U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
CENTER FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
CINCINNATI, OHIO 45202

HEALTH HAZARD EVALUATION DETERMINATION
REPORT NO. 74-24,92,95-246
DECEMBER 1975

74-24: UNCLE BILL'S PICK-N-PAY MARKET, NO. 10
7011 WEST 130th
MIDDLEBURG HEIGHTS, OHIO 44212

74-92: MADSEN'S VALU CENTER
46 PARK LANE
MANKATO, MINNESOTA 56001

74-95: KROGER COMPANY
BOX 1772
LOGAN, WEST VIRGINIA 25601

I. TOXICITY DETERMINATION

At the request of authorized representatives of employees working at the above supermarkets, the National Institute for Occupational Safety and Health (NIOSH) has conducted evaluations of potential hazards to employee health found in the meat cutting and wrapping department of each supermarket. Meat department employees were interviewed, examined, given pre- and post-shift pulmonary function tests, and a pre- and post-shift sample of blood was obtained from each employee. Limited environmental sampling for particular substances emitted by the hot wire cutting of polyvinyl chloride (PVC) meat wrapping film was conducted.

Based on (1) data collected in these supermarkets; (2) information obtained in previous Health Hazard Evaluations of supermarket meat department operations; (3) information available in the published and unpublished literature; and (4) information obtained from public and private sources, the following statements are made which should be generally applicable to retail meat cutting and wrapping operations which utilize hot wire cutting of PVC meat wrapping films and thermal activation of meat package price labels.

Hot wire cutting of PVC meat wrapping films and thermal activation of price labels can release irritant substances into the meat wrapping work environment. Breathing zone concentrations of the irritant substances emitted are low when compared to established occupational health exposure standards. Employees are at no apparent risk of exposure to vinyl chloride monomer from the hot wire cutting of PVC films since no measureable concentrations of vinyl chloride monomer could be found in the emissions from hot wire cutting of the films. This finding is consistent with the extremely low levels of residual monomer reported to be present in the finished wrapping films.

Exposure to air contaminants emitted into the meat wrapping environment can produce acute health effects in retail meat department employees. The effects relate primarily to eye, nose and throat irritation. Individuals with bronchial asthma and other types of chronic obstructive respiratory disease may develop bronchospasm (acute narrowing of the airways) as the result of exposure to the irritants emitted. It can not be determined

from these studies whether actual allergic sensitization and resultant bronchial asthma occurs from exposure to these contaminants. If actual allergic sensitization does occur, it does not appear to be common.

Irritant substances may be absorbed on small aerosol particles which are also present in the emissions from hot wire cutting of PVC film and thermal activation of price labels which may facilitate the transport of irritants into the airways of the respiratory system. There is a possibility that changes may occur in the small airways of the lung as the result of exposure to these contaminants. The significance of these changes, if real, cannot be determined from the available data.

The high reported prevalence of chronic respiratory symptoms in the meat wrappers studied suggests possible long term effects from exposure to the air contaminants in the meat wrapping environment. (Symptoms were reported by individuals employed at each of the three supermarkets covered by this evaluation.) The significance of chronic symptoms can not be determined since, in general, pulmonary function test results for individuals studied were within normal limits. It is possible that the duration of exposure is not yet sufficient to result in spirometric changes.

To completely answer all questions regarding possible effects from exposure to these air contaminants would require careful study of large numbers of exposed individuals over time using sophisticated pulmonary function testing equipment. Since the Health Hazard Evaluation investigation mechanism can not select employee study populations, but must instead work with those individuals submitting requests for evaluation of particular work places, and since these investigations are necessarily of short term nature, it does not appear probable that definitive information will result from the intermittent and limited studies of meat wrappers studied under this mechanism. As evidenced by the data collected to date, much has been learned about the potential health effects from exposure to air contaminants in the meat wrapping environment and more may be learned from future Health Hazard Evaluation investigations, however, many major questions regarding long term effects of exposure remain unanswered and will remain so until definitive protracted studies can be performed.

Until definitive information is available every effort should be made to reduce air contaminant concentrations in the meat wrapping environment. This can be accomplished by utilizing mechanical film cutting devices or at least low or controlled temperature film cutting devices. Price labeling units should be operated using minimum activation temperatures. Whenever possible, wrapping and labeling should be conducted in well ventilated surroundings. Local exhaust ventilation of thermal cutting and thermal activation units would be expected to significantly reduce contaminant levels.

Persons with bronchial asthma and clinically significant chronic obstructive pulmonary disease should avoid exposure to poorly controlled meat wrapping work environments. Meat department employees who experience adverse symptomatology and feel it is related to their working environment should report the symptoms to their employer and/or physician.

II. DISTRIBUTION AND AVAILABILITY OF THE DETERMINATION REPORT

Copies of this Determination Report are available upon request from the Hazard Evaluation Services Branch, NIOSH, U.S. Post Office Building, Room 508, 5th and Walnut Streets, Cincinnati, Ohio 45202. Copies have been sent to:

a) Uncle Bill's Pick-N-Pay Market, No. 10
7011 West 130th
Middleburg Heights, Ohio 44212

Madsen's Valu Center
46 Park Lane
Mankato, Minnesota 56001

Kroger Company
Box 1772
Logan, West Virginia 25601

b) Authorized Representatives of Employees

c) U.S. Department of Labor - Regions III and V

d) NIOSH - Regions III and V

For the purposes of informing the approximately 20 affected meat department employees, the employers will promptly "post" the Determination Report in prominent places near where affected employees work for a period of 30 calendar days.

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 written request by any 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.

The National Institute for Occupational Safety and Health (NIOSH) received such requests from authorized representatives of meat department employees working at the above mentioned retail supermarkets. The requests were precipitated by employee concern for the potentially toxic effects of exposure to substances emitted by the thermal cutting of polyvinyl chloride (PVC) packaging films in use in the three meat departments.

NIOSH and its organizational predecessor the Bureau of Occupational Safety and Health (BOSH) have investigated various aspects of the health problems

reported by persons working in supermarket meat departments during the past six years[1,2,3]. Investigatory work has been conducted as technical assistance to state and local health agencies, and in response to requests for Health Hazard Evaluations from authorized representatives of meat cutting and wrapping employees. In addition, NIOSH has communicated with a number of health researchers, film manufacturers, label stock manufacturers, grocery chains, union officials, insurance companies, lawyers, and other health agencies to keep abreast of information being developed regarding this problem. This Health Hazard Evaluation Determination will discuss information developed in field work conducted at the three supermarkets involved in these most recent health hazard evaluation requests, as well as, information developed in cooperation with film and label manufacturers, grocery chains and other health researchers. Information developed in past health hazard evaluation investigations will also be included.

Most investigatory work performed to date has concentrated on the relationship of employee exposure to the air contamination generated by the hot-wire cutting of PVC packaging films. Recently, researchers at the University of Oregon suggested that fumes from the hot-melt adhesive used to affix price labels to packages of wrapped meat also contribute to the ailments of meat department employees[4]. This report will address both of these potential hazards and give some perspective to their relative importance.

DESCRIPTION OF MATERIALS, OPERATIONS - CONDITIONS OF EXPOSURE

A. Background Information

Over the past several decades a variety of packaging materials and techniques have been utilized to wrap fresh meat. With the advent of refrigerated, self-service meat display cases came the popularity of clear plastic packaging films. Among film materials which have been widely used are cellophane, rubber hydrochloride, polyethylene, polystyrene, polyvinylidene chloride, and polyvinyl chloride[5]. Since its introduction in 1963-4, polyvinyl chloride (PVC) has grown to be the predominant fresh meat packaging material in use today. Usage estimates vary considerably, but approximately 80 to 90 million pounds of PVC film are used in the wrapping of meat each year. Another 30 to 35 million pounds are used to wrap produce and other products[6].

Meat wrapping is usually performed in the meat departments of retail supermarkets. A few grocery chains cut and wrap meat in central distribution facilities and some meat wholesalers wrap sections of animal carcass with PVC film prior to shipment to retail outlets. A typical retail supermarket meat department employs one to two full-time meat wrappers and several meat cutters. In some areas, part-time meat wrappers work in several markets during a normal week. According to union[7] and industry[6] estimates, there are between 75 and 100 thousand persons employed as meat wrappers in the United States. The large majority of these meat wrappers work in the nation's 40 to 45 thousand supermarkets[8] with the remainder employed by butchershops and packing houses.

Most retail meat cutting departments are separated from the main store area and are usually maintained at several degrees below normal room temperature (i.e. 50-60°F). Minimal ventilation is supplied to these work areas to reduce refrigeration requirements and transportation of contaminants from other sections of the establishment into the meat cutting and wrapping area. Meat wrapping and labeling stations are typically located inside the mildly refrigerated meat departments.

B. Wrapping and Labeling Equipment/Hand Wrapping Procedure(2)

A wide variety of hand operated, semi-automatic, and automatic meat wrapping and labeling equipment is in use. In general, the automatic machines which wrap, seal, weigh and label utilize a serrated knife blade or movable shear to cut the film. For the most part, semi-automatic machines which weigh and label after hand wrapping, and hand wrapping machines utilize hot or heated wire film cut-off. At least one manufacturer of semi-automatic and hand wrapping equipment is now employing a guarded-blade film cut-off mechanism and other manufacturers of similar equipment are marketing machines with controlled temperature "smokeless" cut-off elements. In practically all situations, price labels are printed, heated to activate the hot-melt adhesive, and then either manually or mechanically applied to the wrapped package of meat. The temperature of the price label heating element can be regulated by the operator.

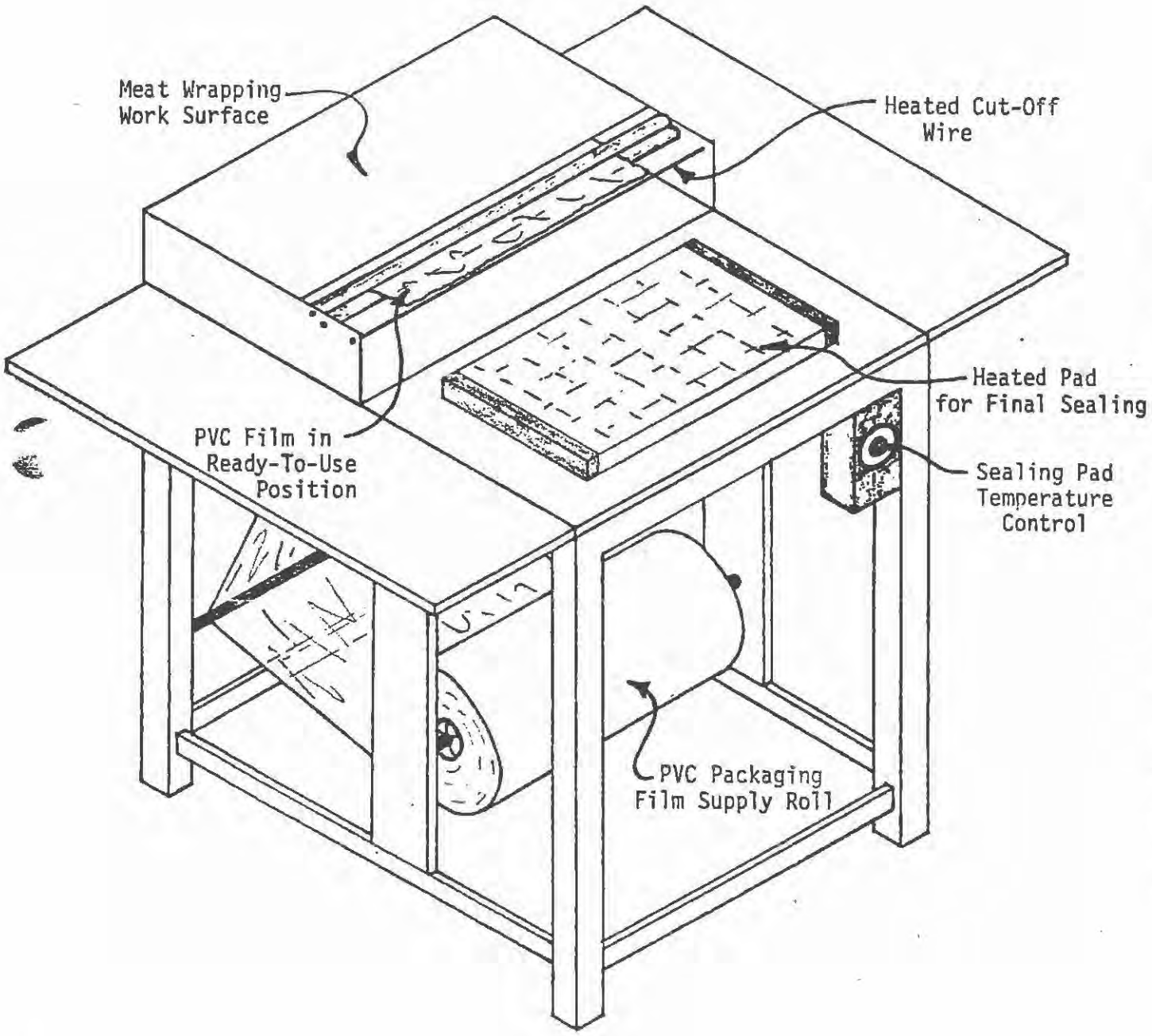
Although some of the newer wrapping equipment provides a means to control sealing temperature and cut-off wire temperature, most of the older equipment lacks one or both of these features. Hand wrapping equipment is durable, relatively uncomplicated, and can be expected to give several years of service. Consequently, many vintage machines are still in use today. A "typical" hand wrapping machine is shown in Figure 1.

The hand wrapping of meat involves: (1) pulling out a desired length of film, (2) wrapping the film around the tray or cut of meat, (Note: Cuts of meat are usually placed on paper or plastic trays before wrapping.), (3) severing the film from the supply roll using the hot-wire cut-off, (4) folding the film ends under the package, and (5) sealing the folded ends under the package by touching the package to the heated sealing pad. Most machines apply a mechanical tension to the film so that it retreats a few millimeters from the hot wire after cutting. This tension is intended to prevent the film from smoldering on the wire and causing it to become dirty and smoke. This tension also makes the film somewhat more difficult to pull from the supply roll and is often found to be improperly adjusted in the field. The sealing pad is maintained at a temperature sufficient to cause the film layers to adhere to one another after brief contact with the pad. Hand-held sealing irons are used very infrequently with PVC packaging films.

After wrapping each package of meat is weighed and labeled. Most markets employ integrated scale and labeling systems. That is, the scale furnishes information to the printer which automatically computes and prints the price, etc. on the label. Printed labels are then heated to activate their adhesive coating and then applied to the package. Depending on the degree of

FIGURE 1

Typical Hand-Wrapping Machine



automation, the labels are either manually or mechanically applied to the meat packages. Often a combination of both manual and mechanical labeling is utilized to accomodate irregular package shapes, etc. The temperature of the label heating element can be regulated to suit the speed of the wrapping process and the surface temperature of the meat packages.

C. Manufacture of PVC Meat Packaging Film[9,10]

PVC meat packaging film is made from PVC resin (polymerized vinyl chloride) and selected additives. The additives serve to (1) control deteriorative physiochemical reactions within the material during compounding, manufacture and film use, (2) impart desired properties (e.g. stretch, oxygen permeability, fog resistance, etc.) to the finished film product, and (3) control the migration of film constituents (e.g. monomer, plasticizer, etc.). Since the film does come into direct contact with meat, all film ingredients can potentially migrate into the meat and are therefore classified as "indirect" food additives. As such, film materials and ingredients are approved by the federal Food and Drug Admininstration.[11]

Commercially important PVC meat wrapping films have been found to have similar formulations.[1] Plasticizers (di-2-ethylhexyl adipate which is commonly referred to as dioctyl adipate, and epoxidized soybean oil) can comprise up to 30% of a film. Stabilizers (e.g. calcium-zinc stearate, epoxidized soybean oil), antifog agents (e.g. polyoxethylene derivatives of sorbitan monooleate, glycerol monooleate), lubricants (e.g. stearic acid) and colorants together make up 2-6% of a film. It is important to note that the above general formula information applies only to PVC films used to package fresh meat. PVC films used to wrap produce, cured meat, cooked meat, etc. may employ somewhat different additives.

Most PVC meat packaging film is manufactured by the compound-melt blown-bubble extrusion process. A relatively small amount of film is manufactured by the solvent casting process. Although these film making processes are widely applied in industry, the operating parameters, techniques, and accessory equipment are basically developed by each manufacturer and are considered proprietary. Film ingredients are melted or dissolved, mixed, blown-bubble extruded or solvent cast, and the finished film is wound on rolls and cut to size for sale. Oriented or heat-shrinkable PVC films are manufactured in a similar fashion with controlled stretching and heat-setting techniques. The finished film has a thickness of several thousandths of an inch (typically 0.0075 inches).

D. Thermally Activated Price Labels - Adhesive Composition and Label Manufacture[12,13]

Price labels used in meat retailing are usually made from English finish or litho paper stocks. The label material must readily absorb the ink impressions from the printer and the ink and paper must be capable of withstanding the heat encountered in the adhesive activation process (typically 225 to 475°F).

Adhesives used in price labeling must securely affix the labels to meat packages so that they cannot be easily removed by shoppers, and the label must stay in place even at low temperatures. To achieve these adhesive performance characteristics, label manufacturers are currently using a hot-melt or thermally activated adhesive containing a solid plasticizer. On heating, the plasticizer softens and application to a package of meat wrapped in PVC film forms a film-label bond which can be as strong or stronger than the film. To some degree the adhesive becomes part of the film.

Presently, most supermarket chains buy printed, adhesive-coated label stock from label suppliers. At least one chain buys blank adhesive-coated label stock and prints their own labels.

Since the early 1960's, label adhesives have contained dicyclohexyl phthalate (a solid plasticizer) as a major constituent (more than 60% by weight) and small amounts of a variety of polymers and elastomers which do not contain halogens and are not epoxy or urethane compounds. Prior to the use of dicyclohexyl phthalate, diphenyl phthalate was utilized in label adhesives.

Adhesive ingredients are combined in a water emulsion/dispersion and applied to the paper stock by a knife coating process. Coated label stock is dried and wound into rolls. Later the label stock is printed with the design/advertising requested by the customer. Label stock can be stored for long periods (years) provided that the material is kept cool and dry. Some of the adhesive ingredients do tend to sublime, however.

V. SUBSTANCES TO WHICH MEAT WRAPPERS AND CUTTERS ARE EXPOSED

A. Emissions from Hot-Wire Cutting of PVC Packaging Film

1. Review of Previously Reported Findings

The thermal degradation of PVC (not the film) has been studied extensively.[14,15] The rate of heating and the final decomposition temperature together with other variables influence the character of decomposition products released from the polymer. Dehydrochlorination which primarily results in macromolecule cross-linking, chain scission, and creation of polyene sequences has been measured at temperatures as low as 80 C.[16,17] Dehydrochlorination becomes auto-accelerating above about 200 C[14], and is essentially complete at 300 C.[18] Hydrogen chloride comprises 96-99% of the decomposition products during dehydrochlorination.[15] As decomposition temperature is raised from 300 C to approximately 600 C a variety of volatile substances are liberated. Boettner et al,[18] studying the 25-600 C decomposition interval, found over 50 substances to be emitted from PVC. For the pure polymer the major decomposition products were carbon dioxide, hydrogen chloride and carbon monoxide. Benzene, methane, ethane, toluene and propane were found in excess of one milligram per gram of polymer. All of the other compounds including residual vinyl chloride monomer did not exceed one milligram per gram of pure polymer.

The thermal decomposition products of PVC meat wrapping film were first examined by the Bureau of Occupational Health.[1] In a study directed toward identifying the "volatile" irritant/toxic decomposition products, samples of film from several manufacturers were heated for one hour at temperatures ranging from 200-230 C. The decomposition products were separated by gas chromatography and the most prominent substances were identified by mass spectrometry. The following substances were found to be emitted by all film samples: hydrogen chloride, chlorobutane, benzene, toluene, 1-chloro-2-ethyl hexane, and 2-ethyl-1-hexanol. The latter two substances were assumed to be plasticizer breakdown products. Benzyl chloride was randomly found as a decomposition product from a few film samples. An oily substance, presumed to be the film plasticizer, was observed to condense in the analytical apparatus but was not positively identified. Subsequent environmental measurements made in supermarket meat departments detected only trace concentrations (less than 1 ppm) of hydrogen chloride.

Bovee et al[19] examined the thermal decomposition of meat packaging films from six manufacturers. Gram-sized film samples were heated for up to 30 minutes at several temperatures while decomposition products were condensed in an ice bath and later analyzed by gas chromatography and mass spectrometry. Decomposition products from multi-milligram sized samples were directly injected into a gas chromatograph from a pyrolyzer accessory and the peaks identified by mass spectrometry. Using a solids inlet probe, multi-microgram sized samples of film were introduced into a mass spectrometer and analysis was made from combined spectra. Cutting characteristics, smoke formation, dehydrochlorination, etc. was studied in the laboratory using a controlled temperature hot wire. Gas chromatography and mass spectrometry were used to analyze trapped "smoke" samples. The gas chromatograph used in these studies was programmed from 30-300 C at 6 degrees/minute.

This study found the chromatograms of the different films to be similar at a decomposition temperature of 180 C with one film showing two unique additives displaying adipate-like mass spectra. The primary decomposition product of the various films was found to be a plasticizer identified as diisooctyl adipate (di-2-ethylhexyl adipate). Isooctanol (2-ethyl-1-hexanol), a plasticizer breakdown product, was emitted from all film samples and varying amounts of Ionol (butylated hydroxy toluene) was emitted by several of the films. A number of substances were observed to be present in very small quantities and were not identified. The hot wire was observed to sluggishly melt through films at 150 C; smoke was observed above 175 C; and hydrogen chloride was detected above 230 C. Analysis of the smoke from the hot wire showed it to be 99% diisooctyl adipate (di-2-ethylhexyl adipate).

In a study undertaken to learn more about air contamination generated by the actual wrapping process, Van Houten et al[20] installed a film cutting and sealing machine in a sealed laboratory chamber. Wrapping conditions were varied from normal to artificially severe. Air contaminants were collected at a point directly over the cut-off wire and in the meat wrapper's breathing zone. Cut-off temperature was varied between 180-360 F(82-183 C) by modifying the machine wiring to include a variable voltage control and thermistor to

measure cut-off wire temperature. Before modification the non-adjustable cut-off wire temperature of the machine used in this study was approximately 350-360 F(177-183 C).

Under the most severe test conditions (i.e. operating the machine at a "greatly exaggerated production rate" allowing the film to decompose and smolder on the cut-off wire maintained at 360 F(183 C)) a breathing zone hydrogen chloride concentration of 0.3 mg/M^3(0.2 ppm) and a total particulate concentration (directly over the wire) of 19 mg/M^3 were measured. Subsequent analysis of total particulate samples by extraction and gas chromatography showed them to contain approximately 75-80% dioctyl adipate (di-2-ethylhexyl adipate).

Under normal operating conditions, concentrations of total particulate and dioctyl adipate measured directly over the wire were 0.7 and 0.25 mg/M^3 respectively at a cut-off wire temperature of 360 F(183 C). Operating normally at a wire temperature of 220 F(105 C), 0.35 mg/M^3 of total particulate and 0.14 mg/M^3 of dioctyl adipate were found directly above the wire. Although breathing zone hydrogen chloride concentrations were not measured under normal operating conditions, they can be safely assumed to have been much below the 0.3 mg/M^3 (found directly over the wire) and $<$0.1 mg/M^3 (found in the breathing zone) at wire temperatures on 360 F(183 C) and 220 F(105 C) respectively.

It was determined that a cut-off wire temperature of 215-230 F(102-110 C) was satisfactory for the film used in this study. Reducing the cut-off wire temperature from 360 F(183 C) to 220 F(105 C) afforded a near 50% reduction in emission of total particulate and dioctyl adipate under normal operating conditions.

Reduction of emissions from thermal cutting of PVC film by lowering cutting element temperature has also been recently reported by James.[21] Using a controlled temperature "cool rod" cutting element maintained at approximately 275 f(135 C), it was demonstrated that emissions of hydrogen chloride were significantly less from the "cool rod" cutter than from the uncontrolled hot-wire cutters. Average hydrogen chloride concentrations measured in the breathing zones of meat wrappers performing normal wrapping procedures were found to be 0.57 ppm using the hot-wire cutting elements and 0.03 ppm using the "cool rod" cutting element.

The most recent pyrolytic study of PVC meat wrapping film was conducted by Jaeger and Hites.[22] A sample of film known to contain di-2-ethylhexyl adipate was pyrolyzed at 275-350 F(135-177 C) for 1.5 hours and the condensed acetone-soluble decomposition products compared with substances acetone-extracted from another sample of the film. Gas chromatographic and mass spectrophotometric analyses of these acetone soluble materials showed them both to contain di-2-ethylhexyl adipate. Thus, pyrolytic evaporation of the intact plasticizer was confirmed.

2. Recent NIOSH Investigations

In conjuction with these most recent health hazard evaluation investigations and in response to requests made by the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA), NIOSH has conducted a limited amount of field environmental sampling and evaluation work.

During the spring of 1974, NIOSH was requested by OSHA to investigate potential employee exposures to vinyl chloride monomer associated with the fabrication and use of PVC products. As part of our response to this request, measurements for vinyl chloride monomer in the emissions for the hot-wire cutting of PVC packaging films were made. With the cooperation of a grocery chain headquartered in Cincinnati, Ohio, a series of experiments was performed using three commercially available PVC packaging films and several film cutting/wrapping machines. The film cutting/wrapping machines utilized were modified so that the cutting element temperature could be varied over a wide range.

Using a Wilks MIRAN Infrared Gas Analyzer, measurements for vinyl chloride monomer were made directly over the cutting elements while element temperature and film cutting conditions were varied. Even under the most severe operating conditions, (i.e. piling large amounts of film on the cutting element) no vinyl chloride monomer was detected over the entire range of operating temperatures. Absorbance readings were made at wavelengths of 10.9 and 9.8 micrometers. Spectra between 8.0 and 14.5 micrometers were also examined. Under these operating conditions, the lower limit of detection for the Wilks instrument was approximately 1 to 2 ppm of vinyl chloride monomer.

Measurements for vinyl chloride monomer were also made at each of the supermarkets involved in these health hazard evaluations. In one situation the Wilks instrument was used, but due to voltage fluctuation problems, no meaningful data was obtained. Charcoal tube sampling methods were employed in the two remaining markets. Operating conditions were varied over a wide range and again no vinyl chloride monomer was detected in the plume of emissions for the cutting elements. The lower limit of detection for the charcoal tube collection and gas chromatographic analysis method utilized is approximately 0.2 ppm of vinyl chloride monomer.

In addition to measurements for vinyl chloride, measurements for hydrogen chloride were made in each of the three supermarkets. As has been previously determined by other researchers, less than 1 ppm of hydrogen chloride was found in the meat wrappers' breathing zones. Under very severe conditions, a few parts per million (less than 5 ppm) of hydrogen chloride were found in the plume of emissions an inch or so from the cutting element. Gas detector tubes were utilized to make these field determinations.

B. Emissions from Thermal Activation of Price Label Hot-Melt Adhesive[12,13]

Thermal activation of adhesive coated price labels is performed by heating the label from the printed side. The activation temperature achieved by this process is a function of the heating element temperature, the thickness of the label paper, and the duration of label contact with the heating element. Given sufficient contact time, a heating element temperature of approximately 150 F(66 C) would cause the adhesive to soften and become sticky. In practical labeling applications, however, the contact time is on the order of fractions

of a second to several seconds. Therefore, heating element temperatures must be raised to transfer adequate heat during the heating interval. With contact times of less than a second, a heating element temperature of 300-400 F(149-205 C) is commonly required to provide adequate activation. Higher temperatures may be required for high speed equipment, and for labeling frozen or very cold packages.

Whenever the contact time at a particular heating element temperature exceeds the time necessary for adequate activation, the potential exists for excess emissions from the activation process. In hand labeling operations, a jam in the flow of packages can result in prolonged contact of the labeling material with the heating element. In some cases the labels may become scorched and smoke may be observed.

By examining the formulations of price label adhesives, it was determined that the major ingredient, dicyclohexyl phthalate, and/or its breakdown products would comprise an important portion of the emissions from the adhesives during activation. Other proprietary adhesive ingredients (i.e. thermoplastic polymers and elastomeric polymers not containing halogens) individually present in small quantities, were recognized to have known breakdown products comprised basically of hydrocarbons and small amounts of aldehydes, alcohols, carboxylic acids, etc.

Information was obtained from a plasticizer producer regarding the thermal decomposition products of dicyclohexyl phthalate.[23] A 10 milligram sample of dicyclohexyl phthalate was placed in a boat contained in a heated tube and heated for 30 and 60 seconds at 200-210 C. The emissions from the sample were directly analyzed by gas chromatography and mass spectrometry. The materials emitted, expressed in terms of parts per million based on sample weight, were as follows:

	30 seconds	60 seconds
Cyclohexanol	90 ppm	130 ppm
Cyclohexyl Ether (Dicyclohexyl Ether)	43 ppm	92 ppm
Phthalic Anhydride	10 ppm	113 ppm
Cyclohexyl Benzoate (Cyclohexyl Ester of Benzoic Acid)	5 ppm	38 ppm

Under these experimental conditions the plasticizer itself did not volatilize appreciably.

C. Toxicity of Substances Emitted into the Meat Wrapping Environment: Exposure Criteria

From the data available at this time it seems reasonable to conclude that the major emissions from the hot-wire cutting of PVC film are di-2-ethylhexyl adipate and hydrogen chloride. Di-2-ethylhexyl adipate is used in PVC films because of its low temperature performance characteristics and

because of its very low toxicity by route of ingestion. In fact, "...the oral lethal dose for di-2-ethylhexyl adipate is so high as to be practically indeterminate."[24] Di-2-ethylhexyl adipate is not an irritant to the skin or eye. Only very sparse information is available with regard to the inhalation toxicity of di-2-ethylhexyl adipate. In one unpublished study[23], 10 rats were exposed for 4 hours to 900 mg/M^3 (59 ppm) of di-2-ethylhexyl adipate generated at 89°C and observed for 14 days. None of the rats died and no untoward behavioral reactions were observed.

Hydrogen chloride has a sharp odor and acid taste. It can be detected by most persons at concentrations of 1-5 ppm. At slightly higher concentrations (5-10 ppm), exposure to hydrogen chloride is immediately irritating and disagreeable[25,26]. The current health standard for occupational exposure to hydrogen chloride (see Table I) is 5 ppm (7 mg/M^3) and since the standard is a "ceiling value," unprotected employees should never be exposed to concentrations in excess of 5 ppm. The hydrogen chloride standard is based on data which were interpreted to indicate that a ceiling exposure level of 5 ppm would be "...sufficiently low to prevent toxic injury, but on the border of severe irritation."[27]

In the process of cutting PVC film with a hot-wire, an aerosol of di-2-ethylhexyl adipate is formed. It is possible that some of the hydrogen chloride emitted attaches itself to the aerosol particles of di-2-ethylhexyl adipate. This type of gas/particle interaction has been observed in other situations (e.g., sulfur dioxide and soot particles), in particular, with hydrogen chloride and soot/water particles associated with fires involving chlorinated polymeric materials.[28,29] Hydrogen chloride deposited on aerosol particles (several micrometers in diameter) could get past the defenses of the upper respiratory tract and affect the lungs. Moderate concentrations of hydrogen chloride (not in combination with particles) are usually removed by the moist surfaces of the nose, throat, etc.

Individuals with chronic respiratory disease may be adversely affected by concentrations of hydrogen chloride below 5 ppm or by hydrogen chloride/di-2-ethylhexyl adipate aerosol. These individuals would normally be more susceptible to the pulmonary effects of irritant chemicals.

Complete information regarding the total spectrum of emissions from the thermal activation of price labels is not available. However, a discussion of the toxicity of the thermal decomposition products of dicyclohexyl phthalate (the major ingredient of price label adhesives) is in order.

Pertinent toxicologic information dealing with cyclohexyl ether (dicyclohexyl ether) and with cyclohexyl benzoate (cyclohexyl ester of benzoic acid) could not be found in the literature.

The effects of cyclohexanol at moderate and low exposure levels are basically irritative in nature. After three to five minutes of exposure to 100 ppm of cyclohexanol, human subjects found the effects of the vapors on the eyes, nose, and throat to be objectionable. The current health standard for 8-hour time-weighted-average occupational exposure to cyclohexanol of 50 ppm (200 mg/M^3) (see Table I) is based on this information and the absence of strong evidence suggesting more serious systemic toxicity.[27]

Phthalic anhydride is known to be a potent skin, eye, and upper respiratory irritant. Skin and pulmonary sensitization to phthalic anhydride may occur.[30] Pulmonary sensitization to phthalic anhydride can cause bronchial asthma and may be associated with specific IgE antibody against phthalic anhydride when measured by the radioallergosorbent test (RAST).[31] It may now be possible to determine sensitivity to phthalic anhydride using this diagnostic procedure. The current health standard for 8-hour time-weighted-average occupational exposure to phthalic anhydride is 2 ppm (12 mg/M^3) (see Table I) and is derived from the above data together with information regarding the toxicity of other strong irritants (i.e. sulfuric and nitric acids).[27]

Only limited data concerning the toxic effects of the combined thermal degradation emissions from dicyclohexyl phthalate are available. Rats have been exposed to the vapors generated by heating dicyclohexyl phthalate to 400 F (205 C).[23] One of six rats died within 24 hours following a 6-hour exposure to a nominal vapor concentration of 9,000 mg/M^3. The surviving rats were observed for 14 days and sacrificed. No gross pathologic changes were observed. During the exposure the animals were noted to have ocular discharge and labored breathing.

The two standard sources of criteria used to assess workroom concentrations of air contaminants in this evaluation are: (1) recommended threshold limit values (TLV's) and their supporting documentation as set forth by the American Conference of Governmental Industrial Hygienists, ACGIH (1974); and (2) occupational health standards as promulgated by the U.S. Department of Labor (Federal Register, June 27, 1974, Title 29, Chapter XVII, Subpart G, Table G-1). Recommended TLV's and Federal standards are the same for the irritant materials involved in this evaluation. TLV's and Federal standards have not been established for the plasticizers (di-2-ethylhexyl adipate and dicyclohexyl phthalate) and for cyclohexyl ether and cyclohexyl benzoate which are involved in this evaluation. Consequently, these materials are not included in the table to follow.

Table I: Occupational Health Exposure Standards/ACGIH TLV's

Substance	Permissible Exposure
Hydrogen Chloride	5 ppm (7mg/M^3) C[a]
Cyclohexanol [b]	50 ppm (200 mg/M^3)
Phthalic Anhydride [b]	2 ppm (12 mg/M^3)

ppm = parts of vapor or gas per million parts of contaminated air.

mg/M^3 = approximate milligrams of substances per cubic meter of air.

[a]Ceiling value: Employee exposure should never exceed permissible exposure

[b]Time-weighted-average standard: Employee exposure averaged over 8 hours should not exceed permissible exposure.

VI. CLINICAL STUDIES

A. Background and Review of Literature

Pulmonary complaints associated with exposure to air contaminants generated by the hot-wire cutting of PVC meat packaging films were first reported in an unpublished study conducted by the Bureau of Occupational Safety and Health.(1) This study noted that formal complaints from meat wrappers were reported as early as the summer of 1969. In some of these early cases, respiratory involvement was reported to have been sufficiently severe to result in hospitalization and loss of work.

The first clinical study of meat wrappers was conducted by NIOSH in 1972-3 in response to requests for Health Hazard Evaluations of supermarket meat departments.(2) Histories were gathered from a total of 35 meat wrappers in two geographically separated locations. Respiratory questionnaires and pre- and post-shift pulmonary function testing were administered to 17 basically healthy meat wrappers and to 20 control subjects. No significant differences in pulmonary function testing were observed between the two groups after one shift of wrapping meat with PVC film. Subjects reported to their local union hall before and after work for pulmonary function testing and questionnaire administration. A higher prevalence of cough, phlegm, and history of hay fever and asthma was noted in meat wrappers. The study concluded that a sizable percentage of meat wrappers suffer from mild symptoms, primarily eye, nose and throat irritation, and that a portion of affected meat wrappers who have an underlying predisposition to respiratory difficulties may experience pulmonary involvement. A later analysis of the pulmonary function data from this study suggested that some degree of small airways involvement may have been present in the meat wrappers studied.(32)

A great deal of national interest followed the report of Sokol et al.[33] These investigators reported three cases of what they described as "meat wrappers asthma." The patients were middle-aged women who smoked cigarettes and demonstrated reversible airway obstruction on pulmonary function testing. None demonstrated peripheral eosinophilia, skin test reactivity to common allergens, or family history of allergy. Between 20 minutes and 5 hours following exposure to meat wrapping with a particular PVC film, each patient reported the development of dyspnea and wheezing. Cough and chest tightness were also noted. These symptoms were reported to disappear by two patients when exposure was terminated, but persisted even away from exposure in the third patient. Wheezing was heard on auscultation of the chest. The three patients were not studied at work, but reported to a hospital where examinations and laboratory studies were performed.

An epidemiologic study consisting of administered questionnaires was recently conducted in 152 supermarkets in Houston, Texas.[34] This study was precipitated by the reporting of two cases of "meat wrappers asthma" to the Houston City Health Department in January, 1974. One hundred and forty-five meat wrappers, 150 meat cutters/butchers and 150 grocery clerks, etc. were studied. Approximately 9% of the meat wrappers studied reported multiple respiratory symptoms which included wheezing, shortness of breath, and chest pain or tightness (versus 1.3% for meat cutters/butchers and 3.3% for clerks). Most of the wrappers reporting multiple respiratory symptoms were smokers. However, smoking itself or in combination with the refrigerated environment did not adequately explain the increased symptomatology in meat wrappers. In most cases these respiratory symptoms were not severe enough to cause the wrappers to seek medical attention or treatment. A significantly greater prevalence of symptoms suggesting eye, nose and throat irritation was also found in meat wrappers.

The study additionally suggested an increased prevalence of acute respiratory illnesses in the wrappers, which was not related to working in a refrigerated environment. The investigators commented that "meat wrappers asthma" was not an appropriate designation for this constellation of acute and chronic respiratory symptoms related to meat wrapping.

Andrasch et al[4] has recently reported the results of a questionnaire survey of 165 meatwrappers in the Portland, Oregon metropolitan area and the results of inhalation provocation studies of a selected group of workers.

Fifty-eight percent of the workers completed the questionnaire and approximately two-thirds reported a variety of occupationally related symptoms. Fifty-seven percent of the symptomatic workers reported respiratory symptoms which included exertional dyspnea, cough, wheezing and chest pains. Thirty percent reported symptoms suggestive of nose and throat irritation. Several workers reported the occurrence of acute asthmatic attacks occurring 10 minutes to 4 hours after starting work. Twenty-two percent of the responding wrappers reported an atopic background. Smokers presented more severe respiratory symptoms than nonsmokers but had equal occurrence of mucous membrane irritation.

Bronchial provocation studies with emissions from hot-wire cutting of PVC films were conducted with 11 meat wrappers who demonstrated abnormal pre-exposure pulmonary function test results and in some cases mild peripheral eosinophilia. During exposure, rhinorrhea was noted in 7 wrappers; cough, tightness of the chest, and sore throat in 5; dyspnea, exhaustion and wheezing in 4; and throat soreness in 2 patients. Persistently decreased pulmonary function test results were noted in 5 subjects. Four patients had a mean decrease in arterial oxygen tension of 22 mm Hg.

Nine of 13 patients challenged with emissions from heating price label material (exposure 30 seconds to 20 minutes) developed immediate acute asthmatic reactions. Four of these subjects also experienced a delayed asthmatic reaction occurring 6 to 8 hours after exposure. Cyanosis, tachycardia, sweating and dizziness were noted in 5 patients. Other symptoms reported included shakiness, and burning of the nose and throat in 4 patients; headache, muscle aching and nausea in 3; rhinorrhea and weakness in 2; and vomiting and increased hoarseness in one. Marked reductions in pulmonary function tests were noted (forced vital capacity (FVC) decreased 66%, forced expiratory volume in one second (FEV_1) decreased 49%; maximal mid-expiratory flow decreased 44%). A mean decrease in arterial oxygen tension of 25 mm Hg was noted in 9 patients.

The authors concluded that the emissions from thermally activating price labels are the principal cause of "meat wrappers asthma," but that the entire spectrum of this disease has to be interpreted as a complex response from exposure to both emissions from hot-wire cutting of PVC film and from thermal activation of price lables.

B. Recent NIOSH Health Hazard Evaluation Investigations

Three supermarkets were visited on the following dates:

Uncle Bill's Pick-n-Pay Market, No. 10: April 11, 1974
Middleburg Heights, Ohio 44212

Madsen's Valu Center: August 22, 1974
Mankato, Minnesota 56001

Kroger Company: October 4, 1974
Logan, West Virginia 25601

A total of 7 meat wrappers and 8 meat cutters were studied. Each subject completed a modified respiratory questionnaire and performed pre- and post-shift pulmonary function testing. Pre- and post-shift complete blood and total eosinophil counts were also performed. The data collected in these three most recent Health Hazard Evaluation investigations will be discussed with other data collected in past investigations in the next section of this report.

C. Summary of NIOSH Health Hazard Evaluation Studies of Meat Wrappers and Cutters

1. Combined Study Population

Twenty-four meat wrappers, 8 meat cutters and 20 control subjects (office personnel and store clerks) make up the population studied. Data concerning age, sex and smoking history of the subjects are shown in Table II. While meat wrappers were commonly women, meat cutters were usually men. The three groups were of similar age, but there was a greater number of meat wrappers who were cigarette smokers. The mean duration of wrapping in the meat wrappers was 12.5 years (range 1 to 26 years).

Table II: Combined Study Population

	Number	Mean Age (years)	Sex		% Smokers
			Male	Female	
Meat Wrappers	24	41	12	12	50
Meat Cutters	8	40	6	2	25
Controls	20	40	14	6	20

2. Methods

Investigations were performed at or near the workplace in each case. The meat cutters worked in the same general area as the meat wrappers. Each subject was administered a modified respiratory questionnaire which included questions on past medical history, cigarette smoking, previous occupational exposures, current respiratory status and adverse effects allegedly arising from work.

Pulmonary function testing was performed on each of the 52 workers at the beginning and end of the workshift. Thirty-seven subjects were tested using a waterless, high fidelity, precalibrated spirometer equipped with an air temperature probe (Ohio Medical Products, Madison, Wisconsin). In 15 subjects tests were performed using a precalibrated wedge-bellows spirometer (Vitalograph Medical Instrumentation, Kansas City, Missouri). Precalibration was made using a calibration syringe prior to field study. Forced vital capacity (FVC) and forced expiratory volume at one second (FEV_1) were measured in all subjects. Maximum expiratory flow rates at 50 and 25 percent of forced vital Capacity (V_{50} and V_{25}) were measured in 37 subjects (utilizing the waterless high fidelity spirometer). Maximum mid-expiratory flows (MMF) were determined for 15 subjects using the wedge-bellows spirometer. Pre- and post-shift complete blood and total eosinophil counts were performed on 15 subjects (7 meat wrappers and 8 meat cutters).

3. Results

a. Symptomatology Away from Work

Respiratory and nasal symptoms occurring away from work were common in both meat wrappers and cutters (see Table III). Two of the 8 meat cutters reported the diagnosis of bronchial asthma and were being treated by their physicians. One other meat cutter had symptoms suggestive of allergic rhinitis. Thus, 3 of 8 meat cutters had chronic symptoms which could have been related to underlying bronchial asthma or allergic rhinitis. This may, in part, explain the frequently reported symptoms away from work in meat cutters.

Approximately one-third of the meat wrappers had complaints of chronic cough and/or sputum or dyspnea on exertion. A physician's diagnosis of asthma or allergic rhinitis was noted in 17 percent (4 of 24) of the meat wrappers.

Table III: Symptoms Away from Work

Symptom	Percent Reporting Symptoms		
	Meat Wrappers (n = 24)	Meat Cutters (n = 8)	Controls (n = 20)
Cough and/or sputum	37	75	10
Dyspnea on exertion	32	50	0
Wheezing	14	37	5
Frequent chest illnesses	4	12	0
Asthma/Allergy history	17	25	0
Nasal symptoms	14	62	0

b. Symptomatology at Work

The symptoms occurring at work as reported by the subjects are shown in Table IV. The mean duration of meat wrapping performed during the day of the respective study was 5.8 hours (range 0.5 to 8.0 hours).

Table IV: Symptoms at Work

Symptom	Percent Reporting Symptoms			
	Meat Wrappers		Meat Cutters (n=8)	Controls (n=20)
	Total (n-24)	Symptomatic (n=16)		
Throat	45	62	37	0
Eye	36	50	37	15
Nasal	14	19	50	0
Cough	23	31	37	0
Chest Tightness	27	37	50	0
Wheezing	9	12	12	0
Shortness of Breath	36	50	50	0
Chest Pain	18	25	37	0
Smokers	50	44	25	20

Sixty-seven percent (16 of 24) of the meat wrappers had at least one symptom which they attributed to work. The most common complaints were related to throat, eye, and nasal symptoms. These included dry or sore throat; burning, itchy or tearing eyes; and stuffy or runny nose. The frequency of throat, eye, and nasal symptoms in the 16 symptomatic meat wrappers were 62, 50 and 19 percent respectively. Symptoms of cough, chest tightness, wheezing, shortness of breath, and chest pain occurred in 31, 37, 12, 50 and 25 percent of the symptomatic meat wrappers respectively. Twenty-five percent (4 of 14) of the symptomatic meat wrappers had a physician's diagnosis of bronchial asthma or allergic rhinitis. Forty-five percent (7 of 16) of the symptomatic meat wrappers were cigarette smokers. These individuals represent 58 percent (7 of 12) of all smoking meat wrappers. Forty-four percent (7 of 16) of the symptomatic meat wrappers had chronic complaints of cough and/or sputum, and 37 percent (6 of 16) reported chronic dyspnea on exertion.

The meat cutters did report a high frequency of symptoms at work. The group of meat cutters is small and of those reporting symptoms three were those individuals who were previously identified as having bronchial asthma and/or allergic rhinitis.

During the performance of these investigations, workers were carefully questioned regarding their opinion as to the cause of their work-related symptoms. In general, all workers expressed the opinion that emissions from the hot wire cutting of PVC film were responsible. A few workers felt that the refrigerated working environment or a pre-existing medical condition may be contributing to the symptoms experienced at work. At the time of the respective field visits, none of the workers were questioned specifically about the emissions from the thermal activation of price labels. Following the presentation of Andrasch, et al.[4], workers at each of the last three supermarkets studied were contacted by phone. Thirteen of the original 15 workers studies were questioned regarding emissions from the label machinery. All workers denied ever noticing any objectionable emissions. A few mentioned that a label would occassionally be scorched by the heating unit, but that their work stations were sufficiently far away from the labeling machinery that the occasional emissions (light smoke) did not present a noticeable problem.

c. Pulmonary Function Tests

Results of pulmonary function testing are shown in Table V. The mean pre-shift FVC (forced vital capacity) and FEV_1 (forced expiratory volume at one second) were within normal limits for all groups. No significant differences in pre- and post-shift pulmonary function test results were noted for any group.

Table V: Pulmonary Function Test Results, Pre- and Post-Shift (Mean ± 1 Standard Deviation)

	Meat Wrappers				Meat Cutters		Controls	
	Total (n=24)		Symptomatic (n=16)		(n-8)		(n=20)	
Tests	Pre-	Post-**	Pre-	Post-**	Pre-	Post-**	Pre-	Post-**
FVC	4.18±1.11 (n=24)	4.12±1.10 (n=24)	4.10±1.0 (n=16)	4.06±1.0 (n=16)	4.36±1.11 (n=8)	4.31±0.97 (n=8)	4.11±1.19 (n=20)	4.08±1.16 (n=20)
*% of Pred.	99±18		99±14		102±13		105±17	
FEV	3.29±0.88 (n=24)	3.25±0.87 (n=24)	3.34±0.86 (n=16)	3.29±0.87 (n-16)	3.48±0.84 (n=8)	3.40±0.83 (n=8)	3.34±1.06 (n=20)	3.29±1.04 (n=20)
*% of Pred.	101±20		103±18		105±20		110±17	
MMF	3.61±0.98 (n=7)	3.78±0.86 (n=7)	3.78±0.95 (n=6)	3.96±0.79 (n=6)	3.16±0.94 (n=8)	3.10±1.01 (n=8)	------	-----
$\dot{V}_{50}$	3.66±1.14 (n=17)	3.65±1.25 (n=17)	3.95±1.13 (n=10)	3.85±1.33 (n=10)	-------	------	4.41±1.76 (n=20)	4.34±1.68 (n=20)
$\dot{V}_{25}$	1.17±0.64 (n=17)	1.11±0.58 (n=17)	1.31±0.72 (n=10)	1.23±0.68 (n=10)	-------	------	1.53±0.76 (n=20)	1.48±0.90 (n=20)

FVC = forced vital capacity (liters)

FEV_1 = forced expiratory volume at one second (liters)

MMF = maximum mid-expiratory flow (liters/second)

$\dot{V}_{50}$ = maximum expiratory flow at 50 percent of forced vital capacity (liters/second)

$\dot{V}_{25}$ = maximum expiratory flow at 25 percent of forced vital capacity (liters/second)

* Predicted values for FVC and FEV_1 are taken from:

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** Post-shift test results were not significantly different from pre-shift values ($p > 0.05$)

d. Blood Analyses

The results of tests performed on blood drawn from 15 subjects (7 meat wrappers and 8 meat cutters) who were part of the latest health hazard evaluation investigations are presented in Table VI. Mean pre- and post-shift values for white blood cell count and total eosinophil count are presented with their respective (±) standard deviations.

Table VI: Results of Blood Analyses

	White Blood Cell Count		Total Eosinophil Count	
	Pre-Shift	Post-Shift	Pre-Shift	Post-Shift
Meat Wrappers	8081±1730	7944±2077	187±115	212±137
Meat Cutters	7268±2289	7953±1853	230±101	134±89

No significant pre- to post-shift increases in mean white blood cell or total eosinophil counts were observed.

e. Symptomatic Meat Wrapper

In the course of these most recent health hazard evaluation investigations, a particularly interesting case of an affected meat wrapper was encountered. Prior to employment as a meat wrapper, this person had no remarkable health problems and was a non-smoker. Information regarding this particular case will be presented because of the nature of the documented medical data available.

The subject was a 37 year-old woman who had worked as a meat wrapper for a total of 16 years. She described the development of a non-productive cough and exertional dyspnea occurring two years prior to our contact with her. She denied cigarette smoking and there was no previous history of wheezing, allergic rhinitis, serious chest illness, or family history of asthma or hay fever.

The subject stated that beginning in November, 1973, (5 months prior to our visit) following a change to a new wrapping film, that she began noticing shortness of breath, tightness of the chest; chest pain, cough, skin rash and swelling of the eyes. She related having experienced a similar problem 5 years before when the same film was put into use for a short time. According to the subject, the chest symptoms were not present during the first 1 to 1.5 hours of wrapping, but appeared later in the work day. The respiratory symptoms reportedly

became worse as the work week progressed and also occurred at home. During the weekend the symptoms were reported to disappear but would reappear and progressively worsen during the work week. She did consult a physician who treated her with corticosteriods. This relieved the facial swelling, but the shortness of breath persisted. Her respiratory symptoms reportedly disappeared following the discontinuation of the use of the new meat wrapping film.

Three weeks prior to our visit to her place of employment, the new wrap was again introduced and her symptoms returned. She described the new PVC wrap as being a "heavy wrap" as compared to the "light wrap" utilized previously. Several days before our visit, the subject sought medical treatment and was referred to an allergist for complete work-up. Skin tests were found to be negative for animal dander, feathers, cottonseed, pollen, mold, dust, tree, grass, ragweeds, and housedust. The physician noted wheezing which cleared during the period the patient was off work. Two days prior to our visit, the subject performed pulmonary function tests at a private hospital laboratory. At the time of this testing the subject was symptomatic and was still being treated with medication by her physician.

The NIOSH study team saw the subject on her first day back at work. The subject stated that her respiratory symptoms had recently completely cleared. The subject was observed while wrapping meat with the "heavy wrap" for six hours. During the shift she became symptomatic, complaining of dry sore throat, progressively worse cough, a feeling of tightness in the chest, and shortness of breath. Physical examinations performed at intervals through the shift were entirely negative including the absence of wheezing and rhonchi. There was no significant change in white blood cell count or total eosinophil count over the observed shift. Pulmonary function test results from studies performed by NIOSH at her place of employment and from studies performed two days before by the private hospital laboratory are shown in Table VII. No significant response in pulmonary function tests to three inhalations of isoproterenol given at the end of the workshift was observed. The pre-shift MMF was 71 percent of predicted but increased to 86 percent of predicted by the end of the day indicating a greater than 20 percent improvement (This was without isoproterenol inhalation).

Tests taken two days earlier, when the subject was still symptomatic and under treatment, showed reduced MMF, abnormal closing capacity, and an abnormal closing capacity/total lung capacity ratio. In addition, there was a small improvement in FEV_1 and significant improvement in MMF following administration of bronchidilators.

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Table VII: Pulmonary Function Test Results of a Symptomatic Meat Wrapper

Tests	Private Lab Test Results (2 days before NIOSH testing)	NIOSH Pulmonary Function Testing at Work	
		Pre-Shift	Post-Shift
FVC (% predicted)	95	91	91
FEV_1 (% predicted)	85	91	94
MMF (% predicted)	57	71	86
% Improvement Following Bronchidilator			
FEV_1	9.3	4.6	
MMF	43	0	
Other Parameters (% Pred.)			
Peak Expiratory Flow Rate	93		
V_{50}	59		
CC/TLC	131		
CC	128		
RV	96		
TLC	97		

CC = Closing Capacity
RV = Residual Volume
TLC= Total Lung Capacity

VII. DISCUSSION OF EVALUATION FINDINGS

The present evaluation of available data demonstrates that no acute changes in pulmonary function testing occurred in 24 meat wrappers exposed to air contaminants in the meat wrapping environment while at work. Additionally, in a group of 7 meat wrappers and 8 meat cutters, no significant increase in post-shift white blood cell and total eosinophil count occurred. The meat cutters were noted, in fact, to have a fall in total eosinophil count.

Approximately one-third of the 24 meat wrappers studied had chronic complaints of cough, sputum and dyspnea on exertion. These data are consistent with those of Falk and Portnoy[34] and suggest that chronic exposure to air contaminants in the meat wrapping environment may lead to chronic respiratory complaints.

In contrast to the report of Andrasch et al[4], no apparent cause-effect relationship can be made in this study between emissions from price label activation and respiratory complaints. Thirteen of the 15 most recently

studied workers denied noticeable effects from price label emissions. Recently, however, a state health agency reported to NIOSH a possible case of a meat wrapper with symptoms related to the price labeling process. This case has not been followed up by NIOSH[35]

No relationship was observed between cigarette smoking in meat wrappers and the likelihood of developing respiratory symptoms. Twice as many meat wrappers as controls were cigarette smokers (50 versus 20 percent). Falk and Portnoy[34], in a larger study, concluded that meat wrappers who smoke were at greater risk of developing respiratory symptoms than non-smoking meat wrappers.

Several of the workers in this study did relate symptoms to the use of a specific meat wrap. Due to the small numbers of workers available for study, it was not possible to statistically confirm this observation. Falk and Portnoy[34] could not relate a greater prevalence of respiratory complaints to a specific meat wrap.

The designation "meat wrappers asthma" is a misnomer. Classic bronchial asthma is characterized by wheezing, eosinophilia, and reduced FEV_1 and MMF.[36] Symptomatic meat wrappers in these present investigations did not demonstrate these findings. Those workers with diagnosed bronchial asthma, however, seemed more likely to complain of wheezing and cough at work. Characteristically, individuals with bronchial asthma have hyper-reactive airways which develop bronchoconstriction following exposure to many non-specific irritants.[36,37] Vagally mediated subepithelial cough-reflex receptors, as well as, other mechanisms may be important in this regard.[38,39,40] As previously discussed, emissions from hot wire cutting of PVC film and from thermal activation of price labels contain substances known for their irritative effects (e.g. hydrogen chloride, etc.).

The report of Andrasch et al[4] is difficult to evaluate since the challenge experiments with price label emissions were not comparable to actual working conditions and, in general, constituted exaggerated exposures. Although bronchospasm and reduced FEV_1 were demonstrated in selected patients, it is not clear from the report whether individuals had preexisting bronchial asthma. In addition, it is not apparent whether the effects noted were the result of actual sensitization or a consequence of direct irritation.

The detailed pulmonary function studies (private laboratory and NIOSH) performed on our most symptomatic meat wrapper suggest possible involvement of the small airways of the lung. Normal FEV_1 and FVC, but reduced MMF and V_{50}, and elevated CC and CC/TLC (demonstrated 2 days prior to this NIOSH study) are findings reported to indicate small airways disease.[41,42,43] Patients with bronchial asthma may show evidence of persistent abnormalities of small airways even during a period of remission.[44,45] Complaints of chest tightness and dyspnea could be manifestations of this process. Interestingly, asymptomatic cigarette smokers have also been reported to show normal spirometric testing but have pathologic and physiologic evidence of small airways disease.[46,47] Macklem[47] has postulated that chronic obstructive pulmonary disease (e.g. emphysema and/or chronic bronchitis)

in its beginning stage is manifested by involvement of the small airways (2 millimeters and less in diameter). At this stage the usual spirometric tests such as FEV_1 or FVC are normal. It is only after many years that the individual becomes symptomatic and develops abnormalities on routine pulmonary function testing (FEV_1 and FVC). This theoretical mechanism may be pertinent if air contaminants in the meat wrapping environment are capable of causing small airways disease. Absorption of irritative substances on small aerosol particles (several micrometers in diameter) contained in the emissions from film hot wire cutting and label activation may facilitate the transport of the irritants into the airways.

Fifteen to 20 years and more of exposure to contaminants in the meat wrapping environment may be necessary before changes occur in the pulmonary function tests. It is conceivable that in the present study, the pulmonary function testing equipment used was not of sufficient sensitivity to detect changes in small airways. It must be noted, however, that in the portion of the workers studied, no significant changes in pre- and post-shift MMF, V_{50} and V_{25} were observed when these tests were performed. Changes in these tests have been reported as indicative of small airways disease[41,42].

Whether there is an additive effect on small airways of cigarette smoking and exposure to the meat wrapping environment is not known, but Falk and Portnoy[34] have reported more symptoms in meat wrappers who smoked.

Measurements for vinyl chloride monomer in the emissions from hot wire cutting of PVC film were negative. Methods utilized were sensitive to approximately 0.2 ppm. These measurements indicate that meat department employees have no demonstrable exposure to vinyl chloride from the hot wire cutting of PVC meat wrapping film. These findings are consistent with the extremely low residual monomer levels reported to be present in the finished film by film manufacturers and the Food and Drug Administration.

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