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A MORTALITY STUDY
OF
PETROLEUM REFINERY WORKERS
PROJECT OH-1
September 15, 1974

Prepared for
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PREFACE

This report is based on research sponsored by the American Petroleum Institute.

The conclusions drawn from these studies are those of the investigators, and inquiries concerning the research should be addressed to them.

Copies of this report may be purchased from the Institute at $2.00 per copy. Requests from non-profit institutuions for complimentary copies will be considered.

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other substances, but may have been a function of differing physical demands in job categories with different exposures, and of social and economic differences in the different exposure groups.

3. Mortality from respiratory cancer increased with increased exposure, but was nevertheless below the expected value in the high exposure group.

4. Mortality from lymphomas was greater than expected, though not statistically significant, in all exposure groups, with a suggestion of increased mortality with increased exposure.

5. Although the excess was not significant, mortality from genital cancer increased with increased exposure, and was greater than the expected value in the medium and high exposure groups. However, one of the deaths was a worker with 2 years service, without which the mortality would have been less than expected.

In an occupational group whose general mortality experience is very favorable, the mortality rate from lymphomas is conspicuous because it exceeds the expected value and appears to be exposure related. Since the excess is neither large nor statistically significant, it may be a chance occurrence. Nevertheless, a detailed investigation of the work and medical histories of the lymphoma cases is desirable, in order to determine if there are possible alternative explanations.

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A MORTALITY STUDY OF PETROLEUM REFINERY WORKERS

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September 15, 1974

I. SUMMARY AND CONCLUSIONS

A mortality study of petroleum refinery workers was carried out in 17 refineries. The study group consisted of every worker employed in the refineries for at least a year between January 1, 1962 and December 31, 1971. Ninety four percent of the study population of 20163 workers were successfully traced to determine their vital status as of December 31, 1971. The study population represented the equivalent of 137,153 years of observation. There were 1165 deaths, for 1145 of which death certificates were obtained.

The bulk of the study population were long-term employees. Sixty four percent of the group, representing 76 percent of the years of observation, were men hired before 1952 who were still employed in 1962.

The major findings of the study were:

1. The Standardized Mortality Ratio (SMR) for all causes of death was 69.1, significantly less than the expected SMR of 100 in a comparable U. S. male population.
2. Mortality from cardiovascular-renal diseases, digestive cancer, and ulcers of the stomach and duodenum was highest in men with the lowest estimated exposure to atmospheric hydrocarbons. The trend did not appear to be explainable in terms of probable exposure to

Oil and Gas Journal (1). The sample of workers was obtained by selecting a sample of 17 refineries from the listing in the Oil and Gas Journal, and taking every eligible worker in each refinery sampled.

The sample of refineries was not random, but was a purposive sample designed to give a reasonably representative distribution with respect to geographic area, ownership and size. In practice, the sample was taken in three stages. First, four refineries were chosen, two large and two small, in order to assess the practical problems of data collection and to get an estimate of the yield of eligible workers compared with the number in the current work force. Second, this sample was augmented to obtain, by the end of 1972, a fairly representative group of seven refineries. Third, during 1973 ten more refineries were added to reach the total study population of 20163 workers.

Table 1 shows the distribution of all refineries and of the sample of refineries by capacity and by United States Census region. The sample overrepresents the large refineries while omitting the smallest ones. This resulted from the necessity of obtaining a broad representation by company in the larger refineries, and from the belief that, since the larger plants account for the great majority of workers, it was appropriate to allow them a greater representation.

Table 2 shows the distribution by United States Census region of the 20163 workers in the study population compared with the United States population. The South is substantially overrepresented in the

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II. INTRODUCTION

In January, 1972, TCA Inc. began a study of the health of petroleum refinery workers under the sponsorship of the American Petroleum Institute. The purpose of the study was to evaluate the general assumption that the health of the American petroleum refinery worker is better than that of his counterpart in the general population and, if this assumption is invalid, to characterize the variance from the general population and the factors associated with it.

The investigation took the form of a historical prospective study of mortality in a sample of workers in United States petroleum refineries. The general approach was to identify a group of about 20,000 workers who had been employed in refineries in the past, and to determine whether they were alive at the end of 1971. The study was designed to answer two specific questions:

1. Is the observed mortality in petroleum refinery workers significantly different from what would be expected in a similar population of United States males without such occupational exposure?
2. Does the observed mortality in petroleum refinery workers vary significantly with date, duration and circumstances of employment?

III. SELECTION OF REFINERIES

The study population for this investigation was a sample of workers from the 251 United States refineries listed in the 1971 census of the

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5. Date and place of death for those known to have died.

6. Last known address for those who had left employment.

In consultation with a refinery safety engineer, job titles were divided into three broad exposure categories. Although specific job titles differed from one refinery to another, the high exposure category (category A in Table 9) contained laboratory, maintenance and salvage recovery jobs while the low exposure (category C) contained plant security, utility, purchasing and motor transport jobs. All other jobs were considered to be medium exposure (category B), recognizing that some job titles classed as medium, such as "laborer," probably include a range of exposures depending on where in a refinery a man actually worked.

The typical plant record system consisted of a unit record, usually a folder, for each worker. Generally the unit record contained one or two summary sheets with the desired information. These were microfilmed at the plant and assembled at a central location for coding and processing. In several instances plants were able to provide a computer printout giving the required information for the current work force, from which the work force as of the end of 1971 could be reconstructed.

In almost all plants, up-to-date information on retirees was available. Often, copies of the death certificates were available for those who had died.

V. FOLLOW-UP OF STUDY POPULATION

Workers who had left employment, and those few retirees whose

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study population, while the North Central region is similarly under-represented. This is an inevitable consequence of the concentration of refineries in the former area, and its implications will be examined below.

IV. DATA COLLECTION

All eligible workers in each sample refinery were included in the study. An eligible worker was defined as an hourly employee, not clerical, who had worked in the refinery for at least one year between January 1, 1962, and December 31, 1971. This definition included those employed as of the latter date, those who had retired or died on or before that date, and those who had left employment on or before that date.

However, in Refinery No. 5 a review of the records during processing revealed that records for men who had quit or had been discharged were kept only for 1 year, unless the employee had died on the job. To avoid the resulting bias, only pensioners from Refinery No. 5 were included in the study, their contribution to the data being counted from the date of their retirement.

For each eligible worker the following information was obtained from plant personnel records:

1. Date of birth.
2. Date of hire.
3. Most recent job title.
4. Date of retirement or termination, where appropriate.

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in this group is reflected in Figure 2, which shows that the overwhelming majority of the study population was part of the current work force at the time the study began. Figure 3 shows that over 60 percent of the study population was 35 years of age or older at the time of entry into the study.

Figure 4 shows the distribution of the study population by date of hire. The majority of the group were not only employed as of the starting date of the study, but had been hired before 1950.

Since mortality varies by race, an attempt was made to estimate the racial distribution of the study population. This could not be done directly, since race is not usually recorded in personnel documents. However, each refinery in the study was asked to provide the racial distribution of its current work force and, if possible, an estimate of the distribution in the mid-1960's, reporting the results as White (including Mexican and Latin Americans), Black, and other. Sixteen refineries responded, five of which were able to provide data for some time in the mid-sixties in addition to current data. The percent of Black workers is currently 11.8, and of other non-Whites 0.3, for workers other than office and clerical. The corresponding estimated figures for the mid-sixties are 7.9 and 0.2 respectively. It therefore appears that the racial composition of the study population was not grossly different from that of the United States male population, which during the study period ranged between 10 and 11 percent non-White.

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status was unknown, were traced to determine whether they had died during the study period. The follow-up process began with a form letter which was sent to the last known address of the worker (Attachment A). If there was no response and the letter was not returned, a reminder card was sent after approximately four weeks (Attachment B). If the letter was returned as undeliverable, the procedure diagrammed in Figure 1 was used to obtain a current address and to determine the status of the worker. Table 3 shows the results of the follow-up. The section headed "Status in Plant Records" shows the data which were available from refinery records. The section headed "Follow-up Status" shows the results of the follow-up. The overall follow-up rate is 94 percent, the bulk of the missing workers being from Plant 1. Of the 1165 known deaths, death certificates have been received for 1145 cases.

VI. CHARACTERISTICS OF THE STUDY POPULATION

Table 4 shows the distribution of the study population by birthdate and years of service up to the time of death, termination, retirement, or the closing date of the study, whichever came first. The average length of service was 20 years, and the majority of the study population had more than 20 years service. (Length of service may be slightly overestimated, since breaks in service due to temporary layoffs were not deducted from each worker's record).

Figures 2 and 3 show the distribution of the study population by year of entry into the study and by age at entry. The low turnover

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number of deaths below what was calculated from national data. On the other hand, the study population was concentrated in the South, where mortality is highest, and deficient in the North Central region, where mortality is lower than average, which would tend to raise the true number of expected deaths. It appeared that the net result of these compensating biases would not seriously disturb conclusions based on the United States male population.

VIII. RESULTS

Standardized Mortality Ratios were calculated as described above for overall mortality and for the major causes by which federal mortality statistics are usually published (omitting cancer of the uterus, diseases of infancy, and other inappropriate causes). Table 6 shows these SMR's for the entire population whose vital status had been determined, that is, omitting the men who had not been traced.

In Table 7 the study population is divided into those hired before the starting date of the study, January 1, 1962, versus those hired on or after that date, and SMR's for the same causes are shown for each group. The group hired before the beginning of 1962 represents workers who had some occupational exposure ten or more years before the closing date of the study.

In Table 8, SMR's are shown for those hired before January 11, 1952, versus those hired later. Since a worker had to be in the active work force after January 1, 1962, in order to be in the study, the men hired before 1952 constitute a group with at least ten years of occupational

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VII. STANDARDIZED MORTALITY RATIOS

The usual method of characterizing the risk of death in a population studied prospectively is to compare the number of deaths occurring in the study population with the number which would have been expected if the study group had had, at each age and time period, the same mortality as a comparable non-exposed population. In order to do this, the number of years of observation contributed by each worker to each age interval must be calculated and classified by the date of birth of the worker. Table 5 shows such calculations for the total study population. For example, workers born between 1920 and 1924 contributed 10128 person-years to the age group 45-49, which age they attained over a time period roughly centered around the year 1967. The number of deaths which one would expect to occur in this cohort in the age interval 45-49 is then 10128 multiplied by the death rate at age 45-49 in 1967 in a comparable non-exposed population. The total of such figures over all the cells in the table is the number of expected deaths in the study population. The conventional measure of risk is then the Standardized Mortality Ratio (SMR), which is the number of deaths actually observed, expressed as a percentage of the expected number.

The most convenient population to choose as an unexposed standard population is all United States males, since rather detailed mortality rates by age, cause and year are available. This population was in fact used as a standard.

However, the study population had a smaller proportion of non-whites than the nation as a whole, which would tend to lower the true expected

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for those hired after the start of the study is 36, based on 11 deaths.

Table 8 separates those hired before 1952 from those hired later. Again, the stability of the study population is evidenced by the fact that the former group constituted 64 percent of the study population and contributed 76 percent of the person-years. The mortality pattern in those hired prior to 1952 is similar to that of the total group, except that the mortality from genital cancer is again less than expected. The SMR for those hired in 1952 or later is 57, based on 61 deaths. The few large SMR's in the latter group are based on too few cases to evaluate their significance.

Compared with the total population, those hired before 1962 and those hired before 1952 represent successively more exposed groups, in terms of length of exposure and length of time since exposure began. Comparing the SMR's in these groups, there is essentially no trend in mortality from cardiovascular-renal disease except for rheumatic fever, hypertensive disease not involving the heart, and chronic nephritis and renal sclerosis. The latter two conditions have only 5 and 6 cases, respectively, and all three occur throughout at less than the expected rates.

Some of the malignancies show an upward trend, namely lung cancer, leukemia and the lymphomas. Only the last of these has more deaths than expected. Cancers of other sites show trivial upward or downward trends.

Table 9 partitions the study population by estimated exposure into high (A), medium (B) and low (C) groups. In each exposure category the

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exposure (subject to some errors due to gaps in employment) whose tenth year was reached at least a decade before the closing date of the study.

Table 9 shows SMR's by estimated exposure to hydrocarbons.

An SMR of 100 for any cause indicates a mortality equal to that which would be expected in the standard population. An SMR different from 100 may occur by chance, especially if the number of deaths is small or if the deviation from 100 is small. Therefore, for each SMR which was based on 5 cases or more, the statistical significance of the deviation from 100 was tested using an adaptation of a formula of Chiang (2). Those SMRs which had a probability of less than .05 of occurring by chance alone are indicated by a single asterisk. Those with a probability of less than .01 are indicated by two asterisks.

The overall mortality of the study population is favorable, with a mortality equal to 69 percent of what would be expected in a comparable U. S. male population. The favorable experience occurs for all causes of death except cancer of the genital organs and lymphomas. In most cases the SMR's are significantly less than 100 at the 1 percent level of significance. (Table 6)

In Table 7 those hired before the starting date of the study are compared with those hired later. The former group constituted 76 percent of the total study population and contributed 90 percent of the person-years. Therefore, the mortality pattern in the group hired earlier is essentially identical with that of the whole group, except that the SMR from genital cancer is slightly less than 100. The SMR

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Among other causes, ulcers of the stomach and duodenum decrease with increasing exposure, as do homicides, while motor vehicle accidents and suicides increase with increasing exposure.

IX. DISCUSSION

The mortality of employed populations is usually less than that of the general population. This phenomenon may be due partly to pre-employment selection, both by the employer through physical examinations, and by the employee who is not likely to seek work if he has a serious disease. It may further be due partly to the higher standard of living enjoyed by regularly employed individuals.

In any case, in the absence of a specific occupational hazard the favorable experience tends to extend to all causes of death. Even when a definite hazard increases the mortality from a specific cause, the overall mortality is often better than expected. Table 10 shows SMR's for all causes obtained in several recent studies of various occupational groups (3-10). Although for technical reasons SMR's obtained from different studies are not strictly comparable, the SMR of 69 in the present case is certainly consistant with the anticipated picture of a favorable overall mortality.

It is possible that the observed SMR in this study may be low because there are a disproportionate number of deaths among the 1120 workers who were not found. However, in order for this factor to have resulted in the observed SMR of 69 when the true SMR was 100, about half of the untraced workers would have to have died almost immediately

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pattern of generally favorable mortality (i. e., less than expected) for all causes is maintained, with the exceptions noted below.

Overall mortality and mortality from the major cardiovascular-renal diseases as a group decrease with increasing exposure. Within the cardiovascular-renal group the trend is generally the same for specific causes. Where this is not true, the highest SMR is nevertheless in the lowest exposure group. The exception is chronic nephritis and renal sclerosis, where the number of cases is very small. For several causes whose overall SMR is below 100, the SMR in the low exposure group is above 100. However, with the exception of arteriosclerotic heart disease such SMR's are based on very few cases.

Malignant neoplasms as a class are highest in the low exposure group. Within the class, some malignancies appear to increase with increasing exposure while others decrease.

The cancers which show an increased risk with increasing exposure are those of the buccal cavity and pharynx, respiratory system and genital organs. Those which decrease with increasing exposure are cancers of the digestive system, urinary cancer, and somewhat equivocally, leukemia. Lymphomas show higher SMR's in both the high and low groups than in the medium one. It is important to note, however, that all these SMR's are below 100, with the following exceptions. The leukemia SMR exceeds 100 in the low exposure group, the genital cancer SMR exceeds 100 in the high and medium exposure groups, and the lymphoma SMR exceeds 100 in all groups.

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The justification for the second criterion is that a cause of death which shows a substantial change with increasing exposure merits attention on the basis of the trend, whether or not the actual SMR's exceed 100 or exceed the overall SMR.

The basic comparison by date of hire is the total study population versus those hired before 1962 versus those hired before 1952. As was pointed out in earlier sections, those hired before 1962 worked on the average more than one year before entering the study, those hired before 1952 worked on the average ten years or more before entering the study, and both groups entered the study as of the end of 1962. The effect of pre-employment screening will be minimal in the latter two groups, since such screening will not ordinarily detect those men who are likely to die several decades after being hired. Therefore one would expect workers hired before 1962 to have higher SMR's than the total group for conditions which occur in both younger and older men and which are detectable by a pre-employment examination.

The comparison by level of exposure warrants several comments. The first is that the classification used here is based on the current or final job title. To the extent that workers move across exposure groups during their working careers, these job titles may not adequately characterize their exposure history. Also, the exposure being measured is to atmospheric hydrocarbons, so that "medium" or "low" exposure may sometimes imply a relatively high exposure to other substances. Finally, jobs with different exposure levels are likely to involve different amounts of physical activity and to represent different

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after they were terminated, a most unlikely event. It may nevertheless be true that the SMR would increase somewhat if the follow-up were more complete, and a further follow-up of the untraced men through Social Security records would be extremely desirable.

Given that a lower mortality than that of the general population is the norm for employed populations, a question arises as to what criteria should be used to identify those causes which show an increased risk as a result of occupational exposure.

One criterion is of course to look only at those causes whose SMR's exceed 100, with or without the requirement of statistical significance. Another is to look at those causes whose SMR's are substantially greater than the overall SMR for the group in question, whether or not they are greater than 100.

Although it is intuitively appealing, the latter approach is difficult to justify when it leads to the possible indictment of a cause (such as arteriosclerotic heart disease in Table 6) whose SMR is highly significantly less than 100, simply because it is greater than the SMR for all causes.

In the present study a cause of death will be considered substantively significant (i. e., worthy of further discussion) if (a) its SMR is based on 5 or more cases and exceeds 100, or (b) it shows a change of more than 10 percent with date of hire or level of exposure, where at least some of the SMR's are based on 5 or more cases.

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a slight tendency to occur in the lower exposure groups.

The small size of the low exposure group makes the SMR's in that classification less reliable, except for common diseases such as arteriosclerotic heart disease. In general, however, it is clear that the cardiovascular-renal diseases tend to occur in that group.

One explanation may be that workers who become partially disabled from cardiovascular disease are transferred to positions in purchasing and plant security, which are low exposure categories. Another may be that, since the preponderance of high exposure jobs are in maintenance, the physical demands of the job may tend to prevent the development of cardiovascular disease. If one postulates that the trend is related to exposures to other substances, one would expect such other exposures to be greatest in the medium exposure group, which includes asphalt workers, grease plant workers, and lubricating oil workers. In fact, the latter group tends to be closer to the high exposure group than to the low exposure group in cardiovascular mortality. There appears to be no explanation in terms of occupational exposure to account for the observed trend.

Malignant neoplasms

Lymphomas and cancers of the genital organs have SMRs above 100 in the total group but show no substantial trends by date of hire. Leukemia shows a slightly higher SMR in those hired before 1952 than in the total group, but this is at least partly due to pre-employment

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socioeconomic levels. All these factors may affect mortality differentials by exposure level.

Specific causes of death are reviewed below, by major cause groups, and examined in the light of the criteria given above.

Major cardiovascular-renal diseases

Only nephritis and renal sclerosis showed a substantively significant trend by hire date. Since the number of cases is quite small and the highest SMR is 62.5, it does not appear that this trend indicates any real association with date of hire. The trend for rheumatic fever and rheumatic heart disease is almost significant. However, this is probably an artifact of the pre-employment screening process, in which cases were screened out of the work force at the time of hiring. New cases would have developed over time, but in those hired more recently there would have been less time for the cases to develop.

Vascular lesions of the central nervous system, arteriosclerotic heart disease and non-rheumatic endocarditis show a decreased risk with increased exposure. In the case of arteriosclerotic heart disease, the SMR in the low exposure group is 103.4. Hypertensive heart disease shows an increase with increasing exposure, but the highest SMR is 38.6, and a change of 1 or 2 cases from the high to the medium or low exposure group would have obliterated or reversed the trend. Other cardiovascular diseases show equivocal trends, although as a group they show

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whose exposures must greatly exceed that of a resident population near a refinery, nevertheless has a SMR below 100. The effect of cigarette smoking and socioeconomic level on this trend could not be evaluated.

The genital cancers are of interest because there is an upward trend with exposure, and because the SMR's in the high and medium exposure categories are above 100. However, the excess in the medium exposure group includes one case with 2 years employment, without which the SMR would be below 100. Table 11 is a listing of the actual cases with age at death, duration of employment, and a verbatim quote of the entry on each death certificate. Fourteen of the 17 deaths were due to cancer of the prostate, which is close to the proportion to be expected in the general population. There is nothing in Table 11 to indicate an unusual pattern, and the SMRs are not statistically significant.

The lymphomas show an SMR above 100 in all exposure groups. There is no clear cut trend with exposure. However, the highest SMR, in the lowest exposure group, is based on only 4 cases, and a difference of 2 cases would have made it the lowest SMR, and shown a positive trend with exposure. The excess mortality here may be additionally important because an exposure-related excess mortality from lymphomas has been observed in vinyl plastic workers (TCA, unpublished) some of whom are exposed to an array of volatile additives in addition to vinyl chloride itself.

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screening, which can reasonably be expected to have largely eliminated the disease in newly hired workers.

Like the cardiovascular-renal diseases, the SMR for all malignant neoplasms is highest in the low exposure category, while the values for the high and medium categories are almost equal. Unlike the cardiovascular diseases, however, different specific causes show well defined but contradictory trends.

Cancer of the digestive system decreases with increasing exposure. (Leukemia and urinary cancer show similar trends, but the numbers of cases are such that a change of 3 or 4 cases could reverse the trend). As in the case of the cardiovascular diseases, it does not appear that the high SMR in the lowest exposure category is explainable by postulating exposures to other substances, since here again the highest SMRs would then be expected in the medium exposure category.

Respiratory and genital cancers increase with increasing exposure. This is also true of cancer of the buccal cavity and pharynx, but the number of cases is too small to constitute a reliable trend, and the SMRs are quite low.

In the case of respiratory cancer, the trend is based on a relatively large number of cases. Even though the trend is clear cut, the SMR in the high exposure group is still below 100. It is not clear how this result should be interpreted as it bears on the finding of apparently increased lung cancer mortality in areas adjacent to some oil refineries (11). On the one hand there is a upward trend in this study with increasing exposure. On the other, the high exposure group,

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Table 12 is a listing of the 24 deaths in this cause group with age at death, length of employment and a verbatim quote of the death certificate entry. The percentage and age distribution of deaths due to Hodgkins disease are about equal to that in the general male population, but there are relatively fewer deaths from lymphosarcoma and relatively more from multiple myeloma and reticulum cell sarcoma together. Further investigation of the circumstances of these deaths appears warranted.

Other causes of death

Mortality from ulcers of the stomach and duodenum exhibits the same trend as mortality from digestive cancer, i.e., decreased mortality with increased exposure, but is based on few deaths. The various trends with exposure for such causes of death as homicide, suicide and motor vehicle accidents should be considered as indicators of the economic and social differences among the exposure groups, rather than as consequences of any occupational exposure.

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Table 1

Number of Refineries and Number Sampled, by Capacity, by Census Regions and Geographic Divisions

Regions	Geographic Divisions	Totals/ No. Sampled	Capacity in Barrels ≤ 20M	21M-50M	51M-100M	>100M
All		251/17	119	58/3	39/3	35/11
Northeast		21/3	8	4	4	5/3
	New England	1	1	-	-	-
	Middle Atlantic	20/3	7	4	4	5/3
North Central		53/4	18	17/1	11/2	7/1
	East North	35/3	12	9/1	7/1	7/1
	West North	18/1	6	8	4/1	-
South		101/8	50	18/2	16	17/6
	South Atlantic	8	7	-	-	1
	East South	15/3	9	3/1	1	2/2*
	West South	78/5	34	15/1	15	14/4
West		76/2	43	19	8/1	6/1
	Pacific	41/2	18	9	8/1	6/1
	Mountain	35	25	10	-	-

*Physically only one refinery but for records counted as two.

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Table 3

Study Population of Refinery Workers by Plant Number

Plant Number	Total	Status in Plant Records				Followup Status			Death Certificates		Percent Followup
		Now Working	Retired	Term.	Died	Alive	Dead	Unknown	Rec'd	Not Rec'd	
All	20163	13724	3575	2150	714	17878	1165	1120	1145	20	94
1	3439	1791	458	1094	96	2876	143	420	139	4	88
2	619	395	127	91	6	570	9	40	9	0	94
3	651	468	135	22	26	599	43	9	43	0	98
4	195	141	37	9	8	180	12	3	12	0	98
5	69	0	69	0	0	59	10	0	10	0	100
6	1960	1381	424	62	93	1766	152	42	151	1	98
7	2625	1806	604	113	102	2371	198	56	196	2	98
8	505	351	94	50	10	454	19	32	19	0	94
9	1666	954	513	117	82	1382	153	131	149	4	92
10	4999	3838	769	220	172	4588	261	150	257	4	97
11	684	421	58	194	11	556	22	106	22	0	85
12	563	492	3	63	5	510	6	47	6	0	92
13	336	262	42	16	16	307	22	7	22	0	98
14	246	206	21	12	7	230	7	9	6	1	96
15	299	262	17	13	7	279	9	11	9	0	96
16	129	96	16	10	7	113	10	6	10	0	95
17	1178	860	188	64	66	1038	89	51	85	4	96

June 10, 1974

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Table 2

Number and Percent of Study Population
by United States Census Region, and Percent of 1960
United States Population by Census Region

U.S. Census Region	Study Population		U.S. Population
	No.	%	%
Northeast	3803	18.8	24.9
North Central	1420	7.0	28.8
South	10882	54.0	30.8
West	4058	20.1	15.4
Total	20163	100.0	100.0

June 10, 1974

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Table 5

Person Years of Observation by Year of Birth and Age
for Petroleum Refinery Workers

Age	Total	Year of birth													
		1885-1889	1890-1894	1895-1899	1900-1904	1905-1909	1910-1914	1915-1919	1920-1924	1925-1929	1930-1934	1935-1939	1940-1944	1945-1949	1950-1954
All	137153	3	40	2637	11590	16569	19741	20267	22113	17857	11174	5877	5555	3405	325
15-19	145												11	58	76
20-24	4232											107	1121	2753	249
25-29	6988										332	2082	3478	594	
30-34	9085									595	4744	3393	443		
35-39	14568								957	7734	5494	383			
40-44	20130							889	10059	8578	604				
45-49	21322						922	9322	10128	950					
50-54	20196					795	9230	9202	969						
55-59	18172				637	7872	8809	854							
60-64	13964			275	5652	7257	780								
65-69	7141		5	1555	4939	642									
70-74	1191	2	21	803	362	3									
75-79	18	1	13	4											
80-84	1		1												

June 19, 1974

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Table 4

Number of Petroleum Refinery Workers by Birth Date and Years of Service*

Birth Year	Total	Years of Service										
		1-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54
Total	20163	4283	1360	673	1880	3877	4209	1679	1348	734	117	3
1885-1889	1					1						
1890-1894	5					2	1	2				
1895-1899	341			1	35	73	25	59	76	61	10	1
1900-1904	1462		1		53	407	189	257	285	220	49	1
1905-1909	2010	1	1	3	44	248	579	288	445	344	56	1
1910-1914	2333	5	7	10	92	350	976	392	392	107	2	
1915-1919	2399	12	30	30	170	554	982	469	150	2		
1920-1924	2616	38	50	58	299	915	1044	212				
1925-1929	2240	116	108	130	462	1011	413					
1930-1934	1585	183	257	214	615	316						
1935-1939	1212	529	377	196	110							
1940-1944	1723	1279	413	31								
1945-1949	1843	1727	116									
1950-1954	393	393										

*As of date of termination, date of retirement or December 31, 1971, whichever was earlier.

June 11, 1974

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TABLE 6

OBSERVED DEATHS/EXPECTED DEATHS AND STANDARDIZED MORTALITY RATIOS BY CAUSE, JAN. 1, 1962, TO DEC. 31, 1971, IN ALL MALE EMPLOYEES OF PETROLEUM REFINERIES

Cause of death with I.C.D. number	obs/exp	SMR
All causes	1165/1685.54	69.1**
Tuberculosis (001-009)	3/12.10	24.8
Tuberculosis of respiratory system (001-008)	3/11.45	26.2
Malignant neoplasms (140-205)	265/327.52	80.9**
Malignant neoplasms, buccal cavity and pharynx (140-148)	5/11.98	41.7*
Malignant neoplasms, digestive organs and peritoneum (150-159)	81/95.71	84.6
Malignant neoplasms, respiratory system (160-164)	90/112.71	79.9**
Malignant neoplasms, genital organs (171-179)	17/16.83	101.0
Malignant neoplasms, urinary organs (180-181)	6/16.82	35.7*
Leukemia and aleukemia (204)	10/12.18	82.1
Lymphomas (200-203, 205)	24/19.26	124.6
Diabetes mellitus (260)	10/24.34	41.1*
Major cardiovascular and renal diseases (330-334, 400-468, 592-594)	632/873.60	72.3**
Vascular lesions affecting CNS (330-334)	53/105.16	50.4**
Rheumatic fever & chronic rheumatic heart dis. (400-402,410-416)	12/17.04	70.4
Arteriosclerotic heart disease (420)	496/602.67	82.3**
Nonrheumatic endocarditis (421, 422)	7/29.06	24.1**
Hypertensive heart disease (440-443)	11/35.88	30.7*
Other hypertensive disease (444-447)	5/7.80	64.1
Chronic & unspecified nephritis & renal sclerosis (592-594)	6/10.68	56.2
Influenza and pneumonia (480-493)	10/34.86	28.7**
Ulcer of stomach and duodenum (540,541)	12/13.54	88.6
Appendicitis (550-553)	0/1.70	0
Hernia and intestinal obstruction (560, 561, 570)	1/5.84	17.1
Gastritis, duodenitis, enteritis and colitis (543, 571, 572)	3/4.57	65.6
Cirrhosis of liver (581)	21/50.80	41.3**
Hyperplasia of prostate (610)	0/1.94	0
Symptoms, senility and ill-defined conditions (780-795)	13/24.80	52.4*
All other diseases (residual)	73/134.65	54.2**
Motor vehicle accidents (810-835)	30/56.88	52.7**
Other accidents (800-802, 840-962)	39/62.70	62.2**
Suicide (963, 970-979)	23/37.30	61.7**
Homicide (964, 980-985)	10/18.40	54.3**
Number of workers	19043	
Person-years	137153***	

*significant at 5% level.
**significant at 1% level.
***totals for person-years do not precisely agree in all tables because of rounding.

June 10, 1974

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TABLE 9

OBSERVED DEATHS/EXPECTED DEATHS AND STANDARDIZED MORTALITY RATIOS BY CAUSE, JAN. 1, 1962, TO DEC. 31, 1971, IN MALE EMPLOYEES OF PETROLEUM REFINERIES, BY JOB CLASSIFICATION WITH RESPECT TO HYDROCARBON EXPOSURE

Cause of death with I.C.D. number	Job classification A		B		C	
	obs/exp	SMR	obs/exp	SMR	obs/exp	
All causes	481/733.06	65.6**	512/751.74	68.2 **	172/203.86	
Tuberculosis (001-019)	1/5.29	18.9	2/5.38	37.2	0/1.44	
Tuberculosis of respiratory system (001-008)	1/5.00	20.0	2/5.09	39.3	0/1.33	
Malignant neoplasms (140-205)	113/142.00	79.6**	113/146.17	77.3**	39/39.81	
Malignant neoplasms, buccal cavity and pharynx (140-148)	3/5.21	57.6	2/5.35	37.4	0/1.43	
Malignant neoplasms, digestive organs & peritoneum (150-159)	34/41.41	82.1	36/41.68	86.4	11/11.74	
Malignant neoplasms, respiratory system (160-164)	43/48.84	88.0	38/50.37	75.4*	9/13.63	
Malignant neoplasms, genital organs (171-179)	9/7.21	124.8	8/7.50	106.7	0/2.18	
Malignant neoplasms, urinary organs (180-181)	2/7.27	27.5	3/7.51	39.9	1/2.08	
Leukemia and aleukemia (204)	3/5.31	56.5	3/5.42	55.4	1/1.47	
Lymphoma (200-203, 205)	11/8.42	130.6	9/8.58	104.9	4/2.29	
Diabetes mellitus (260)	7/10.57	66.2	3/10.85	27.6	0/2.97	
Major cardiovascular and renal diseases (330-334, 400-468, 592-594)	262/378.81	69.2**	272/389.37	69.9**	98/106.90	
Vascular lesions affecting CNS (330-334)	16/45.46	35.2**	26/46.81	55.5**	11/13.16	
Rheumatic fever & chronic rheumatic heart dis. (400-402, 410-416)	5/7.49	66.8	2/7.58	26.4	5/1.99	2
Arteriosclerotic heart disease (420)	209/261.36	80.0**	211/268.75	78.5**	76/73.49	1
Nonrheumatic endocarditis (421, 422)	2/12.57	15.9	3/12.95	23.2	2/3.61	
Hypertensive heart disease (440-443)	6/15.55	38.6**	5/15.98	31.3**	0/4.40	
Other hypertensive disease (444-447)	3/3.41	88.0	1/3.46	28.9	1/0.94	1
Chronic & unspecified nephritis & renal sclerosis (592-594)	0/4.69	0	5/4.74	105.5	1/1.26	
Influenza and pneumonia (480-493)	2/15.19	13.2	7/15.48	45.2**	1/4.26	
Ulcer of stomach and duodenum (540, 541)	4/5.89	67.9	6/6.03	99.5	2/1.64	1
Appendicitis (550-553)	0/0.74	0	0/0.76	0	0/0.20	
Hernia and intestinal obstruction (560, 561, 570)	0/2.53	0	1/2.60	38.5	0/0.72	
Gastritis, duodenitis, enteritis & colitis (543, 571, 572)	2/1.99	100.5	1/2.04	49.0	0/0.55	
Cirrhosis of liver (581)	9/22.40	40.2**	9/22.57	39.9**	3/5.86	5
Hyperplasia of prostate (610)	0/0.83	0	0/0.86	0	0/0.26	0
Symptoms, senility and ill-defined conditions (780-795)	2/10.85	18.4	10/11.04	90.6	1/2.94	3
All other diseases (residual)	26/58.53	44.4**	33/59.97	55.0**	14/16.31	8
Motor vehicle accidents (810-835)	15/25.04	59.9**	12/25.36	47.3**	3/6.53	4
Other accidents (800-802, 840-962)	15/27.70	54.1**	22/27.84	79.0	2/7.19	2
Suicide (963, 970-979)	13/16.51	78.7	8/16.55	48.3**	2/4.26	4
Homicide (964, 980-985)	2/8.19	24.4	5/8.17	61.2	3/2.05	14
Number of workers	8146		8704		2511	
Person-years	60730***		60804***		15-8***	

* Significant at 5% level.
** Significant at 1% level.
*** Actual person-years do not appear at

DBZ0014186

TABLE 8

OBSERVED DEATHS/EXPECTED DEATHS AND STANDARDIZED MORTALITY RATIOS BY CAUSE, JAN. 1, 1962, TO DEC. 31, 1971, IN MALE EMPLOYEES OF PETROLEUM REFINERIES, BY DATE OF HIRE

Cause of death with I.C.D. number	Hired before 1/1/52		Hired 1/1/52 or later	
	obs/exp	SMR	obs/exp	SMR
All causes	1104/1578.30	69.9**	61/107.29	56.9**
Tuberculosis (001-019)	3/11.35	26.4	0/0.75	0
Tuberculosis of respiratory system (001-008)	3/10.76	27.9	0/0.69	0
Malignant neoplasms (140-205)	253/313.62	80.7**	12/11.91	86.3
Malignant neoplasms, buccal cavity and pharynx (140-148)	3/11.54	26.0	2/0.44	454.5
Malignant neoplasms, digestive organs & peritoneum (150-159)	76/92.53	82.1	5/3.18	157.2
Malignant neoplasms, respiratory system (160-164)	90/109.00	82.6*	1/3.71	27.0
Malignant neoplasms, genital organs (171-179)	15/16.22	92.5	2/0.61	327.9
Malignant neoplasms, urinary organs (180-181)	6/16.33	36.7**	0/0.50	0
Leukemia and aleukemia (204)	10/11.18	89.4	0/1.00	0
Lymphoma (200-203, 205)	23/17.58	130.8	1/1.68	59.5
Diabetes mellitus (260)	10/22.90	43.7**	0/1.44	0
Major cardiovascular and renal diseases (330-334, 400-468, 592-594)	614/840.78	73.0**	18/32.86	54.8**
Vascular lesions affecting CNS (330-334)	52/101.50	51.2**	1/3.68	27.2
Rheumatic fever & chronic rheumatic heart dis. (400-402, 410-416)	12/15.60	76.9	0/1.44	0
Arteriosclerotic heart disease (420)	479/581.78	82.3**	17/20.90	81.3
Nonrheumatic endocarditis (421, 422)	7/28.03	25.0**	0/1.04	0
Hypertensive heart disease (440-443)	11/34.55	31.8**	0/1.33	0
Other hypertensive disease (444-447)	5/7.23	69.2	0/0.57	0
Chronic & unspecified nephritis & renal sclerosis (592-594)	6/9.60	62.5	0/1.08	0
Influenza and pneumonia (480-493)	10/32.64	30.6**	0/2.22	0
Ulcer of stomach and duodenum (540,541)	12/12.92	92.9	0/0.63	0
Appendicitis (550-553)	0/1.57	0	0/0.13	0
Hernia and intestinal obstruction (560, 561, 570)	1/5.58	17.9	0/0.27	0
Gastritis, duodenitis, enteritis & colitis (543, 571, 572)	3/4.26	70.4	0/0.32	0
Cirrhosis of liver (581)	19/46.77	40.6**	2/4.03	49.6
Hyperplasia of prostate (610)	0/1.92	0	0/0.01	0
Symptoms, senility and ill-defined conditions (780-795)	13/22.83	56.9**	0/1.98	0
All other diseases (residual)	70/125.74	55.7**	3/8.87	33.8
Motor vehicle accidents (810-835)	23/41.12	55.9**	7/15.76	44.4**
Other accidents (800-802, 840-962)	31/51.02	60.8**	8/11.68	68.5
Suicide (963, 970-979)	18/31.03	32.2**	5/6.27	79.7
Homicide (964, 980-985)	9/12.25	73.5	1/6.16	16.2
Number of workers	12203		6849	
Person-years	102120***		32180***	

*significant at 5% level.

**significant at 1% level.

***Individual person-years do not precisely agree in all tables because of rounding.

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Table 11

Deaths in Petroleum Refinery Study Population Due to Malignant Neoplasms, Genital Organs

Study No.	Age at Death	Years Worked	Cause as Given	Autopsy
2278	59	21	Inanition (9 mos.) Metastatic ca. prostate (3 yrs.) Primary ca. prostate (10 yrs.)	no
0164	65	41	Carcinomatosis (6 mos.) Carcinoma prostate (11 yrs.)	-
1831	65	38	Cardiac arrest (5 min.) Multiple metastases (mos.) Carcinoma prostate (mos.)	-
2148	44	26	Metastatic embryonal carcinoma from right testicle	yes
2206	64	40	Acute pulmonary edema (12 hrs.) Carcinoma of prostate with extensive metastases (14 mos.)	no
2584	64	33	Uremia Carcinoma prostate (2 yrs.)	-
0371	55	31	Acute respiratory & cardiac arrest (1 - 2 hrs.) Intracranial pressure due to metastatic carcinoma (2 - 3 wks.) Carcinoma prostate with widespread metastasis (3½ yrs.)	yes
1410	66	22	Cardiac arrest Acute congestive heart failure Widespread carcinoma of the prostate	no

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Table 10

Results of Follow-up in Several Occupational Groups

Study Population	Number Observed	Years of Observation	SMR All causes	Reference
Asbestos building product workers	12,402	1951-1963	88	Enterline & Kendrick, 1967
Asbestos friction material workers	7,510	"	89	Enterline & Kendrick, 1967
Asbestos textile plant workers	1,843	"	121	Enterline & Kendrick, 1967
Cotton textile workers	6,281	"	88	Enterline & Kendrick, 1967
White underground uranium miners	3,414	1950-1967	159	Lundin et al, 1969
Steelworkers	59,072	1953-1961	82	Lloyd & Ciocco, 1969
Asbestos insulation workers > 20 years	250	1946-1965	139	Tabershaw et al, 1970
Coke oven workers	4,661	1951-1966	98	Redmond et al, 1972
Asbestos maintenance service, etc.	438	1941-1969	124	Enterline et al, 1972
Asbestos insulation workers > 20 years	370	1963-1971	198	Hammond & Selikoff, 1972
Asbestos insulation workers	17,800	1967-1971	136	Hammond & Selikoff, 1972
Uranium mill workers	662	1950-1967	99	Archer et al, 1973
Lead smelter workers	2,352	1946-1970	107	TCA, Inc., unpublished
Lead battery plant workers	4,680	1946-1970	99	TCA, Inc., unpublished
Vinyl chloride workers	8,384	1942-1972	75	TCA, Inc., unpublished

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Table 12

Lymphoma Deaths in Petroleum Refinery Study Population

Study No.	Age at Death	Years Worked	Cause as Given	Autopsy
2366	61	38	Reticulum cell sarcoma (3-6 mos.)	yes
2707	59	22	Lymphosarcomatosis (generalized) (3 mos.) Lymphosarcoma of the stomach (6 mos.)	no
3176	68	31	Reticulum cell sarcoma (1½ yrs.)	yes
3854	34	14	Acute cor pulmonale (4 days) Tumor replacement of lungs - Hodgkins disease (2 yrs.)	yes
0167	59	20	Hypostatic pneumonia Multiple myeloma	-
1850	67	21	Multiple myeloma (6 yrs.)	no
2014	57	26	Lymphosarcoma IV B with leukemia (6 yrs.) (Bronchopneumonia)	yes
2019	52	25	Multiple myeloma	no
2154	66	42	Pneumonia (3 days) Multiple myeloma (? 1 yr.)	-
2464	68	34	Septic shock Pneumonia Multiple myeloma	no
2450	45	24	Hodgkins disease (6 mos.) (Diabetes mellitus)	yes

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Table 11. continued

1660	64	32	Pneumonia (3 days) Ca. of prostate	no
4445	71	35	Adenocarcinoma of prostate with metastasis	no
4548	67	24	Carcinoma of prostate (1 yr.)	no
4655	71	20	Cerebral thrombosis Metastatic ca. of prostate (6 mos.)	no
4754	64	27	Carcinoma of prostate with metastasis	no
4929	68	46	Generalized metastasis (3 mos.) Cancer of prostate (3 yrs.)	no
4972	59	35	Carcinoma of prostate with metastasis generalized (1 yr.)	no
0212	33	10	Metastatic lesions of l. axilla and mediastinum (10 mos.) Seminoma testicle	no
0974	20	2	Toxemia Metastatic carcinoma Carcinoma testis	-

June 10, 1974

DBZ00141191

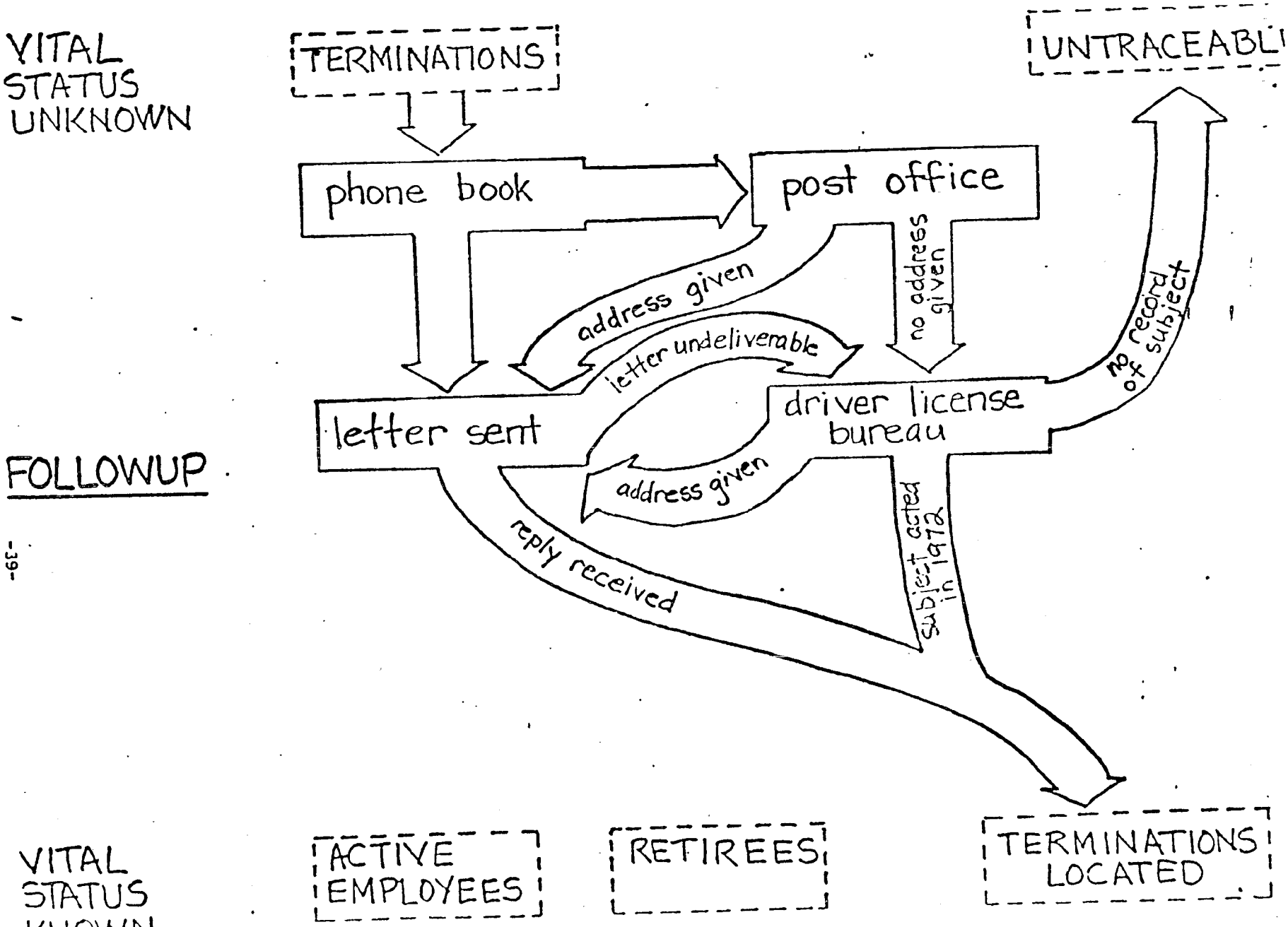


FIGURE 1

DBZ0014192

Table 12, continued

0299	61	19	Respiratory failure Malignant lymphoma, type not diagnosed, terminal	no
0868	53	27	Acute pulmonary edema and congestion Secondary to multiple myeloma	yes
0923	59	24	Reticulum cell sarcoma, primary site not determined	-
1087	64	20	Circulatory failure (24 hrs.) Secondary anemia (9 mos.) Multiple myeloma (9 mos.)	-

June 10, 1974

DBZ0014193

Figure 2

—Percentage Distribution by Year of Entry into Study, for 20163 Petroleum Refinery Workers

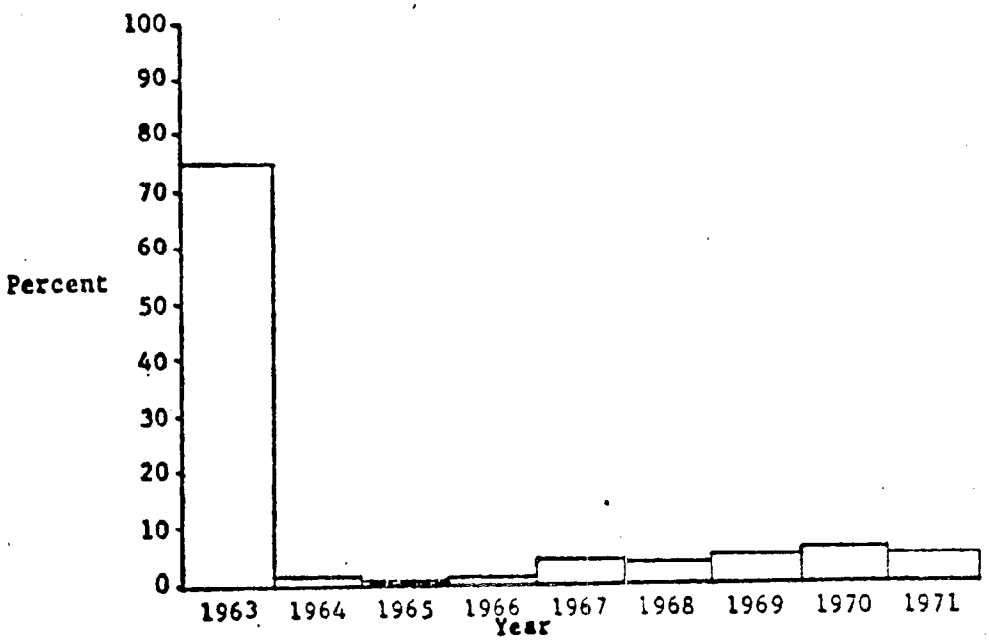
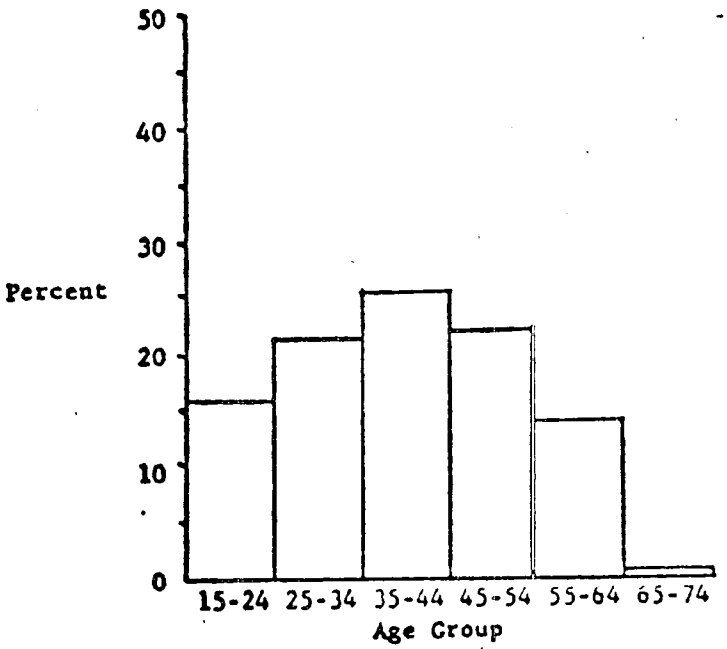


Figure 3

Percentage Distribution by Age at Entry* into Study, for 20163 Petroleum Refinery Workers



*Entry into study was on January 1, 1963, or one year after hiring, whichever was later.

DBZ0014194

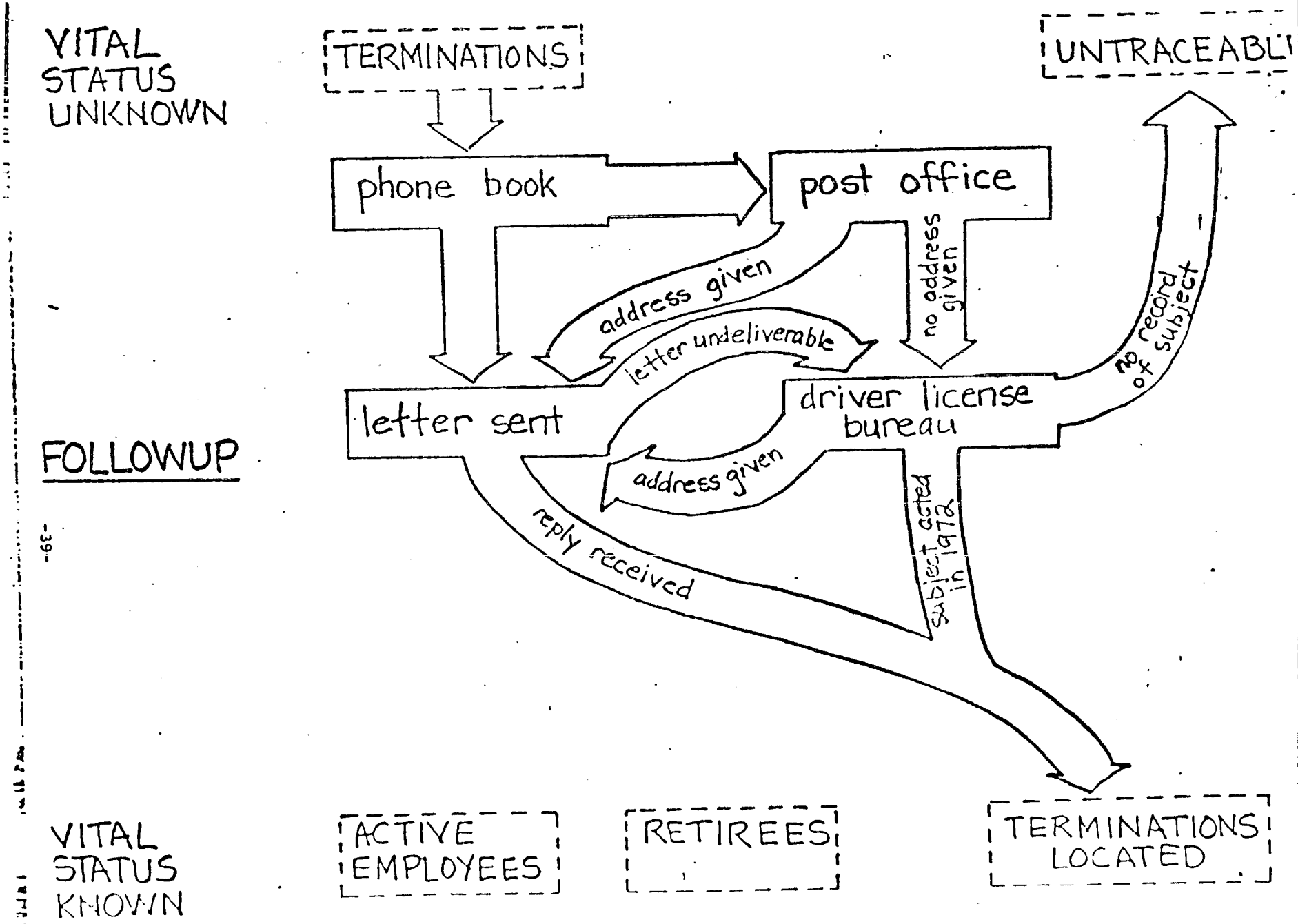


FIGURE 1

DBZ0014195

Figure 2

Percentage Distribution by Year of Entry into Study, for 20163 Petroleum Refinery Workers

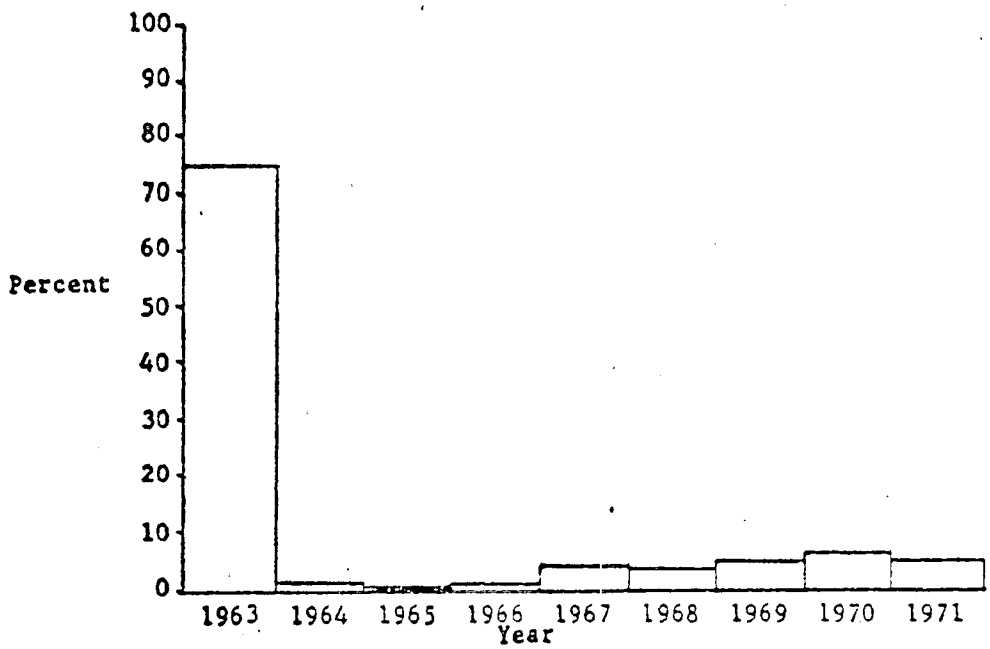
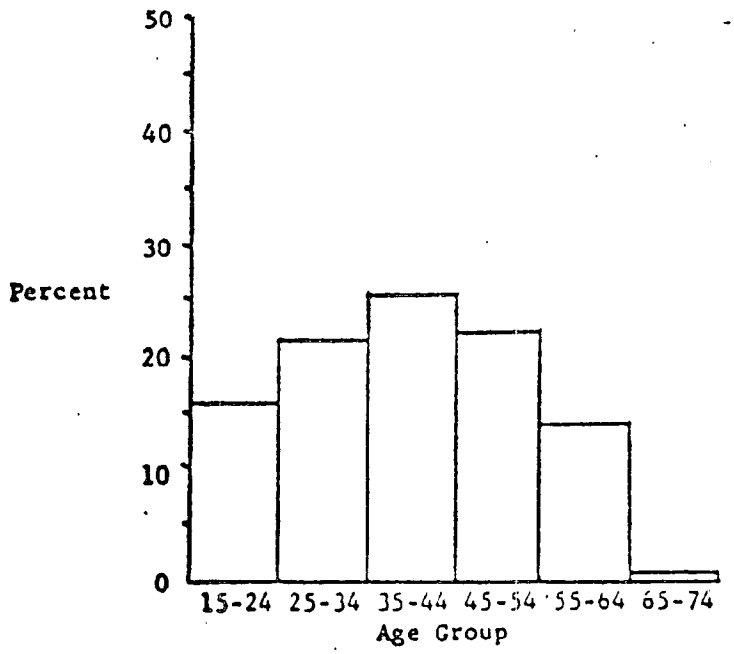


Figure 3

Percentage Distribution by Age at Entry*into Study, for 20163 Petroleum Refinery Workers



*Entry into study was on January 1, 1963, or one year after hiring, whichever was later.

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Tabershaw-Cooper Associates, Inc.
2180 MILVIA STREET, BERKELEY, CALIFORNIA 94701
MAILING ADDRESS: P.O. BOX 772

Irving R. Tabershaw, M.D., President
W. Clark Cooper, M.D., Secretary-Treasurer

Dear

We are a research firm concerned with the health of workers in industry in the United States. We have been asked to study certain occupations in order to determine the health of men who have at one time or another worked in these occupations.

To accomplish this we need to know if those men we are interested in were alive on December 31, 1971. For any of the men who died on or before that date, we need to know the place and date of death. With these facts, we can compare the health statistics of our men with the general population.

To assist us, can you provide information regarding the person whose name appears below? A stamped, addressed return envelope is enclosed for your reply. If you have any questions about our work, feel free to write me at the address above or call collect at (415) 845-3355.

Needless to say, any information you give us is strictly confidential.

Thanks for your cooperation and assistance with this project.

Sincerely,

W. Clark Cooper, M.D.

Name: Birthdate:

Was above named man alive as of 12/31/71? _____

If deceased prior to 12/31/71:

Date of death _____

Place of death (city and state)

_____

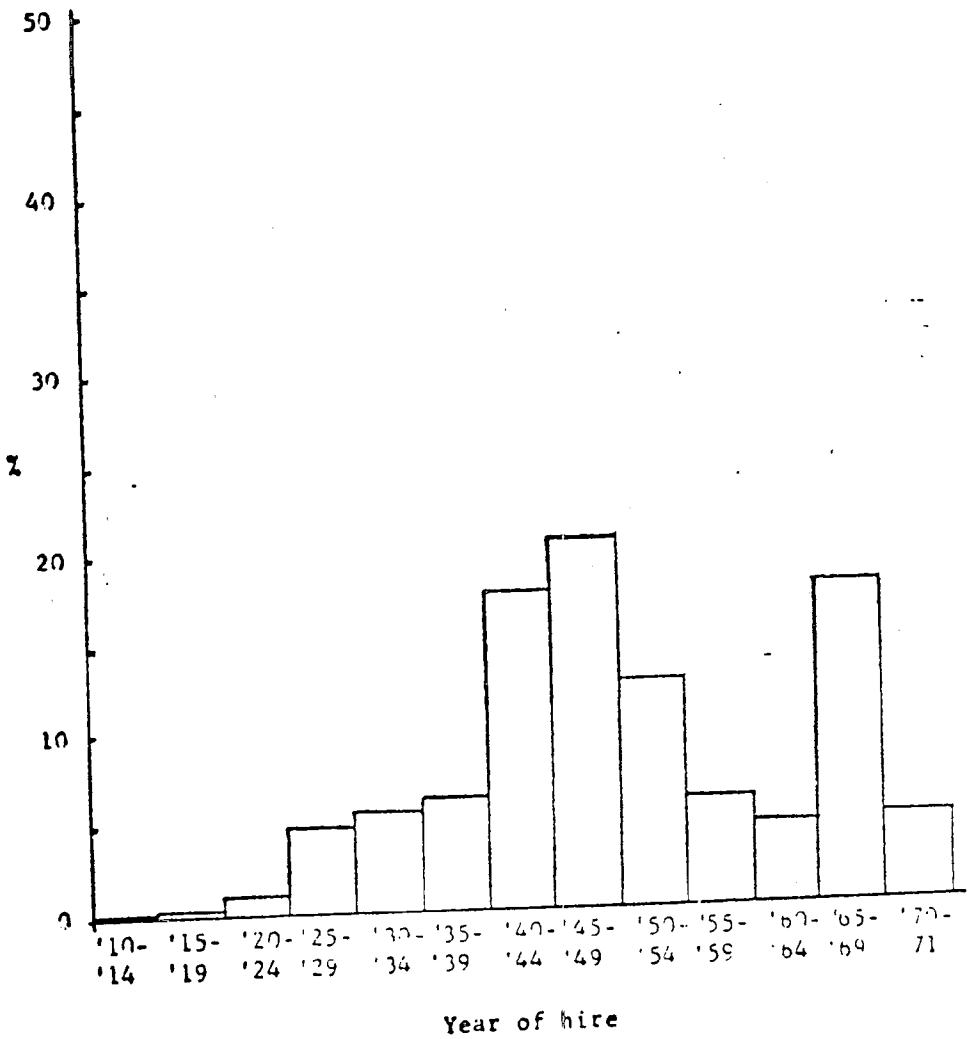
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ATTACHMENT A

DBZ0014197

Figure 4

Percentage Distribution by Date of Hire
in Five Year Increments
for 20163 Petroleum Refinery Workers



DBZ0014198

Tabershaw-Cooper Associates, Inc.
P.O. Box 772
Berkeley, California 94701

Recently we sent you a letter requesting information to complete our health research stu
Please help us by filling out the attached card
No postage is necessary. The information you give us will be kept strictly confidential.
Thank you for your cooperation.

Sincerely,

W. Clark Cooper, M

Tabershaw-Cooper Associates, Inc.
P.O. Box 772
Berkeley, California 94701

return postage guaranteed

Name:

Birthdate:

Was above named man alive as of 12/31/71? _____

If deceased prior to 12/31/71:
Date of death _____

Place of death (city and state)

_____

BUSINESS REPLY MAIL

Tabershaw-Cooper Associates
2180 Milvia Street
Suite 104
Berkeley California 94704

DBZ00141199