

**WELDING FUMES AS A CAUSE OF IMPAIRED  
LUNG FUNCTION IN SHIPYARD WORKERS**

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# ABBREVIATIONS

## Abbreviations used in the text

abbr	index	unit
A	age	years
ACB <sub>1</sub>	interaction term age * CB <sub>1</sub>	years
ACB <sub>2</sub>	interaction term age * CB <sub>2</sub>	years
ACT	dummy variable for the activity score (1=inactive, 0=active)	1,0
ACTCB <sub>2</sub>	interaction term ACT * CB <sub>2</sub>	years
ACTW <sub>1</sub>	interaction term ACT * W <sub>1</sub>	years
ACTW <sub>2</sub>	interaction term ACT * W <sub>2</sub>	years
ACTWCB	interaction term ACT * WCB	-
AW <sub>1</sub>	interaction term age * W <sub>1</sub>	years
AW <sub>2</sub>	interaction term age * W <sub>2</sub>	years
AWCB	interaction term age * WCB	years
CB	ever a caulker/burner	-
CB <sub>1</sub>	index of exposure of the caulker/burners in the confined and semiconfined spaces	years
CB <sub>2</sub>	index of exposure of the caulker/burners on the ship	years
CC	closing capacity	ml
CC%	(closing capacity/total lung capacity)*100	%
CV	closing volume	ml
CV%	(closing volume/vital capacity)*100	%

ERV	expiratory reserve volume	l
EVC	expiratory vital capacity	l
EXP NSm	exposed non-smoker	-
EXP Sm	exposed smoker	-
$f_{C45}$	cardiac frequency at oxygen uptake of 45 mmols	beat min <sup>-1</sup>
FEV	forced expiratory volume	l
FEV <sub>1</sub>	forced expiratory volume in one second	l
FEV <sub>1</sub> %	(FEV <sub>1</sub> /vital capacity) * 100	%
FFM	fat free mass	Kg
FVC	forced vital capacity	l
He	helium	-
HT	Height	-
IGW	inert gas welding	
K	Keilven (unit of temperature measurement)	°K
K <sub>CO</sub>	transfer coefficient (T <sub>lCO</sub> /VA)	mmol min <sup>-1</sup> KPa <sup>-1</sup> l <sup>-1</sup>
MEFV	maximum expiratory flow volume curve	-
MMAW	manual metal arc welding	-
MAW	metal arc welding	-
N <sub>2</sub> Diff	nitrogen difference index	N <sub>2</sub> %
$\dot{n}CO_2$	carbon dioxide output	mmol min <sup>-1</sup>
$\dot{n}O_2$	oxygen uptake	mmol min <sup>-1</sup>
$\dot{n}O_{2max}$	maximum oxygen uptake	mmol min <sup>-1</sup>
NSm	nonsmoker	-
OAGW	oxyacetylene gas welding	-
p	level of significance	%

PEFR	peak expiratory flow rate	$l\ s^{-1}$
$\dot{Q}$	perfusion	$ml\ min^{-1}$
r	correlation coefficient	
R	respiratory exchange ratio	-
R <sub>1.0</sub>	R at $\dot{n}O_2$ of 45 mmol	-
RV	residual volume	l
RV%	(residual volume/total lung capacity)*100	%
SCB <sub>1</sub>	interaction term SMOKING * CB <sub>1</sub>	years
SCB <sub>2</sub>	interaction term SMOKING * CB <sub>2</sub>	years
SLIII	slope of phase III of the closing volume curve	$N_2\% \ l^{-1}$
Sm	dummy variable for smoking	1,0
SW <sub>1</sub>	interaction term SMOKING * W <sub>1</sub>	years
SW <sub>2</sub>	interaction term SMOKING * W <sub>2</sub>	years
SWCB	interaction term SMOKING * WCB	-
TGW	Tungustin gas welding	-
TLC	total lung capacity	l
T <sub>lco</sub>	transfer factor for carbon monoxide for the lung	$mmol\ min^{-1}\ KPa^{-1}$
TLV	threshold limit value	$mg\ m^{-3}$
W	ever a welder	1,0
W <sub>1</sub>	index of exposure of the welders in confined and semiconfined spaces	years
W <sub>2</sub>	index of exposure of the welders on the ship	years
WCB	ever a welder or a caulker/burner	



	(index of exposure)	1,0
WCB <sub>1</sub>	index of exposure of the very young workers in confined and semiconfined spaces (target and control workers)	years
WT	(Weight/height <sup>2</sup> )	kg HT <sup>-2</sup>
$\dot{V}$	ventilation	l min <sup>-1</sup>
V <sub>A</sub>	alveolar volume	l
VC	vital capacity	l
$\dot{V}_{e45}$	exercise ventilation at 45 mmols of $\dot{n}O_2$	l min <sup>-1</sup>
$\dot{V}_{max25}$	flow rate when 25% of VC remains in the lung	l s <sup>-1</sup>
$\dot{V}_{max50}$	flow rate when 50% of the VC remains in the lung	l s <sup>-1</sup>
$\dot{V}/\dot{Q}$	ventilation and perfusion ratio	
V <sub>T30</sub>	tidal volume at exercise ventilation of 30 litre per minute	l

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## ABSTRACT

Welders and caulker/burners are usually exposed to heavy clouds of fumes. These fumes contain some gases and particulates which are potentially harmful. There have been several surveys of the health of welders since 1936. These studies demonstrated an association between exposure to fumes and respiratory symptoms. However, no long term effect of fumes on respiratory function has been established. The gases and particulates in the fumes from welding and caulking/burning are very small in size and on this account are capable of reaching the small airways in the periphery of the lung. If welding fumes are harmful to the lung small airway dysfunction should be present in the younger workers. In view of this, in the present study relatively young men were examined and tests specific to small airway function were used.

The subjects for this study were male Caucasian workers aged 18 - 47 years, mean age 31.5 years. The target sample comprised 181 welders and 151 caulker/burners and the control sample comprised 181 other tradesmen. The two samples were selected from the same yard. Anthropometry, respiratory symptom and occupational questionnaires, cough frequency questions, forced spirometry, single breath nitrogen test, transfer factor, and an exercise test were performed. The results were submitted to multiple regression analysis. The target workers were compared with the control subjects. Comparisons were

also made within the groups of welders and caulker/burners separately. A subsample of the whole selected subjects (age 20 - 25 years) was examined separately to investigate the early effects of fumes on the lung of exposed young workers.

In the whole population, compared with the controls, the welders and caulker/burners were found to have significantly higher prevalence of wheeze symptom, and fume exposure interacted with age to increase breathlessness on exertion in the older subjects. In the very young workers (age 20- 25 years) chronic cough and phlegm (chronic bronchitis, MRC) was significantly higher among the target workers compared with the controls. In the group of welders smoking interacted with fumes to increase wheeze in the workers who smoked while increased fume exposure in the older subjects was associated with increased breathlessness on exertion.

In the whole population the mean values of closing volume (CV%) and closing capacity (CC%) were significantly higher in the target workers compared with the controls. This effect was independent of age and smoking which were also important. In the subsample of the very young workers similar effects were found, and in addition the mean value of the residual volume (RV%) in the target group was significantly higher than that in the control group. In the whole population fume exposure enhanced the deterioration with age in forced expiratory volume ( $FEV_1$ ) and forced vital capacity (FVC) significantly more in the target workers than in the control subjects. These indices were not affected by exposure in the very young workers.

Amongst the group of welders, increased levels of exposure to fumes (duration and intensity) enhanced the deterioration with age in CV%, CC%, breathlessness on exertion and  $T_{lCO}$ . High exposure was also associated with decreased  $K_{CO}$  in the workers who smoked.

Amongst the caulker/burners, increased levels of exposure to fumes enhanced the deterioration with age in CV%, CC%, slope of phase III (SLIII), nitrogen difference index ( $N_2$  Diff) and RV%.

The findings of the present study are evidence that high levels of fumes from welding and burning or other factors related to these trades, cause long term impairment of lung function of shipyard welders and caulker/burners.

## INTRODUCTION

### OBJECTIVES AND STRATEGY

#### GENERAL OBJECTIVE

To investigate the role of fumes from welding (and related activities) as a cause of impaired lung function in shipyard workers.

#### SPECIFIC OBJECTIVES

To answer the following questions:

1. What is the prevalence of respiratory abnormality among shipyard workers ?
2. Is there an association between exposure to welding and burning fumes and:
  - a. respiratory symptoms and chest illnesses
  - b. impaired respiratory function
  - c. impaired performance during submaximal exercise ?
3. Are the abnormalities present in young shipyard workers exposed only to present day conditions or the past ?



## STRATEGY

Answers to these questions require background knowledge of chronic obstructive lung disease, of the working environment of the shipyard workers, of the constituents and previously reported effects of welding fumes, and of the physiological tests used to assess the welders and burners. These topics are considered in chapter 1 to 3. Chapter 4 describes the subjects and methods of the present study, chapters 5 and 6 present the results, chapter 7 includes discussion of the results, this is followed by the conclusion and summary chapters.

CHAPTER 1CHRONIC OBSTRUCTIVE LUNG DISEASE

The community problem of diseases of the respiratory tract has for centuries been dominated by mortality from pneumonia and pulmonary tuberculosis. The introduction of effective chemotherapy, first for pneumonia and then for tuberculosis, has reduced the importance of these conditions. Industrialized countries which have controlled these diseases have become aware of the problem of death from respiratory failure, and of the existence in many persons of chronic disease of the airways and of the lung parenchyma (WHO 1960). Consequently a number of epidemiological surveys on the prevalence of chronic bronchitis have been carried out in different countries especially in the United Kingdom and the United States of America (Higgins et al 1956; Fletcher et al 1959; College of General Practitioners 1961; Brinkman and Coates 1962; Ferris & Anderson 1962; Goldsmith et al 1962; Deane et al 1965; Holland et al 1965). Considerable new knowledge has been gained on the prevalence and severity of the chronic obstructive lung disease and on the underlying aetiology.

## 1.1 DEFINITION OF CHRONIC BRONCHITIS

Since the late 1950s and early 1960s several reports have been published on the definition of chronic obstructive lung diseases (Ciba Guest Symposium, 1959; American Thoracic Society, 1962). However, the definition and classification of chronic bronchitis by the British Medical Research Council (1965) is the one widely accepted and in use for clinical and epidemiological studies. Three forms of the disease were defined by the MRC:

### 1.1.1 Simple chronic bronchitis

This form is defined as chronic or recurrent increase in the volume of mucoid bronchial secretion sufficient to cause expectoration.

### 1.1.2 Chronic or recurrent mucopurulent bronchitis

This form of the disease is defined as chronic or recurrent mucopurulent bronchitis in which the sputum is increased persistently (for a part of every day for a year or more) or intermittently (for at least two periods of not less than a week over three consecutive years). Localized lung diseases must be excluded as the predominant cause of these symptoms before mucopurulent bronchitis is diagnosed.

### 1.1.3 Chronic obstructive bronchitis

This form of the disease is defined as chronic bronchitis in which there is persistent, widespread narrowing of the intrapulmonary airways, at least on expiration, causing increased resistance to air flow.

The term "chronic bronchitis" without qualification may be used to describe any of these forms of the disease. The definitions are based entirely on the clinical and functional manifestations of the disease.

### 1.2 DEFINITION OF EMPHYSEMA

By contrast emphysema was defined in anatomic terms (American Thoracic Society, 1962) as an alteration of lung architecture characterized by abnormal enlargement of air spaces with accompanying destruction of alveolar walls involving the terminal nonrespiratory bronchioles and beyond.

### 1.3 EPIDEMIOLOGY OF CHRONIC OBSTRUCTIVE LUNG DISEASE

In recent years, several studies have estimated the prevalence of chronic airway obstruction in widely separated areas of the world. In the past two decades, three advances have made it possible to gain even more information from epidemiologic studies of chronic obstructive lung disease:



1. the development of a well tested, broadly applicable, standard respiratory questionnaire (BMRC, 1960),
2. the availability of simple devices and techniques for objective tests of pulmonary function,
3. the formulation and wide acceptance of definitions and classifications of these diseases suitable for use in epidemiologic studies (MRC, 1965; American Thoracic Society, 1962).

These methodologic improvements permit more accurate comparison of epidemiologic studies of separate population groups by different investigators (Holland et al, 1965; Boudik et al, 1970; Hultti et al, 1977).

#### 1.3.1 Mortality statistics

There are great international variations in the mortality rates for bronchitis. In 1970, the male specific death rate for ages 55-64 in England and Wales was 154.1, in USA it was 63.0, in France it was 19.8 and in Egypt the rate was 257.2 per 100,000 deaths (WHO, 1970). The high rates in Britain and in Egypt are obvious. Although some of the differences may reflect differences in the diagnostic habit, important factors in the past have been the high tobacco consumption and the high atmospheric pollution in Britain (Royal College of Physicians, 1970), and the rapid industrialization with increased air pollution and the high consumption of tobacco in Egypt (Megahed,



1966). These factors have now decreased, which is being reflected in a decreased mortality; in 1981 the age specific death rate per 100,000 in Britain became 60.1 and in Egypt, in 1979, it became 144.9 (WHO, 1983).

### 1.3.2 Morbidity statistics

Extensive population surveys have been carried out in different parts of the world in an attempt to determine the prevalence of chronic obstructive lung disease. The estimated prevalence in men aged 45 - 65 years is 10 to 40% (Oswald et al, 1953; College of General Practitioners, 1961; Ferris & Anderson, 1962; Colley & Holland, 1967; Boudik et al, 1970; Muller et al, 1971; Gulsvik, 1979).

The following are important determinant factors in the occurrence of chronic obstructive lung disease:

1. Age and sex (College of General Practitioners, 1961; Fletcher et al, 1959; Ferris and Anderson, 1962; Crofton & Crofton, 1963; Muller et al, 1971; Gulsvik, 1979; WHO, 1983).
2. Smoking (College of General Practitioners, 1961; Ferris & Anderson, 1962; Brinkman & Coates, 1963; Holland et al, 1965; Cederlof et al, 1966; Boudik et al, 1970; Doll & Peto, 1976; Huhti et al, 1977; Bosse et al, 1981).
3. Socioeconomic status (College of General Practitioners, 1961; Colley & Holland, 1967; Boudik et al, 1970)

4. Occupation ( Higgins et al, 1956; Stuart-Harri & Hanley, 1957; Colley & Holland, 1967; Enterline, 1967; Pemberton, 1968; Hunter, 1969; Cochrane et al, 1979; Anderson et al, 1979; Glover et al, 1980; Chan-Yeung et al, 1980; Dosman et al, 1980; Jain & Patrick, 1981; Rom et al, 1981; Beck et al, 1982; Kauffmann et al, 1982; Hanke et al, 1984)
5. Familial factor (Larson & Barman, 1965; Hole & Wasserman, 1965; Cohen et al, 1975; Higgins & Keller, 1975; Kuepper et al, 1977; Kawakami et al, 1981).
6. Environmental air pollution (Daly, 1959; Reid, 1964; Oswald et al, 1953; College of General Practitioners, 1961; Oshima et al, 1964; Holland et al, 1965; Raj, 1984).

#### 1.4 CLINICAL MANIFESTATIONS

Evidence exists that substantial lung pathology may be present in patients complaining of no respiratory symptoms during life (Petty et al, 1965; Michell et al, 1968). Thus chronic obstructive lung disease remains asymptomatic or nearly so for many years before it is detected on the basis of early established symptom complex and by physiologic testing.

In the very early stages of chronic bronchitis and emphysema when pathologic and functional abnormalities are confined to the small airways, no symptoms or only a dry cigarette cough may be present. Later in bronchitis, cough gradually becomes more continuous; it then

occurs during the day as well as in the morning and may keep the subject awake at night. Cough becomes productive and with infection sputum becomes green or yellow and increases in volume . At first these respiratory infections may be mild, but later it may last for longer periods and the subject may have to be off work for many weeks during the winter. Later in middle age, the patient experiences wheeze and dyspnoea. Still later, the patient is liable to develop right-sided heart disease (cor pulmonale); the dyspnoea becomes more severe and may be accompanied by marked wheeze. In the late stages of emphysema, the major disability is breathlessness with little or no cough, sputum and wheeze unless acute or chronic bronchitis is present (Guenter & Welch, 1982).

In the early stages of the disease the general condition may be good. In the symptomatic stage of chronic bronchitis, cyanosis may or may not be evident depending on the severity of the hypoxemia, the cardiac output and the haemoglobin content. Chronic bronchitis with cyanosis and peripheral oedema due to right heart failure have been referred to as "blue bloaters" (Dornhorst, 1955) and chronic obstructive lung disease "Type B" (Burrows et al, 1964). Clubbing of the fingers is usually absent.

The patient with advanced emphysema and little bronchitis is, on the other hand, generally pink, but complains of severe respiratory distress and is referred to as "Pink Puffer" (Dornhorst, 1955) and chronic obstructive lung disease "Type A" (Burrows et al, 1964). He frequently looks emaciated due to weight loss.

Chronic obstructive lung disease is characterized by a reduction



of airflow through the conducting airways and mismatching of ventilation/perfusion in the lung. These physiological abnormalities result from anatomical thickening of bronchial walls (chronic bronchitis), or airway collapse from loss of radial traction of elastic tissues (emphysema).

In established but uncomplicated chronic bronchitis, there is evidence of lung overinflation with an enlarged residual volume and functional residual capacity, the total lung capacity being either normal or slightly increased. The vital capacity is either normal or low, depending on the relative size of the residual volume.

In emphysema, as a result of chronic hyperinflation of the lung, the total lung capacity is often greater than normal. The striking features are increased residual volume and functional residual capacity. The vital capacity may be nearly normal in size or it may be reduced because of the hyperinflation and increased residual volume.

In established cases of chronic bronchitis and emphysema, there is marked reduction in forced expiratory volume over time ( $FEV_1$ ), in peak expiratory flow (PEF), in forced expiratory flow over the middle portion of expired vital capacity ( $FEF_{25-75}$ ), and in flow at low lung volumes ( $\dot{V}_{max50}$  ;  $\dot{V}_{max25}$ ).

In emphysema the static compliance of the lungs is greater than normal due to destruction of the elastic tissue.

Advanced cases of emphysema and chronic bronchitis are characterized by increased physiological dead space due to gross mismatching of ventilation and perfusion. Slope of alveolar plateau

and  $N_2$  index of the single breath nitrogen test are usually abnormally high.

The transfer factor (diffusion capacity) of the lung is reduced particularly in emphysema due to mismatching of  $\dot{V}/\dot{Q}$  and destruction of alveolar wall and pulmonary capillary bed.

#### 1.5 EARLY DIAGNOSIS OF CHRONIC OBSTRUCTIVE LUNG DISEASE

Disease which leads to chronic obstruction is one of the most important and frustrating health problems in different parts of the world (WHO, 1983). Its treatment is particularly frustrating because by the time the patient seeks medical help because of shortness of breath or because a screening test has revealed abnormal pulmonary function, the disease is generally incurable and has bad prognosis (Burrows & Earle, 1969; Petty et al, 1976). In earlier disease, however, the cessation of smoking and treatment with bronchodilator drugs in patients with mild disease was associated with symptomatic improvement (Baker et al, 1970), and improvement of small airway function (McFadden & Linden, 1972).

Several studies have demonstrated that the major site of obstruction in chronic obstructive lung disease is in peripheral airways of internal diameter 2mm or less (Hogg et al, 1968; Anthonisen et al, 1968; Scott & Steiner, 1975; Amaducci et al, 1977; Gelb et al, 1981; Fairshier & Wilson, 1981).

It has been established that conventional tests of lung mechanics are insensitive to changes in small airways (Tai & Read, 1967; Levine et



al, 1970; Sobol et al, 1973; Macklem, 1972), because the resistance of airways smaller than 2mm inside diameter is normally a small component ( about 20% ) of the total pulmonary resistance (Macklem & Mead, 1967; Hogg et al, 1968; Macklem et al, 1969), and considerable obstruction may be present in them with little effect on pulmonary resistance (Brown et al, 1969). Therefore, disease of peripheral airways with serious clinical symptoms may appear as a "silent zone" (Mead, 1970) in routine pulmonary function tests (Macklem, 1972; McCarthy & Milic Emili, 1973; Gelb et al, 1973; McFadden et al, 1974; Marazzini et al, 1977; Cosio et al, 1978)

The frequent occurrence of chronic bronchitis and emphysema together is well known (Emerson, 1981). Several studies have demonstrated the significant association between obstruction in peripheral airways and centrilobular emphysema (Mclean, 1958; Anderson & Foraker, 1962; Cosio et al, 1980; Petty et al, 1984). They suggested that obstruction in the peripheral airways might be the link between chronic bronchitis and emphysema. If this suggestion is true, one way to predict the progression from chronic bronchitis to emphysema might be to diagnose peripheral airway disease before it has become extensive and while it is still curable.

Since advances in prevention and treatment of chronic obstructive lung disease may depend on early diagnosis, it is important to use simple noninvasive sensitive tests to detect small airway obstruction.

Several tests have been introduced which are sensitive and can detect early dysfunction of small airways. These are: frequency dependence

of compliance (Woolcock et al, 1969; Ingram & O'Cain, 1971), closing volume (Buist & Ross, 1973; McCarthy et al, 1973; McCarthy et al, 1972; Solliday et al, 1973; Lapp et al, 1976), slope of alveolar plateau (Buist & Ross, 1973 ; Oxhoj et al, 1977) and maximal expiratory flow volume curves (Gelb & Macanally, 1973; Zamel et al, 1973; Malo & LeBlanc, 1975; Guyatt et al, 1975).

Whereas frequency dependence of compliance is difficult and needs considerable subject co-operation, the single breath nitrogen test and flow volume curves are simple and easy for most subjects to do and can be used for mass screening with mobile equipment.

Recently several studies have demonstrated that pathological changes in the small airways are related to abnormalities of the pulmonary function tests designed to detect small airway diseases (Cosio et al, 1978; Cosio et al, 1980; Petty et al, 1980; Berend et al, 1981; Nemery et al, 1981; Wright et al, 1984).

It is clear that these tests are of great potential for use in epidemiological surveys and screening programmes to identify subjects at high risk of developing chronic obstructive lung disease or those in the early stages of the disease where it is still amenable to treatment.

## CHAPTER 2

### ARC WELDING AND THE RESPIRATORY SYSTEM

Arc welding is an important and expanding technique used in many branches of the engineering and shipbuilding industries. The term arc welding applies to a large group of welding processes that use an electric arc as the source of heat to melt and join metals.

#### 2.1 EQUIPMENT FOR WELDING:

##### 2.1.1 The Welding Arc

The electric arc is the heat source for a variety of the most important welding processes, because it is an easily produced high intensity source. It is an electric discharge between two electrodes which takes place through ionised gas known as the plasma. With a high-current arc at atmospheric pressure, extremely high temperatures, from 5000 to 50000°K, can exist in the axis of the arc. This heat melts the base metal in the immediate area, the electrode metal and the electrode covering or flux; together they produce the alloy which on cooling forms the weld (Andrews, 1978).

### 2.1.2 The electrode

The electrode is a complex metallurgical product consisting of a core wire or rod on to which a compounded mineral and alloy covering is extruded which is both refractory and insulating. It serves to carry the current and sustain the electric arc between its tip and the base metal.

Electrodes are of two types according to whether or not they are melted. If it is not melted away in the process of welding, the electrode is said to be non-consumable (e.g Carbon or Tungsten). When this is used, a separate rod or wire can be used to supply filler metal if needed. The electrode when melted is said to be consumable, and because the detached droplets form part of the weld, the material of the electrode is usually similar to that of the base metal. Any arc-welding system in which the electrode is melted off to become part of the weld is described as " metal arc welding ".

There are many types of electrodes. The main differences between them are in the flux coating. Three main groups of electrodes are used for mild steels in most fabrication:

1. Rutile electrodes have a high proportion of titanium oxide in the flux coating.
2. Basic electrodes have a coating which contains calcium and other carbonates and fluorspar.
3. Cellulose electrodes have a high proportion of combustible



organic materials in their coating.

Mild steel wires are the most common type used (Gray & Spence, 1982). The electrode is clamped in an electrode holder which is joined to the power source by a cable.

### 2.1.3 The coating or flux

The covering on an electrode has several advantages: it stabilizes the arc, provides a gas and a flux layer to protect the arc and metal from atmospheric contamination, controls weld-metal reactions and permits alloying elements to be added to the weld metal.

Of the many ingredients in the covering of electrodes for welding mild steel, the most important are cellulose, titanium oxides- usually in the natural form of rutile-, mineral silicates, iron oxides, basic carbonates such as limestone, fluorspar, ferrosilicon, sodium silicate and iron powder (Flintham, 1966).

## 2.2 WELDING PROCESSES

The following are the most common welding processes in the shipbuilding industry:

### 2.2.1 Manual metal arc welding

Manual metal arc welding is the most used welding process in shipbuilding and repair industries because it can be used in all welding positions with mild alloy, heat and corrosion- resisting



steels, and with some copper and nickel base alloys (Flintham, 1954; Phillip, 1980).

In this process, an arc is struck between the electrode and the work piece which completes the return circuit to the electricity supply. The arc melts both the electrode and the immediate superficial area of the work piece. Electromagnetic forces created in the arc help to throw drops of the molten electrode on to the molten area of the work piece where the two metals fuse to form the weld pool. The flux contributes to the content of the weld by direct addition (Andrews, 1982).

#### 2.2.2 Gas shielded welding

This process is used for welding aluminium, titanium, and nickel alloys; also it is used with carbon and carbon manganese steels.

In this process of welding, a bare wire electrode is used and a shielding gas is fed around the arc weld pool. This gas prevents contamination of the electrode and weld pool by air, and provides a local atmosphere giving a stable arc. The process is known as metal inert gas (MIG) when argon or helium gases are used. If tungsten electrode is used the process is called tungsten inert gas (TIG). When carbon dioxide or a mixture of argon and carbon dioxide are used the process is then called metal active gas welding (MAG) (Gray & Spence, 1982).

### 2.2.3 Submerged arc welding

In this welding process a bare wire is used and the flux is added in the form of powder which covers completely the weld pool and end of the electrode wire. The arc is completely enclosed, and high current can be used which gives the weld pool a deep penetration into the base metal and so thicker sections can be welded (Andrews, 1978).

### 2.2.4 Oxyfuel gas welding

Oxyfuel gas welding is an inclusive term used to describe any welding process that uses a fuel gas combined with oxygen to produce a flame. Acetylene is usually used as the fuel for oxyfuel gas welding.

This process is best applied on thin plates to produce welds in metal sheets and thin-walled and small diameter piping (Ross, 1954).

## 2.3 SHIPBUILDING STEEL

Mild steel is the main steel used in shipbuilding. It has certain features which make it suitable for shipbuilding such as: reasonable cost, easily welded with simple techniques and equipment, chemical composition suitable for flame cutting without hardening, ductility, and resistance to corrosion (Walton, 1964).

### 2.3.1 Chemical composition

The chemical composition of mild steel used in shipbuilding differs according to its grade. It consists mainly of iron, carbon, manganese, silica, sulphur, phosphorus, nickel, and chromium.

Iron constitutes about 98 per cent of mild steel, and the odd 2 per cent of other materials gives it strength and hardness.

Development in steel production and alloying techniques have resulted in the availability of higher strength steels for ship-construction. These higher tensile strength (HTS) steels, have adequate ductility and weldability, in addition to their increased strength. The increased strength results from the addition of alloying elements such as vanadium, chromium, nickel, and niobium (Stern, 1980).

### 2.3.2 Steel preparation

Preparation of steel for hull construction usually takes place in the preparation shops where plates and sections received from the steel mills are converted into the correct shapes and sizes, ready for assembly. The sequence of events is as follows:

#### 1- Levelling or plate straightening

Steel plates arriving from steel mills are often slightly distorted, and have to be straightened. This is achieved by using a plate rolls machine.

#### 2- Shot blasting and priming

Steel plates and sections as delivered to the shipyard are usually

covered by a layer of mill scales and rust. This must be removed by intensive bombardment of both sides with abrasive particles (shot) to provide a rust-free clean surface for subsequent painting. The clean steel is coated with a shop primer immediately after cleaning to avoid re-rusting.

### 3- Cutting and shaping

Various machines and equipment are used for cutting and shaping of the rectangular steel plates which form the subassemblies, assemblies and units.

#### 2.3.3 Steel fabrication

After preparation, the finished plates are welded together to form units. This process is known as fabrication. Generally, the fabrication process is split up into two parts:

1. One part is concerned with small fabricated units called subassemblies.
2. The second part is concerned with large units called assemblies or blocks.

Subassembly is carried out in a workshop which is often an extension of the preparation shop to enable prepared materials to be transported quickly and easily to it. This shop is usually equipped with handling equipment, e.g cranes.

The main fabrication shop is a larger place; often it is the largest single place in the shipyard.



The various units which have been produced in the fabrication shops are welded together either on a slipway or in a building dock to form the complete ship (Acker & Bartlett, 1980).

**Fitting-out areas:**

The main fitting-out shops necessary in most shipyards are: a pipe manufacturing shop, a joiner's shop, a fitting shop, a blacksmith's shop and a rigger shop.

**2.4 WORKING ENVIRONMENT OF WELDERS AND CAULKER/BURNERS**

Welding and burning are an essential part of shipbuilding and repairing. The welders join metal plates using different welding methods while the caulker/burners clean the plates, cut it using burning methods and prepare the edges of the metal plate by buffing. Both the welders and burners work very close to each other. During ship construction welders and burners are exposed to a wide range of working conditions. These conditions vary from totally enclosed during fabrication of large assemblies, to welding performed on the ground in the open air. Generally, working conditions can be classified into:

1. Confined which occurs when work is performed inside compartments in the shed or below decks on the ship.
2. Semiconfined which occurs when work is performed inside compartments which has at least one side open.
3. Open which occurs during fabrication of subassemblies in the open



air.

Welding and related processes produce heavy clouds of fumes which contaminate the workroom air of welders and caulker/burners. These fumes contain various metals and gases. The composition of fumes depends on the elements present in the flux, in the base metal and its coating and in the welding rod. Additional factors are the shielding gas, and any combination of atmospheric constituents due to heat generated during the process of welding (Steel, 1964; Oliver & Molyneux, 1975; Akbarkhanzadeh, 1979; Evans et al, 1979; McKelvie, 1981; Grey & Hewitt, 1982).

Many environmental studies of workroom air pollution of welders have identified several components in welding fumes. Among the identified particulate components are: iron, zinc, copper, manganese, titanium, vanadium, niobium, cadmium, magnesium, mercury, lead, chromium, nickel, and flouride.

Among the identified gases are: ozone, oxides of nitrogen, carbon monoxide, sulphur dioxide, and phosgene (Challen et al, 1958; De-Kretser et al, 1964; Steel & Sanderson, 1966; Steel, 1968; Morley & Silk, 1970; Pantucek, 1975; Oxhoj et al, 1979; Cecchetti, 1985).

Ozone is produced mainly in shielded gas welding (Roe, 1959; Lunau, 1967) while oxides of nitrogen are produced mainly with metal arc and oxyacetylene welding (Roe, 1959; Morley & Silk, 1970). Phosgene can be produced by welding metals degreased with trichlorethylene or a chemically- related solvent (Doig & Challen, 1964). Carbon monoxide is produced in greater concentrations with CO<sub>2</sub> arc welding

(De-Kretser et al, 1964).

The threshold limit value (TLV) for total fume exposure in the air of workshops is 5mg/cubic meter (Moreton, 1981). However, welders and caulker/burners working in confined and semiconfined spaces are exposed to fume levels much higher than the recommended TLVs, and even ventilation systems usually fail to reduce the concentration of the fumes to a recommended level (Smith, 1967; Steel & Sanderson, 1966; Akbarkhanzadeh, 1979).

Most of the gases and particulates in welding fume are well known for their toxic properties on the respiratory system (Morgan & Seaton, 1975; Parkes, 1982). If such gases and metals can get access to the respiratory passages, they may be destroyed, widely distributed throughout the body, or remain in the lung, where they may exert a wide variety of effects. The resulting irritation and inflammatory changes in the respiratory tract may be mild, but they can lead to changes within the lung which result in respiratory symptoms and function disturbance such as airway obstruction, restrictive defect, and impairment of oxygen transfer from the air to the blood.

The major part of particulate fume in welding has a diameter of one micrometer (The Welding Institute, 1976), and is thus able to reach all parts of the respiratory tract including the terminal nonciliated bronchioles and alveoli.

The lung burden of metals in welders is known to be high compared with nonexposed workers; this is exposure related (Kalliomaki et al, 1978; Kalliomaki et al, 1979; Kalliomaki et al, 1983). Although iron

oxide is the main compound detected in lungs of welders other metals are present in small quantities. These metals may act synergistically and should be taken into account in the overall assessment of the hazard of inhaled fumes (Steel & Sanderson, 1966).

## 2.5 RESPIRATORY HAZARDS OF WELDING

The working environment of welders and burners involves several health hazards. Perhaps the most dangerous hazards in shipbuilding welding are those associated with the toxic fume constituents which have the toxic potential to produce lung damage as well as systemic effects (Hickish, 1964; Baxter, 1971; Kauffman, 1971; Ross, 1978; Zielhuis and Wanders, 1985).

The possible hazardous respiratory effects of welding fume have been investigated extensively since the beginning of this century, both indirectly by studying mortality and sickness absence among welders and directly by studying the prevalence of respiratory diseases in welders.

### 2.5.1 Mortality of welders from respiratory causes

The immediate circumstances of man and the direct hazards of his work are major factors in determining mortality rates.

Because welders and burners are exposed to toxic agents and to carcinogens, including chromium, nickel, and arsenic (Parkes, 1982), attention has been paid to mortality of welders and burners from chronic respiratory diseases and lung cancer. Several mortality



studies in different parts of the world have shown excess mortality of welders and caulker/burners from respiratory diseases (The Registrar General, 1978; Beaumont & Weiss, 1980; Polednak, 1981; Newhouse et al, 1985), and from lung cancer (Breslow et al, 1954; Bolt et al, 1978; The Registrar General, 1978; Beaumont & Weiss, 1980; Polednak, 1981; Beaumont & Weiss, 1985; Becker et al, 1985; Newhouse et al, 1985). However, some studies failed to demonstrate excess mortality from cancer among welders (Dunn and Weir, 1965; McMillan & Pethybridge, 1983).

#### 2.5.2 Absenteeism due to respiratory causes

Absenteeism is usually used in retrospective studies as indirect evidence of ill health due to certain occupational exposures (Taylor, 1974; Jedrychowski, 1976). Retrospective studies of welders have demonstrated higher absence rates attributed to respiratory diseases, particularly lower respiratory diseases, than among control subjects (Fawer et al, 1982; McMillan and Molyneux, 1981), and smoking enhanced this (McMillan, 1981).

#### 2.5.3 Welder's pneumoconiosis

Pneumoconiosis is defined as the reaction of the lungs to inhaled dust and the resultant alteration in their structure excluding neoplasms, asthma, chronic bronchitis, and emphysema (Gross, 1983). In a certain percentage of welders who have been employed for 10 to 15 years, particularly in confined spaces, roentgenographic changes

take place in the lungs (Sadoul, 1983). These changes are mainly small nodular opacities, ranging from 0.5 mm to about 2 mm in diameter, throughout the entire lung field, but heaviest in the middle thirds of each lung about the hilar region (Kleinfeld et al, 1969; Attfield & Ross, 1978). Large confluent opacities do not occur.

Doig and McLaughlin in 1936 were the first to describe abnormal radiographic findings in the lungs of electric arc and oxyacetylene welders and suggested that the shadows might be caused by the deposition of iron oxides in the lung. The condition became known as welder's siderosis and for many years most published reports suggested that the condition was harmless, where no fibrosis nor lung function impairment were found in welders with siderosis (Doig & McLaughlin, 1948; Morgan & Kerr, 1963; Kleinfeld et al, 1969).

However, arc welder's pneumoconiosis appears to be more than benign siderosis resulting from particular iron deposition; simultaneous exposure to other constituents in the welding fumes may alter the pathologic picture, including a more complicated fibrotic reaction (Charr, 1955; Charr, 1956; Harding et al, 1958; Meyer et al, 1967; Stanescu et al, 1967; Guidotti et al, 1978; Vallyathan et al, 1982).



#### 2.5.4 Metal fume fever

This is a fairly common acute occupational hazard associated with welding in shipyards. This condition has been variously known as welder's metal fume fever, welder's ague, Monday fever, and the smothers (Hunter, 1969).

It is induced by inhalation of freshly formed fumes of oxides of several metals such as zinc, copper, cadmium, magnesium, iron, manganese, aluminum, and nickel (Drinker, 1922; Schiotz, 1945; Ross, 1974; Hunter, 1969; Pierce, 1983). This condition usually occurs in welders who perform welding in poorly ventilated enclosed spaces (Drinker et al, 1927; Ross, 1974; Sanderson, 1968).

The symptoms usually start shortly after exposure. It consists of sudden onset of thirst, dry throat, dry cough, nausea and a metallic taste in the mouth (Drinker et al, 1927). Later the worker has headache, rigors, profuse sweating, pyrexia, fatigue, muscular ache and pains, aching in the chest, and a feeling of generalized weakness (Drinker et al, 1927; Hunter, 1969; Ross, 1974; Pierce, 1983). A leucocytosis is usually present, and there may be reduction in the vital capacity (Stugis et al, 1927).

The illness is usually of short duration and self limited. Complete recovery occurs usually before 24 hours and always before 48 hours. The recovered worker usually acquires a transient immunity against this illness which may be lost during a weekend away from work (Drinker et al 1927). In such cases the recurrence of the illness after working on a Monday gives rise to the name "Monday fever". In

rare cases pneumonia may follow an attack of metal fume fever (Ross, 1974).

#### 2.5.5 Respiratory Symptoms and Lung Function

The prevalence of respiratory disorders in welders has been investigated since the 1930s. Clinical case reports and the results of epidemiologic studies of welders have been published from different parts of the world. The following is a review of the literature concerning the respiratory effects of inhalation of welding fumes.

Charr in 1955 reported histologic evidence of fibrosis associated with the deposition of iron oxides in the lungs of two welders. Later in 1956, he presented three other cases with similar histologic findings in welders with no history of exposure to silica. All three had respiratory symptoms of cough and dyspnoea, and physiologic impairments suggestive of emphysema.

Mann and Lecutier in 1957 reported the case of a welder with tuberculosis who had been engaged in welding for 25 years. Although the patient had minimal symptoms, ventilatory studies demonstrated a reduction in ventilatory capacity. Histologic study of tissue removed by lobectomy revealed very high content of iron with smaller amounts of silica. There was considerable emphysema.

Friede and Rachow in 1961 described a welder with cor pulmonale. This welder had welded in a poorly ventilated confined space for 13 years. Tissue removed at lung biopsy demonstrated diffuse

interstitial fibrosis with thickened alveolar septa. Studies of the welding electrodes showed it to be predominantly iron. However, the coating contained 3.4% silica in addition to copper, manganese, magnesium, calcium, and aluminum. They postulated that the fibrosing activity of iron oxide might be modified by the presence of silica to produce a diffuse interstitial fibrosis rather than a localized nodular fibrosis typical of silica alone.

Morgan and Kerr in 1963 studied seven welders with siderosis. The length of exposure varied from 10 to 28 years. Although there were several welders with abnormalities in pulmonary function tests, the authors could not attribute any to exposure to welding fumes per se.

Stanescu et al in 1967 studied 16 welders with siderosis in a metallurgic plant and 13 healthy nonexposed workers. Seven of the welders had some exertional dyspnoea and three complained of cough, but only three of these subjects were smokers. Spirographic values were generally within the normal range, but the arc welders had statistically significant reduction in static and functional compliance. The authors felt that this decrease in compliance could be due to deposition of iron per se and/or due to associated fibrosis. They concluded that arc welding should be considered an occupation with cumulative hazards.

Kleinfeld et al in 1969 studied 25 arc welders who had an average duration of welding experience of 18.7 years. A group of 20 men, matched for age, living in the same area but having no previous exposure to occupational dusts or fumes were selected as the control



population. Smoking habits of the two groups were comparable. No significant difference in respiratory symptoms or lung function test results was observed between welders and controls. In welders, exposure to fumes was not associated with impairment of lung function.

Spacilova and Koval in Prague in 1975 examined 36 arc welders and 20 male controls. The control subjects had not been exposed to occupational dust or fumes and had normal cardiopulmonary systems. Smoking habits were similar in both groups. 30% of welders with siderosis had chronic bronchitis. Compared with welders without bronchitis, chronic bronchitic welders had a lower FVC. There were no significant differences in lung function studies between welders without chronic bronchitis and controls.

Hunnicuttt et al in 1964 carried out one of the first studies to include a large number of welders and properly selected controls. 100 shipyard electric arc welders and an equal number of unexposed workers were examined. Both groups were selected randomly from the employees of the same yard. Welders had over 10 years welding experience and were below the age of 60 years. Welders had significantly lower forced expiratory volume ( $FEV_1$ ), maximum expiratory flow rate (MEFR), and maximum mid expiratory flow rate (MMEFR) than did the controls. The differences were not significant if the welders did not smoke. The authors concluded that the adverse effects of smoking and welding fumes might be synergistic.

Fogh et al in Denmark in 1969 studied 156 welders and 152 controls. About half the welders were picked up from shipyards; the



others were employed in different plants. Controls were selected from the same workplace as the welders. They found that symptoms of chronic bronchitis and impairment of lung function increased with increased tobacco consumption for welders of the older age groups.

Peters et al in 1973 studied three groups of workers in a shipyard. 61 welders, 63 pipe fitters, and 63 pipe coverers. Age and smoking habits were similar in the three groups. There were no statistical differences in lung function test results between welders and pipe fitters. However, when welders were compared to pipe coverers, who had a greater exposure to asbestos dust, residual volume was higher in welders and total lung capacity was lower in pipe coverers. When the three shipyard groups were compared with pipe fitters from another yard without fume or asbestos exposure, all three groups were found to have significantly lower FVC, FEV<sub>1</sub>, and PEFR. In addition the authors used prediction equations derived from pulmonary function based on Boston policemen. They found that the values for their welders and pipe fitters were considerably depressed when compared with those for policemen of the same height and weight.

Barhad et al in Romania in 1975 examined 173 shipyard welders and 100 controls from the same yard. Dyspnoea and wheeze were significantly higher in welders than in controls. FEV<sub>1</sub> was significantly decreased in welders with more than 10 years of exposure, in those with dyspnoea, and in those with history of wheezing or asthma.

Antti-Poika et al in Finland in 1977 studied 157 welders and 108 controls in engineering shops. Both groups were matched for age,

smoking habits, and social class. Welders had increased prevalence of simple chronic bronchitis than controls. There were no significant differences in lung function test results between welders and controls.

Ross in 1978 examined the health records of 926 welders over a period of six years, and compared them with 755 controls from other trades excluding boiler makers. He found that older smoking welders had significantly higher attacks of pneumonia, chronic bronchitis and other respiratory illnesses than controls.

Oxhoj et al in Sweden in 1979 investigated 119 shipyard welders who had welded for five years or more and 90 clerks, who had never welded, as controls. Controls were selected from the same yard as the welders and were matched with them for age, smoking habits, and height. The respiratory symptoms chronic coughing, wheezing, and dyspnoea were more prevalent in welders than in controls. The indices of small airway function, CV% and CC%, were significantly higher in nonsmoking and exsmoking welders than in controls with similar smoking habits. No significant differences in other lung function test results were observed. The authors concluded that these findings could be attributable to deposition of welding fumes in the small airways or alveoli.

McMillan and Heath in 1979 examined shipyard welders and comparable controls. Their findings were essentially negative. However, there was a positive correlation between increase in residual volume over the shift and level of pollutants to which welders were exposed. In 1984, McMillan and Pethybridge in the same

yard studied 135 welders aged 45 years and over and an equal number of other tradesmen. Both groups were matched for sex, age, smoking habits and potential for exposure to asbestos. Dyspnoea was significantly higher in welders than in controls. Compared with controls, welders had significantly greater increase in residual volume with increased age.

Akbarkhanzadeh in the United Kingdom in 1980 investigated 209 shipyard welders, and 109 clerks from the same yard who served as controls. The prevalence of chronic bronchitis was higher among smoking welders than among the controls. The forced expiratory volume and transfer factor were significantly lower in welders than in controls. The author concluded that age and smoking enhanced the effect of welding fumes.

Hyden et al in 1984 studied 258 welders and an equal number of controls from engineering factories. Controls were selected from the same sections as the welders and were matched with them for age. Most of the welders had worked in large buildings with good ventilation. Upper respiratory infections were a more frequent cause of sickness absence among welders than among controls. Welders who smoked had a higher prevalence of chronic phlegm production than controls. Lung function test results were similar in both groups. However, flow rates at low lung volumes ( $\dot{V}_{\max 50}$ ,  $\dot{V}_{\max 25}$ ) were significantly lower in smoking welders than in smoking controls.

Sjogren and Ulvarson in 1985 studied 64 aluminium, 46 stainless steel, and 149 rail road track welders. Control groups consisted of 176 nonwelding industrial, and rail road workers. All groups of



welders had significantly more respiratory symptoms than controls. Welders working with inert gas welding (IGW) on aluminium had more respiratory symptoms at higher ozone concentrations than at lower concentrations. Lung function test results were similar in welders and controls.

Murr et al in France in 1985 studied 536 welders and 558 controls from the same electro-mechanical plant. Prevalence of chronic bronchitis was higher in welders than in controls, but this difference did not reach statistical significance. Among the different lung function tests which were compared in welders and controls, only transfer factor was significantly reduced in welders than in controls.

Lyngenbo et al in Denmark in 1985 studied 74 nonsmoker welders and a matched group of 31 non-exposed subjects. The symptoms, cough, wheeze, chronic bronchitis and dyspnoea, were more frequent in welders than in controls. Compared with controls, welders had significantly lower TLC, VC, FEV<sub>1</sub>, FVC, PEF, MEF<sub>75</sub>, and transfer factor. Also closing volume and slope of alveolar plateau were significantly higher in welders than in controls. The authors concluded that welding fumes could initiate respiratory symptoms and produce impairment of lung function.

Kilburn et al in the USA in 1985 examined 148 male shipyard welders in Los Angeles. They were grouped according to their smoking habits. These welders were compared to smoking specific groups from a random sample of Michigan males. Welders had more chronic bronchitis, wheezing, and dyspnoea than did the controls. FEV<sub>1</sub> and



FVC were significantly reduced in nonsmoking welders, and these effects were significantly higher in smoking welders. However, in this study welders were exposed to the high level of air pollution in Los Angeles.

Zober and Wlittle in Germany in 1985 examined 305 welders selected from different companies in the metal working industry, and a group of 100 workers who served as controls. Age and smoking habits were similar in both groups.

Environmental measurements revealed that welders were exposed to concentrations of fumes which exceeded the safe levels, especially when work was done in confined spaces.

Respiratory tract diseases were more frequent in the welders than in the controls. Chronic bronchitis was more prevalent in nonsmoking welders over the age of 43 years than in the controls. However, these differences did not reach statistical significance. All respiratory tract disorders were more prevalent in welders who smoked than in nonsmoker welders. The prevalence of restrictive and obstructive lung diseases was higher in the older nonsmoker welders than in their controls.

The authors concluded that age and smoking were the main aetiological factors, and that they enhance the effect of welding fumes.

Although the published results revealed contradictory evidence, the general impression conveyed by the literature indicates that welders suffer more from lower and upper respiratory symptoms than do unexposed workers.

Reviewing the literature revealed that most of the positive findings

relating welding to respiratory disorders were reported from studies of shipyard workers; where negative findings were reported the welders were from engineering shops. Working conditions in shipyards are different from those in engineering factories in that shipyard welders generally work in confined spaces particularly on ships where fume concentrations usually exceed recommended levels. This could be an indirect indication that welding fumes in high concentrations could produce adverse respiratory effects. If this is so damage done by welding fume should be exposure related.

### CHAPTER 3

#### LUNG FUNCTION TESTS

Measurements of pulmonary function are of great value in judging the presence and degree of functional impairment. In cross-sectional respiratory surveys, pulmonary function tests help evaluate groups and individuals at risk of chronic obstructive lung disease.

Several lung function tests are available and have been used and evaluated extensively in respiratory epidemiological surveys (Fairbairn et al 1962; Higgins & Keller 1973; McCarthy et al 1975; Tattersall et al 1978; Love et al 1980). The following is a short account on the physiological and clinical importance of the lung function tests used in the present study.

#### 3.1 MEASUREMENT OF LUNG VOLUMES (FIG. 1)

Total lung volume is divided into four volumes (tidal volume, residual volume, expiratory reserve volume, and inspiratory reserve volume), and four capacities (total lung capacity, vital capacity, inspiratory capacity, and functional residual capacity) (Pappenheimer et al, 1950).

### 3.1.1 Vital capacity

Expired vital capacity (VC) is the maximal volume exhaled by maximal voluntary effort following fullest inspiration. It is the difference between total lung capacity (TLC) and residual volume (RV). Therefore, VC reflects the relative changes of TLC and RV. Vital capacity is reduced in restrictive disorders of the lung such as in pulmonary fibrosis when the TLC decreases proportionately more than the RV (Zohman & Williams 1959). Also, in long-standing obstructive disorders with hyperinflation such as in emphysema, chronic bronchitis and asthma, VC is reduced when the RV is increased proportionately more than the TLC (Woolf 1952; Fairbairn et al 1962; Burrows et al 1965 (a); Burrows et al 1965 (b)).

The measurement of reduced VC alone, then, is of little value and provides a nonspecific assessment of decreased ventilatory reserve.

### 3.1.2 Residual volume

Residual volume (RV) is defined as the quantity of air which remains in the lung after maximal expiration. It is usually expressed as a per cent of TLC (RV/TLC %). This ratio is normally no more than 30% in subjects under the age of 60 (Birath, 1944). In chronic obstructive lung disorders such as in chronic bronchitis and emphysema this ratio is usually elevated due to air trapping in the lung (Baldwin et al 1948; Curtis et al, 1955; Williams and Zohman 1959; Burrows et al, 1965). Raised residual volume was found to be a



consistent abnormality in mild bronchitic and asymptomatic asthmatics where other spirometric tests of lung function were within normal range (Levine et al, 1970; McFadden & Linden, 1972). The mechanism for this air trapping may be related to early obstruction in small airways in chronic bronchitis (Hogg et al, 1968).

### 3.1.3 Total Lung Capacity

The total lung capacity is the total volume of gas in the lungs following a maximal inspiration. TLC depends on the maximum distensibility of the lung and on the capacity of the chest wall to expand. It is reduced with certain restrictive lung disorders such as pulmonary fibrosis (Cotes 1979; Harrison 1981) because the lung has decreased distensibility (increased recoil). On the other hand, TLC is increased in emphysema (Baldwin et al 1948; Gaensler, 1955; Burrows et al, 1965; Harrison 1981) because the lung has lost its elastic recoil and become very compliant. Therefore, it can expand to a great volume with very low distending forces; the chest wall can then expand without major opposition from the lung (Saunders, 1977).

## 3.2 MEASUREMENT OF FORCED EXPIRATION (FIG. 2)

Measurement of VC has severe limitations in the assessment of ventilatory abnormalities. Gaensler in 1951 showed that the forced vital capacity (FVC) manoeuvre, with expired volume recorded as a function of time, was a useful way of demonstrating the reduced rate of expiratory air flow in patients with chronic obstructive lung

disease. In analyzing the forced expiratory volume-time curve several measurements can be readily performed such as forced expiratory volume in the first second, the ratio of such a volume to the total FVC and the peak expiratory flow rate.

### 3.2.1 Forced expiratory volume

The forced expiratory volume ( $FEV_1$ ) is the volume of gas exhaled during the first second following initiation of forced expiration from TLC. It provides information on airway obstruction because of its time dependence.  $FEV_1$  is decreased in chronic obstructive lung disorders (Woolf 1959; Fairbairn et al 1962; Burrows et al 1965). It is also low in restrictive lung disease, but is decreased in proportion to the decrease in FVC (Zohman & Williams 1959). Therefore  $FEV_1$  should be interpreted in relation to FVC.

### 3.2.2 Forced expiratory volume ratio

This is the forced expiratory volume expressed as a percentage of the total FVC ( $FEV_1/FVC\%$  or  $FEV_1\%$ ). This test has been widely used in screening studies of chronic obstructive lung disease, and has been found to be very reproducible (Higgins & Keller 1973; McCarthy et al 1975; Love et al 1980).

A normal young adult can expire over 75 per cent of his FVC in the first second (Gaensler 1951).  $FEV_1\%$  linearly decreases with age (Cotes 1979).

$FEV_1\%$  is decreased in chronic obstructive lung disease (Fairbairn

1962; Burrows et al 1965). It is normal or increased in pure restrictive disorders (Harrison 1981).

In normal subjects, VC and FVC are similar. With increasing airway obstruction, the VC can remain in the normal range while dynamic compression of the airways and air trapping diminish the FVC (Conrad 1984). When this occurs, use of the ratio to differentiate between restrictive and obstructive disorders becomes less useful.

### 3.2.3 Peak expiratory flow rate

Peak flow rate (PEFR) is the maximum expiratory flow of gas sustained at the mouth for 10 ms during a forced expiration starting from TLC. PEFR is a useful test in screening studies because it is easy to carry out (Elebute & Femi-Pearse 1971) and the equipment for its measurement are eminently portable (Wright & McKerrow 1959; McDermott & McDermott 1977). PEFR depends on calibre of the airways, voluntary expiratory muscular effort, and on the VC (Harrison 1981). It correlates well with FEV<sub>1</sub> (Ritchie 1962; Kuperman & Riker 1973). PEFR is reduced in chronic obstructive lung disease due to increased resistance to air flow (Fairbairn et al 1962; Ritchie 1962; Cotes 1979).

### 3.3 MEASUREMENT OF SMALL AIRWAY FUNCTION

Since the demonstration that conventional spirometric tests are insensitive to small airway dysfunction, several tests which are specific to small airway diseases have been introduced. The clinical and epidemiological importance of these tests were presented in chapter one. The maximal flow volume curve, and the single breath nitrogen test are of particular interest in screening studies and will be discussed in the following sections.

#### 3.3.1 Maximal expiratory flow volume curve

The expiratory flow volume curve (MEFV) is obtained by plotting the maximal expiratory flow ( $\dot{V}_{\max}$ ) against the relevant lung volume during the performance of a FVC manoeuvre (Hyatt & Black 1973). The curve is used to derive the flow rate at specified lung volumes during expiration; for screening purposes the reference volumes are usually 50 per cent ( $\dot{V}_{\max 50}$ ), and 75 per cent ( $\dot{V}_{\max 25}$ ) of the VC (fig. 3).

$\dot{V}_{\max 50}$  and  $\dot{V}_{\max 25}$  are being increasingly used as more specific tests of small airway function (Gelb & McAnally 1973; Zamel et al 1973; Malo & LeBlanc 1975; Guyatt et al 1975). Diseases which reduce the elastic recoil or decrease the calibre of the conducting airways reduce  $\dot{V}_{\max 50}$  and  $\dot{V}_{\max 25}$ .



### 3.3.2 Single breath nitrogen test

The single breath nitrogen method depends on the alveolar nitrogen concentration gradient down the lung which exists after a full slow VC breath of oxygen from RV. This nitrogen concentration gradient depends, in turn, on the ratio of the regional preinspiratory lung volume and the volume of oxygen delivered to that region. At RV basal alveoli are smaller than apical alveoli; at TLC they are about the same size. Therefore, during full slow inspiration of pure oxygen, more oxygen goes to the base than to the apex, and nitrogen concentration is higher at the apex than at the base. During the subsequent expiration the onset of basal airway closure is signalled by a rise in the nitrogen concentration of predominantly apical origin. Nitrogen concentration at the mouth is plotted against change in volume (fig. 4).

An expired nitrogen trace shows four phases:

Phase I: Zero concentration as the dead space gas is expelled.

Phase II: A sharply rising concentration due to a mixture of dead space and alveolar gas.

Phase III: A plateau, with cardiogenic oscillations, composed of a mixture of alveolar gas from all regions.

Phase IV: A sudden sharp rise in concentration as basal airways begin to close and the gas comes mainly from upper lung regions with relatively high nitrogen concentrations. Phase IV is called closing volume (Holland et al 1968).

Three indices can be obtained from a trace:

1. Closing volume:

This is defined as the volume above RV at which the small airways at the base of the lung begin to close. CV is usually expressed as a percentage of VC (CV/VC% or CV%). The absolute lung volume at which closure begins (CV+RV) is called closing capacity (CC) and is expressed as a percentage of TLC (CC/TLC% or CC%).

2. Nitrogen difference index of lung mixing ( $N_2$  Diff):

This is the change in nitrogen concentration between 750 & 1250 ml from start of expiration.

3. Slope of phase III (SL III):

This is the slope of alveolar plateau ( $N_2$  l<sup>-1</sup>) between 30% VC and onset of Phase IV.

While increased CV indicates premature closure of small airways, increased  $N_2$  Diff and SLIII indicate improper mixing of gases inside the lung (Fowler, 1949; Comroe and Fowler, 1951; Kjellmer et al, 1959; Oslen & Gilson, 1960; Malmberg et al, 1963; Otis et al, 1956; Anthonisen et al, 1970; Sterk et al, 1981; Oxhoj et al, 1977; Buist & Ross, 1973)

Compared with the conventional spirometric tests such as FEV<sub>1</sub>, MEFV curve and CV tests are less reproducible (McCarthy et al 1975). However, as the conventional spirometric tests are insensitive to small airway dysfunction, the use of MEFV curve and CV test in screening studies aiming at early detection of small airway disease is justified (Love et al 1980; Buist 1984).

### 3.4 THE SINGLE BREATH TRANSFER FACTOR FOR THE LUNG FOR CO

The single breath method for diffusing capacity is the most commonly used means for assessing CO transfer, primarily for the ease and noninvasiveness of the test. It is one of the recommended screening tests for diseases characterized by gas exchange impairment (Ferris et al 1978).

The transfer factor for CO ( $T_{lCO}$ ) is a nonspecific test for the gas exchange function (diffusing capacity) of the lung. This technique requires the inhalation of a VC breath containing tracer amount of carbon monoxide and helium with a timed period of breath holding during which carbon monoxide transfers to the pulmonary capillary blood. The rate of transfer of CO from alveolar gas to pulmonary capillary blood per kilopascal driving pressure is the transfer factor measured in millimoles per minute per kilopascal ( $\text{mmol min}^{-1} \text{KPa}^{-1}$ ).

A reduction in diffusing capacity of the lung occurs with loss of alveolar surface area, thickening of the alveolar membrane, loss of alveolar capillary bed, increase in  $\dot{V}/\dot{Q}$  mismatch (which increases the physiological dead space), or with decrease in the amount of HB available for CO transfer in the lung capillaries. A reduced  $T_{lCO}$  is most commonly seen with emphysema, interstitial lung disease or pulmonary vascular disease (Shepard et al 1955; Ogilvie et al 1957; Bates 1958; Lenfant & Pace 1965; Bedell & Ostiguy 1967; Cotes 1979). It is also reduced in smokers (Lyons et al 1957; Van Ganse et al 1972), and in mild bronchitis (Levine et al, 1970).



The  $T_{lco}$  expressed per litre of alveolar volume is called transfer coefficient or diffusion constant ( $K_{CO}$  or  $T_{lco}/VA$ ). The units are  $mmol\ min^{-1}\ kPa^{-1}\ l^{-1}$ . Its purpose is to correct for the effect of lung volume on measurement of  $T_{lco}$ .

### 3.5 EXERCISE TESTS

Breathlessness on exertion and effort intolerance are major symptoms in patients with chronic airway obstruction (Brown et al 1977). The symptoms are assessed by questionnaire and by having the patient perform an exercise test: this yields an objective assessment of exercise tolerance and can unmask functional abnormalities that are absent under resting conditions (Wasserman & Whipp 1975; Jones et al 1982).

Exercise testing measures the responses of cardiovascular and respiratory systems to the dual metabolic loads of oxygen uptake ( $\dot{V}O_2$ ) and carbon dioxide output ( $\dot{V}CO_2$ ).

The measurement of  $\dot{V}O_{2max}$  is often disagreeable for the subject and not without risk (Cotes, 1971) so a submaximal procedure is used (Cotes 1972; Spiro 1974).

In a progressive exercise test which is performed on a cycle ergometer or a treadmill, the work rate is increased by standard increments, usually at one or two minutes intervals. Oxygen consumption, average ventilation ( $\dot{V}_E$ ), heart rate ( $f_C$ ) and tidal volume ( $V_t$ ) are measured (Cotes 1979). The quantities are displayed graphically and used to obtain, by interpolation, the following



indices:

1. Exercise ventilation index ( $\dot{V}_{e45}$ ):

This is the exercise ventilation at an oxygen uptake of 45mmols  $\text{min}^{-1}$  (1 litre  $\text{min}^{-1}$ ) (fig. 5).

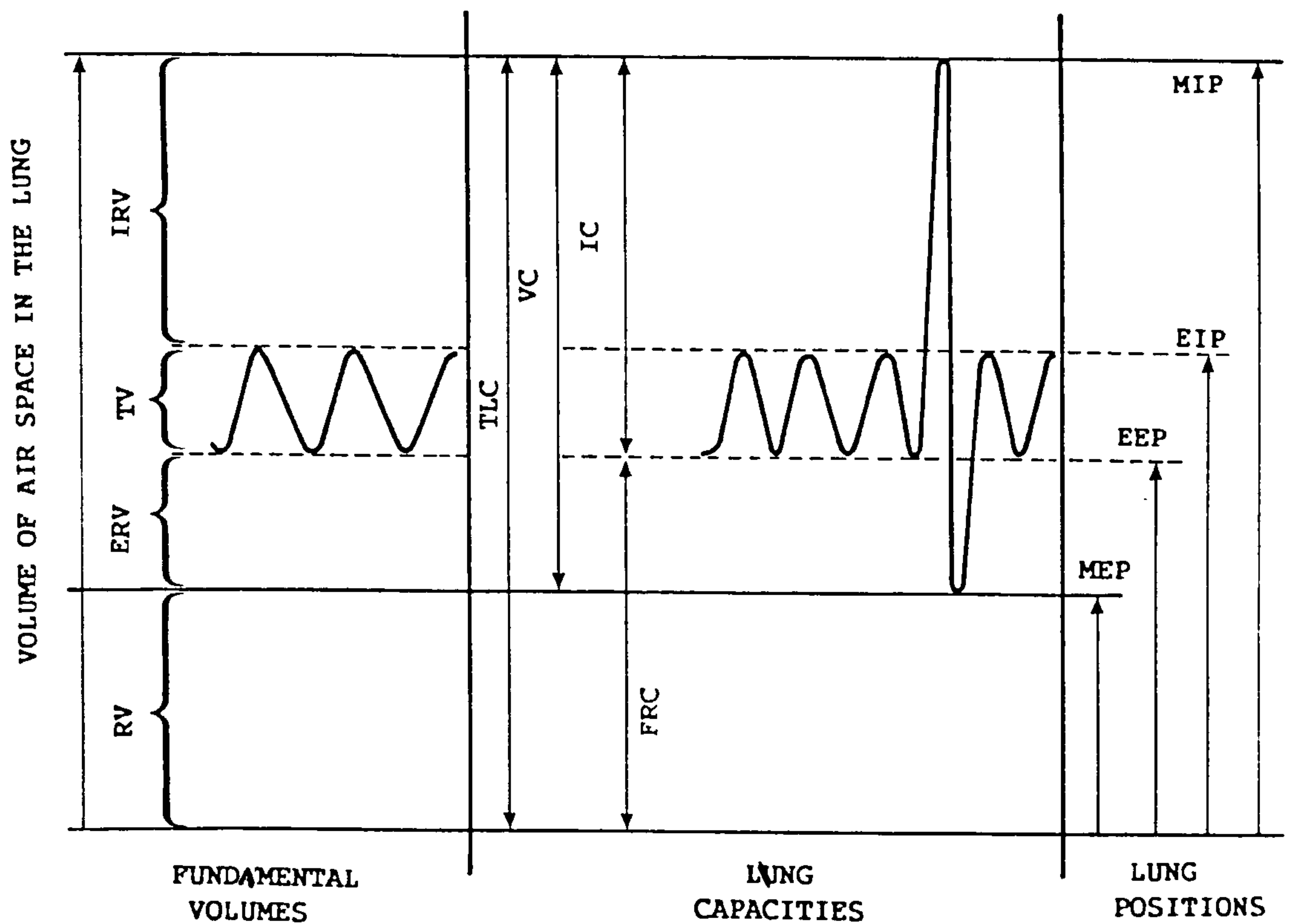
2. Tidal volume Index ( $V_{t30}$ ):

This is the tidal volume at a ventilation of 30 l  $\text{min}^{-1}$  (fig. 6).

3. Cardiac frequency index ( $f_{C45}$ ):

This is the cardiac frequency at an  $\dot{n}O_2$  of 45 mmols  $\text{min}^{-1}$  (fig. 7).

Figure 1: DEFINITIONS OF LUNG VOLUMES, CAPACITIES AND POSITIONS



IRV=inspiratory reserve volume  
 TV =tidal volume  
 ERV=expiratory reserve volume  
 RV =residual volume  
 TLC=total lung capacity  
 VC =vital capacity

IC =inspiratory capacity  
 FRC=functional residual capacity  
 MIP=maximal inspiratory position  
 EIP=endinspiratory position  
 EEP=endexpiratory position  
 MEP=maximal expiratory position

Figure 2 (a): NORMAL FORCED EXPIROGRAM

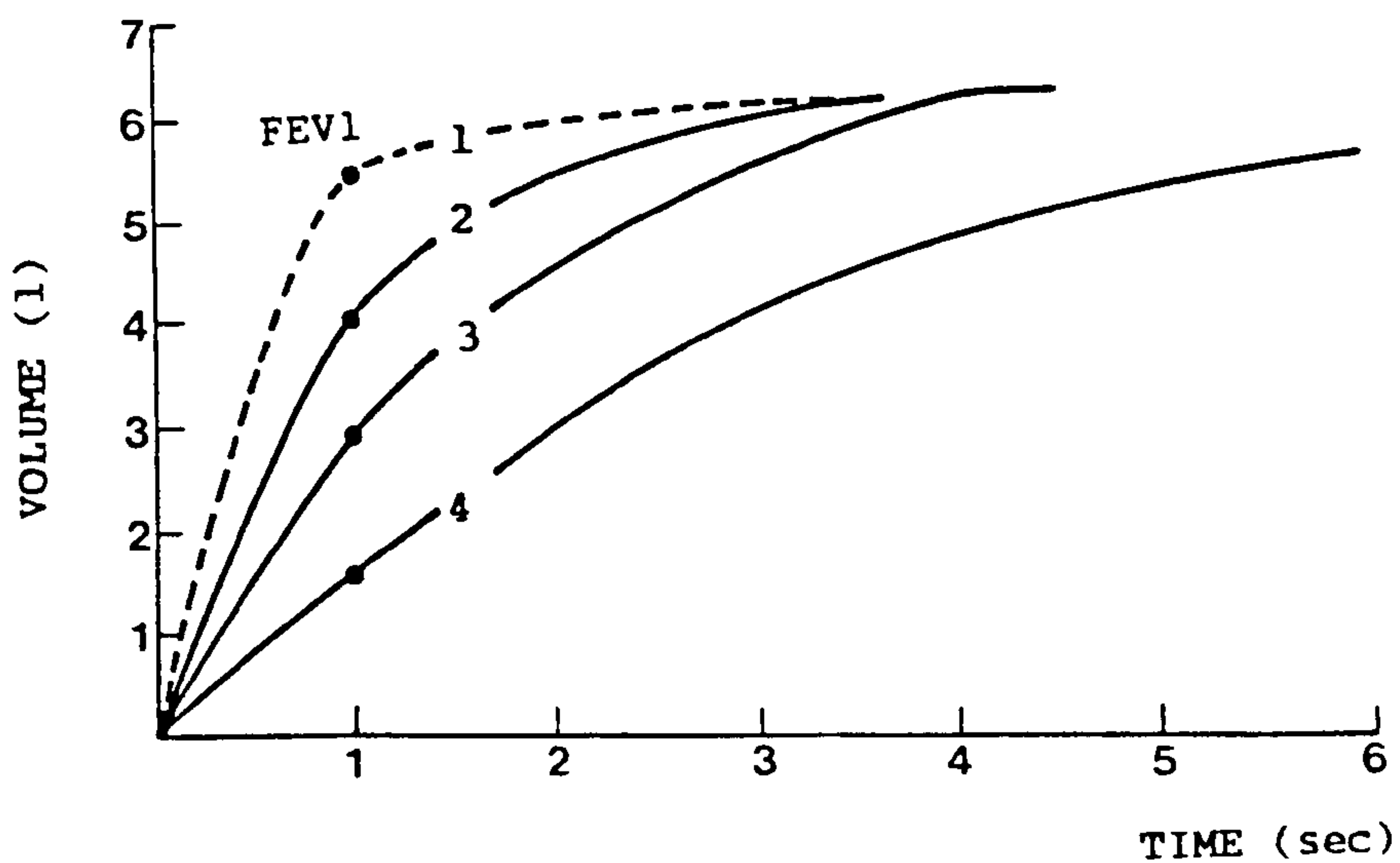
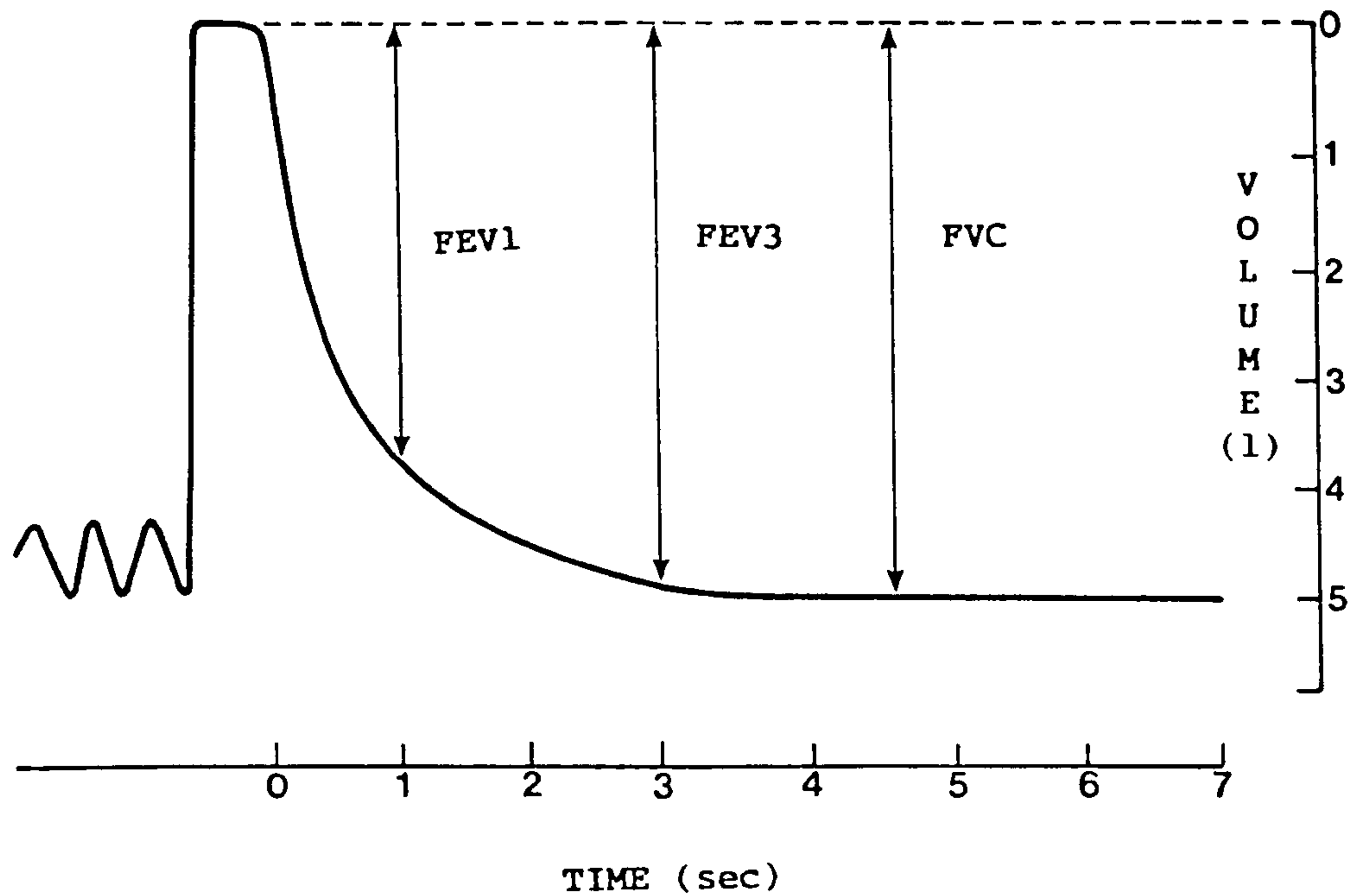
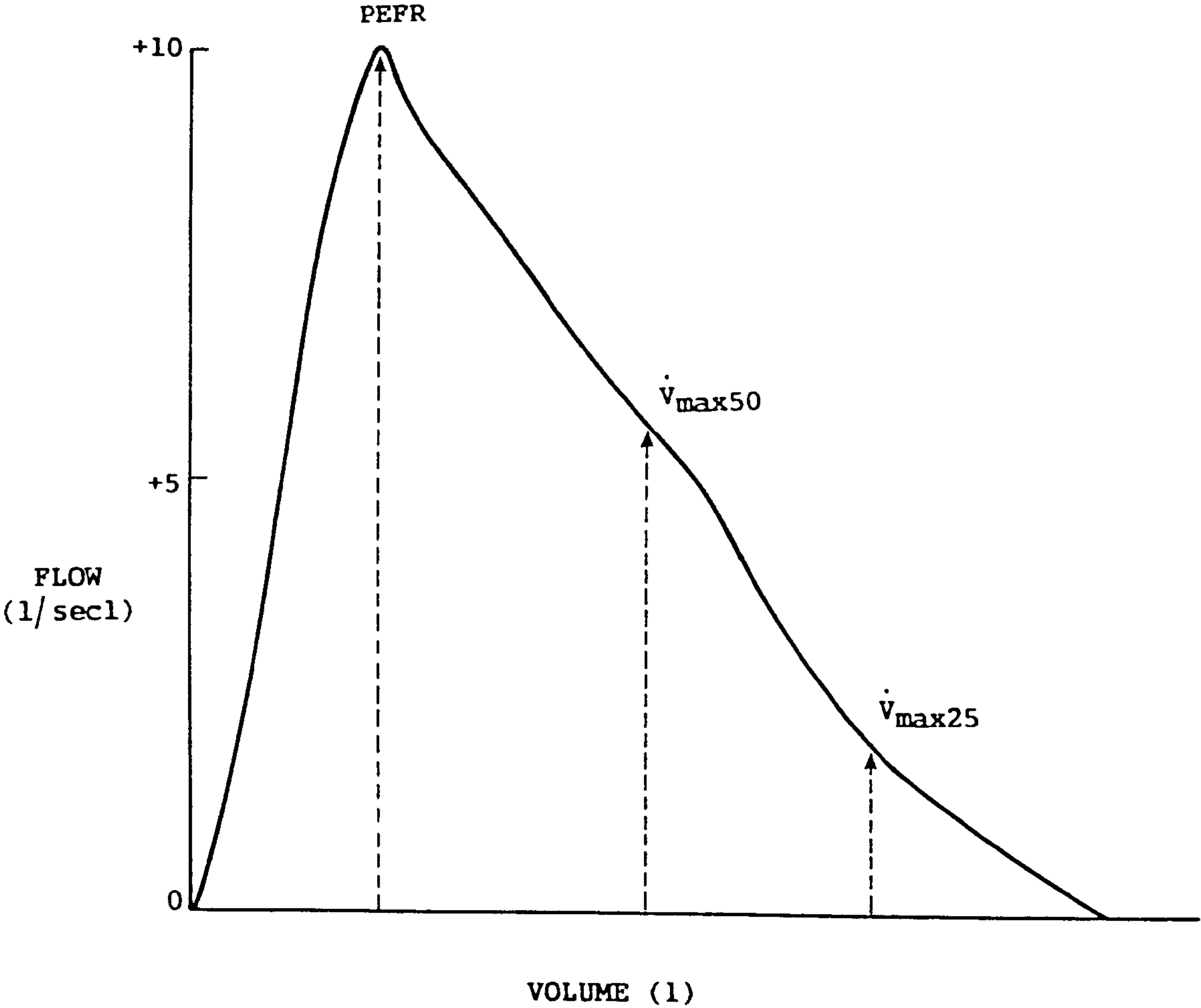


Figure 2 (b): THE MEASUREMENT OF FEV1 IN:

- (1) normal subject
- (2) a patient with mild airway obstruction
- (3) a patient with moderate obstruction
- (4) and a patient with severe airway obstruction

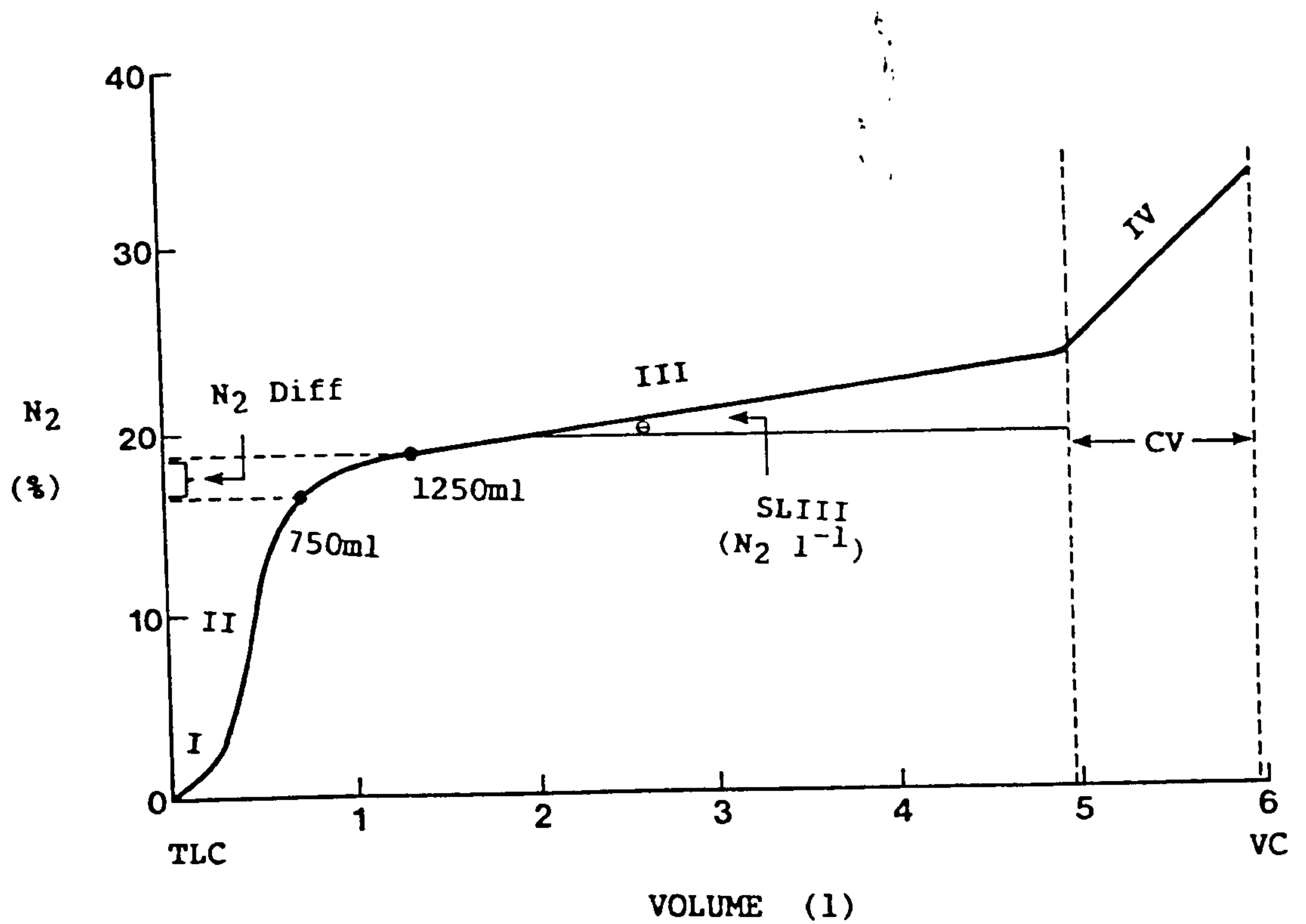
Figure 3: MAXIMAL EXPIRATORY FLOW VOLUME CURVE



A typical flow volume curve indicating the PEFR, the  $\dot{V}_{\max 50}$  and  $\dot{V}_{\max 25}$  points.



Figure 4: NITROGEN CLOSING VOLUME CURVE



A typical single breath nitrogen closing volume curve indicating closing volume (cv), slope of phase III (SLIII), and  $N_2$  Diff indices (See the text for details).

Figure 5: RELATIONSHIP OF THE MINUTE VENTILATION  
VOLUME TO THE OXYGEN UPTAKE

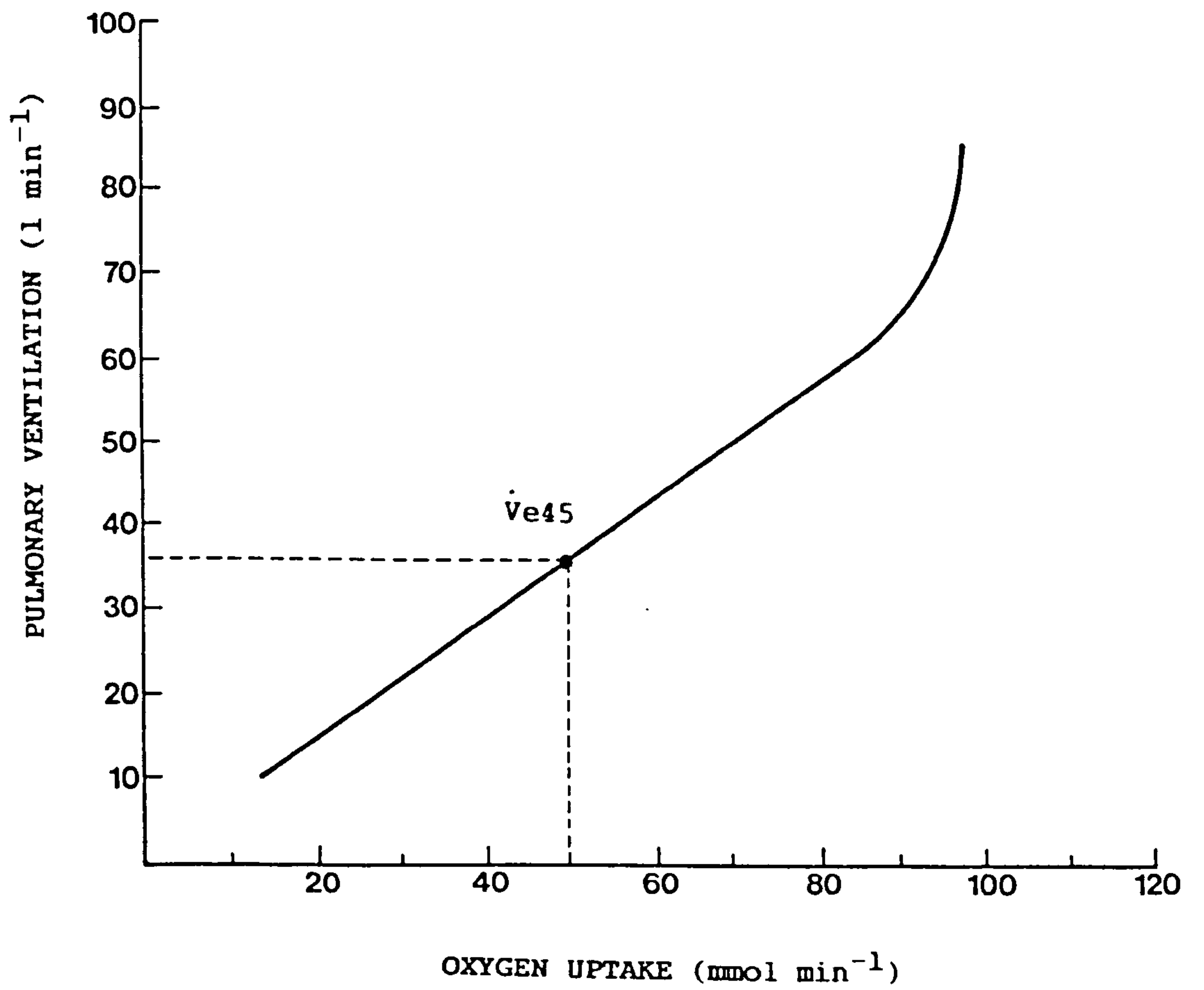


Figure 6: RELATIONSHIP OF THE CARDIAC FREQUENCY AT  
OXYGEN UPTAKE DURING EXERCISE

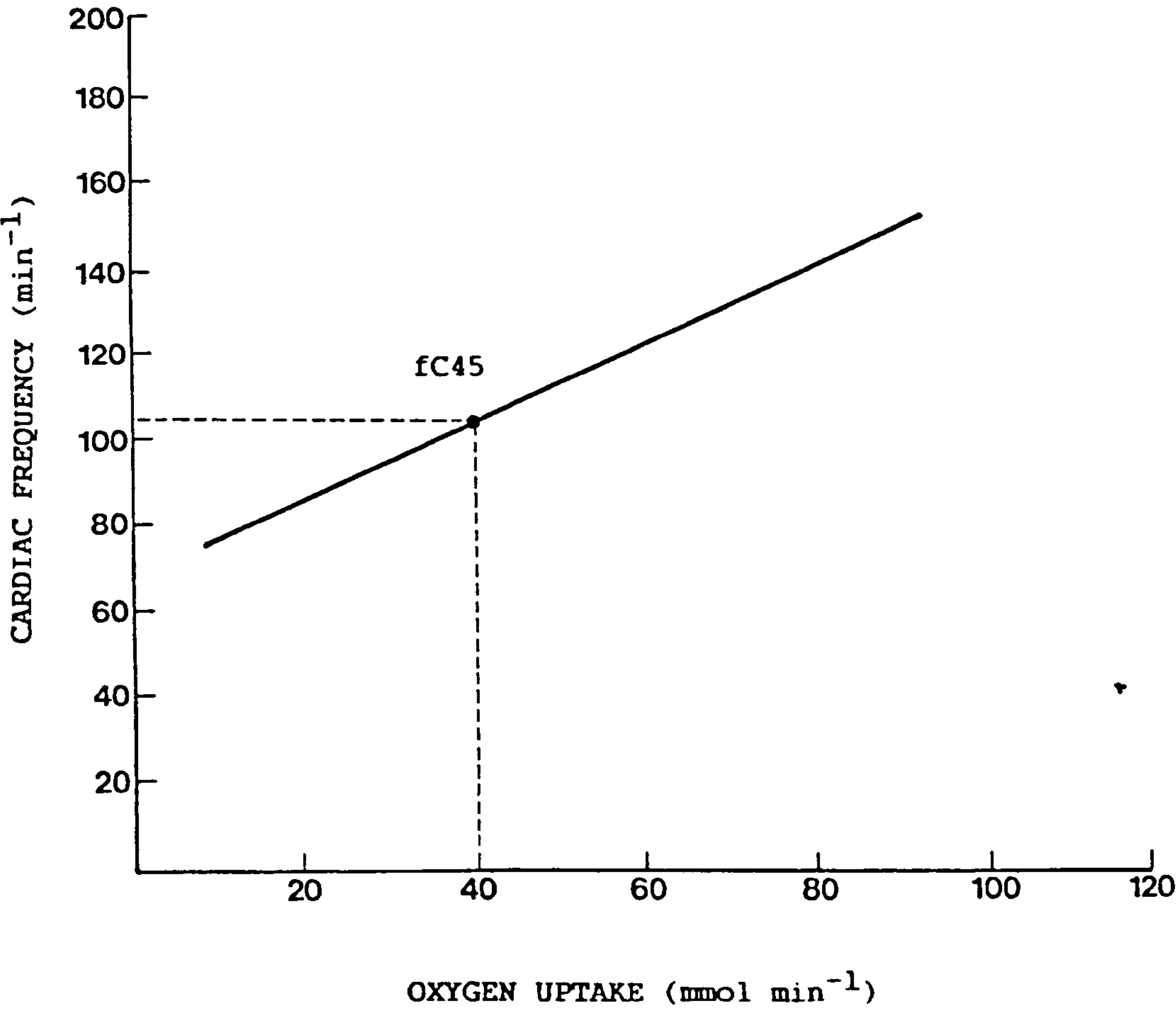
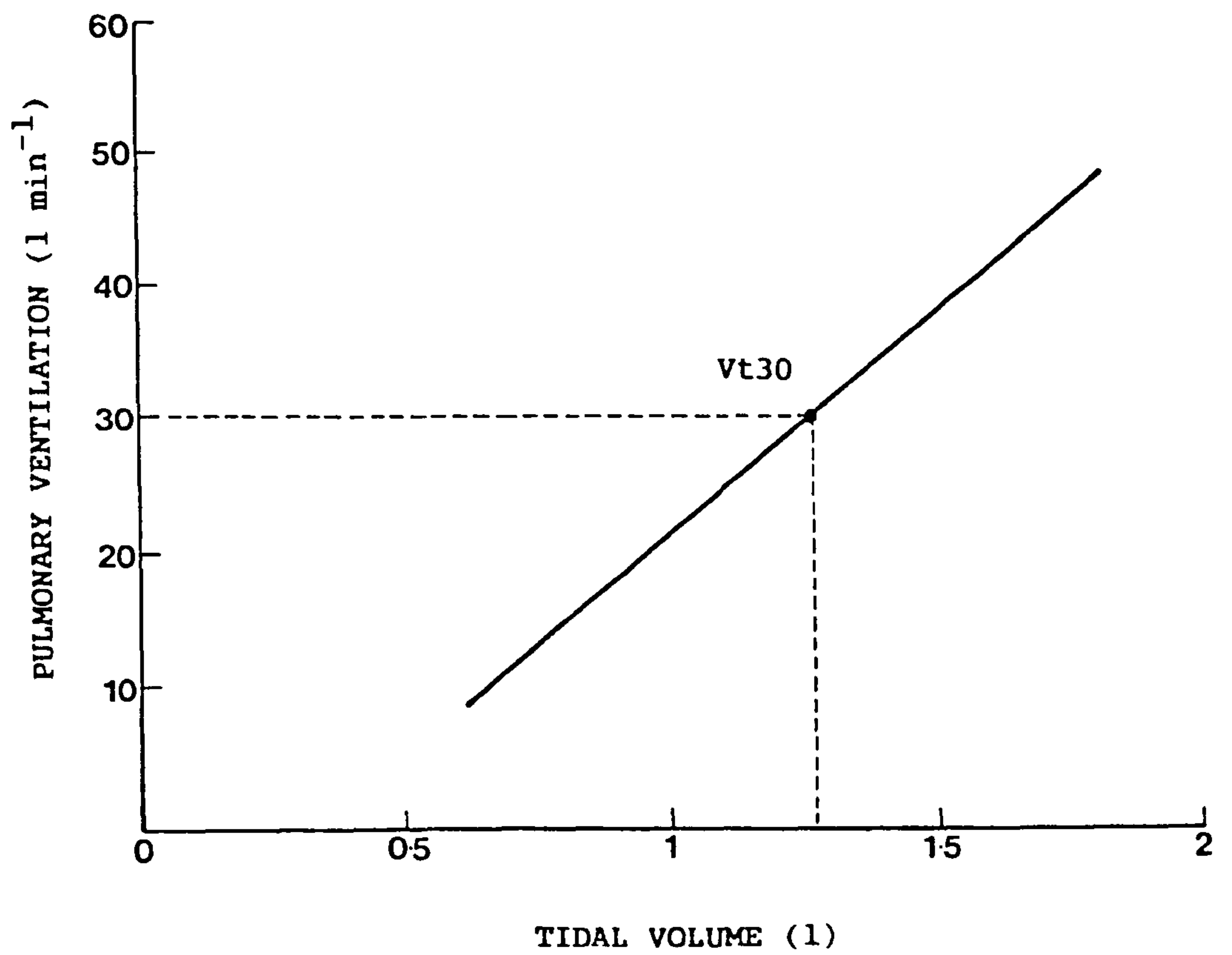


Figure 7: RELATIONSHIP OF THE TIDAL VOLUME TO THE  
VENTILATION MINUTE VOLUME DURING EXERCISE





## CHAPTER 4

### SUBJECTS AND METHODS

The main stages in the methodology and the conduct of this study will be discussed under the following headings:

- 1- Technical design.
- 2- Statistical design.
- 3- Administrative design.
- 4- Operational design.

#### 4.1 TECHNICAL DESIGN

This part covered choice of design, choice of the study population, sources of data, exploratory studies, pilot study, and methods of data collection.

##### 4.1.1 Choice of design

A cross sectional study was chosen as the epidemiologic design. The method can provide an estimate of the prevalence and severity of disease in a population and can be used to look for a dose and response relationship which if present provides evidence of causation; it also yields information on which to set up hygiene standards (Schilling 1980). The design had the further advantage that the practical field work could be completed within the available time (i.e not exceeding 18 months).

#### 4.1.2 Choice of the population

Workers in the four Swan Hunter Shipyards were chosen as the target population to be studied. This shipyard was chosen because:

1. It was the largest employer of welders and caulker/burners in the Tyne Side area,
2. The yard had plenty of work in progress so there was no reason to expect large scale redundancies
3. The processes were well established so there were not likely to be period of large scale technological changes or other disruptions during the field study.

##### 4.1.2.1 The target workers

The welders and caulker/burners aged 18 - 45 years, at the start of the survey, were identified. There were 393 welders and 394 caulker/burners (table 1). The welders and caulker/burners, separately, were stratified into 5 age groups (18 - 24, 25 - 30, 31 - 35, 36 - 40 and 41 to 45 years). 40 workers were selected randomly from each group.

However, during the course of the survey several welders and caulker/burners were made redundant because of the company's increasing financial problems. Redundancy was made either voluntary or on the basis of last in first out. Most of those who left the

yard were very young workers (table 1).

Workers who left the yard were replaced randomly by others from the same age groups.

The numbers and age categories of those who left the yard or failed to attend in spite of repeated appointments are given in tables 1 & 2. Thus by the end of the survey the total number of the current welders and caulker/burners was 390 of whom 332 were examined, 35 failed to attend in spite of repeated appointments, 20 refused to take part in the study, and 3 were long term sick (table 2).

#### 4.1.2.2 The controls

The control subjects resembled the target workers in sex as all were males, in race since all were Caucasian and in socioeconomic status because all were manual workers in the same shipyard. None had ever been a welder or caulker/burner. They were matched for age group over the range 18 - 45 years.

They included electricians, joiners, fitters, platers, carpenters, plumbers and painters.

Recruitment by the random selection was not possible as management could not allocate the necessary time for men in busy parts of the yard. Instead the controls were invited to volunteer by shop stewards, supervisors of the different departments and advertisement at the yards. Only Caucasian male workers who were aged 18 - 45 years were accepted; their total number at the start of the survey was 2088 workers and the proportion who attended in the different age

groups was in the range of 6% to 10%; the number analysed was 181 (table 3).

#### 4.1.3 Exploratory study

This included the following steps:

1. Meetings with trades Union representatives (including shop stewards), managers, safety officers, and occupational health physicians. In these meetings the aim and the proposed plan of work were explained. Discussions were undertaken to clarify points related to running of the work. Their opinions and predictions on the difficulties that could be encountered were taken into consideration. Also, permission for visiting the four yards were obtained.
2. Exploratory visits were made to the shipyards. The purpose of these visits was to acquaint the author with the industry and to provide an opportunity for close observation of different occupations in the different departments of the yards.

#### 4.1.4 Pilot study

Before starting to examine the workers, a pilot study was undertaken. The main purposes of this step were:

1. To test the efficiency of the questionnaire forms and to reveal any modification which was needed.



2. To estimate time needed to interview and examine the workers.
3. To be acquainted with the various difficulties that could be met with at the execution of the study, so as to avoid them and/or to deal with them.

In this pilot study 20 workers from different departments at Hebburn shipyard were examined. The following points emerged:

1. Interview, clinical examination and investigation of each worker took on the average two hours.
2. The procedures should be split between two days with not more than 5 working days between.
3. Up to six workers could be seen on each working day.
4. Three other test operators would be needed to help the author collect survey information in the time available.
5. The occupational questionnaire was modified, and a few questions were added.

#### 4.1.5 Sources and methods of data collection

##### I- Records in the personnel department:

Computer lists including personal details of the workers were scrutinized. Transfer sheets were used to obtain data such as trade of the worker, his name, his works number, and his date of birth.

## II- Workers

Data were collected from the selected workers by:

### 1. Questionnaires:

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Each worker was asked a questionnaire on respiratory symptoms and smoking habit, on occupational history, and on cough frequency.

#### a. MRC questionnaire on respiratory symptoms (Appendix A)

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Respiratory symptoms were recorded using the 1976 version of the MRC questionnaire on respiratory symptoms (MRC 1960,1976). The questionnaire had been tested in a variety of different conditions and had been shown to be a reproducible and accurate way of collecting such information (Morgan et al 1964; Holland et al 1966; Lebowitz et al 1976; Samet et al 1978; Ferris et al 1978).

The first page of the questionnaire commenced with the name of the worker, his address, sex, date of birth, civil state, and occupation followed by the name of the interviewer and date of interview.

The second page contained questions on respiratory symptoms such as cough, phlegm production, breathlessness, wheezing, bouts of asthma. Also it contained questions on diseases of the lung, of the chest wall, of the heart, and on hay fever.

The questions on coughing and expectoration (i.e one through

six) referred directly to simple chronic bronchitis. The diagnosis of simple chronic bronchitis was established when the subject answered yes to question three and question six, the diagnosis of cough was established if the subject answered yes to questions 1 and 2, and the diagnosis of phlegm was established if the subject answered yes to questions 4 and 5.

The questions on periods of cough and phlegm (7a & 7b) referred to severity of the disease; questions on chest illnesses (11a, 11b & 11c) referred to recurrent mucopurulent bronchitis (MRC 1965).

The questions on wheezing (9a, 9b, 10a, & 10b) were aimed at providing information about bronchial asthma, and where asthma was established, the worker was also asked at what age it first occurred and its final occurrence. The diagnosis of wheeze was established if the subject answered yes to questions 9a & b.

Question eight and its subdivisions were aimed at providing information about breathlessness and its grading. Grade 1 was established if the subject answered no to question 8a and grade 4 was established if he answered yes to question 8c.

Questions 12 and its subdivisions on previous illnesses such as injuries or operation on the chest, heart troubles, bronchitis, pneumonia, pleurisy, pulmonary tuberculosis, bronchial asthma, and hay fever were aimed at finding particular causes for bronchitis and to reveal whether

breathlessness was due to pulmonary or cardiac causes.

In the analysis the respiratory symptom variables, cough, phlegm, wheeze, bronchitis and asthma were used as dummy variables where score 1 was given if the symptom was present and score 0 was given if it was absent.

The third page of the questionnaire contained information on smoking habits (13 through 21). All the nine questions were about inhalation of the smoke, the age the subject started smoking regularly and amount of tobacco consumption. Current smokers were asked if they had been cutting down smoking over the past year and the reason for that. A worker was considered a smoker if he had smoked at least one cigarette daily for as long as a year. Exsmokers were those who had given up smoking for at least six months prior to the date of examination.

Other questions were added to the questionnaire on the possible occurrence of head cold in the past eight weeks, on personal and family allergy, and on physical activity outside working hours.

**b. Questionnaire on occupational history (Appendix B)**

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This questionnaire was used to obtain information about duration and intensity of exposure to welding fumes, and to establish indices for exposure.

Questions one and two were asked to all workers, and they



referred to exposure to welding fumes in the yards in general.

Questions three and four and its subdivisions were directed to the welders. Question three referred to duration in years the welder had been doing welding; while question four and its subdivisions referred to types of welding.

Question five through eight were directed to caulker/burners. Question five referred to duration in years the worker had been caulking/burning. Question six and seven referred to proportion of time the worker had been doing caulking and/or burning. Question eight referred to the proportion of time the worker had spent doing buffing.

Questions nine through 15 were directed to both trades. Questions nine through 11 referred to proportion of time the worker had spent in open, semiconfined, and in confined spaces. Questions 14 and 15 and its subdivisions referred to proportion of time the worker had spent in the shed and on the ship. Questions 12 and 13 referred to the use of dust extraction and whether it was used on each job or on certain jobs.

Questions 16 through 18 referred to asbestos exposure.

Question 19 and its subdivisions referred to exposure to dusts other than welding fumes.

Question 20 and its subdivisions referred to keeping animals

and birds at home.

c. Question on cough frequency (Appendix C)

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In normal persons cough is an occasional event during the day. Cough is due to irritation of the mucous membrane anywhere in the respiratory tract. It is most commonly an indication of infection of the airways or lung parenchyma. Other important causes are cigarette smoking (especially in the morning) and occupational exposure to irritant dust and environmental pollution.

Cough is a graded symptom, so information about its frequency and severity is an important tool in occupational respiratory survey to compare different groups of workers. A quantitative estimate of cough frequency was introduced by Field in 1974. This was adapted from a technique for grading psychiatric symptoms developed by Ingham (1965).

This was based on the theory that if a number of statements describing different severities of cough can be ranked in a unique order according to severity, then certain pairs from these statements can be chosen such that the midpoint between two statements can also be uniquely ordered. The midpoint between two statements determines whether the subject will select the weaker statement or the stronger one.

A series of six statements describing cough frequency and severity in general terms was used (Appendix C). Pairs of

statements were chosen to give a suitable scale (Field 1974). The chosen pairs of statements were printed on plain cards, one pair of statements to each card. The two statements on each card were given numbers 1 & 2. On some cards the weaker statement appeared first; on others the stronger appeared first. Each card was given a number on the reverse side equal to the position of the midpoint of its pair of statements on the scale.

The worker was instructed to select the statement which most closely resembled his cough.

The cards were shuffled face downwards and the deck was cut until card number four or five appeared on the top. The cards were presented in turn from the top of the deck and workers' answers were recorded in a score sheet.

The score sheet comprised three rows and nine columns. The top line represented the numbers of the cards (the midpoints). For each card there was two boxes, situated one below the other, numbered 1 & 2. These numbers indicated the first and second statements on the card. The corresponding boxes were crossed according to the statements selected from each card. All the stronger statements appeared on the bottom line, while the weaker ones appeared on the middle line. This format permitted the score to be read directly from the score sheet and showed any inconsistency in the responses. The score was indicated by the number of the card at which the responses crossed over to the upper line. Only

one shift point appeared. More than one shift point indicated that the worker was not consistent in his answers. For score nine all answers occurred on the bottom line, while for score one all answers occurred on the middle line.

Cards from a second set, including the cross over point, were presented again to the worker as a check on his consistency. The responses on the second presentation were recorded as the actual score.

## 2. Anthropometric measurements

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Body measurements were made using standard equipment and procedures (Cotes 1979).

### Equipment

The following equipment was used:

- A Harpenden stadiometer fixed to the wall of the mobile laboratory.
- A high flat-topped stool.
- A standard weighing machine.
- A Harpenden skin caliper.
- A Harpenden anthropometer.

The stadiometer was calibrated frequently during the survey period using a metal rod of known length. The weighing machine was calibrated by using known weights.

### Method

The worker was asked to strip to the waist and to remove his



headwear and footwear.

The standing height was measured with the subject standing erect and as tall as possible, with the feet together, and the heels, calf, buttocks and back touching the stadiometer. The observer then applied gentle upward traction to the angles of the mandibles.

The sitting height was measured by the same procedures but with the subject seated on a stool with the buttocks relaxed.

The skin folds were measured using a Harpenden skin caliper (Holtain). Measurements were made on the left side of the body at four sites: over the midpoint of the front and back of the upper arm (over the biceps and triceps areas), below the angle of the scapula, and just above and medial to the anterior superior iliac spine. The sites were marked with a skin pencil. Skin fold at the defined area was picked up between the thumb and the forefinger; a reading was taken two to three seconds after the caliper had been applied.

Weight was obtained in pounds and later was converted into kilograms by the computer.

Fat free mass (FFM), and body fat as percentage of weight (%Fat) were obtained from the weight and skin fold measurements. The %Fat was obtained from a regression equation based on the sum of the four skin fold measurements (Durnin & Womersley 1974).

The FFM was estimated from weight and %Fat as follows:

$$\text{FFM} = \text{Weight} * (100 - \% \text{Fat}) / 100 \text{ (Kg)} \text{ (Cotes 1979)}$$

### 3. Single breath nitrogen test

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#### Equipment (photo 1)

The following equipment was used:

- temperature and relative humidity chart.
- cylinders containing 100% O<sub>2</sub>.
- mouthpieces
- Hewlett-Packard pulmonary computer system model 47804A.

#### Description of the computer:

It is composed of a nitrogen meter, pneumotachograph coupled to a transducer, A/D converter and a calculator. A numeric identifier code and analog signals from nitrogen concentration, volume and flow were converted to digital data by an A/D converter (H-P 47310A) and fed to a H-P 9825a computer. Flow and volume signals were obtained from a pneumotach<sup>o</sup>graph (H-P 21073 A/B), coupled to a H-P 47304A transducer. Nitrogen concentration was sensed by an H-P 47302A nitrogen analyser.

Data were fed on line to the calculator. At the end of the test a print out showing a nitrogen washout trace and ventilatory changes against time were obtained using H-P 9871A printer. The curve showed the estimated point of onset of phase IV and the regression line through the alveolar plateau (fig 9).

The onset of phase IV was determined by examination of the slopes (N<sub>2</sub>% change per volume change) at intervals along phase III. It began at 30% of expired VC (EVC), and examined all the

data points between 30% and 60%, and a regression line was determined. Then this line was extrapolated to 80% EVC and all data points between 60% and 80% EVC were compared with this line to reveal whether the data points deviated from the regression line. A permanent departure was defined as an upward deviation of the data points from the extrapolated line greater than three times the height of the cardiogenic oscillations. If the oscillations were small (less than 0.3% N<sub>2</sub>), an upward deviation which was maintained over more than 10% of the EVC was regarded as a departure.

Once a departure point was found the programme worked back, starting at the end of the interval, examining each data point until a point within 0.3% N<sub>2</sub> of the regression line was found. This point was considered as the onset of phase IV.

If no departure point was found, the beginning and end points for the regression line were extended by further 10% increments and the procedure was repeated until a departure was found or the end of the curve was reached. If no departure point was detected, a closing volume of zero was recorded.

The slope of the regression line between 30% EVC and the onset of phase IV, or if there was none, to the end of the trace was recorded as the slope of phase III.

The nitrogen difference index (N<sub>2</sub> diff) was determined by measuring N<sub>2</sub>% difference between 1250ml and 750ml of EVC.

TLC was calculated from the volume inspired and nitrogen concentration in expired and initial gas (Craven et al 1976):



$$TLC = [(VI * FAN_2) - (VD * FAN_{2T})] / (FAN_2 - FAN_{2T})$$

where

-VI was the volume inspired.

-FAN<sub>2</sub> was the inspired alveolar N<sub>2</sub> concentration.

-FAN<sub>2T</sub> was the mean expired N<sub>2</sub> concentration.

-VD was the predicted dead space (Hart et al 1963).

The RV was calculated from TLC and VC. CV was expressed as per cent of VC (CV%); CC was the sum of CV and RV and it was expressed as per cent of TLC (CC%).

#### Calibration:

The calibration routine was arranged internally so a series of procedures was offered for checking and calibrating different parts of the system.

Temperature, pressure and relative humidity of the examination room were fed to the computer each morning and this was repeated three times a day.

The 47302A Nitrogen analyser was adjusted daily to compensate for the ambient nitrogen concentration. This was performed by adjusting the needle valve, which regulates the vacuum to the nitrogen detector, and the front panel GAIN control.

The 47304A Flow Transducer (Pneumotach<sup>o</sup>graph) volume was checked three times each day using a one and a half litre syringe to examine its accuracy.

#### Method

The single breath nitrogen test was performed using the Anthonisen's modification (Anthonisen et al 1969) of the Fowler



single breath nitrogen test (Fowler 1949), except that no breath holding was allowed between inspiration and expiration. Inspiratory and expiratory flows were controlled voluntarily by the worker to be between 0.3 and 0.5 l s<sup>-1</sup> by having him observe a meter display of the flow tracing. The test procedure was explained to the worker, and the worker performed a test with the machine switched off to become accustomed to the breathing manoeuvre. The manoeuvre was performed as follows:

A worker seated quietly, breathed through a mouthpiece in a relaxed way. During these first preliminary breaths the calculator computed the average tidal volume and established the end-tidal baseline. When the base line was fixed, the worker was asked to continue the current relaxed expiration all the way out to the residual volume level. During this expiration, the inspired gas was switched automatically to oxygen, when the subject exhaled one half of his tidal volume below the end-tidal base line. From RV the subject inspired 100% O<sub>2</sub> slowly to TLC, then without breath holding, the subject expired slowly to RV. The worker was encouraged by the operator to perform the test in a correct way.

A curve was accepted if the following criteria were fulfilled (National Heart and Lung Institute 1973):

- expiratory and inspiratory flow rates were below 0.5 l s<sup>-1</sup>,
- no breath holding,
- difference between inspired and expired VC was less than 5%,
- differences in EVC between blows did not exceed 10%,

-no step change in the expired  $N_2$  concentration with continued oscillations after the step.

The graphical outprint of the  $N_2$  washout curve and volume changes against time allowed the author to assess the quality of performances.

A minimum of three tests and a maximum of seven were performed. On average each subject performed five tests. A two minutes rest between each blow was allowed. The best three traces (with largest EVC), were chosen. The mean of the three values for each measurement was recorded as the final value. When only two acceptable traces were obtained, the mean of the two values was chosen. When only one acceptable trace was obtained, the worker was discarded from the series.

All workers were asked to do the single breath nitrogen test ( $n= 513$ ). 30 workers failed to attend. 77 workers found the test difficult and could not produce acceptable traces. Data on five workers were rejected because the traces were not readable. Therefore, the actual number of valid cases was 401. Of the 112 workers, 81 were target workers (44 caulker/burners and 37 welders) with mean age of 33 years and mean  $FEV_1$  of 3.98 l, and 31 controls with mean age of 31 years and mean  $FEV_1$  of 3.99 l (table 4). The characteristics of these workers and those of the subjects seen were compared in Appendix B.

#### 4. Measurement of forced expiration and MEFV curves

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##### Equipment (photo 2)

The following equipment was used:

- disposable cardboard mouthpieces, a nose clip, and tubing,
- X Y plotter (JJ Instruments type PL200),
- McDermott spirometer (McDermott & McDermott 1977).

The spirometer had a polythene bellows of 10 litres capacity. The bellows drives a potentiometer from which a voltage proportional to volume changes is fed into the microprocessor which has a digital display. The spirometer was operated from re-chargeable batteries. The microprocessor had two outputs, one to a X-Y plotter and the other to a mono tape cassette recorder. The signals recorded on the tape cassette records were fed into a H-P programmable calculator (type 9830A) for calculation of flow and volume.

At the end of each blow, the observed and calculated values of FVC and  $FEV_1$  and the calculated values of  $PEFR$ ,  $\dot{V}_{max50}$ , and  $\dot{V}_{max25}$  were displayed sequentially and were recorded by the operator. The flow volume curve was then displayed on the X-Y plotter.

The flow volume curve traces and the observed values of FVC were used to assess the quality of performances.

The spirometer was calibrated before each session using a calibration orifice and a standard weight; the equipment was

adjusted for changes in the room temperature.

### Method

The worker sat on a high stool, with loose neckwear and his nose was clipped. The test procedure was explained to him by the operator. The worker inhaled maximally to TLC from the room air, then exhaled as fast and as hard as possible through the mouthpiece till he reached RV. The worker was encouraged by the operator during the blow. At least five blows were obtained on each worker. A rest period of two minutes was allowed after each blow. The highest value for each measurement on the different blows was recorded as the final value for the measurement. The following were the criteria for valid blows: the FVC did not differ from the largest FVC by more than 5%, the PEFR did not differ from the largest one by more than 10%, and the selected curves had similar overall shape.

### 5. Measurement of the transfer factor

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The transfer factor for Carbon Monoxide for the lung ( $T_{lCO}$ ) was measured by the single breath method (Cotes 1979).

#### Equipment (photo 3):

The Morgan automated transfer test apparatus was used. It consists of the following parts:

- a carbon monoxide analyser,
- an oxygen analyser,
- a helium analyser,



- an eight litres dry spirometer,
- a programmable controller unit,
- a motorized valve box assembly carried on a tripod stand. It had multiple connections to the spirometer, to the gas analysers, to the test gas cylinder, and to the room air. It contains an inspire bag and an expirate sample collector bag. The selector tap on the valve box assembly can be set to different positions, and was automatically controlled by the programmable controller,
- a pump on the carbon monoxide analyser. This was used to draw gas through the apparatus at a rate of  $0.5 \text{ l min}^{-1}$ .,
- tubes containing calcium chloride and soda lime to remove  $\text{CO}_2$  and water vapour,
- test gas cylinders (containing gas mixtures of 14% Helium, and 0.28% CO diluted in room air).

The gas analysers were calibrated and checked for linearity, and the spirometer was checked for leaks frequently during the course of the survey.

#### Method

The test procedure was explained to the worker; he sat in position and the nose was closed by a nose clip. The valve box was adjusted to a convenient height for the worker. He breathed normally through the mouthpiece for a few breaths to become accustomed to breathing onto the valve box. Then he made a complete expiration to residual volume, inhaled a vital capacity breath of the test gas from the inspire bag held his breath for 10 seconds, and exhaled to his residual volume. As soon as the

indicated volume of dead space washout (900 ml) had been achieved, the selector tap was switched automatically to sample collection position and a 900 ml sample of the alveolar gas was collected in the expirate sample collector bag. The alveolar gas from the expirate bag was drawn through the analysers at a rate of  $0.5 \text{ l min}^{-1}$ .

The operator recorded concentration of Helium, Carbon Monoxide, and Oxygen, and the digital displays indicating effective inspired and breath hold time.

The volume changes which were recorded on the kymograph were used to assess the quality of the measurement.

After a rest period of about 10 minutes the worker performed another Tl test.

The  $T_{lco}$  was calculated using the following formula (Cotes 1979):

$$T_{lco} = 53.6 * V_A/t * \text{Log}[(F_{I,co} * F_{A,He}) / (F_{I,He} * F_{A,co})]$$

$\text{mmol min}^{-1} \text{ KPa}^{-1}$ .

where

- $V_A$  was the effective alveolar volume,
- $t$  was the breath hold time,
- $F_{I,co}$  was the fractional concentration of inspired CO,
- $F_{A,co}$  was the fractional concentration of alveolar CO,
- $F_{I,He}$  was the fractional concentration of inspired He,
- $F_{A,He}$  was the fractional concentration of alveolar He,
- 53.6 was a constant which allows  $T_{lco}$  to be calculated in  $\text{mmol min}^{-1} \text{ KPa}^{-1}$ , from measurements of volume made in litres BTPS,

time in seconds, and gas concentrations in fractions. The constant also includes a factor that converts natural logarithms to logarithms to base 10.

## 6. Exercise tests

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### Equipment (photo 4)

The following equipment was needed:

- a calibrated cycle ergometer (Ergomed 740 Siemens),
- Mouthpieces, nose clip, and tubing.
- a respiratory plastic two-way flap valve (Lloyd) which had low resistance and 0.05 litre dead space,
- a rotatory vane anemometer for recording ventilation; it was attached to a microprocessor with a digital display (Ventilation monitor Morgan),
- a mixing chamber for expired gas,
- gas analysers: a paramagnetic meter for oxygen, and an infra red analyzer for carbon dioxide (PK Morgan Ltd).
- a computer for on line recording and presentation of results (Morgan Dragon),
- a cardioscope for visual display of heart beats during exercise (Rigel SM801),
- a 1-lead monitor electrocardiograph (Devices),
- an ECG recorder with 12 leads,
- prejelled disposable electrodes (Silver/Silver chloride 888),
- Sphygmomanometer and a stethoscope,

-Resuscitation equipment such as defibrillator, syringes and drugs.

The output from the anemometer,  $O_2$  and  $CO_2$  gas analysers, together with ECG signals were fed on line to the computer. These measurements together with  $\dot{V}O_2$ ,  $\dot{V}CO_2$ , and gas exchange ratio (R) were printed out each half a minute during the exercise. At the end of the test, graphs were printed out relating  $\dot{V}_E$ , fC, R to  $\dot{V}O_2$  and  $V_t$  to  $\dot{V}_E$ .

The intermediate results were used to determine when exercise should stop, to assess the quality of the performance of the worker, and to derive by interpolation the  $\dot{V}_E$  and fC at 45 mmols of  $\dot{V}O_2$ .

#### Calibration procedure:

The anemometer was checked before each exercise session using a calibrated syringe. One litre of gas was ejected through the mouthpiece four times at different flow rates. The value displayed at the ventilation monitor was checked each time. This procedure was repeated till repeatable results were obtained at different flow rates.

$O_2$  and  $CO_2$  analyzers were calibrated initially using gas mixture made up with a Wösthoff pump: the calibrations were checked before each period using a standard gas mixture (Approximately 16%  $O_2$  and 4%  $CO_2$  in nitrogen).

The resistance to the flow of gas for the whole system was less than 2 cm H<sub>2</sub>O at flow rate of 85 l min<sup>-1</sup>.

#### Method



The worker was taken to the examination room and a medical history was obtained concentrating on certain points such as activity related symptoms, medication, and hospital admissions. Blood pressure was measured. Then the worker was asked to strip to the waist and to remove his watch and neck chain. Then his heart and chest were examined and a 12 lead ECG was recorded and scrutinized by the author. Workers were not allowed to take the exercise test if one or more of the following were found:

- a history of angina pectoris or myocardial infarction,
- a history of organic cardiac disease e.g heart failure,
- the worker had heart disease e.g mitral stenosis,
- the ECG revealed ischaemic changes, or evidence of organic cardiac abnormalities,
- the worker had been taking hypotensive drugs, or had a high blood pressure.

The worker was then taken to the exercise room, where the test was explained to him and the equipment was described in simple words chosen to minimise apprehension. Then, he sat on the cycle ergometer and the saddle height was adjusted to ensure a comfortable cycling position. The electrodes were applied and connected to the cardioscope and ECG monitor recorder. A CM5 lead was recorded and scrutinized during the test. The ECG recorder had a time device which marked the ECG every minute. The fC was measured from the recorder output. The ECG was displayed on the cardioscope's screen all the time during the test, this enabled the author to monitor the rhythm and to spot

any ischaemic changes that might occur.

The test was performed as follows:

The worker breathed through the mouthpiece for two minutes, with the nose clip on, and without pedalling. Then he pedalled for one minute at a zero load to obtain the necessary pedalling frequency (60 per minute), and to become accustomed to breathing through the valve. At this point a work rate of 15 W was imposed. At the end of each minute the work rate was increased by an equal amount. The worker stopped pedalling when exchange ratio exceeded R1.0.

The exercise test was stopped if one or more of the following was met with:

- the worker felt severe pain in the chest,
- the worker felt severe breathlessness,
- the worker became dizzy or giddy,
- the worker felt severe pain in the legs
- if the ECG revealed one or more of the following:

- \* frequent ventricular ectopics of six or more per minute,
- \* frequent runs of three or more of ventricular ectopics,
- \* atrial fibrillation if was absent at rest,
- \* depression of ST segment (more than 2 mm),
- \* inversion of T wave or appearance of Q wave,
- \* appearance of bundle branch block pattern

All workers over the age of 25 years were invited to perform the exercise test (345 workers). 45 workers failed to attend to do the

test, and four subjects were rejected due to health problems (e.g ECG abnormalities or hypertension).

The actual number of workers who performed the progressive exercise test was 296. Data on ten workers were rejected because of equipment problems. Therefore, the valid number of cases for the exercise test were 286. Of the 59 workers, 22 workers were controls with mean age of 31 years and mean FEV<sub>1</sub> of 4.00 l, and 37 target workers (23 welders and 14 caulker/burners) with mean age of 37 years and mean FEV<sub>1</sub> of 3.88 l (table 5). The characteristics of these workers and those of the subjects seen were compared in Appendix B.

## 4.2 STATISTICAL DESIGN

### 4.2.1 Steps in preparation and analysis of the data

The following steps were followed to handle the raw data, to establish indices for exposure to welding fumes and to analyse the data:

#### 1. Data preparation

At the end of the field work, the raw data were coded and transformed into coding sheets. The results were checked by a second person. The data were placed into IBM 370 computer files by direct typing on a terminal. Two persons at the university computing laboratory, separately, typed the data into the computer files, then the output files were checked against each other for typing mistakes. The raw data files were transformed

into SPSSx system files, where the SPSSx programmes were used to analyse the data (Nie, 1983). Different statistical procedures (e.g means and standard deviations, frequencies, scattergram and listing of cases) were used to check the validity of the data and to spot any error.

## 2. Measurement of exposure to fumes

Preliminary enquiry had shown that the fume concentrations in confined and semiconfined spaces were higher than that in open spaces, and higher on the ship than in the shed, so the following indices of frequency and severity of exposure to fumes were obtained from the occupational questionnaire:

### a. EVER WELDER or CAULKER/BURNER (WCB)

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This index was obtained from the answers of the worker: YES or NO to job welder or caulker/burner. This index was used to compare welders and caulker/burners with other tradesmen.

### b. EXPOSURE1

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This index was defined as duration of exposure of a welder (W1) or a caulker/burner (CB<sub>1</sub>) in confined and semiconfined spaces. It was expressed mathematically as:

EXPOSURE1= duration of exposure to fumes \* ( percentage of working time spent in confined and semiconfined spaces)/100.

This index was used to study the association between



occupational exposure and lung function impairments. The units of measurement were years.

c. EXPOSURE2

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This index was defined as duration of exposure of a welder (W2) or a caulker/burner (CB<sub>2</sub>) to fumes on the ship. Workers who had been working mainly on the ship were given score one, and those who had been working mainly in the shed were given score zero. The index was expressed mathematically as follows:

EXPOSURE2 = duration of exposure to fumes \* (score 1 or 0).

This index was used to compare welders who had been working most of their time on the ship to those who had been working mainly in the shed. The same applied to the caulker/burners. The units of measurement were years.

In order to assess the accuracy of the answers of the workers, 21 workers were asked the occupational questionnaire on two occasions. The mean values of the indices obtained on the two occasions were compared and scattergrams were plotted (Appendix B)

### 3. Statistical analysis of the data

a. Descriptive statistics:

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Personal characteristics of the workers expressed as means

and standard deviations, as well as prevalence of respiratory symptoms among the target and control workers were calculated. These results were presented as bar charts and histograms. The results from multiple regression analyses were presented as regression equations (tables) and as line graphs of the different dependent variables on age.

b. Independent variables used in the analysis:

-----

The different independent variables used in the analyses were:

- 1) age (years),
- 2) height (mm),
- 3) smoking as a dummy variable (smoker and exsmoker= 1, life long nonsmoker= 0),
- 4) WT (weight/height<sup>2</sup>): as weight and height were highly correlated weight was included in the analysis as weight/height<sup>2</sup> so as to make it independent of height.
- 5) exposure index ever a welder or a burner (WCB) to compare the target and control subjects (WCB= 1, control= 0),
- 6) W<sub>1</sub>(exposure of the welders in confined spaces "years"),
- 7) CB<sub>2</sub> (exposure of the caulker/burners on the ship "years"),

- 8) FFM (kg),
- 9) inactivity score ( inactive "ACT"= 1, active= 0),
- 10) interaction term between age and WCB (AWCB),
- 11) interaction term between smoking and WCB (SWCB),
- 12) Interaction term between age and  $W_1$ (AW1),
- 13) interaction term between smoking and  $W_1$ (SW1),
- 14) interaction term between age and  $CB_1$  (ACB<sub>2</sub>),
- 15) interaction term between smoking and  $CB_1$  (SCB<sub>2</sub>)

c. Dependent variables used in the analysis:

-----

- 1) Respiratory symptoms: cough, phlegm, wheeze, bronchitis, and asthma (as dummy variables) and breathlessness score (1 - 4).
- 2) Lung function indices: TLC (l), FVC (l), FEV<sub>1</sub> (l), FEV<sub>1</sub>%, PEFR (l s<sup>-1</sup>), RV%,  $\dot{V}_{max50}$  (l s<sup>-1</sup>),  $\dot{V}_{max25}$  (l s<sup>-1</sup>), CV%, CC%, SLIII (N<sub>2</sub>% l<sup>-1</sup>), N<sub>2</sub> Diff (N<sub>2</sub>%), T<sub>lco</sub> (mmol min<sup>-1</sup> KPa<sup>-1</sup>), K<sub>co</sub> (mmol min<sup>-1</sup> KPa<sup>-1</sup> l<sup>-1</sup>),  $\dot{V}_{e45}$  (l), f<sub>C45</sub> (beat min<sup>-1</sup>), and V<sub>T30</sub> (l).

d. Analytical statistics:

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**Model of statistical analysis**

Multiple regression analysis (MRA) was used to investigate the association between occupational exposure and lung function impairment and respiratory symptoms. The relevant lung function index or respiratory symptom variable was the dependent variable and the index of exposure was the predictor variable.

Lung function was very dependent on age and stature and was affected by smoking. Therefore age, stature and smoking were included in the analysis as control independent variables.

**Allowance for interaction:**

interaction is present when the effect of a predictor variable on a dependent variable is influenced by the magnitudes of other predictor variables. For example the effect of fume exposure on lung function might manifest itself as an increase in the decline with age; similar interaction might occur between exposure and smoking, the exposure effect being greater on smokers than on nonsmokers. Interaction might also occur between smoking and age. In order to test for the presence of these interactions the appropriate multiplicative terms (e.g age \* exposure) were included in the analyses as independent variables. When interaction is present between two variables (e.g exposure



and age) their effects should be considered together.

The regression analysis was performed using the least squares method and the general form of the regression equation for the additive model was as follows:

$$Y' = C + B_1X_1 + B_2X_2 + \dots + B_kX_k$$

where

-Y' was the estimated value for Y (the criterion variable)

-Xs were the independent variables ( $X_1$  through  $X_k$ )

-C was the Y intercept. It was the value of Y when Xs equal zero

- $B_k$  were the partial regression coefficients. The  $B_i$  measured the slope of the regression line i.e the unit change in Y per unit change in  $X_i$  when the rest of the k independent variables were held constant. Also  $B_i$  can be viewed as the simple B for the regression of Y on the residuals of  $X_i$  from which the rest of the k independent variables are taken out. The model with interaction terms in the case of two predictor variables was as follows:

$$Y' = C + B_1X_1 + B_2X_2 + B_3X_1X_2$$

$$\text{if } X_2 = 1$$

$$Y' = (C + B_2) + (B_1 + B_3)X_1$$

$$\text{if } X_2 = 10$$

$$Y' = (C + 10B_2) + (B_1 + 10B_3)X_1$$

thus both the constant term and the slope of Y' on  $X_1$  are affected by the specific choice of  $X_2$ .

The relationships were considered statistically

significant only if they reached the 1 per cent level.

#### 4.3 ADMINISTRATIVE DESIGN

##### 4.3.1 Training

The author underwent training on the methods discussed including lung function tests, MRC questionnaire, reading of 12 lead ECG, scrutiny of exercise ECG, use of defibrillator and the management of cardiac arrest.

##### 4.3.2 Personnel

The author conducted the single breath nitrogen washout test, asked the questions on cough frequency, examined the workers clinically and by electrocardiography to detect any contra indications to their performing test exercise and monitored the ECGs during exercise. Miss NG Bridges asked the MRC questionnaire, the occupational questionnaire and performed the anthropometry, Dr DJ Chinn conducted the forced spirometry and transfer factor test, and Miss JJ Weller performed the exercise test. The field work was conducted under the supervision of Dr JE Cotes and Dr J Reed.

#### 4.4 OPERATIONAL DESIGN

##### 4.4.1 Preparatory phase

This phase covered the period from April 1982 through November 1982.

##### 4.4.2 Phase of data collection

This phase covered the period from November 1982 through July 1984.

##### 4.4.3 Handling of the raw data phase

This phase covered the period from August 1984 through November 1984.

##### 4.4.4 Statistical analysis phase

This phase covered the period from December 1984 through April 1985. During this period the data were statistically analysed using different statistical tools e.g simple and multivariate analyses.

##### 4.4.5 Reporting, writing up, and preparation of the thesis

This phase covered the period from May 1985 into 1986 when the thesis was submitted.

**Table 1: Number of workers at the start of the survey and those who left the yard during the survey period**

		<b>WELDERS</b>		<b>CAULKER/BURNERS</b>	
		<b>available</b>	<b>left</b>	<b>available</b>	<b>left</b>
		<b>(in 1982)</b>		<b>(in 1982)</b>	
<b>41 - 45</b>	<b>59</b>		<b>2</b>	<b>55</b>	<b>30</b>
<b>36 -</b>	<b>54</b>		<b>4</b>	<b>58</b>	<b>38</b>
<b>31 -</b>	<b>54</b>		<b>22</b>	<b>55</b>	<b>36</b>
<b>25 -</b>	<b>143</b>		<b>81</b>	<b>151</b>	<b>70</b>
<b>18 - 24</b>	<b>83</b>		<b>73</b>	<b>75</b>	<b>41</b>
<b>TOTAL</b>	<b>393</b>		<b>182</b>	<b>394</b>	<b>215</b>



Table 2: The current target workers at Swan Hunter Shipyard

	AVAILABLE	EXAMINED	F.T.A	REFUSED	SICK
41 - 45	82	70	7	4	1
36 -	70	54	10	5	1
31 -	51	41	6	3	1
25 -	143	129	9	5	-
18 -	44	38	3	3	-
TOTAL	390	332	35	20	3

F.T.A = failed to attend

Table 3: Distribution of the other tradesmen by age groups

	TOTAL NUMBER	VOLUNTEERS (%)
	(in 1982)	
41 - 45	244	21 (8.6%)
36 -	305	20 (6.6%)
31 -	264	17 (6.4%)
25 -	634	62 (9.8%)
18 -	641	61 (9.5%)
TOTAL	2088	181 (8.7%)

Table 4: Characteristics of the workers on whom no closing volume data were obtained

	CONTROLS	TARGET
41 - 45	8 (25.8%)	19 (23.5%)
36 -	3 (9.7%)	15 (18.5%)
31 -	3 (9.7%)	7 (8.6%)
25 -	8 (25.8%)	28 (34.6%)
18 -	9 (29.0%)	12 (14.8%)
TOTAL	31 (17.1%)	81 (24.4%)
MEAN AGE	30.86 ± 8.93	32.92 ± 7.97
MEAN HEIGHT	175.7 ± 6.40	172.9 ± 6.51
MEAN WEIGHT	74.95 ± 11.3	74.90 ± 11.28
SMOKING		
Sm	17 (55%)	55 (68%)
NSm	14 (45%)	26 (32%)
MEAN FEV <sub>1</sub>	3.99 ± 0.58	3.92 ± 0.66

Table 5: Characteristics of the workers on whom no exercise data were obtained

	CONTROLS	TARGET
41 - 45	2 (9.2%)	12 (32.4%)
36 -	3 (13.6%)	11 (29.7%)
31 -	3 (13.6%)	3 (8.1%)
25 -	14 (63.6)	10 (27.0%)
TOTAL	22 (24.7%)	37 (14.5%)
MEAN AGE	30.94 ± 5.57	37.50 ± 6.57
MEAN HEIGHT	173.06 ± 7.65	174.67 ± 6.53
MEAN WEIGHT	74.02 ± 9.72	72.27 ± 8.92
SMOKING		
Sm	13 (59%)	29 (78%)
NSm	9 (41%)	8 (22%)
MEAN FEV <sub>1</sub>	4.03 ± 0.44	3.87 ± 0.69



Figure 8: COMPUTER OUTPUT FOR THE CLOSING VOLUME TEST

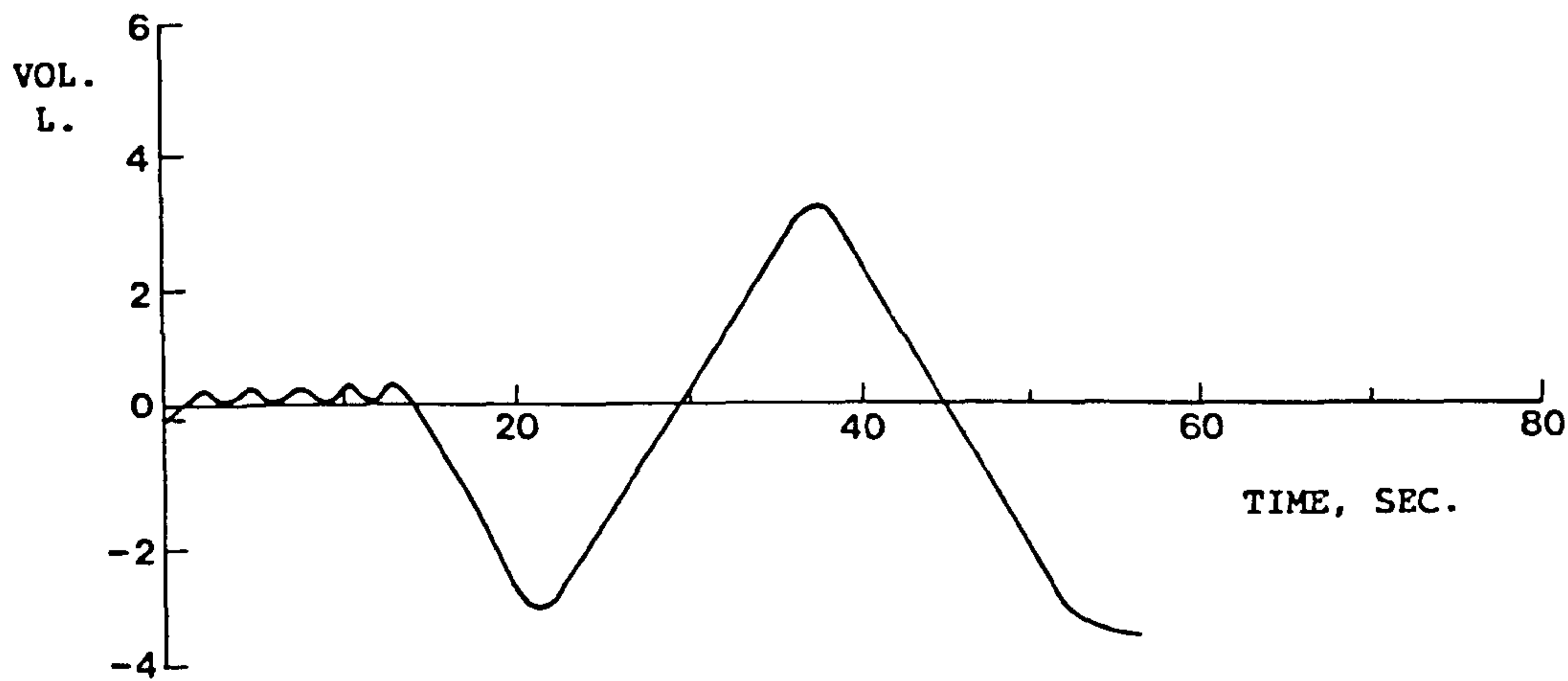
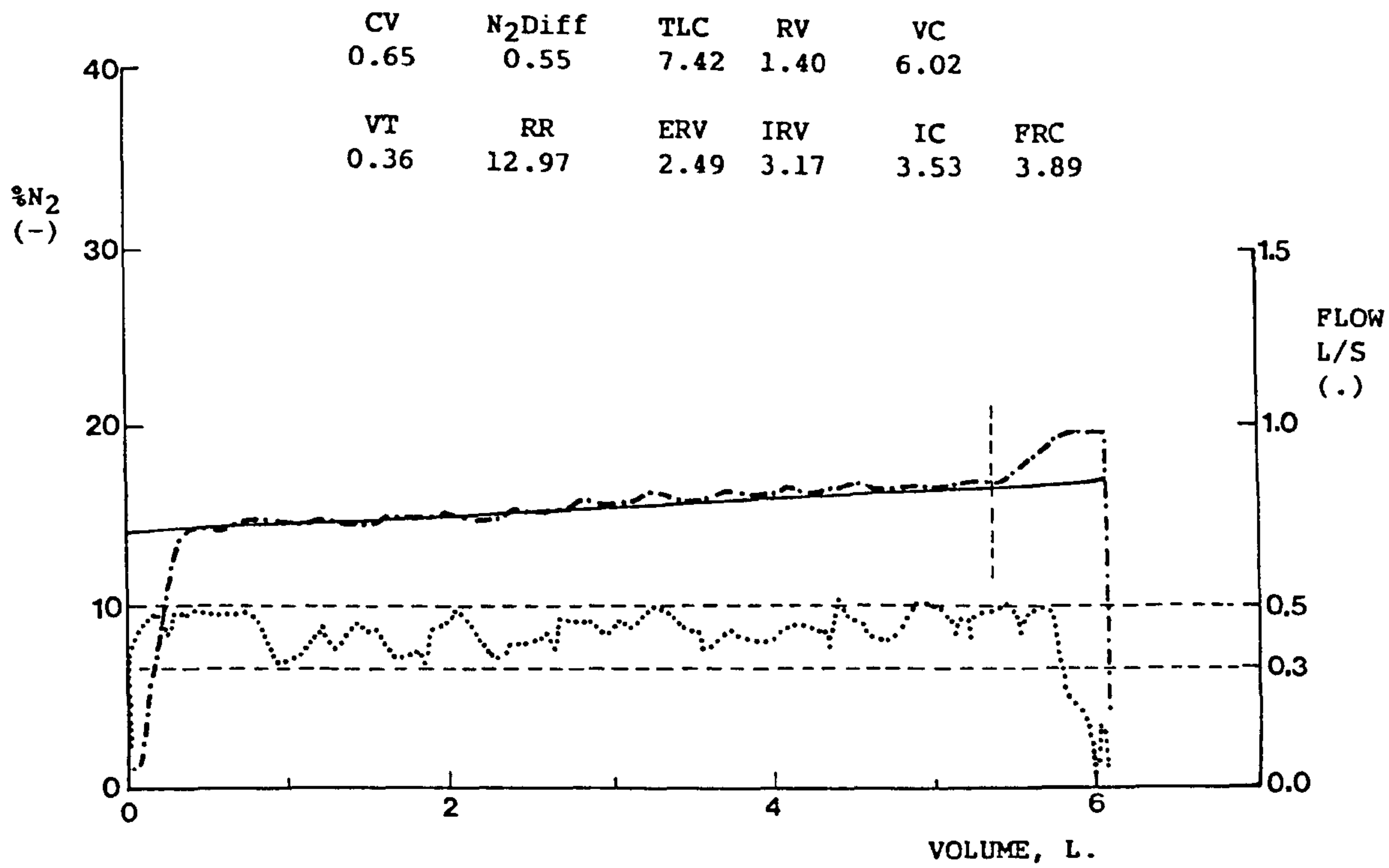




Photo 1: THE SINGLE BREATH NITROGEN EQUIPMENT





Photo 4: THE EXERCISE TEST EQUIPMENT

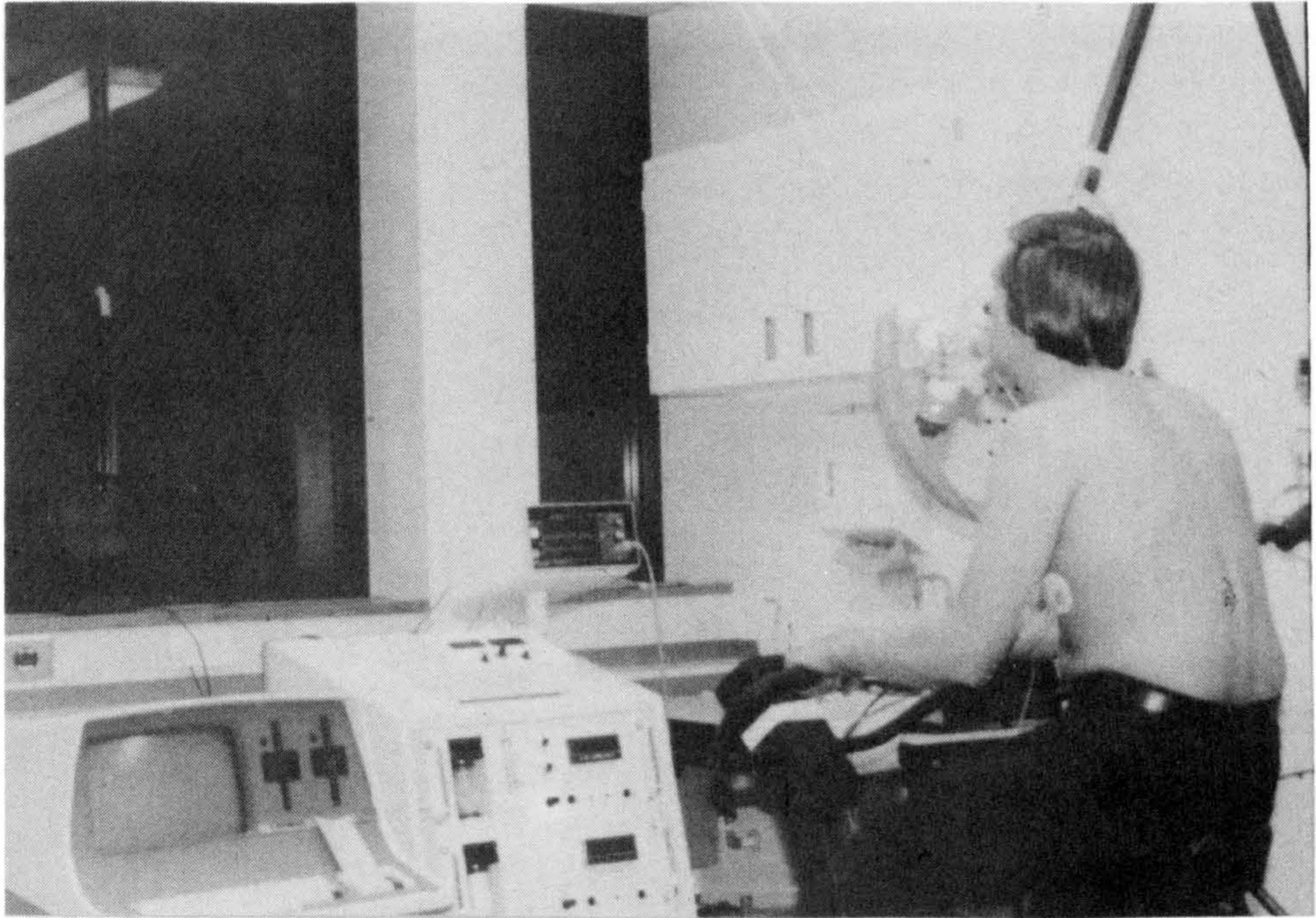




Photo 2: THE MAXIMAL EXPIRATORY FLOW VOLUME CURVE  
EQUIPMENT

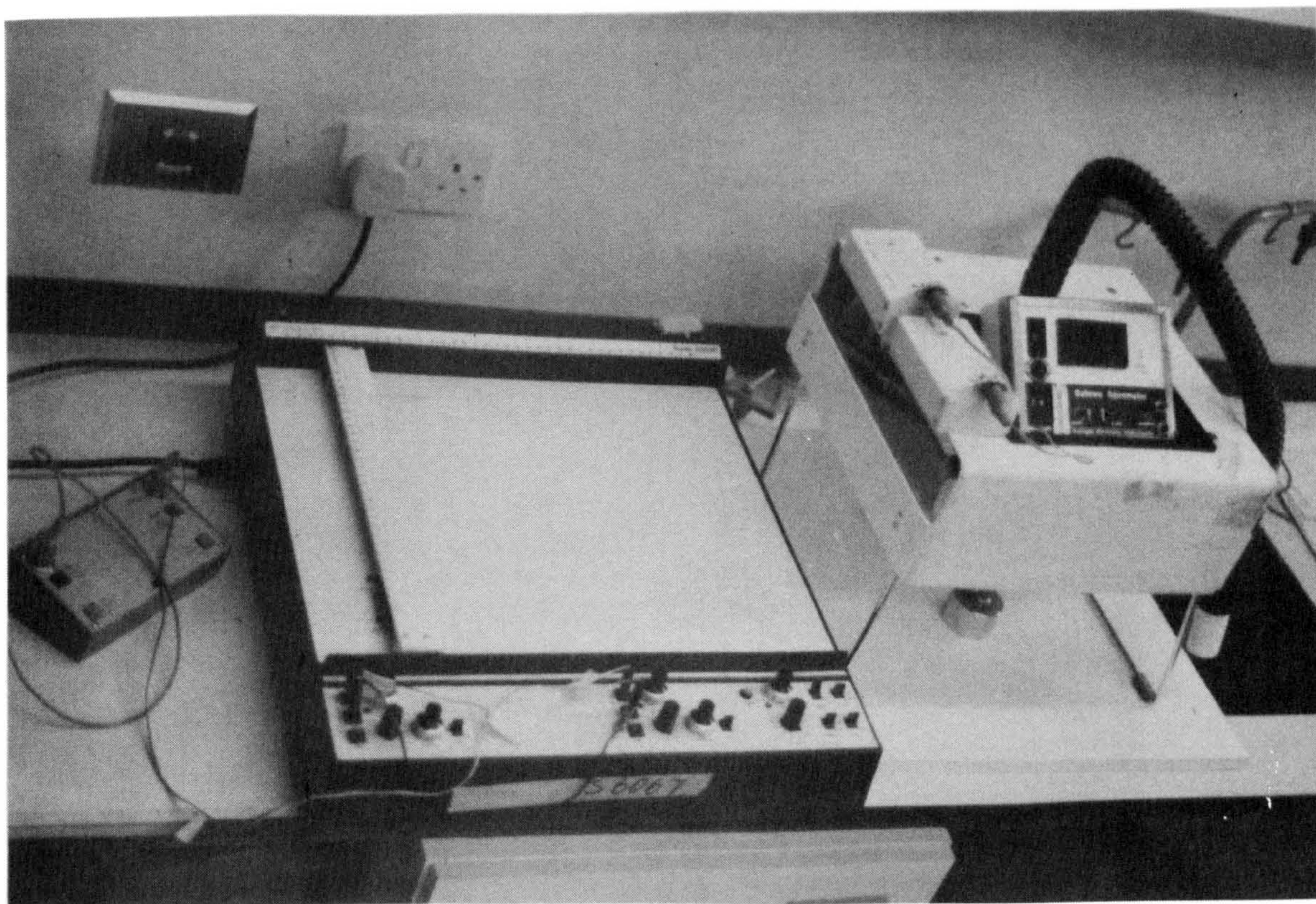
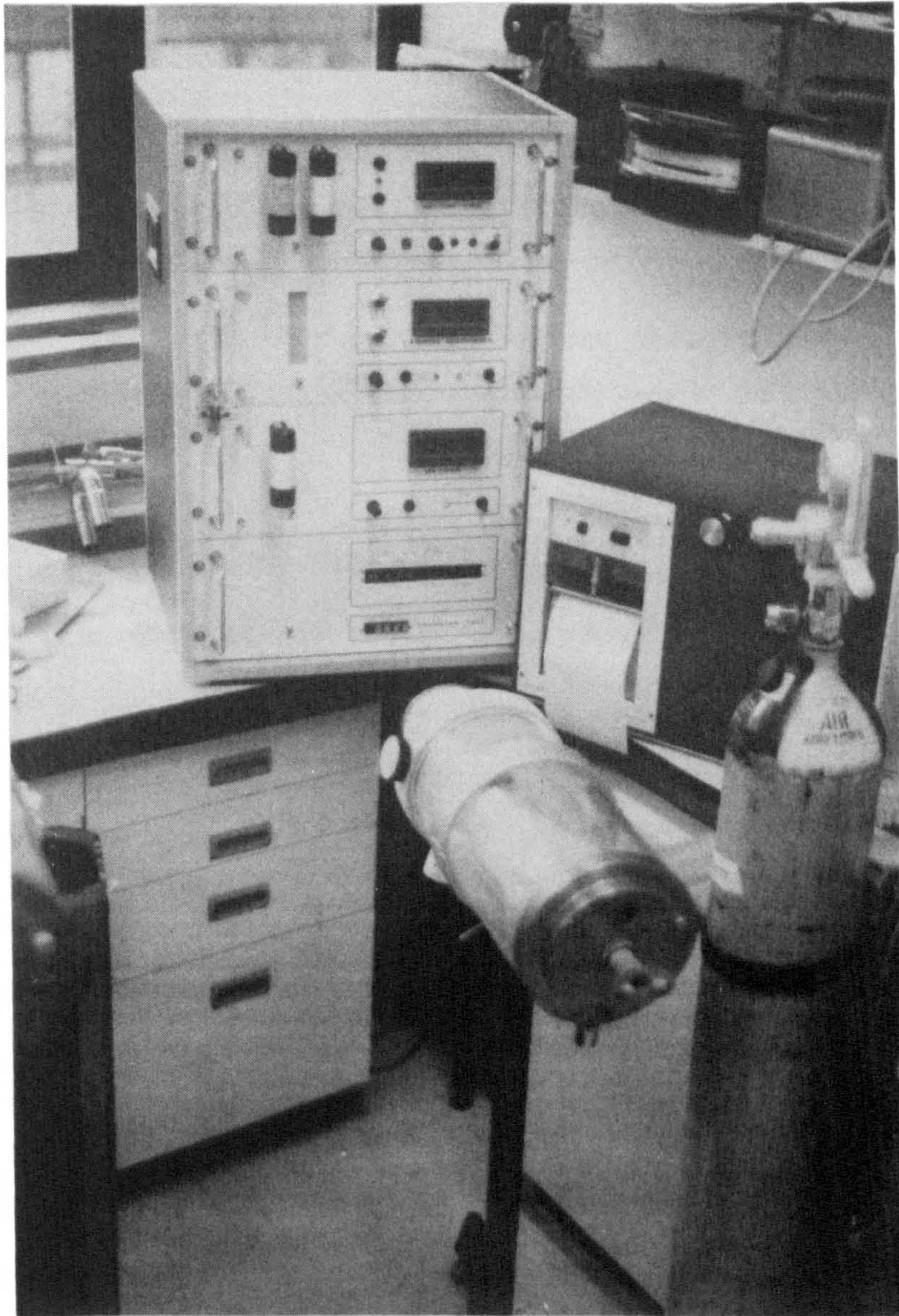




Photo 3: THE CARBON MONOXIDE TRANSFER FACTOR TEST  
EQUIPMENT





CHAPTER 5RESULTS A5.1 DESCRIPTION OF THE EXPOSED AND CONTROL WORKERS5.1.1 DISTRIBUTION ACCORDING TO AGE, BODY DIMENSIONS, TRADE, AND SMOKINGHABIT

The sample comprised a target group of 181 welders and 151 caulker/burners who had been exposed to welding fumes, and a control group of 181 other tradesmen (fig. 10) who had not done welding or burning. They were relatively young males, mean age 31.5 years, age range 18.36 to 47.41 (fig. 9).

Compared with the controls, the welders and caulker/burners were slightly older. The percentage of welders and caulker/burners who were under the age of 30 years was 45.2 compared to 65.7% of the controls. On the other hand, 39.5% of the welders and caulker/burners were over the age of 35 years compared to 24.3% of the controls (table 7).

Although the controls were significantly taller than the welders and caulker/burners, no significant differences in weight or in FFM between both groups were found (fig. 11 to 13).

A higher proportion of the welders and caulker/burners (46.99%) were smokers than in the control sample (28.73%), and a lower proportion

were nonsmokers- welders and caulker/burners 31.93%, controls 56.35%. The proportion of ex-smokers was higher among welders and caulker/burners than among the other tradesmen (21.08% compared to 14.92% respectively). These differences were statistically significant where  $\chi^2 = 29.9$  and  $p = 0.001$  (fig. 14).

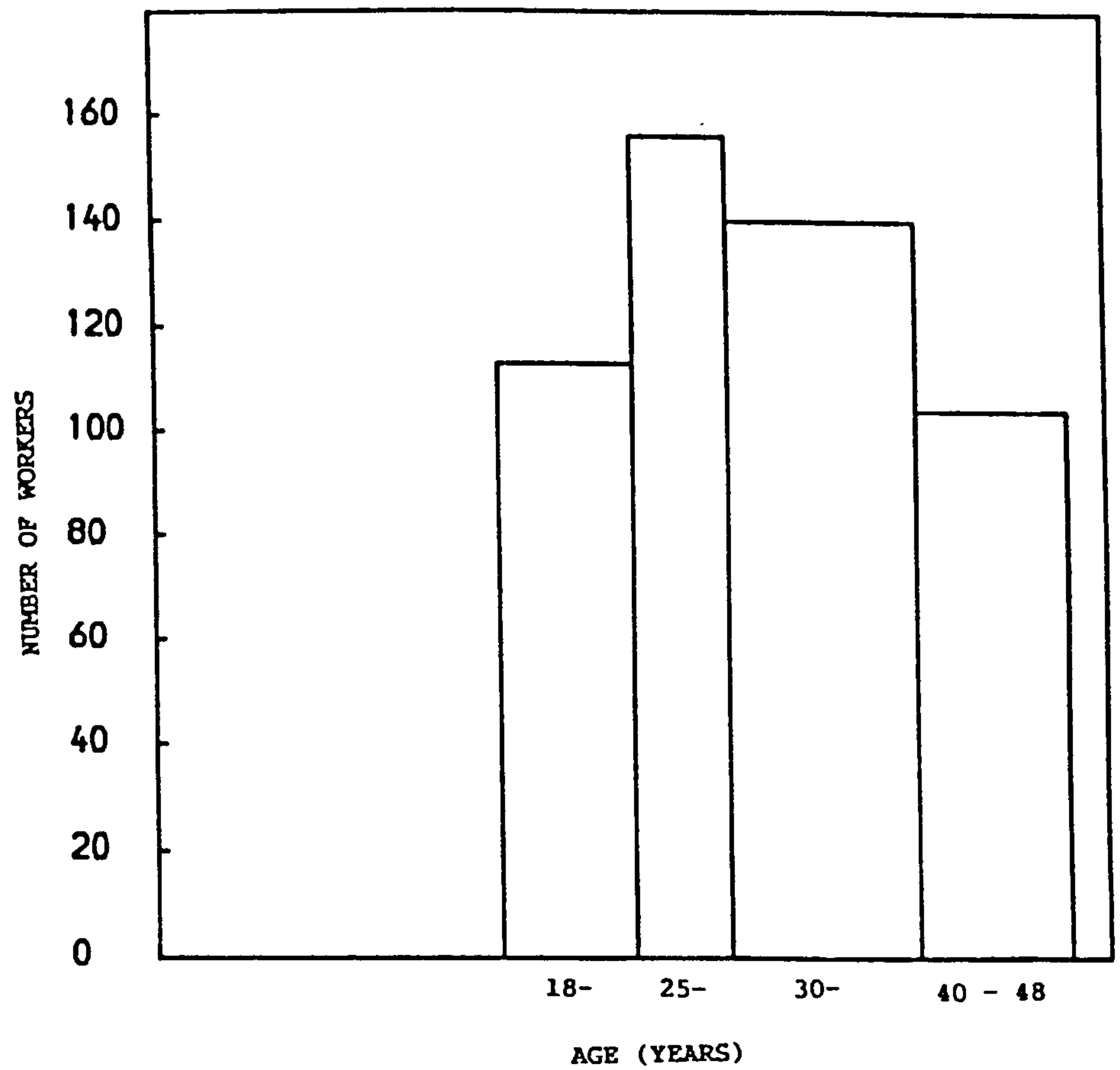


Figure 9: Distribution of exposed and control workers according to age

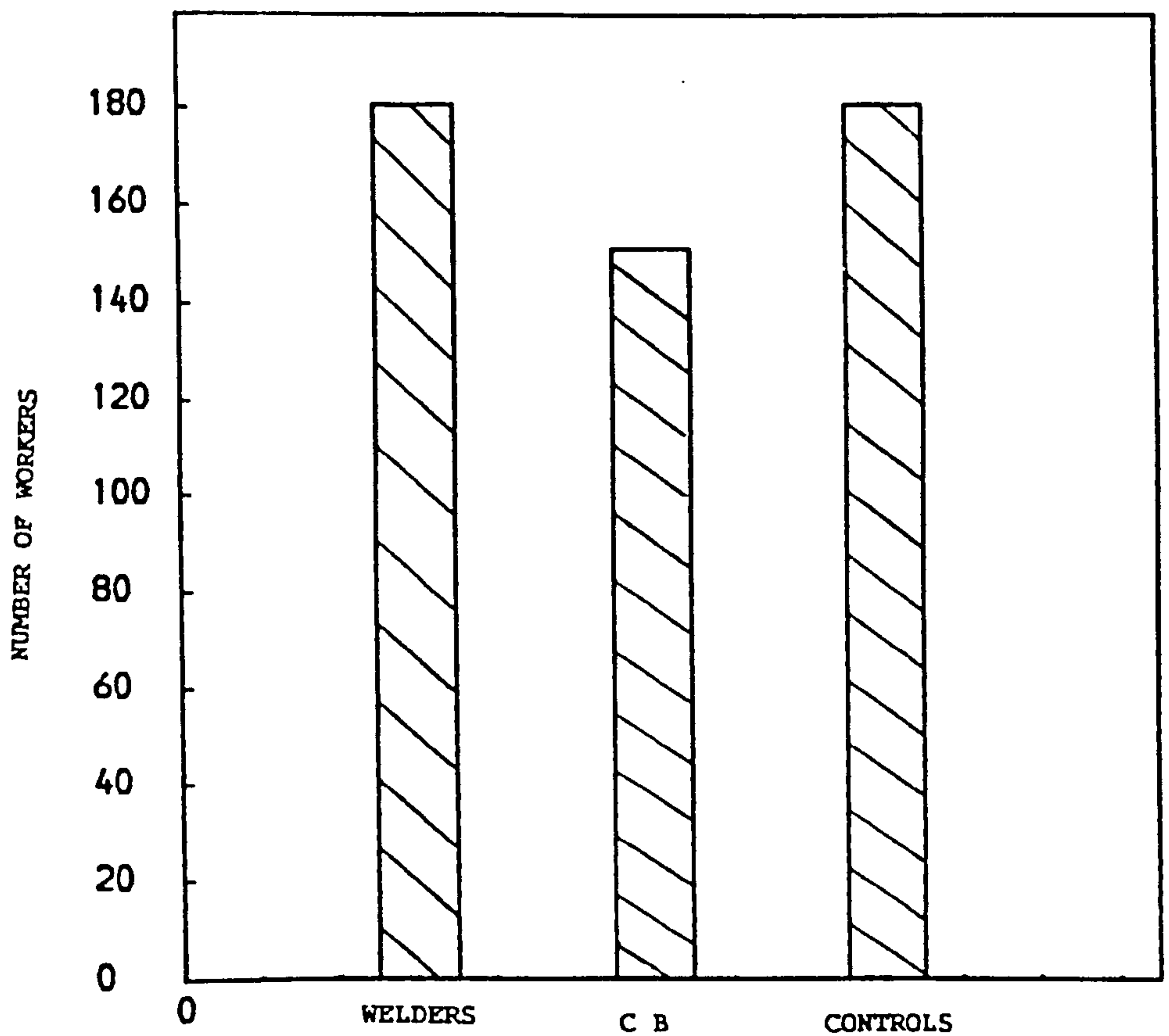


Figure 10: Distribution of exposed and control workers according to occupation (513 exposed and control workers)



**Table 6: Distribution of the exposed and control workers according to age and occupation**

	18-	25-	30-	35-	40-48
	%	%	%	%	%
W & C/B	47	103	51	51	80
	14.16	31.02	15.36	15.36	24.10
CONTROLS	66	53	18	20	24
	36.46	29.28	9.94	11.05	13.26

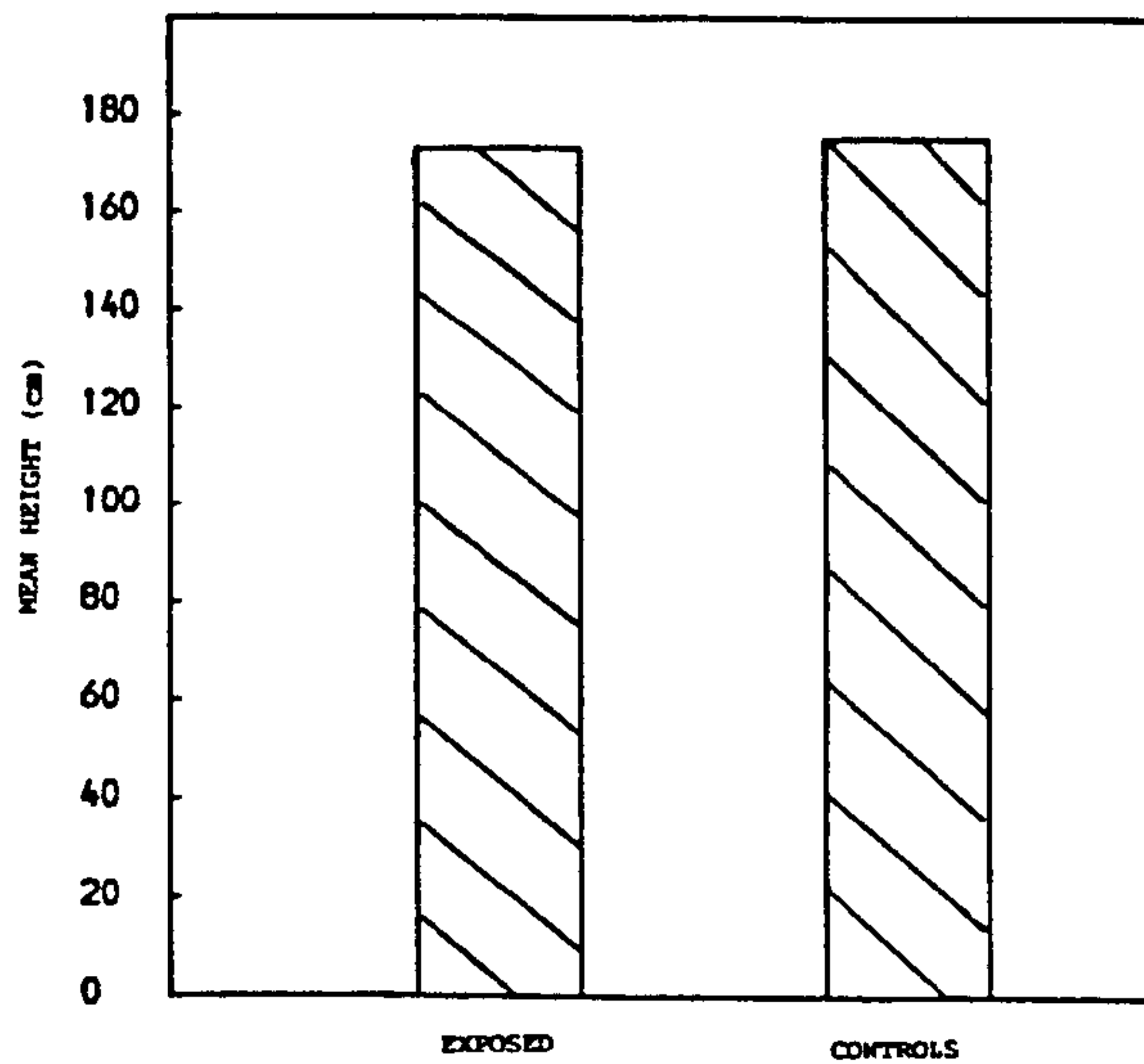


Figure 11: Mean value of height in the exposed and control workers

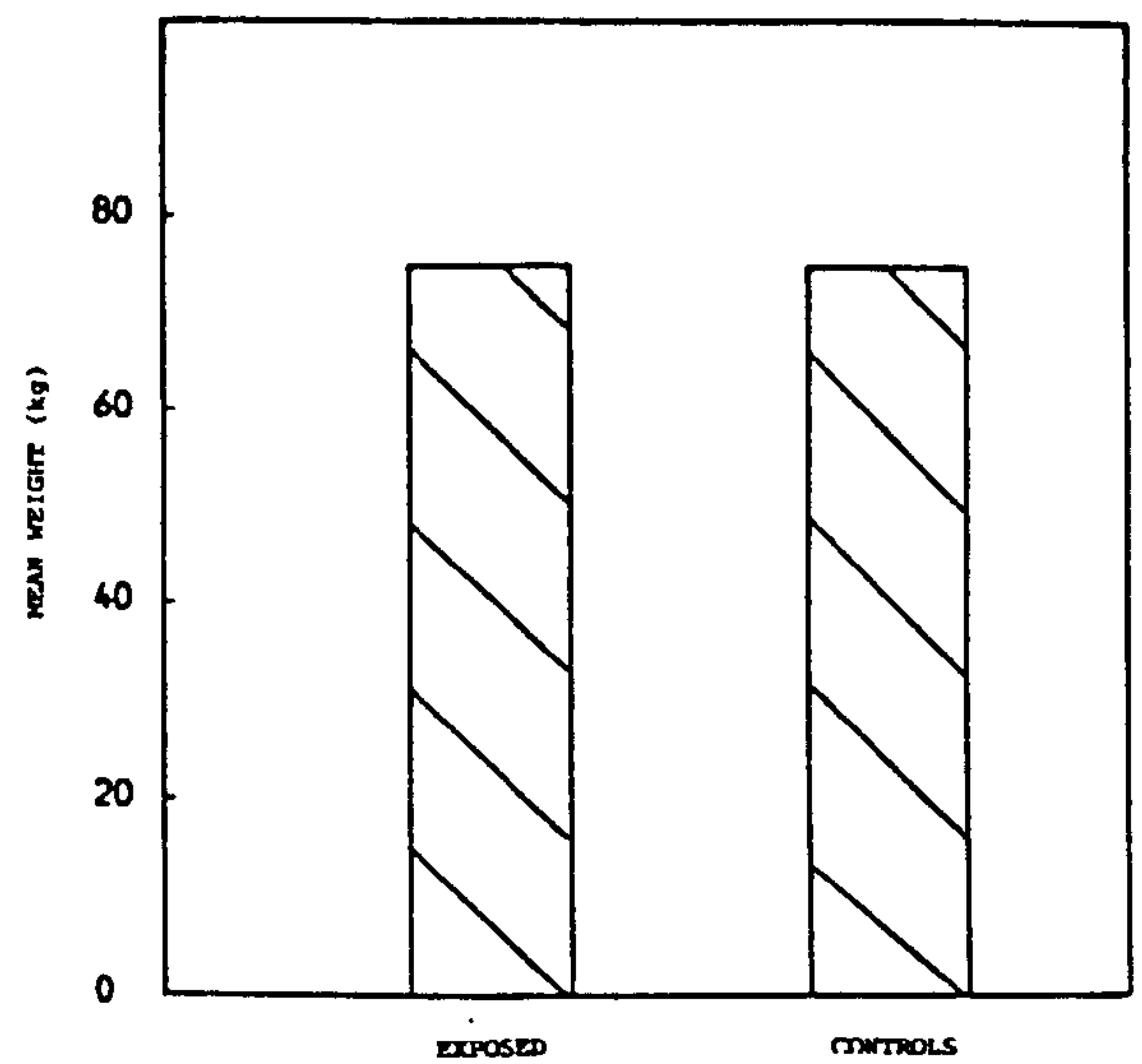


Figure 12: Mean value of weight in the exposed and control workers

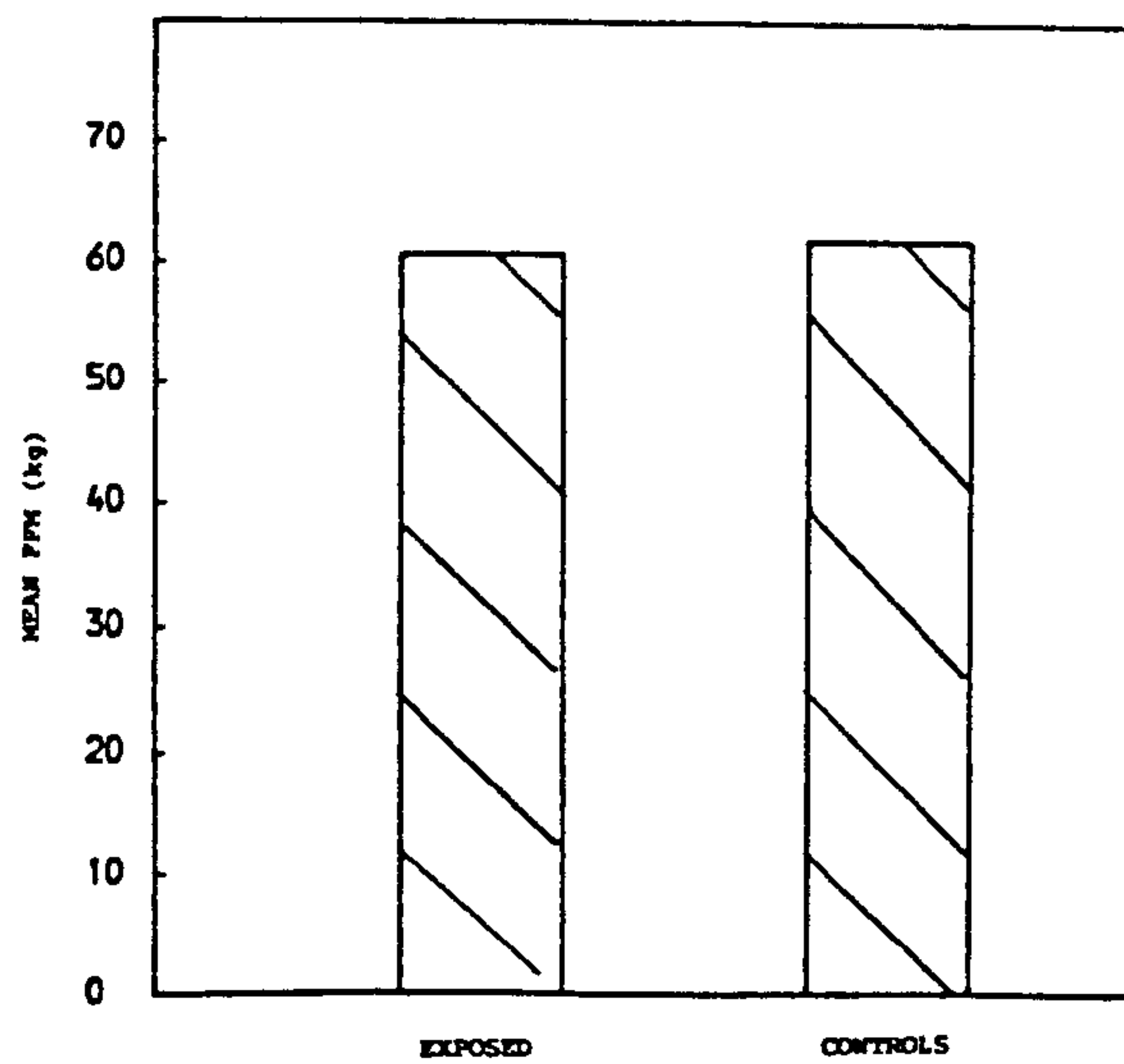


Figure 13: Mean value of FPM in the exposed and control workers

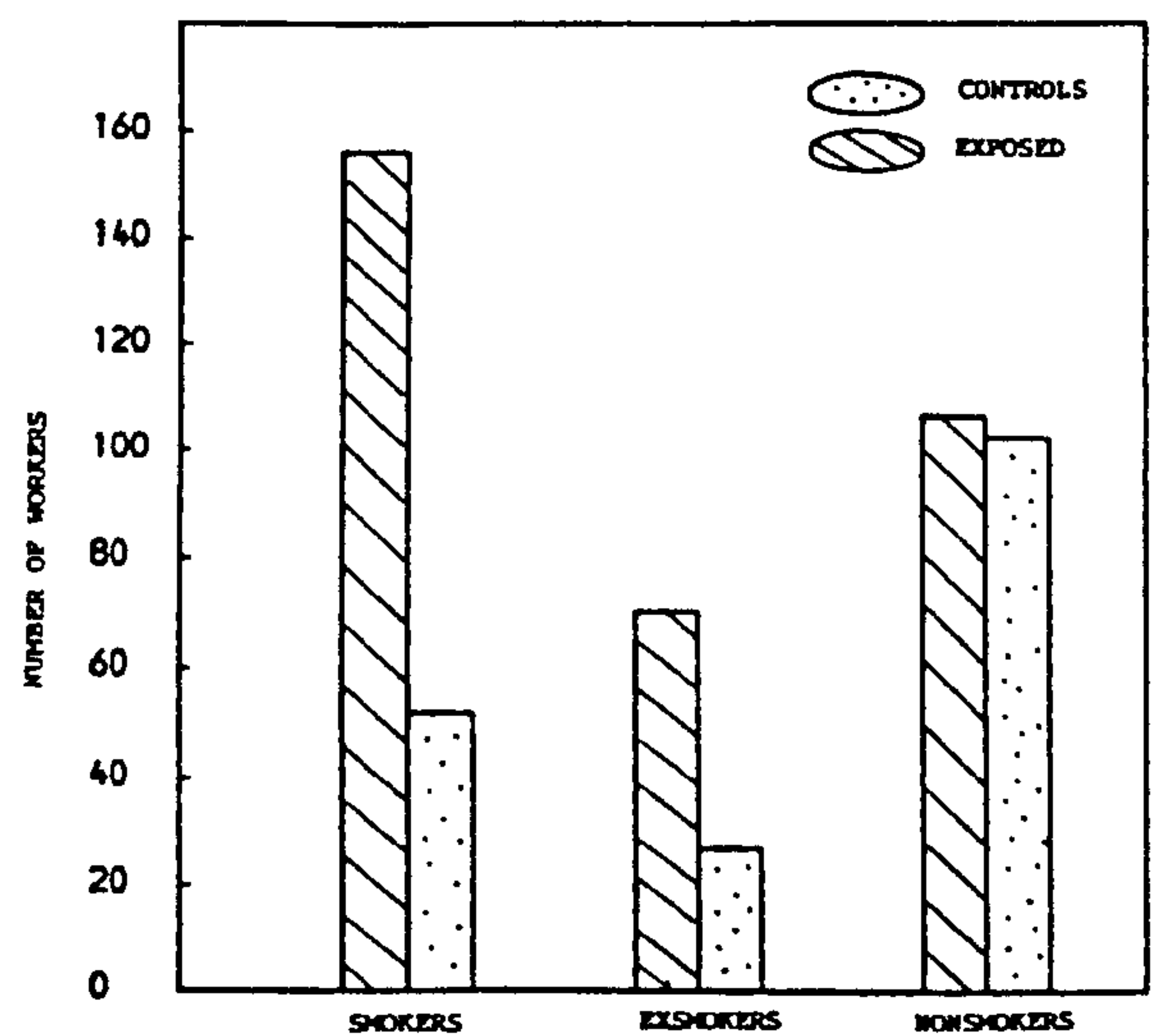


Figure 14: Distribution of the exposed and control workers according to smoking habit

#### 5.1.2 EXPOSURE TO WELDING FUMES IN THE SHIPYARD

Fig (15) shows the distribution of the exposed and control workers according to general exposure to welding fumes in the course of their work in the yards. All the welders and caulker/burners as well as a great proportion of the controls (91.71%) said that they were exposed to welding fumes in the course of their work in the yards.

Fig (16) shows the distribution of welders according to type of welding used. A large proportion of the welders used mainly metal arc welding (95%). Other types of welding were used occasionally e.g oxyacetylene gas welding (OAGW) by 38% of men, inert gas welding (IGW) by 46%, and other types of gas welding by 47%.

None of the welders used oxyacetylene gas welding as the main type of welding, while few welders used mainly IGW (3.3%), and other types of gas welding (3.3%).

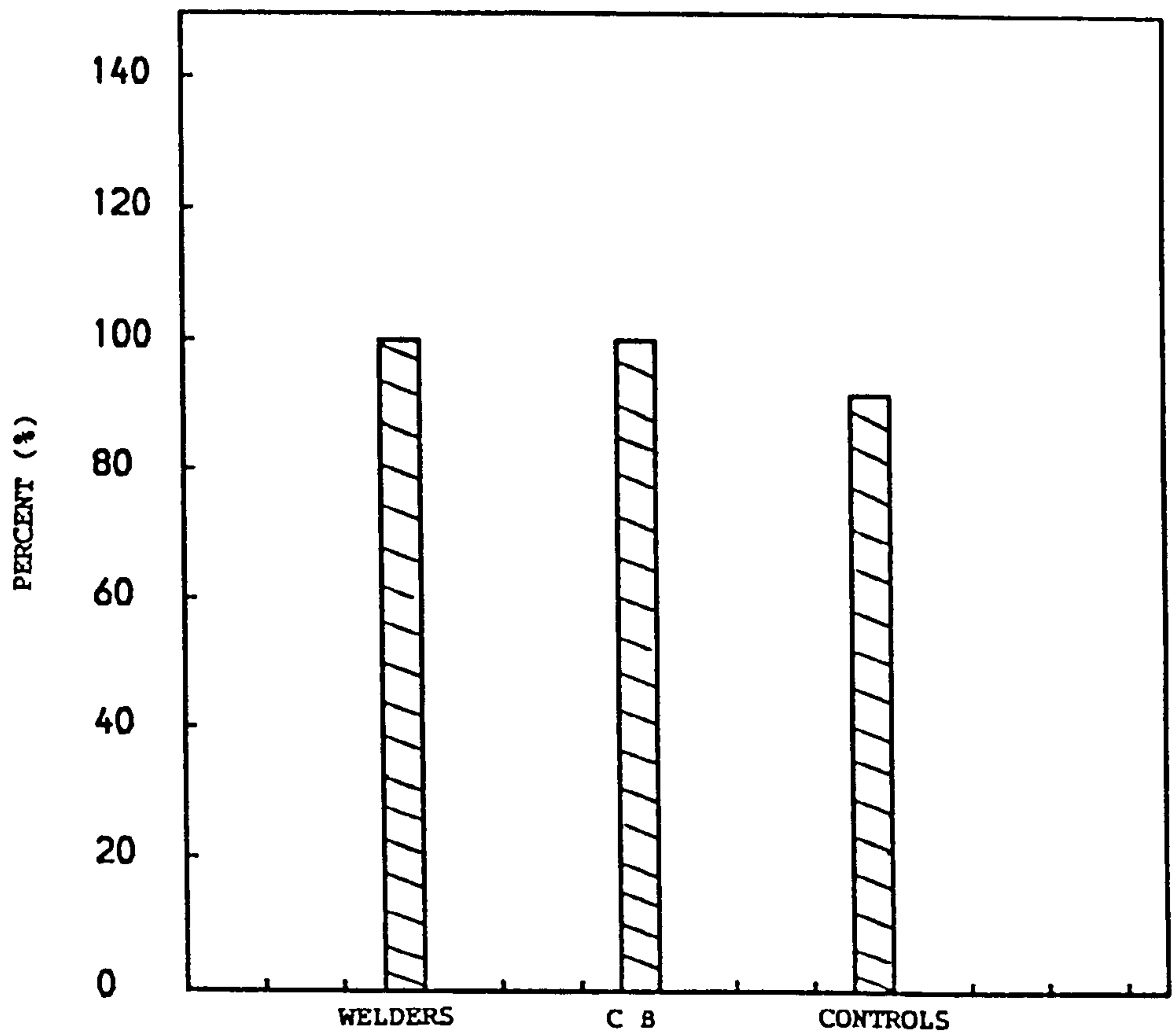


Figure 15: Distribution of the exposed and control workers according to exposure to welding fumes

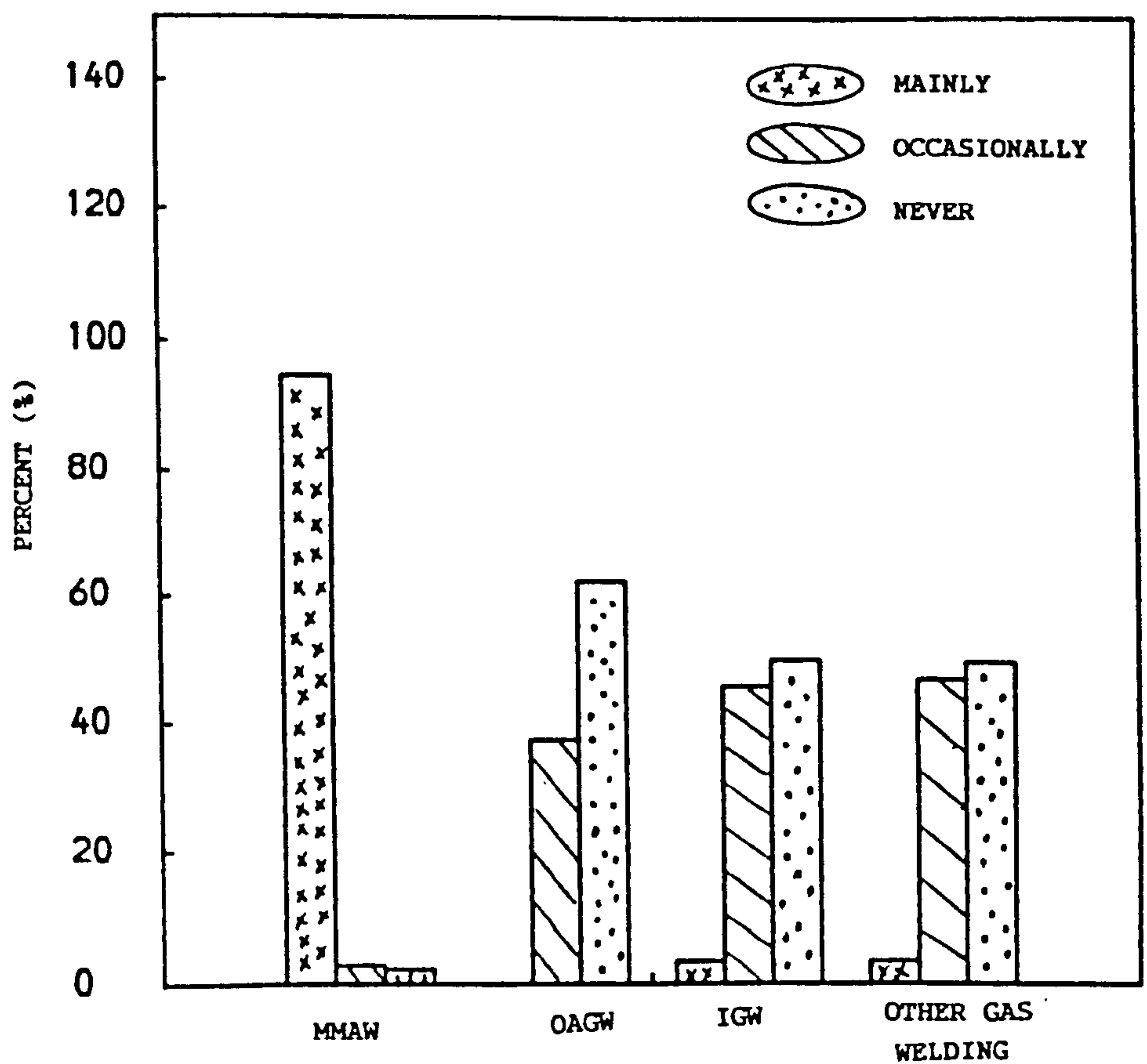


Figure 16: Distribution of the welders according to type of welding used



### 5.1.3 EXPOSURE TO ASBESTOS IN THE YARDS

A greater proportion of welders (40.33%) had previously used asbestos cloth at work compared to caulker/burners (19.9%) and to other tradesmen (24.9%). These differences were statistically significant (fig. 17).

A very low proportion of welders and of caulker/burners had previously worked with asbestos (5.0 and 4.0% respectively) compared with the controls (22.7%). This difference was statistically significant where  $\chi^2 = 40.35$  and  $p = 0.000$  (fig. 18).

A greater proportion of the controls (56.4%) worked near others using asbestos than did the welders (51.38%), and caulker/burners (45.7%). However, these differences were not statistically significant (fig. 19).

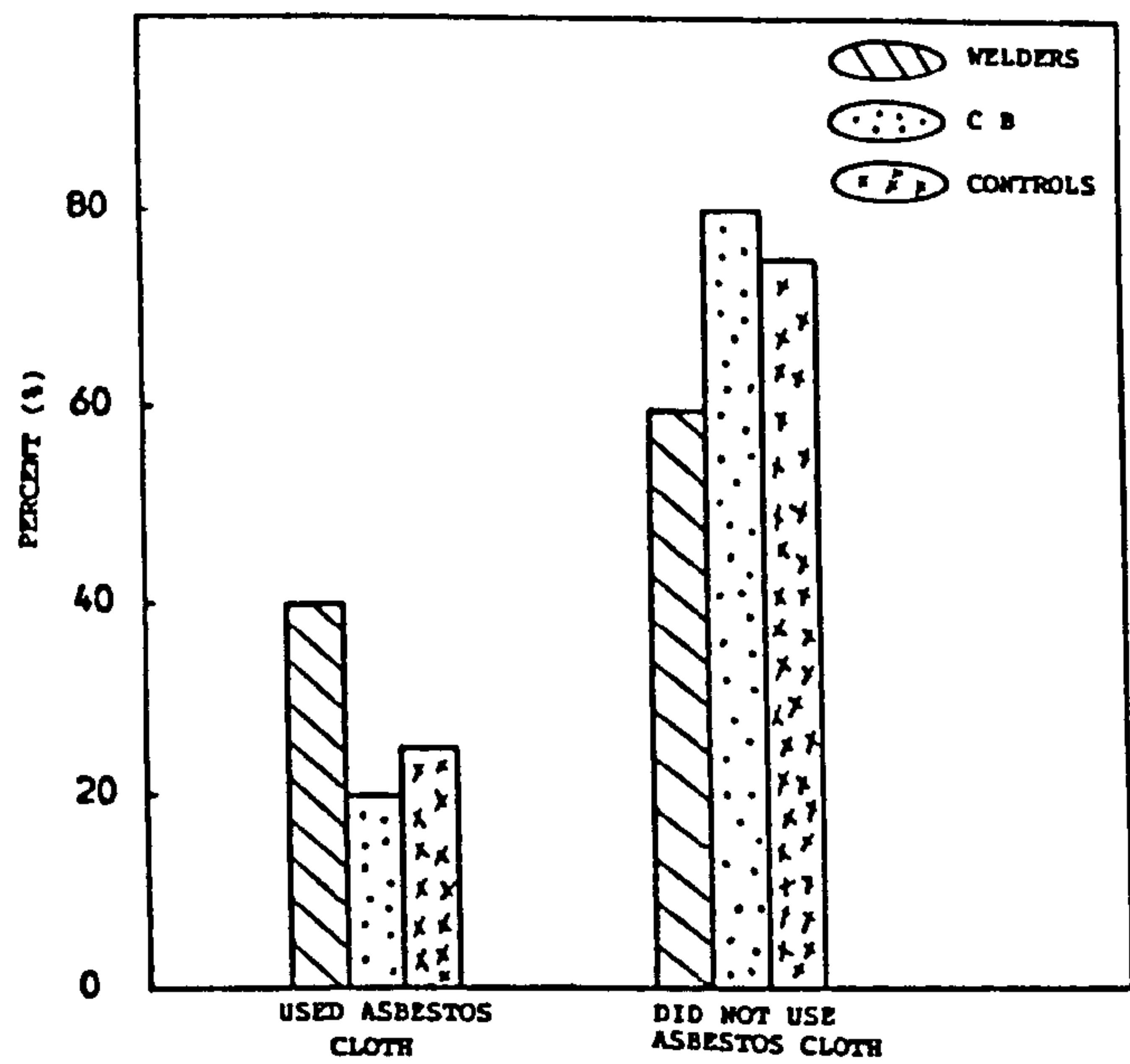


Figure 17: Distribution of the exposed and control workers according to using asbestos cloth at work

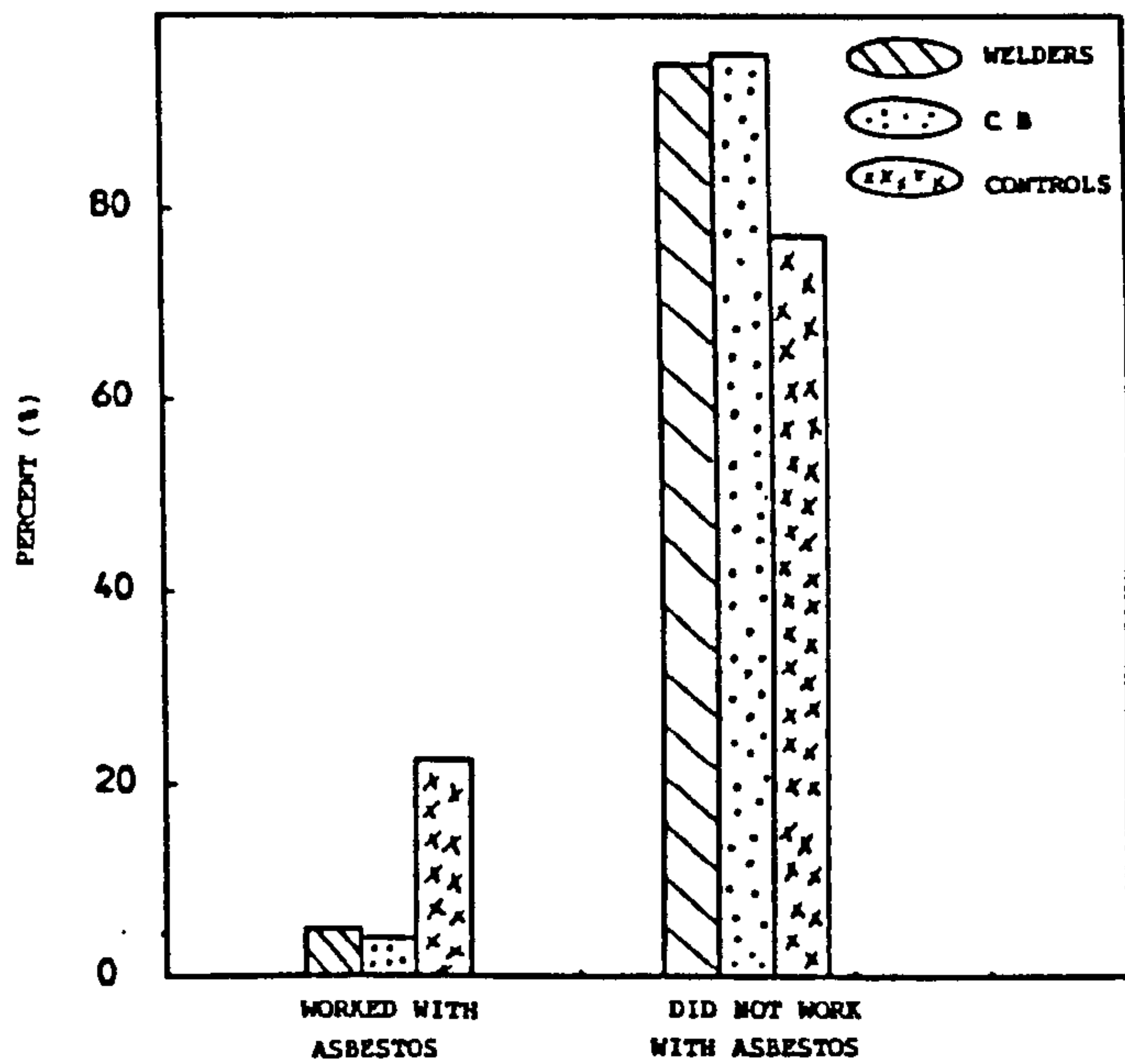


Figure 18: Distribution of the exposed and control workers according to working with asbestos

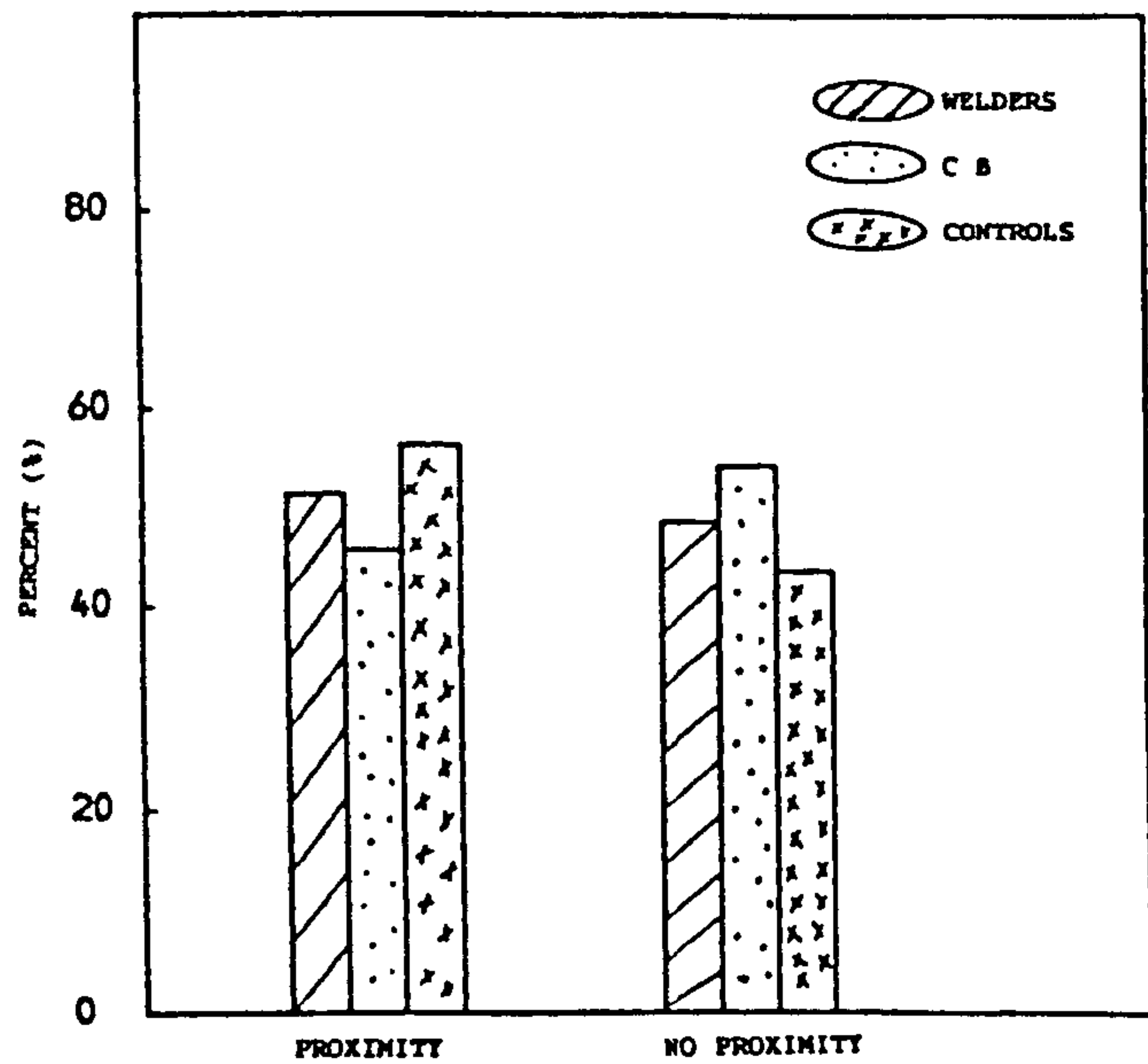


Figure 19: Distribution of the exposed and control workers according to working near others using asbestos

## 5.2 COMPARISON BETWEEN THE TARGET AND CONTROL WORKERS

### 5.2.1 RESPIRATORY SYMPTOMS

The aim of this section was to describe the prevalence of respiratory symptoms among the exposed and control populations and to compare them. Allowance for smoking and age differences between the two groups as well as investigation of the significant determinants of respiratory symptoms will be presented in chapter 6.

Fig (20) shows the distribution of exposed and control workers according to cough frequency score. A large proportion of the controls had score 1 (51.3) compared to the welders and caulker/burners (38.9%). Similar proportions of welders and caulker/burners, and controls had cough score 2-3 (24.4% and 26.9% respectively). A larger proportion of welders and caulker/burners had score 4-6, and 7-9 (33.7% and 3.0% respectively) compared to the controls (20.2% and 1.6 respectively). These differences were statistically significant where  $\chi^2 = 8.8$  and  $p = 0.03$ .

The prevalence of cough, wheeze and breathlessness was higher among the welders and caulker/burners than among the controls ( $\chi^2 = 4.47$  &  $p = 0.03$ ,  $\chi^2 = 16.38$  &  $p = 0.0001$  and  $\chi^2 = 3.99$  &  $p = 0.05$  respectively); although the prevalence of phlegm and chronic bronchitis was higher among the welders and caulker/burners, these differences were not statistically significant (fig. 21, 22, 23, 24 & 26).

The prevalence of asthma was similar in both the welders and caulker/burners and the controls (fig. 25).



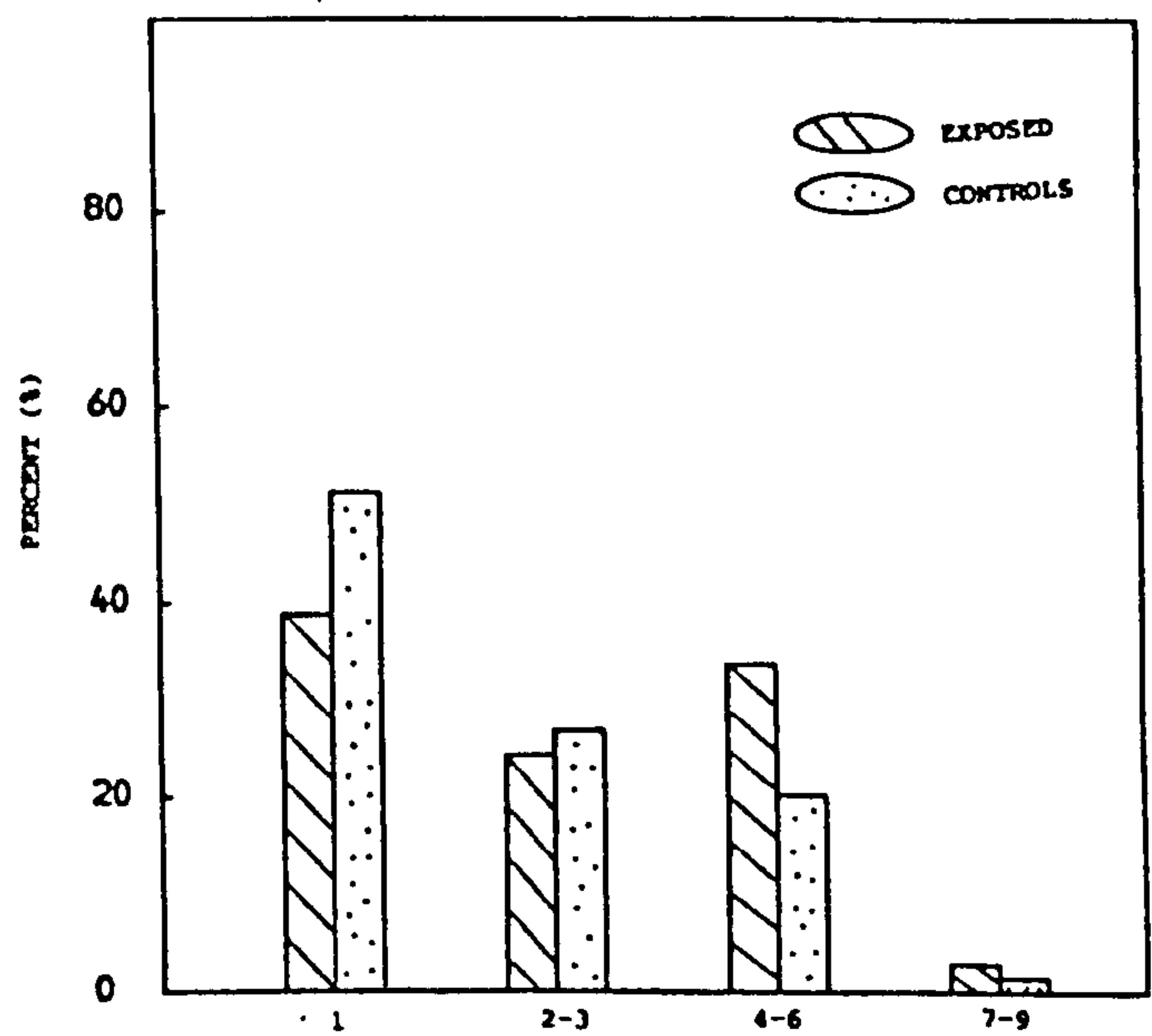


Figure 20: Distribution of the exposed and control workers according to cough frequency score

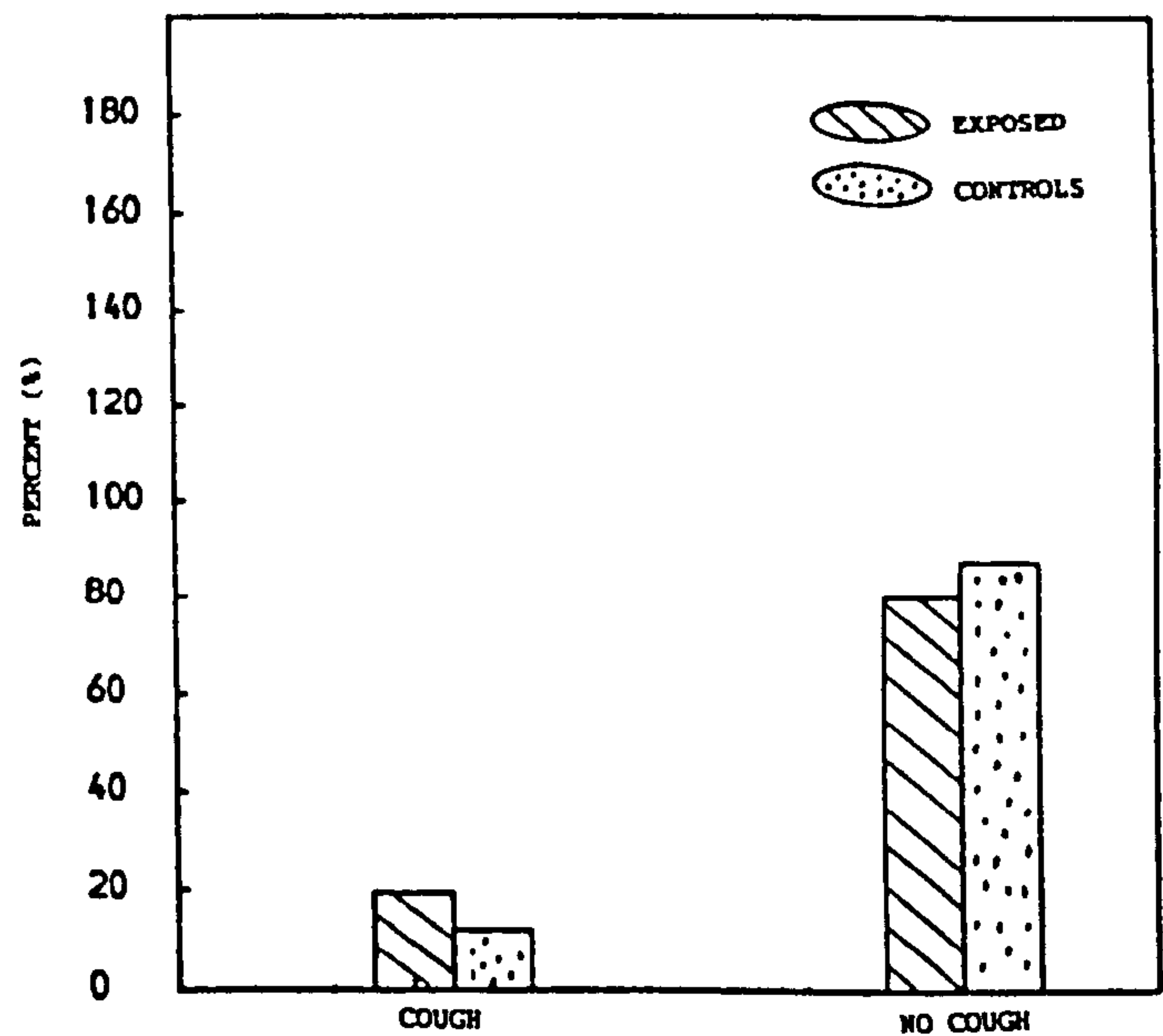


Figure 21: Distribution of the exposed and control workers according to prevalence of cough

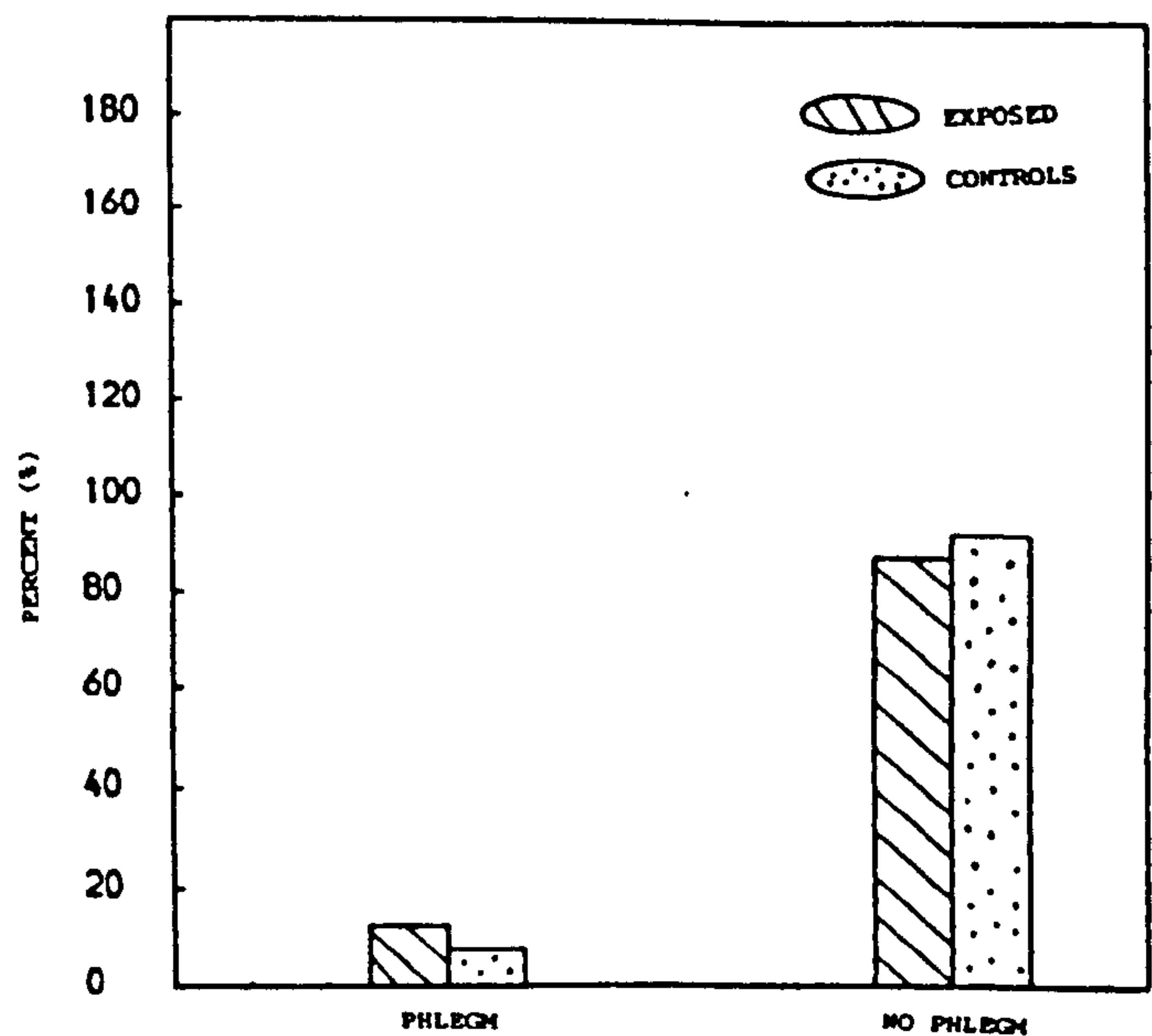


Figure 22: Distribution of the exposed and control workers according to prevalence of phlegm

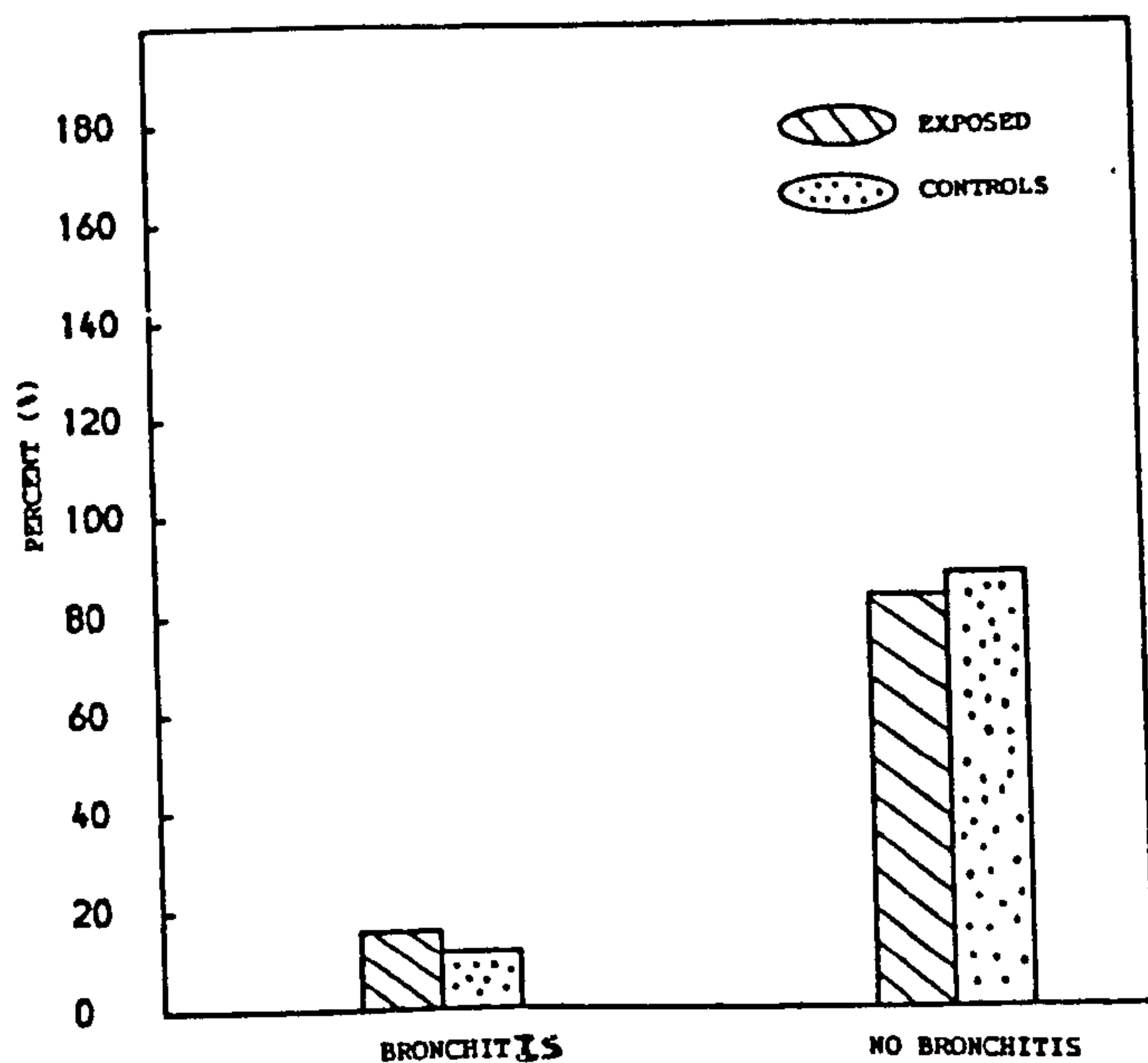


Figure 23: Distribution of the exposed and control workers according to prevalence of chronic bronchitis

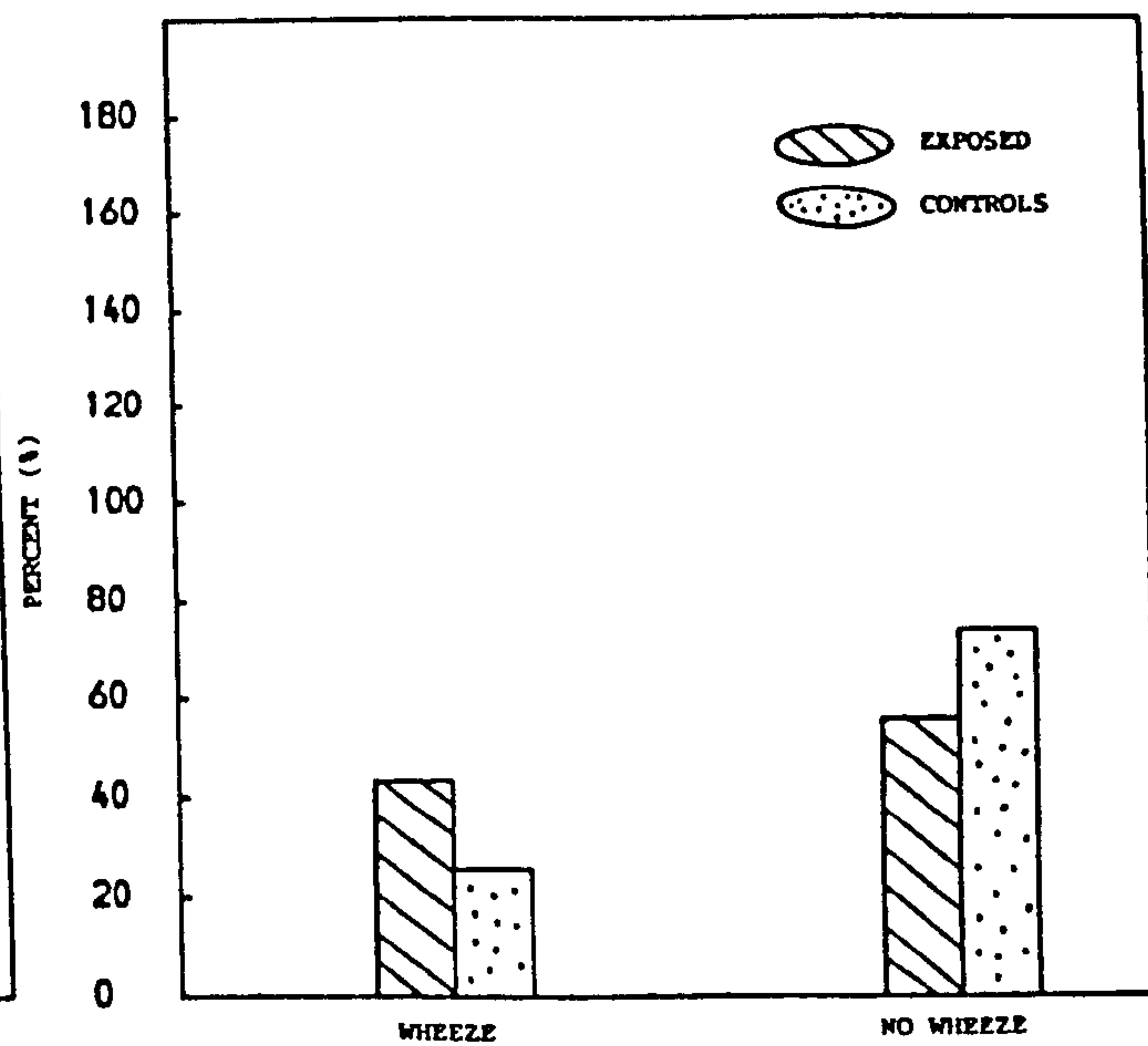


Figure 24: Distribution of exposed and control workers according to prevalence of wheeze

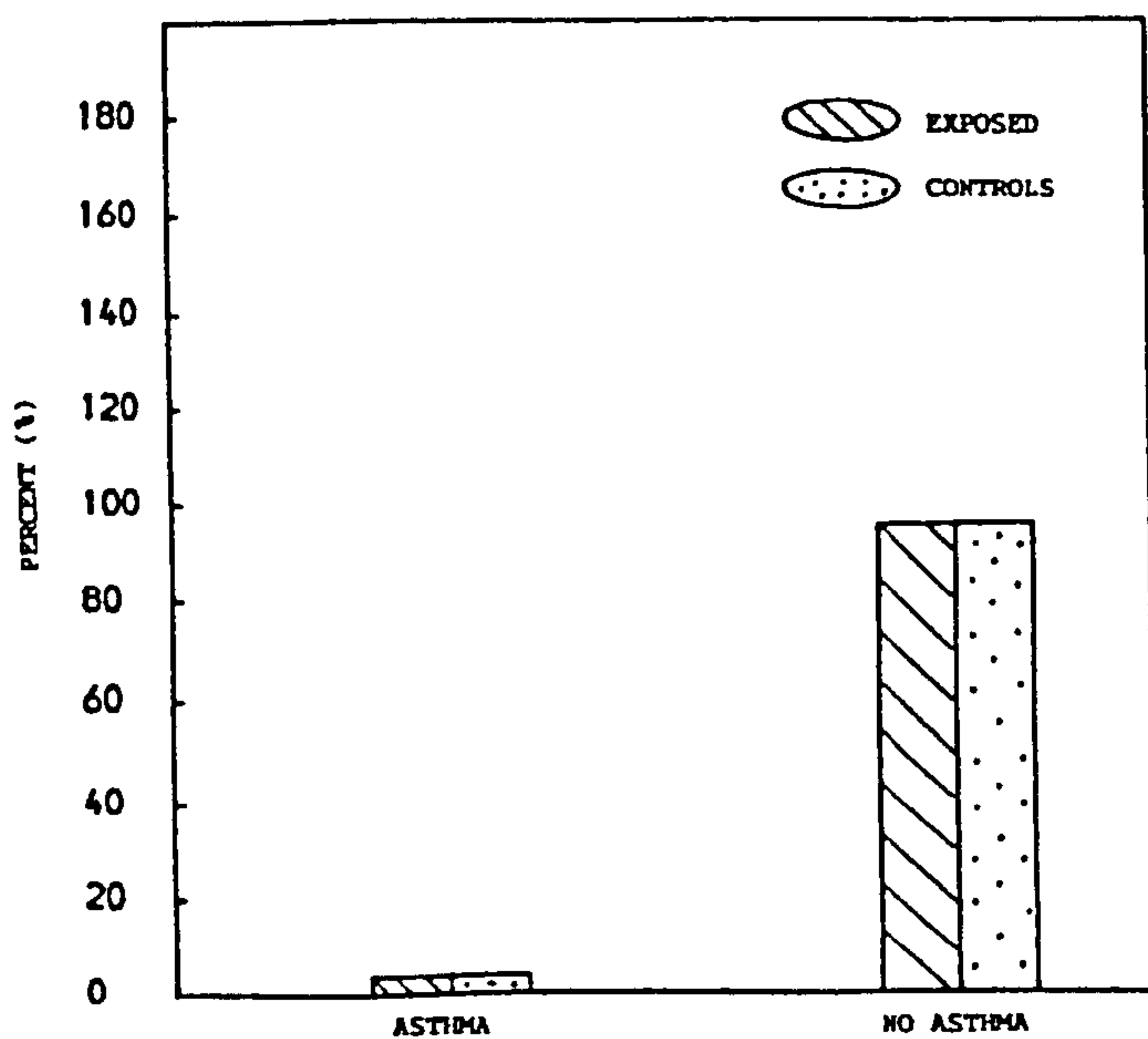


Figure 25: Distribution of the exposed and control workers according to prevalence of Asthma

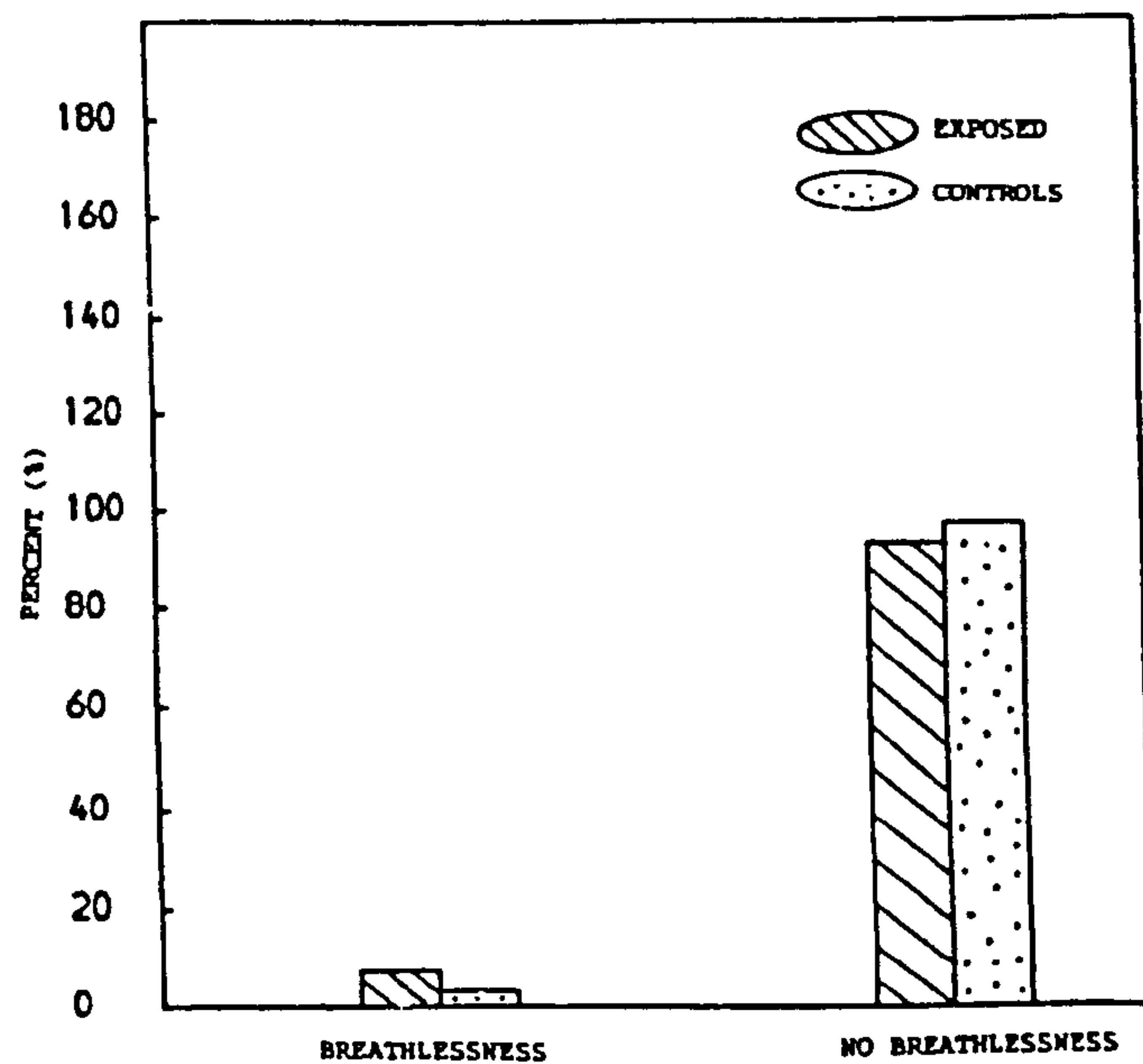


Figure 26: Distribution of the exposed and control workers according to prevalence of breathlessness

### 5.2.2 LUNG FUNCTION INDICES

The aim of this section was to describe the mean values of the different lung function indices for the exposed and control populations and to compare them. Allowance for differences in height, age and smoking habit, as well as investigation of the significant determinants of the lung function indices will be presented in chapter 6.

Compared with the controls, the welders and caulker/burners had significantly higher CV%, CC%, and RV%, and significantly lower TLC, VC, FEV<sub>1</sub>, PEFR,  $\dot{V}_{\text{max25}}$  and T<sub>lco</sub> (the p values = 0.000 except for PEFR and  $\dot{V}_{\text{max25}}$  p= 0.03 and 0.01 respectively); the values of the rest of the lung function indices for both groups were not significantly different (Table 6.1.5).

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Table 6.1: Comparison of the different lung function  
indices between the exposed and control workers

	EXPOSED		CONTROLS		t-test
	MEAN	SD	MEAN	SD	
TLC	6.39	0.826	6.73	0.877	3.93 ***
VC	4.82	0.662	5.17	0.653	5.14 ***
RV	1.56	0.372	1.56	0.362	0.05
FVC	5.18	0.715	5.50	0.684	4.87 ***
FEV <sub>1</sub>	3.98	0.652	4.24	0.593	4.41 ***
FEV <sub>1</sub> %	76.72	7.260	77.13	6.350	0.64
PEFR	10.03	1.730	10.36	1.550	2.15 *
RV%	24.42	4.504	23.12	3.794	2.95 ***
V <sub>max50</sub>	5.00	1.549	5.10	1.405	0.73
V <sub>max25</sub>	1.92	0.698	2.09	0.704	2.49 ***
CV%	16.40	6.57	12.20	5.49	6.49 ***
CC%	36.60	7.21	32.30	6.30	5.85 ***
SLIII	1.30	0.932	1.20	0.50	0.72
N <sub>2</sub> Diff	1.00	0.685	0.90	0.37	1.47
T <sub>lco</sub>	11.62	1.999	12.82	3.32	5.06 ***
K <sub>co</sub>	1.84	0.502	1.87	0.25	0.75
V <sub>e45</sub>	23.29	2.84	23.67	4.64	0.83
f <sub>C45</sub>	107.2	12.73	104.31	10.35	1.17
V <sub>T30</sub>	1.62	0.321	1.86	0.409	1.41

\*= 0.05>p>0.01 \*\*= 0.01>p>0.001 \*\*\*= p<0.001

CHAPTER 6RESULTS B6.1 MULTIPLE REGRESSION ANALYSIS

The aim of this chapter was to:

1. Compare the mean values of lung function in the target and control workers while allowing for the other factors that can affect the function of the lung.
2. Study the changes in the lung function indices with variation of exposure to fumes in the welders and burners separately.
3. To study the effect of fumes in very young workers (subsample of the whole selected workers, age 20 - 25 years, mean age 22 years).

The analysis was undertaken separately for each index of exposure. The index of exposure WCB (ever a welder or a caulker/burner) was used to compare the welders & burners with the controls, the indices  $W_1$  (exposure in confined and semiconfined spaces) and  $W_2$  (exposure on the ship) were used to study the welders only, and the indices  $CB_1$  (exposure in confined and semiconfined

spaces) and  $CB_2$  (exposure on the ship) were used to study the caulker/burners only.

In some instances interaction occurred between smoking and indices of exposure. The effects of age were also in the expected direction but in many instances the age effect was accentuated by exposure to fumes. The exposure indices for welders  $W_1$  and  $W_2$  and for caulker/burners  $CB_1$  and  $CB_2$  respectively gave similar results. In the following sections results obtained for the exposure indices  $WCB$ ,  $W_1$  and  $CB_2$  will be presented.

The line graphs which were used to show the regression of the lung function indices on age were for the workers with average height and/or weight depending on whether these variables were significant in the regression analysis or not, and the effect of smoking was allowed for.

#### 6.1.1 WELDERS & BURNERS (WCB) VERSUS CONTROLS

The independent variables for this part of the analysis were age (years), height (mm), WT (weight/height<sup>2</sup>), the exposure index WCB as a dummy variable (exposed= 1, control= 0), smoking as a dummy variable (smoker and exsmoker= 1, nonsmoker= 0), the interaction term between age and WCB (AWCB) and the interaction term between smoking and WCB (SWCB). The interaction terms were included in the analysis to study the nature of relationship between exposure and age, also exposure and smoking.

The respiratory symptom, wheeze, was significantly higher in the exposed than in the control workers; this effect was independent of age and smoking, since the regression coefficients on AWCB and SWCB did not differ significantly from zero. By contrast the breathlessness score was negatively correlated with the interaction term AWCB indicating that with advancing age the breathlessness score was significantly greater in the exposed than in the control workers (table 7).

For the lung function indices FVC and FEV<sub>1</sub> the relationship between age and WCB (exposure) was similarly interactive and not simply additive where the decline in these lung function indices with advancing age was significantly greater in the exposed workers than in the controls (table 8 and figs 46 and 47). The PEF<sub>R</sub> and T<sub>1CO</sub> were lower in the exposed workers than in the controls but these relationships did not reach the 1 per cent level of significance



(tables 8 and 10 and figs. 48 and 51).

The mean values of CV% and CC% were significantly higher in the exposed than in the control workers. These effects were independent of age and smoking (table 9 and figs 49 and 50).

Table 7: REGRESSION EQUATIONS DESCRIBING  
RESPIRATORY SYMPTOMS

	WHEEZE	BREATHLESSNESS
CONSTANT	0.0761	1.021
AGE	0.0036	-0.00004
SMOKING	0.261***	0.031
WCB	0.120**	-0.293**
AWCB	-	0.010***
SWCB	-	0.006

\*= 0.05 ≥ p >0.01 \*\*= 0.01 ≥ p > 0.001 \*\*\*= p≤ 0.001

Table 8: REGRESSION EQUATIONS DESCRIBING  
FVC, FEV<sub>1</sub> & PEFR

	FVC	FEV <sub>1</sub>	PEFR
CONSTANT	-5.082	-2.152	-1.115
AGE (years)	-0.011*	-0.026**	-0.004
SMOKING (1,0)	-0.139	-0.148**	-0.349
WCB (1,0)	0.338	0.330	1.106
AWCB	-0.015**	-0.013***	-0.040*
SWCB	0.111	0.098	0.257
HEIGHT (mm)	0.006***	0.004***	0.006***

\*= 0.05 ≥ p > 0.01    \*\*= 0.01 ≥ p > 0.001    \*\*\*= p ≤ 0.001

Table 9: REGRESSION EQUATIONS DESCRIBING  
CV%, CC%, RV%,  $\dot{V}_{\max 50}$  &  $\dot{V}_{\max 25}$

	CV%	CC%	$V_{\max 50}$	$V_{\max 25}$
CONSTANT	-1.563	14.833	3.313	1.830
AGE (years)	0.439***	0.572***	-0.068***	-0.051***
SMOKING (1,0)	2.950***	2.478***	-0.237	-0.105*
WCB (1,0)	2.034***	1.670**	0.249	0.072
HEIGHT (mm)	-	-	0.002**	0.001***

\*= 0.05  $\geq$  p >0.01 \*\*= 0.01  $\geq$  p > 0.001 \*\*\*= p $\leq$  0.001



Table 10: REGRESSION EQUATIONS DESCRIBING  
T<sub>lco</sub> & K<sub>co</sub>

	T <sub>lco</sub>	K <sub>co</sub>
CONSTANT	-9.412	2.560
AGE (years)	-0.076***	-0.011***
SMOKING (1,0)	-0.947***	-0.209***
WCB (1,0)	-0.498*	0.027
HEIGHT (mm)	0.013***	-0.0005
WT	9632.07**	2100.7***

\*= 0.05 ≥ p >0.01 \*\*= 0.01 ≥ p > 0.001 \*\*\*= p≤ 0.001

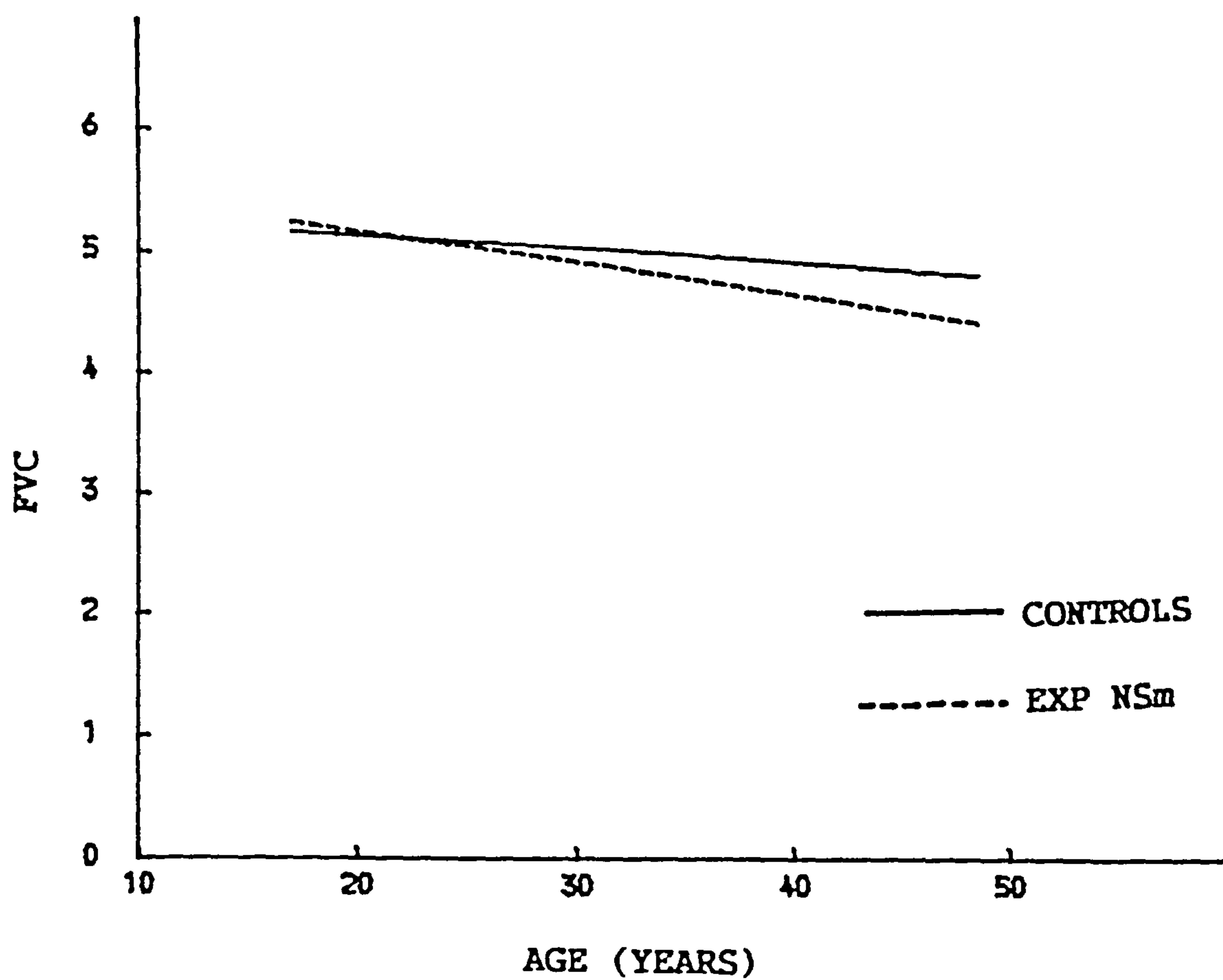


Figure 46: Regression of FVC on age in the exposed and control workers

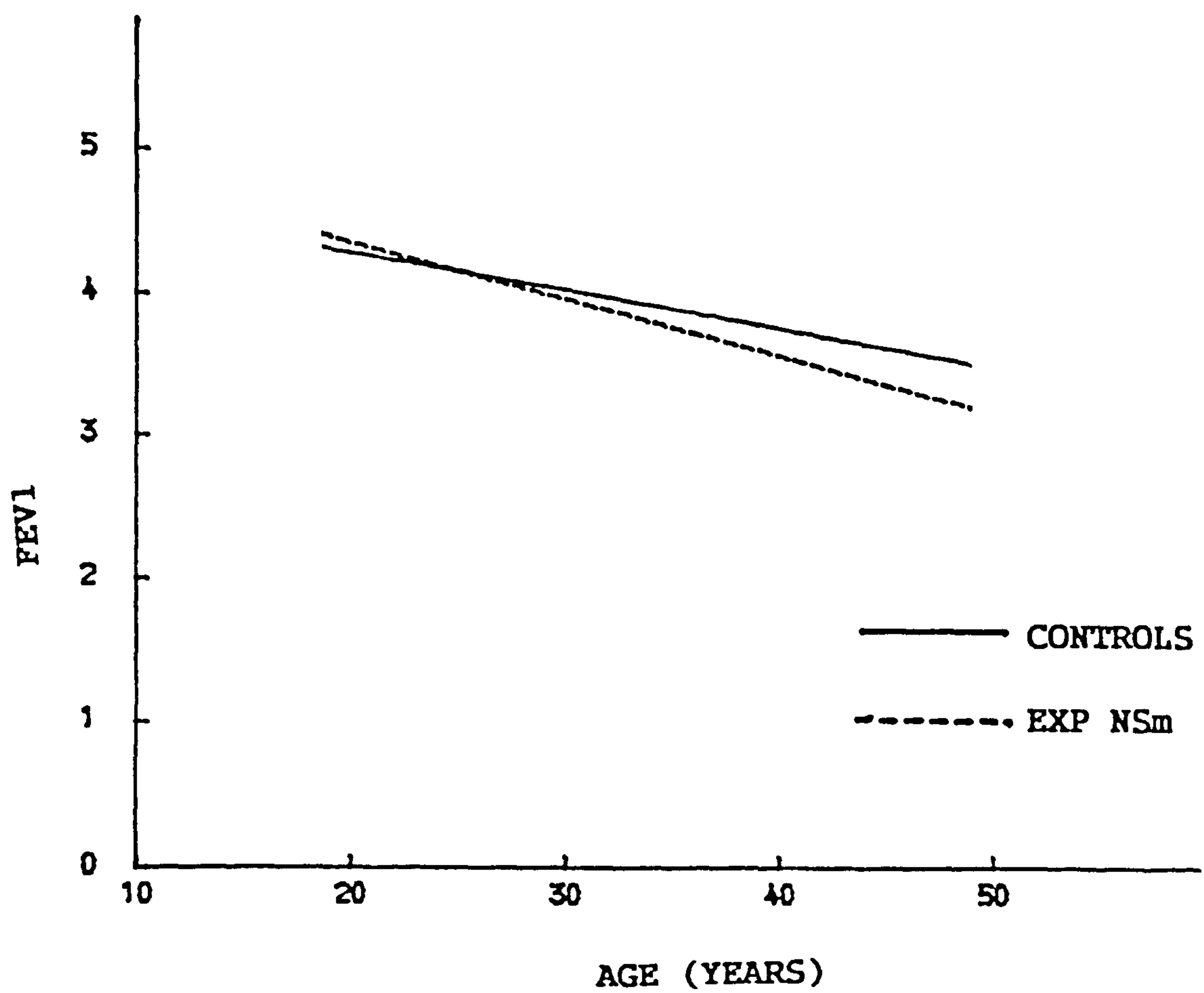


Figure 47: Regression of FEV1 on age in the exposed and control workers

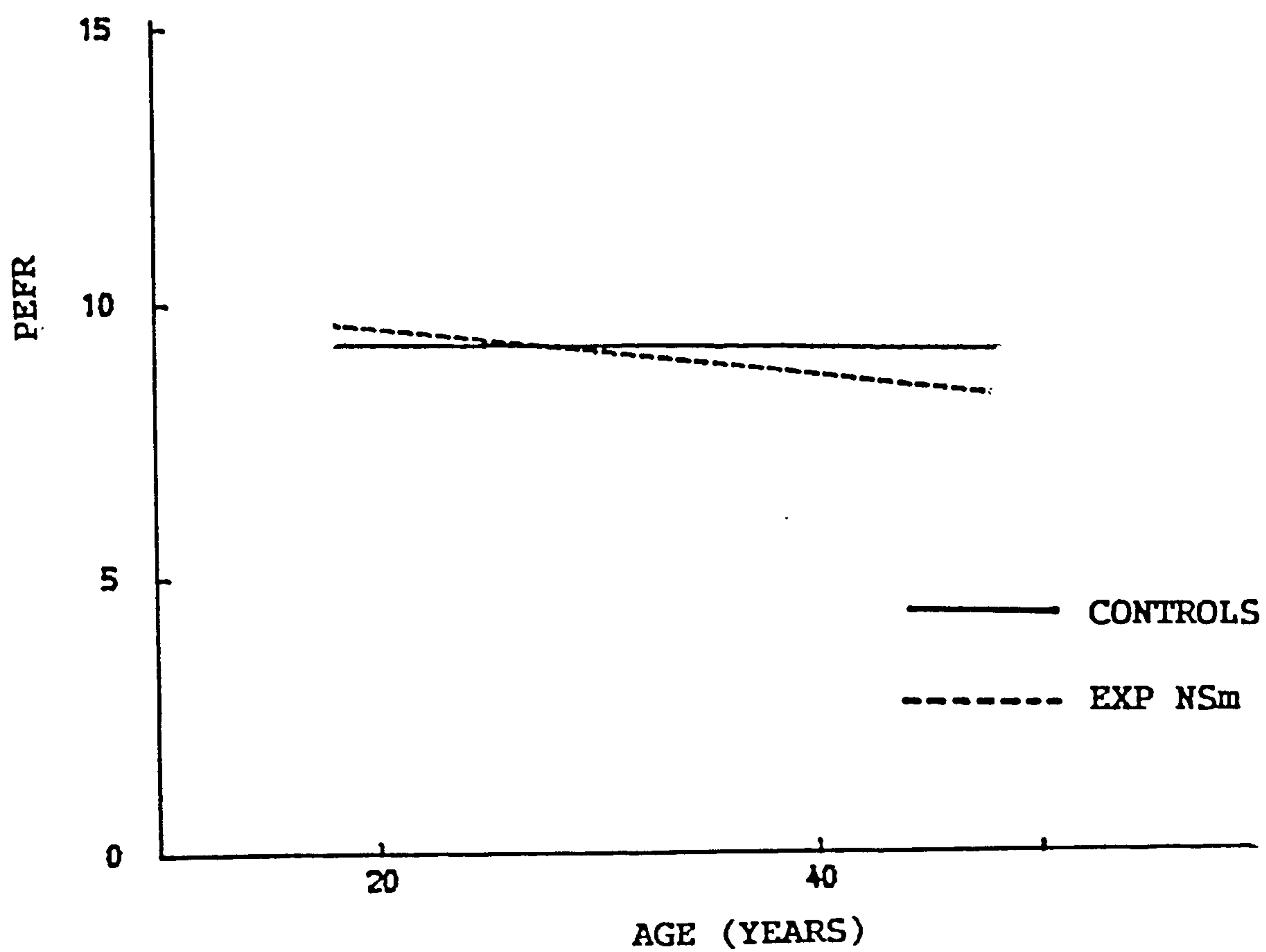


Figure 48: Regression of PEFR on age in the exposed and control workers



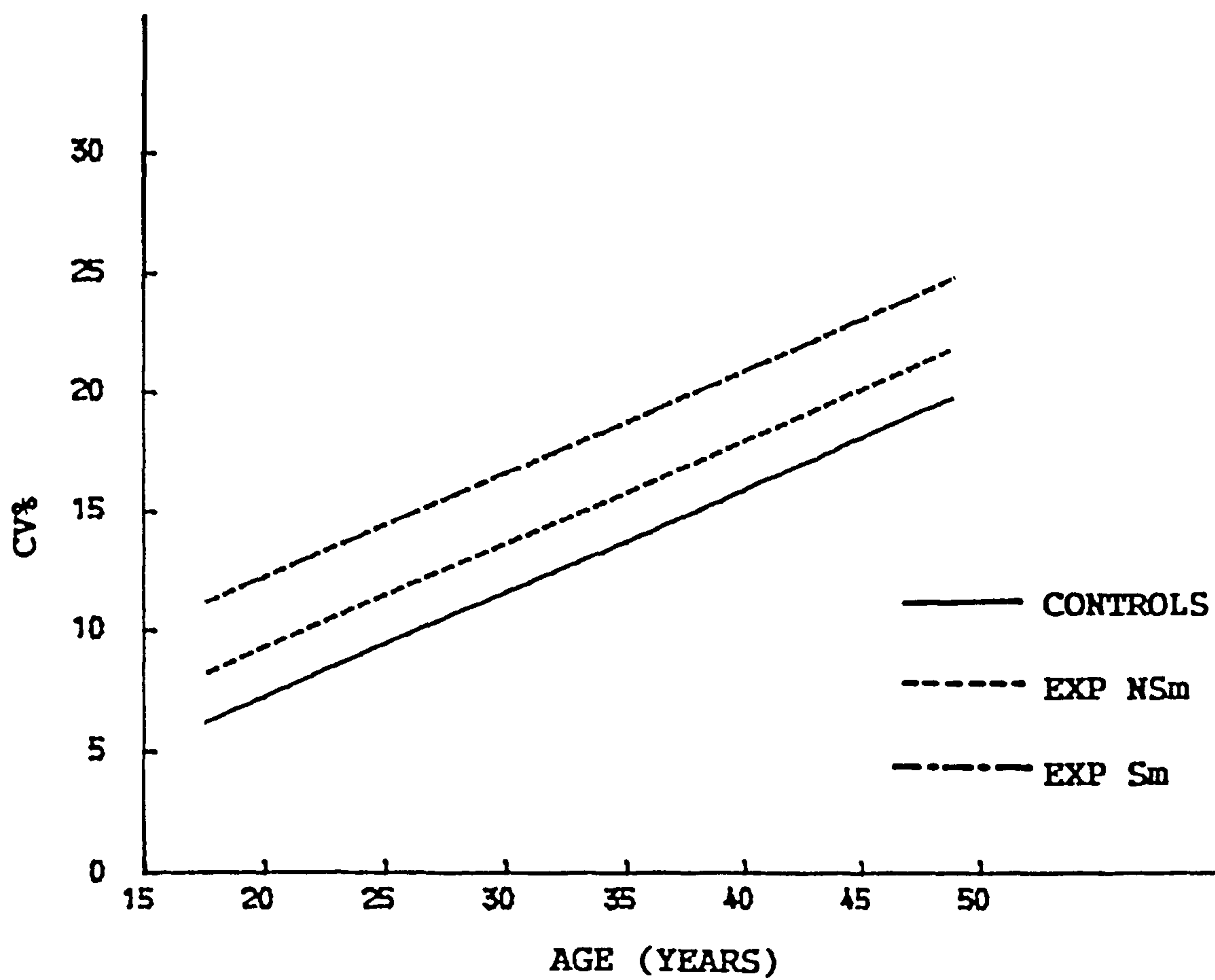


Figure 49: Regression of CV% on age in the exposed and control workers

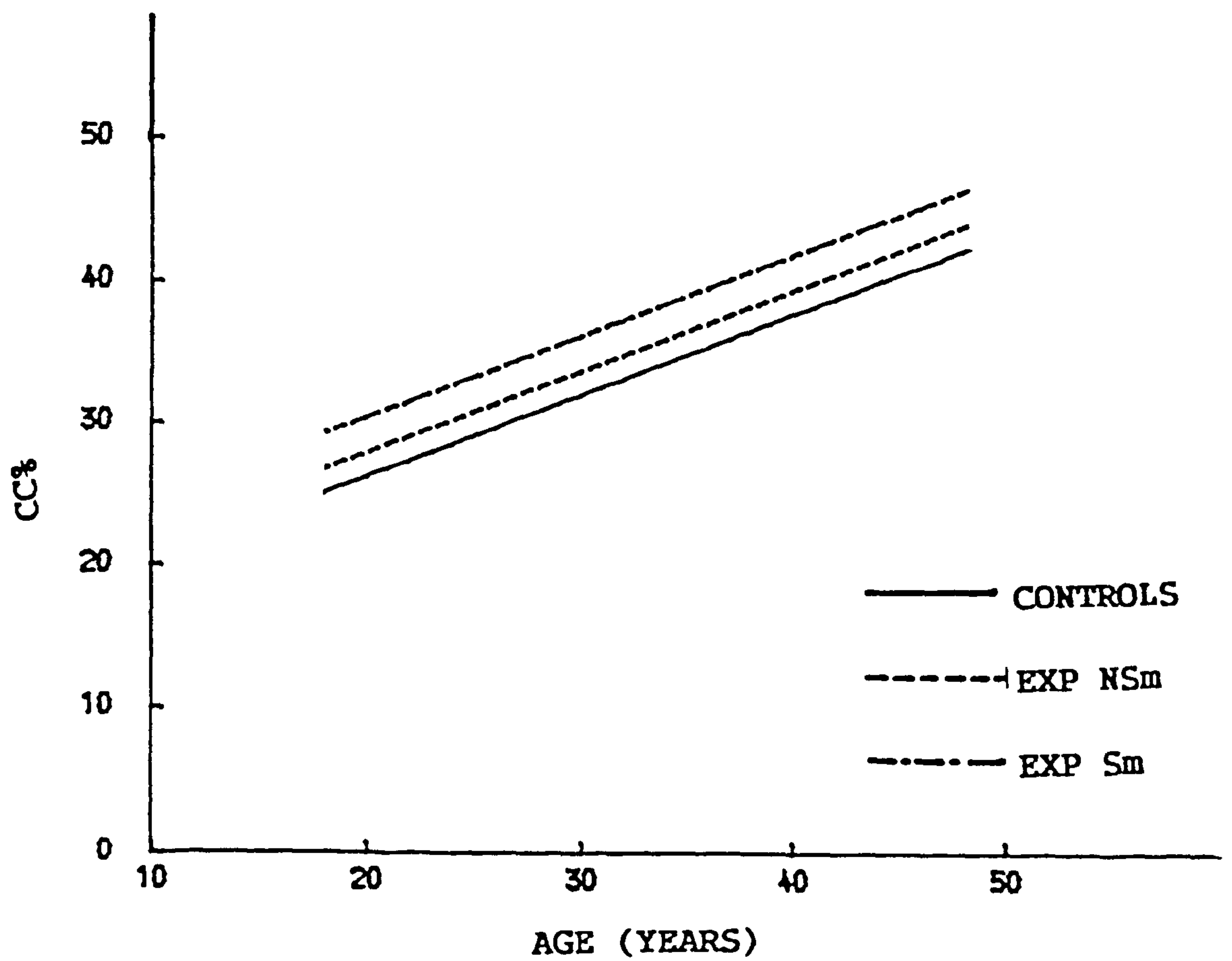


Figure 50: Regression of CC% on age in the exposed and control workers

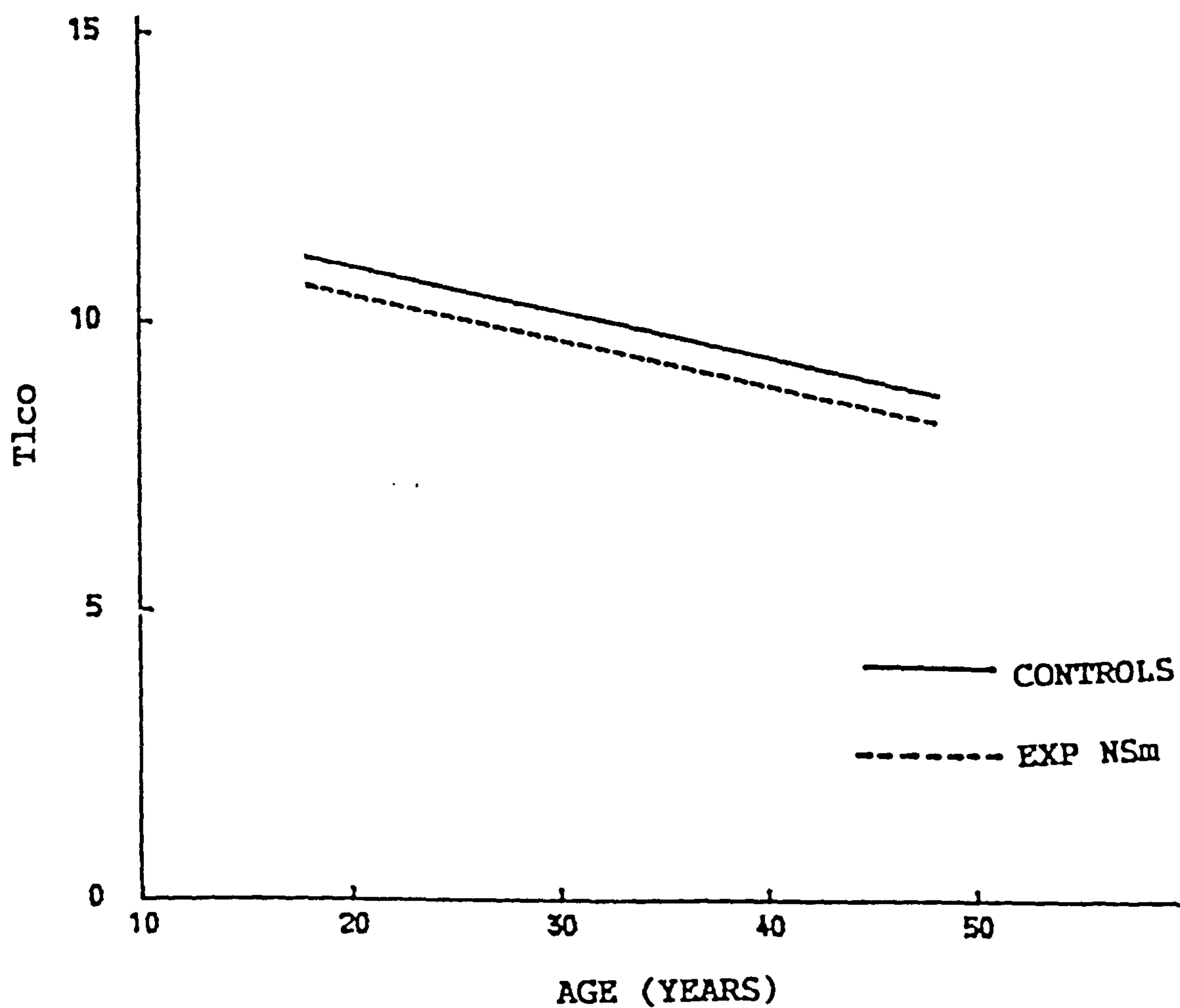


Figure 51: Regression of Tlco on age in the exposed and control workers

### 6.1.2 WELDERS:

The aim of this part of the analysis was to study the relationship of lung function and respiratory symptoms to the overall duration and intensity of exposure to welding fumes in welders.

The independent variables for this part of the study were age (years), height (mm), WT (weight/height<sup>2</sup>), smoking as a dummy variable (smokers and exsmokers= 1, nonsmokers= 0), the exposure index  $W_1$  (duration of exposure to fumes in confined and semiconfined spaces in years), the interaction term between  $W_1$  and age ( $AW_1$ ) and the interaction term between  $W_1$  and smoking ( $SW_1$ ).

Smoking interacted with welding fumes to increase the wheeze score of heavily exposed welders, while increased duration of exposure in the older workers was associated with increased breathlessness score (table 11).

Tables 12, 13 & 14 and figs 52 to 56 show that increased exposure to fumes accentuated the decline in lung function with age as described by  $T_{1CO}$ , CV% and CC%. Smoking interacted with welding fumes to decrease  $K_{CO}$  of the heavily exposed welders. By contrast the decline in  $K_{CO}$  with age was less in men who were heavily exposed. Increased exposure to fumes in the welders was significantly associated with increased  $f_{C45}$ , by contrast, exposure was independent of  $\dot{V}_{e45}$  and  $V_{T30}$  (table 15).



Table 11: REGRESSION EQUATIONS DESCRIBING  
RESPIRATORY SYMPTOMS

	WHEEZE	BREATHLESSNESS
CONSTANT	0.604	1.443
AGE (years)	-0.003	-0.006
SMOKING (1,0)	-0.003	-0.190**
W <sub>1</sub> (years)	-0.045	-0.055
AW <sub>1</sub>	0.003	0.001**
SW <sub>1</sub>	0.023***	0.019*

\*= 0.05 ≥ p >0.01 \*\*= 0.01 ≥ p > 0.001 \*\*\*= p ≤ 0.001

Table 12: REGRESSION EQUATIONS DESCRIBING  
FEV<sub>1</sub> & FEV<sub>1</sub>%

	FEV <sub>1</sub>	FEV <sub>1</sub> %
CONSTANT	-3.838	78.308
AGE (years)	-0.016	-0.023
SMOKING (1,0)	0.016	0.037
W <sub>1</sub> (years)	0.092*	1.161*
AW1	-0.002*	-0.029*
SW1	-0.008	-0.051
HEIGHT (mm)	0.005***	-0.002

\*= 0.05 ≥ p >0.01 \*\*= 0.01 ≥ p > 0.001 \*\*\*= p≤ 0.001

Table 13: REGRESSION EQUATIONS DESCRIBING  
CV%, CC% &  $\dot{V}_{\max 50}$

	CV%	CC%	$\dot{V}_{\max 50}$
CONSTANT	19.972	35.027	-3.247
AGE (years)	-0.082	0.076	0.014
SMOKING (1,0)	5.846***	5.271**	-0.187
W <sub>1</sub> (years)	-1.784***	-1.933***	0.250
AW1	0.047***	0.050***	-0.007*
SW1	-0.268	-0.177	-0.002
HEIGHT (mm)	-	-	0.004*

\*= 0.05 ≥ p > 0.01    \*\*= 0.01 ≥ p > 0.001    \*\*\*= p ≤ 0.001

Table 14: REGRESSION EQUATIONS DESCRIBING  
T<sub>lco</sub> & K<sub>co</sub>

	T <sub>lco</sub>	K <sub>co</sub>
CONSTANT	-12.845	5.088
AGE (years)	-0.005	-0.059***
SMOKING (1,0)	-1.289*	0.272
W <sub>1</sub> (years)	0.121	-0.03
AW <sub>1</sub>	-0.013**	0.004***
SW <sub>1</sub>	0.021	-0.046**
HEIGHT (mm)	0.013***	-0.001
WT	10048.5**	2680.4

\*= 0.05 > p > 0.01 \*\*= 0.01 > p > 0.001 \*\*\*= p ≤ 0.001



Table 15: REGRESSION EQUATIONS DESCRIBING  
THE EXERCISE INDICES

	$V_{T30}$	$f_{C45}$	$\dot{V}_{e45}$
CONSTANT	0.464	184.44	8.535
AGE (years)	0.002	-0.248	0.154**
SMOKING (1,0)	0.051	-0.794	0.710
$W_1$ (years)	0.0001	0.509**	0.004
HEIGHT (mm)	0.0006	-0.033	0.003
ACT (1,0)	0.032	-5.079***	0.083
WT	-237.014	-32589.85	9783.37

\*= 0.05  $\geq$  p >0.01 \*\*= 0.01  $\geq$  p > 0.001 \*\*\*= p $\leq$  0.001

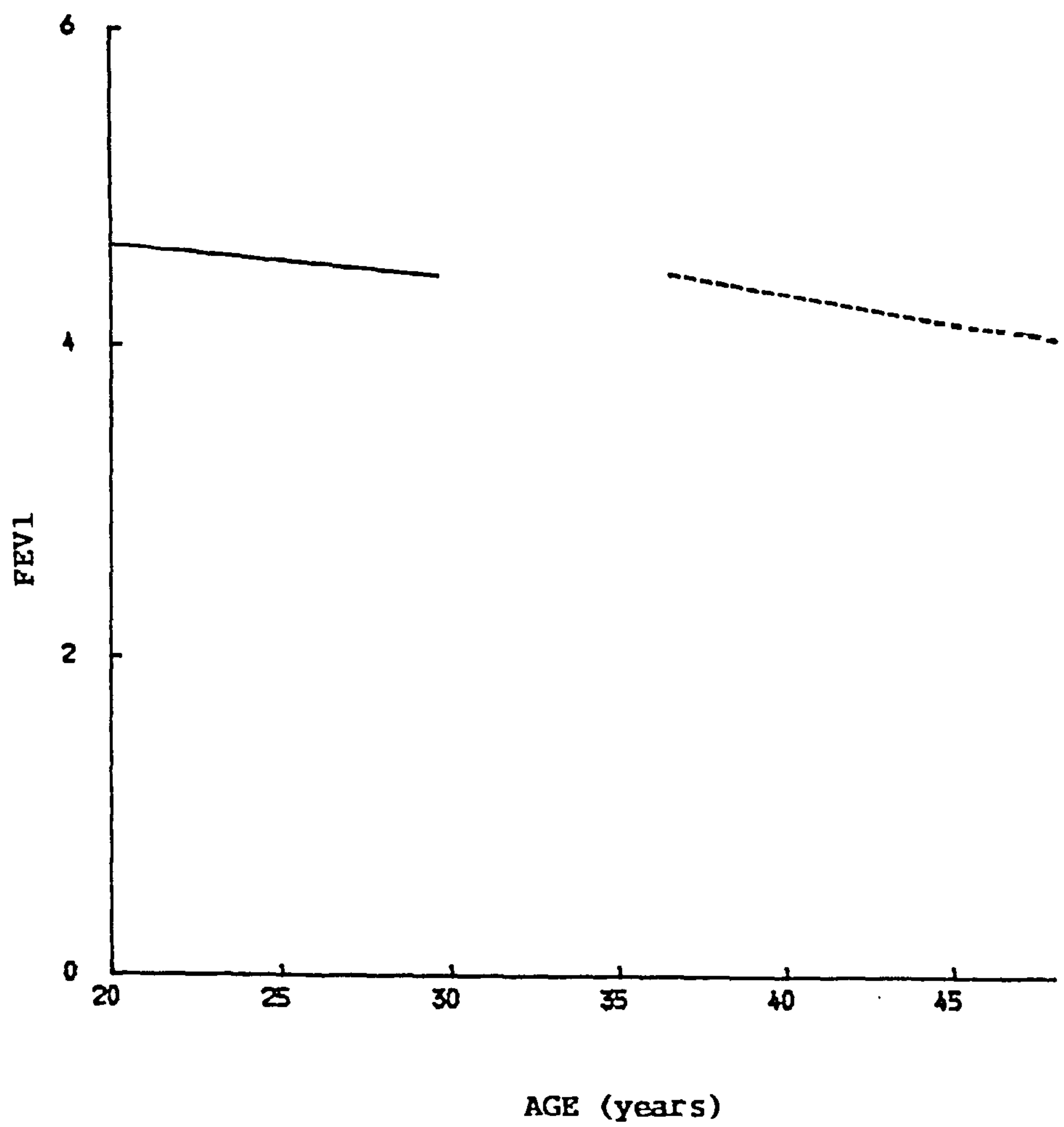


Figure 52: Regression of FEV1 on age at 2 (—) and 10 (---) year levels of exposure to fumes

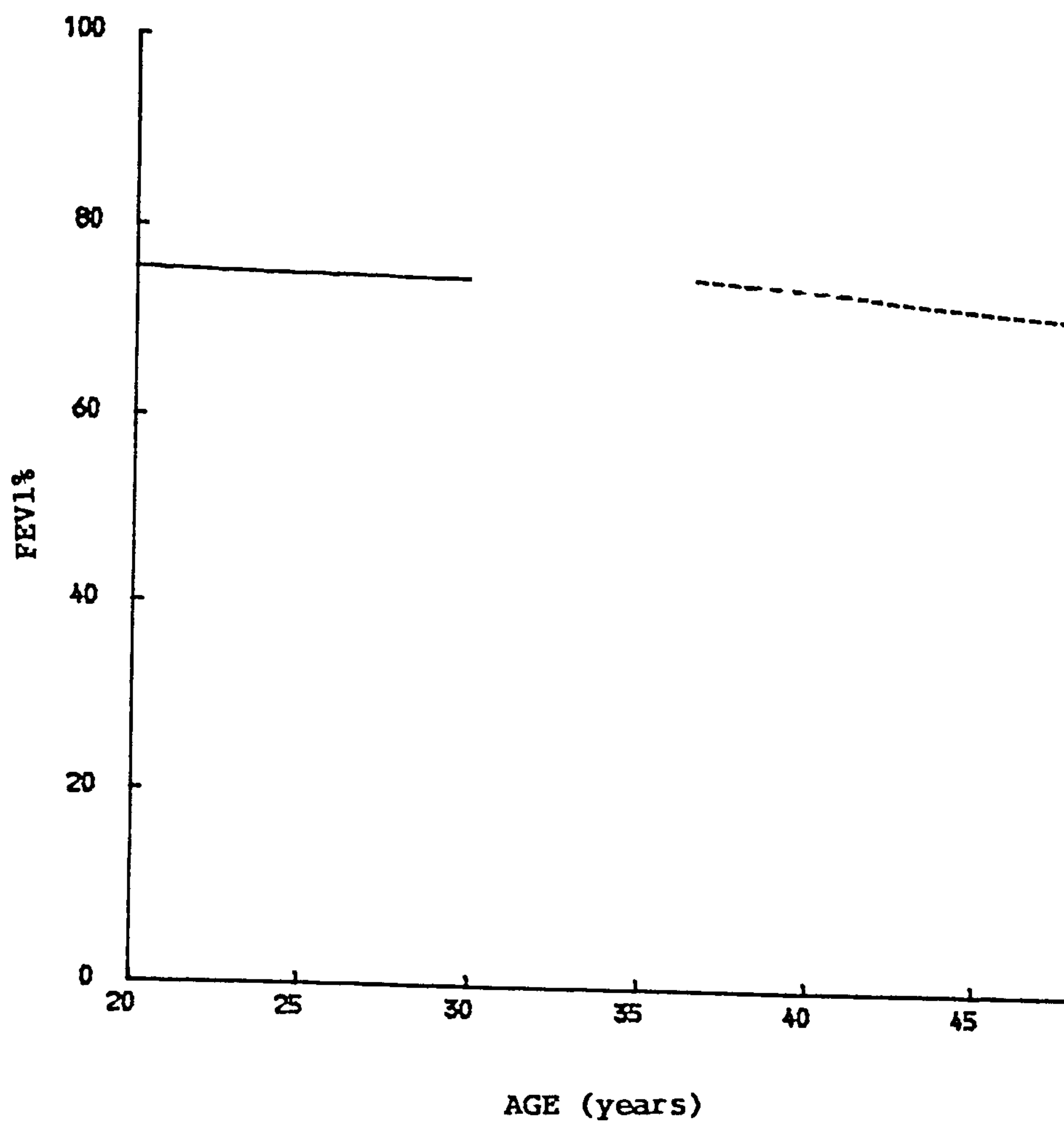


Figure 53: Regression of FEV1% on age at 2 (—) and 10 (---) year levels of exposure to fumes

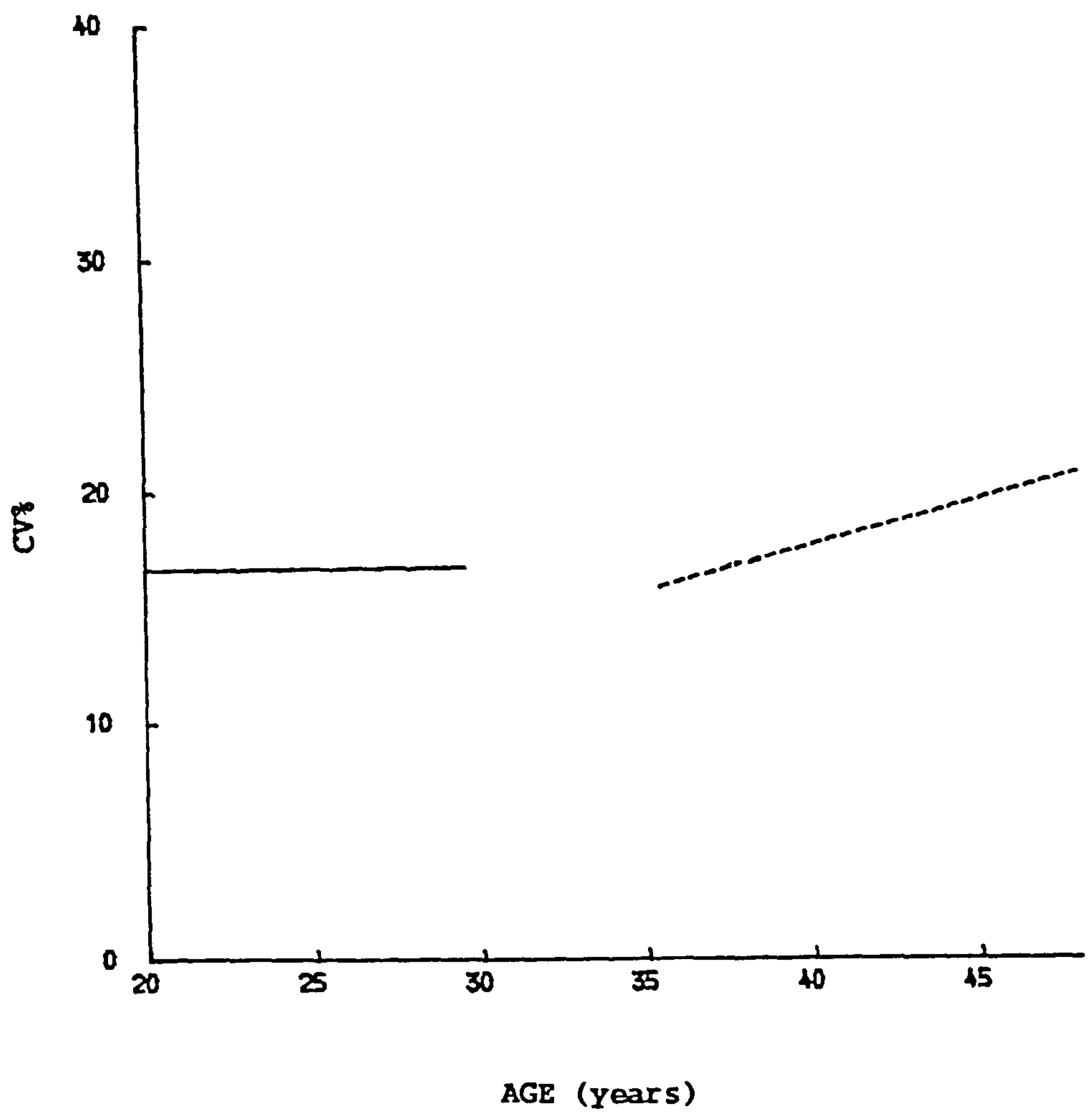


Figure 54: Regression of CV% on age at 2 (—) and 10 (---) year levels of exposure to fumes



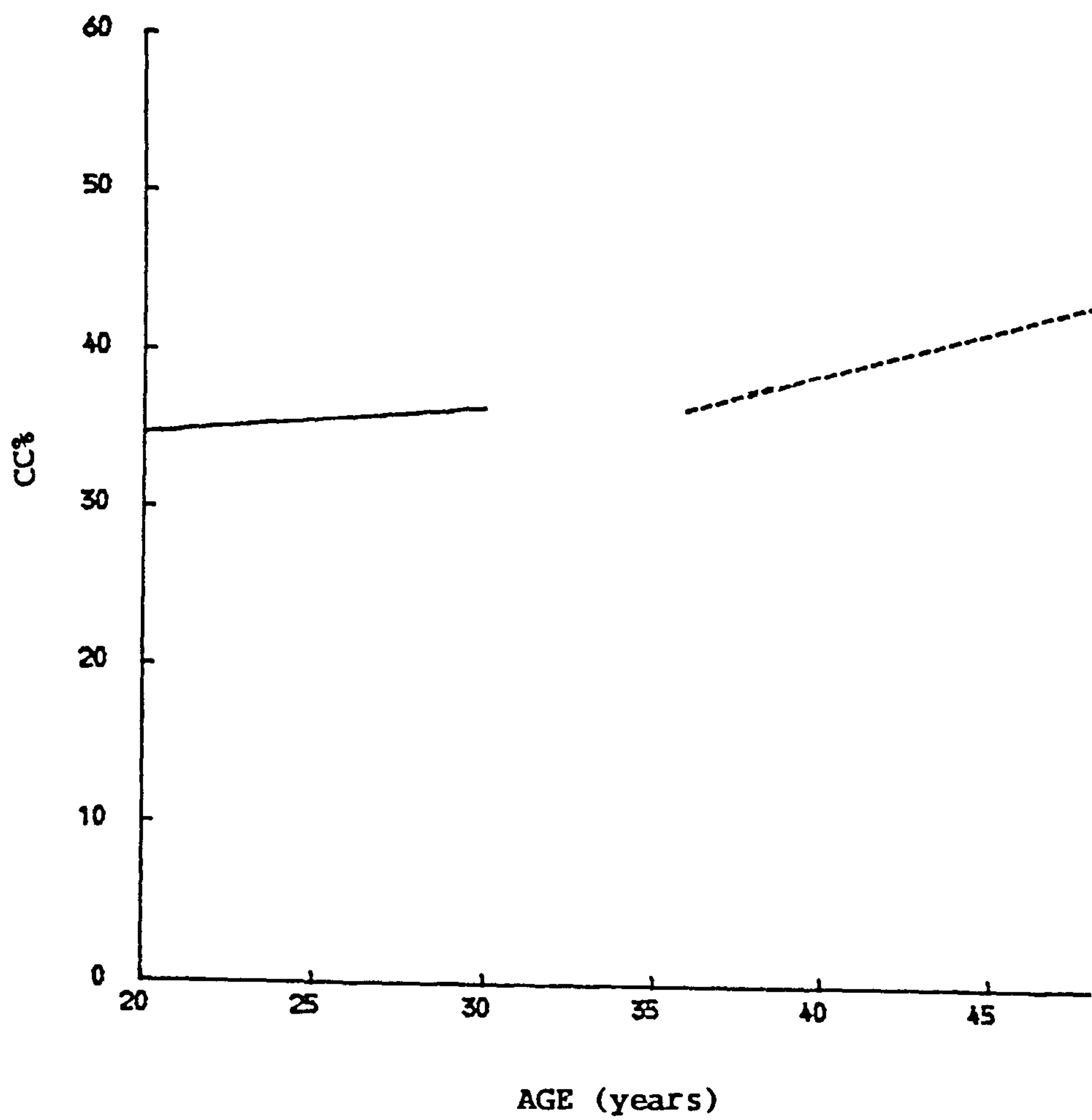


Figure 55: Regression of CC% on age at 2 (—) and 10 (---) year levels of exposure to fumes

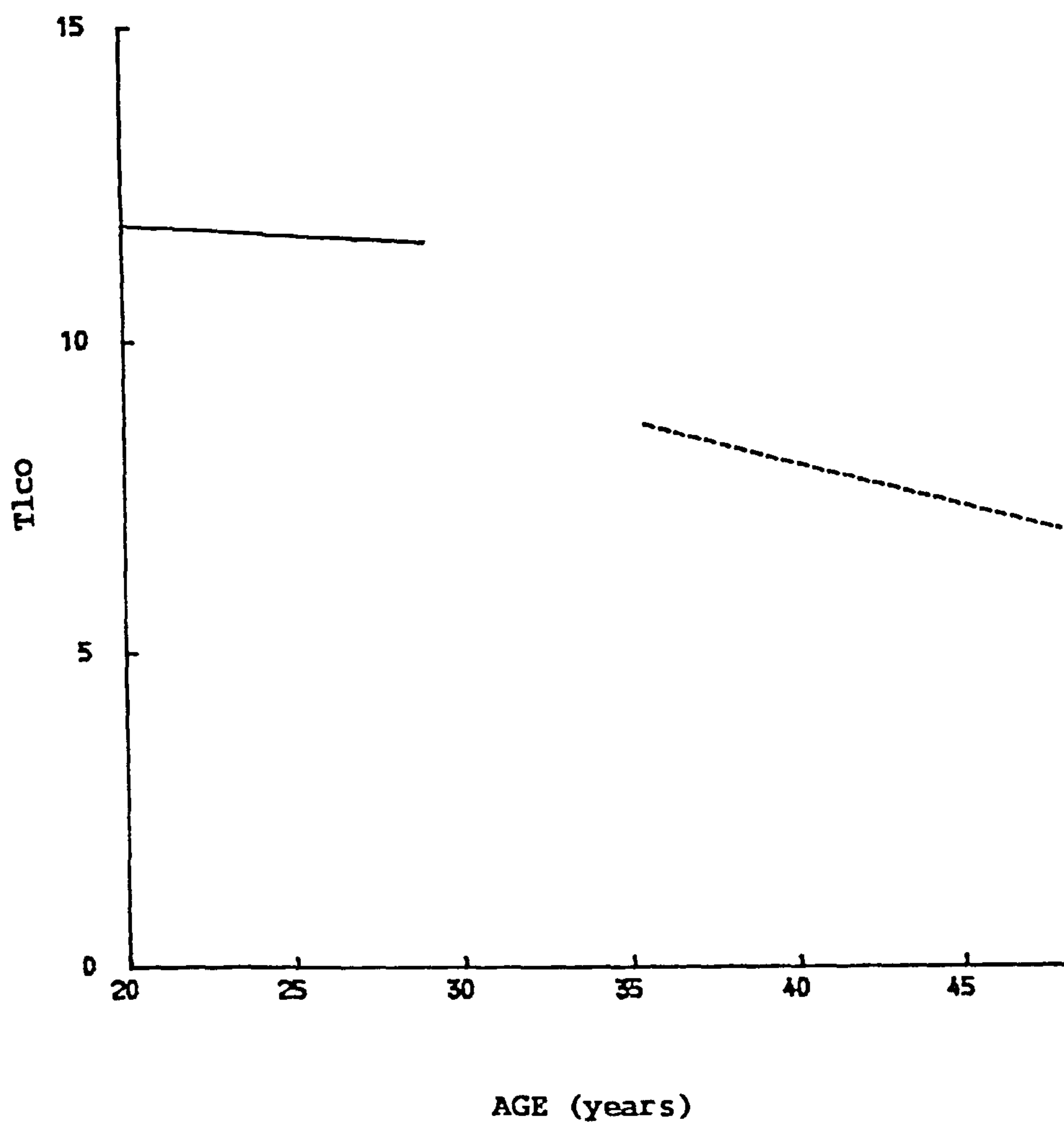


Figure 56: Regression of Tlco on age at 2 (—) and 10 (---) year levels of exposure to fumes

### 6.1.3 CAULKER/BURNERS

The aim of this part of the analysis was to study the relationship of lung function and respiratory symptoms to duration of exposure to above average concentrations of fumes in the caulker/burners. The independent variables were age (years), height (mm), WT (weight/height<sup>2</sup>), smoking as a dummy variable (smokers and exsmokers=1, nonsmokers= 0), exposure to fumes on the ship (CB<sub>2</sub> "years"), the interaction term between age and CB<sub>2</sub> (ACB<sub>2</sub>), and the interaction term between smoking and CB<sub>2</sub> (SCB<sub>2</sub>).

Tables 17 and 18 and figs. 58 to 60 show that increased exposure to fumes accentuated the decline in lung function with age as described by CV%, CC%, SLIII, N<sub>2</sub> Diff and RV%. No significant association between exposure to fumes in the caulker/burners and Tlco, Kco,  $\dot{V}_{e45}$ , V<sub>T30</sub> or f<sub>C45</sub> (tables 19 and 20). Although increased exposure to fumes in the older caulker/burners was associated with decline in FVC, FEV<sub>1</sub> and PEF<sub>R</sub> these relationships did not reach the 1 per cent level of significance where p was less than 0.05 but was greater than 0.01 (table 17).

Table 16: REGRESSION EQUATIONS DESCRIBING  
THE RESPIRATORY SYMPTOMS

BREATHLESSNESS	
CONSTANT	0.992
AGE	0.003
SMOKING	-0.028
CB <sub>2</sub>	-0.055*
ACB <sub>2</sub>	0.001*
SCB <sub>2</sub>	0.016*

\*= 0.05 ≥ p > 0.01    \*\*= 0.01 ≥ p > 0.001    \*\*\*= p ≤ 0.001



Table 17: REGRESSION EQUATIONS DESCRIBING  
FVC, FEV<sub>1</sub>, FEV<sub>1</sub>%, PEFR & RV%

	FVC	FEV <sub>1</sub>	PEFR	RV%
CONSTANT	-4.725	-1.608	-3.508	13.64
AGE	-0.002	-0.022*	0.037	0.066
SMOKING	0.014	-0.179	-0.147	-0.714
CB <sub>2</sub>	0.080*	0.063	0.264**	-0.822**
ACB <sub>2</sub>	-0.002*	-0.002*	-0.008*	0.021**
SCB <sub>2</sub>	-0.0001	0.012	0.018	0.044
HEIGHT	0.006***	0.004***	0.007***	0.005

\*= 0.05 ≥ p > 0.01    \*\*= 0.01 ≥ p > 0.001    \*\*\*= p ≤ 0.001

Table 18: REGRESSION EQUATIONS DESCRIBING  
CV%, CC%,SLIII & N<sub>2</sub> Diff

	CV%	CC%	SLIII	N <sub>2</sub> Diff
CONSTANT	9.527	29.971	2.494	1.496
AGE (years)	0.122	0.154	-0.045*	-0.023
SMOKING (1,0)	4.465**	2.648	0.545	0.388
CB <sub>2</sub> (years)	-0.936*	-1.377**	-0.169*	-0.109*
ACB <sub>2</sub>	0.029**	0.039***	0.006**	0.004**
SCB <sub>2</sub>	-0.279	-0.174	-0.042	-0.032

\*= 0.05 ≥ p >0.01 \*\*= 0.01 ≥ p > 0.001 \*\*\*= p≤ 0.001

Table 19: REGRESSION EQUATIONS DESCRIBING

 $T_{lco}$  &  $K_{co}$ 

	$T_{lco}$	$K_{co}$
CONSTANT	-11.614	1.444
AGE (years)	-0.013	-0.008
SMOKING (1,0)	-1.636***	-0.275***
CB <sub>2</sub> (years)	0.017	-0.0005
ACB <sub>2</sub> (years)	-0.004	-0.0005
SCB <sub>2</sub> (years)	0.067	0.009
HEIGHT (mm)	0.012***	-0.00006
WT	11726.35**	3537.19***

\*= 0.05  $\geq$  p > 0.01 \*\*= 0.01  $\geq$  p > 0.001 \*\*\*= p  $\leq$  0.001

Table 20: REGRESSION EQUATIONS DESCRIBING  
THE EXERCISE INDICES

	$\dot{V}_{e45}$	$V_{T30}$	$f_{C45}$
CONSTANT	19.328	-0.041	141.115
AGE (years)	0.066	0.0009	0.119
SMOKING (1,0)	0.219	0.099	-3.940
CB <sub>2</sub> (years)	-0.035	-0.004	-0.007
ACT (1,0)	-0.609	0.068	-3.358
HEIGHT (mm)	0.001	0.0009	-0.022
WT	-870.433	-552.225	24125.1

\*= 0.05  $\geq$  p >0.01 \*\*= 0.01  $\geq$  p > 0.001 \*\*\*= p $\leq$  0.001



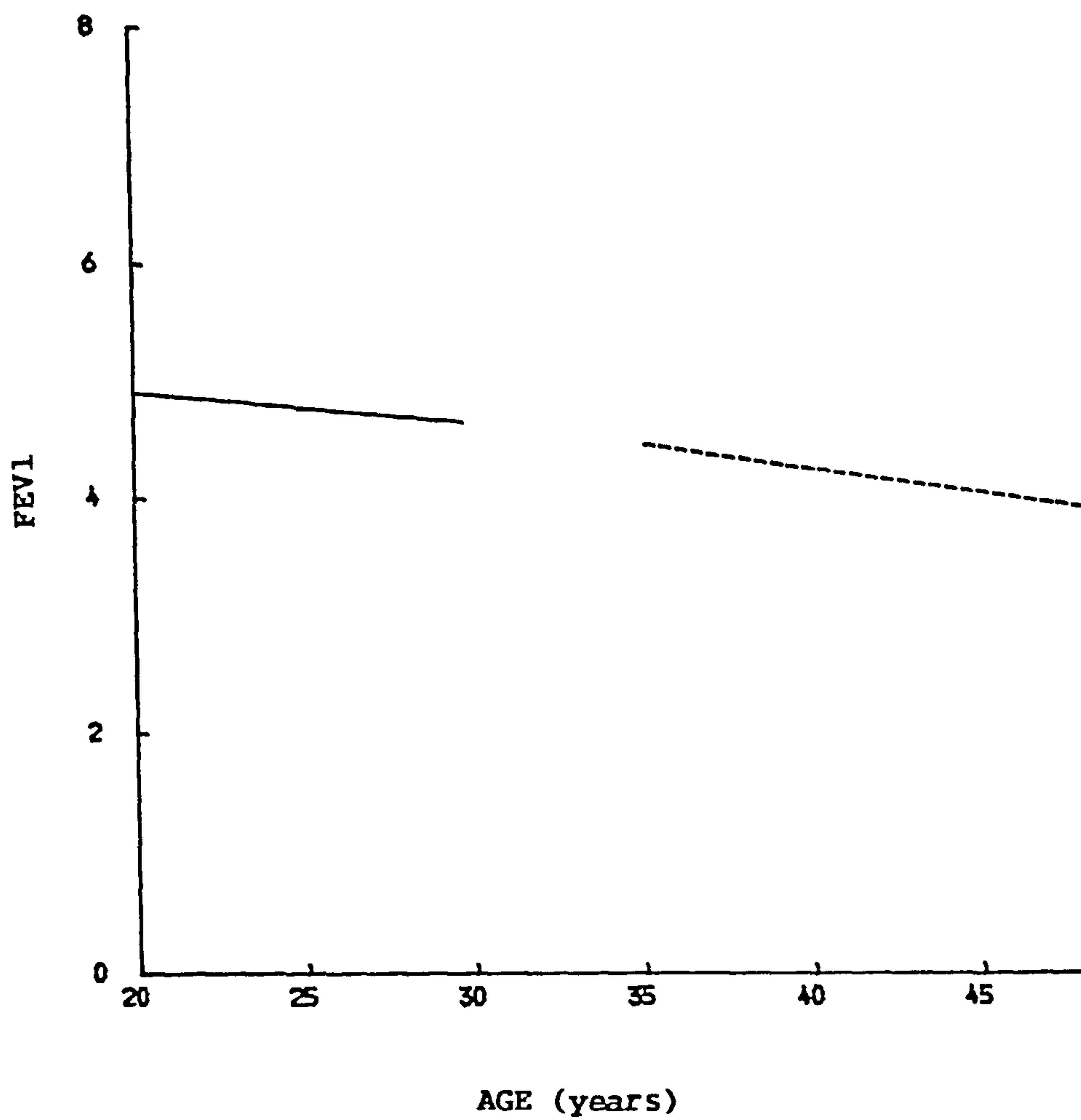


Figure 57: Regression of FEV1 on age at 2 (—) and 10 (---) year levels of exposure to fumes

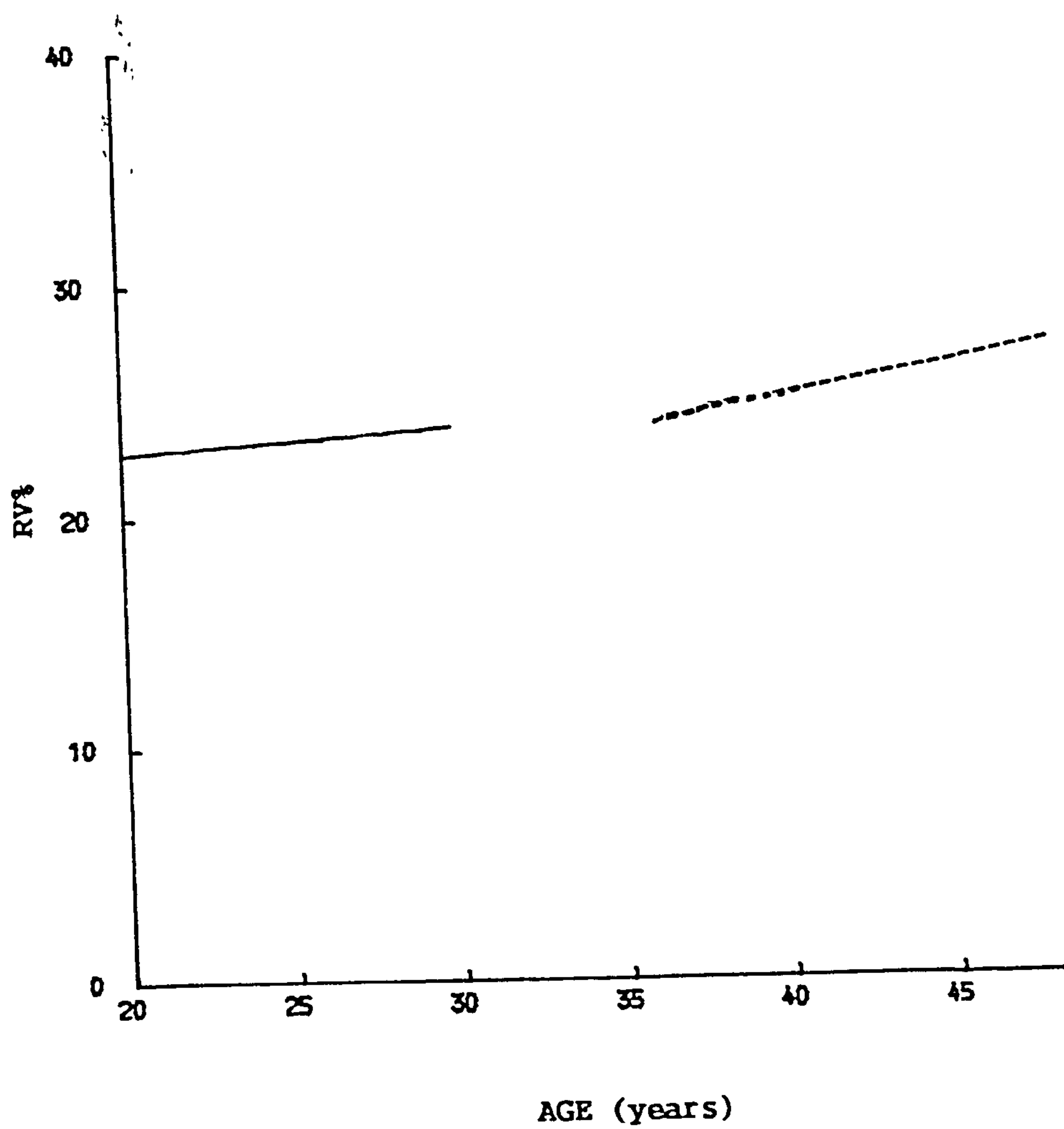


Figure 58: Regression of RV% on age at 2 (—) and 10 (---) year levels of exposure to fumes

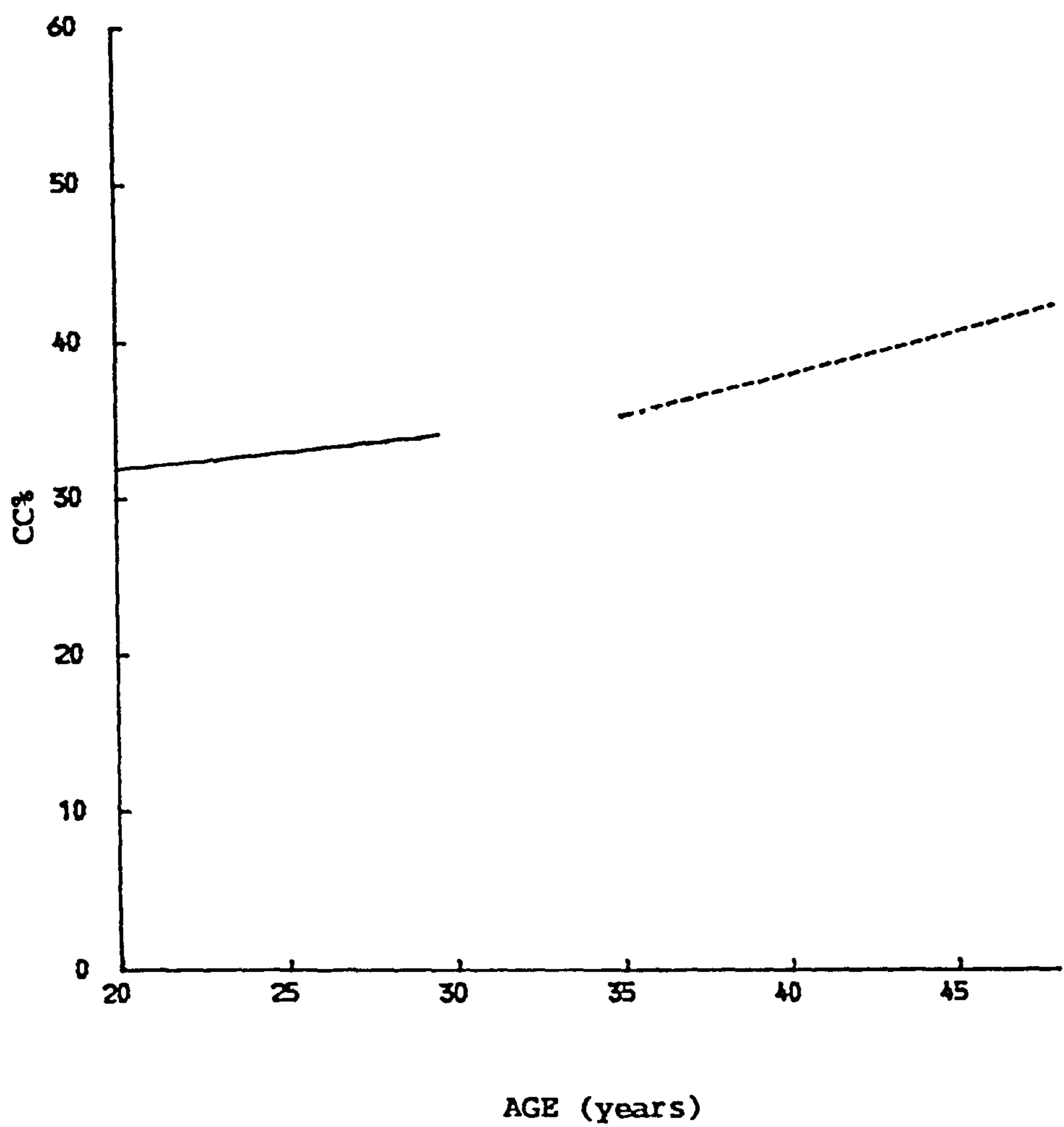


Figure 59: Regression of CC% on age at 2 (—) and 10 (---) year levels of exposure to fumes

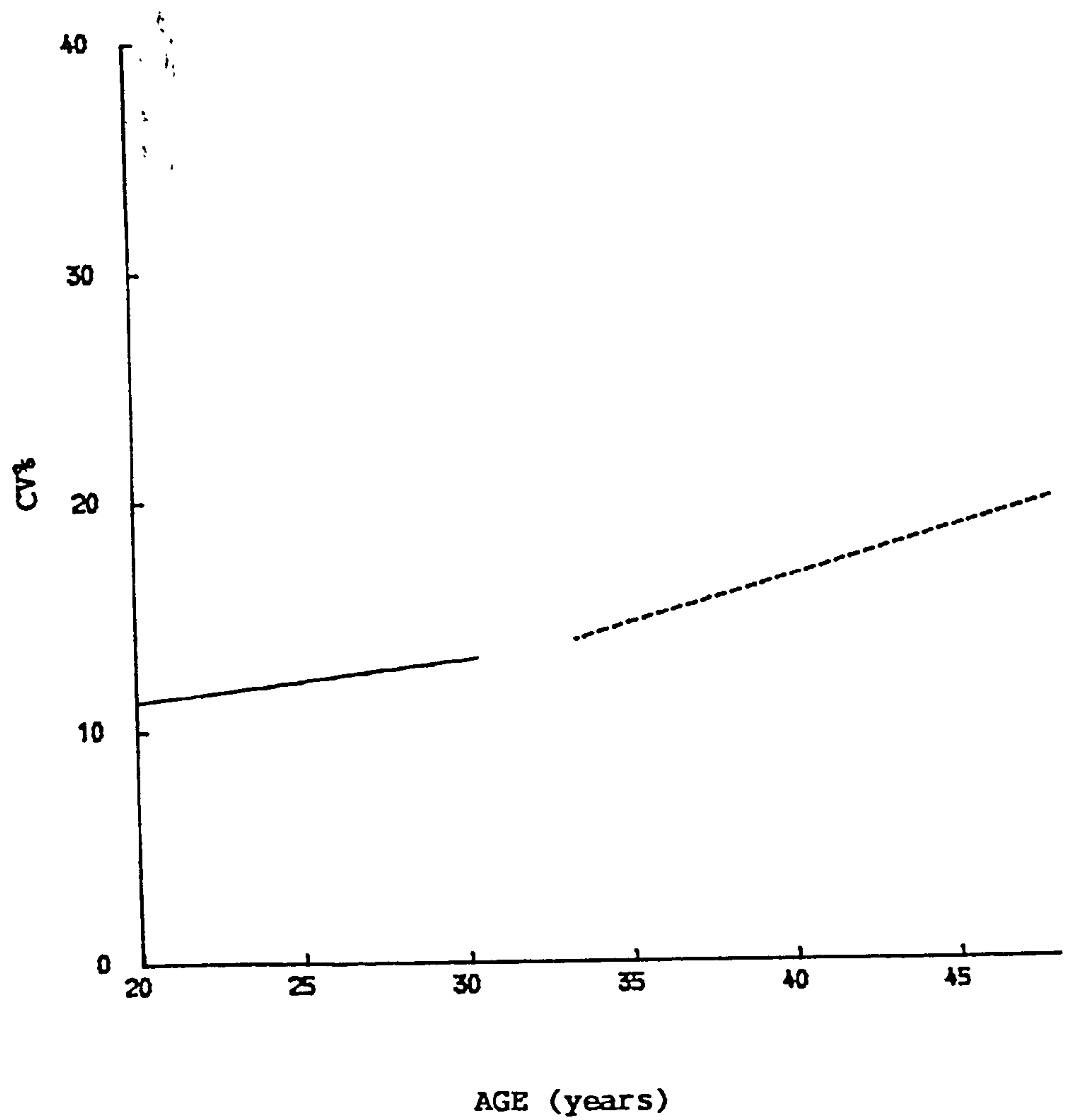


Figure 60: Regression of CV% on age at 2 (—) and 10 (---) years of exposure to fumes



#### 6.1.4 YOUNG WORKERS AGED 20 - 25 YEARS

The aim of this section was to examine the effects of welding and burning fumes on the very young workers. A subsample of the whole selected workers including all the welders and burners and other tradesmen aged 20 - 25 years (number = 105 workers) was used for this part of the analysis. Two indices for exposure to welding fumes were used: WCB (ever a welder or a caulker/burner) and duration of exposure to fumes in the confined and semiconfined spaces (WCB<sub>1</sub>). Age had no effect on the lung function over that narrow range of age, and was not included in the analysis.

##### 6.1.4.1 WELDERS & BURNERS (WCB) VERSUS CONTROLS

Table (21) shows that smoking was associated with increased wheeze. Independent of smoking and height, the mean values of CV%, CC% and RV% were significantly higher for the welders and caulker/burners compared with the controls. The other lung function indices were not significantly different in the two groups.

Table 21: Regression equations describing  
CV%, CC%, RV%, CHRONIC BRONCHITIS AND WHEEZE

	Constant	Smoking (1,0)	WCB (1,0)	Height (mm)
CV%	7.566	2.233 *	5.093***	-
CC%	27.05	1.843	5.583***	-
RV%	-11.254	0.219	2.124**	0.018**
WHEEZE	0.126	0.236**	0.180*	-

\*= 0.05  $\geq$  p >0.01 \*\*= 0.01  $\geq$  p > 0.001 \*\*\*= p $\leq$  0.001

#### 6.1.4.2 EXPOSURE IN CONFINED AND SEMICONFINED SPACES (WCB<sub>1</sub>)

In this part of the analysis duration of exposure to fumes in confined and semiconfined spaces (WCB<sub>1</sub>) was calculated for all the workers (target and control n= 105), scores for the controls were 0 while those for the welders and burners ranged from 1 - 6 years. Table 22 and figs 61 and 62 show the results obtained on the young workers.

Smoking was significantly associated with CV%, CC%, and bronchitis. Independent of smoking and height, WCB<sub>1</sub> was significantly associated with increased CV%, CC%, and bronchitis. The other lung function indices were not significantly related to exposure.

Table 22: Regression equations describing  
CV%, CC%, CHRONIC BRONCHITIS AND DYSPNOEA

	Constant	Smoking (1,0)	WCB <sub>1</sub> (years)	SWCB <sub>1</sub> (years)
CV%	8.338	3.303***	0.521***	-
CC%	27.96	3.065***	0.514***	-
CHRONIC				
BRONCHITIS	-0.021	0.141***	0.021***	-
DYSPNOEA	1.010	NS	NS	0.02 *

\*= 0.05>p>0.01 \*\*= 0.01>p>0.001 \*\*\*= p≤0.001

NS: Nonsignificant



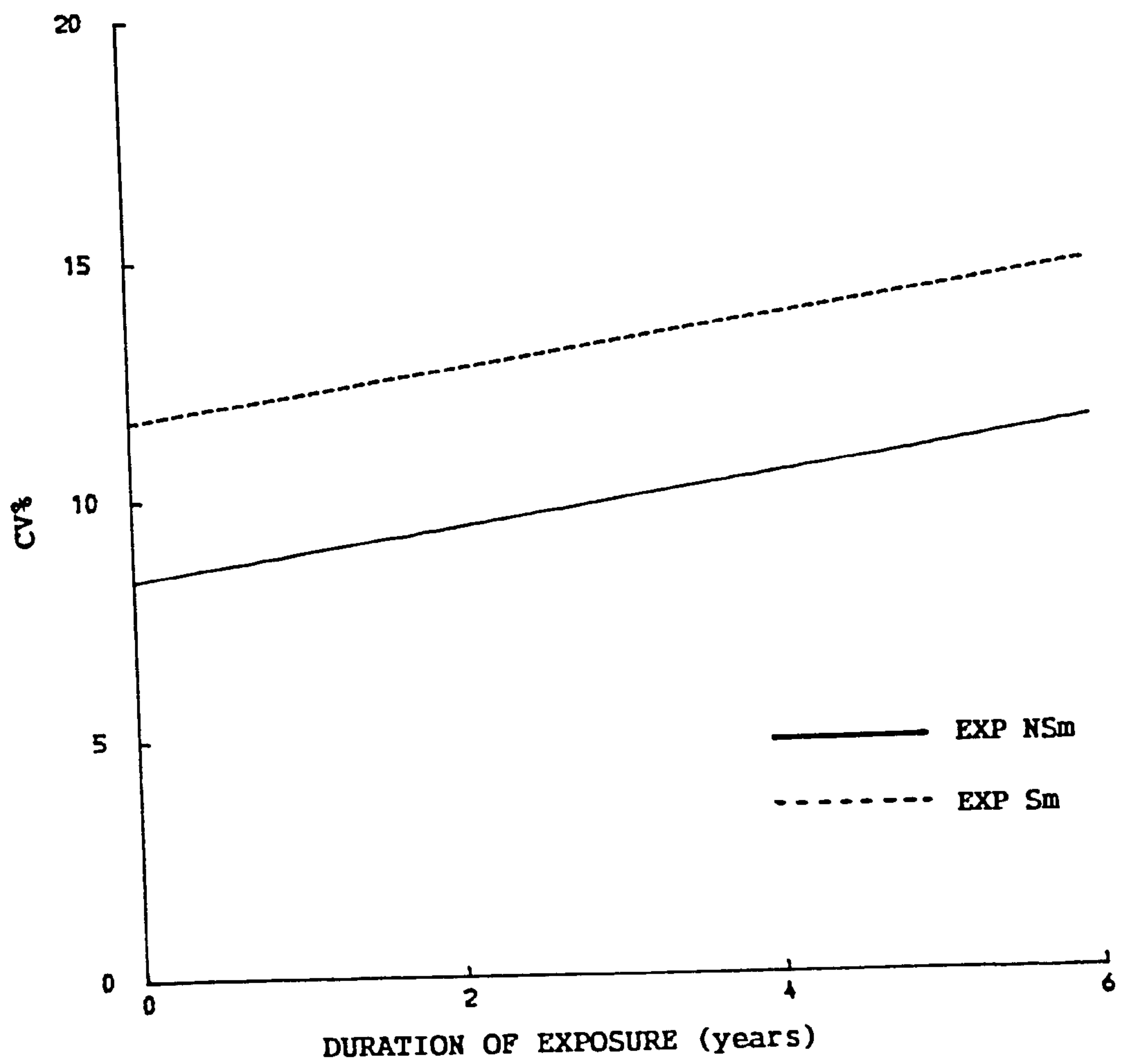


Figure 61: Regression of CV% on duration of exposure in the smoker and nonsmoker workers

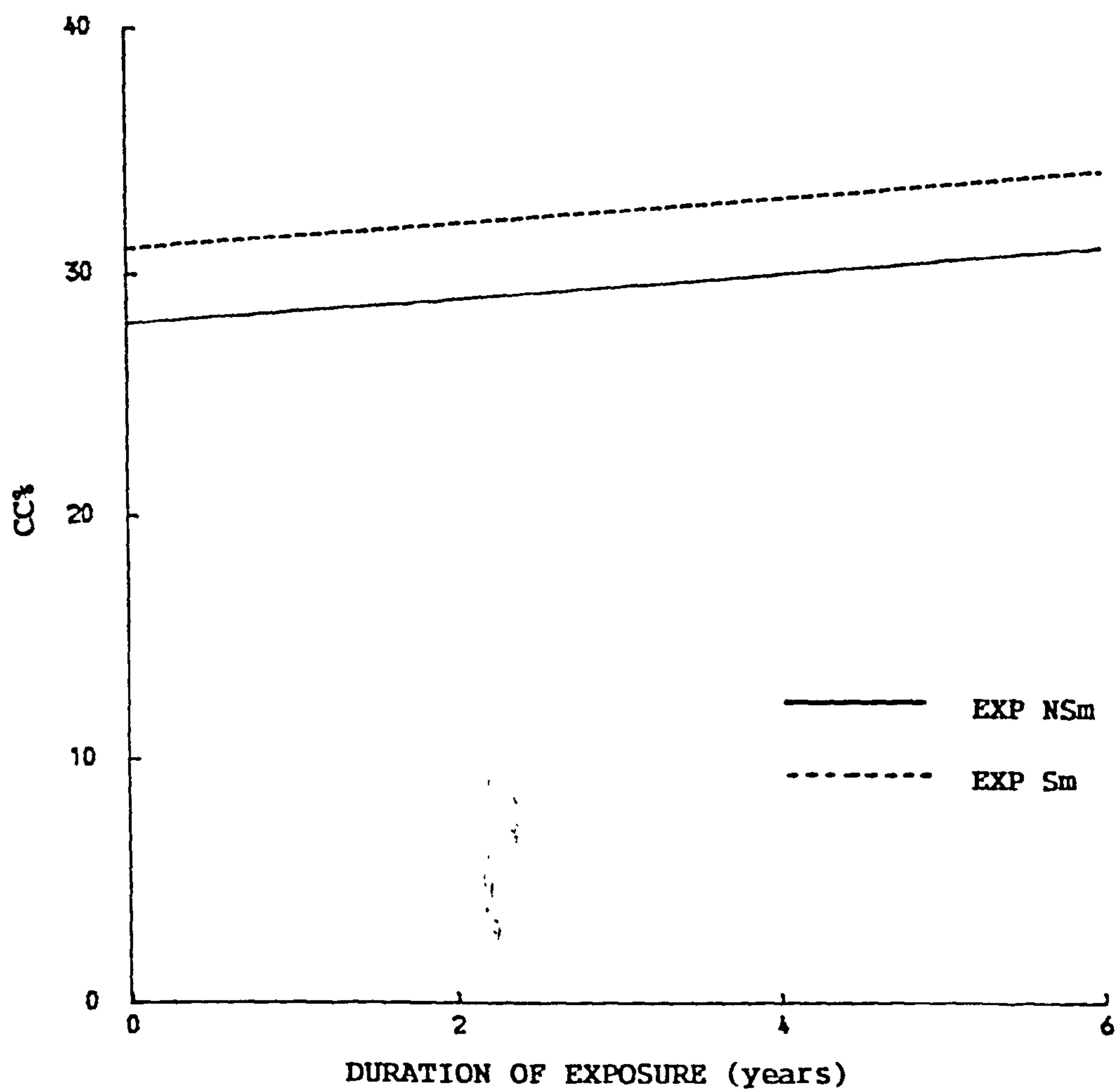


Figure 62: Regression of CC% on duration of exposure in the smoker and nonsmoker workers

## CHAPTER 7

### DISCUSSION

During ship construction welders and burners are exposed to heavy clouds of fumes, most of which are potentially harmful.

There have been several surveys of the health of welders over the past 50 years. These studies demonstrated an association between exposure to fumes and respiratory symptoms. However, no long term effect of fumes on respiratory function has been established.

The gases and particulates in the fumes from welding and burning are very small in size (less than 1 micrometer in diameter) and on this account capable of reaching the small airways in the periphery of the lung. These are the primary site of obstruction in chronic obstructive lung disease (Hogg et al 1968; Anthonisen et al 1968; Gelb et al 1981; Fairshier & Wilson 1981). However, conventional tests of lung function (e.g FEV<sub>1</sub>) are insensitive to changes in small airways (Tai & Read 1967; Levine et al 1970; Macklem 1972; Sobol et al 1973). This is because the resistance of small airways (< 2mm internal diameter) contributes only about 20% to the total pulmonary resistance (Macklem & Mead 1967; Macklem et al 1969; Hogg et al 1968). Thus even doubling the small airway resistance causes at the most a 20% change in pulmonary resistance (Brown et al 1969). In most of the previous studies conventional spirometry was used, this would have underestimated any impairment which was mainly confined to

the small airways.

In view of this, in the present study tests specific to small airway function e.g closing volume, slope of alveolar plateau, and maximal expiratory flow volume curves (Buist & Ross 1973; McCarthy et al 1973; Zamel et al 1973; Guyatt et al 1975; Lapp et al 1976) were used in addition to the conventional spirometry to study the long term effect of welding fumes on the lung function of welders and burners. The transfer factor for the lung was also measured and the cardiorespiratory response to exertion was examined by using exercise tests.

## 7.1 SELECTION OF THE WORKERS

### 7.1.1 The target workers

Among the objectives of this study was to examine the early effects of welding fumes on the lung of exposed workers, therefore relatively young workers (mean age 32.9, age range 18 - 47 years) were selected. Because most of the workers join the shipyard at the age of 16 years and spend two years as apprentices, the minimum age of the workers in this study was defined as 18 years. A disproportionate number of the employed workers (aged 18 - 45 years) in 1982 was under the age of 30 years (table 1), therefore a stratified random sample was selected.

Several difficulties were met with during the conduct of the survey. The main difficulty was that many workers were made



redundant because of the increasing financial problems of the company. Most of these job losses (particularly in the welders) were among the young recently employed workers where their redundancy payments were much less than those for the older workers with longer periods of employment. Apart from their age distribution (table 1) it was impossible to get relevant information on those who left the yards because of the limited time and resources available for the field work. If the occurrence of respiratory symptoms had been one of the criteria for redundancy then those men who remained would have been particularly healthy and this could have led to underestimation of the effect of exposure to fumes. However, there was no general awareness of respiratory disability due to exposure to fumes among the workers nor knowledge of it by the management. So it is unlikely that this was a factor in the redundancies

Thus this study describes the respiratory health of welders and caulker/burners currently employed at the Swan Hunter Shipyards. It throws no comparable light on those who left the the yards during the course of the survey, or on those who had left in the past years before the survey was conducted.

#### 7.1.2 The controls

The controls for this study were men in other trades working in the same yard as the target workers. They should have been representative of all such men but this was not possible because the management could not spare the groups of workers in busy parts of the

yard. Instead the controls were invited to volunteer by shop stewards, foremen, and advertisement at the yard. The controls were matched with the target workers in sex (where all were males), in race and genetic background (where all were Caucasians), in social class (where all were manual workers e.g electricians, joiners, platers, fitters, riggers, plumbers and painters) and in age over the range of 18 - 45 years. The matching for age was less satisfactory than for the other variables (table 6); in addition the controls were taller than the target workers. The mean differences whilst significant were relatively small ( $175.3 \pm 6.5$  cm compared with  $173.1 \pm 6.5$  cm) but contributed to the absolute differences in lung function overall between controls and target workers (chapter 5). These effects were allowed for by including age and height in the multiple regression analysis. The age distribution of those who did not volunteer was given in table 4. It was not possible to get other information on these workers (page 161).

The self selection of the controls could also have introduced error if it had led to men volunteering on account of having developed respiratory symptoms from working along side welders. Thus some previous studies found that the prevalence of respiratory symptoms was similarly high in both the welders and controls (Fogh et al 1969; Peter et al 1973). The present study revealed that 92% of the controls were exposed to fumes during their working in the yards. However, their exposure was mainly in the open and here concentration of fumes is usually within the recommended Threshold Limit Value (TLV), by contrast concentration of fumes at the breathing zone of

welders in confined and semiconfined places often exceeds the TLV (Akbarkhanzadeh, 1979). Any errors on this account were allowed for by looking for significant trends within the groups of welders and caulker/burners separately. In the event both sets of analyses yielded similar results so the errors introduced by imperfect selection of the control subjects were not material.

#### 7.1.3 Workers with missing information

Closing volume data were missing on 112 workers (81 target and 31 control workers), their age distribution and personal characteristics were given in table 4. Compared with men on whom measurement were made the lapses did not differ significantly in age, height or weight (Appendix B tables 28 & 29, page 228 - 231).

Among the target group, the proportions of smokers were similar in both groups, and FEV<sub>1</sub> was not significantly different. On the other hand, among the control group those with missing information on closing volume test included a higher proportion of smokers; the FEV<sub>1</sub> of these men was lower compared with the remainders; the difference was that to be explained from the difference in smoking habit.

Exercise data were missing on 59 workers (37 target and 22 control workers); their age distribution and personal characteristics were given in table 5. Among the target workers both groups had similar age, height and weight. Although more smokers were included in the group with no exercise information, FEV<sub>1</sub> was similar in both groups. On the other hand those with no exercise information among



the control group were younger and lighter than the rest of the workers but  $FEV_1$  was similar in both groups (Appendix B table 30 & 31, page 228 - 233).

Thus the workers with missing information (closing volume and exercise data) were not markedly different in personal characteristics and in  $FEV_1$  from the workers in the corresponding groups, and omission of this information was unlikely to have materially affected the results.

## 7.2 MODEL OF STATISTICAL ANALYSIS

Multiple regression analysis is the standard method for studying association between exposure and response in occupational lung diseases. It has been used extensively in research in this field. Among the factors which determine the function of the lung are age, sex, race, body dimensions, social class, smoking habit and physical activity outside working hours. It was impossible to match the controls with the target workers in all these variables. However, the controls closely resembled the target workers in sex, race, social class and age range. Therefore multiple regression was used to compare the mean values of different lung function indices in the control and target workers while allowing for differences in the unmatched variables between the two groups. Multiple regression was also used to study the variation in lung function with exposure to above average levels of fumes in the welders and caulker/burners separately.



Some 17 lung function tests and respiratory symptoms were used as dependent variables in the analysis so the risk of getting significant effects by chance was not inconsiderable. The risk was minimised by considering as significant only those relationships where the level of significance ( $p$ ) was 1% or less.

The expected effects of fume were in the same direction as the effect of age and of smoking and might have acted synergistically. To examine this probability the model was extended to include the appropriate interaction terms. In addition in order to investigate the early effects of fume exposure a separate analysis was carried out on the results for those men in the survey population who were in age range 20 to 25 years.

In population studies the function of the lung increases with age to reach a peak in the age range 23 to 25 years, then declines with advancing age. Thus an analysis of men aged 25 years and over might also have been appropriate. However when the present lung function results were standardised for height then plotted against age no such pattern was apparent. Nor was there evidence for an accentuated decline in the older men such as might have been described by the inclusion of a term for age squared in the regression. Thus the present overall analysis based on linear age seemed to be appropriate. A more complete model might have been necessary if the survey had been planned to include older subjects.

### 7.3 ESTIMATION OF EXPOSURE TO WELDING AND BURNING FUMES

During ship construction, caulking, burning and welding are carried out in the sheds as well as on the ship. Working on the ship under the deck entails exposure to fumes mainly in confined spaces, while in the shed exposure is mainly in semiconfined and open spaces. Dust extraction system was introduced into the shipyard in the mid 1960s. However, most workers claimed it was difficult to move the tubings and hose of the ventilation system into the confined spaces (e.g double bottom ). Once there the suction was often found to be insufficient to reduce the dust. Most workers did not use it, and those who did failed to use it regularly. Several previous studies found that the ventilation systems failed to reduce fume concentration to the recommended level and that the concentration of welding fumes in confined and semiconfined spaces were much higher than in open spaces, personal exposure also varied very much from one welder to another and for the same welder on different occasions (Steel & Sanders 1966; Smith 1967; Akbarkhanzadeh 1979).

The effect of welding fumes on the lung is likely to be cumulative, so the duration as well as the intensity of exposure to fumes should be taken into account. Thus in the present study indices of exposure to fumes were established to reflect duration as well as intensity of exposure. The first index ever a welder or a burner (WCB) was used to compare the target with the control workers. Because exposure to fumes was higher in confined and semiconfined spaces compared with exposure in open spaces, the second index (exposure 1) was

constructed to reflect duration of exposure of the welder (W1) or the burner (CB<sub>1</sub>) in such places. Working in confined spaces was mainly on board ship whilst work in open spaces was mainly in the sheds; so the former entailed the heavier exposure. This was the basis for the third index (exposure 2) which was the time spent working on board ship as a welder (W2) or a burner (CB<sub>2</sub>). Thus exposure 1 and exposure 2 reflected duration of exposure to above average levels of fumes. An experienced interviewer obtained this information using a detailed occupational questionnaire. It was easy for the workers to recall time spent in confined spaces because they were paid extra money for that work. Also it was easy for them to recall the duration of exposure to fumes as most of them had started their working life as apprentices in the yard (age - 16 years). In order to assess the accuracy of the responses of the workers to the occupational questionnaire, the questionnaire was repeated on 21 workers (Appendix B tables 25 & 26 and figs 63 to 65). Generally the responses on the second occasion were highly correlated with those on the first one. The mean duration of exposure to fumes, the mean proportion of time spent in confined and semiconfined spaces and the mean value of the estimated index of exposure in confined spaces were not significantly different on the two occasions. Also responses to exposure on the ship and exposure in the shed were very similar, where the responses were different in only one worker. Duration of exposure to fumes was also highly correlated with age - 16 years ( $r=0.8$  in the caulker/burners and  $r=0.7$  in the welders). Thus, although the exposure indices were crude, they were



reproducible. In addition the analyses based on the three indices gave similar estimates of the contribution of exposure to respiratory impairment so the information contained in the different indices was at least consistent. The similarity was greater for the caulker/burners than for the welders amongst whom the index  $W_1$  (exposure in confined and semiconfined spaces) was associated with more marked impairment than was the case for  $W_2$  (exposure on the ship rather than in the shed). This could have been due to the nature of the work in the shed. The welders worked mainly in semiconfined places where their exposure to fumes was moderately high, yet in the index  $W_2$  such work was rated as having a low level of exposure. On the other hand, most of the work of the caulker/burners in the shed was in open places to prepare and cut the metal plates and exposure in confined and semiconfined places was mainly on the ship.

Measurement of welding fume concentrations in the working environment or in the breathing zone of the individual workers during the survey would have produced information on present exposures. For the reasons given earlier (page 166) no such measurements were attempted but there might be need for it in future especially if, as seems likely, the present working conditions are affecting health of recent recruits to the industry.



#### 7.4 INFORMATION OBTAINED ON RESPIRATORY SYMPTOMS AND LUNG FUNCTION

Information on respiratory symptoms was obtained by the standard British MRC questionnaire. The spirometry, single breath nitrogen test, the single breath transfer test, and the exercise test were performed using standard equipment and according to standard techniques. The equipment was calibrated frequently to ensure accuracy of the measurements. The three test operators who helped the author to collect the data as well as the author were well trained in lung function measurement and in interviewing workers. Every care was taken to ensure the quality of the measurement. The author asked the cough frequency questionnaire, conducted the single breath nitrogen test, examined the workers clinically and performed and scrutinized the ECGs before and during the exercise test.

#### 7.5 TYPES OF WELDING AND EXPOSURE TO ASBESTOS IN THE YARD

Manual Metal Arc Welding (MMAW) is the commonest type of welding in ship building. It is easy to use in different positions and to weld different types of plates. The present study showed that it was the main type of welding in the Swan Hunter shipyard. Other types of welding were used occasionally.

Asbestos is good insulating material. It is used in ship building either as asbestos sheets or spray to cover pipes, boilers, deckheads and bulkheads. The use of asbestos has been banned in the

shipyards since 1970. However, dismantling of old lagging (delagging) produces large amounts of dusts, but this is mainly a problem of ship repair. The present shipyard was mainly engaged in building new ships and the workers were relatively young, so a very low proportion of welders and caulker/burners used asbestos. In the present study exposure to asbestos was not significantly associated with impairment of lung function or increased respiratory symptoms.

#### 7.6 SMOKING HABIT

A higher proportion of the target workers were smokers or exsmokers and a lower proportion had never smoked compared to the controls. The reason for the lower proportion of life long nonsmokers was unclear. The high proportion of exsmokers could have been due to the men experiencing the effects of interaction of smoking with fume exposure for which there was objective evidence from the present analysis. Many men probably gave up smoking in consequence. This finding was consistent with that of Barhad et al who in 1975 found an excess of dyspnoea and wheeze in welders which was most marked among exsmokers.

## 7.7 EFFECT OF SMOKING

Smoking is a well recognized factor in the aetiology and pathogenesis of chronic obstructive lung disease and there is strong evidence that smoking is significantly associated with death from chronic bronchitis (Doll & Peto 1976). Numerous sample surveys of respiratory symptoms in the population have shown a much higher prevalence of cough and phlegm among smokers than among nonsmokers (College of General Practitioners 1961; Holland et al 1965; Bosse et al 1981). The present study confirmed these observations where smoking was the main factor which contributed to increase cough, phlegm, chronic bronchitis and wheeze, and was associated with impaired function of the small airway (e.g increased CV%, CC%, SLIII and N<sub>2</sub> Diff) and reduced transfer factor and K<sub>CO</sub>. It was possibly also associated with decreased FEV<sub>1</sub> but this relationship was not statistically significant either when smokers and exsmokers were grouped together or when smokers and life long nonsmokers were compared (table 25). Thus in the present study of relatively young men (mean age 31.5 years) smoking was associated with increased respiratory symptoms, impaired small airway function and reduced transfer factor for the lung. A greater effect of smoking on the function of the lung might have been observed if older workers had been included in the analysis.

## 7.8 EFFECT OF FUME EXPOSURE

The findings of the present study provide evidence of an excess of respiratory symptoms and impairment of lung function in the fume-exposed workers.

### 7.8.1 Respiratory symptoms

#### Wheeze

The fume-exposed workers in the present study reported significantly more wheeze on most days or nights than the controls. Similar observation was also reported by other studies (Barhad et al 1975; Oxhoj et al 1979; Lyngenbo et al 1985). The present study revealed also that smoking was an important determinant factor, and increased exposure to fumes in the smoking welders (but not caulker/burners) was associated with increased wheeze. Thus exposure to above average levels of fumes and smoking interacted to increase wheeze in the welders.

#### Asthma

The degreasing materials which are used to clean the metal plates contain resins and isocyanates, also welding fumes contain particles of chromium and nickel; these materials are sensitizing agents (Keskinen et al 1980; Novey et al 1983). In the present study history of asthma was similar in both the fume-exposed workers and controls.

#### Breathlessness



In the present study, increased breathlessness on exertion was significantly higher in the older fume-exposed workers compared with the controls. Similar findings were also reported by other studies (Barhad et al 1975; Oxhoj 1979; McMillan and Pethybridge 1984; Lyngenbo et al 1985). The effect was also present in the welders as a group but not the caulkeyburners. Thus exposure to high levels of fumes interacted with age to increase breathlessness in the welders.

#### Cough and phlegm

Several previous studies have demonstrated excess of the cough symptom among welders compared with controls (Oxhoj et al 1979; Sjogren and Ulvarson 1985). The present study revealed that cough was significantly more prevalent among the smokers compared with nonsmokers, but no difference was found between the fume-exposed workers and controls.

The cough symptom (MRC, 1976) does not give information about the frequency and severity of cough. Field in 1974 introduced a cough score which is an estimate of cough frequency and severity. In the present study, the cough score was higher in the smokers than controls but was not significantly different in the fume exposed workers compared with the controls.

In the present study phlegm production was significantly associated with smoking, but was similar in both the fume-exposed and control workers. This observation is consistent with most of the other studies and contradicting those observed by Oxhoj et al (1979) and Hyden et al (1984).

#### Chronic bronchitis

The association between smoking and symptoms of chronic bronchitis is well documented (College of General Practitioners 1961; Boudik et al 1970). The present study, also, demonstrated that smoking was significantly associated with increased chronic bronchitis. Some studies have demonstrated excess prevalence of chronic bronchitis among welders compared with controls (Fogh et al 1969; Antti-poika et al 1977; Murr et al 1985). In the present study this relationship was apparent for the subsample of the very young workers (aged 20 - 25 years). It was not apparent for the whole sample. The lack of significance between exposure and chronic bronchitis in the whole sample might have been due to selective recruitment to the control group of older volunteers with respiratory symptoms or to selective loss by redundancy of target workers with respiratory symptoms.

#### Comment

Smoking was the most important determinant of chronic cough, phlegm and wheeze. Exposure to fumes contributed to wheeze and breathlessness and in welders and caulker/burners compared with men in other trades. The effect was more marked in the welders where exposure interacted with age to increase the grade of breathlessness of older welders and with smoking to increase the likelihood of wheeze in developing in a smoker. Welders suffered more respiratory symptoms from their exposure compared with the caulker/burners.

## 7.8.2 LUNG FUNCTION CHANGES

Chronic obstructive lung disease is characterised by a reduction of airflow through the conducting airways and mismatching of the ventilation and perfusion in the lung. These physiological abnormalities result from anatomical thickening of bronchial walls (large as well as small ones), or airway collapse from loss of radial traction of elastic tissue.

### 7.8.2.1 Effect of smoking

In the present study smoking was significantly associated with impairment of indices of small airway function (CV%, CC%, SLIII, N<sub>2</sub> Diff) and reduced T<sub>lco</sub> and K<sub>co</sub>. However it was independent of the rest of the lung function indices.

### 7.8.2.2 Effect of fume exposure

#### Indices of large airway (FEV<sub>1</sub> and PEF<sub>R</sub>)

In the present study fume exposure and age interacted to significantly increase the decline of FEV<sub>1</sub> in the older welders and caulker/burners compared with the controls. The decrement of FEV<sub>1</sub> per annum was 26 ml/year for the controls and 39 ml/year for the fume-exposed workers. These rates were significantly different at the 1% level. The decrement in PEF<sub>R</sub> was also apparently greater in the fume-exposed workers but this relationship did not reach the 0.01



level of significance ( $0.05 < p < 0.01$ ). These findings are in agreement with other studies who have found that welders had significantly lower FEV<sub>1</sub> and PEF<sub>R</sub> compared with the controls ( Peter et al 1973; Barhad et al 1975; Lyngenbo et al 1985; Zober and Weltle 1985), and that smoking enhanced this effect (Hunnicutt et al 1964). In the subsample of very young workers the FEV<sub>1</sub> and PEF<sub>R</sub> were independent of fume exposure.

For the welders the extent of exposure to fumes interacted with age to apparently accentuate the decline of FEV<sub>1</sub> and FEV<sub>1</sub>% with age ( $0.05 < p < 0.01$ ). In the caulker/burners FEV<sub>1</sub> and PEF<sub>R</sub> were similarly affected. However these effects were not significant at the 1% level of probability.

Thus compared with the controls the fume-exposed workers appeared to suffer more from large airway obstruction.

#### Indices of small airway

The major site of obstruction in chronic obstructive lung disease is in peripheral airways of internal diameter 2mm or less (Hogg et al 1968; Anthonisen et al 1968; Gelb et al 1981) and considerable obstruction may be present in them with little effect on pulmonary resistance (Brown et al 1969). Recently several studies have demonstrated that pathological changes in the small airway are related to abnormalities of the lung function tests designed to detect small airway diseases (Cosio et al 1980; Nemery et al 1981; Wright et al 1984). In the present main study and also in the subsample of very young workers fume-exposure was associated with a significantly higher CV% and CC% compared with the controls. These



effects were independent of those due to age and smoking which were also important. The findings were consistent with those of Oxhoj et al (1979) who observed an effect of fume exposure in welders who were non-smokers; these authors did not observe a similar effect in smokers.

In the present study fume exposure did not affect  $\dot{V}_{\max 50}$  and  $\dot{V}_{\max 25}$ . In this the results differed from those of Hyden et al (1984) who observed a significant relation in welders who smoked.

Amongst the present welders fume exposure and age interacted to increase CV% and CC% in the older workers, while amongst the present caulker/burners fume exposure and age interacted to increase CV%, CC%, SLIII, N<sub>2</sub> Diff and RV%. Although in the welders increased exposure to fumes in the older subjects was associated with decreased  $\dot{V}_{\max 50}$ , but this relationship was significant only at the 0.05 level.

Thus compared with the controls the present fume-exposed workers had evidence for significant small airway obstruction which was present even in the very young workers. Age and smoking were also important. The changes were readily detected using closing volume indices which in this respect appeared to be more sensitive than the corresponding flow volume curve indices.

#### Lung volumes

Some studies found that TLC, FVC and VC were significantly lower in the welders than in controls (Spacilova and Koval 1975; Peters et al 1973; Lyngenbo et al 1985; Zober and Weltle 1985). In the present study, also, the decline of FVC with advancing age was greater in the fume-exposed workers compared with the controls, while no significant

differences in TLC or VC were found between both groups. Increased levels of exposure to fumes in the older caulker/burners (but not in the welders) were associated with greater decline of FVC. These effects were absent in the subsample of young workers.

Smoking was not significantly associated with impairment of lung volume.

Thus fume from welding did not appear to produce restrictive effects and the observed reduction in FVC (forced vital capacity) appeared to be due to small airway obstruction increasing the residual volume due to increased dynamic compression of the airways because the VC (the slow vital capacity) as well as TLC (total lung capacity) were not reduced.

#### T<sub>lco</sub> and K<sub>co</sub>

One of the major causes of reduced T<sub>lco</sub> (transfer factor) in chronic airflow obstruction is increased physiological dead space due to mismatching of ventilation and perfusion. Destruction of the alveolar wall and pulmonary capillary bed are additional factors in emphysema. In restrictive disorders of the lung, reduced lung volume is the main cause for reduced T<sub>lco</sub>.

Some studies found that T<sub>lco</sub> was significantly lower in welders than in controls (Cotes et al 1984; Murr et al 1985; Lyngenbo et al 1985). In the present fume-exposed workers the mean value of T<sub>lco</sub> was lower compared with the controls, however, the relationship was significant only at the 0.05 level. K<sub>co</sub> was not reduced significantly. Smoking and age were significantly associated with reduced T<sub>lco</sub> and K<sub>co</sub>. In welders the decline in T<sub>lco</sub> with age was increased significantly as a

result of high exposure, by contrast the decline of  $K_{CO}$  with age was reduced. Exposure interacted with smoking to reduce the  $K_{CO}$  of smoking welders.

The probable reduction of  $T_{lCO}$  appeared to follow the obstruction in the small airways with increased physiological dead space. TLC was not increased and there was no association with breathlessness as might have been the case if the reduction was due to emphysema.

#### Exercise test

The exercise test was used to study the cardiorespiratory response of the workers to exertion. Some studies demonstrated that  $\dot{V}_{e45}$  (exercise ventilation at 45 mmol  $\dot{n}O_2$ ) and  $f_{C45}$  (cardiac frequency at 45 mmol  $\dot{n}O_2$ ) increased in patients with airflow obstruction (Spiro 1975; Spiro 1979; Cotes 1982), and that  $V_{T30}$  (tidal volume at ventilation of 30 l  $min^{-1}$ ) was reduced in restrictive lung disease (Cotes 1982). In the present study no differences between the fume-exposed and control subjects were found, but increased exposure to fumes in the welders was associated with increased  $f_{C45}$ . This was probably due to a detraining effect of work in confined spaces, it affected particularly those men who took little exercise in their leisure time. The exercise indices did not appear to be sensitive to impairment which was confined mainly to small airways.

Thus compared with the controls, the fume-exposed workers had impaired small airway function (increased CV%, and CC%), a reduced lung volume (FVC) and reduced transfer factor. The  $FEV_1$  was also significantly reduced but not the  $FEV_1\%$ . So the reduction in  $FEV_1$



reflected changes in lung volumes rather than obstruction of large airways though this was present to some extent because the PEF<sub>R</sub> was also reduced (only at the 5% level). The small vital capacity was probably due to the obstruction of small airways. Similarly the reduced transfer factor in the exposed workers probably reflected impaired ventilation and mixing of the gases inside the lung due to impairment of small airway function.

The pattern of the respiratory symptoms followed the pattern of impairment of the lung function. Wheeze in the fume-exposed workers was probably due to narrowing of airways (decreased FEV<sub>1</sub> and increased CV%, and CC%). Amongst the welders the relationship was significant only in workers who smoked, so smoking interacted with fumes to increase this symptom. Breathlessness on exertion was more prominent in the older fume-exposed workers than in controls. In the welders breathlessness was significantly related to exposure in the older subjects. Breathlessness may have been due to increased narrowing of small airways contributing to an enlarged physiological deadspace and hence to increased ventilation on exertion. However, in some groups it could also have been due in part to the reduction in ventilatory capacity.

The caulker/burners worked along side the welders and were exposed to welding fumes in addition to exposure to fumes and dusts from burning, caulking and buffing of the metal plates. In both groups increased exposure in older workers was associated with impairment of small airway function (increased CV% and CC%) while in the welders more respiratory symptoms (breathlessness and wheeze) and



reduced  $T_{1CO}$  and  $K_{CO}$  were found. The apparent differences in the responses of the welders and caulker/burners (table 24) probably reflected differences in exposure to fumes with the welders more affected from their exposure than the caulker/burners. Thus the two groups should be treated separately in future studies.

When the subsample of very young workers was examined the early effects of fume exposure appeared to be mainly impairment of small airway function (increased CV%, CC% and RV%). The peculiar finding was the increased chronic bronchitis among the exposed young workers, this difference was not apparent when the whole population was examined. This could be due to the self selection of the controls with the older subjects who volunteered were those suffering from bronchitis, or it could be due to early retirement of exposed workers who had symptoms.

The effect of exposure to fumes was very similar to that produced by smoking where both were associated with increased respiratory symptoms and impairment of lung function.

The findings of the present study are evidence that fumes from welding and burning or other factors related to these trades cause long term impairment of the lung function of shipyard welders and caulker/burners.

Table 23: Results obtained on the main study and on the subsample

EFFECT OF FUME		
	SUBSAMPLE	WHOLE POPULATION
	(n=105)	(n=513)
CV%	+ ***	+ ***
CC%	+ ***	+ **
RV%	+ **	NS
FVC	NS	- ** \$
FEV <sub>1</sub>	NS	- *** \$
PEFR	NS	- * \$
Tlco	NS	- *
WHEEZE	+ *	+ **
DYSPNOEA	+! *	+ *** \$
BRONCHITIS	+ ***	NS
*= 0.05 $\geq$ p > 0.01 **= 0.01 $\geq$ p > 0.001 ***= p $\leq$ 0.001 NS= not significant != if smoker \$ = in older subjects + & - = direction of effect		

Table 24: Differences in exposure related responses in the welders  
and burners

	WELDERS	BURNERS
CV%	+ *** \$	+ ** \$
CC%	+ *** \$	+ *** \$
SLIII	NS	+ ** \$
N <sub>2</sub> Diff	NS	+ ** \$
RV%	NS	+ ** \$
FVC	NS	- * \$
FEV <sub>1</sub>	- * \$	- * \$
FEV <sub>1</sub> %	- * \$	NS
PEFR	NS	- * \$
$\dot{V}_{\max 50}$	- * \$	NS
T <sub>lco</sub>	- ** \$	NS
K <sub>co</sub>	- ! ***	NS
Breathlessness	+ ** \$	+ * \$
Wheeze	+ ! ***	NS

\*= 0.05  $\geq$  p > 0.01 \*\* = 0.01  $\geq$  p > 0.001 \*\*\* = p  $\leq$  0.001  
 NS = not significant != if smoker  
 \$ = in older subjects  
 + & - = direction of effect

Table 25: Comparison between two models including smoking variable

	SMOKERS & EXSMOKERS	SMOKERS
	V	V
	NONSMOKERS	NONSMOKERS
COUGH	+ ***	+ ***
PHLEGM	+ ***	+ ***
BRONCHITIS	+ ***	+ ***
WHEEZE	+ ***	+ ***
COUGH SCORE	+ ***	+ ***
CV%	+ ***	+ ***
CC%	+ ***	+ ***
SLIII	+ ***	+ ***
N <sub>2</sub> Diff	+ ***	+ ***
T <sub>lco</sub>	- ***	- ***
K <sub>co</sub>	- ***	- ***

\*= 0.05  $p > 0.01$  \*\*= 0.01  $p > 0.001$  \*\*\*=  $p \leq 0.001$

- & + = direction of effect.



CHAPTER 8CONCLUSIONS AND RECOMMENDATIONS

The conclusions that emerged from this study were:

1. The possibility that fumes and gases from welding and burning processes constitute a health hazard could not be ruled out.
2. The early effects of the fumes and gases appeared to be narrowing of small lung airways and increased chronic cough with phlegm production (chronic bronchitis, MRC). The changes affect young men with<sup>i</sup>n a few years of their joining the industry.
3. The prevalence of wheeze was significantly greater among the welders and caulker/burners compared with the controls and age interacted with fume exposure to increase breathlessness score in the older welders and caulker/burners.
4. The welders and caulker/burners had significantly increased CV% and CC% compared with the controls, and with advancing years the decrement in FVC and FEV<sub>1</sub> was significantly greater in the welders and caulker/burners than in the controls.
5. Increased exposure to above average level of fumes in the older

welders was associated significantly with increased breathlessness, CV% and CC%, while in the older caulker/burners it was associated with increased CV%, CC%, SLIII, N<sub>2</sub> Diff and RV%.

6. In the welders smoking interacted with fume exposure to enhance the development of wheeze and reduce K<sub>CO</sub> in a smoker.
7. Cigarette smoking was associated with significant increase in respiratory symptoms (chronic cough, phlegm production and wheeze) and impairment of lung function (increased CV%, CC%, SLIII, N<sub>2</sub> Diff and reduced T<sub>lco</sub> and K<sub>CO</sub>).

These results suggest that more should be done to protect the health of shipyard welders and burners. The measures might include:

(a) better respiratory protection by any of the many methods which are available (e.g efficient local exhaust ventilation, personal respirators etc)

(b) better health education including more active discouragement of smoking

(c) identification of affected persons at any early stage when the condition might still be reversible.

Much is already being done along these lines so there is no certainty that any additional measures would be effective. The degree of success should therefore be monitored by appropriate study of exposed persons. The study would need to be longitudinal. The

evidence of the present investigation suggests that to be useful, at least for very young workers the surveillance should include a questionnaire of respiratory symptoms (BMRC 1966) and the closing volume test.

CHAPTER 9SUMMARY

Welding is the commonest method for joining metals, and is widely used in the ship building and engineering industries. During ship construction welders and burners are exposed to heavy clouds of fumes. These fumes contain some gases and particulates which are potentially harmful.

There have been several surveys of the health of welders over the past 50 years. These studies demonstrated an association between exposure to fumes and respiratory symptoms. However, no long term effect of fumes on respiratory function has been established.

The particulates and gases in the welding fumes are very small in size and can reach all parts of the respiratory passages including the small airways.

If welding fumes are harmful to the lung, small airway dysfunction should be present in the young workers. In most of the previous studies conventional lung function tests (e.g. FEV<sub>1</sub> and FVC) were used. These methods are insensitive to changes in the small airway function.

Thus in the present study comprehensive measurements of pulmonary function (using conventional tests, tests specific to changes in the small airways and exercise tests to study the cardiothoracic response to effort) were conducted.



The aim of the present study was to investigate the role of exposure to welding fumes as a cause of lung function impairment among shipyard workers, and to investigate the early effect of welding fumes on the lung of young exposed workers.

This study was carried out at SWAN HUNTER shipyard, which is the largest shipyard at Tyne-Side. All available welders and caulker/burners aged 18-47 years were examined (no= 332), and a proportion of other tradesmen served as controls (no= 181). The controls were volunteers approached through the Safety Committee made up of Union-appointed Safety Representatives. They were matched with the target group in sex, race, and social class.

Each worker was asked three detailed questionnaires: MRC questionnaire on respiratory symptoms, cough frequency questions, and occupational questionnaire. Anthropometry, single breath nitrogen test, maximal ventilatory flow volume test, transfer factor for carbon monoxide, and progressive exercise test were conducted on each worker.

Indices for exposure were established, using the occupational questionnaire, to reflect both duration and intensity of exposure of welders and burners to fumes generated by these types of work.

The data were analysed using standard statistical techniques: paired t-test, Chi square and multiple regression analysis.

Although the fume-exposed and control workers had similar weight and lean body mass, they were different in age, height and smoking habit.

Higher proportions of the welders and caulker/burners were smokers

and exsmokers (46.99% and 21.08% respectively) compared with the controls (28.73% and 14.92% respectively). These differences were statistically significant.

Manual metal arc welding was the main method of welding in this shipyard, and mild steel was used to build ships.

Exposure to asbestos was not a major hazard for the target workers as only 4.97% of the welders and 3.97% of caulker/burners used asbestos at work. On the other hand, the corresponding figure for the control subjects was 22.7%.

To investigate the early effects of fumes, the workers aged 20 - 25 years in the study population were examined as a separate group (no=105). Compared with the controls the fume-exposed workers had significantly higher CV%, CC% , RV% , wheeze and chronic bronchitis. Breathlessness was higher in the workers who smoked.

In the whole population the mean values of CV% and CC% in the target group were significantly higher than in the controls. The decline of FEV<sub>1</sub> and FVC with advancing age was greater in the fume-exposed workers compared with the controls. Exposure to fumes in the target group enhanced the effect of age to increase respiratory symptoms (wheeze and breathlessness on exertion). All these relationships were highly significant ( $p < 0.01$ ). The PEF and T<sub>lco</sub> were also reduced but this difference did not attain the 1% level of significance.

In the welders, increased levels of exposure to fumes (duration and intensity) enhanced the deterioration with age in CV% , CC% and breathlessness on exertion and T<sub>lco</sub>. High exposure was also

associated with decreased  $K_{CO}$  and increased wheeze in workers who smoked. All these relationships were highly significant ( $p < 0.01$ ).  $FEV_1$ ,  $FEV_1\%$  and  $\dot{V}_{max50}$  were also reduced but the level of significance was low ( $0.05 < p > 0.01$ ).

In the caulker/burners, increased levels of exposure to fumes enhanced the deterioration with age in  $CV\%$ ,  $CC\%$ ,  $SLIII$ ,  $N_2$  Diff and  $RV\%$  (indices of small airway function). These relationships were highly significant ( $p < 0.01$ ).  $FEV_1$ ,  $FVC$ , and  $PEFR$  were reduced and breathlessness was increased but the level of significance of these relationships was low ( $0.05 < p > 0.01$ ).

It was concluded that in these relatively young workers aged 18 - 47 years (mean age 31.5 years), fumes from welding and caulking/burning caused narrowing of small lung airways and increased wheeze and breathlessness on exertion. The men needed better protection from the fumes by efficient exhaust ventilation or personal respirators. Early identification of affected persons was important. Improved health education which includes more vigorous attitude to cigarette smoking was recommended. However, since much was already being done along these lines there is no certainty that additional measures would be effective. The degree of success should therefore be monitored by appropriate study of exposed persons. The study would need to be longitudinal. It was recommended that at least for the very young workers the surveillance should include a questionnaire of respiratory symptoms and the closing volume test.



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Appendix AMRC QUESTIONNAIRE ON RESPIRATORY SYMPTOMS(1976)

Surname

First name

Address

Serial number

Sex            M=        F=

Date of birth

Name at birth if different from above

Own doctor name

Address

Other identifying data

Civil state

Occupation

Industry

Ethnic group

Interviewer

Date of interview



-----  
Use the actual wording of each question. Put 1 = Yes, 2 = No, or  
or other code as indicated in boxes. When in doubt record as no.  
-----

#### Preamble

I am going to ask you some questions, mainly about your chest. I  
should like you to answer YES or NO wherever possible.

#### Cough

1 Do you usually cough first thing in the morning in the winter?

2 Do you usually cough during the day or at night in the winter?

#### If Yes to 1 or 2

3 Do you cough like this on most days as much as three months each  
year?

#### Phlegm

4 Do you usually bring up phlegm from your chest first thing in the  
morning in the winter?

5 Do you usually bring up any phlegm from your chest during the day -  
or at night- in the winter?

#### If Yes to 4 or 5

6 Do you bring up phlegm like this on most days for as much as three  
months each year?

**Periods of cough and phlegm**

7a In the past three years have you had a period of (increased) cough and phlegm lasting for three weeks or more?

If Yes

7b Have you more than one such period?

**Breathlessness**

-----  
If the subject is disabled from walking by any condition other than heart or lung disease, omit question 8 and enter 1 here []  
-----

8a Are you troubled by shortness of breath when hurrying on level ground or walking up a slight hill?

If Yes

8b Do you get short of breath walking with other people of your own age on level ground?

If Yes

8c Do you have to stop for breath when walking at your own pace on level ground?

**Wheezing**

9a Does your chest ever sound wheezing or whistling?

If Yes

9b Do you get this on most days - or nights?

10a Have you ever had attacks of shortness of breath with wheezing?

**If Yes**

10b Is/was your breathing absolutely normal between attacks? **Chest illnesses**

11a During the past three years have you had any chest illness which has kept you from your usual activities for as much as a week?

**If Yes**

11b Did you bring up more phlegm than usual in any of these illnesses?

**If Yes**

11c Have you had more than one illness like this in the past three years?

**Past illnesses**

Have you ever had:

12a An injury or operation affecting your chest

12b Heart trouble

12c Bronchitis

12d Pneumonia

12e Pleurisy

12f Pulmonary tuberculosis

12g Bronchial asthma

12h Other chest troubles

12i Hay fever

**Tobacco smoking**

13a Do you smoke ?

If No

13b Have you ever smoked as much as one cigarette a day (or one cigar a week or an ounce of tobacco a month) for as long as a year?

\* If no to both parts of question 13, omit remaining questions on smoking.

14a Do (did) you inhale the smoke?

If Yes

14b Would you say you inhaled the smoke

slightly = 1, moderately = 2, or deeply = 3 ?

15 How old were you when you started smoking regularly?

16a Do (did) you smoke manufactured cigarette?

If Yes

16b How many do (did) you usually smoke per day on weekdays?

16c How many per day at weekends?

16d Do (did) you usually smoke plain [=1] or filter tip [=2] cigarettes?

16e What brands do (did) you usually smoke?

-----

17a Do (did) you smoke hand rolled cigarettes?

If Yes

17b How much tobacco do (did) you usually smoke per week in this way?



17c Do (did) you put filters in these cigarettes?

18a Do (did) you smoke a pipe?

If Yes

18b How much pipe tobacco do (did) you usually smoke per week?

19a Do (did) you smoke small cigars?

If Yes

19b How many of these do (did) you usually smoke per day?

20a Do(did) you smoke other cigars?

If Yes

20b How many of these do (did) you usually smoke per day?

For present smokers

21a Have you been cutting down your smoking over the past year?

For ex-smokers

21b When did you last give up smoking?

**Additional Questions:**

22a Have you had a history of allergy?

22b Have you had a family history of allergy?

23a Do you do regular exercise?

**If Yes**

23b Is it competitive?

23c What does your training consist of?

**SCORE FOR HABITUAL ACTIVITY (OUTSIDE WORKING HOURS)**

1) No additional activity

2) Physical activities 1-2/week (or cycling to work less than 2 miles)

3) Physical activities 3-4/week (or cycling to work 2-5 miles)

4) Physical activities more than 4 activities/week (or cycling to work more than 5 miles).

Appendix BQUESTIONNAIRE ON OCCUPATIONAL HISTORY

Name Mr:

Works Number:

Interviewer:

1. Have you ever done welding in the course of your work? [Yes, No]
2. Have you been exposed to welding fumes in the course of your work? [Yes, No]

-----

**For welders only**

3. How many years have you been welding?
4. a- Do or did you always use metal arc/stick welding?  
 - Never            - Occasionally            - Mainly            []
- b-have you ever used oxyacetylene gas welding?  
 - Never            - Occasionally            - Mainly            []
- c- Have you ever used inert gas welding?  
 - Never            - Occasionally            - Mainly            []

-----

**For Caulker/Burners only:**

5. How many years have you been caulking/burning?
6. In the past year what proportion of your time has been spent:  
 caulking                      %

burning %

7. Previous to this, what proportion of your time has been spent caulking/burning:

caulking %

burning %

8. On what proportion of occasions do you do your own buffing?

%

-----

9. What proportion of your work has been in the open?

%

10. Of the remainder, how much of your work has been in semi-confined?

%

11.....and confined spaces?

12. In which year did you start using dust extraction? [ ]

13. Do you use it on every job? Yes [ ] No [ ]

if no state what proportion you do use it on-----

14. In the past year have you worked :

mainly in the sheds [ ]

mainly on the ship [ ]

or has your time been split equally between the two? [ ]

15. Previous to this have you worked :

mainly in the sheds

mainly on the ship

or has your time been split equally between the two? [ ]

-----



**Asbestos exposure**

16. Have you ever used asbestos cloth at work?

Yes [] No []

17. Have you done any lagging or delagging or other work with asbestos-not just working near others working with asbestos?

Yes [] No []

if yes type-----

and when-----

18. Have you ever worked near others working with asbestos?

Yes [] No []

-----

**Other Dust Exposure**

19. Have you been exposed to other occupational dust or fumes?

Yes [] No []

if yes specify-----

20. Do you keep pigeons or budgerigars?

Yes [] No []

if no, have you kept them in the past?

Yes [] No []

**B-1    REPEATABILITY OF THE EXPOSURE INDICES**

In order to assess the accuracy of the responses of the workers to the occupational questionnaire, the questionnaire was repeated on 21 workers (welders and caulker/burners). These workers were selected randomly and the responses on the two occasions (range 4 weeks to 12 months) were compared (tables 26 and 27 and figs 63 to 65).

The mean values of duration of exposure to fumes (Q3 or 5), percent time spent in confined and semiconfined spaces (Q10+11), and the estimated index of exposure on the second occasion were not significantly different from those on the first occasion (table 27).

The most consistent responses were those to duration of exposure to fumes (Q3 or 5) where responses on the two occasions were highly correlated ( $r=0.98$ ). The largest difference was 4 years in one subject.

The maximum difference for responses to per cent time spent in confined and semiconfined spaces was 30% in two workers. However, the responses on the two occasions were highly correlated ( $r=0.7$ ).

The maximum difference between index of exposure on the two occasions was 10 years in one worker. The estimated indices on the two occasions were highly correlated ( $r=0.8$ ).

Among the 21 workers only one gave inconsistent responses for exposure on the ship and in the shed (table 26).

Table 26: Repeatability of occupational questionnaire and estimates of exposure

SUBJECTS	FIRST INTERVIEW				SECOND INTERVIEW			
	Q3	Q10	INDEX	MAINLY	Q7	Q19	INDEX	MAINLY
	OR Q5	+ Q11	EXPl	-SHIP -SHED	OR Q12	+ Q20	EXPl	-SHIP -SHED
1	12	100	12	SHIP	8	70	5.6	SHIP
2	30	50	15	SHIP	30	50	15	SHIP
3	10	85	8.5	SHIP	10	85	8.5	SHIP
4	28	75	21	SHIP	29	70	20.3	SHIP
5	12	50	6	SHIP	14	50	7	SHIP
6	26	80	20.8	SHIP	23	50	11.5	SHIP
7	9	80	7.2	SHIP	9	98	8.82	SHIP
8	8	90	7.2	SHIP	9	67	6.03	SHIP
9	12	100	12	SHIP	9	95	9.5	SHIP
10	13	90	11.7	SHIP	13	90	11.7	SHIP
11	9	98	8.82	SHIP	10	90	9.9	SHIP
12	11	50	5.5	SHIP	11	50	5.5	SHIP
13	24	85	20.4	SHIP	25	80	20.8	SHIP
14	8	95	7.6	SHIP	8	100	8	SHIP
15	22	94	20.68	SHIP	21	50	10.5	SHIP
16	8	90	7.2	SHIP	7	95	6.65	SHIP
17	20	90	18	SHIP	20	90	18	SHIP
18	11	90	9.9	SHIP	11	70	7.7	SHIP
19	10	70	7	SHED	11	70	7.7	SHED
20	16	70	11.2	SHED	16	70	11.2	SHIP
21	13	95	12.35	SHIP	13	95	12.35	SHIP

INDEX EXPl= duration of exposure \* ( % time spent in confined and semiconfined spaces)/100

Q = question (the occupational questionnaire )

Table 27: Differences between answers from the first and second interviews

	FIRST OCCASION		SECOND OCCASION		t-test
	MEAN	SD	MEAN	SD	
Q3 OR 4	14.86	7.09	14.62	7.15	0.108
Q10+Q11	82.24	16.03	75.48	17.98	1.287
INDEX EXP1	11.91	5.33	10.58	4.53	0.867



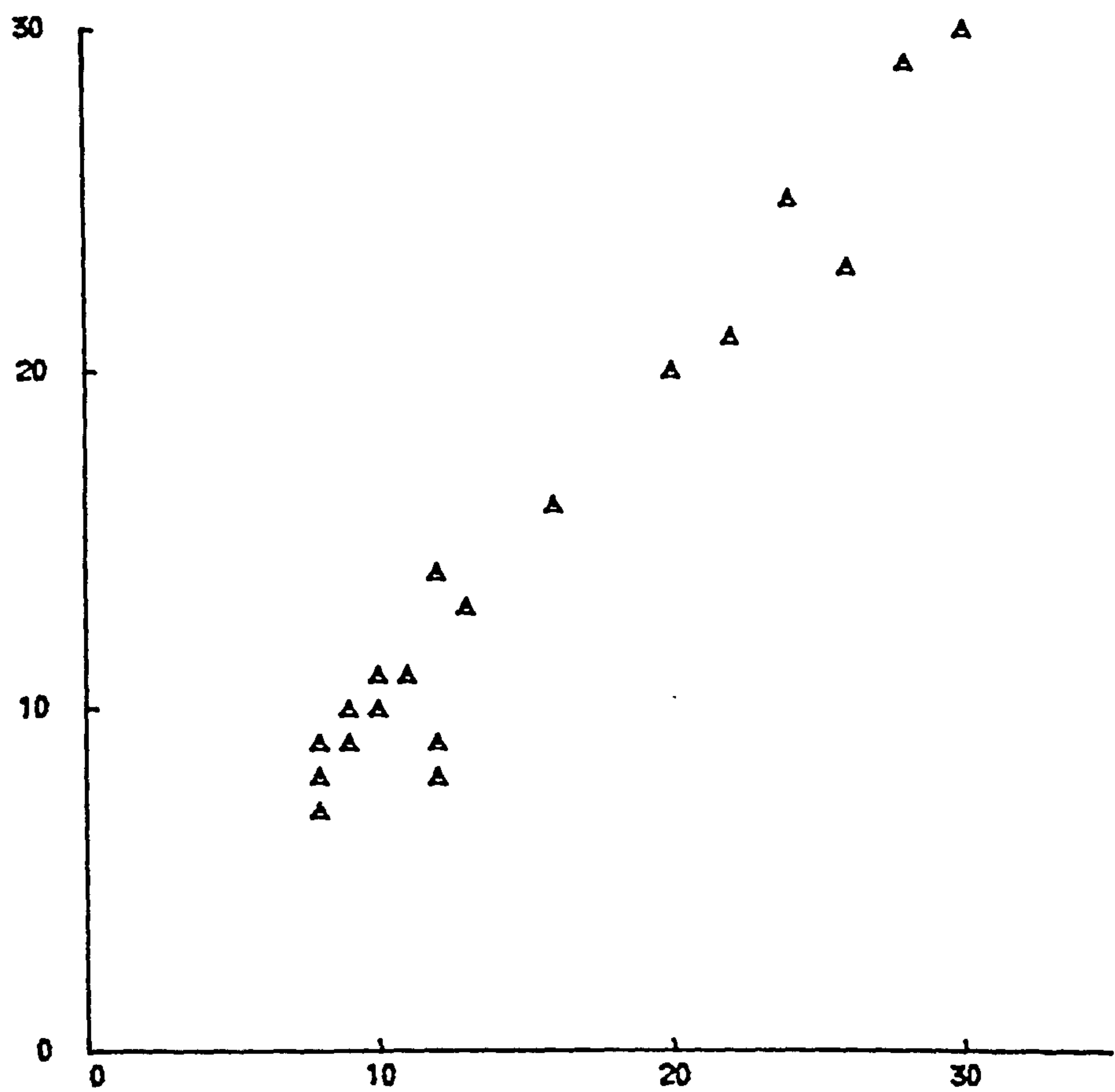


Figure 63: Scattergram for the answers on Q3 or 5 on the two occasions. The correlation coefficient was 0.98

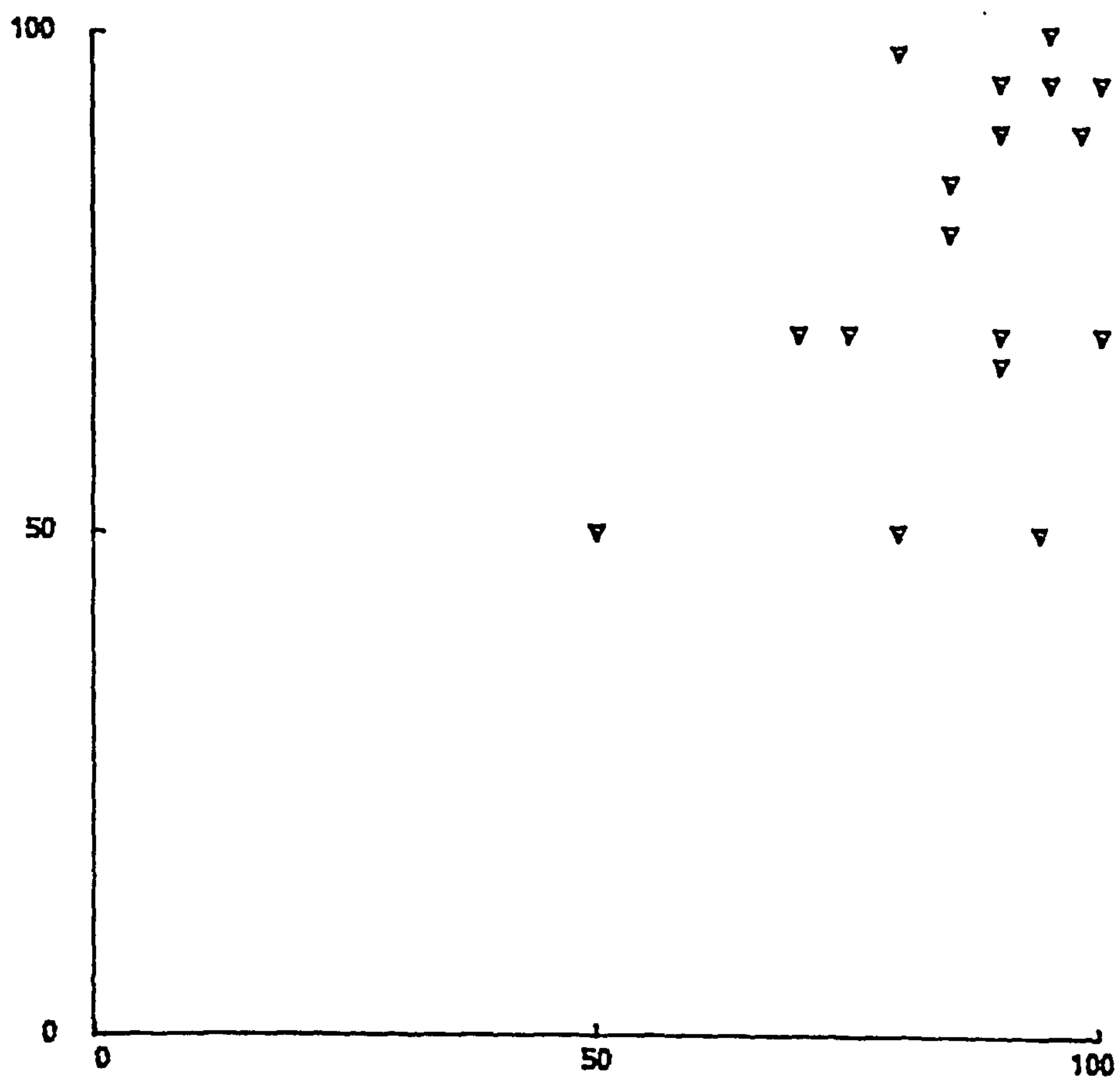


Figure 64: Scattergram for the answers on Q10 + 11 on the two occasions. The correlation coefficient was 0.66

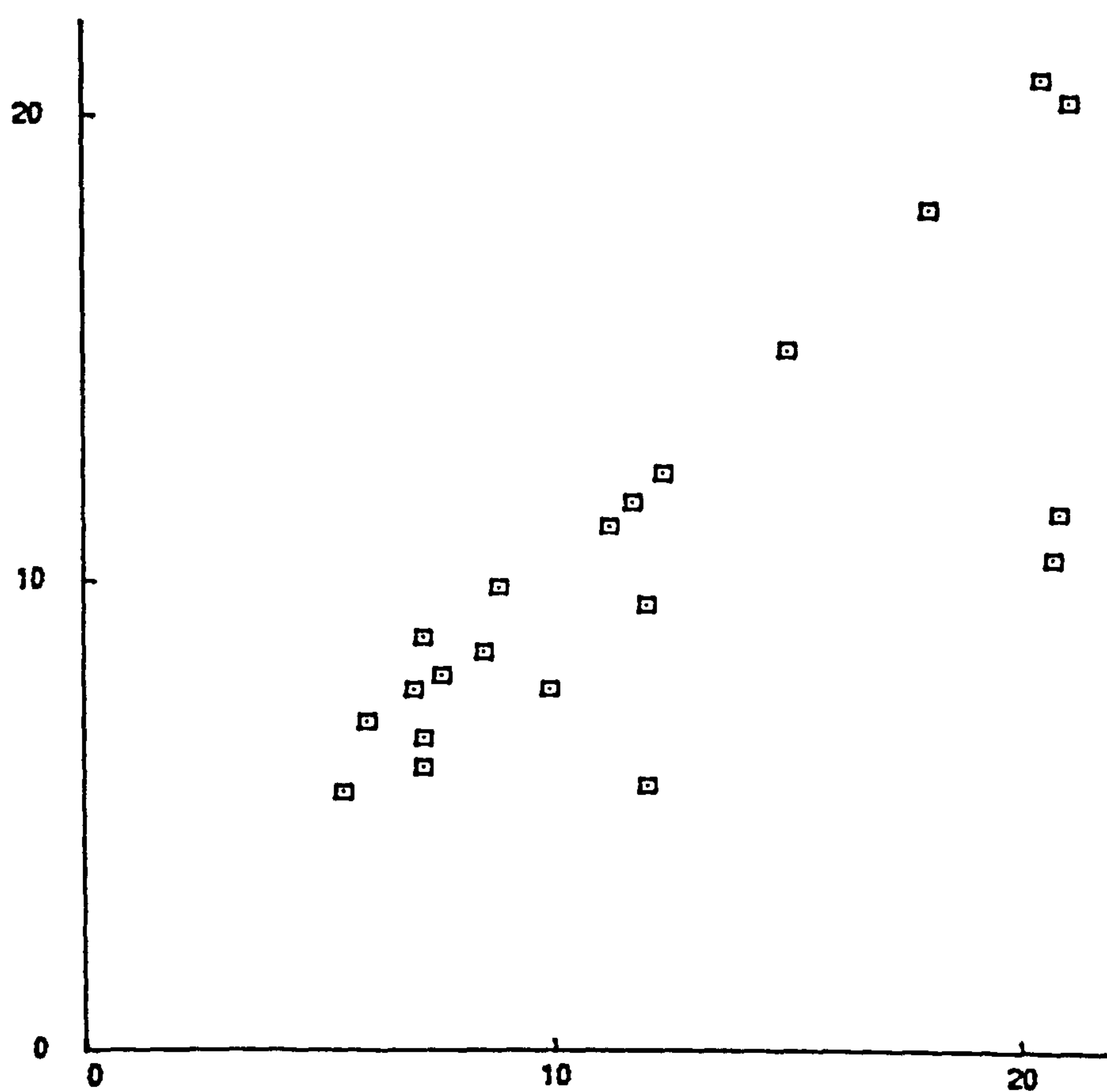


Figure 65: Scattergram for the EXPOSURE1 INDEX on the two occasions.

The correlation coefficient was 0.79

**B-2    DESCRIPTION OF THE WORKERS WITH NO CV INFORMATION**

Table 28 shows comparison between the workers with no closing volume (CV) data (n= 81) with the rest of the workers in the target group (n=251). No significant differences were found in age, height, and weight between the two groups and smoking habit was nearly the same in both groups. The forced expiratory volume (FEV<sub>1</sub>) was also similar in both groups.

Table 29 shows comparison between the workers with no closing volume data (n= 31) with the rest of the workers in the target group (n= 150). Although the differences in age, height, and weight were not significantly different between the two groups, more smokers were among the former, and FEV<sub>1</sub> was significantly lower compared with the rest of the control workers.

**B-3    DESCRIPTION OF THE WORKERS WITH NO EXERCISE INFORMATION**

Table 30 shows comparison between the workers with no exercise data (n=37) with the rest of the target workers (n=219). No significant differences were found in age, height, or weight between the two groups. Although more smokers were among the former group, FEV<sub>1</sub> was similar in both groups.

Table 31 shows comparison between the workers with no exercise data (n=22) with the rest of the workers in the control group (n=67). Age and weight were significantly lower in the former group and more smokers were among these workers. However, height and FEV<sub>1</sub> was



similar in both groups.

Table 28: Comparison between the target workers with no CV data with  
the rest of the workers

	WITH CV DATA	NO CV DATA	t-test
AGE	32.90 $\pm$ 7.59	32.92 $\pm$ 7.97	0.019
HEIGHT	172.85 $\pm$ 6.51	173.76 $\pm$ 6.29	0.910
WEIGHT	74.95 $\pm$ 11.32	74.90 $\pm$ 11.28	0.033
SMOKING			
Sm	174 (68.5%)	55 (66.7%)	
NSm	77 (31.5%)	26 (33.3%)	
FEV <sub>1</sub>	3.99 $\pm$ 0.649	3.92 $\pm$ 0.66	0.833

Table 29: Comparison between the control workers with no CV data with  
the rest of the workers

	WITH CV DATA	NO CV DATA	t-test
AGE	28.77 $\pm$ 7.34	30.86 $\pm$ 8.92	1.222
HEIGHT	175.66 $\pm$ 6.40	173.58 $\pm$ 6.59	1.609
WEIGHT	75.27 $\pm$ 9.092	72.96 $\pm$ 9.22	1.273
SMOKING			
Sm	63 (42%)	17 (51.6%)	
NSm	87 (58%)	14 (48.4%)	
FEV <sub>1</sub>	4.28 $\pm$ 0.59	3.99 $\pm$ 0.58	2.526

Table 30: Comparison between the target workers with no exercise data  
with the rest of the workers

	WITH EXERCISE DATA	NO EXERCISE DATA	t-test
NUMBER	219	37	
AGE	35.27 $\pm$ 6.80	37.50 $\pm$ 6.57	1.283
HEIGHT	172.69 $\pm$ 6.25	174.67 $\pm$ 6.53	1.716
WEIGHT	76.28 $\pm$ 11.62	74.02 $\pm$ 9.72	1.269
SMOKING			
Sm	143 (65%)	29 (78%)	
NSm	76 (35%)	8 (22%)	
FEV <sub>1</sub>	3.85 $\pm$ 0.65	3.87 $\pm$ 0.69	0.164



Table 31: Comparison between the control workers with no exercise data with the rest of the workers

	WITH EXERCISE DATA	NO EXERCISE DATA	t-test
NUMBER	67	22	
AGE	36.02 $\pm$ 5.98	30.94 $\pm$ 5.57	3.644
HEIGHT	175.88 $\pm$ 6.39	173.06 $\pm$ 7.65	1.559
WEIGHT	78.06 $\pm$ 9.57	72.27 $\pm$ 8.92	2.594
SMOKING			
Sm	35 (52%)	13 (59%)	
NSm	32 (48%)	9 (41%)	
FEV <sub>1</sub>	4.05 $\pm$ 0.61	4.03 $\pm$ 0.44	0.167

Appendix CQUESTIONNAIRE ON COUGH FREQUENCY**Cough frequency statements**  
-----

- 1- I RARELY EVER COUGH.
- 2- I COUGH OCCASIONALLY.
- 3- I COUGH A LITTLE ON MOST DAYS.
- 4- I COUGH A LITTLE EVERY DAY.
- 5- I COUGH A LOT EVERY DAY.
- 6- I COUGH ALL THE TIME.

The following set of cards was used:

Card number 1

-----

(1) I RARELY EVER COUGH

(2) I COUGH OCCASIONALLY

-----

Card number 2

-----

(1) I COUGH A LITTLE ON MOST DAYS

(2) I RARELY EVER COUGH

-----

Card number 3

-----

(1) I COUGH OCCASIONALLY

(2) I COUGH A LITTLE ON MOST DAYS

-----

Card number 4

-----

(1) I COUGH A LITTLE EVERY DAY

(2) I COUGH OCCASIONALLY

-----

Card number 5

-----

(1) I COUGH A LITTLE ON MOST DAYS

(2) I COUGH A LITTLE EVERY DAY

-----

Card number 6

-----

(1) I COUGH A LOT EVERY DAY

(2) I COUGH A LITTLE ON MOST DAYS

-----



Card number 7

-----

(1) I COUGH A LITTLE EVERY DAY

(2) I COUGH A LOT EVERY DAY

-----

Card number 8

-----

(1) I COUGH ALL THE TIME

(2) I COUGH A LITTLE EVERY DAY

-----

Card number 9

-----

(1) I COUGH A LOT EVERY DAY

(2) I COUGH ALL THE TIME

-----

## The cough score sheet

**NAME :**

WORK'S NUMBER:

1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9

1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1

2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2

COUGH SCORE =