Elevator Company - Division of International Milling Company, Cargill Incorporated, and General Mills.

A number of other agencies including OSHA and the State of Wisconsin and Minnesota had been previously requested by AFGM to aid in the evaluation. Subsequently it was determined that the University of Wisconsin-Extension School for Workers - Mr. Richard Ginnold[1] and the Specialized Center of Research in Pulmonary Diseases, Departments of Medicine and Preventative Medicine - John Rankin, M.D.[2] had been actively investigating the problem.

IV. HEALTH HAZARD EVALUATION

A. Description of Process - Conditions of Use

Grain is shipped into the Port of Duluth-Superior by truck and railroad. During the season when the Port is open, most grain is shipped out by ship either to domestic lake ports or to foreign ports. Otherwise shipment is by rail. In 1973, traffic was particularly heavy due to the Russian wheat deal.

Most of the grain arriving at the Port has been previously dried and cleaned to some extent at country elevators. The length of storage prior to arrival at the Port varies from rather short for grain coming in shortly after the fall harvest to considerable lengths of time for grain shipped shortly before the harvest to make room for the new grain.

Since elevators will not accept grain with active pests it is customary for shippers to fumigate the grain in transit. Although this is supposed to be done in an approved manner and properly labeled, this is not always the case. Lack of labeling and excessive dosing occur with moderate frequency. On arrival at the elevators the grain is inspected and graded by State and elevator workers. Samples are taken by probe from within the load and subjected to a sniff test by the inspector and also to laboratory analysis. If passed, the grain is then dumped into receiving bins and transferred by conveyor belt to the top of the storage bins. The dumping itself may be completely mechanical, or in the case of rail box cars may involve men operating mechanical scoops known as "bobcats" to empty remaining grain from the car. Grain is emptied from the bottom of the bins and transferred to other bins or to the loading facilities by conveyor

belt. Besides receiving and shipping, the elevators clean the grain, weigh the grain, mix the grain when indicated, store the grain, and treat the grain with suitable insecticides and fumigants. The grain is monitored by temperature for weevil activity and turned over or fumigated as indicated.

B. Progress of the Evaluation

1. Initial Visit

A team of NIOSH investigators (Flesch, Thoburn, and Gilles) visited the Port of Duluth-Superior on April 1-2, 1975. A conference was held with Local 118 AFGM officials and a representative of Congressman Obey's office to review information they had obtained regarding the problem over the past 2-3 years.

Following that meeting a visit was made to one of the elevators in the area where grain handling activities could be observed to a limited degree, although this was not the primary season for such activity. A walk-through survey of one elevator was conducted and information related to its current and historical work activities, handling, and treatment of grain obtained.

2. Study Design

Following the initial visit information was obtained in follow-up contacts with OSHA, State and University of Wisconsin. After careful review of this information, it was decided that NIOSH would concentrate its activities primarily on the potential problems from exposure to chemicals (fumigants) used to treat the grain rather than the various grain dusts. Little evidence was available to determine environmental concentrations and health problems experienced either during periods of treating grain within the elevator houses or in handling in-transit treated grain upon entry to the elevator via trucks or rail cars.

John Rankin, M.D. had conducted in-depth medical studies[2] on some 307 grain workers in the Port area in late 1974. Although results were not available at this time in the investigation, it was decided that his results should be utilized in lieu of further NIOSH medical studies at this time. Dr. Rankin's study protocol and findings, recently made available to NIOSH, are presented in detail in a later section of this report, IV. D. MEDICAL EVALUATION.

3. Follow-up Environmental Study

A NIOSH environmental study was planned to incorporate environmental air sampling at each of the elevators operating in the Port during a period of the year when grain handling activities were expected to be high.

Plans were made to determine exposure levels of workers to grain fumigants and total grain dusts, to obtain photographs of operations, to review recent records of grain handling and fumigant application and to observe work practices and procedures.

Grain handling activities were at a minimum in the spring and summer months of 1975, however officials of the AFGM reported a continuing increase in the number of incoming and outgoing shipments of grain in September, 1975.

NIOSH completed its plans, notifying Congressman Obey, and management and labor officials of each of the Port elevators; a team of industrial hygienists (Flesch, Gilles, Hollett, Rosensteel, Ruhe, Borcherding, Rivera, Geissert, and Kominsky) conducted on-site evaluations during the week of October 6-10, 1975.

C. Environmental Evaluation

1. Methods of Sampling and Analysis

Potentially toxic substances to which grain elevator workers might be exposed in the course of the activities were (a) dusts from a variety of grain and grain by-products including wheat, barley, oats, rye, corn, canary seeds, sunflower seeds, and others, and (b) a host of fumigants including methyl bromide, phosphine (released from Phostoxin®), carbon tetrachloride, ethylene dichloride, ethylene dibromide, carbon disulfide, and malathion.

Elevator operators were outfitted with air sampling apparatus to obtain their breathing zone exposures to the above mentioned substances (except malathion, which was the agent used to treat some outgoing shipment of grain to foreign countries, but had not been employed in any facilities recently).

Four sampling systems were worn by each outfitted worker to obtain an integrated exposure over as much of his work period during the day of sampling as possible.

The "phosphine" sampling train consisted of a pre-filter (combination fibrous glass and cellulose AA filter and backup pad) to remove particulate, followed by a three-piece light-tight cassette containing silver-nitrate impregnated filters to absorb the contaminant gas. A battery-powered Sipin* pump pulled air through the train at a flow rate of 50 cc/min. The sampling and analytical method is based upon that reported by Hughes and Jones[3]. Analysis of samples was performed by the NIOSH laboratory in Cincinnati.

The second (carbon disulfide) and third (carbon tetrachloride, methyl bromide, ethylene dichloride, ethylene dibromide) sampling systems utilized two glass tubes containing activated charcoal in series to collect organic vapors. Sipin vacuum pumps maintained air flow collection rates at 50 cc/min. Laboratory analyses were separately performed for the above contaminants utilizing standard gas chromatographic techniques[4] by a NIOSH contract laboratory (ARLI) in Monrovia, California.

*Mention of commercial products does not constitute endorsement by NIOSH.

The fourth sample collected total airborne particulates (grain dusts) on a pre-weighed vinyl metricel (VM) filter contained in two-piece cassette. Air flow rates of 1.5 liters/min. were maintained by battery-powered Mine Safety Appliance vacuum pumps. Gravimetric analyses for total weight gain on particulate laden filters were performed in the NIOSH Laboratory at Salt Lake City, Utah.

In addition to the sampling conducted to determine longer-term, integrated average exposures over the work shift, direct-reading, Drager indicator tubes were used in a supplemental attempt to locate and define short-term or instantaneous exposures which might be occurring to fumigants or other trace by-product gaseous contaminants.

Drager indicator tubes with manufacturers stated range of detection were:

methyl bromide (5-50 ppm);
phosphine (0.1-40 ppm);
carbon tetrachloride (10-100 ppm);
carbon disulfide (13-288 ppm);
ethylene dibromide (10-100 ppm);
ammonia (5-70 ppm);
sulfur dioxide (1-20 ppm);
carbon dioxide (0.1-1.2 vol.%)

2. Evaluation Criteria

a. Known Toxic Effects of Substances Investigated

(1) Grain Dust[5]

In general, development of respiratory complaints and possible disability have been recognized as a hazard to millers and other grain handlers for some time. There is often a large allergic component to the more severe of the problems particularly allergy to molds and smuts which may grow on moist grain and are especially likely to become airborne when the grain is later dried. There is also allergy to the grain itself which is more pronounced with barley dust and oats dust than with wheat. In addition to the allergic component, there is a mechanical irritancy to the dust. The ill effects of exposure to the dust are more likely to occur in persons with a personal or family history of allergies, such as hay fever, food intolerances or drug sensitivities, or in persons who smoke, or on particularly heavy exposures. Although there is some silica in the grain dust, this does not appear to be of major importance. The size of dust particles is very important in how far into the respiratory system they can travel (how respirable it is); in the case of grain dust much of it is in the respirable size range.

Of the medical problems caused by grain dust, those due to allergy are the most severe. Except in massive exposure, these start as a mild problem which gets worse on continued exposure, but remain reversible on cessation of exposure for a fair length of time. A rhinitis is probably the first symptom which can be found. A productive cough is the next, more serious

symptom. Continued exposure can lead to a progression of wheezing and/or shortness of breath after prolonged exposure, later any exposure. In these latter stages of progression the lung changes may not be readily reversible, if reversible at all. X-ray may show some pulmonary fibrosis.

Grain fever does not directly relate to allergy nor directly to progressive, permanent injury, but rather to the dust. It is characterized by general discomfort, chills and fever following first exposure to the dust, or on return to exposure after more than a week's absence from work or on particularly heavy exposure. The grain mite, if present, can cause grain itch.

(2) Methyl Bromide[6]

Methyl bromide rapidly volitilizes at room temperature when its sealed container is opened, making it possible to get high concentrations of methyl bromide rapidly. Further, except at concentrations high enough to cause immediate drowsiness, methyl bromide does not give any immediate warning of its presence, even at harmful concentrations. Methyl bromide may cause a feeling of illness, headache, drowsiness, nausea, vomiting, tremors, unconsciousness and even death. It also irritates the lungs, even at levels not causing immediate symptoms, although these effects are usually delayed. They may go on to pulmonary edema, pneumonia and death. In contact with the skin severe burns may result if the liquid is unable to evaporate freely because of clothing. Repeated exposure to methyl bromide could lead to a chronic poisoning known as bromism. Symptoms[7] commonly include mental and emotional disturbances with impaired thought and memory, drowsiness, dizziness and irritability. There may also be delirium, delusions, hallucinations, and mania. Other symptoms may include tremors, thick speech and a skin rash. Recovery from chronic bromide poisoning is slow.

(3) Phosphine (decomposition product of Phostoxin®)[8]

Phostoxin® is marketed in tablet or pellet form and, being composed of primarily aluminum phosphide (55%) and ammonium carbamate (41%), decomposes upon exposure to the atmosphere to form the toxic gas, phosphine (PH_3) The rate of decomposition varies dependent upon the moisture content and temperature of the environment and commodity being treated.

Phosphine is a highly toxic gas. Symptoms such as diarrhea, nausea and vomiting, tightness of the chest and cough, headaches and dizziness have been reported in a number of workers exposed intermittently at air concentrations up to 35 parts of phosphine per million parts of contaminated air (ppm), but averaging 10 ppm in most cases; there were no cumulative effects. Between 1900 - 1958, 59 cases of phosphine poisoning, including 26 deaths have been recorded.

(4) Trade Name Products

Coop Weevil Killer Fumigant contains ethylene dichloride and carbon tetrachloride. Weevilcide®, Diamond Premium Brand Fumigant and Serafume® are primarily carbon tetrachloride. They all have carbon disulfide as a secondary ingredient, and in the case of Serafume®, some ethylene dichloride as well.[1]

(5) Carbon Tetrachloride[9]

Carbon Tetrachloride can enter the body by inhalation, ingestion or skin absorption. Inhalation may cause headache, dizziness, weakness, blurred vision, tiredness, coma and death. Ingestion may additionally cause nausea, vomiting, and abdominal distress. Other symptoms include narrowing of the field of vision and liver and kidney damage. Skin absorption may be sufficient to enhance or cause these symptoms. Chronic, low level exposure may lead to the eye changes or the liver or kidney damage. Additionally, there appears to be an increased risk of cancer in a damaged liver. The toxic effects of carbon tetrachloride exposure are made worse by concurrent exposure to alcoholic beverages. Repeated skin contact may also cause a rash due to defatting of the skin.

(6) Ethylene Dichloride[10]

Ethylene dichloride gives acute symptoms somewhat similar to those of carbon tetrachloride although the likelihood of liver injury appears to be somewhat less and visual changes were not reported. Skin absorption, although present is not expected to cause much of a problem, although defatting and chapping may occur. No cancer studies were reported.

(7) Carbon Disulfide (Carbon Bisulfide)[11]

Carbon disulfide (carbon bisulfide) may also be absorbed through the skin in addition to inhalation or swallowing. Symptoms may include headache, nausea and vomiting, fall in blood pressure, dizziness, unconsciousness and death. The liquid and vapors are quite irritating to eyes, nose and skin. If the liquid is trapped against the skin it can cause severe burns. Repeated exposure can lead to nervous system damage with muscle weakness, numbness, feelings of pins and needles, unsteady walking and difficulty with speech, swallowing, sleep and memory. One can also have tiredness, irritability, depression, suicidal tendencies and psychosis. Other chronic effects which carbon disulfide may cause include high blood pressure, increased hardening of the arteries, liver and kidney damage and stomach problems. It may cause a rash by defatting the skin.

(8) Malathion[11]

Malathion is one of the least toxic organophosphate insecticides. If sufficient insecticide is absorbed by inhalation, ingestion or skin absorption one can get tightness in the chest, wheezing, headache with aching behind the eyes, blurred vision, watering of eyes, nose and mouth, nausea, vomiting abdominal pain and diarrhea.

Skin absorption can lead to isolated sweating and twitching. More severe symptoms may include generalized sweating, weakness, convulsions and coma, but these are unlikely.

b. Environmental Criteria

Three primary sources of environmental evaluation criteria are utilized by NIOSH in assessing the potential toxicity for exposures to the substances encountered in this evaluation: (1) NIOSH Criteria Documents with recommended standards for occupational exposure; (2) American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV's) with their supporting documentation, and (3) Federal Occupational Health Standards promulgated by the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA).

Environmental exposure criteria selected as the best available for the substances under investigation are as follows:

Substance	Environmental Criteria 8-hour time weighted average
Grain dust	N.A.*
Carbon tetrachloride(1)	2 ppm (12 mg/M^3)
Carbon disulfide(2,3)	20 ppm (60 mg/M^3)
Ethylene dichloride(2)	50 ppm (200 mg/M^3)
Methyl bromide(2)	20 ppm (80 mg/M^3)
Phosphine(2,3)	0.3 ppm (0.4 mg/M^3)
Malathion(1,3)	15 mg/M^3

*N.A. - no acceptable criterion exists for grain dust - NIOSH has scheduled for development a Criteria Document for grain handlers (FY 81). OSHA currently enforces the "nuisance dust standard" of 15 mg/M^3 - total dust, and 5 mg/M^3 - respirable dust to this environment.

() References refer to the three sources of criteria cited above.

3. Environmental Results and Discussions

Tables 1-8 display in detail the log of environmental sampling and results obtained for the elevator workers' breathing zone exposures to grain dust and fumigants during the periods of the NIOSH survey from October 7-9, 1975.

Elevator A

All grain handling activities normally in operation were functioning during the day of sampling, except for truck unloading. Workers commented that due to that lack of truck unloading and favorable weather, conditions in the area were not as dusty as usual; none related any health problems on the day of testing; none knew of any recent fumigation carried out in the house (in this case Phostoxin® had been used in the past); nor were any recent shipments of grain into the facility known or thought to have been treated with fumigant (no labels/placards).

Review of sampling results in Table 1 indicates the only fumigant detected was carbon tetrachloride (at trace quantities in 9 of 12 samples); as expected significant grain dust exposures were observed in most areas of the facility - the lower and upper annex, and the hopper unloading and car dock areas. Chemical indicator tube samples taken at the unloading docks were all below detection limits.

Elevator B

Grain handling activities were in normal operation on the day of the NIOSH survey. Grain handled was 75% wheat and 25% barley. The car and truck dump stations controlling these operations were completely enclosed, so that operators' exposures at this site were minimal. Any incoming grain determined to be infested was customarily treated by a licensed exterminator - three such cars had recently been treated with methyl bromide and were being held in the yard until the fumigant dissipated to acceptable residual levels (via detector tube tests). Fumigants had reportedly not been utilized in the house for the last two years. None of the workers sampled related any health problems on the day of testing.

Review of the sampling results in Table 2 indicates only one sample produced a detectable (i.e., ethylene dibromide) but non-significant exposure to fumigant. Grain dust exposures were experienced at all operations throughout the facility up to a concentration of 19.9 mg/M^3 for the annex operation.

Elevator C

Activities on the day of sampling were somewhat below normal: receipts approximated 50% of the levels experienced during the previous two weeks of operation;outgoing shipments were near normal. Treatment of grain at this facility had reportedly not occurred in the last six months. Workers reported detecting odors of some incoming shipments (unlabeled) of fumigated grain.

Their practice upon such detection was to place the car at the end of the yard until the odor disappeared. Disposable dust masks are provided to workers on a voluntary basis.

Results of personal air samples are presented in Table 3. Trace concentrations of carbon tetrachloride were detected in the 11 samples collected; however the concentrations were not significant. None of the other fumigants were detected. Grain dust breathing zone concentrations were grossly elevated above 'nuisance dust' standards for the bobcat operator (23.9-118 mg/M^3)unloading grain and for the lower annex operator (56.9 mg/M^3). Detector tubes samples throughout the facility during the day were completely without a positive response. Workers reported no health problems or symptoms on the day of testing.

Elevator D

Operations at the car dumping station were somewhat below normal (19 cars vs. 35 normal) due to mechanical failures on the day of the NIOSH survey. Grain unloaded was primarily duram wheat. At the truck dump, 57 trucks were unloaded, slightly below normal. Enclosed areas for operator control of these activities are provided. Treatment of grain is not normally practiced at this facility, except for malathion or some outgoing shipments required by customer specifications; Weevilcide®, and Phostoxin® had been used previously, however no such treatment had occurred in the past 2-1/2 years.

Review of sampling results presented for this facility in Table 4 indicate no detectable exposures to any of the fumigants investigated; detector tube sampling of a number of truck receipts similarly produced no detectable fumigant levels. Grain dust concentrations for car and truck dump operators reflected the degree of protection afforded by the enclosed operator stations (a 5-10x reduction compared to open-area dust levels). None of the workers sampled reported health problems on the day of the testing.

Elevator E

Rail car and truck receiving was in operation, as well as loading out of grain onto a ship on the day of the survey. Enclosed areas are provided for the car and truck dump operators. Treatment of grain at this elevator is accomplished with Weevilcide® (82% CCl_4 and 16% CS_2) only and applied by supervisory personnel on Friday nights. During the previous two years, a log of such treatments on six (6) dates is recorded.

Review of sampling results for this elevator in Table 5 indicate the only fumigant detected was carbon tetrachloride, at trace quantities throughout the facility. Detector tube sampling results at the car dump and inspection station were negative. Grain dust concentrations ranged from 0.2 (scale floor weigher) to 6.6 mg/M^3 (old annex operator). None of the workers sampled reported health problems on the day of the survey.

Elevator F

A total of 73 railcars (43 box, 30 hopper cars) and 74 trucks unloaded grain, primarily spring and duram wheat, on the day of the survey. No recent treatment of grain had occurred at this facility. Weevilcide had been used years ago, however, current fumigation procedures utilize Phostoxin® pellet application within bins on second-shift operations as may be needed. Outgoing shipments on occasion require treatment with malathion, however, none had occurred during the year.

Results of personal and area air sampling displayed in Table 6 indicate no detectable levels of any of the fumigants tested in either elevator facility, X or S except for carbon tetrachloride at minimal residual concentrations. Car operators in S elevator were exposed to total grain dust concentrations averaging up to 7.3 mg/M^3; truck dump operators exposures at X averaged 4.2 and 6.2 mg/M^3 respectively. No workers sampled expressed any health problems on the day of the survey.

Elevator G

Forty-six (46) rail cars and 72 trucks unloaded grain on the day of the survey. Car and truck dump operators control areas are completely closed.

Results of personal samples in Table 7 indicate trace quantities of carbon tetrachloride in all samples; no other fumigants were detected. Total grain dust levels for annex operators ranged from 4.8 to 15.2 mg/M^3; probers and cableman working in the yard had dust exposures averaging 1.6 to 2.9 mg/M^3. No workers reported any health problems on the day of the survey.

Elevator H

Rail and car dump operations were active, however, no trucks were unloaded on the day of sampling. A review of personal sampling results in Table 8 indicates that no fumigants were detected in any samples throughout the activities of operators in the facility. Considerable personal exposures to total grain dust were measured: 7 of 10 samples ranged from 9.7 to 35.9 mg/M^3; three of these workers reported symptoms of eye irritation on the day of the testing.

Summary Results

Eight grain elevator facilities were operative in the Port area during the week of October 7-9, 1975. Approximately ninety (90) elevator operators were sampled in their normal activities for total grain dust and fumgant exposures. Overall a considerable amount of grain was handled during the period, primarily incoming by rail and truck. Time-weighed-average airborne "total grain dust" concentrations in breathing zones of a number of handlers exceeded OSHA nuisance dust standards (no standard exists for grain dusts per se)- the maximum values at each facility ranged from 6.6 to 118 mg/M^3. These maximum levels are markedly lower than those measured during the OSHA inspections conducted in May 1974.(1)

Concurrent, NIOSH-documented integrated exposures to fumigants during this period were nearly non-existent - only trace concentrations of carbon tetrachloride were found (in five of eight elevators); other fumigants sampled for but not detected by either integrated or spot sampling methods included phosphine, methyl bromide, carbon disulfide ethylene bromide and ethylene chloride. Fumigation procedures within the elevator had not been practiced in recent months; nor had the receipt of "suspect" incoming shipments been reported frequently during this season compared to previous years.

Adverse health effects were not experienced by workers during the survey, except for the occurrence of eye irritation which was experienced by a few workers under very dusty conditions. Several of the NIOSH survey team experienced eye irritation and flu-like symptoms during the conduct of the survey.

D. Medical Evaluation

The following represents a description and presentation of results of the medical study of the Port elevator workers conducted by Dr. Rankin. NIOSH interpretation and discussion of these findings was sent to Dr. Rankin and his approval for inclusion into this report was received in December 1976.

1. Evaluation Design[2]

> "We studied 307 grain workers from eight different companies operating in the Superior-Duluth area of northern Wisconsin and Minnesota. This population represented 75% of the members of Local 118 of the American Federation of Grain Millers working in November of 1974. They were all men, between the ages of 20 and 62 years with a mean age of 38.9 $\pm$ 12. Mean height was 69.1 $\pm$ 2.6 inches (range 63.5 to 76.5), mean weight was 183 $\pm$ 29.2 pounds (range 112 to 294 pounds). The average length of employment was 12.5 $\pm$ 9.7 years with a range from less than 1 year to 37.5 years. Most of the grain handlers worked in the elevators throughout the 12 months of the year and for at least 8 hours per day but up to 16 hours a day during the busiest season (which is July through November).
>
> Fifty-one workers (17%) lived on farms but only 33 had been full time farmers in the past. Twenty-six had worked in a steel mill for a year or more but only 3 of them for more than 3 years. Seven had worked in shipyards for more than 1 year but less than 3 years.

Fifty-nine percent of the population studied were smokers, 22% were ex-smokers and 19% non-smokers.

One hundred and ninety-one subjects (64%) had been exposed to grain dust on the day of the testing. Eighty-four (28%) had been exposed the day before, and the remainder more than two days before the testing period.

All subjects completed a self-administered, standardized questionnaire with emphasis on respiratory symptoms, smoking habits, occupational and non-occupational exposure, as well as present and past personal and family histories of pulmonary and non-pulmonary diseases. All subjects were interviewed and their chests examined by one of three University of Wisconsin Center physicians.

* * * * *

Posterior anterior chest radiograms were obtained and interpreted by two observers independently."

Dr. Rankin included pulmonary function studies of forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC), forced expiratory flow between 25 and 75% of the FVC ($FEF_{25-75\%}$), instanteous forced expiratory flows after 50% and 75% of the FVC had been exhaled (FEF 50% and FEF 75%), and diffusing capacity for Carbon Monoxide (D_{CO}). He did closing volumes on a randomized sample of the study group.

Other tests included precipitin tests on serum samples of 298 workers to detect precipitating antibodies against fungal and grain dusts extracts; intradermal skin testing of 294 workers with commercial extracts of various dusts and pollens; and prick testing 217 workers with saline extracts from grain and settled grain elevator dust and 258 workers with commercial extracts of grains. One hundred county highway workers were used as controls for the precipitin tests for grain and grain dust extracts and 1072 office workers undergoing routine health survey examinations done by the Wisconsin Department of Health and Social Services were used as controls for the fungal antigen precipitin tests.

2. Evaluation Methods and Interpretation(2)

Pulmonary Function Studies.

FEV_1, FVC, FEF 25-75% were recorded on a 13.5 liter Collins spirometer.

FEF 50% and FEF 75% were measured from three reproducible maximal expiratory flow volume curves obtained using a wedge spirometer and displayed on an XY recorder and averaged.

Closing volumes were determined by the method of Anthonisen et al.[12] The mean of three acceptable traces were recorded, D_{CO} was measured by the single breath method of Ogilvie et al.[13]

Results of these tests were compared to predicted values for each worker using Morris et al[14] to predict FVC, FEV_1 and FEF 25-75% FEF 50% and FEF 75% were predicted using Bass[15] and D_{CO} was predicted using Ogilvie et al.[13]

Dr. Rankin considered abnormal pulmonary function "to be present when FEV_1/FVC was less than 70%, FVC was less in 80% of predicted, FEF 25-75%, FEF 50%, FEF 75% were less than one standard deviation of predicted and D_{CO} was less than 80% of the predicted value."

Precipitin Tests.

The tests were performed by the gel immuno diffusion method of Flaherty et al.[16]
Extracts of Penicillium rubrum, P. casei, Fusarium, Alternaria, Thermoactinomyces vulgaris (two strains), T. candidus, Aspergillus fumigatus (two strains), Micropolyspora faeni, and Hormodendrum were prepared according to the methods of Flaherty et al.
Saline extracts from samples of settled grain dusts from the workers' own elevators were similarly prepared.[16]
Commercially available extracts of barley, oats and rye from Hollister-Stier, Spokane, Washington were used.
Pigeon serum extracts were prepared by the methods of Fink, Barboriak and Sosman.[17]

Skin Tests.

Intradermal testing used 0.02 ml of 100 unit/ml commercial extracts for mixed grasses, mixed trees, ragweed, mixed insects, alternaria and rat hair, and 0.02 ml of 10 unit/ml commercial extract for flax.
Prick testing used a 1/100 dilution of commercial extracts of barley, oats and rye.
Additionally, saline extracts of grain and settled grain elevator dust were prepared by the methods of Flaherty et al[14] and lyophilized. Prick testing used a 1.0 mg/ml strength of these extracts.

For all the skin tests, Dr. Rankin considered "an induration graded at 8 mm or more as a positive skin test, if less than 8 mm it was considered questionable and tests with no reaction were considered negative. For group data analysis the questionable were considered as negatives."

Analysis of Data[2]

"Several analytical methods and statistical procedures were used to properly quantify and interrelate the clinical and physiologic responses obtained. Standard descriptive statistics were used to present all responses into frequency distributions and group means. Inter and intra-variability were expressed as standard deviations or standard errors. Cross tabulation was used to compute contingency tables for discrete variables such as the relationship of smoking and normal and abnormal pulmonary function. Chi-square analysis was used to determine whether the variables in question were significantly different. Multiple regression analysis was used to examine the relationship of pulmonary function with length of employment, age and smoking history. The level of significance was derived from the resultant F test. In addition, a separate contingency table analysis utilizing a log-linear model was needed to examine the relationship between the many categorical variables such as smoking history and clinical symptoms for specific grain elevators."

3. Results and Discussion

Dr. Rankin reported his results as follows:[2]

"Clinical Findings. Symptoms during exposure to grain dust present in the working environment were claimed by a large number of workers (Table 9). The severity of symptoms varied among individuals. In general, the workers subjective estimation of dust concentrations in the environment and the type of grain being handled appeared to correlate with the severity of the symptoms induced or aggravated by exposure to grain dust. The symptoms were usually felt immediately upon exposure and relieved in minutes or, more often, one or more hours after cessation of exposure. Some individuals, however, continued to have symptoms throughout the night into the next morning and working day. The symptoms occurred daily, weekly or monthly depending upon the grain handled, the concentration of the dust, the location of the job assignment, the time of the year, and perhaps the atmospheric conditions. The workers considered that durum wheat, barley, rye and spring wheat and oats (in order of significance) were the most bothersome grain dusts and the most frequent inducers of symptoms. Although 73% of the workers considered durum wheat responsible for their symptoms: barley dust was equally irritating to 53% of the workers, rye to 43%. spring wheat to 35% and oats to 31% of the workers. Corn and sunflower seed dusts were the least irritating. Barley was considered the most common inducer of skin itching.

"Respiratory symptoms during exposure to grain dust were claimed by three-fourths of the workers. Both cough, (76% of the workers) and wheezing (42% of the workers] were significantly more common among smokers than non-smokers. For the purpose of statistical analysis, ex-smokers and non-smokers were combined because no significant differences were found between the two groups. Age had no apparent effect on the frequency of these two symptoms. Dyspnea on exertion was suffered by 45% and chest tightness, burning or aching by 49% of the workers. These effects were unrelated to smoking habits and age.

"Symptoms of eye and nose irritation were also common (77% and 64% respectively). These effects were independent of age, smoking history and length of employment. Eye burning, itching, scratching and redness during exposure were often followed by swelling of eyelids and secretions, which in some instances resulted in difficulty to open their eyes the following morning. Nasal symptoms of stuffiness and rhinorrhea often persisted throughout the night.

"There was a history compatible with grain fever, i.e. fever, chills after a day's exposure to grain dust following variable periods of absence from work due to occasional lay-offs or strikes, vacation periods or massive heavy exposures in 18.6% (57). There were an additional 33 workers who claimed fever and/or chills during or after exposure who were not clear-cut cases of grain fever. Among these workers with history of grain fever or fever there was the same number of workers with precipitating antibodies than without precipitating antibodies to grain dusts.

"Chronic or persistent symptoms are also presented on "Table 9. * * * * * *"Chronic bronchitis was considered to be present if the subjects reported having usually brought up phlegm, mucus or sputum from the chest in the morning and/or during the day for at least three months of each year. Abnormal airway function was said to be present if the patient had chronic bronchitis by history and/or wheezing on auscultation of the lungs or abnormal forced expiratory volume in one second as a percent of forced vital capacity (FEV_1 % FVC) and/or abnormal forced mid-expiratory flow (FEF 25-75%).

"Dyspnea on Exertion. Grade I was considered to be present when the worker was troubled with shortness of breath while hurrying on level ground or up a slight hill. Those subjects with shortness of breath developing while walking with other people their own age on level ground depicted Grade II dyspnea. Grade III was depicted when they had to stop for a breath while walking at their own pace on level ground and Grade IV when shortness of breath was experienced while dressing or walking about their house.

"Complaints of cough, expectoration and wheezing were common among the workers. Most of the workers who had chronic, persistent cough, i.e. cough that persisted beyond exposure to grain dust during days of lay-offs and vacation stated that it was aggravated by exposure to grain dust. Thirty-seven percent of the workers had chronic bronchitis. The prevalence of chronic bronchitis, persistent cough, wheezing, as well as wheezing on most days, was significantly higher among smokers than non-smokers. They did not, however, bear a significant relationship with length of employment.

"The history of asthma was present in only 7 workers. History of allergic rhinitis was apparent in 14-20% of the workers.

"Chest illness, such as bronchitis, pneumonia, which disabled the workers to do their usual activities was reported by 209 (69%). One hundred and six (35%) claimed between 2-5 episodes; whereas 18 (6%) reported more than 5 episodes a year. Pneumonia was found in the past history of 44 (14.7%) and bronchopneumonia in an additional 6 (2%). Thoracic surgery has been performed on two subjects. One had a correction of the patent ductus arteriosus at age 4 and the other had drainage of an empiema 30 years earlier.

"Families' histories revealed that 28 workers (9.3%) had at least one relative with asthma and 18 (6%) with hay fever.

"Physical Examination. Grain dusts were found deposited on the exposed skin surfaces as well as nostrils of most workers who had come to be examined directly from work. Wheezing on auscultation of the lungs was detected in 68 (22.7%) of the workers. In 33 of them, it was diffuse, bilateral and obvious during expiration whereas in 35 subjects it was noticeable only during forced expiration. Unilateral or bilateral rales labeled as moist or crepitant were found in 17 (5.3%). Bilateral inspiratory crepitant rales were found in 8 subjects. Dyastolic blood pressures of 90 or above were found in 69 subjects. Twenty-three of those had dyastolic pressures of 91 or above.

"Chest Radiograms. There were no chest radiograms compatible with diffuse interstitial lung disease.

"There were extensive pleural calcifications in one case. This worker was a 50 year old grain prober or inspector who had worked in the grain elevator for 18 years. There was unilateral blunting of costophrenic angles in four radiograms. Small calcified hilar or parenchymal nodules were found in 6. There was severe cardiomegaly with changes compatible with mitral and aortic valve disease in one case.

"Pulmonary Function Studies. The mean actual value and standard deviation of tested functions on the entire sample of grain handlers

and their distribution by age is presented in Table 10. "A steady decline from age 20 to over 60 years old to be noted in FVC (Δ-22.5%), FEV_1 (Δ-32%), FEF 25-75% (Δ-46%), PEF 50 (Δ-26%) and D_{CO} (-16.7%). As expected, comparable decline in absolute values of lung function with length of employment was also observed. However, when the length of employment was related to a percent predicted value which adjusted for age and height, there was no noticeable decline in function with length of employment. The effects of age, body size (height and weight), smoking history, length of employment and place of employment (company) on lung function was analyzed by multiple regression analysis using a log linear model for contingency table analysis. There was a significant correlation between lung function and age ($p < .001$), height ($p < .001$) and smoking history ($p < .001$) (Table 10 and Fig. 1). However, length of employment was not a significant factor in lung function nor was the place of employment.

"The most predominant effect on lung function was that of smoking where significant negative correlations were noted in all functions except FVC in the current smokers. An analysis of ex-smokers indicated a significant negative correlation only with respect to FEF 25-75% and PEF 50%. The absolute values for all pulmonary functions and smoking history are presented in Table 11. Apparent step-wise decline in function with smoking habit may be noted. The number of subjects with abnormal lung function are presented in Figure 1. Evidence of a significant reduction in ventilatory flow prevailed in FEF 25-75%, FEF 50% and FEF 75% (26 to 37% of total sample).

"Airways Dysfunction. Evidence of abnormal airways function was present in 200 (65%) of the workers in the study and it was more common among smokers than non-smokers (Table 12).

"Abnormal Diffusing Capacity Without Evidence of Airways Obstruction. It was present in 14 of the workers. Eleven of them were smokers, 2 were ex-smokers. There was one non-smoker. Chronic bronchitis was present in 8 of the 14 and a past history of pneumonia was recorded in three. Interestingly, nine of the 14 worked in elevator #4 and each of the other five were from a different elevator.

"The Relationship Between the Symptoms and Pulmonary Function. Those workers who complained of wheezing had a significantly higher frequency of abnormal FEF 25-75% ($p < .0002$), FEF_1, FEF 50% and FEF 75% ($p < .005$). There was no apparent relationship between chronic bronchitis as defined here and any of the lung functions tested. Those workers with airways dysfunction had a significantly higher incidence of respiratory symptoms on exposure than those without airways dysfunction.

"There was a significantly higher incidence of abnormal FEF 25-75% ($p < .05$) and FEF 75% ($p < .01$) amongst those workers with respiratory symptoms during exposure (cough, expectoration, wheezing, dyspnea and chest tightness) than amongst those without. There was no significant difference between the incidence of abnormal FEV_1, FVC, FEF 50% and D_{CO}.

"The proportion of people with wheezing, nasal symptoms and cough during exposure was significantly different among the eight elevator companies ($p < .05$ for cough and nasal symptoms and $p < .01$ for wheezing). These differences between elevators could not be explained on the basis of age distribution, smoking habits or length of employment. Using linear models for contingency table analysis, two of the elevators had a significantly higher proportion of symptomatic workers than the others. In Company #1, nasal symptoms, chest tightness, throat symptoms, cough, wheezing and dyspnea and in Company #5, throat symptoms, dyspnea, wheezing and chest tightness were more common than in the other companies. On the other hand, Company #2 had the lowest proportion of symptomatic workers.

"The effects of the day of the last exposure to grain dust in relation to the day the worker was tested, on the frequency of abnormal lung functions was analyzed taking into consideration their smoking habits, age and height. There was no significant difference in the frequency of abnormal lung functions between those exposed to grain the same day, the day before or two or more days before the testing that could be accounted on the basis of the exposure date alone.

"Precipitin Tests. One hundred and forty-four (38.4%) of the tested workers had precipitating antibodies to one or more of the antigens (Table 13). Ninety-four (31.1%) had precipitins to one or more of the grain dust antigens. Forty-two (19.0%) had precipitins to one or more of the fungal antigens. Twenty-two subjects had precipitins to both grain and fungal antigens. The prevalence of precipitins to each specific antigen tested is also presented in Table 13.

"The prevalence of precipitins in relation to length of employment had a bi-modal distribution with peak incidence in those who worked less than five years and those who had worked between 15-25 years as grain operators. There was no apparent relationship to age (Table 13).

"Although there was no statistical significant correlation between symptoms on exposure and precipitins to grain dust or pulmonary function abnormalities and precipitins (Figure 2), there was a higher proportion of these without precipitins who complained of cough, wheezing and dyspnea during exposure and of abnormal FEF 25-75%.

"There was no correlation between past history of grain fever and the presence of the precipitating antibodies.

"Of the one hundred county highway workers, who were tested as control subjects, 52% had precipitins to one or more of the grain or grain dusts antigens. There was a high proportion of highway workers with precipitins to durum wheat. The frequency of precipitins to durum wheat and to two of the mixed grain dusts antigens (B & D) was also higher on the county workers than on the grain handlers. The frequency of precipitins to spring wheat was lower. The frequency of the precipitins to mixed dust (G & H) were similar.

"Skin Tests. The results of the skin tests are represented on Table 14. Of the 297 workers tested against pollens, mixed insects alternaria, rat hair and flax, 82 were positive to one or more of these antigens. There were 15 to 17% frequency of response to extracts of rye, oats and barley obtained from a commercial source and injected intradermally. The incidence of positive tests to these allergens in the general population is not known but the frequency of response to flax and mixed insects was considered high.

"Reactions to two extracts of grain dusts was seen in 11% and 8.8% of the 216 tested with these antigens but the reactions to specific grain extracts of durum wheat, spring wheat, soybean was generally lower.

"Twenty-five of the 45 subjects that can be considered to be allergic because of their reactivity to pollens also had skin reactions to grain extracts. Only 20-30% of those with reactions to grain dust were allergic individuals.

"There were no correlations between skin reaction to barley, oats and rye and precipitins tests to these same antigens.

"There was a significantly higher proportion of wheezing on exposure ($p < .02$) and perhaps chest tightness ($p < .1$) and history of wheezing among skin reactors to grain or grain dust antigens than among non-reactors (Figure 3). There was no correlation between other symptoms and skin reactivity.

"There was a significantly higher frequency of abnormal FEF 50% and FEF 75% among workers with skin reactivity to common allergens (pollens, alternaria, rat hair and flax), and of FEF 75% among those with reactivity to grain dust antigens (Figure 3b). There was a significantly negative correlation between the frequency of abnormal D_{CO} and skin reactivity to the common antigens (Figure 3b). "

Dr. Rankin summarized his results as:[2]

"1. We found a very high proportion of workers with eye, nasal and respiratory symptoms during exposure to the working environment. The workers considered durum wheat, barley and rye the most frequent inducer of symptoms. Although cough and wheezing upon exposure were more commonly found in smokers than non-smokers, most of the adverse effects were independent of age, smoking history and length of employment. A history of "grain fever" was found in 18.6%.

"2. In addition, when compared to the general population (Table 15) a greater proportion of workers had persistent respiratory symptoms, such as cough (40%), expectoration (37%) and recurrent wheezing (52%), which suggests that the repeated and recurrent exposure to grain dust may have a chronic effect on their airways. These findings were more common amongst smokers (53-42-59%, respectively). However, even among non-smokers, persistent respiratory symptoms were frequent (21-30-36% respectively).

"Thirty-seven percent of the workers had chronic bronchitis which was more common among smokers (42%) than among non-smokers (28%). Chest illnesses such as chest colds, bronchitis and pneumonia, which did not permit the workers to do their normal activities, was claimed by 69%, one half of which claimed 2-5 episodes a year and 10% more than 5 episodes a year.

"3. Thirty-seven percent of the workers showed evidence of airways obstruction on pulmonary function tests. Airways obstruction was most prevalent in smokers (46%) compared to non-smokers (22%).

"4. Evidence of airways disease on abnormal airways characterized by symptoms of chronic bronchitis and/or wheezing on auscultation of the lungs and/or abnormal FEV_1 % FVC and/or abnormal FEF 25-75%, was present in 65%. It was more predominant among smokers (75%) compared to non-smokers (54.5%).

"5. Thirty-eight percent of the workers had precipitating antibodies to one or more of the antigens tested. Thirty-one percent had precipitins to one or more of the grain dust antigens and 19% had precipitins to one or more of the fungal antigens.

"There was no significant correlation between symptoms on exposure and precipitins or between pulmonary function abnormalities and precipitins.

"6. A high frequency of skin reactivity to intradermal injection of mixed insect and flax antigen was found. There was a significantly higher proportion of workers with wheezing upon exposure to grain dust ($p < .02$) among skin reactors to grain or grain dust antigen than among non-reactors. There was also a significantly higher frequency of abnormal FEF_{50} and FEF_{75} among workers with skin reactivity to common allergens (pollens, alternaria, rat hair and flax) and of FEF75 among those with reactivity to grain dust antigens than among those without reactivity.

"7. Although cigarette smoking is a major contributing factor in the incidence of airways disease in the present study, the high proportion of abnormalities found in the non-smoker indicates that the working environment also plays a major role. The mechanism by which airborne grain dust induces the respiratory mucosa irritation is not yet clear and needs further investigation."

V. RECOMMENDATIONS

A. Further study is needed on the health effects of work in grain elevators. NIOSH has both planned and ongoing research studies to generate criteria for a recommended standard for grain handlers by 1981. This criteria would include health hazards from occupational exposure to both grain dusts and fumigants and recommend appropriate work practices, controls, environmental and medical monitoring and surveillance necessary to protect the health and safety of workers.

B. Subsequent to the environmental-medical evaluations of Port elevators described in this HHE Report, NIOSH has engaged in three further associated activities as follows:

(a) Environmental monitoring and assistance during the treatment and subsequent handling of grain with Phostoxin® at a Port elevator (Ref. 18).

(b) An environmental-medical evaluation of grain handling activities at an elevator facility in Oregon (Ref. 19), and

(c) Assistance in training efforts of Port elevator supervisory staff and workers in environmental monitoring for fumigants (Ref. 20).

C. Based upon the results of the environmental-medical-training efforts and until the detailed and comprehensive criteria document for grain handlers is developed by NIOSH, the following recommendations are offered to provide worker protection, surveillance and health maintenance in these facilities.

1. The Port management and labor officials should continue their efforts to implement the use of available direct reading

monitors in the screening of incoming suspect grain shipments for fumigants, and routinely monitor the work environment when grain is treated in-house and pre-treated grain is transported and shipped through and out of the facility.

2. Application and treatment of grain can be safely accomplished (See NIOSH TA 76-55 report re Phostoxin®). A written program of procedures for such usage should be developed for the fumigant utilized - primarily Phoxtoxin® or carbon tetrachloride containing formulations (Weevilcide®). Personnel, time and location restrictions should be developed to minimize potential employee exposure. Advance notice and appropriate labeling should be employed.

3. Engineering controls including local exhaust ventilation should be implemented as soon as possible to reduce employee exposure to grain dusts. Such controls were being planned or installed at a number of elevator facilities per OSHA abatement procedures.

4. In the interim and until such controls can be shown effective, NIOSH approved respirators and protective clothing should be provided and used by workers as appropriate to protect against over exposure to both grain dusts and fumigants.

5. Initial employment chest X-ray and pulmonary function studies with follow-up 1-2 year intervals depending on the workers' age are recommended.

6. Initial employment blood profiles for assessment of liver function with appropriate follow-up are recommended based on length of employment, work place and employee age.

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Tab[illegible] RHE 75-11
Gra[illegible]evator A : Personal Breathing Zone Concentr[illegible].ons (mg/M^3) of Airborne Grain Dust and Fumigants from Samples Collected on October 7, 1975 (2)

Job Title/Location	Sampling Period	Grain Dust	PH_3*	CS_2*	CCl_4	CH_3Br*	$EtCl_2$*	$EtBr_2$*
Scale Floor Level 4	9:45 - 16:00	0.8	<0.11	<0.32	<0.09	<0.11	<5.3	<0.01
Scale Floor Level 4	9:45 - 16:00	1.4	<0.10	<0.33	<0.09	<0.10	<5.1	<0.01
Scale Floor Level 4	9:48 - 16:00	1.0	<0.12	<0.35	<0.08	<0.10	<5.1	<0.01
Upper Annex Level 2	10:08 - 16:13	4.2	<0.12	<0.36	0.32	<0.11	<5.3	<0.01
Upper Annex Level 2	10:08 - 16:13	4.5	<0.14	<0.35	0.27	<0.13	<6.5	<0.01
Upper Annex Level 2	10:10 - 16:13	6.2	<0.18	<0.39	0.19	<0.10	<5.1	<0.01
Bobcat Car Docks	10:30 - 16:30	5.3	<0.10	<0.38	0.16	<0.17	<8.5	<0.01
Bobcat Car Docks	10:37 - 16:30	9.4	<0.11	<0.33	0.10	<0.11	<5.3	<0.01
Hopper Unload # 3 Dock	10:40 - 16:30	17.6	<0.14	<0.37	0.11	<0.11	<5.7	<0.01
Lower Annex Basement	10:55 - 15:47	6.9	<0.11	<0.26	0.24	<0.09	<4.7	<0.01
Lower Annex Basement	11:00 - 15:47	4.7	<0.15	<0.31	0.21	<0.09	<4.4	<0.01
Lower Annex Basement	11:05 - 15:48	15.1	<0.15	<0.28	1.7	<0.09	<4.7	<0.01
Env. Criteria		N.A.	0.4	60	12	60	200	145
Detectable limit, µg micrograms per sample			2	2	0.001	0.6	30	0.05

* - All sample results were below detectable limits

Table . RHE 75-11
Grain Elevator B : Personal Breathing Zone Concentrations (mg/M^3) of Airborne Grain Dust and Fumigants from Samples Collected on October 7, 1975 (2)

Job Title/Location	Sampling Period	Grain Dust	PH_3*	CS_2*	CCl_4	CH_3Br*	$EtCl_2$*	$EtBr_2$*
Cleaner - Bin Floor	10:32 - 14:48	7.8	<0.14	<0.45	<0.06	<0.08	<3.8	16.5
Cleaner - Bin Floor	10:40 - 14:47	6.0	<0.19	<0.51	<0.06	<0.08	<3.8	<0.06
Laborer - Scale Floor	10:50 - 15:03	8.3	<0.18	<0.48	<0.08	<0.10	<4.8	<0.01
Scale Floor Operator	10:55 - 15:04	7.8	<0.17	<0.42	<0.07	<0.09	<4.4	<0.01
Spouter Operator	11:00 - 15:10	8.6	<0.13	<0.48	<0.12	<0.14	<7.1	<0.01
Annex Operator	11:23 - 15:10	19.9	<0.17	<0.51	<0.07	<0.08	<4.0	<0.01
Annex Operator	11:30 - 15:02	7.8	<0.19	<0.77	<0.08	<0.10	<4.8	<0.01
Car Dump Helper	11:53 - 14:53	4.7	<0.22	<0.20	<0.06	<0.07	<3.4	<0.01
Car Dump Helper	12:06 - 14:55	7.0	<0.24	<0.25	<0.06	<0.07	<3.6	<0.01
Prober	12:11 - 14:51	2.5	<0.28	<0.27	<0.06	<0.07	<3.5	<0.01
Scale Floor-Area	13:22 - 15:55	9.3	-	-	-	-	-	-
Lower Annex - Belt #1	13:26 - 16:00	7.7	-	-	-	-	-	-

Tab. : RHE 75-11
Grain Elevator C : Personal Breathing Zone Concentrations (mg/M^3) of Airborne Grain Dust and Fumigants from Samples Collected on October 7, 1975[2]

Job Title/Location	Sampling Period	Grain Dust	PH_3*	CS_2*	CCl_4	CH_3Br*	$EtCl_2$*	$EtBr_2$*
Chief Weigher	12:40 - 17:53	2.6	<0.11	<0.25	0.01	<0.08	<4.2	<0.01
Assistant Weigher	12:46 - 17:55	4.7	<0.13	<0.27	0.02	<0.08	<4.1	<0.01
Assistant Weigher	12:29 - 17:50	6.2	<0.11	<0.24	0.05	<0.07	<3.6	<0.01
Truck Dump Operator	12:36 - 16:58	2.0	<0.11	<0.33	0.01	<0.09	<4.6	<0.01
Lower Annex Operator	12:50 - 17:15	56.9	<0.15	<0.34	0.07	<0.09	<4.7	<0.01
Annex Operator	12:40 - 17:32	14.1	<0.15	<0.27	0.07	<0.09	<4.7	<0.01
Bobcat Operator	12:49 - 17:07	118.8	<0.23	<0.31	0.02	<0.09	<4.6	<0.01
Bobcat Operator	13:00 - 17:10	11.2	<0.14	<0.33	0.03	<0.10	<4.8	<0.01
Bobcat Operator	12:52 - 17:00	23.9	<0.21	<0.47	0.10	<0.13	<6.2	<0.01
Dockman	13:00 - 16:51	0.8	<0.17	<0.37	0.04	<0.11	<5.6	<0.01
Oiler	12:45 - 17:19	8.6	<0.15	<0.30	0.07	<0.12	<5.8	<0.01

Tab. 4: RHE 75-11
Grain Elevator D

Personal Breathing Zone Concentrations (mg/M^3) of Airborne Grain Dust and Fumigants from Samples Collected on October 8, 1975

Job Title/Location	Sampling Period	Grain Dust	PH_3*	CS_2*	CCl_4	CH_3Br*	$EtCl_2$*	$EtBr_2$*
Weigher - Truck Dump	09:50 - 16:08	1.2	<0.16	<0.50	<0.09	<0.11	<5.6	<0.01
Truck Dump Operator	09:55 - 16:15	3.1	<0.16	<0.43	<0.10	<0.12	<5.8	<0.01
Truck Dump Area	10:00 - 16:26	16.5	<0.14	<0.53	<0.16	<0.19	<9.4	<0.02
Pitman - Car Dump	10:10 - 15:30	2.0	<0.12	<0.56	<0.14	<0.17	<8.3	<0.01
Switchman - Car Dump	10:13 - 15:30	1.4	<0.11	<0.43	<0.17	<0.20	<10.0	<0.02
Car Dump Operator	10:18 - 15:30	1.3	<0.13	<0.42	<0.12	<0.14	<7.1	<0.01
Car Dump - Pit Area	10:22 - 15:30	22.2	<0.22	<0.56	<0.14	<0.18	<8.8	<0.01
Mixer - Basement	10:30 - 16:00	2.2	<0.17	<0.33	<0.07	<0.08	<4.1	<0.01
Mixer Helper	10:30 - 16:00	1.5	<0.11	<0.25	<0.06	<0.08	<3.8	<0.01
Upper Bin Floor Operator	10:55 - 15:45	9.7	<0.18	<0.31	<0.08	<0.09	<4.6	<0.01

Table 5: RHE 75-11
Grain Elevator E : Personal Breathing Zone Concentrations (mg/M^3) of Airborne Grain Dust and Fumigants from Samples Collected on October 8, 1975

Job Title/Location	Sampling Period	Grain Dust	PH_3*	CS_2*	CCl_4	CH_3Br*	$EtCl_2$*	$EtBr_2$*
Car Dump Operator	10:09 - 16:20	2.9	<0.09	<0.21	0.06	<0.06	<3.1	<0.01
Truck Dump Operator	10:21 - 16:18	3.3	<0.14	<0.21	0.06	<0.08	<3.9	<0.01
Weigher - Scale Floor	10:38 - 16:19	1.8	<0.12	<0.27	0.08	<0.07	<3.4	<0.01
Receiving Car Weigher	10:45 - 16:19	1.3	<0.12	<0.23	0.10	<0.07	<3.3	<0.01
Spouter	10:55 - 15:55	5.5	<0.19	<0.27	0.07	<0.10	<5.0	<0.01
Old Annex Operator	11:11 - 16:00	6.6	<0.15	<0.32	0.13	<0.08	<4.1	<0.01
New Annex Operator	11:20 - 16:20	5.4	<0.12	<0.33	0.08	<0.08	<4.0	<0.01
Houseman - Feed Tender, Old Annex	11:32 - 16:21	3.6	<0.18	<0.30	0.08	<0.10	<5.0	<0.01
Houseman - Feed Tender, New Annex	11:40 - 16:20	6.1	<0.15	<0.33	0.07	<0.10	<5.0	<0.01
Chief Weigher - Scale Floor	13:00 - 16:18	0.2	<0.26	<0.15	0.08	<0.05	<2.3	<0.01
Annex Operator	12:57 - 16:17	1.7	<0.20	<0.20	0.03	<0.06	<3.0	<0.01

Table 6: RHE 75-11
Grain Elevator F

Personal Breathing Zone Concentrations (mg/M^3) of Airborne Grain Dust and Fumigants from Samples Collected on October 9, 1975

Job Title/Location	Sampling Period	Grain Dust	PH_3*	CS_2*	CCl_4	CH_3Br*	$EtCl_2$*	$EtBr_2$*
Truck Dump Operator - X	10:10 - 16:07	6.2	Sample Lost	<0.43	0.07	<0.11	<5.4	<0.01
Truck Dump Operator - X	10:07 - 16:07	4.2	Sample Lost	<0.50	0.08	<0.12	<5.9	<0.01
Sampler/Prober - X	10:28 - 16:00	0.6	<0.13	<0.61	0.32	<0.15	<7.3	<0.01
Car Dump Operator - X	10:16 - 16:15	2.2	<0.13	<0.51	0.35	<0.13	<6.7	<0.01
Car Dump Operator - X	10:30 - 16:05	1.7	<0.10	<0.45	0.09	<0.09	<4.6	<0.01
Car Dump Area - X	10:26 - 16:15	1.4	<0.20	<0.40	0.13	<0.13	<6.5	<0.01
Car Opener - S	10:45 - 16:00	7.2	<0.19	<0.65	0.19	<0.19	<9.7	<0.01
Car Opener - S	10:50 - 16:00	7.3	<0.16	<0.91	0.25	<0.21	<10.7	<0.02
Car Opener - S	10:50 - 16:00	2.4	<0.15	<0.47	0.10	<0.15	<7.7	<0.01
Send-up Man - S	10:56 - 16:00	5.8	<0.20	<0.57	0.13	<0.18	<8.8	<0.01
Legman Main - S	11:00 - 16:10	3.4	<0.15	<0.59	0.17	<0.24	<12.0	<0.02
Area - Receivers S	11:05 - 16:00	3.8	<0.13	<0.37	0.24	<0.10	<5.1	<0.01

Table 7: RHE 75-11
Grain Elevator G : Personal Breathing Zone Concentrations (mg/M^3) of Airborne Grain Dust and Fumigants from Samples Collected on October 9, 1975

Job Title/Location	Sampling Period	Grain Dust	PH_3*	CS_2*	CCl_4	CH_3Br*	$EtCl_2$*	$EtBr_2$*
Prober	09:52 - 15:57	1.8	<0.12	<0.27	0.08	<0.07	<3.5	<0.01
Prober	09:56 - 15:56	1.6	<0.11	<0.24	0.06	<0.07	<3.5	<0.01
Cableman	10:07 - 16:17	2.9	<0.20	<0.15	0.03	<0.04	<2.0	<0.01
Inspector - QC Lab	10:21 - 16:11	1.8	<0.16	<0.10	0.03	<0.04	<1.9	<0.01
S. Annex Operator	12:33 - 16:20	6.7	<0.16	<0.21	0.03	<0.05	<2.5	<0.01
N. Annex Operator	12:58 - 16:23	15.2	<0.19	<0.20	0.11	<0.06	<3.2	<0.01
Annex Operator Truck Dump	13:16 - 16:25	4.8	<0.24	0.29	0.32	<0.08	<4.0	<0.01

Tab. 8: RHE 75-11
Grain Elevator H : Personal Breathing Zone Concentrations (mg/M^3) of Airborne Grain Dust and Fumigants from Samples Collected on October 9, 1975

Job Title/Location	Sampling Period	Grain Dust	PH_3*	CS_2*	CCl_4	CH_3Br*	$EtCl_2$*	$EtBr_2$*
Railcar Sweepman	09:38 - 15:40	15.1	<0.13	<0.22	<0.08	<0.09	<4.6	<0.01
Car Dump Operator	09:36 - 13:50	10.9	<0.12	<0.36	<0.06	<0.08	<3.7	<0.01
Prober	09:54 - 16:20	2.4	<0.11	<0.25	<0.08	<0.09	<4.6	<0.01
Main Floor Man	10:12 - 16:03	9.7	<0.10	<0.24	<0.04	<0.05	<2.6	<0.01
Annex Man - 2 House	10:40 - 16:24	11.6	<0.15	<0.29	<0.07	<0.09	<4.3	<0.01
Spoutman - 2 House	10:47 - 16:26	35.9	<0.14	<0.17	<0.04	<0.05	<2.6	<0.01
Weigher - 2 House	10:57 - 16:18	0.7	<0.13	<0.23	<0.06	<0.08	<3.7	<0.01
Annexman - 3 House	11:12 - 16:20	2.2	<0.11	<0.30	<0.08	<0.09	<4.5	<0.01
Cleaner - 4 House	11:22 - 15:55	12.9	<0.42	<0.35	<0.07	<0.08	<3.8	<0.01
Floorman - 4 House	12:25 - 14:55	12.1	<0.28	<0.27	<0.09	<0.11	<5.6	<0.01

Table 9. RHE 75-11:Port of Duluth Superior Grain Elevators

CLINICAL DATA OF THE ENTIRE SAMPLE OF GRAIN ELEVATOR OPERATORS AND BY SMOKING HABIT (-)

FREQUENCY OF SYMPTOMS	ALL n	ALL %	SMOKER	EX-SMOKER	NON-SMOKER	P
Eyes Sx	231	77.0	77	72	84	NS
Nasal Sx	191	63.7	65	60	66	NS
Cough	227	75.7	85	60	66	<0.025
Expectoration	185	61.7	64	59	61	NS
Wheezing	125	41.7	48	37	29	<0.005
Dyspnea	136	45.3	48	48	36	NS
Chest Discomfort	146	48.7	51	49	43	NS
Throat	113	37.7	40	32	38	NS
Fever and/or Chills	90	30.0				
PERSISTENT AND RECURRENT SYMPTOMS						
Morning Cough	134	44.7	56	29	29	
Daytime Cough	184	61.3	73	44	46	
Persistent Cough	121	40.3	53	24	21	<0.005
Morning Expectoration	160	53.3	61	38	48	
Daytime Expectoration	158	52.7	61	46	36	
Chronic Bronchitis	110	36.7	42	28	30	<0.01
Wheezing	156	52	59	46	36	<0.005
Wheezing w/colds	135	45				
Wheezing other than colds	90	30				
Wheezing on most days	41	13.7	16	8	11	<0.01
Wheezing w/exercise	69	23.0				
Attacks: Wheezing & Dyspnea	93	31				
Dyspnea GR I	97	32	34	29	29	
Dyspnea GR II	25	8.3				
Dyspnea GR III	8	2.7				

	ALL		SMOKER	EX-SMOKER	NON-SMOKER	P
	n	%				
Dyspnea GR IV	10	3.3				
History of Asthma	7	2.3				
Rhinitis Other than "Colds"	44	14.7				
History of Pneumonitis	44	14.7				
"Grain Fever" Syndrome	57	18.6				
Family Histories of Asthma	28	9.3				
Family Histories of Hay Fever	18	6.0				
Auscultatory Findings						
Wheezing	68	22.7				
Bilateral Inspiratory Rales	8	2.7				

Table 10. RHE 75-11:Port o uth Superior Grain Elevators

PULMONARY FUNCTION OF THE ENTIRE SAMPLE OF GRAIN ELEVATOR OPERATORS AND BY AGE GROUP[2]

FUNCTION	n	x ± SD	2 -29 (97) x ± SD	30-39 (47) x ± SD	40-49 (86) x ± SD	50-59 (58) x ± SD	69-69 (10) x ± SD
$FEV_{1.0}$ ml	298	3869 ± 809	4406 ± 635	4070 ± 662	3582 ± 727	3370 ± 726	3070 ± 569
FVC ml	296	4916 ± 858	5352 ± 730	5187 ± 774	4696 ± 736	4425 ± 886	4158 ± 593
FEF 25-75% L/Min.	298	226 ± 96	274 ± 52	233 ± 80	192 ± 77	205 ± 123	148 ± 55
FEF 50% L/Min	295	4.4 ± 1.8	5.0 ± 1.7	4.5 ± 1.7	4.0 ± 1.7	3.8 ± 1.7	3.7 ± 1.9
FEF 75% L/Min	295	1.4 ± .7	2.0 ± .7	1.4 ± .5	1.1 ± .5	1.0 ± .6	.71 ± .3
CV % VC	45	16.6 ± 9	10 ± 4	17 ± 9	23 ± 10	19 ± 5	25 ± 5
D ml CO/min/mmHg	297	31.7 ± 6	33.5 ± 5.5	32.6 ± 5.3	31.4 ± 6.8	29 ± 5.0	27.8 ± 5.4
D /VA	297	6.3 ± 1.2.	6.7 ± 1.1	6.2 ± 1.3	6.2 ± 1.2	5.9 ± 1.1	6.0 ± 1.3

In parenthesis are the number of workers in each age group.

Table 11. RHE 75-11:Port ıluth Superior Grain Elevators

Pulmonary Function in Smokers, Ex-Smokers and Non-Smokers[2]

	Smokers			Ex-Smokers			Non-Smokers		
	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD
$FEV_{1.0}$ 1/min.	177	3819	± 856	65	3831	± 799.2	56	4071	± 630.3
FVC 1/min.	177	4897	± 895	65	4946	± 893	56	4942	± 691
FEF 25-75% 1/min.	177	214.9	± 89.30	65	213.9	± 84.93	56	275.3	± 113.34
FEF 50%, 1/sec.	176	4.216	± 1.739	64	4.424	± 1.822	55	5.111	± 1.624
FEF 75%, 1/sec.	176	1.419	± 7235	64	1.372	± .7278	55	1.679	± .7378
D_{CO} ml/min/mmHg	177	30.29	± 5.491	65	33.46	± 6.897	55	34.19	± 5.155
DL/VA $\frac{\text{ml/min/mmHg}}{\text{liter}}$	177	6.040	± 1.1835	65	6.478	± 1.1994	55	6.943	± .8764

Table 12. RHE 75-11:Port of Duluth Superior Grain Elevators

ABNORMAL AIRWAYS FUNCTION IN THE TOTAL SAMPLE AND IN SMOKERS AND NON-SMOKERS[2]

	All n = 298		Smoker n = 177	Non-Smoker n = 121
	n	%	%	%
Chronic Bronchitis	110	37.0	42.4	28.0
Auscultatory Wheezing	68	22.7	28.0	13.0
Abnormal FEV_1, % FVC	39	13.0	17.0	6.0
Abnormal FEF 25-75%	110	36.8	46.0	22.0
Any of the above	200	65.0	75.7	54.5

Table 13. RHE 75-11:Port of Duluth Superior Grain Elevators

PREVALENCE OF PRECIPITATING ANTIBODIES AND FUNGAL ANTIGENS(2)

To Grain or Grain Dust Antigens	Grain Elevator Workers (n = 300)		County Highway* Workers (n = 100)
	n	%	%
G. Dust (G.M.) (#6)	68	22.9	22.0
H. Dust Conveyor Belt (#8)	51	17.2	22.0
D. Grain Dust (#8)	16	5.4	11.0
C. Durum Wheat (#8)	14	4.7	39.0
B. Dust (#3)	14	4.7	9.0
E. Spring Wheat (#4)	13	4.4	1.0
F. Rye (#1)	6	2.0	1.0
A. Soybean (#5)	2	0.7	0.0
I. Rye 1:10 (H/S)	12	4.0	0.0
J. Barley 1:10 (H/S)	11	3.7	0.0
K. Oats 1:10 (H/S)	3	1.0	0.0
L. Linseed	7	2.4	0.0
Positive to One or More Antigens	94	31.3	52.0

To Fungal Antigens	Grain Elevator Workers (n = 300)		Office Workers* (n = 1072)
	n	%	%
Penicillium Rubrum	20	6.7	0.7
Fusarium	8	2.7	
Alternaria	7	2.4	
T. vulgaris (H/S)	5	1.7	0.9
Micropolyspora faeni	3	1.0	2.4
Hormodendrum	3	1.0	
Penicillium casei	2	0.7	0.7
Thermoactinomyces vulgaris (Marsh)	2	0.7	
T. candidus (Kosky)	2	0.7	
Aspergillum fumigatus (1022)	1	0.3	2.1
Aspergillum fumigatus (6)	1	0.3	
Positive to One or More Antigen	42	19.0	5.3
To One or More of All Tested Antigens	114	38.4	

(2) ...el in parenthesis identifies the source of antigens: (#) identifies ...evator company; (H/S) Hollister-Steir, Spokane, Washington; (name or number) identifies strain used.

*Serum samples obtained from workers undergoing routine health survey examinations done by the Wis. Dept. of Health and Social Services.

Table 14. RHE 75-11:Port of Duluth Superior Grain Elevators

SKIN TESTS (2)

		Positive* %			Positive* %
A.	Grass (Mixed)	8.5	C.	Durum Wheat (#8)	2.8
	Trees (Mixed)	6.1		Spring Wheat (#4)	0.5
	Ragweed	4.7		Soybean (#6)	2.3
	Mixed Insects	14.8		Grain Dust (#4)	11.0
	Alternaria	3.7		Grain Dust (#8)	8.8
	Rat Hair	3.7		Rye, H/S	17.8
	Flax	2.0		Oats, H/S	15.8
				Barley, H/S	17.4

* Immediate wheal larger than 8 mm in diameter at 10 min.

H/S. Extracts obtained from Hollister-Steer, Spokane, Washington

The numbers in parenthesis identifies source of the grain or grain dust from which the antigenic extracts were prepared.

Table 15. RHE 75-11:Port of Duluth Superior Grain Elevators

SYMPTOMS COMPARISION OF GRAIN ELEVATOR OPERATORS WITH OTHER POPULATION STUDIES (2)

	Smith et al. (41)	Williams et al.	Klienfeld et al.	Tse et al.	Our Study
n	216	502	55	68	300
Age		20-65	22-72		20-63
	%	%	%	%	%
Cough (persistant)	27	35	27.3	50	40
Expectoration (persistant)	19	--	--	--	37.7
Wheezing	--	--	16.4	--	52
Past History - Pneumonia	10	11	5	--	14.7
Chest Radiogram of DILD*	2.3	--	--	--	0
Grain Fever	27	6.1	32.7	28	18.6
On exposure cough	--	34.9	--	--	75.7
On exposure wheezing	--	18.5	--	(43)[x]	41.7
On exposure dyspnea	--	15.5	--	--	45.3
On exposure eye symptoms	--	46	--	--	77.0
On exposure nasal	--	23	--	--	77.0
On exposure chest tightness	--	8	--	(43)[x]	48.7
Abnormal FEV1	--	--	--	18.0	13.0
Abnormal FEF_{25-75}	--	--	--	30.0	36.8
Wheezing on auscultation	--	--	12.7	--	22.7
Chronic cough and expectoration					
- Smoker	--	43	45.5	50.0	52.0
- Non-smoker	--	23	0.0	25.0	22.0
Dyspnea on exertion					
- Smoker	--	17.5	45.5	31.0	34.0
- Non-smoker		4.9	4.5	8.3	29.0

[x] 43% had both tightness in chest and wheezing

Criteria for inclusion in this category may have been slightly different.

* DILD - Chest radiogram compatible with diffuse interstitial lung disease or diffuse "fibrosis"

FIGURE 1

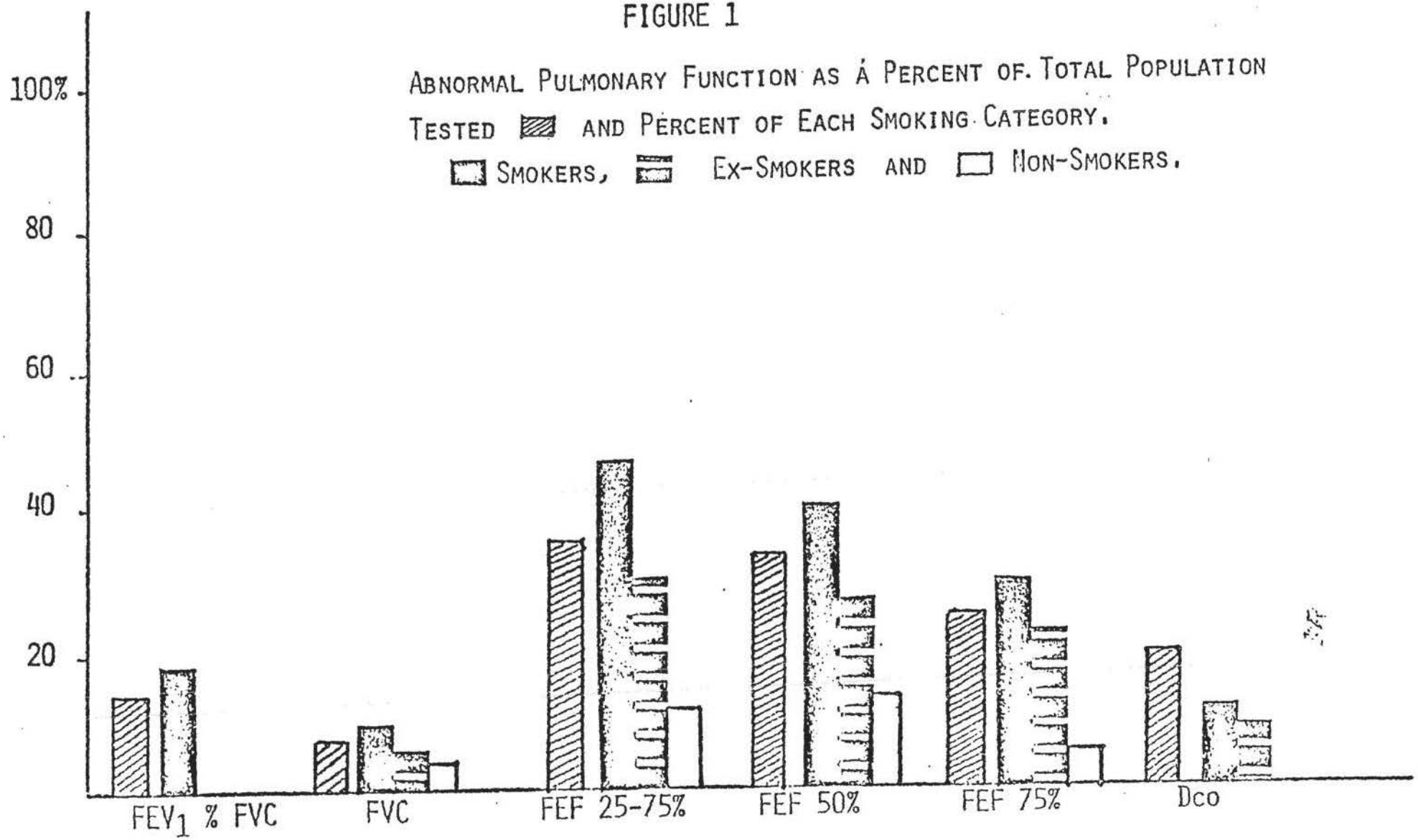
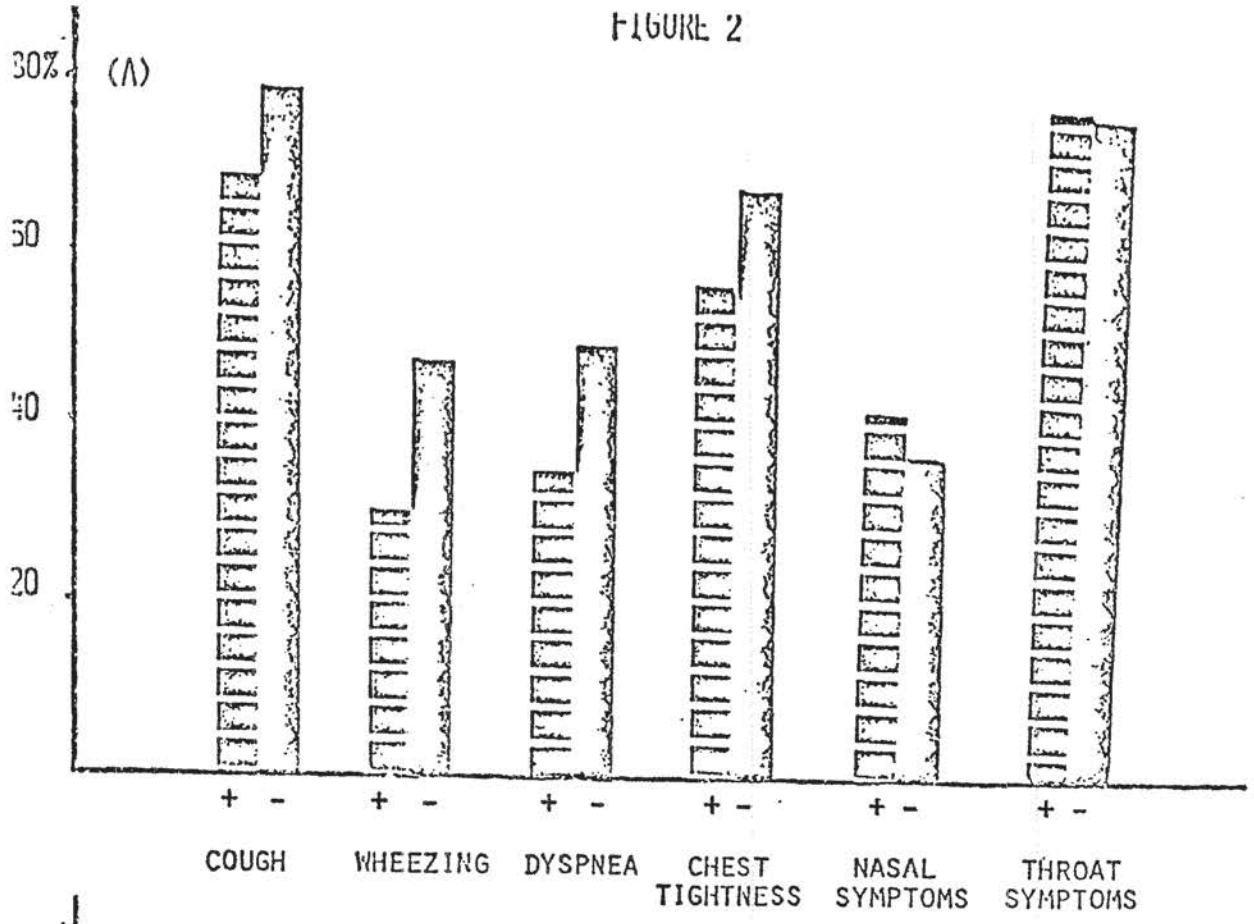
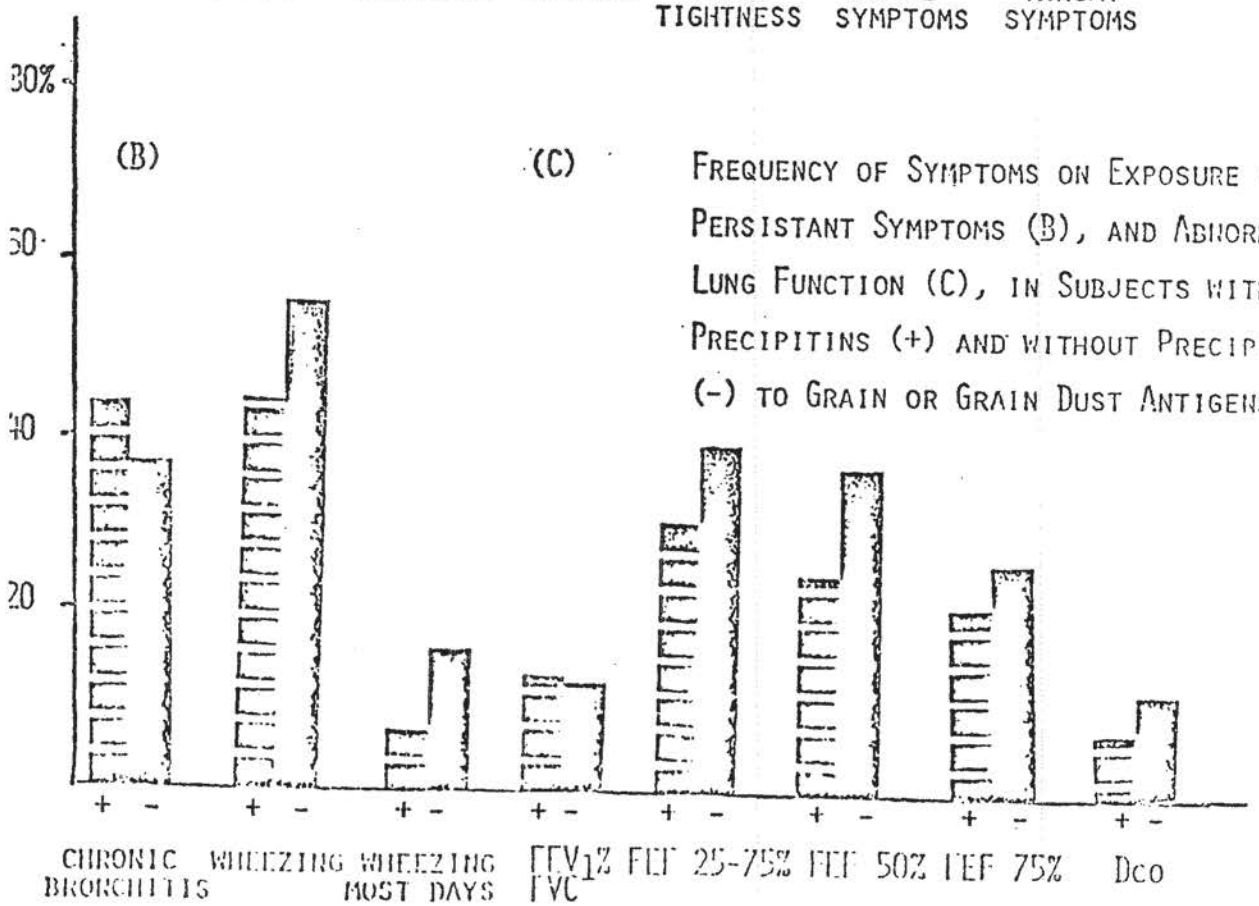

ABNORMAL PULMONARY FUNCTION AS A PERCENT OF TOTAL POPULATION TESTED AND PERCENT OF EACH SMOKING CATEGORY.
SMOKERS, EX-SMOKERS AND NON-SMOKERS.
100%
80
60
40
20
FEV1 % FVC
FVC
FEF 25-75%
FEF 50%
FEF 75%
Dco

FIGURE 2





FREQUENCY OF SYMPTOMS ON EXPOSURE (A), PERSISTANT SYMPTOMS (B), AND ABNORMAL LUNG FUNCTION (C), IN SUBJECTS WITH PRECIPITINS (+) AND WITHOUT PRECIPITINS (-) TO GRAIN OR GRAIN DUST ANTIGENS.

FIGURE 3A

FREQUENCY OF SYMPTOMS ON EXPOSURE IN POSITIVE (+) AND NEGATIVE (-) SKIN REACTORS TO COMMON ALLERGENS (C) AND TO GRAIN OR GRAIN DUST ANTIGENS (G).

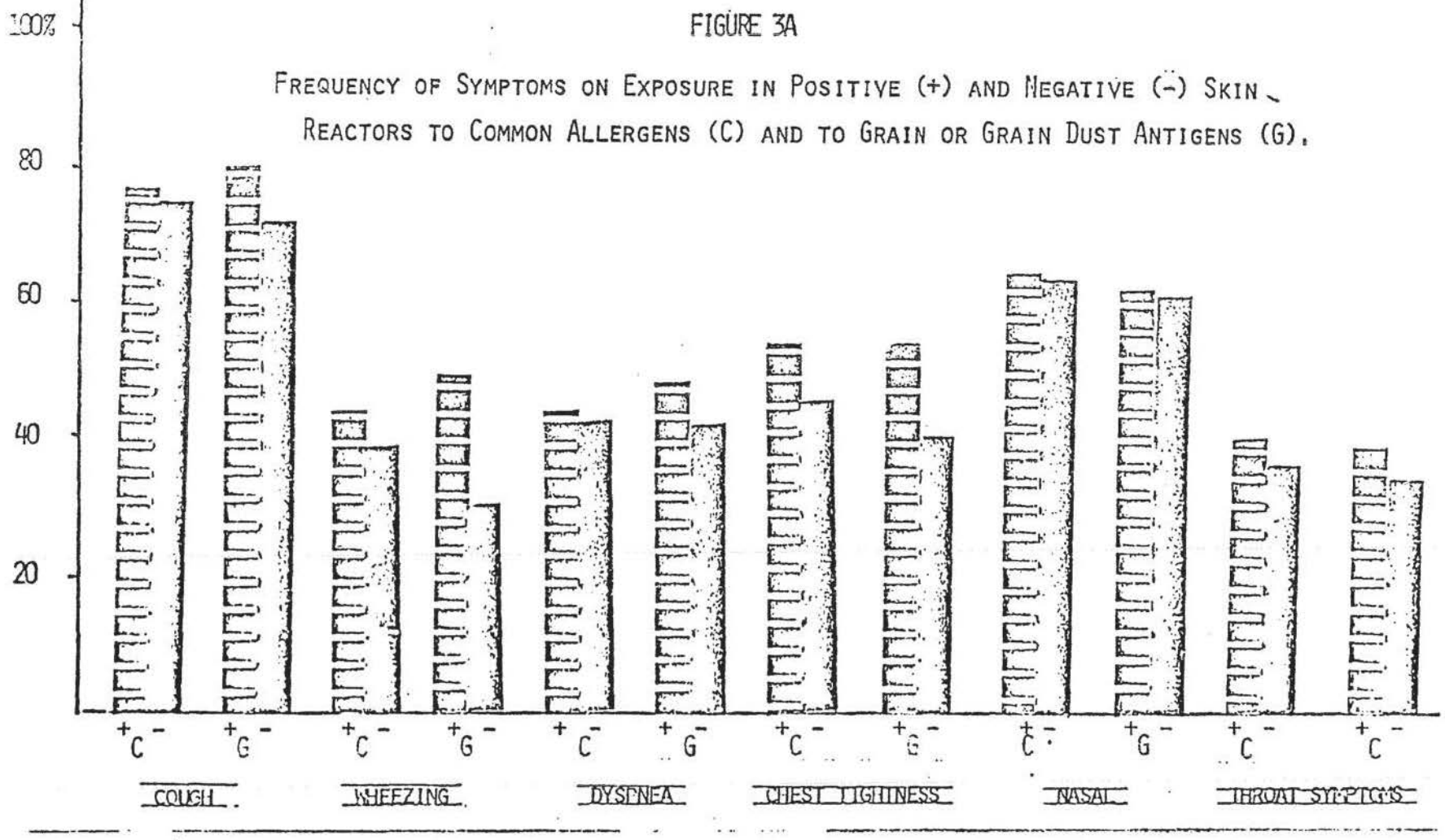
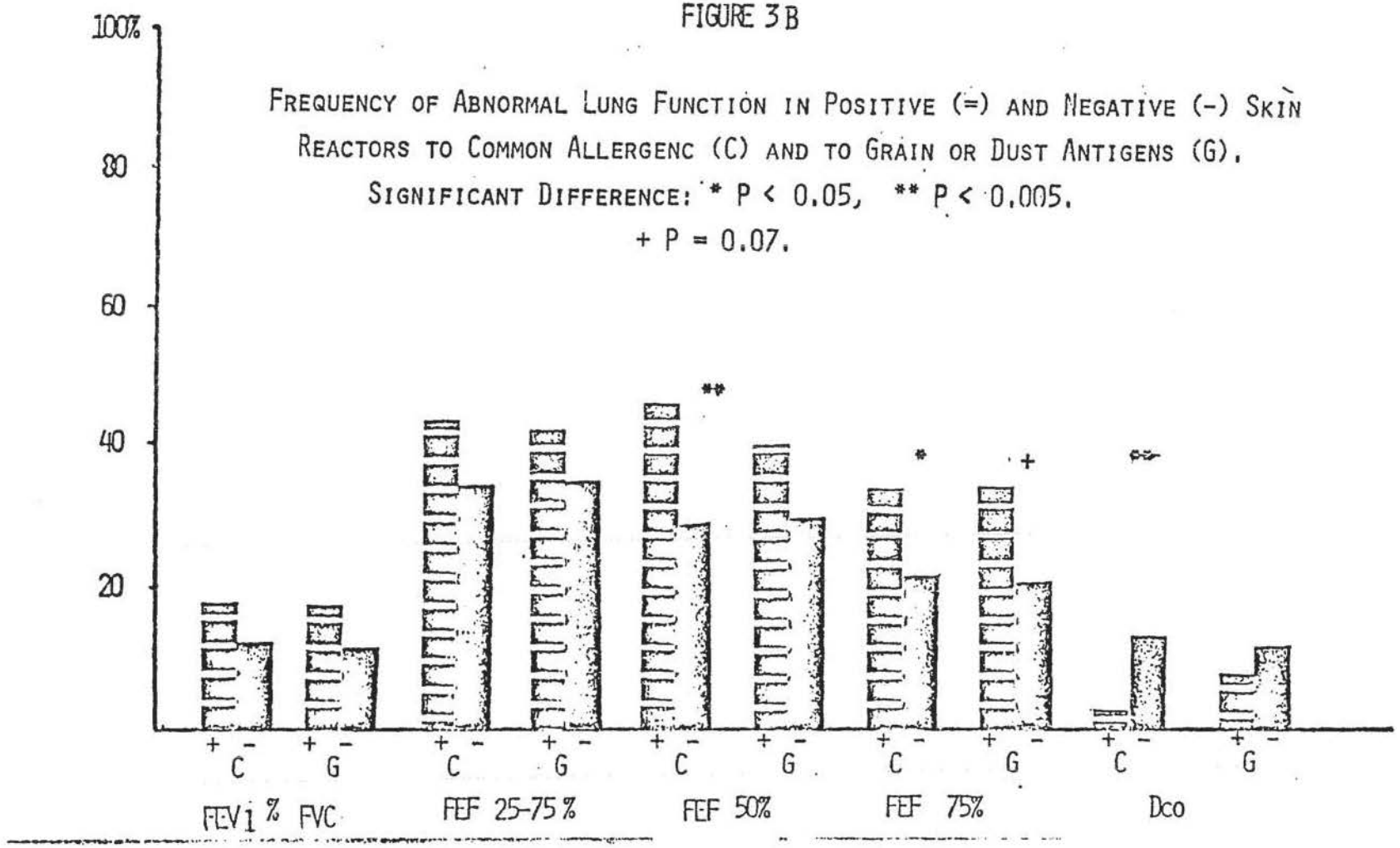


FIGURE 3 B



FREQUENCY OF ABNORMAL LUNG FUNCTION IN POSITIVE (=) AND NEGATIVE (-) SKIN REACTORS TO COMMON ALLERGENC (C) AND TO GRAIN OR DUST ANTIGENS (G). SIGNIFICANT DIFFERENCE: * $P < 0.05$, ** $P < 0.005$. + $P = 0.07$.