Lung Function Tests in Steel Works

With Special Reference to Mixing Efficiency

A Thesis Presented by

AHMED ZAKY EL-SEWEFY

M.B. Bch., D.I.H., D.M.,

For the Degree of

Doctor of Philosophy

of

The University of Sheffield

Department of Preventive Medicine

1966

....

CONTAINS PULLOUTS

To

Nour El-Sewefy

ACKNOWLEDGMENT

This study was carried out in the Department of Preventive Medicine and Public Health at Sheffield University, while I was receiving a scholarship from the U. A. R. Government.

It is impossible for me to express my thanks to all those who co-operated in this study. I would, however, particularly like to mention Mr. J. W. Roe, the lecturer, of Industrial Hygiene at Sheffield University for proposing the study, for his guidance and all the valuable advice and help during the whole period of my work under his supervision. I am grateful to all the staff of the department, who so willingly gave their time before, during and after the survey, particularly Professor Knowelden, Dr. Brown and Miss Ashton. I wish also to thank Mr. Alan Handyside for his help in computing the results.

I am also grateful to (S.P.T.) and (E.S.C.), managers and volunteers, for making this survey possible particularly Dr. Trevethick, Dr. Sinclair and Mr. Peacock. I also thank Miss C. Hartley for the typing of this thesis.

Finally I am much obliged to the U.A.R. Government for supporting me and my family.

Contents

SUMMARY

In 1952-53 a survey was carried out in a Steelworks, in order to compare the state of the lungs of furnace repairers, working with silica bricks, with that of a group of rolling mill workers. This showed that, apart from age and the presence or absence of a history of specific Pulmonary diseases, the principal factor which influenced the symptoms and the results of quantitative tests was Tobacco consumption. When allowance was made for these, a slight difference could be discerned to the disadvantage of the group of bricklayers working with silica bricks.

After a lapse of twelve years, this study was repeated in order to ascertain the deterioration of the different groups in respect of lung function.

During this follow-up study the co-operation of the potential subjects was much less complete than in the original investigation, only 43 bricklayers and

dismantlers participated out of a possible 150 remaining from the original study; while from the rolling mills 67 out of 128 volunteered. The changes observed in the two groups showed no consistent differences.

The ratio of residual volume to total lung capacity increased in almost all subjects. The amount of the increase did not differ significantly between the mill workers and the furnace repairers.

In respect of mixing efficiency, some individuals improved while others deteriorated. In the case of the mill workers the mean change was - 4% which is less than the standard error of the difference, while for the furnace repairers the change was + 7.1% (S.E. 3.30) which is significant at the 5% level. These may be compared with an expected change of about - 4.5%.

The values of the Maximum Breathing capacity showed a marked decline. However, an uncertain proportion of this must be attributed to personal differences between the observers.

Symptoms:-

It was observed in an earlier study that, whereas among the rolling mill workers there was consistent and in some cases significant association between smoking on the one hand and chest symptoms on the other, among the furnace repairers this association was reduced.

These relationships persisted twelve years later. The investigation was extended to further groups of workmen in another firm to determine whether these associations are more general.

In the second firm employees in the following departments were examined:-

The departments were arbitrarily classified as clean and dusty.

Clean	Dusty
Joiners	Foundry
Bar Mill	Siemens' Melting Shop
Machine Shop	Furnace Repairers.

The results were analysed by the technique of multiple regression analysis, non quantitative factors were introduced as artificial variables; by this means it was found that there is no difference in lung function tests between the clean and dusty jobs.

For analysis of chest symptoms the subjects were divided into:-

1) Non Smokers.
2) Moderate Smokers.
3) Heavy Smokers.

and standardized rates were calculated for these symptoms for each group.

It was found that the symptoms among heavy smokers of all ages were very much commoner than among moderate and non smokers.

In addition at all ages and for all Tobacco consumption the symptoms were slightly more common among the dusty jobs than the clean ones.

CHAPTER 1

INTRODUCTION

It is generally supposed that exposure to the dust, smoke, and irritant gases which occurs in a steelworks must have a deleterious effect upon the lungs of the workers exposed to this atmosphere. Further, the possibility exists that the dust from furnace linings containing appreciable amounts of silica may cause pulmonary fibrosis in exposed workers. It is probable that those steelworks employees engaged on repairing, dismantling and reconstructing open hearth furnaces are more exposed to silica dust than others. Accordingly, in 1952-53 a survey was carried out at a Sheffield steelworks in order to compare the condition of a group of furnace repairers with that of a similar number of men employed in rolling mills.

The incidence of X-ray abnormality (pneumoconiosis grade I or more) was not significantly different in the two groups, and the spirometric measurements and tests of lung functions which were applied showed slight differences only. These differences occurred only in respect of bricklayers, a group of men who because they were "skilled" have been employed only as furnace bricklayers, or in the building trade since they were apprenticed. The differences only became clear when the comparisons were restricted to non-smokers of equivalent age.

In view of current concern with the possible influence of occupational conditions on the development of chronic bronchitis it appeared that it might be instructive to repeat these measurements on the same group of workers in order to determine whether there has been any difference in the degree to which their lung function has deteriorated.

The first part of this thesis describes the result of this follow up study.

C H A P T E R 2

REVIEW OF LITERATURE

In 1950 Mclaughlin et al carried out an investigation of 3.059 workers in 19 foundries. They found that the crude figures of mean vital capacity showed a general reduction with increasing severity of lung change for each of the Iron, Steel and mixed dust exposure groups, and when allowance for age is made, it is found that for the Iron exposure group - there is still a reduction in vital capacity with increasing lung change, the reduction being significant between X ray groups I and II and between X ray groups 1 and X ray groups 111 and IV. The reductions in the mixed iron and steel groups were not significant and no reduction was observed in the steel group.

In 1955 Gilson and Hugh Jones undertook an investigation with the object of determining the precise course of the breathlessness in South Wales Coal Mines and of relating its severity to the X ray changes in the lungs. They used a battery of pulmonary tests. Their results showed that the dyspnea on exertion occurring in men with Pneumoconiosis is due mainly to a reduction in the maximum ventilatory capacity of the lungs, though there is also an increase in the ventilatory requirements for exercise.

In 1959 Higgins, Cochrane et al designed an investigation to compare the prevalence of bronchitis and respiratory disability in a representative sample of miners, foundry workers and other industrial groups living in Staveley, Derbyshire, a town of some 18,000 inhabitants, and to study some of the possible aetiological factors. They showed that in the pure foundry workers there is no higher prevalence of respiratory symptoms and bronchitis nor a lower ventilatory capacity than the men in non dusty occupations. On the other hand the group of mixed foundry workers did appear materially worse. They also found the following:-

A - Dust Exposure

The figures for symptoms according to the number of years spent on the coal getting shift do not suggest that the total quantity of coal dust played a very large part in the development of symptoms.

B - Tobacco Smoking

Smoking is associated with an increase in respiratory symptoms and a reduction in ventilatory capacity.

C - Atmospheric Pollution

No striking difference between town and country was observed in the prevalence of persistent cough and sputum or dyspnea.

In 1960 Gilson and Olsen in an Anglo-Danish comparison on respiratory symptoms, bronchitis and ventilatory capacity in men aged 55-64 found that in Rønne and in two agricultural areas in the U.K. the prevalence of symptoms is significantly lower in Rønne. The mean (I.M.B.C.) is significantly higher in Rønne (106 L/m) than in the U. K. samples (92 L/m). The differences are not explicable on the basis of differences in height, weight, density of population or atmospheric pollution, but possibly on smoking habits.

There are more non-smokers in Rønne and many fewer cigarette smokers than in the U. K. sample. Only in the small groups of non-smokers are there no physiological or clinical differences between Rønne and the U. K. sample. In Rønne there was a significantly lower (I.M.B.C.) and poorer single-breath N_2 clearance in the pure cigarette smokers than in the cigar smokers, despite similar tobacco consumption. Also the higher average I.M.B.C. in Rønne supports the conclusion that there is a real difference in the prevalence of non-specific chronic chest illness in the two countries.

In 1961 Nadel and Comroe studied the "acute effects of inhalation of cigarette smoke on air way conductance and found that air way resistance was higher in women smokers, although there was no such difference between men who smoked and those who did not. These workers also found that the air way resistance of all their subjects was raised by the inhalation of cigarette smoke, and that this effect could be reversed or prevented by inhaling an aerosol of Iso Prenaline.

In 1962 Higgins and Oldham in a five year follow-up study of ventilatory capacity in miners and ex-miners with and without simple Pneumoconiosis with a control group of non-mining groups, assessing the effect of ageing, mining, dust exposure and tobacco smoking. The change in (I.M.B.C.) between the two surveys appeared to be independent of age.

An average decline of 1.865 $\pm$ 0.274 litres per minute each year in the (I.M.B.C.) was observed, and this fall was not significantly increased either by mining or by exposure to coal dust as measured by the number of years spent working underground.

In non-miners the (I.M.B.C.) fell more over the five years in the smokers than in the non-smokers or ex-smokers, and within the smoking group there was an increasing fall with increasing tobacco consumption. This was found to be less clear in miners and ex-miners.

A greater fall in (I.M.B.C.) was observed in those with respiratory symptoms than in those without. The pattern is more consistent for the non-miners than for the miners and ex-miners.

Prime et al (1963) undertook an investigation on the acute effect of smoking on the air way resistance using body plethysmograph and peak flow meter. He concluded that air way resistance is higher in cigarette smokers than in a parallel group of non-smokers. The smoking of one cigarette increased air way resistance in both smokers and non-smokers, whereas the inhalation of Iso Prenaline reduced the air way resistance in both groups.

Motley (1963) studied the pulmonary function in Diatomite Industry. He followed up 38 Diatomite workers on the job, after 3 to 5 years exposure. He found that progression in pulmonary function changes was present in 14 of 38 cases restudied, and was of a severe degree in 4 of the group. A slight improvement was noted in one case. He then compared the different lung tests being used, and mentioned that:-

1) Arterial Blood Oxygen saturation was the consistent change noted in all 14 cases.

2) The decrease in the exercise oxygen uptake was the second best measurement, and changes on the ventilatory side (timed vital capacity and M.B.C.) were of value in two cases.

The changes observed in the residual air were not a significant factor in the evaluation of progression in this study.

The follow-up study revealed no progression in the X ray appearance of the workers.

In 1964 - an Anglo-American comparison of the prevalence of bronchitis was carried out by Reid et al. By using similar respiratory symptoms questionnaires and a single lung function test (The Wright Peak Flow Meter)in the two countries they found that the prevalence of "simple bronchitis" (chronic phlegm production) differs little between American town and the rural and urban areas of Britain and that the relation to cigarette smoking in particular is obvious in the results from both countries. On the other hand, "complex bronchitis" with repeated chest illness and breathlessness is more common among older men in this country. After differences in age distribution and smoking habits have been taken into account the "complex bronchitis" appears to be about equally common in the American town and in the rural areas of Britain. It is much more common, however, in the British towns and cities, especially among men.

The results of their lung-function tests are consistent with the suggestion, of a higher prevalence of a more severe form of bronchitis among older males living in British urban conditions.

M.R.C. Report 1966: on Chronic Bronchitis and Occupation reported that:- Epidemiological evidence indicates that cigarette smoking, atmospheric pollution, geographical location and uncharacterized socio-economic factors are associated with the differences in the incidence rates for chronic bronchitis. Coal miners in whom these same associations are observed, are exposed to relatively high dust concentrations. However, on present evidence intensity of dust exposure does not appear to be a very significant factor in determining the prevalence of bronchitis in this group of workers.

C H A P T E R 3

POPULATION

Initially this Respiratory function survey has been carried out in one Steelworks (S. P. T.) on workers in the furnace building department, and on rolling mill workers.

The aim was to find out:- The difference in lung functions between a group of men exposed to dust and smoke, from the furnaces, and a control group not exposed to such atmosphere after 12 years of exposure.

The earlier survey included around 400 bricklayers, and around 300 workers in the rolling mills as control. In 1964 the survey was repeated.

We went through all the old names and their files were revised both in the Labour Office and Medical Department. We identified the workers still employed with the firm, those who had retired or left, and the dead. Some workmen had changed their addresses, others had left the district, or gone abroad; all this information was recorded on special personal cards. The causes of death were obtained either from the Medical Department, or from their Death Certificates.

We met the Trade Union Representatives, and a Representative of the Management. We discussed the aim and the safety of these tests, agreement was reached and promise of help was received.

The next step was to write an explanatory memorandum which was circulated to the workmen concerned. This explained the aim of the survey, asked for help and co-operation, and reminded the men of the tests carried out in 1952; it was also mentioned that the new tests would show if there were any respiratory effects after twelve years of exposure to their jobs. Finally it was mentioned that the investigation was supported by their Trade Unions, and that it was voluntary.

Lists were made of the names of the subjects already examined in 1952-54. We handed them to each responsible department, and explained to the staff in charge the aim of the test, how many subjects we needed every morning, and afternoon. We then transferred all the equipment to the Medical Department of the factory, a convenient place for the concerned departments.

We started with the Bricklayers' Department, and during the first four weeks, we received full co-operation. Subsequently there was a decline in the numbers attending, this was attributed by the management to the unrest caused by a re-organization which involved a re-deployment of the labour force. Eventually the flow of volunteers ceased altogether, when only 89 out of a possible 300 men had been examined.

We then turned to the Bar Mill workers; they were always willing to co-operate and we got 185 volunteers out of 250 workers.

In the Strip Mill, the methods of payment made it difficult to release the number and the subjects required. Most of the volunteers we tested were under 20 years old with a total of only 60 subjects.

Sixty-seven of 128 Bar Mill workmen already seen in 1952 were examined and only 43 out of a possible 150 men in the Bricklayers' Department were examined, due to the re-deployment of the labour force.

After one month of persistent trying, we were persuaded to give up and we removed our equipment. Meanwhile we sent letters to the retired, and those who had left, asking for their help and co-operation in coming to the University in order to repeat the lung tests done in 1952-54. One-hundred and twenty letters were sent and we received the following replies:-

1) Only 7 agreed to co-operate and they were collected by car from their homes and returned after the test.

2) Forty-eight did not reply.

3) Seventeen letters were returned by the Post-Office of which five had been addressed to persons who were known to have gone away.

4) Five refused to co-operate.

5) Ten widows replied, some of them were kind enough to mention the date and cause of death of their husbands

We extended the investigation to a group of workers in another Steelworks (E. S. C.)

Here we were able to examine; 40% of the Siemens' Melting Shop and Bricklayers' Department, 55% of Heat Treatment Shop, 60% of Joiners' Shop, 64% of Bar Mill Shop, 51% of Foundry workmen including:- Fettlers, Burners, Welders, Shot Blasters.

TABLE OF TOTAL EXAMINED

(S. P. T.)

1.	Number of men examined in 1952-54 and still present	-	150 in Bricklaying Department.
	" " the above " " 1964-66	-	43 " " "
2.	Number of men examined in 1952-54 and still present	-	128 " Bar Mill Department
	" " the above " " 1964-66	-	67 " " " "
3.	Total number of Furnace Repairers examined in 1964-66	-	89 persons.
4.	" " " Bar Mill and Strip Mill " " " "	-	245 "

(E. S. C.)

1.	Total number of men in Dusty jobs examined (Foundry - Melting Shop - Bricklaying Department)	-	264 persons
2.	Total number - of men in clean jobs examined (Bar Mill - Joiners - Machine Shop)	-	227 persons

C H A P T E R 4

WORKING ENVIRONMENT

All the men investigated worked in factories close to the river Don between Sheffield and Rotherham. In this area there is a high background pollution consisting of smoke and ash particles from domestic, and industrial chimneys and locomotives.

Assessment of the dustiness of the atmosphere by particle count is, therefore, likely to show only very slight differences which will appear insignificant against the fluctuating background of smoke particles. However, some information derived from gravimetric sampling is available and the following table summarises this:-

Department	Total Solids in mgm/cubic meter	Ash in mgm/cubic meter
(1) Bar Mill at S.P.T. Dust under 5μ	.3 to 1.1	.02 to .17
(2) Strip Mill Dust under 5μ	Generally lower than Bar Mill	
(3) Melting Shop at S.P.T. Dust under 5μ	.4 to 3	.2 to 1.5
(4) Melting Shop at S.P.T. Total dust	4 to 60	3 to 40
(5) Foundry at E.S.C. Dust under 5μ	.03 to 1.4	.02 to 1.0

The dust from the Bar Mill was probably smoke similar in composition to the external air. X-ray crystallographic examination showed no crystalline silica and calcium sulphate was the main crystalline component. One sample taken very close to the rolls showed a little Fe_3O_4.

The dust from the Melting Shop contained quartz up to 10% of the ash, also occasionally crystobalite. Most samples contained more than 60% total silica which was presumably present as a glass, formed with the oxides of calcium, magnesium and iron, while some was probably present as mullite. The Melting Shop samples were taken in and around furnaces in the process of dismantling and rebuilding.

The quartz content of the dust from the foundry at E.S.C. was commonly 10 to 15% and occasionally reached 20%.

For comparison the suspended matter in outdoor air ranges from .2 to .5 mgm/ cubic meter with .03 to .08 mgm ash/cubic meter in the winter. The summer figures are lower but with a higher proportion of ash.

Finally it should be mentioned that bricklayers, dismantlers and rolling mill workers are in many cases subject to considerable thermal stress.

C H A P T E R 5

APPARATUS

M.B.C. APPARATUS

The apparatus is similar to the one designed and used by the Pneumoconiosis Research Unit (McKerrow 1952), and described by Cotes (1965). It is a modified Douglas Bag system.

The subject re-breathes from the bag, this will keep the moisture of the air and prevents acapnea. The expansion contraction of the bag is allowed through the provision of the box with valves. It thus operates as a pump. The output of this "pump" is measured by a dry gas meter. By interposing an expansion chamber between the "pump" and the meter overloading of the meter at peak expiratory flow is avoided. The valves used are of the "j" type.

Description

The apparatus consists of an aluminium box closed by a centrally perforated "perspex" lid, through this hole passes a well-fitted bent tube connected to a balloon, and on the outside to the mouth piece. In the bottom of this box there are three small openings covered by valves. On one side of this box there are two openings, one connected to the atmosphere and the other to an expansion chamber. In between the box and the bellows is a 2-way stop cock which when switched to one side will connect the box to the expansion chamber or away. Air is admitted to the expansion chamber through the non-return valve. This chamber is connected by a top tube to a dry gas meter, which gives the measurement of gas in cubic feet (Cotes 1965). The temperature of the gas was usually recorded in the exit tube from the gas meter.

GAENSLER APPARATUS

This apparatus was used to measure F.E.V.$_{.75}$ F.V.C., and indirect M.B.C. It is that described by Gilson and McKerrow 1960.

CLOSED CIRCUIT HELIUM APPARATUS

The apparatus used is based on that described by McMichael (1939) for the measurement of the Functional Residual Air, except that Helium is used as the indicator gas instead of Hydrogen. It has been shown by Gilson and Hugh-Jones that the closed-circuit method using Helium and a Katharometer is an accurate and relatively rapid method of determining the Functional Residual Air. It can also be used to measure the rate at which Helium is mixed with the air in the lungs, but for this purpose the circuit must be modified in certain respects (see fig. 1)

A. Pump

In the apparatus described by Gilson and Hugh Jones 1949, the rate of circulation and mixing in the main circuit was not material as ample time could be given for equilibrium to be established before a final galvanometer reading was taken, but for the plotting of a mixing curve it is desirable to have as rapid a circulation as possible in the main circuit. The pump we used was a high speed fan with an output when in circuit of about 150 litres/minute. We used a lamp of 60 watts in series with the fan, so that when the lamp was switched on, the fan started.

B. Katharometer

The one we used is manufactured by "Cambridge Instrument Company," one in a side circuit leading from the outflow

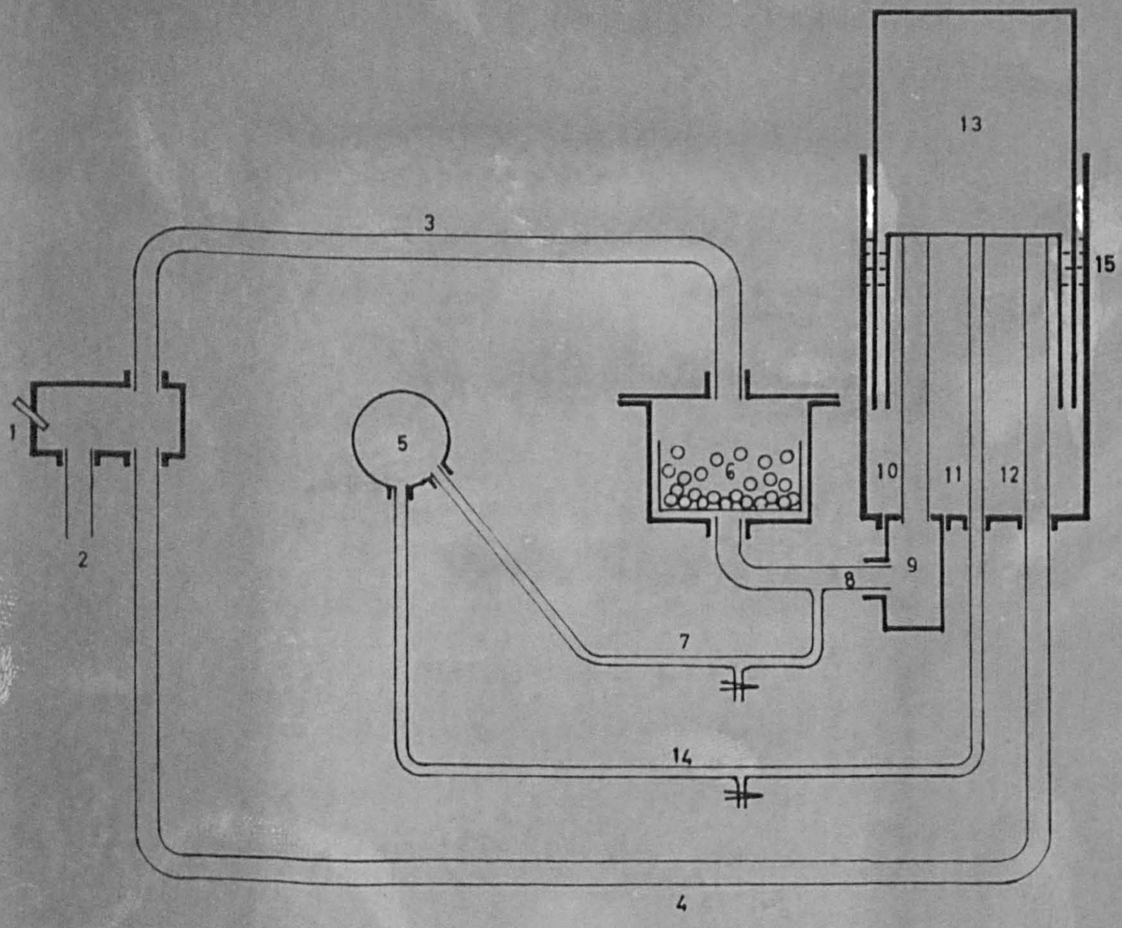

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

Fig I

1 - 3 way tap.

2 - Tube connected to a balloon and oxygen supply for wash-out.

3 - 8
10 - 12 - 4 : Main gas circulation tubes.

5 - Katharometer block.

6 - 7 - 14 Katharometer circulation tubes.

9 - fan.

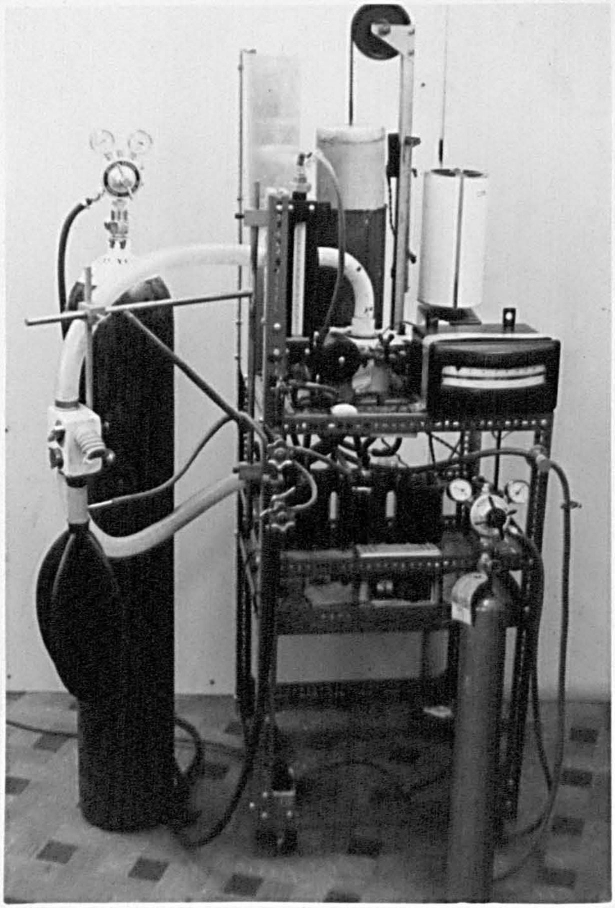
13 - spirometer bell.

15 - outer jacket containing water seal.

of soda lime canister to the pump inlet. The instrument consists of two pairs of resistances arranged as a bridge. One pair sealed in pure oxygen saturated with water, and the other pair accessible to the gas stream. The galvanometer records the change in potential across these when the open pair are in contact with a gas mixture whose thermal conductivity differs from that of pure moist O_2. It is calibrated from 0-15% Helium in oxygen over a ten-inch deflection, and is provided with a switch, so that for calibration purposes it can be made to measure the total current flowing in the circuit. The cells used are the "Exide type L.L.Z.G. - 2. Three cells with a total constant voltage of 6.3 volts." These were charged weekly to keep their voltage constant. The current flowing in the instrument is checked immediately before and at the end of each run. It is important that the gas mixture should pass through the main oxygen scrubber before reaching the Katharometer. The scrubber contains 800 grammes of soda lime and this was renewed after six tests.

C. Temperature

Two thermometers were used, one for the gas temperature, the second in the spirometer water. The gas temperature was usually higher than the water temperature. Our results are corrected according to the gas temperature.



D. An Event Recorder

An event recorder is fitted and is so connected that it records on the top of the chart by pressing a switch (Briscoe 1952). A mark is made on the chart each time the reading of the Katharometer is recorded.

E. A Syphon Water Level Indicator - is inserted into the water seal of the spirometer jacket so that the level of this may be kept constant.

F. Rotameter - fixed on the front of the apparatus (see picture.) The addition of oxygen to the spirometer was measured by a rotameter. This facilitated the adjustment of the oxygen supply to compensate for the subjects consumption.

G. Oxygen supply:-

From an oxygen cylinder connected to a manifold tube with two fine adjustment valves.

1) Connects to a balloon through a wash bottle containing water and is used to wash out the lungs.

2) Connects to the oxygen flow meter for replacing the oxygen consumed during the test.

   A larger bore tap is connected to the spirometer and used to wash out the spirometer and to supply oxygen to the spirometer rapidly when needed.

H. Helium - supplied to the circuit through a reduction valve.

DETECTION OF LEAKAGE

As a consequence of the method of construction of the apparatus, all the likely sources of leakage were on the negative pressure side of the circulating fan. In consequence any leaks resulted in an increase in the volume.

Routinely before beginning a measurement, the drum was allowed to rotate for a few minutes with the fan on. In the absence of leakage the record was level.

The volume of the circuit dead space with the spirometer empty is 5.08 litres.

C H A P T E R 6

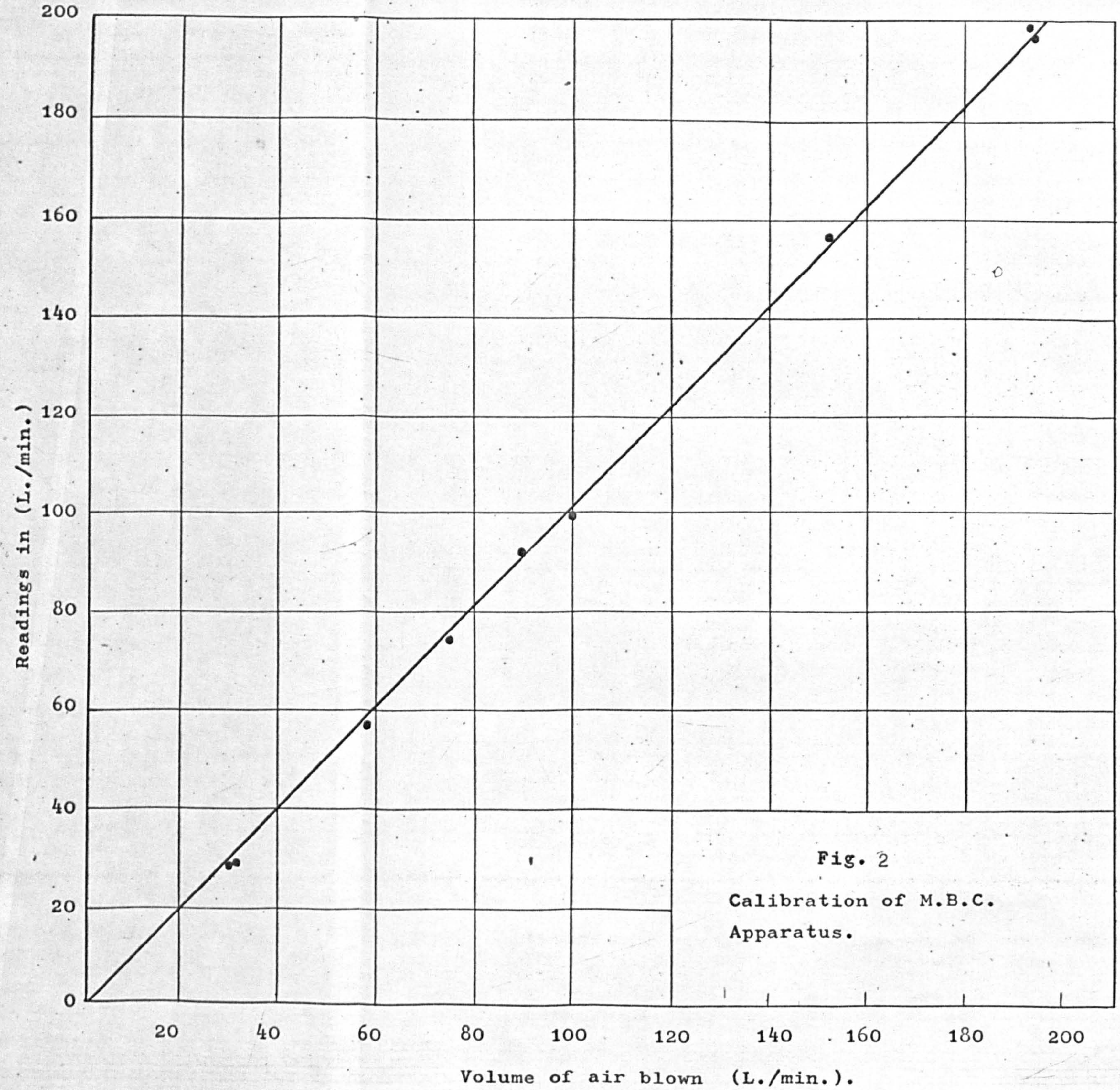


Fig. 2

Calibration of M.B.C. Apparatus.

CALIBRATION OF APPARATUS

1 Gaensler Apparatus

The calibration is checked by determining the volume which is drawn into the apparatus through a restricted orifice (supplied by the makers), when a standard weight is added to the normal counter weight. The volume of gas admitted is determined when the timer has been accurately calibrated, and its constancy serves as a check on the behaviour of the timer. (For the particular apparatus used the volume was 1.65 litres for .75 second, or 2.14 litres for 1 second.)

II Calibration of the M.B.C. Apparatus

The gas meter was calibrated against a rotameter. By using a pump with a 100 litres reservoir and a control valve, steady flows through the gas meter were established. The time required for a flow of two cubic feet to be registered by the meter was measured and the corresponding volume was calculated from the rotameter reading and the time. The meter volume was plotted against the (assumed true) volume derived from the rotameter reading. (See fig. 2)

Closed-circuit Helium Apparatus

Calibration of the Katharometer

The design of the Cambridge Katharometer makes no provision for the stabilization of the current in the circuit, consequently for a given applied voltage, the total current consumption of the instrument depends upon the composition of the gas in the cell. It is, therefore, necessary to define the condition under which the instrument is used and to calibrate it accordingly. For the most precise measurements a constant current regime is to be recommended, but this involves re-setting the series resistance before each reading, and this is impracticable under the condition which we required for the measurement of mixing efficiency. In this use the current is adjusted when the Helium concentration is approximately 14%. Calibration curves have, therefore, been prepared according to three regimes.

(1) With the instrument adjusted when containing pure moist oxygen.

(2) With the instrument adjusted when containing 14% Helium.

(3) With the instrument adjusted when containing the experimental mixture.

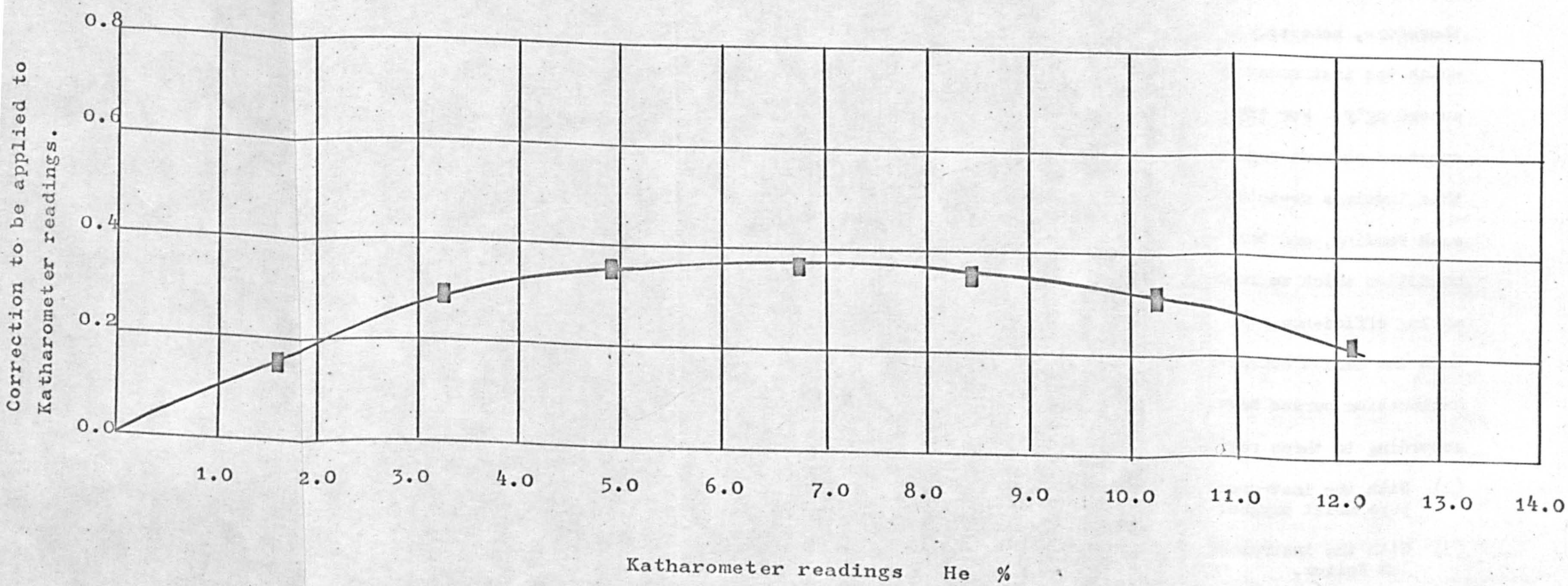


Fig. 4 Calibration of the Katharometer

Correction curves corresponding to these three regimes are plotted. Gas mixtures for calibration purposes were prepared by diluting measured volumes of moist Helium with moist oxygen to a predetermined volume of (1.095 Litres.) Although gases were handled over water, and therefore, were very close to saturation, it was found advisable to bubble them through a small wash bottle before they were passed into the katharometer. It is essential to take precautions to prevent liquid water entering the katharometer. The most important of these are to maintain a slow flow through the katharometer and at intervals to blow the whole system out with dry filtered air. See fig 4.

SPIROMETER DEAD SPACE DETERMINATION

For the determination of the spirometer dead space, we used the method of Meade (Gilson and Hugh Jones 1949). The spirometer was emptied and a zero mark was recorded on the drum (V_d). The spirometer was then flushed repeatedly with oxygen, and the bell set at an arbitrary level near zero (V_1). The level was recorded on the drum. A known volume (V_{He}) of Helium was added from a gas-pipette, and, after the gas was mixed, the galvanometer reading was recorded (C_{He}). A second equal volume of Helium was added and by the gradual addition of more oxygen (with continual mixing) the Katharometer reading was brought back to C_{He}. The volume was then recorded on the drum (V_2). The initial concentration of Helium in the spirometer $= C_{He} = \dfrac{V_{He}}{V_d + V_1}$

and the final concentration $\dfrac{2\,V_{He}}{V_d + V_2} = C_{He}$

$$\therefore \quad \frac{2\,V_{He}}{V_d + V_2} = C_{He} = \frac{V_{He}}{V_d + V_1}$$

$$\therefore \quad 2\,V_d + 2\,V_1 = V_d + V_2$$

or $V_d = V_2 + 2\,V_1$

Dead space (mean of 3 determinations) 5.08 L. Standard error of mean = .01 L.

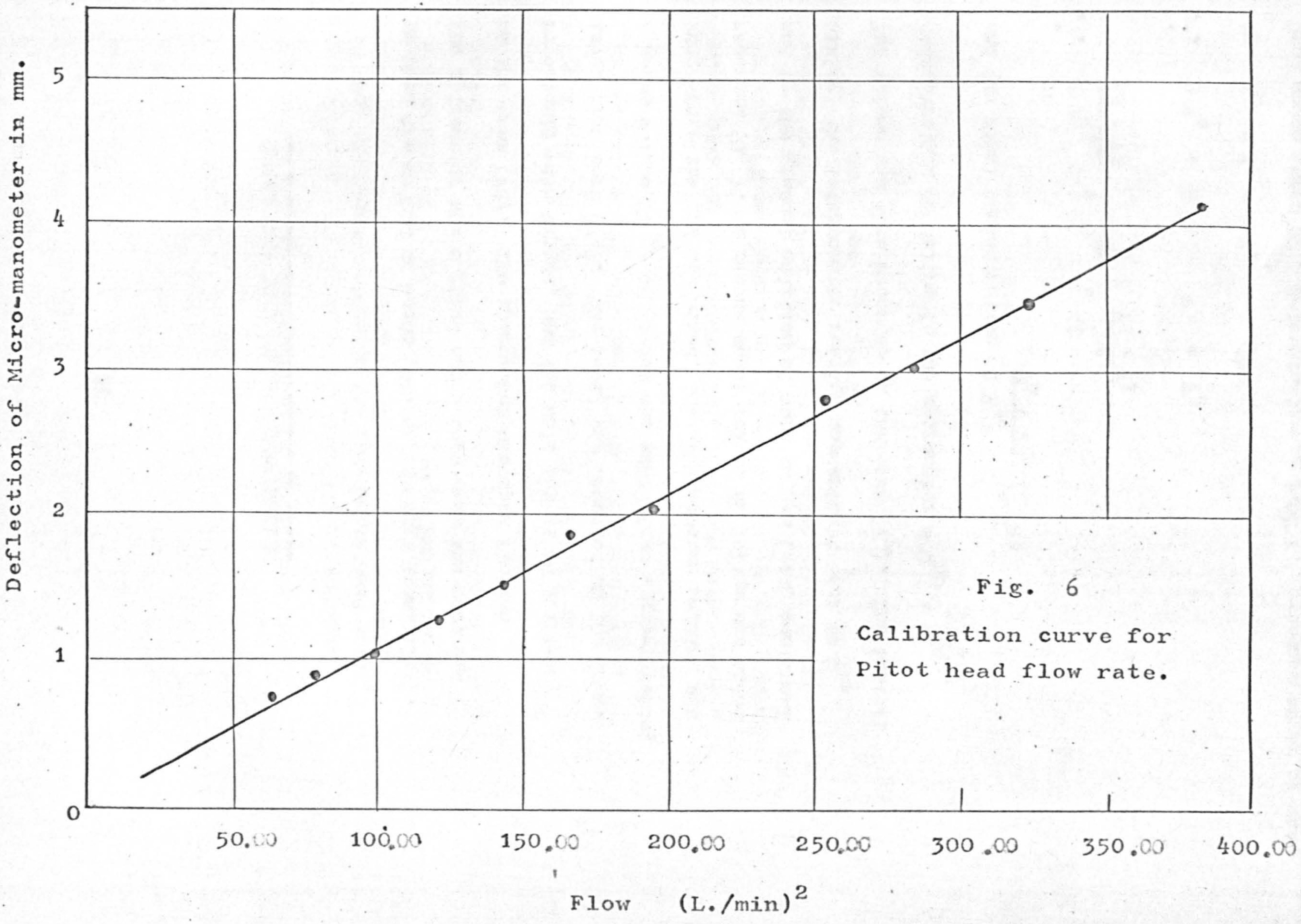


Fig. 6

Calibration curve for Pitot head flow rate.

DETERMINATION OF THE CIRCULATION TIME

The volume of air circulated by the fan was determined by introducing into the spirometer a pitot head connected to a micro-manometer. This flow measuring arrangement was calibrated in situ, because it became apparent that the flow conditions near the pitot head depended upon the rest of the circuit.

The spirometer circuit was opened adjacent to the mouth piece. Air was delivered from a pump through a rotameter at this point. It was then possible to calibrate the micro-manometer reading against the rotameter. The manometer reading was plotted against the square of flow $(L./min.)^2$ as measured by the rotameter. The relation proved to be satisfactorily linear. See Fig 6.

The spirometer circuit was then restored and the flow measured under various conditions.

1 - By using different soda lime particle size.

2 - With the canister empty.

3 - Without canister.

4 - Different lamp watts from 60 - 100 watts.

See table 1.

TABLE 1

	Deflection of the Micro-Manometer		Pressure Difference	L./min.
Pitot head in spiro circuit,	3.81	1.23	2.58	157
using 100 watts lamp	3.72	1.21	2.51	152
Bell at zero level	3.70	1.21	2.49	150
using 60 watts lamp	3.50	1.20	2.30	147
No basket No soda lime	5.60	1.20	4.4	230
Empty basket	5.35	1.20	4.15	197
Refill basket (60 watts lamp)	3.30	1.00	2.30	147
4/8 mesh soda asbestos	5.92	3.10	2.82	162.5
	6.03	3.10	2.93	165
	6.10	3.10	3.00	170
After leaving overnight and adding further 100 gms. soda asbestos after 25 min.	4.10	1.40	2.70	160
	4.10	1.40	2.70	160

Calibration of closed circuit Helium mixing machine V.S. simple spirometer. Measurements done September, 1954, and thereabouts. Assumed dead space of correction 260 c.c.

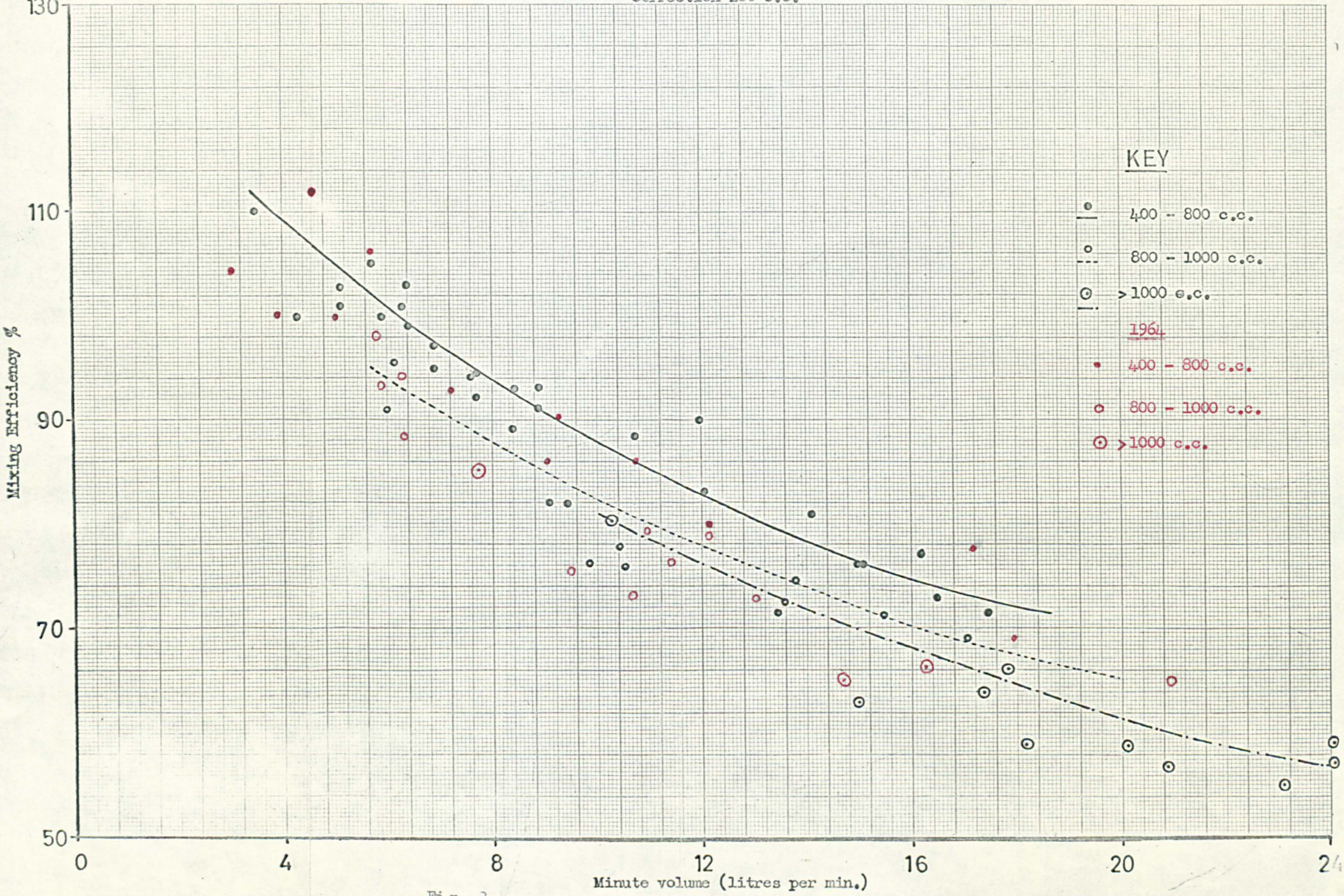


Fig. 3

CALIBRATION OF CLOSED-CIRCUIT HELIUM APPARATUS

Although as is shown by the measurements of Page 29 ... mixing of gas in the closed-circuit Helium apparatus is rapid. There is an unavoidable lag in response, and, this is of greater importance the greater the minute volume.

In order therefore to allow for differences of this kind, the machine was standardized by determining the mixing efficiencies of "a simple spirometer" at varying tidal volumes and breathing rates.

"The apparent mixing efficiencies" were calculated and the results are plotted against the minute volume in Fig 3.

This figure shows results obtained in 1954 for comparison with those obtained at present time. The dead space of the system i.e. the volume of the tube and tap connecting the "Lung spirometer" to the Helium apparatus was measured at 260 c.c.s. and this was allowed for in the calculations.

It can be seen from the figure that for a given mixing efficiency "the apparent mixing efficiency" is inversely related to the tidal volume.

This could be explained on the assumption that the true dead space is less than the measured volume.

C H A P T E R 7

PROCEDURE

1 - History

The subject was asked questions from the M.R.C. "Questionnaire on respiratory symptoms, 1960."

11 - Anthropometry

Body measurements were made to check the comparability of the groups selected and to enable a correction to be made for the effects of height or weight or both. Standing height was measured with the subject in stockinged feet. Sitting height was recorded seated, thighs horizontal, feet on the floor. Weights were measured to the nearest pound in stockings, trousers and shirt.

111 - $F.E.V._{75}$ and F. V. C. measurements

The subject was shown how to carry out the test. He was asked to take a very big breath, hold it, then blow through the mouth piece as fast and as deep as he could, and to continue blowing as forcibly as he could. (Gandevia). The readings for $F.E.V._{75}$ and F.V.C. were recorded. This test was repeated three times.

IV

The volunteer was then seated on a chair in front of the closed circuit Helium apparatus, he was shown how to use the mouth piece and the nasal clip properly, and was finally asked to sit comfortably on the chair. First a normal spirogram was recorded with the spirometer three-quarters full with oxygen. Three vital capacities were recorded. Then the oxygen flow was switched through the oxygen flow meter to the spirometer and the volume of oxygen required to keep the spirogram level was measured. The subject was then switched off the spirometer and asked to take a few minutes rest. During this period, oxygen was run into the oxygen bag. At the same time the spirometer was washed out with oxygen from 8 - 10 times until the galvanometer read zero. Meanwhile the person was asked to start breathing from the oxygen bag to wash the nitrogen from his lungs. Oxygen supply to this bag was moistened by passing it through water in a Wolff's bottle (to prevent dryness of the throat.) He was allowed to breath pure oxygen from 5 - 10 minutes depending on his lung condition already known from the

M. R. C. questionnaire. When the galvanometer read zero the spirometer was emptied completely. A top line was drawn on the graph, the drum was stopped and Helium was added to the circuit, this drew a vertical line on the chart at the same time an event mark was recorded corresponding to this line. These formed a zero time mark. The katharometer current was then adjusted and the initial Helium concentration read. It usually ranged from 13% to 15%. The drum was then switched on. The three-way tap was switched at the end of a normal expiration from the oxygen bag to the circuit, at the same time the oxygen flow was started at a predetermined rate. Helium concentration started to fall rapidly at the start, then more slowly as the mixing process neared completion. The galvanometer was read at intervals. The time of each reading was shown on the top of the chart. When the reading was steady for at least one minute, it was assumed that the mixing was complete. At this time the subject was switched from the circuit and oxygen input turned off at the same time. The katharometer was then checked and a galvanometer reading was taken. The temperature of the gas and water were recorded, and the subject was allowed to rest a few minutes.

V Maximum Breathing Capacity

The subject was seated in front of the M.B.C. machine. The initial gas meter reading was recorded. The subject was then shown how to do the test properly. He was asked to breathe as fast and as deep as possible for 15" (Gandevia) as indicated by a stop watch. The valve was switched to the bellow side at the start of the test, at the end of the 15" the valve was switched to the opposite side, and the subject was allowed a few minutes rest in between each test. At the same time the final gas meter reading was recorded. This test was repeated three times and the gas temperature was always recorded at the end of the test. The average of the three readings was taken.

C H A P T E R 8

RESULTS

(1) F.E.V.$_{75}$ and F.V.C. from gaensler apparatus by direct reading.

(2) F.R.C. from the closed Helium circuit apparatus, by a calculation the same for mixing efficiency.

(3) Residual Volume by subtracting expiratory reserve from the F.R.C.

(4) Inspiratory Reserve by measuring on the chart of the inspiratory reserve, then this is corrected for temperature the same for expiratory reserve.

(5) Vital Capacity this is measured on two separate occasions on each subject on different pieces of apparatus:-

  (1) Gaensler apparatus which gives direct result of F.V.C. This is always larger than the V.C. The largest reading is the one we considered.

  (2) V.C. is recorded on the closed circuit Helium spirometer used to measure the F.R.C. and M.E. This is measured and the mean 3.V.C. is usually taken. (Cotes 1965).

(6) Total lung capacity by the addition of vital capacity to R.V. or by the addition of inspiratory reserve to F.R.C. they are almost the same.

(7) Tidal volume is the mean of tidal volumes of the F.R.C. tracing.

Calculation for F.R.C.

$$\text{(apparatus D.S. + volume of gas added to the spirometer in litres)} \times \frac{\text{Initial Helium Concentration}}{\text{Final Helium Concentration}} = (x)$$

$$(x) - \left(\text{apparatus D.S.} + \left(\text{volume of gas added to the spirometer in litres} + \text{60 c.c. for mouth piece D.S.}\right)\right) = \text{F.R.C.}$$

F.R.C. x temperature correction = final result of F.R.C.

Direct M.B.C.

Direct by finding the difference between the final reading and the initial reading x 28.3 to change cubic feet into litres x temperature correction. The average of the three readings is the one considered.

Intrapulmonary mixing - treatment of results

Workers have employed various methods for the derivation of some index of mixing from the series of observations which result from such a measurement. The different indices so obtained were reviewed by Gilson and Hugh Jones (1955). They prefer indices based on the number of breaths required to achieve a given degree of gas replacement to those which use only the total volume of ventilation required. In this work two indices have been used, Gilson and Hugh-Jones' overall index Io, and a crude adaptation of this, designed to reduce the influence of the subjects' tidal volume on his apparent mixing efficiency.

In principle Io, is the ratio of the theoretical number of breaths required for a 90% approach to equilibrium between the spirometer and the lungs, on the assumption that each breath is completely and instantaneously mixed with the gas in the lungs or in the spirometer, as appropriate.

Using the following symbols:-

F = Volume of gas in lungs at the end of normal expiration.

T = Tidal volume.

d = Dead space.

Te= Effective tidal volume.

V = Volume of spirometer at the end of normal expiration.

M_o, M_n, M_∞ = the concentration of helium in the spirometer initially, after n breaths and after a very large number of breaths. l_o, l_n, l_∞ = the corresponding concentrations in the lungs. It may be shown that:-

$$\frac{M_o - M_n}{M_o - M_\infty} = 1 - \left(\left[\frac{F}{F + T}\right] \left[\frac{V - T}{V}\right]\right)^{r}$$

For 90% mixing $$\frac{M_o - M_n}{M_o - M_\infty} = 0.9$$

therefore $$\left(\frac{F}{F + T} \times \frac{V - T}{V}\right)^{r} = .1$$

$$r \log \left(\frac{F}{F + T} \times \frac{V - T}{V}\right) = -1$$

.˚. expected no. of breaths for 90% mixing

is $$r_{90\%} = \frac{-1}{\log\left(\frac{F}{F + T} \times \frac{V - T}{V}\right)}$$

In calculating Io it is desirable to allow for the apparatus dead space d_a; the expression for $r_{90\%}$

then becomes $$r_{90\%} = \frac{-1}{\log\left(\frac{F}{F + Te} \times \frac{V - Te}{V}\right)}$$

where $Te = T - d_a$

Io is defined as $\frac{r_{90}}{n_{90} - 1} \times 100\%$. where n_{90} is the observed no. of breaths to reach a 90% approach to equilibrium. $n_{90} - 1$ replaces n_{90} in order to allow for the lag in the Katharometer.

The overall index so calculated seldom if ever exceeds 75% even in young healthy adults.

This "built-in" mixing defect is due to several factors of which the most important are:- the lag of the Katharometer which is constant and corresponds to a variable number of breaths depending upon the respiratory frequency; the non instantaneous mixing in the spirometer and the neglect of the subject's dead space. In order to overcome the above disadvantages of Io, which are particularly apparent when an individual's mixing is to be repeated after a lapse of time, the second index Ie has been used in this laboratory. For the calculation of Ie, T_e is replaced by $T_{e'}$ = Te - 150 ccs (where T is expressed in ccs.) and $n_{90} - 1$ is replaced by $n_{90} - n_L$ where n_L is found from inspection of the semi-logarithmic mixing curve and is approximately (respiratory frequency) ÷ 6. In addition Io and Ie of a simple spirometer have been determined for a range of tidal volumes and respiratory frequencies.*

* the spirometer was equipped with a propeller in the space beneath the bell, and it was found that the experimental value of Ie was not increased if this was rotated at 2.900 r.p.m. for the duration of the test; it was therefore concluded that the mixing in the spirometer was effectively instantaneous.

The dead space of this spirometer was 260 cc as measured by the water capacity of the connecting tube; however, it was found that for a given minute volume Ie was more nearly independent of tidal volume if the dead space was taken as 235 ccs.

The final values of the mixing efficiencies reported in the text are corrected for the deficient mixing of the spirometer. That is to say the calculated Ie or Io as the case may be is divided by the value of Ie or Io determined for the single spirometer at the appropriate breathing rate and tidal air.

These values are reported as "mixing efficiencies" M.E.

In summary:

$$M.E._2 = \frac{Ie}{Ie\ spiro} \qquad \text{or} \qquad M.E._1 = \frac{Io}{Io\ spiro}$$

$$Ie = \frac{V_{90}}{n_{90} - n_1} = \frac{-1}{(n_{90} - n_1)\log} \frac{F}{F + T - 150} \times \frac{V - T + 150}{V}$$

$$\text{Ie. spiro} = \frac{-1}{n'_{90} - n'_{1}} \log\left(\frac{F'}{F' + T' - 235} \times \frac{V' - T' + 235}{V'}\right)$$

$$\text{Io} = \frac{\gamma_{90}}{n_{90} - 1} = 1 \Big/ n_{90} . \log\left(\frac{F}{F + T} \times \frac{V - T}{V}\right)$$

$$\text{Io spiro} = -1 \Big/ n'_{90} . \log\left(\frac{F'}{F' + T' - 260} \times \frac{V' - T' + 260}{V'}\right)$$

The primed symbols n' refer to the simple spirometer which is assumed to provide perfect mixing.

CHAPTER 9

12 YEARS FOLLOW UP STUDY

The aim of this study was to compare the changes in lung function occurring in the two groups previously studied i.e. Bricklayers and Rolling Mills.

Measurements of mixing efficiency, percentage residual volume, and M.B.C., made in 1952-3 and in 1964 are compared for 43 workers from the bricklayers' department, and 64 from a rolling mill. The workers in the bricklayers' department are divided into three categories:-

a) Bricklaying group.
b) Bricklayer's labourers.
c) Dismantlers.

Lung Function Tests

I - M.B.C.

It is found in almost every case that there is a large fall in the measured M.B.C. as between 1952-1964. However, comparison of the average M.B.C. for men of 20-25 found in 1952 and men of the same age 1963 shows a large difference (See appendix 2.) One is forced to conclude that the large difference is at least partly due to observer difference.

II - $\frac{R.V.}{T.L.c.}$ %

The ratio of the residual volume/total lung capacity shows an increase over the 12 years in almost every case. The average increase does not differ significantly between the two groups. The average increase in Bricklayers is + 4.88% S.D. 7.48 S.E. 1.15 while in the Rolling Mills the average increase is + 6.95% S.D. 7.0 S.E. 0.87. The difference between the groups is statistically non significant.

III - M.E.

By comparing the M.E.% in both groups in 1952-54 and 1964 the following is found:-

(1) There is an average increase in the M.E. from 1952 to 1964 in the Bricklaying Department = + 7.1% - S.D. 21 - S.E. 3.30.

(2) On the contrary in the Rolling Mill, there is an average decrease in M.E.% = -4.19 S.D. 15.94 - S.E. 2.10.

The diminution in M.E. for the Rolling Mill is comparable with the change which would be inferred from the overall value of the regression of M.E. on age which was observed in 1952-54 (See tables V-XII appendix 2.)

CHANGES IN CHEST SYMPTOMS OVER 12 YEARS PERIOD

In the Rolling Mill and Bricklayers' Department the population is divided into groups by their ages in 1952.

a) up to 29 years old　　b) 30 - 39 years old

c) 40 - 49 " "　　d) 50 and over.

The results are tabulated. (See tables XII-XX appendix 3.)

THE DEATHS

By following up the Factory records, it is found that 30 persons died in the Bricklayers' Department and 8 died in the Rolling Mills, but this does not include men who died after leaving the firm.

By calculating the mean differences, S.D., S.E., and significance tests of the differences in both furnace bricklayers and rolling mill workers, it is found that in cases of:-

(1) Mixing Efficiency

There is an increase in M.E. over the 12 years period in all age groups. In case of the furnace bricklayers, this increase is statistically significant at the 1% level in age group 50 +, but in case of the control group, this persistent increase is not noticed.

In age group (30 - 39) there is a decrease over the 12 years period which is statistically significant at the 1% level.

In age group (- 30) there is also a decrease which is not significant.

On the contrary there is a non significant increase in the change in age group (50 +).

A negligible increase is noticed in age group (40 - 49) see tables 2&3.

As used in the department of preventive medicine, the closed circuit helium method has given a standard deviation of 5.0%, on the mixing efficiency calculated without allowing for anatomical dead space ($M.E._1$).

If an alternative method of calculating the mixing efficiency ($M.E._2$) was used, in which an arbitrary correction of 150 cc was made for the anatomical dead space, the standard deviation was increased to 7.1%, while the mean value was increased in approximately the same proportion as the standard deviation.

The amounts and directions of the changes in $M.E._2$ are displayed in Fig 5, where the present 1964 values of the $M.E._2$ are plotted against those found in 1952.

The 45° line represents no change. The inner pair of parallel lines define the standard deviation and the outer pair correspond to the 99 percentile limits (2.56 x standard deviation)*

If it is accepted that the technique employed in both measurements was adequate, these results are incompatible with an explanation relying on chance variation.

For the rolling mill men aged <40, the significant deviations are negative, and these might be attributed to ageing.

Of the remainder, who show many increases well beyond the 99 percentile, it may be suggested that the earlier measurements were in some cases made when the subjects were influenced by some acutely acting irritant.

* These limits were derived from an independent series of measurements which we carried out in 1955-56 on a group of volunteers who attended an interval over a period of 18 months.

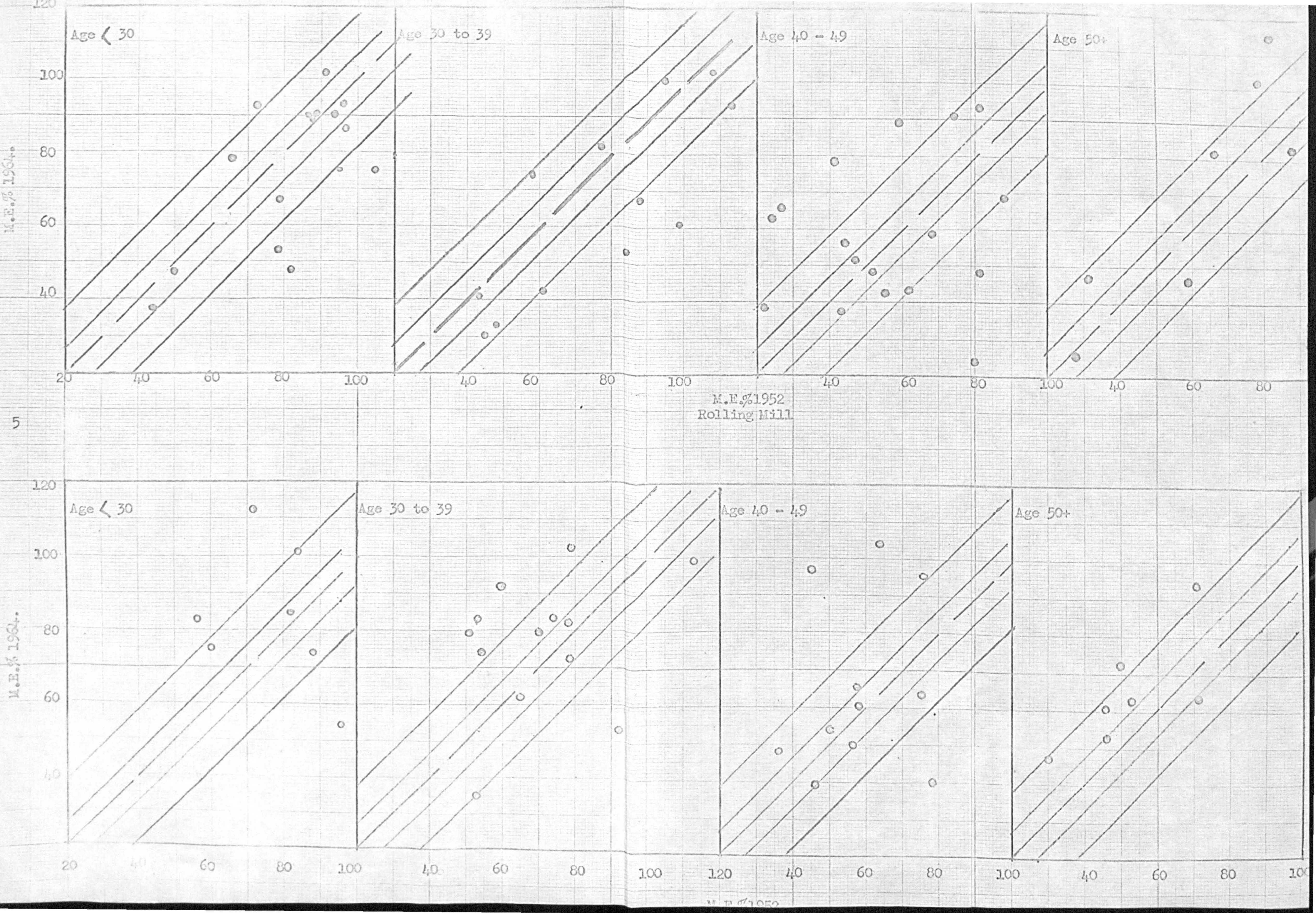

Age < 30
Age 30 to 39
Age 40 - 49
Age 50+
M.E.% 1964.
M.E.%1952
Rolling Mill
Age < 30
Age 30 to 39
Age 40 - 49
Age 50+
M.E.% 1964.

Fig. 5

This suggestion is in line with the fact that during the three years just prior to this study the open-hearth furnaces in which the bricklayers mainly worked were replaced by electric arc furnaces, made from different materials. On the other hand no explanation can be advanced for the large increases shown by six of the rolling mill workers.

$\frac{R.V.}{T.l.c.}$ %

The mean change in $\frac{R.V.}{T.l.c.}$ % over twelve year - period is always on the positive side in all age groups in case of the rolling mill workers. This increase in percentage is found to be statistically significant at 0.1% level in age groups (-30, 30 - 39 and 40 - 49), and is significant at the 5% level in age group 50+. See table.4 A similar finding applies to the furnace bricklayers, except in age group (- 30) where the difference over the 12 year period is not significant. The mean change in age groups (30 - 39 and 50+) is statistically significant at the 1% level and is significant at the 5% level in age group 40 - 49. See tables 4&5.

It can be said that there is no occupational change over the 12 year period and, that this increase agrees with that expected from the age gradient observed in the same population in 1952.

Table 2

Bricklayers S.P.T.
(1952 & 64 results)

M. E. (1964 - 1952)

Age Group in 1952	No per group	Average difference	S.D.	S.E.
- 30	7	+ 6.29	27.32	11.15
30 - 39	13	+ 5.62	21.30	6.15
40 - 49	13	+ 6.08	22.56	6.51
50 +	7	+ 13 xx	8.83	3.61

xx significant at 1% level

Table 3

Rolling Mills S.P.T. -
(1952 and 1964 results)

<u>M. E.</u> (1964 - 1952)

Age Group in 1952	No per group	Average difference	S.D.	S.E.
- 30	17	- 7.24	15	3.75
30 - 39	15	- 11.13 xx	13.40	3.58
40 - 49	20	+ 0.25	25.12	5.76
50+	7	+ 10.14	14.59	5.96

xx significant at 1% level

Table 4

Bricklayers S.P.T.
(1952 & 64 results)

$\frac{\text{R.V.}}{\text{T.L.c.}}$ (1964 - 52)

Age Group in 1952	No per group	Average difference	S.D.	S.E.
- 30	7	- 1.43	4.76	1.94
30 - 39	13	+ 7.62 xx	6.57	1.90
40 - 49	15	+ 5.07 x	8.19	2.19
50 +	7	+ 8.57 xx	- 4.44	1.81

xx significant at 1% level
x " " 5% "

Table 5

Rolling Mills S.P.T. -
(1952 and 1964 results)

$\frac{R.V.}{T.L.c.}$ (1964 - 1952)

Age Group in 1952	No per group	Average difference	S.D.	S.E.
- 30	20	+ 6.50 xxx	6.16	1.41
30 - 39	17	+ 7.24 xxx	4.57	1.14
40 - 49	21	+ 6.67 xxx	4.80	1.10
50 +	7	+ 8.43 x	6.40	2.61

x significant at 5% level
xxx " " 0.1% "

CHAPTER 10

Interpretation of 1964-66 results

I E.S.C.

From the spirometric measurements, the residual volume is calculated as a percentage of total lung capacity, the $\frac{F.E.V._{75}}{F.V.C.}$ and the mixing efficiency.

These quantities are relatively independent of body size, and it is therefore possible to consider them without reference to other anthropometric measurements. The mean values of the $F.E.V._{75}$ and V.C. are also tabulated.

The means are given for 10 year groups and are separated according to smoking habits and dustiness or otherwise of employment. It is thus possible to examine the results for differences which might be attributable to the nature of the work and to the effects of smoking.

1. $\frac{F.E.V._{75}}{F.V.C.}$:

In both dusty and non-dusty employment, this ratio is greater for non-smokers in almost every age-occupation group, but only in two age groups of (40 - 49 and 50-59) is the difference statistically significant at the levels indicated in tables. 6&7.

2. M.E.% :

In clean jobs M.E.% is greater in almost all non-smoker groups, in age groups (40 - 49) however the smokers have a non-significantly higher mixing efficiency. In dusty jobs there is a higher average M.E. in non-smokers; and this is statistically significant in age groups (50 - 59), and on the other hand in age groups (20 - 29 and 60 - 64) the M.E. is greater in smokers than non-smokers but statistically non-significant. There is no significant difference in M.E. between clean and dusty jobs. See tables.8&9.

3. $\frac{\text{R.V.}}{\text{T.L.C.}}$

In both dusty and clean jobs the ratio is greater for smokers in almost every age-occupation group, but only over the ages of (30-39) in clean jobs and, (30-39, 40-49 and 50-59) in dusty jobs is the difference statistically significant at the levels indicated in tables.10&11.

II S.P.T.

The same division is used as in case of (E.S.C.)

1. $\frac{\text{F.E.V.}_{.75}}{\text{F.V.C.}}$

This ratio does not differ significantly between smokers and non smokers. For some age groups there is a difference which generally favours non-smokers.

Comparing dusty with non-dusty occupations, the differences are again slight but generally favour the clean jobs.

See tables.12&13.

2. M.E.%

The comparisons between smokers and non-smokers and between clean and dusty workers taken age group by age group show no significant differences. On the other hand in the non-dusty occupations, the non-smokers have at every age a higher M.E. While for the dusty occupations, there is no such consistent trend.

When the dusty occupations are compared with the non-dusty ones, the differences appear to depend on smoking habit, that is to say, that the non-smokers in dusty occupations appear to have slightly lower M.E. on the average than the non-smokers in clean jobs. See tables 14 and 15.

3. $\frac{\text{R.V.}}{\text{T.L.c.}}$ %

It appears that there is no consistent difference between the mean values of this ratio for workers in dusty and non-dusty situations. Slight differences generally favour the non-smokers. See tables 16 and 17.

In both (E.S.C.) and (S.P.T.) F.E.V.$_{.75}$ and V.C. results are tabulated, but these values are not of great importance because they depend on body size. See tables XXI - XXVIII appendix 4.

Table 6

Average $\frac{F.E.V.}{F.V.C}75\%$ in Dusty Jobs (E.S.C.)

Age Group years old	Av. age	No. of persons per group	Smoking habit	Av. $\frac{F.E.V}{F.V.C}75\%$	S.D.	S.E.
Below 20	-	-	-	-	-	-
From 20 - 29	26.46	13	-	75	6.24	1.80
	25.16	38	+	70	9.44	1.55
From 30 - 39	34.39	17	-	71	6.88	1.72
	33.66	41	+	69	7.21	1.14
From 40 - 49	43.69	16	-	71.74**	7.42	1.92
	44.11	47	+	63.40**	9.16	1.34
From 50 - 59	55.67	15	-	66.56**	9.65	2.54
	54.18	37	+	55.37**	11.62	1.94
From 60 - 64	62	4	-	55	5.64	3.26
	61.78	9	+	63	14.32	5.06

** Significant at 1% level

\- Non-smokers or ex-smokers for 1 year or more

\+ Smokers: 10 cigarettes/day or more

Table 7

Average $\frac{F.E.V.}{F.V.C.}$75% in Clean Jobs (E.S.C.).

Age Group years old	Av. age	No. of persons per group	Smoking habit	Av. $\frac{F.E.V}{F.V.C}$75%	S.D.	S.E.
Below 20	17.14	7	-	75	9.38	3.83
	18.25	4	+	71	4.12	2.38
From 20 - 29	25	12	-	71	8.66	2.61
	25.55	38	+	69	7.04	1.16
From 30 - 39	33.52	17	-	71	8.00	2.0
	35.52	23	+	66	7.56	1.61
From 40 - 49	44.82	11	-	67.33*	9.58	3.03
	45.75	28	+	58.05*	13.15	2.53
From 50 - 59	55.07	14	-	65.51**	7.84	2.17
	54.56	27	+	56.08**	12.33	2.42
From 60 - 64	62.25	8	-	64	9.00	3.40
	61.56	16	+	63	9.85	2.54

* Significant at 5% level

** Significant at 1% level

Table 8

Average M.E.% in Dusty Jobs (E.S.C.)

Age Group years old	Av. age	No. of persons per group	Smoking habit	Av. M.E.	S.D.	S.E.
Below 20	-	-	-	-	-	-
From 20 - 29	26.33	12	-	63	17.44	5.26
	25.16	38	+	70	13.15	2.16
From 30 - 39	34.44	16	-	66	17.86	4.61
	33.66	41	+	62	14.80	2.34
From 40 - 49	43.69	16	-	62	16.70	4.31
	44.11	47	+	56	16.12	2.38
From 50 - 59	55.67	15	-	64**	16.82	4.49
	54.18	37	+	50**	14.93	2.49
From 60 - 64	62	4	-	40	7.81	4.51
	61.78	9	+	49	19.29	6.82

** Significant at 1% level

Table 9

Average M.E.% in Clean Jobs (E.S.C.)

Age Group years old	Av. age	No. of persons per group	Smoking habit	Av. M.E.	S.D.	S.E.
Below 20	17.14	7	−	74	11.96	4.88
	18.25	4	+	70	11.79	6.81
From 20 – 29	25.00	12	−	76	12.40	3.74
	25.55	38	+	67	15.57	2.56
From 30 – 39	33.52	17	−	65	15.56	3.89
	35.52	23	+	65	15.31	3.26
From 40 – 49	45.30	10	−	53	9.59	3.19
	45.75	28	+	55	17.06	3.28
From 50 – 59	55.07	14	−	54	13.38	3.71
	54.56	27	+	49	15.00	2.94
From 60 – 64	62.25	8	−	56	13.30	5.03
	61.56	16	+	50	16.67	4.30

Table 10

Average $\frac{R.V.}{T.L.C.}$% in Dusty Jobs (E.S.C.)

Age Group years old	Av. age	No. of persons per group	Smoking habit	Av. $\frac{R.V.}{T.L.C.}$	S.D.	S.E.
Below 20	-	-	-	-	-	-
From 20 - 29	26.46	13	-	28	9.49	2.74
	25.16	38	+	27	5.92	.97
From 30 - 39	34.29	17	-	25*	5.71	1.43
	33.66	41	+	30*	8.37	1.32
From 40 - 49	43.69	16	-	29.56**	6.44	1.66
	44.11	47	+	36.26**	7.28	1.07
From 50 - 59	55.67	15	-	37**	5.72	1.53
	54.18	37	+	45**	8.97	1.50
From 60 - 64	62	4	-	39	3.56	2.06
	61.78	9	+	47	9.59	3.39

* Significant at 5% level

** Significant at 1% level

Table 11

Average $\frac{R.V.}{T.L.C.}$% in Clean Jobs (E.S.C.)

Age Group years old	Av. age	No. of persons per group	Smoking habit	Av. $\frac{R.V.}{T.L.C.}$	S.D.	S.E.
Below 20	17.14	7	-	24	7.04	2.87
	18.25	4	+	26	5.26	3.04
From 20 - 29	25.00	12	-	25	7.81	2.36
	25.55	38	+	27	6.37	1.05
From 30 - 39	33.52	17	-	26*	6.48	1.62
	35.52	23	+	31*	5.64	1.20
From 40 - 49	45.30	10	-	35	7.16	2.39
	45.75	28	+	37	9.81	1.89
From 50 - 59	55.07	14	-	37	5.42	1.50
	54.56	27	+	40	9.38	1.84
From 60 - 64	62.25	8	-	38	6.24	2.36
	61.56	16	+	43	7.07	1.83

* Significant at 5% level

Table 12

Average $\frac{F.E.V._{75}}{F.V.C.}$ % in Bricklayers' Department (S.P.T.)

Age Group years old	Av. age	No. of persons per group	Smoking habit	Average $\frac{F.E.V._{75}}{F.V.C.}$	S.D.	S.E.
Below 20	-	-	-	-	-	-
From 20 - 29	25.33	3	-	67	5.52	3.91
	24.60	10	+	69	5.20	1.73
From 30 - 39	33.75	8	-	67	5.53	2.09
	34.89	9	+	68	6.66	2.36
From 40 - 49	43.20	5	-	69	9.39	4.70
	44.05	18	+	62	12.53	3.04
From 50 - 59	54	8	-	65	6.75	2.55
	54.14	14	+	58	13.08	3.63
From 60 - 64	62.50	2	-	70**	.71	.71
	61.25	4	+	49**	8.82	3.40

** Significant at 1% level

Table 13

Average $\frac{F.E.V._{75}}{F.V.C.}$ % in Rolling Mills (S.P.T.)

Age Group years old	Av. age	No. of persons per group	Smoking habit	Average $\frac{F.E.V._{75}}{T.L.C.}$ %	S.D.	S.E.
Below 20	17.75	8	-	73	5.20	1.96
	18	13	+	70	7.14	2.06
From 20 - 29	23.36	11	-	74	5.0	1.61
	24.44	34	+	68	9.11	1.59
From 30 - 39	32.83	6	-	67	6.08	2.72
	34.37	41	+	68	8.72	1.38
From 40 - 49	47	5	-	67	2.96	1.48
	46.92	13	+	64	6.95	2.01
From 50 - 59	53.80	5	-	71	4.58	2.29
	54.09	23	+	63	8.66	1.85
From 60 - 64	62	4	-	60	16.09	9.29
	61.77	13	+	61	7.00	2.02

Table 14

Average M.E.% in Bricklayers' Department (S.P.T.)

Age Group years old	Av. age	No. of persons per group	Smoking habit	Average M.E.	S.D.	S.E.
Below 20	-	-	-	-	-	-
From 20 - 29	25.33	3	-	66	12.21	8.63
	24.60	10	+	66	7.55	2.52
From 30 - 39	33.75	8	-	63	17.78	6.72
	34.89	9	+	56	17.69	6.26
From 40 - 49	43.20	5	-	51	8.47	4.37
	44.05	18	+	57	6.08	1.47
From 50 - 59	54	8	-	51	12.73	4.81
	54.14	14	+	52	11.81	3.28
From 60 - 64	62.50	2	-	38	14.14	14.14
	61.25	4	+	41	12.25	7.07

Table 15

Average ME. % in Rolling Mills (S.P.T.)

Age Group years old	Av. age	No. of persons per group	Smoking habit	Average M.E.	S.D.	S.E.
Below 20	17.75	8	-	62	33.02	12.48
	18	12	+	59	8.23	2.48
From 20 - 29	23.36	11	-	66	14.56	4.61
	24.58	33	+	60	19.60	3.47
From 30 - 39	32.83	6	-	64	21.95	9.81
	34.37	41	+	52	19.75	3.12
From 40 - 49	47	5	-	55	7.06	3.53
	46.53	15	+	44	19.16	5.12
From 50 - 59	53.80	5	-	58	15.72	7.86
	54.09	23	+	43	16.43	3.50
From 60 - 64	62	4	-	46	18.92	10.92
	61.77	13	+	41	13.82	3.99

Table16

Average $\frac{R.V.}{T.L.C.}$ % in Bricklayers' Department (S.P.T.)

Age Group years old	Av. age	No. of persons per group	Smoking habit	Average $\frac{R.V.}{T.L.C.}$	S.D.	S.E.
Below 20	-	-	-	-	-	-
From 20 - 29	25.33	3	-	23	5.52	3.90
	24.60	10	+	27	9.43	3.14
From 30 - 39	33.75	8	-	28	6.66	2.52
	34.89	9	+	28	5.05	1.79
From 40 - 49	43.20	5	-	30	4.47	2.23
	44.05	18	+	36	10.77	2.61
From 50 - 59	54	8	-	36	7.33	2.77
	54.14	14	+	37	6.13	1.70
From 60 - 64	62.50	2	-	51	7.75	7.75
	61.25	4	+	43	16.50	9.53

Table 17

Average $\frac{R.V.}{T.L.C.}$% in Rolling Mills (S.P.T.)

Age Group years old	Av. age	No. of persons per group	Smoking habit	Average $\frac{R.V.}{T.L.C.}$	S.D.	S.E.
Below 20	17.75	8	-	26	5.83	2.20
	18	13	+	22	4.36	1.26
From 20 - 29	23.36	11	-	25	5.21	1.65
	24.44	34	+	25	5.56	.97
From 30 - 39	32.83	6	-	25	3.46	1.55
	34.37	41	+	30	7.35	1.16
From 40 - 49	47	5	-	35	5.59	2.80
	46.53	15	+	39	6.16	1.65
From 50 - 59	53.80	5	-	35	7.14	3.57
	54.09	23	+	39	5.83	1.24
From 60 - 64	62	4	-	38	6.56	3.79
	61.77	13	+	44	9.50	2.74

CHAPTER 11

ANALYSIS OF CHEST SYMPTOMS IN DUSTY AND CLEAN JOBS

For the analysis of chest symptoms (cough, cough and phlegm, wheeze and dyspnoea), the subjects were divided into :-

1) Non-Smokers
2) Moderate Smokers (- 10 cig/day)
3) Heavy Smokers 10 cig or more/day)

and these subjects were also divided into age groups:-

a) Under 30 years of age
b) 30 - 39
c) 40 - 49
d) 50 and over.

The same division was applied to clean and dusty jobs and age standardized rates were calculated see tables XXIX to XXXVI appendix 5.

I Cough and Cough with Sputum

Irrespective of the conditions of work, the prevalence of these symptoms was directly related to the amount smoked; this is true both of a crude comparison and after the different age compositions of the smoking groups have been allowed for (standardized prevalence ratio).* As between different jobs this prevalence varies erratically. For example, in the heavy smoking group, the clean jobs show a higher prevalence both of cough and cough with sputum (S.P.T.), whereas the reverse is true at (E.S.C.)

II Wheezing

The incidence of this symptom seems to be related to smoking, though this is not clearly shown; at (E.S.C.) alone there was a

* In order to calculate the expected no. with symptoms in each cell of tables XXIX to XXXVI, the overall proportion of symptom - positive persons in the age group concerned was multiplied by the no. of men at risk in each sub-group.

slight association between this symptom and the dustiness of the job.

III DYSPNOEA

There is possibly a slight excess of this symptom in heavy smokers as compared with the remainder. At (E.S.C.) the dusty jobs carry a similar excess but at (S.P.T.) the situation is reversed. When tested by the chi-squared method, it was found that the slight association between dustiness of work and frequency of symptoms were not significant in (S.P.T.) but of significance in (E.S.C.) On the other hand the association between smoking and the incidence of the symptoms cough, wheeze, and cough with sputum were in every case significant or highly significant. Subjective dyspnoea showed no association with smoking or with the dustiness of the job. Tables 18 to 25.* relate the incidence of symptoms to smoking without reference to differences of employment. Here the chi-squared test shows that the association between the amount smoked and the symptoms cough, and cough with sputum is highly significant in both (S.P.T.) and (E.S.C.) and that wheezing is also highly significant in (E.S.C.) and significant in (S.P.T.). On the other hand there is no significant

* The observed and expected values in tables 18 to 25 are derived from tables XXIX to XXXVI in appendix 5 respectively.

association between smoking and dyspnoea at either firms. Tables 26-33 show the ratios of chest symptoms observed to expected after standardizing for differences in smoking habit. At (S.P.T.) the incidence of the symptoms does not differ significantly between clean and dusty jobs. At (E.S.C.) the symptoms cough, cough with sputum and wheeze were more common in the dusty environments; the differences were significant at the levels $P = < 1\%$, $P = < 5\%$ and $P = < 1\%$ respectively.

In order to decide whether the incidence of a particular symptom shows the influence of the dustiness or otherwise of the worker's employment, it was necessary to allow for possible differences in smoking habits.

To do this, the total number of men in a given age-smoking group reporting the symptom is divided in the proportion of the expected numbers as found in tables XXIX to XXXVI of the appendix. The two numbers thus obtained are the expected numbers of men reporting the symptom in the dusty and non dusty jobs respectively.

The observed and the expected numbers are separately summed for the dusty and for the non-dusty jobs and may then be compared.

The results of this comparison are shown in tables 26 to 33.

Table 18

THE INCIDENCE OF CHEST SYMPTOMS TO SMOKING (All jobs combined)

E.S.C.

1 COUGH

	Non-Smokers	- 10 cig/day	10 cig/day or more
Total observed	12	4	115
Total expected	37.70	13.84	79.49
Deviation	- 25.70	- 9.84	+ 35.51
$\frac{(\text{Deviation})^2}{\text{expectation}}$	17.52	6.996	15.86

$\chi^2 = 40.38$

$\phi = 2$

$P = < 0.1\%$

Table 19

THE INCIDENCE OF CHEST SYMPTOMS TO SMOKING (All jobs combined)

E.S.C.

2 COUGH AND PHLEGM

	Non-Smokers	- 10 cig/day	10 cig/day or more
Total observed	10	3	95
Total expected	31.04	11.46	65.59
Deviation	- 21.04	- 8.46	+ 29.41
$\frac{(\text{Deviation})^2}{\text{expectation}}$	14.26	6.245	13.187

$\chi^2 = 33.69$

$\phi = 2$

$P = < 0.1\%$

Table 20

THE INCIDENCE OF CHEST SYMPTOMS TO SMOKING (All jobs combined)

E.S.C

3 WHEEZE

	Non-Smokers	- 10 cig/day	10 cig/day or more
Total observed	43	8	142
Total expected	55.88	20.49	116.56
Deviation	- 12.88	- 12.49	+ 25.44
$\frac{(\text{Deviation})^2}{\text{expectation}}$	2.97	7.61	5.55

$\chi^2 = 16.13$

$\phi = 2$

$p = < 0.1\%$

Table 21

THE INCIDENCE OF CHEST SYMPTOMS TO SMOKING (All jobs combined)

E.S.C.

4 DYSPNOEA

	Non-Smokers	- 10 cig/day	10 cig/day or more
Total observed	32	10	81
Total expected	35.68	13.85	73.39
Deviation	- 3.68	- 3.85	+ 7.61
$\frac{(\text{Deviation})^2}{\text{expectation}}$	0.38	1.07	0.79

$\chi^2 = 2.24$

$\phi = 2$

Table 22

THE INCIDENCE OF CHEST SYMPTOMS TO SMOKING (All jobs combined)

S.P.T.

1 COUGH

	Non-Smokers	- 10 cig/day	10 cig/day or more
Total observed	7	3	73
Total expected	20.763	5.707	56.540
Deviation	- 13.763	- 2.707	+ 16.460
$\frac{(\text{Deviation})^2}{\text{expectation}}$	9.12	1.28	4.79

$\chi^2 = 15.19$

$\phi = 2$

$p = < 0.1\%$

Table 23

THE INCIDENCE OF CHEST SYMPTOMS TO SMOKING (All jobs combined)

S.P.T.

2 COUGH AND PHLEGM

	Non-Smokers	- 10 cig/day	10 cig/day or more
Total observed	5	2	61
Total expected	16.985	4.690	46.44
Deviation	- 11.985	- 2.690	+ 14.56
$\frac{(\text{Deviation})^2}{\text{expectation}}$	8.46	1.54	4.56

$\chi^2 = 14.56$

$\phi = 2$

$P = < 0.1\%$

Table 24

THE INCIDENCE OF CHEST SYMPTOMS TO SMOKING (All jobs combined)

S.P.T.

3 WHEEZE

	Non-Smokers	- 10 cig/day	10 cig/day or more
Total observed	14	4	90
Total expected	27.199	7.18	73.65
Deviation	- 13.199	- 3.18	+ 16.35
$\frac{(\text{Deviation})^2}{\text{expectation}}$	6.405	1.408	3.63

$\chi^2 = 11.443$

$\phi = 2$

$p = < 0.5\%$

Table 25

THE INCIDENCE OF CHEST SYMPTOMS TO SMOKING (All jobs combined)

S.P.T.

4 DYSPNOEA

	Non-Smokers	- 10 cig/day	10 cig/day or more
Total observed	12	2	44
Total expected	14.967	4.295	38.65
Deviation	- 2.967	- 2.295	+ 5.35
$\frac{(\text{Deviation})^2}{\text{expectation}}$	0.59	1.23	0.74

$\chi^2 = 2.56$

$\phi = 2$

Table 26

CHEST SYMPTOMS TO EXPECTED INCIDENCE AFTER STANDARDIZING FOR DIFFERENCES IN SMOKING HABIT

E.S.C.

1 COUGH

Job	Ratio	Non-Smokers	- 10 cig /day	10 cig/day or more	Total obs.no. / " exp. "	$\frac{(\text{Deviation})^2}{\text{expectation}}$
Clean	obs.no. / exp.no.	6 / 5.76	1 / 2.27	34 / 47.75	41 / 55.78	3.90
Dusty	obs.no. / exp.no.	6 / 6.24	3 / 1.73	81 / 67.25	90 / 75.22	2.91

$\chi^2 = 6.81$

$\phi = 1$

$P = < 1\%$

Table 27

CHEST SYMPTOMS TO EXPECTED INCIDENCE AFTER STANDARDIZING FOR DIFFERENCES IN SMOKING HABIT

E.S.C.

2 COUGH AND PHLEGM

Job	Ratio	Non-Smokers	- 10 cig /day	10 cig/day or more	Total obs.no. / Total exp.no.	$\frac{(\text{Deviation})^2}{\text{expectation}}$
Clean	obs.no. / exp.no.	4 / 5.0	1 / 1.67	30 / 39.12	35 / 45.79	2.54
Dusty	obs.no. / exp.no.	6 / 5.0	2 / 1.33	65 / 55.88	73 / 62.21	1.87

$\chi^2 = 4.41$

$\phi = 1$

$P = < 5\%$

Table 28

CHEST SYMPTOMS TO EXPECTED INCIDENCE AFTER STANDARDIZING FOR DIFFERENCES IN SMOKING HABIT

E.S.C.

3 WHEEZE

Job	Ratio	Non-Smokers	- 10 cig /day	10 cig/day or more	Total obs.no. / Total exp.no.	$\frac{(\text{Deviation})^2}{\text{expectation}}$
Clean	obs.no. / exp.no.	16.0 / 21.54	3 / 4.63	49 / 59.94	68 / 86.11	3.81
Dusty	obs.no. / exp.no.	27 / 21.46	5 / 3.37	93 / 82.06	125 / 106.89	3.07

$\chi^2 = 6.88$

$\phi = 1$

$p = < 1\%$

Table 29

CHEST SYMPTOMS TO EXPECTED INCIDENCE AFTER STANDARDIZING FOR DIFFERENCES IN SMOKING HABIT

E.S.C.

4 DYSPNOEA

Job	Ratio	Non-Smokers	- 10 cig /day	10 cig/day or more	Total obs.no. / Total exp.no.	$\frac{(\text{Deviation})^2}{\text{expectation}}$
Clean	obs.no. / exp.no.	15 / 16.03	5 / 5.60	31 / 35.08	51 / 56.71	0.57
Dusty	obs.no. / exp.no.	17 / 15.97	5 / 4.40	50 / 45.92	72 / 66.29	0.49

$\chi^2 = 1.06$

$\phi = 1$

Table 30

CHEST SYMPTOMS TO EXPECTED INCIDENCE AFTER STANDARDIZING FOR DIFFERENCES IN SMOKING HABIT

S.P.T.

1 COUGH

Job	Ratio	Non-Smokers	- 10 cig /day	10 cig/day or more	Total obs.no. / Total exp.no.	$\frac{(\text{Deviation})^2}{\text{expectation}}$
Clean	obs.no. / exp.no.	5 / 4.35	2 / 2.50	53 / 50.68	60 / 57.52	0.11
Dusty	obs.no. / exp.no.	2 / 2.65	1 / 0.50	20 / 22.32	23 / 24.48	0.09

$\chi^2 = 0.20$

$\phi = 1$

Table 31

CHEST SYMPTOMS TO EXPECTED INCIDENCE AFTER STANDARDIZING FOR DIFFERENCES IN SMOKING HABIT

S.P.T.

2 COUGH AND PHLEGM

Job	Ratio	Non-Smokers	- 10 cig /day	10 cig/day or more	Total obs.no. / Total exp.no.	(Deviation)^2 / expectation
Clean	obs.no. / exp.no.	3 / 3.29	1 / 1.75	44 / 42.06	48 / 47.10	0.017
Dusty	obs.no. / exp.no.	2 / 1.71	1 / 0.25	17 / 18.94	20 / 20.90	0.039

$\chi^2 = 0.056$

$\phi = 1$

Table 32

CHEST SYMPTOMS TO EXPECTED INCIDENCE AFTER STANDARDIZING FOR DIFFERENCES IN SMOKING HABIT

S.P.T.

3 WHEEZE

Job	Ratio	Non-Smokers	- 10 cig /day	10 cig/day or more	Total obs.no. / Total exp.no.	$\frac{(\text{Deviation})^2}{\text{expectation}}$
Clean	obs.no. / exp.no.	9 / 9.13	2 / 3.0	65 / 62.89	76 / 75.02	0.013
Dusty	obs.no. / exp.no.	5 / 4.87	2 / 1.0	25 / 27.11	32 / 32.98	0.029

$\chi^2 = 0.042$

$\phi = 1$

Table 33

CHEST SYMPTOMS TO EXPECTED INCIDENCE AFTER STANDARDIZING FOR DIFFERENCES IN SMOKING HABIT

S.P.T.

4 DYSPNOEA

Job	Ratio	Non-Smokers	- 10 cig /day	10 cig/day or more	Total obs.no. / Total exp.no.	$\frac{(\text{Deviation})^2}{\text{expectation}}$
Clean	obs.no. / exp.no.	6 / 6.91	1 / 1.0	35 / 29.79	42 / 37.70	0.49
Dusty	obs.no. / exp.no.	6 / 5.09	1 / 1.0	9 / 14.21	16 / 20.30	0.91

$\chi^2 = 1.40$

$\phi = 1$

CHAPTER 12

DISCUSSION

I Follow up study

For reasons mentioned in chapter 9, the large fall in the average maximum breathing capacity must be attributed at least partly to a personal factor. That is to say to a difference in the degree to which the observers in 1952 and in 1964 were able to secure the co-operation of the subjects. It is not possible to make any allowance for this. The measurements of mixing efficiency are not subject in the same degree to personal factors in the experimenter, nor are they directly dependent upon the subjects co-operation; though if the latter is not forthcoming to an adequate degree no result can be obtained. One would expect that intrapulmonary mixing would become more imperfect with increasing age; and this is borne out by the observations of most workers that the mixing efficiency of a group of men is negatively correlated with age.

The earlier steelworks study showed a regression on age of the overall index between - .4% and -.5% per annum. This corresponds to a fall of between 5% and 6% in the overall index during the period between the two studies. However, more detailed examination of the results of the earlier study shows that the greater part of all the fall occurs between 20 and 40 years of age. Thus for those subjects between 20 and 40 years old at the time of the initial study a decline of about 10% in the mixing efficiency would be expected, while for those over 40 the expected decline is less than half of this.

The results for the older age-group also show much greater scatter. The results for the rolling mill workers agree with this. The mixing efficiencies of the bricklayers seem to have altered in a more erratic manner. A similar difference between the two groups appears in respect of the percentage residual volume. Here the earlier study showed a regular increase with age from 20 to about 55 years of almost .45% per year, corresponding to an increase of 5.4% over a 12 year interval. For the rolling mill workers the percentage residual volume has increased fairly regularly by an amount rather greater than this. For the furnace repairers however, although the average change is about that predicted, the individual changes are erratic.

As was to be expected there was an increase over the twelve year period in the proportion of men who reported respiratory symptoms. However, the numbers involved are too small to make a valid comparison between the two groups.

There is no evidence that the workers exposed to dust deteriorated more rapidly than their contemporaries in cleaner work by objective tests or according to their symptoms.

II 1964 - 66 Study

E. S. C.

As seen in chapter 10, the average $\frac{F.E.V._{.75}}{F.V.C.}\%$ is greater for non-smokers than for smokers, in some age groups at a significant level, this applies to both clean and dusty jobs. Comparing dusty with non-dusty occupations, the differences are slight and non significant.

In case of mixing efficiency non-smokers have on the whole a larger average value than the smokers in clean jobs, this difference is not persistent in case of dusty jobs. On the other hand the difference in mixing efficiency between clean and dusty jobs is not significant and has no consistent trend.

The percentage residual volume is always larger in case of smokers than non-smokers in both clean and dusty jobs, i.e. the nature of the jobs has minimal effect in comparison to smoking.

S. P. T.

In this firm $\frac{F.E.V._{.75}}{F.V.C.}\%$ does not differ significantly between smokers and non-smokers. Comparing dusty and non-dusty occupations, the differences are again slight but generally favour the clean jobs.

<u>M.E.</u> In the clean jobs, the non-smokers have a higher M.E. while for the dusty occupations, there is no such consistent trend. When the dusty occupations are compared with the non-dusty ones the differences appear to depend on smoking habit.

$\frac{R.V.}{T.L.C.}$ Slight differences generally favour the non-smokers, and it appears that there is no consistent difference between workers in dusty and non-dusty jobs.

<u>Chest Symptoms</u>

As noticed in chapter 11, the prevalence of cough, cough with sputum and wheeze is directly related to the amount of cigarettes smoked. By relating the incidence of symptoms to smoking without reference to differences of employment using the Chi-squared test, it is found that the association between the amount smoked and the symptoms cough, cough with sputum and wheeze is of significance in both (E.S.C.) and (S.P.T.). On the other hand, standardizing for differences in smoking habit, it is found that at (S.P.T.) the incidence of the symptoms cough, cough with sputum and wheeze does not differ between clean and dusty jobs. While in case of (E.S.C.) the same symptoms are significantly more common in the dusty occupations.

In summary, it seems that smoking has a more deleterious effect on both lung function tests and on the prevalence of chest symptoms than the nature of the job.

CHAPTER 13

CONCLUSION

From this survey we found that cigarette smoking is the main cause which affects the Respiratory Symptoms and Lung Function tests in both clean and dusty jobs. Dust, fumes and smoke have also an effect but inferior to smoking.

Also in the following up of the subjects already examined in 1952 in clean and dusty jobs we found that ageing has more effect than the nature of the job itself.

Therefore, so long as smoking is widespread, the improvement in dust control although in many cases essential for the prevention of Pneumoconiosis, is unlikely to be reflected in a diminished incidence of non-specific Pulmonary disease.

Chapter 14

APPENDIX 1

Table i

1952 Results S.P.T.

M.E.% in Furnace Repairers

Age Group	No. of subjects per group	Smoking	Av. M.E.	S.E.
20-29	26	+	52.2	2.57
	7	-	56.7	9.04
30-39	61	+	48.9	2.42
	13	-	49.0	4.05
40-49	89	+	42.8	1.45
	16	-	54.0	2.41
50-59	50	+	40.8	2.02
	9	-	33.4	4.58

Table ii

1952 Results S.P.T.

M.E.% in Rolling Mills

Age Group	No. of subjects per group	Smoking	Av. M.E.	S.E.
20-29	61	+	54.2^{xx}	2.18
	15	-	68.7^{xx}	3.32
30-39	61	+	44.6^{x}	2.17
	15	-	55.5^{x}	4.0
40-49	64	+	40.3^{xxx}	1.59
	12	-	55.6^{xxx}	3.16
50-59	40	+	41.6	2.42
	8	-	46.4	4.15

xxx means statistically significant at 0.1% level.
xx " " " " 1% "
x " " " " 5% "

Table iii

1952 Results S.P.T.

$\frac{R.v.}{T.L.c.}$ in Furnace Repairers

Age Group	No. of subjects per group	Smoking	Av. $\frac{R.v.}{T.L.c.}$	S.E.
20-29	26	+	27.81	1.66
	7	-	27.43	1.97
30-39	61	+	31.37	0.83
	13	-	31.00	2.29
40-49	89	+	36.79	0.90
	16	-	33.18	1.73
50-59	50	+	42.64	1.62
	9	-	40.00	5.78

Table iv

1952 Results S.P.T.

$\frac{R.v.}{T.L.c.}$ in Rolling Mills

Age Group	No. of subjects per group	Smoking	Av. $\frac{R.v.}{T.L.c.}$	S.E.
20-29	61	+	26.18	.66
	15	-	27.13	2.38
30-39	61	+	31.05	1.00
	15	-	30.20	1.26
40-49	64	+	36.08^{x}	0.97
	12	-	27.58^{x}	1.08
50-59	40	+	41.32	1.80
	8	-	35.25	2.69

x means statistically significant at 5% level

A P P E N D I X 2

Table v

Bricklayers' Department (S.P.T.) Age below 30

clock no.	age 1952	age 1964	Av. M.B.C. 1952	Av. M.B.C. 1964	R.V./T.L.C. 1952	R.V./T.L.C. 1964	M.E.% 1952	M.E.% 1964
8461	17	29	128	69	28	29	88	74
8496	20	32	160.5	112	20	26	56	82
7701	23	35	144	102.5	31	25	84	101
8705	23	35	156.5	93	30	24	96	54
8631	25	37	128	107	38	40	60	75
8569	27	39	171	136	24	23	82	84
8448	29	41	94.5	75	38	32	72	112

Table iv

1952 Results S.P.T.

R.v./T.L.c. in Rolling Mills

Age Group	No. of subjects per group	Smoking	Av. R.v./T.L.c.	S.E.
20-29	61	+	26.18	.66
	15	-	27.13	2.38
30-39	61	+	31.05	1.00
	15	-	30.20	1.26
40-49	64	+	36.08 x	0.97
	12	-	27.58 x	1.08
50-59	40	+	41.32	1.80
	8	-	35.25	2.69

x means statistically significant at 5% level

Table v

Bricklayers' Department (S.P.T.) Age below 30

clock no.	age 1952	age 1964	Av. M.B.C. 1952	Av. M.B.C. 1964	R.V./T.L.C. 1952	R.V./T.L.C. 1964	M.E.% 1952	M.E.% 1964
8461	17	29	128	69	28	29	88	74
8496	20	32	160.5	112	20	26	56	82
7701	23	35	144	102.5	31	25	84	101
8705	23	35	156.5	93	30	24	96	54
8631	25	37	128	107	38	40	60	75
8569	27	39	171	136	24	23	82	84
8448	29	41	94.5	75	38	32	72	112

Table vi

Rolling Mills (S.P.T.) Age below 30

Clock no.	age 1952	age 1964	av. M.B.C. 1952	av. M.B.C. 1964	R.V. / T.L.C. 1952	R.V. / T.L.C. 1964	M.E.% 1952	M.E.% 1964
3138	16	28	78	127	21	23	105	75
7834	19	31	142.5	94	22	19	97	86
7046	20	32	88.3	92	35	46	73	92
7036	21	33	136	72.5	31	33	95	75
4873	21	33	167	120	33	34	88	89
7888	21	33	151	91	30	34	82	48
7036	21	33	136	72.5	31	33	95	75
7890	22	34	131.5	93	24	37	87	90
7892	22	34	160	101	20	30	-	86
8285	23	35	135	91	32	36	-	90
7056	23	35	172	154	17	19	79	67
7882	23	35	121.3	89	30	47	44	37
1867	24	36	93	104	25	31	-	74
7808	24	36	136.5	106	22	41	94	90
7071	24	36	153	67	25	30	50	47
9422	25	37	204	75	31	33	96	93
7174	26	38	162.5	114	24	36	88	90
8293	26	38	180	79	24	23	91	101
8282	28	40	140	84	25	39	66	78
7849	29	41	98	87	22	30	79	53

Table viii

Bricklayers' Department (S.P.T.) Age 30 - 39

clock no.	age 1952	age 1964	Av. M.B.C. 1952	Av. M.B.C. 1964	$\frac{\text{R.V.}}{\text{T.L.C.}}$ 1952	$\frac{\text{R.V.}}{\text{T.L.C.}}$ 1964	M.E.% 1952	M.E.% 1964
8408	30	42	150	122	24	28	113	99
8418	30	42	107	80	33	43	65	62
8460	30	42	182	80	34	47	54	74
9174	31	43	150	90	19	24	60	92
8494	31	43	147	73	27	36	78	82
8646	31	43	101	61	29	53	79	72
8524	32	44	152.5	98	20	32	53	35
8554	32	44	112.5	81	28	32	74	83
8897	32	44	144	116	32	31	53	82
Newcombe J.	34	46	95.7	77	27	35	92	53
8845	35	47	98.5	74	27	35	70	79
8828	39	51	120	120	32	36	51	79
8789	39	51	146	124	35	34	79	102

Table viii

Rolling Mills (S.P.T.) Age 30 - 39

Clock no.	age 1952	age 1964	av. M.B.C. 1952	av. M.B.C. 1964	R.V./T.L.C. 1952	R.V./T.L.C. 1964	M.E.% 1952	M.E.% 1964
7841	32	44	91.5	55	34	45	45	30
8281	33	45	163	48	35	43	84	53
7819	34	46	197	101	36	46	48	33
7820	34	46	162.5	117	29	29	95	100
7052	35	47	167.5	100	21	25	113	93
7057	35	47	114	88	40	44	43	41
6121	35	47	128	82	29	39	88	67
7138	36	48	128.5	94	27	36	108	102
Gaskell	36	48	140	53	32	42	61	42
7898	36	48	134.5	79	30	40	77	82
7061	37	49	102	63	25	38	-	85
7913	37	49	120	89	33	38	61	60
7931	37	49	119	61	33	38	-	80
7104	37	49	148	85	35	45	36	27
7821	37	49	99.5	34	44	54	38	17
7863	37	49	150.5	75	28	37	99	61
7062	39	51	140	53	47	42	58	74

Table ix

Bricklayers' Department (S.P.T.) Age 40 - 49

clock no.	age 1952	age 1964	av. M.B.C. 1952	av. M.B.C. 1964	R.V./T.L.C. 1952	R.V./T.L.C. 1964	M.E.% 1952	M.E.% 1964
8712	40	52	104	51	37	37	58	65
8895	41	53	106	47	37	33	45	97
8728	41	53	59.5	34	32	40	76	95
8504	41	53	102	62	43	40	56	50
8566	41	54	157	117	38	32	64	104
8427	41	53	100	25	38	54	-	61
8852	42	54	74.8	83	31	37	73	73
8713	43	55	178	112	32	41	36	48
8433	43	55	102	77	38	40	46	39
7276	43	55	127	87	38	36	50	54
Allen D.	45	57	134	123.5	31	35	-	-
8755	46	58	145	37	37	39	78	84
8473	48	60	97.7	61	34	56	75	63
8458	48	60	78	49	38	55	78	40
9047	49	61	135.5	65	37	42	58	60

Table x

Rolling Mills (S.P.T.) Age 40 - 49

clock no.	age 1952	age 1964	av. M.B.C. 1952	av. M.B.C. 1964	R.V./T.L.C. 1952	R.V./T.L.C. 1964	M.E.% 1952	M.E.% 1964
7824	40	52	109.4	42	33	44	47	52
7065	40	52	133	75.5	22	34	80	24
7084	40	52	106.5	88	29	39	24	62
7111	41	53	135.4	57	34	34	27	65
8042	41	53	118.5	91	26	30	52	48
7900	41	53	120.5	65.5	29	35	81	57
7814	43	55	114	68	49	53	42	32
7092	43	55	144	75	29	40	62	43
7828	43	55	127	59	29	34	74	90
Burton L.	43	55	105	78	28	38	59	89
7041	44	56	138	68	38	39	81	93
7079	46	58	117.5	46	31	36	81	48
7042	47	59	118	51	36	40	41	78
7080	47	59	106.5	31.5	41	45	44	40
7843	47	59	143	66	27	26	68	58
7098	47	59	175.5	67	29	36	88	68
7811	48	60	69.5	19	54	69	-	58
7085	48	60	85	45	41	43	55	42
7087	48	60	96.5	43	36	44	43	37
7823	49	61	112	53	26	43	22	38
7032	49	61	133.3	98	40	45	44	56

Table xi

Bricklayers' Department (S.P.T.) Age 50+

clock no.	age 1952	age 1964	Av. M.B.C. 1952	Av. M.B.C. 1964	$\frac{\text{R.V.}}{\text{T.L.C.}}$ 1952	$\frac{\text{R.V.}}{\text{T.L.C.}}$ 1964	M.E.% 1952	M.E.% 1964
8464	50	62	97	71	44	55	71	94
9323	54	66	127	56	21	31	50	72
8816	54	66	37.8	-	31	50	53	63
8628	58	70	112	50	31	43	66	64
8785	58	70	62.5	-	52	58	46	53
8572	62	74	66.6	31	49	47	30	47
8423	62	74	40.8	-	43	47	47	61

Table xii

12

Rolling Mills (S.P.T.) Age 50+

clock no.	age 1952	age 1964	av. M.B.C. 1952	av. M.B.C. 1964	$\frac{\text{R.V.}}{\text{T.L.C.}}$ 1952	$\frac{\text{R.V.}}{\text{T.L.C.}}$ 1964	M.E.% 1952	M.E.% 1964
7093	50	52	148.5	65	36	40	82	109
7109	50	62	112.5	51	23	39	59	46
7847	51	63	122	72	22	39	66	81
7118	51	63	86.3	53	44	44	31	47
7089	52	64	67.3	64	35	46	88	83
7120	52	64	106	54	25	30	79	102
7868	53	65	73	37	44	50	18	26

A P P E N D I X 3

Table xiii

Bricklayers' Department (S.P.T.) Age below 30

clock no.	age	year	cough	phlegm	wheeze	dyspnoea
8461	17	1952	-	-	-	-
	29	1964	-	-	-	-
8496	20	1952	-	-	-	-
	33	1964	-	-	+	-
7701	23	1952	-	-	-	-
	35	1964	-	-	-	-
8705	23	1952	-	-	-	-
	35	1964	-	-	-	-
8631	25	1952	-	-	-	-
	37	1964	-	-	-	-
8569	27	1952	-	-	-	-
	39	1964	-	-	-	-
8448	29	1952	-	-	-	-
	41	1964	-	-	-	-

Table xiv

Rolling Mills (S.P.T.) Age below 30

clock no.	age	year	cough	phlegm	wheeze	dyspnoea
3138	16	1952	-	-	-	-
	28	1964	+	-	-	-
7834	19	1952	-	-	-	-
	31	1964	+	-	+	+
7046	20	1952	-	-	-	-
	32	1964	-	-	-	-
7036	21	1952	-	-	-	-
	33	1964	-	-	+	-
4873	21	1952	-	-	-	-
	33	1964	-	-	-	-
7888	21	1952	-	-	-	-
	33	1964	-	-	+	-
7036	21	1952	-	-	-	-
	33	1964	-	-	+	-
7890	22	1952	-	-	-	-
	34	1964	-	-	-	-
8285	23	1952	-	-	-	-
	35	1964	-	-	-	-
7056	23	1952	-	-	-	-
	35	1964	-	-	-	-
7882	23	1952	-	-	-	-
	35	1964	+	+	+	-
1867	24	1952	+	+	+	+
	36	1964	+	+	-	+
7808	24	1952	-	-	-	-
	36	1964	-	-	-	-
7071	24	1952	+	-	-	-
	36	1964	-	-	-	-
9422	25	1952	-	-	-	-
	37	1964	-	-	-	-
7174	26	1952	-	-	-	-
	38	1964	-	-	-	-
8293	26	1952	-	-	-	-
	38	1964	-	-	-	-
8282	28	1952	-	-	-	-
	40	1964	-	-	-	-
7849	29	1952	-	-	-	-
	41	1964	-	-	+	-

Table xv

Bricklayers' Department (S.P.T.) Age 30 - 39

clock no.	age	year	cough	phlegm	wheeze	dyspnoea
8408	30	1952	-	-	-	-
	42	1964	+	+	+	-
8418	30	1952	-	-	-	-
	42	1964	-	-	+	-
8460	30	1952	-	-	-	-
	42	1964	-	-	+	-
9174	31	1952	-	-	-	-
	43	1964	+	+	+	-
8494	31	1952	-	-	-	-
	43	1964	+	+	+	+
8646	31	1952	-	-	-	-
	43	1964	-	-	+	-
8524	32	1952	-	-	+	-
	44	1964	+	+	+	-
8554	32	1952	-	-	-	-
	44	1964	+	+	+	-
8897	32	1952	+	-	-	-
	44	1964	-	-	-	-
Newcombe J.	34	1952	-	-	-	-
	46	1964	-	-	+	-
8845	35	1952	-	-	-	-
	47	1964	-	-	-	-
8828	39	1952	-	-	-	-
	51	1964	-	-	+	+
8789	39	1952	-	-	-	-
	51	1964	-	-	-	-

Table xvi

Rolling Mills (S.P.T.) Age 30 - 39

clock no.	age	year	cough	phlegm	wheeze	dyspnoea
7841	32 44	1952 1964	+ +	+ +	- +	- +
8281	33 45	1952 1964	- -	- -	- -	- +
7819	34 46	1952 1964	- -	- -	- -	- -
7820	34 46	1952 1964	- -	- -	- -	- -
7052	35 47	1952 1964	- -	- -	- -	- -
7057	35 47	1952 1964	- +	- +	- +	- -
6121	35 47	1952 1964	- +	- +	- -	- +
7138	36 48	1952 1964	- -	- -	- -	- -
Gaskell	36 48	1952 1964	- +	- -	- +	- +
7898	36 48	1952 1964	- -	- -	- -	- -
7061	37 49	1952 1964	+ +	- -	- -	- -
7913	37 49	1952 1964	- -	- -	- +	+ +
7931	37 49	1952 1964	- -	- -	- -	- -
7104	37 49	1952 1964	+ +	+ +	+ +	- +
7821	37 49	1952 1964	- +	- +	+ +	- +
7863	37 49	1952 1964	- -	- -	- -	- -
7062	39 51	1952 1964	- +	- +	- -	- -

Table xvii

Bricklayers' Department (S.P.T.) Age 40 - 49

clock no.	age	year	cough	phlegm	wheeze	dyspnoea
8712	40 52	1952 1964	- -	- -	- -	- -
8895	41 53	1952 1964	- +	- +	+ +	- +
8728	41 53	1952 1964	- -	- -	- -	- -
8504	41 53	1952 1964	- -	- -	- -	- -
8566	41 53	1952 1964	- -	- -	- -	- -
8852	42 54	1952 1964	- +	- +	+ +	- -
8713	43 55	1952 1964	- -	- -	- -	- -
8433	43 55	1952 1964	- -	- -	- +	- -
7276	43 55	1952 1964	+ +	+ +	+ +	- +
8755	46 58	1952 1964	- -	- -	- +	- +
8473	48 60	1952 1964	- -	- -	- -	- +
8458	48 60	1952 1964	- +	- +	+ +	- -
9047	49 61	1952 1964	+ -	+ -	+ -	- +

Table xviii

Rolling Mills (S.P.T.) Age 40 - 49

clock no.	age	year	cough	phlegm	wheeze	dyspnoea
7824	40 52	1952 1964	- -	- -	- -	- -
7065	40 52	1952 1964	- -	- -	- -	- -
7084	40 52	1952 1964	+ +	- +	+ +	- +
7111	41 53	1952 1964	- -	- -	- +	- -
8042	41 53	1952 1964	- -	- -	- -	- -
7900	41 53	1952 1964	+ +	+ +	- -	- +
7814	43 55	1952 1964	+ +	- -	+ +	+ -
7092	43 55	1952 1964	- +	- +	- +	- -
7828	43 55	1952 1964	- +	- +	- +	- -
Burton L.	43 55	1952 1964	- -	- -	- -	- -
7041	44 56	1952 1964	- -	- -	- +	- -
7079	46 58	1952 1964	- -	- -	- -	- +
7042	47 59	1952 1964	- -	- -	- +	- -
7080	47 59	1952 1964	- -	- -	- -	- +
7843	47 59	1952 1964	- -	- -	- -	- -
7098	47 59	1952 1964	- -	- -	- -	- -
7811	48 60	1952 1964	- +	- +	- +	- +
7085	48 60	1952 1964	+ +	- -	- -	- +
7087	48 60	1952 1964	- +	- +	+ +	+ +
7823	49 61	1952 1964	+ +	- -	+ -	+ -
7032	49 61	1952 1964	- +	- -	- -	- +

Table xix

Bricklayers' Department (S.P.T.) Age 50+

Clock no.	age	year	cough	phlegm	wheeze	dyspnoea
8464	50	1952	-	-	-	-
	62	1964	-	-	+	+
9323	54	1952	-	-	-	-
	66	1964	-	-	-	-
8816	54	1952	+	+	+	+
	66	1964	+	+	+	+
8628	58	1952	+	+	+	-
	70	1964	+	+	+	+
8785	57	1952	-	-	-	-
	69	1964	+	+	+	+
8572	62	1952	-	-	-	-
	74	1964	+	+	-	-
8423	62	1952	-	-	-	+
	74	1964	-	-	-	+

Table xx

Rolling Mills (S.P.T.) Age 50+

clock no.	age	year	cough	phlegm	wheeze	dyspnoea
7093	50 62	1952 1964	− +	− +	− +	− +
7109	50 62	1952 1964	− −	− −	− +	− +
7847	51 63	1952 1964	− +	− +	− +	− +
7118	51 63	1952 1964	− +	− +	− −	− +
7089	52 64	1952 1964	+ −	+ −	+ +	− −
7120	52 64	1952 1964	− −	− −	− −	− −
7868	53 65	1952 1964	− +	− +	− +	− +

APPENDIX 4

Table XXI

Average V.C. in Dusty Jobs (E.S.C.)

Age Group years old	Av. age	No. of persons per group	Smoking habit	Average V.C.	S.D.	S.E.
Below 20	-	-	-	-	-	-
From 20 - 29	26.46	13	-	4.46	.91	.26
	25.16	38	+	4.92	.97	.16
From 30 - 39	34.29	17	-	4.26	.75	.19
	33.66	41	+	4.32	.67	.11
From 40 - 49	43.69	16	-	4.40	.67	.18
	44.11	47	+	4.22	.57	.08
From 50 - 59		15	-	3.88	.53	.14
	54.18	37	+	3.80	.71	.12
From 60 - 64	62.00	4	-	3.39	.81	.47
	61.78	9	+	3.27	.76	.27

Table XXII

Average V.C. in Clean Jobs (E.S.C.)

Age Group years old	Av. age	No. of persons per group	Smoking habit	Average V.C.	S.D.	S.E.
Below 20	17.14	7	-	4.46	.83	.34
	18.25	4	+	4.82	.20	.11
From 20 - 29	25.00	12	-	4.59	1.11	.34
	25.55	38	+	4.85	.77	.13
From 30 - 39	33.52	17	-	4.42	.49	.12
	35.52	23	+	4.63	.60	.13
From 40 - 49	45.30	10	-	3.79	.57	.19
	45.75	28	+	4.15	.51	.10
From 50 - 59	55.07	14	-	3.88	.62	.17
	54.56	27	+	3.81	.86	.17
From 60 - 64	62.25	8	-	3.85	.53	.20
	61.56	16	+	3.10	.52	.13

Table XXIII

Average $F.E.V._{75}$ in Dusty Jobs (E.S.C.)

Age Group years old	Av. age	No. of persons per group	Smoking habit	Average F.E.V.	S.D.	S.E.
Below 20	-	-	-	-	-	-
From 20 - 29	26.46	13	-	3.69	.71	.20
	25.16	38	+	3.62	.64	.11
From 30 - 39	34.29	17	-	3.12	.50	.13
	33.66	41	+	3.17	.52	.08
From 40 - 49	43.69	16	-	3.22*	.73	.19
	44.11	47	+	2.83*	.59	.09
From 50 - 59	55.67	15	-	2.70	.56	.16
	54.18	37	+	2.17	.72	.12
From 60 - 64	62.00	4	-	1.86	.24	.14
	61.78	9	+	1.94	.46	.16

* Significant at 5% level

Table XXIV

Average $F.E.V._{75}$ in Clean Jobs (E.S.C.)

Age Group years old	Av. age	No. of persons per group	Smoking habit	Average F.E.V.	S.D.	S.E.
Below 20	17.14	7	-	3.52	.69	.28
	18.25	4	+	3.60	.25	.15
From 20 - 29	25.00	12	-	3.40	.88	.26
	25.55	38	+	3.54	.64	.11
From 30 - 39	33.52	17	-	3.16	.50	.12
	35.52	23	+	3.27	.60	.13
From 40 - 49	44.82	11	-	2.61	.47	.15
	45.75	28	+	2.54	.61	.12
From 50 - 59	55.07	14	-	2.64	.44	.12
	54.56	27	+	2.20	.76	.15
From 60 - 64	62.25	8	-	2.43*	.63	.24
	61.56	16	+	1.90*	.45	.12

* Significant at 5% level

Table XXV

Average V.C. in Bricklayers' Department (S.P.T.)

Age Group years old	Av. age	No. of persons per group	Smoking habit	Average V.C.	S.D.	S.E.
Below 20	-	-	-	-	-	-
From 20 - 29	25.33	3	-	5.15	.21	.15
	24.60	10	+	5.18	1.25	.42
From 30 - 39	33.75	8	-	4.87	.54	.20
	34.89	9	+	4.81	.43	.15
From 40 - 49	43.20	5	-	4.27	1.00	.50
	44.05	18	+	4.60	1.09	.26
From 50 - 59	54	8	-	3.96	.53	.20
	54.14	14	+	4.08	.56	.16
From 60 - 64	62.50	2	-	3.47	.32	.32
	61.25	4	+	3.63	.77	.45

Table XXVI

Average V.C. in Rolling Mills (S.P.T.)

Age Group years old	Av. age	No. of persons per group	Smoking habit	Average V.C.	S.D.	S.E.
Below 20	17.75	8	-	4.82	.61	.23
	18	13	+	4.87	.41	.12
From 20 - 29	23.36	11	-	4.95	.62	.20
	24.44	34	+	5.16	.75	.13
From 30 - 39	32.83	6	-	4.96	.81	.36
	34.37	41	+	4.48	.81	.13
From 40 - 49	47	5	-	4.19	.36	.18
	46.53	15	+	4.14	.76	.20
From 50 - 59	53.80	5	-	4.54	1.17	.58
	54.09	23	+	3.94	.54	.12
From 60 - 64	62	4	-	3.88	.50	.29
	61.77	13	+	3.46	.65	.19

Table XXVII

Average $F.E.V._{75}$ in Bricklayers' Department (S.P.T.)

Age Group years old	Av. age	No. of persons per group	Smoking habit	Average $F.E.V._{75}$	S.D.	S.E.
Below 20	-	-	-	-	-	-
From 20 - 29	25.33	3	-	3.54	.20	.14
	24.60	10	+	3.78	.69	.23
From 30 - 39	33.75	8	-	3.50	.56	.21
	34.89	9	+	3.45	.37	.13
From 40 - 49	43.20	5	-	2.92	.50	.25
	44.05	18	+	2.95	.71	.17
From 50 - 59	54	8	-	2.58*	.55	.21
	54.14	14	+	2.47*	.73	.20
From 60 - 64	62.50	2	-	2.25	.89	.89
	61.25	4	+	2.01	.38	.22

* Significant at 5% level

Table XXVIII

Average $F.E.V._{75}$ in Rolling Mills (S.P.T.)

Age Group years old	Av. age	No. of persons per group	Smoking habit	Average $F.E.V._{75}$	S.D.	S.E.
Below 20	17.75	8	-	3.35	1.33	.50
	18	13	+	3.85	1.04	.30
From 20 - 29	23.36	11	-	4.02	.50	.16
	24.44	34	+	3.81	.61	.11
From 30 - 39	32.83	6	-	3.73	.41	.18
	34.37	41	+	3.38	.66	.11
From 40 - 49	47	5	-	3.25	.98	.49
	46.92	13	+	2.87	.65	.19
From 50 - 59	53.80	5	-	3.39*	.70	.35
	54.09	23	+	2.54*	.62	.13
From 60 - 64	62	4	-	2.28	.89	.52
	61.77	13	+	2.06	.47	.13

* Significant at 5% level

APPENDIX 5

Table XXIX

E.S.C.

1 - COUGH

Age Group	Job		Non Smokers	Less than 10 cig/day	10 cig. /day or more	Av. age
Under 30	Clean	a)No. in group	20	7	39	24
		b)No. with symptoms (observed)	0	0	3	
		c)No. with symptoms (expected)	2.4	.84	4.68	
		b/c	0	0	.641	
	Dusty	a)No. in group	14	5	40	25
		b)No. with symptoms (observed)	0	0	12	
		c)No. with symptoms (expected)	1.68	.6	4.8	
		b/c	0	0	2.50	
30 - 39	Clean	a)No. in group	18	7	21	35
		b)No. with symptoms (observed)	0	0	5	
		c)No. with symptoms (expected)	3.29	1.28	3.84	
		b/c	0	0	1.30	
	Dusty	a)No. in group	18	3	42	34
		b)No. with symptoms (observed)	1	0	14	
		c)No. with symptoms (expected)	3.29	.549	7.69	
		b/c	.30	0	1.82	
40 - 49	Clean	a)No. in group	11	6	26	45
		b)No. with symptoms (observed)	2	0	10	
		c)No. with symptoms (expected)	3.86	2.11	9.13	
		b/c	.518	0	1.095	
	Dusty	a)No. in group	18	4	49	44
		b)No. with symptoms (observed)	2	1	25	
		c)No. with symptoms (expected)	6.32	1.40	17.199	
		b/c	.316	.714	1.45	
50 + over	Clean	a)No. in group	23	10	39	57
		b)No. with symptoms (observed)	4	1	16	
		c)No. with symptoms (expected)	9.02	3.92	15.29	
		b/c	.443	.255	1.046	
	Dusty	a)No. in group	20	8	43	55
		b)No. with symptoms (observed)	3	2	30	
		c)No. with symptoms (expected)	7.84	3.14	16.86	
		b/c	.383	.637	1.779	
All ages	Clean	a)No. in group	72	30	125	
		b)No. with symptoms (Observed)	6	1	34	
		c)No. with symptoms (expected)	18.57	8.15	32.94	
		b/c	.323	0.123	1.032	
	Dusty	a)No. in group	70	20	174	
		b)No. with symptoms (observed)	6	3	81	
		c)No. with symptoms (expected)	19.13	5.69	46.55	
		b/c	.31	.53	1.74	

Table XXX

E.S.C.

II - COUGH & PHLEGM

Age Group	Job		Non Smokers	Less than 10 cig/day	10 cig./day or more	Av. age
Under 30	Clean	a) No. in group	20	7	39	24
		b) No. with symptoms (observed)	0	0	1	
		c) No. with symptoms (expected)	1.6	.56	3.12	
		b/c	0	0	.320	
	Dusty	a) No. in group	14	5	40	25
		b) No. with symptoms (observed)	0	0	9	
		c) No. with symptoms (expected)	1.12	.4	3.2	
		b/c	0	0	2.81	
30 - 39	Clean	a) No. in group	18	7	21	35
		b) No. with symptoms (observed)	0	0	4	
		c) No. with symptoms (expected)	2.48	.966	2.90	
		b/c	0	0	1.38	
	Dusty	a) No. in group	18	3	42	34
		b) No. with symptoms (observed)	1	0	10	
		c) No. with symptoms (expected)	2.48	.414	5.796	
		b/c	.403	0	1.725	
40 - 49	Clean	a) No. in group	11	6	26	45
		b) No. with symptoms (observed)	1	0	9	
		c) No. with symptoms (expected)	3.38	1.84	7.98	
		b/c	.296	0	1.128	
	Dusty	a) No. in group	18	4	49	44
		b) No. with symptoms (observed)	1	0	24	
		c) No. with symptoms (expected)	5.53	1.23	15.04	
		b/c	.1808	0	1.596	
50 + over	Clean	a) No. in group	23	10	39	57
		b) No. with symptoms (observed)	3	1	16	
		c) No. with symptoms (expected)	7.73	3.36	13.10	
		b/c	.388	.298	1.22	
	Dusty	a) No. in group	20	8	43	55
		b) No. with symptoms (observed)	4	2	22	
		c) No. with symptoms (expected)	6.72	2.69	14.45	
		b/c	.595	.743	1.522	
All ages	Clean	a) No. in group	72	30	125	
		b) No. with symptoms (observed)	4	1	30	
		c) No. with symptoms (expected)	15.19	6.726	27.10	
		b/c	.263	.149	1.107	
	Dusty	a) No. in group	70	20	174	
		b) No. with symptoms (observed)	6	2	65	
		c) No. with symptoms (expected)	15.85	4.734	38.49	
		b/c	.38	.42	1.69	

Table XXXI

E.S.C.

III - WHEEZE

Age Group	Job		Non Smokers	Less than 10 cig/day	10 cig. /day or more	Av. age
Under 30	Clean	a)No. in group	20	7	39	24
		b)No. with symptoms (observed)	2	0	6	
		c)No. with symptoms (expected)	4.6	1.61	9.05	
		b/c	.435	0	.663	
	Dusty	a)No. in group	14	5	40	25
		b)No. with symptoms (observed)	3	0	18	
		c)No. with symptoms (expected)	3.25	1.16	9.28	
		b/c	.923	0	1.94	
30 - 39	Clean	a)No. in group	18	7	21	35
		b)No. with symptoms (observed)	3	1	6	
		c)No. with symptoms (expected)	5.29	2.06	6.17	
		b/c	.567	.485	.972	
	Dusty	a)No. in group	18	3	42	34
		b)No. with symptoms (observed)	6	0	16	
		c)No. with symptoms (expected)	5.29	.88	12.35	
		b/c	1.134	0	1.295	
40 - 49	Clean	a)No. in group	11	6	26	45
		b)No. with symptoms (observed)	2	0	11	
		c)No. with symptoms (expected)	4.63	2.53	10.95	
		b/c	.432	0	1.005	
	Dusty	a)No. in group	18	4	49	44
		b)No. with symptoms (observed)	7	1	27	
		c)No. with symptoms (expected)	7.58	1.68	20.63	
		b/c	.933	.595	1.309	
50 + over	Clean	a)No. in group	23	10	39	57
		b)No. with symptoms (observed)	9	2	26	
		c)No. with symptoms (expected)	13.50	5.87	22.89	
		b/c	.667	.341	1.136	
	Dusty	a)No. in group	20	8	43	55
		b)No. with symptoms (observed)	11	4	32	
		c)No. with symptoms (expected)	11.74	4.696	25.24	
		b/c	0.937	.852	1.268	
All ages	Clean	a)No. in group	72	30	125	
		b)No. with symptoms (observed)	16	3	49	
		c)No. with symptoms (expected)	28.02	12.07	49.06	
		b/c	.571	.248	0.999	
	Dusty	a)No. in group	70	20	174	
		b)No. with symptoms (observed)	27	5	93	
		c)No. with symptoms (expected)	27.86	8.416	67.50	
		b/c	.97	.59	1.38	

Table XXXII

E.S.C.

IV - DYSPNOEA

Age Group	Job		Non Smokers	Less than 10 cig/day	10 cig. /day or more	Av. age
Under 30	Clean	a) No. in group	20	7	39	24
		b) No. with symptoms (observed)	0	0	1	
		c) No. with symptoms (expected)	1.12	.39	2.18	
		b/c	0	0	.459	
	Dusty	a) No. in group	14	5	40	25
		b) No. with symptoms (observed)	0	0	6	
		c) No. with symptoms (expected)	.784	.28	2.27	
		b/c	0	0	2.679	
30 - 39	Clean	a) No. in group	18	7	21	35
		b) No. with symptoms (observed)	2	0	3	
		c) No. with symptoms (expected)	1.49	.58	1.74	
		b/c	1.342	0	1.724	
	Dusty	a) No. in group	18	3	42	34
		b) No. with symptoms (observed)	2	0	2	
		c) No. with symptoms (expected)	1.49	.25	3.49	
		b/c	1.342	0	.573	
40 - 49	Clean	a) No. in group	11	6	26	45
		b) No. with symptoms (observed)	1	0	8	
		c) No. with symptoms (expected)	2.79	1.52	6.60	
		b/c	.358	0	1.212	
	Dusty	a) No. in group	18	4	49	44
		b) No. with symptoms (observed)	5	1	14	
		c) No. with symptoms (expected)	4.57	1.02	12.45	
		b/c	1.094	.980	1.1245	
50 + over	Clean	a) No. in group	23	10	39	57
		b) No. with symptoms (observed)	12	5	19	
		c) No. with symptoms (expected)	12.535	5.45	21.255	
		b/c	.957	.917	.894	
	Dusty	a) No. in group	20	8	43	55
		b) No. with symptoms (observed)	10	4	28	
		c) No. with symptoms (expected)	10.9	4.36	23.435	
		b/c	.917	.917	1.195	
All ages	Clean	a) No. in group	72	30	125	
		b) No. with symptoms (observed)	15	5	31	
		c) No. with symptoms (expected)	17.935	7.94	31.775	
		b/c	.836	.6297	.976	
	Dusty	a) No. in group	70	20	174	
		b) No. with symptoms (observed)	17	5	50	
		c) No. with symptoms (expected)	17.744	5.91	41.615	
		b/c	.96	.85	1.20	

Table XXXIII

S.P.T.

1 - COUGH

Age Group	Job		Non Smokers	Less than 10 cig/day	10 cig./day or more	Av. age
Under 30	Clean	a)No. in group	19	2	46	22
		b)No. with symptoms (observed)	2	0	11	
		c)No. with symptoms (expected)	3.519	.3704	8.52	
		b/c	.568	0	1.29	
	Dusty	a)No. in group	3	1	10	25
		b)No. with symptoms (observed)	0	0	2	
		c)No. with symptoms (expected)	.556	.1852	1.852	
		b/c	0	0	1.0799	
30 - 39	Clean	a)No. in group	7	4	38	34
		b)No. with symptoms (observed)	0	1	17	
		c)No. with symptoms (expected)	2.12	1.21	11.51	
		b/c	0	.826	1.477	
	Dusty	a)No. in group	8	0	9	34
		b)No. with symptoms (observed)	0	0	2	
		c)No. with symptoms (expected)	2.424	0	2.73	
		b/c	0	0	.733	
40 - 49	Clean	a)No. in group	4	3	15	46
		b)No. with symptoms (observed)	0	1	7	
		c)No. with symptoms (expected)	1.652	1.239	6.195	
		b/c	0	.807	1.1299	
	Dusty	a)No. in group	6	1	17	44
		b)No. with symptoms (observed)	0	1	10	
		c)No. with symptoms (expected)	2.478	.413	7.035	
		b/c	0	2.439	1.435	
50 + over	Clean	a)No. in group	11	3	34	57
		b)No. with symptoms (observed)	3	0	18	
		c)No. with symptoms (expected)	4.198	1.145	12.974	
		b/c	.715	0	1.387	
	Dusty	a)No. in group	10	3	15	56
		b)No. with symptoms (observed)	2	0	6	
		c)No. with symptoms (expected)	3.816	1.145	5.724	
		b/c	.524	0	1.048	
All ages	Clean	a)No. in group	41	12	133	
		b)No. with symptoms (observed)	5	2	53	
		c)No. with symptoms (expected)	11.489	3.964	39.199	
		b/c	.435	.5045	1.352	
	Dusty	a)No. in group	27	5	51	
		b)No. with symptoms (observed)	2	1	20	
		c)No. with symptoms (expected)	9.274	1.743	17.341	
		b/c	.2157	.574	1.153	

Table XXXIV

S.P.T.

II - COUGH AND PHLEGM

Age Group	Job		Non Smokers	Less than 10 cig/day	10 cig. day or more	Av. age
Under 30	Clean	a) No. in group	19	2	46	22
		b) No. with symptoms (observed)	2	0	9	
		c) No. with symptoms (expected)	2.812	.296	6.808	
		b/c	.711	0	1.322	
	Dusty	a) No. in group	3	1	10	25
		b) No. with symptoms (observed)	0	0	1	
		c) No. with symptoms (expected)	.444	.148	1.48	
		b/c	0	0	.676	
30 - 39	Clean	a) No. in group	7	4	38	34
		b) No. with symptoms (observed)	0	1	14	
		c) No. with symptoms (expected)	1.81	1.03	9.804	
		b/c	0	.971	1.428	
	Dusty	a) No. in group	8	0	9	34
		b) No. with symptoms (observed)	0	0	2	
		c) No. with symptoms (expected)	2.064	0	2.32	
		b/c	0	0	.862	
40 - 49	Clean	a) No. in group	4	3	15	46
		b) No. with symptoms (observed)	0	0	6	
		c) No. with symptoms (expected)	1.40	1.05	5.25	
		b/c	0	0	1.143	
	Dusty	a) No. in group	6	1	17	44
		b) No. with symptoms (observed)	0	1	9	
		c) No. with symptoms (expected)	2.10	.35	5.95	
		b/c	0	2.86	1.513	
50 + over	Clean	a) No. in group	11	3	34	57
		b) No. with symptoms (observed)	1	0	15	
		c) No. with symptoms (expected)	3.329	.9078	10.2884	
		b/c	.300	0	1.458	
	Dusty	a) No. in group	10	3	15	56
		b) No. with symptoms (observed)	2	0	5	
		c) No. with symptoms (expected)	3.026	.9078	4.54	
		b/c	.661	0	1.101	
All ages	Clean	a) No. in group	41	12	133	
		b) No. with symptoms (observed)	3	1	44	
		c) No. with symptoms (expected)	9.351	3.284	32.150	
		b/c	.321	.3045	1.369	
	Dusty	a) No. in group	27	5	51	
		b) No. with symptoms (observed)	2	1	17	
		c) No. with symptoms (expected)	7.634	1.406	14.29	
		b/c	.262	.711	1.19	

Table XXXV

S.P.T.

III - WHEEZE

Age Group	Job		Non Smokers	Less than 10 cig/day	10 cig. /day or more	Av. age
Under 30	Clean	a)No. in group	19	2	46	22
		b)No. with symptoms (observed)	5	0	19	
		c)No. with symptoms (expected)	6.099	.642	14.766	
		b/c	.8198	0	1.287	
	Dusty	a)No. in group	3	1	10	25
		b)No. with symptoms (observed)	1	0	1	
		c)No. with symptoms (expected)	.969	.321	3.21	
		b/c	1.032	0	.3115	
30 - 39	Clean	a)No. in group	7	4	38	34
		b)No. with symptoms (observed)	1	1	18	
		c)No. with symptoms (expected)	2.55	1.46	13.83	
		b/c	.392	.685	1.301	
	Dusty	a)No. in group	8	0	9	34
		b)No. with symptoms (observed)	1	0	3	
		c)No. with symptoms (expected)	2.91	0	3.276	
		b/c	0.344	0	.916	
40 - 49	Clean	a)No. in group	4	3	15	46
		b)No. with symptoms (observed)	0	1	7	
		c)No. with symptoms (expected)	2.0	1.50	7.5	
		b/c	0	.667	.933	
	Dusty	a)No. in group	6	1	17	44
		b)No. with symptoms (observed)	1	1	13	
		c)No. with symptoms (expected)	3.00	0.50	8.5	
		b/c	.333	2.00	1.529	
50 + over	Clean	a)No. in group	11	3	34	57
		b)No. with symptoms (observed)	3	0	21	
		c)No. with symptoms (expected)	5.0655	1.381	15.66	
		b/c	.592	0	1.34	
	Dusty	a)No. in group	10	3	15	56
		b)No. with symptoms (observed)	2	1	8	
		c)No. with symptoms (expected)	4.605	1.381	6.9075	
		b/c	.434	.724	1.158	
All ages	Clean	a)No. in group	41	12	133	
		b)No. with symptoms (observed)	9	2	65	
		c)No. with symptoms (expected)	15.7145	4.983	51.756	
		b/c	.573	.4014	1.26	
	Dusty	a)No. in group	27	5	51	
		b)No. with symptoms (observed)	5	2	25	
		c)No. with symptoms (expected)	11.484	2.20	21.89	
		b/c	.435	.909	1.142	

Table XXXVI

S.P.T.

IV - DYSPNOEA

Age Group	Job		Non Smokers	Less than 10 cig/day	10 cig. /day or more	Av. age
Under 30	Clean	a) No. in group	19	2	46	22
		b) No. with symptoms (observed)	2	0	2	
		c) No. with symptoms (expected)	.9386	.0998	2.272	
		b/c	2.13	0	0.88	
	Dusty	a) No. in group	3	1	10	25
		b) No. with symptoms (observed)	0	0	0	
		c) No. with symptoms (expected)	.148	.049	.494	
		b/c	0	0	0	
30 - 39	Clean	a) No. in group	7	4	38	34
		b) No. with symptoms (observed)	0	0	8	
		c) No. with symptoms (expected)	1.05	0.60	5.70	
		b/c	0	0	1.403	
	Dusty	a) No. in group	8	0	9	34
		b) No. with symptoms (observed)	1	0	1	
		c) No. with symptoms (expected)	1.20	0	1.35	
		b/c	0.833	0	.741	
40 - 49	Clean	a) No. in group	4	3	15	46
		b) No. with symptoms (observed)	0	0	7	
		c) No. with symptoms (expected)	.784	.588	2.94	
		b/c	0	0	2.381	
	Dusty	a) No. in group	6	1	17	44
		b) No. with symptoms (observed)	0	0	2	
		c) No. with symptoms (expected)	1.176	.196	3.33	
		b/c	0	0	.601	
50 + over	Clean	a) No. in group	11	3	34	57
		b) No. with symptoms (observed)	4	1	18	
		c) No. with symptoms (expected)	5.0655	1.381	15.66	
		b/c	.790	.724	1.149	
	Dusty	a) No. in group	10	3	15	56
		b) No. with symptoms (observed)	5	1	6	
		c) No. with symptoms (expected)	4.605	1.381	6.9075	
		b/c	1.086	.724	.869	
All ages	Clean	a) No. in group	41	12	133	
		b) No. with symptoms (observed)	6	1	35	
		c) No. with symptoms (expected)	7.838	2.669	26.572	
		b/c	.7655	.375	1.317	
	Dusty	a) No. in group	27	5	51	
		b) No. with symptoms (observed)	6	1	9	
		c) No. with symptoms (expected)	7.129	1.626	12.08	
		b/c	.8416	.615	.745	

APPENDIX 6

	Clean Mean	Jobs Standard-ised	S.D.	Dusty Mean	Jobs Standard-ised	S.D.	Difference Clean-Dirty	S.E. of difference of means	
Age (years)	40.76	40.66		40.57	40.66				
Height (inches)	66.42	66.80		67.23	66.80				
Weight (pounds)	162.69	163.80		165.10	163.80				
Tobacco smoked (arbitrary units)	280.04	296.00		313.27	296.00				
Tidal volume	0.645	.667		0.690	0.667				
No. of observations	226			262					
<u>F.R.C.</u>	3.479	3.512	.839	3.579	3.525	.955	- .013	.083	
Allowing for tobacco		3.519			3.509		+ .010		
<u>V.C.</u>	4.204	4.231	.835	4.213	4.165	.835	.027	.076	
<u>F.E.V.</u>	2.873	2.901	.807	2.954	2.924	.796	- .023	.073	
Allowing for tobacco		2.895			2.929		- .034		
M.E.	60.75	60.69%	16.61	59.99	60.14%	17.46	.55%	1.55%	
Allowing for T.V.		61.39			59.35		2.04%	1.55%	= 1.32

The partial regression co-efficients were calculated on mercury computer with the help of Alan Handyside.

REFERENCES

. Attinger E.O., Goldstein M.M., and Segal M.S. (1958). Amer. Rev. Tuberc., 77, 1.

. Bates D.V., and Christie R.V. (1964). Respiratory function in disease. W.B. Saunders, London.

* Bates D.V., and Christie R.V. (1950). Clin. Sci., 9, 17.

* Bates D.V., and Christie R.V. (1952). Ibid., 11, 45.

. Briscoe W.A., Becklake M.R., and Rose T.F. (1951). Clin. Sci., 10, 37.

. Briscoe W.A., and Cournand A. (1958). J. Appl. Physiol., 14, 284.

. Briscoe W.A., and Dubois A.B. (1958). J. Clin. Invest., 37, 1279.

. Briscoe W.A., Forster R.E., and Comroe J.H. (1954). Ibid., 7, 27.

. Christie R.V. (1932). J. Clin. Invest., 11, 1099.

* Comroe J.H., Forster R.E., Dubois A.B., Briscoe W.A. and Carlsen E. (1962). The lung, clinical physiology and pulmonary function tests second edition. Year Book Medical Publishers Inc. Chicago.

* Cotes J.E. (1965) Lung function, assessment and application in medicine. Blackwell Scientific Publications, Oxford.

. Fowler W.S. (1949) J. Appl. Physiol., 2, 283.

* Gandevia B., and Hugh Jones P. (1957) Thorax 12, 290.

* Gandevia B. and Milne J. (1965) Brit. med. J., 1, 450.

* Gilson J.E. and Hugh Jones P. (1955). Lung function in Coal workers pneumoconiosis. Spec. Rep. ser. Med. Res. Council (London) No. 290 H.M.S.O.

* Gilson J.E. and Hugh Jones P. (1949). Clin. Sci., 7, 185.

* Gilson J.E. and Olsen H.C. (1960). Brit. med. J., 1, 450.

. Higgins I.T.T., Cochrane A.L., Gilson J.E., and Woob C.H. (1959). Brit. J. indust., Med., 16, 255.

* Higgins I.T.T. and Oldham P.D. (1962) Brit. J. indust. Med., 19, 65.

. Hinshaw and Garland (1963). Diseases of the Chest second edition. Saunders, Philadelphia, London.

. International Labour Office (1966). Proceedings of the International Conference of Experts on Pneumoconiosis held at Geneva 1965. Geneva.

. Kennedy M.C.S. (1953) Thorax 8, 72.

* McKerrow C.B., McDermott M. and Gilson J.C. (1960) Lancet 1, 149.

* McLaughlin A.I.G. (1950). Industrial lung diseases of iron and steel foundry workers. H.M.S.O. London 1950.

* McMichael (1939) Clin. Sci., 4, 167.

° McMichael and Herald F.J.C. (1939) Proc. Royal Soc. London 126, 491.

° Meneeley G.R. and Kaltreider J. (1949). J. Clin. Invest. 28, 129.

. Motley H.L., Lang L.P. and Gordon B. (1949) Amer. Rev. Tuberc., 59, 270.

* Motley H.L. (1963) Arch. environm. Hlth. 6, 166.

* M.R.C. Report (1966) Chronic bronchitis and occupation Brit. med. J, 1, 101.

. Myers J.A. (1924) Amer. Rev. Tuberc., 9, 49.

* Nadel J.A., and Comroe J.H. (1961) J. Appl. Physiol. 16, 713.

. Nadel J.A. and Tierney (1960) Physiologist 3, 119.

. Otis A.B., McKerrow C.B., Bartlett R.A., Mead J., McIlroy M.B., Selverstone N.J. and Radford E.P. (1955) J. Appl. Physiol., 8, 427.

* Reid D.D., Anderson D.O., Ferris B.J., and Fletcher C.M. (1964). Brit. med. J. 2, 1487.

* Royal College of Physicians of London (1962). Smoking and health. Pitman Medical Publishing Co., Ltd. London.

* Roe J. W. (1964) Personal communication.

* ZAmel N., Youssef H.H., and Prime F.J. (1963). Lancet 1, 1237.

* : Mentioned in the text.