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For questions concerning this correspondence, plese contact Fred Marashi at 918-661-8153.

Very truly yours,

Barbara J. Price
Vice President
Health, Environment & Safety

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Phillips Petroleum Company

CAP Identification Number: 8ECAP-0075
Pursuant to Category: II.B.2.b

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Title of Study: Mortality of Workers in the Styrene-Butadiene Rubber Polymer Manufacturing Industry

Name of Chemical: Styrene and Butadiene Rubber

CAS#: 9003-55-8

Summary: This is an account of an epidemiology study in eight rubber plants in the U.S. and Canada, all of whom produce styrene-butadiene rubber polymer. The study population included males who worked more than one year and whose records included dates of employment and birth. The analyses indicated no significant excesses in mortality for all causes for specific diseases in the total population. There were some cancer sites which were associated with higher SMRs for white males than the overall mortality ratio of 0.78. These indicate areas that need further investigation. The only significant elevated risk identified was in the population of black males for arteriosclerotic heart disease with an SMR of 1.28.

Fiche # 1936

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FINAL REPORT

Mortality of Workers in the
Styrene-Butadiene Rubber Polymer Manufacturing Industry

Prepared under contract to:

International Institute of Synthetic Rubber Producers, Inc.

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Report of Synthetic Rubber Manufacturing Study

Introduction

Many studies in the past have indicated specific health risks which have been associated with the "rubber industry." Most of these studies have not distinguished between the various steps in the manufacture of the original synthetic rubber polymer and the eventual production of rubber products. Often the studies have included all steps from the manufacture of the synthetic polymer to the production of tires or other goods. Previous studies have also included both individuals who worked with natural rubber as well as with synthetic rubbers. Many of the risks which were identified were attributed to steps in the production of goods which would include exposure to multiple materials besides the rubber itself. It was difficult from such studies to determine whether there was a risk from the rubber itself or from the materials used in manufacturing rubber products. A recent NIOSH report has suggested that a risk might be associated with rubber itself. The current study was undertaken to determine whether the production of synthetic rubber, especially styrene and butadiene rubber, is associated with any health risks.

Literature

In the study of occupational disability based on Social Security data from the early 1960's, the morbidity of workers in the rubber industry appeared to be high for malignant neoplasms of the respiratory system, chronic rheumatic heart disease, emphysema and arthritis (1). A study based on the occupations as listed on death certificates in the 1950's indicated that rubber workers aged 20-64 had an increased risk of dying of malignant neoplasms of the colon, respiratory system and the lymphatic and hematopoietic system as well as an increased risk of arteriosclerotic heart disease and chronic rheumatic heart disease (2). Mancuso, in the same period of time, indicated that the proportional mortality of rubber workers in Ohio was high for cancers of the respiratory, genito-urinary and central nervous systems (3). When he expanded this study into a cohort analysis from 1940 through 1964, he found that the death rates for production workers were higher than those of office workers for malignant neoplasms, especially those of the stomach, and diseases of the circulatory, respiratory, digestive and genito-urinary systems (4). As indicated above, most of these workers were probably primarily engaged in the manufacture of end-use rubber products.

Extensive studies of the rubber products industry were undertaken by groups of investigators at North Carolina as well as at Harvard. The study under the North Carolina investigators included all workers who reached the age of 40 or beyond in 1964 who had subsequently been followed for their mortality experience. This study included active workers as well as retired workers (5). The population included individuals who worked in a large tire manufacturing plant in Akron. The data suggested that these workers had an increased risk of lymphosarcoma, leukemia, and stomach cancer and a significant reduction in the risk of accidents and respiratory system tumors. The excess of leukemia was seen only in individuals under the age of 64. The mortality from prostatic cancer was also higher than expected. The cancers were frequently associated with work in areas where compounding, milling, calendaring, extrusion and cementing were in progress. These areas were associated with the beginning production of tires where exposure to chemicals and dusts both from the rubber and the other materials used in product manufacture were possible (6). Cancers of the lymphatic and hematopoietic system were found among the receiving and shipping group, the compounding and mixing, inspection, finishing and repair groups and in the synthetic plant. The excess mortality from lymphatic leukemia was associated with the same groups with the exception of receiving. Arteriosclerotic heart disease was associated with extrusion and cementing as well as work in the synthetic plant, but the deaths were restricted to individuals in the young age groups between 40 and 54. The authors have suggested that the excess mortality from lymphatic leukemias might be associated with solvent exposure in areas of repair and finishing (7).

The study from the Harvard group of investigators also included plants in Akron, Ohio where tire and rubber products and synthetic rubber were manufactured. Workers who had been employed for five years or more within the rubber industry were selected as the cohort population (8). These investigators also found excesses associated with specific areas of the plant. Processing jobs were associated with an excess mortality from intestinal and stomach cancer; tire building had an excess of bladder cancers, brain tumors and lymphatic cancer and myeloma. Excess leukemia mortality was related to work in processing and tire manufacture. Pneumonia was excessive in the tire curing area.

Most of the studies described did not separate risks that might have been due to exposure to the rubber polymer used in the manufacture of rubber products and the multiple other materials and chemicals related to production. Reviews of the toxicity of the basic materials styrene and butadiene suggested that further investigation of the possible health effects fr. potential exposures to these agents would be warranted as noted in the [illegible]ational Agency Research on Cancer (IARC) monographs concerning styrene (9). [illegible] usual effects of this chemical on humans related to neurological and psychological disturbances but the finding of chromosomal aberrations in workers exposed to styrene indicated a need for concern related to possible carcinogenic effects. A summary of possible hazards associated with exposure to butadiene have been summarized in an Environmental Protection Agency (EPA) report (10). Effects on the gastrointestinal system, liver, blood, lipid metabolism, circulation, skin, nervous and respiratory system were noted in reports in the Eastern European literature. Similar reports and concern did not appear in the U.S. and Western European literature. More recent studies will be included in an updated summary of the literature (11).

A recent study by NIOSH (12) has undertaken to investigate possible hazards associated with actual production of the synthetic rubber polymer. The study was conducted in two plants in the Port Neches, Texas area. The total study population who were exposed for six months or more to the manufacture of the rubber was 2,756. The overall mortality was about 80% of that expected for the total U.S. in plant A and 66% in plant B. In the total population for plant A there was a significantly lower mortality from diseases of the lymphatic and hematopoietic tissues especially lymphosarcoma and leukemia than one would expect based on U.S. rates. Plant B had small increases in mortality from lymphosarcoma and from cancers of the male genital organs. None of these differences, however, was significant and in both plants the total numbers of deaths were relatively small. For plant A the investigators separated the population into two cohorts, those who began work between 1943 through 1945 at a time when the synthetic rubber industry was just beginning and those who were employed in a later period. In the early cohort the SMR for tumors of the lymphatic and hematopoietic tissue was high and almost reached significance with a probability between .05 and .1. The SMR for leukemia was 2.78. Although the findings were restricted only to one plant and one cohort group within the plant, the findings did cause concern since the group of workers with the excess would have had the early exposure to SBR polymer production. These data would suggest that exposures to basic substances in the manufacture of synthetic rubber, such substances as styrene, butadiene or other chemicals might be associated with a hazard. In order to examine these issues the current epidemiologic study was undertaken.

SBR Polymer Manufacture

The synthetic rubber industry actually did not exist until 1943. At that time the federal government undertook to construct 15 plants in the U.S. all of which had similar design and all of which were committed to the manufacture of styrene-butadiene r bber. An additional plant was constructed at that time in Canada. The governmental Rubber Reserve Company under the Reconstruction Finance Corporation undertook responsibility for these plants although they were operated by privately owr d rubber companies. Most of the basic processes used in these plants were similar as was the general construction of the plants. Eventually the plants were sold to the individual rubber companies and it is these plants and one in Canada with which the NIOSH and the current study have been concerned. One additional plant has been studied which was built in a later period, 1957, but which has similar design and is also manufacturing styrene-butadiene rubber (SBR). Thus, we have a unique situation in which we are able to study an entirely new industry with a similar plant design, process, and product across all manufacturing sites. Over time these companies have begun to manufacture various other types of rubber but in general their major product is still styrene-butadiene rubber. The workers exposed to these substances should have been relatively young at the time of first start in the new industry and should have had no previous exposure to manufacturing processes. Many of the plants were constructed in the same geographic area because they obtained

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butadiene from the petroleum industry located in Louisiana and Texas. Those that were not near petroleum sources of butadiene usually made this substance from alcohol. By 1944 these plants were producing about 7,000 long tons of rubber per year. The current study will describe the manufacture of rubber in eight of these plants.

The basic method of production of synthetic rubber in these plants was through the reaction of an aqueous emulsion of butadiene and styrene in the presence of a soap solution, polymerization initiators, and regulators to form a high molecular weight polymer with elastic properties (13). Initially, this reaction was carried out at high temperatures (so-called hot rubber), about 50 degrees centigrade, and a pressure of about 60-50 p.s.i. The reaction is usually carried to partial completion at which point it is terminated by the addition of a chemical called "shortstop." Any unreacted monomers of both styrene and butadiene are recovered or "stripped" from the latex. The latex is then coagulated, washed, dried and packaged. The basic materials which are used in the reaction are shown in table 1 (14).

Two major changes took place in most of the plants in the early operations. These were a change from batch to continuous-feed manufacturing process and the addition of low-temperature rubber production. Cold rubber production was begun in the late 1940's to early 1950's in most plants with the temperature of the reaction being reduced to about five degrees centigrade. The ingredients for cold rubber production are listed in table 2 (15). This formula is very similar to that listed in the recent NIOSH report (12). Both hot and cold polymerization were carried out in these plants. Extender oils may be added to high viscosity latex during the coagulation step in the cold rubber production (16).

A new process called solution polymerization rather than emulsion polymerization has been developed which allows the conversion level of monomer to reach about 90% with the use of stereospecific Ziegler-Natta or alkyllithium catalysts in an organic solvent (17). The basic steps in the process are quite similar to those used in emulsion polymerization.

The operations included in the manufacture of SBR polymer are divided into five major areas. The "tank farm" area where the monomers of butadiene and styrene are stored in tanks is usually located in an area remote from the general plant activities and materials are piped from this location into the plant for use. The butadiene which is a gas under normal temperature and pressure requires storage in pressurized tanks. Before using the butadiene from the "tank farm," it is necessary to wash it with caustic to remove the inhibitor which has been added to prevent the active polymerization of the monomer itself. The inhibitor in styrene is not removed because it has a negligible effect on the activity of the styrene and butadiene. The monomers which are recovered from the reacted latex through stripping are mixed with the appropriate pure material and recycled into the manufacturing process.

In the pigment preparation area, solutions of soap, catalysts and antioxidants are made up for use in either the reactor area or finishing area. The chemicals which are involved in these operations include the soaps which are mixtures of fatty acids, usually sodium-based, the catalysts which might be hydroperoxides or peroxysulphates, and the "shortstop" solutions which might be hydroquinones and sulfites or dimethyldithiocarbonates (13). The antioxidants, originally phenyl-beta-naphthylamine or a reaction product of acetone and diphenylamine (13), were also prepared in this area for use in the finishing process.

The reactor area is the location where the polymerization takes place in glass lined water-jacketed steel reactors. The materials in the reactors which are under constant agitation are allowed to polymerize to about 60-70 percent reaction. At the time of discharge from the reactors "shortstop" chemicals are added to terminate the reaction. The latex is then delivered to the blowdown tanks for holding.

In the recovery area the unreacted monomers are recovered from the latex. Butadiene is recovered through a distillation process. Styrene is removed by low pressure steam "stripping" on a column.

The final area of the processing is called the coagulation and finisning area. In this area the latex is stored in large tubs and the antioxidant emulsion is added for preservation of the product during the drying process. The latex is then coagulated through the addition of a brine and concentrated sulfuric acid. With the change in the pH most of the soap is converted into fatty acids. Following this procedure the crumbed product is washed and subsequently shredded, dried, and baled. It is dusted with talc and packaged in plastic wrappers to store for shipment.

Many of the plants visited produced forms of rubber other than SBR. They either did this in separate operations or buildings or in the same operation but at different points in time. Some plants even produced plastics.

The plants also varied according to the additional support operations which were present on site as, for example, antioxidant manufactures. None of these additional operations were very large or included a substantial number of employees. Most plants had a "pilot" processing plant in which new procedures or changes in the current manufacturing processes were tested experimentally. The number of employees in these special operations were also very limited.

Description of Current Study

A. Study Population

The current study assesses the mortality experience of workers in eight rubber plants in the U.S. and Canada, all of whom produce styrene-butadiene rubber polymer. All the rubber plants involved in the study provided the research team direct access to their records. Thus all information which is included in the following report has been obtained directly by the research team from plant records or from those of outside agencies such as Social Security.

The personnel records for each facility were filmed on-site. The available data for each individual included employee name, social security number, information on job history, time of employment as well as birth date and any death information. Records of retirees from the industry, although limited, were also filmed.

The information available from these records was abstracted and placed on a computer tape. The information on jobs was classified into general work areas within the industry and jobs within each area were combined according to related work activities as observed during the initial on-site visit. Further evaluation of this job dictionary should be completed by industrial hygienists from the industry. An individual's jobs were coded according to first job, last job, and longest job held during the period of employment. In the analysis jobs were combined into the four general work areas for comparison, production, utilities, maintenance, and other jobs. Dates of first and last employment were included for determining total duration of work within the industry.

In reviewing the dates of duration of employment of individuals during the analysis, it was determined that records were not complete from the beginning of operations at all plants. In one plant, only blue collar workers' records were included. In three other plants, records had not been retained throughout the period of operation of the industries. In the analysis, we have determined the point at which records appear to be complete for all individuals within the plant. This was done by determining from which point in calendar time forward there were records of workers with both long-term and short-term employment. For example, if we examined employee records for

for 1955 and found that all workers had been employed five years or more then we would know that the records are incomplete for about five years after 1955. We have found the start date for cohort analysis within each of the industries using this method of duration of employment.

The population was followed for vital status by several means. The first method was through the Social Security Administration (SSA). Two submissions of records were completed for the Social Security identification of deaths. This was done both to update the population records through December, 1979 and also to identify those who were assumed living by the Social Security as distinguished from those whose records were unmatched. In the initial submission, the SSA had only identified the deceased members of the population. In the second submission, the SSA separately identified those who were probably alive because they were paying or collecting Social Security benefits, the additional deaths and the population whose vital status could not be determined by the records. The second method of identification of vital status was through the Motor Vehicle Administration in the states in which the plants were located. These systems could not be used to determine the vital status of the Canadian workers. To determine how many individuals were actually deceased of those identified as living by these record systems a direct follow-up of a sample of these U.S. and Canadian workers was completed and will be described below. In addition, all individuals who were unmatched were searched through telephone directories and motor vehicle departments from the local area to determine vital status.

For any individual who was identified as deceased the death certificate was sought from the local health department. The underlying or primary cause of death as well as all other causes of death were classified by a nosologist according to the 8th revision code of the International Classification of

Diseases. Only the primary cause has been used in the analysis so that the coding of deaths would be similar to those of the U.S. population which was used as comparison. For any individual who did not have a cause of death at the time of analysis because a certificate had not yet been received, the individual has been listed as deceased with cause of death undetermined.

The method of follow-up of workers in the Canadian plant was different than that of the U.S. workers since there has been no national insurance system until recently. Most of the personnel records in Canadian rubber plant did not include the numbers related to the Canadian benefit system unless the employee was a recent or current worker. Deaths of workers from the Canadian plant were identified through their own insurance plan which paid a death benefit for anyone who had worked for three years or more in the plant. This benefit was explained to all individuals who were terminating employment with the industry. Since the data from the Canadian plant indicated a similar overall mortality to that of the U.S. plants it was felt that ascertainment of death through this system was very good. Direct follow-up of assumed living in both U.S. and Canada indicated that we missed about the same proportion of deaths through either the U.S. or the Canadian system.

The study population includes males who worked more than one year and whose records included dates of employment and birth. Table 3 indicates the proportion excluded for reason of sex, year of first employment, duration of employment and missing data on dates of employment and birth. Each descending category is exclusive of all workers omitted in preceding categories. Thus, if females are excluded in the first category, all omissions of workers who were employed less than 12 months would be males. Females and short-term workers were excluded because of the difficulty in identifying deaths in these groups. It was also felt that the total exposure to chemicals used in rubber polymer manufacture would have been brief and therefore, probably less important in the total work history of the individual.

Information on race was limited in two of the plants where we would have expected a racial mix (table 4). In one case the total population was not complete from the beginning of processing and the numbers were small. In the second case, the population was three times larger and inclusion of the unknown racial group as white could have influenced the findings. This factor would be particularly important in assessing mortality in the black population. Individuals would be classified by race on the death certificate and thus would correctly designate race for the numerator of the mortality rate but the denominator would be undercounted resulting in an inflated mortality. In order to control for this factor mortality data for the black population had been examined for all plants and for those where information on the racial composition of workers was complete in order to determine whether the findings were similar.

The dates of first production are indicated for each of the plants in table 5. In all cases we have excluded any worker whose records indicated he left employment before the start of production on the assumption that he may have been involved in planning or preparation but not actual processing.

The total number of personnel records which were available for analysis are indicated in table 3 and were 29,179 (table 3). Following the exclusions a total of 13,920 workers or 48 percent of the original group would have been eligible for study. In some of the analyses we have utilized this total population which we classified as cohort II (table 6). When examining the employment characteristics of workers, it appeared that records for early workers were often erratically retained, as seen in table 7, however, we could identify for each plant the year from which record-keeping was complete. Therefore, we have done analyses using two other cohorts, one in which only individuals who started employment after the beginning of complete record-keeping would be included (cohort III on table 6) and one in which all individuals who were employed at the time of the start of complete record-keeping or anytime thereafter were included (cohort I on table 6). Most of the analyses have been done using the worker records defined in Cohort I since that provides the largest population which can be completely identified. In most cases, the conclusions did not differ depending on the definition of the cohort for study.

Follow-up Study

Following identification of deaths through two searches by the Social Security Administration, there were several groups of individuals for whom we still had no information on vital status (about 12%). The first group were 673 individuals who had no or an incorrect number or whose vital status could not be determined by SSA. This would include individuals who were not paying into SSA but had not requested any benefits or submitted a death claim. Their status was unknown. The second group were current workers when we determined the total population and were never sent through SSA. Since the second SSA search included follow-up through 1979 we wished to know the extent of the error if we assumed these workers are alive. These workers numbered 952. For the group assumed living but not employed in 1981 we have selected a 10 percent sample in each plant for a total 553 employees and included them for active follow-up.

Individuals were traced by telephone listings, motor vehicle administration address and last known plant addresses. Telephone verification of worker status was completed before attempting to send a questionnaire. The vital status of the worker was obtained on telephone contact. The questionnaire included data on smoking history, other jobs, and exposures. However, these data have not been analyzed.

We were unable to locate a high percentage of the population using these limited means in the time available. As seen in table 8 only 42 percent of the follow-up group could be traced. Additional methods of tracing could have been completed but with each method the number of additional contacts are usually few and the time required for the effort increased. Of those located we found that about 4 percent of the population which we assume are living are actually dead as shown in table 9. The proportion is slightly higher for those who are unmatched in the Social Security searches than in those we assumed were living. There is little difference in the misclassification rate between Canada and U.S. despite the variation in the method of determining deaths.

The final classification of vital status by plant is indicated in table 10. After correcting the data for vital status as determined by telephone contact and adding a further update for those whom the company knows to be alive through current active employment or retirement, we are left with 10,899 workers known alive, 2097 known dead, and 924 whose status is unknown. For the total group of workers we know the vital status for 93.4 percent of the population. If four percent of terminated living workers are actually dead, then the overall error is probably less than this since current workers are also included in that category. However, if the percent is as high as calculated we might have missed as many as 440 deaths or 17 percent of the total possible deaths. Most studies of occupational groups have not attempted to determine the error in vital status. If the missed deaths are proportionally distributed over all causes then the relationship of each cause to the total mortality will not be altered.

When we terminated data collection we had received 90 percent of the death certificates requested. The completeness of cause of death information differed only slightly by plant with 83 to 96 percent of certificates received.

Method of Analysis

In order to calculate the standardized mortality ratios for workers compared to the general population, a computer program developed by Monson was used. In this program the death rates for U.S. males, white and black, are applied to the total person-years of life in each racial group of workers to determine an expected number of deaths which would have occurred had the rubber workers died at the same rate as the general population. The program uses rates for all deaths as well as for specific causes of death. The calculation not only adjusts for differences in the population by age but also adjusts for calendar time since death rates, especially for specific causes, may change rapidly over time. Therefore, the standardized mortality ratio (SMR) as reported is the ratio of the actual deaths to the expected number of deaths based on U.S. rates adjusted for age and time. The program was modified in order to apply to the population as defined for inclusion. Since we did not include anyone who had worked for less than a year in the plant, it was necessary to withdraw from follow-up all individuals for the first year of their work since they were not at risk of death during that period. Thus, if a man started in 1953 his person-years of follow-up could not start until 1954. This "lagging" modification was applied to all analyses. The period of time from first employment to the time of withdrawal from the study either by death or by termination of the study has been calculated and termed as the period of latency. This period must include the time fr[illegible] first entry into the plant rather than the beginning of the period of follo[illegible] one year later. Every worker, therefore, has had at least one year in which [illegible] [illegible]lop disease or one year of latency.

Analysis was done separately for each of the cohorts defined in table 6. In addition, SMRs are calculated for the white population and the black population and then the ratios were combined. This meant that total ratios were corrected or "controlled" for differences in age, race and calendar time. Plants 3 and 4 had incomplete identification of race for the employed population. Ther-`-re, an analysis was carried out in the three plants which had a black population which represented 10 percent or more of the total population and has complete racial information (plants 6, 7, and 8). The cohorts in these plants have been followed since 1943 and the information on all characteristics within the plants were complete. Therefore, an analysis of the 1943 through 1945 cohort was done in order to provide a comparable analysis to that which NIOSH had reported.

Most of the following analyses will be done with the population of workers who were employed at the time of start of complete record-keeping or who were hired after that time (cohort I). This population will be referred to as "rubber workers" which in this case means employees in the SBR polymer manufacturing. The group was followed from the beginning of the plant production or the time of start of records. The data in table 12 indicate the age distribution and year of entry for both the racial groups. The total eligible population has been reduced by about 312 when the records from incomplete years are excluded for four plants. A total of 1995 deaths have occurred in this cohort through 1979 with the SMR of 81 percent of the value f r the general population. The SMRs calculated for each of the other cohorts l ed in table 6 were almost the same.

.c he black and white populations have been followed on the average about 19 t. : years since the time of first employment. The average age of start is somew. : older than one might expect but this may reflect the older ages of persons staiting work in the early years of the industry. The average

age at death of this population is relatively young, 61 years, which is a reflection of the overall young age of this population. This, in turn, reflects the recency of the development of the industry. Most workers have not yet experienced the high mortality of old age.

The standardized mortality ratios by calendar time are presented in table 14. The overall SMR for black males is slightly higher than that for white males but the combined ratio for both populations is lower than the overall rate for the U.S. males. The overall SMR for each calendar time period is lower in the earlier periods than in the later periods. The low mortality in this population and the increasing mortality trend with time are reflections of the "healthy worker effect" which is most marked in the early periods of employment when the selection process has the strongest influence. That is, immediately after hiring the mortality of workers has lower death ratios compared to the U.S. population and subsequently the ratios rise to become closer to that of the general group. It should also be noted that the ratios for the period 1975-1979 are somewhat lower than in the previous period 1970-1974, even though there had been a steady rise in the ratios prior to that time. This may reflect some missing deaths which were not known to Social Security in the later years. If most of the three to four percent deaths which we found in the assumed living were actually occurring most frequently in the later time periods as we observed then the ratio may be approaching unity.

The standardized mortality ratios by duration of employment and latency or duration of follow-up for the white and black populations are shown in table 15. The data in these tables indicate that the standardized mortality ratios do not appear to increase with the increasing duration of employment but do appear to increase with increasing latency period. In most cases a rise in the mortality ratios in relation to longer periods of employment would signify an assumed "dose-response" relation. The more exposure one had to the industry the greater the risk of death. Instead, in this case, we see a peak about 20-24 years after first exposure. Small numbers in the groups with longer employment may have influenced the ratios. An increase in mortality ratios correlated with latency is more difficult to attribute to exposure within the industry but it may signify an exposure to a toxic material at some point in time and a long period subsequently before disease appears. After about 15 years of latency, the mortality for black males is equal to or exceeds that of the general black population of the U.S. In the white population the standardized mortality does not exceed that of the general population until 35 years of latency have passed although it approaches the U.S. rates about 10 years earlier. These data would suggest that, in an industry as young as that of synthetic rubber polymer production if the latent period for all causes of death is somewhere between 25-35 years after first exposure to the industry, we may not have followed these populations long enough to have identified all the potential hazards.

This relationship of time and mortality is much less impressive than the inter-relationship of duration of employment and latency. As long as the individual is employed or has been working during the same five-year period as his follow-up, he has a very low risk of death compared to the general population. Once he has left employment for about three to five years, there is a sudden increase in mortality. It would be of interest to investigate whether the individuals left the industry because of illness and this increased the post-departure SMR. It is possible that other experiences after leaving the industry also contributed to the risk.

The standardized mortality ratio for selected causes of death are indicated in table 16. The overall ratio for all causes of death in white males is 0.78, a ratio which represents a significantly lower mortality among the rubber workers than in the general population. The mortality ratio for malignant neoplasms is slightly higher with a value of 0.82 but it, too, is a ratio which is significantly below that expected on the basis of the general population. In fact, most of the values seen in this table are significantly below the death rate for that disease in the general population. Since so many ratios were low, we have chosen not to designate those that are significantly low since these figures would not be relevant. There are no causes of death which are significantly higher than one would expect in the general population for white males. According to the accepted procedures in most occupational studies (18) where the ratio for all causes of death is low, a further investigation of causes which are at or slightly above the level of the general population is considered worthy of study. In this case, the sites of interest would include some cancers of the digestive organs, cancer of the larynx, possibly cancers of the testes and kidney, and Hodgkins disease. These diseases all demonstrate a mortality ratio near or above the level of that condition in the general public even though, in general, rubber workers have had a mortality only 78 percent of that of the U.S. white population. This concern is based on an assumption that all diseases should be lowered to the same degree in working populations. That is probably not the case. Thus, further investigation may not reveal any specific exposure in the industry which is associated with these conditions. It would be helpful if we could compare this population to another with a low overall mortality experience. The professional groups we have under study have a comparably low mortality and might be suitable even though they differ socioeconomically.

The standardized mortality ratio for all deaths for the black population of rubber workers is similar to that of the general population of blacks in the U.S. with an SMR of 0.98. Since this population is very small there are very few rates which show a significantly high or low value despite the fact that there are several ratios which are above or below the expected ratio of unity. (A ratio of the unity would suggest that the rubber workers had the same expected risk of death from a specific cause of disease as did the general black population in the U.S.) The only ratio which is significantly higher than the expecced is that of arteriosclerotic heart disease. The risk of death from this disease is 28 percent higher in the rubber workers than in the general population. Several other ratios are somewhat high and may need further investigation but the ratios are based on very small numbers. For those causes which have five or more deaths, the elevated ratios include stomach cancer, lymphopoietic cancers, and vascular lesions of the central nervous system.

The ratios for the total population are not significantly different from the overall U.S. males. In the combined population rates, the white male group is so much larger than the black that all of the findings are similar to those for the white population alone.

The increase in arteriosclerotic heart disease in blacks may be related to the fact that some of the plants did not have complete data on the racial distribution of all workers. Under these circumstances we may be over-estimating the number of deaths among blacks compared to the denominator of black living population. The correct race among deceased individuals could be identified from death certificates but the only way to identify race in the living population was through personnel records or direct contact. Some plants did have complete records of racial distribution. In the three plants in which race was identified on personnel records, we have examined the overall SMR for the black and white populations. Although the SMR for the white population increased to 0.83 for these plants compared to 0.78 for all workers, the ratio for the black has dropped from 0.98 for all plants to 0.81 for these three plants. This would be expected if the condition we described had influenced the observed ratios in blacks. The standardized mortality ratios for specific causes of death in blacks have also decreased in these three plants compared to the total. The black population did not have a significant excess of arteriosclerotic heart disease. Thus, some of the high ratios in blacks was perhaps due to the biased identification of race in the deceased. The standardized mortality ratio for heart disease in the black population, however, is still higher than one would expect based on total U.S. rates (SMR = 1.11). The excess cancer ratios for specific sites seem to be similar to those seen for all workers. It is apparent, however, that these three plants differ from the total population in regard to their risk of mortality for several diseases in both the white and black populations. Therefore, any variation may indicate that the plants have differences in risk depending on their operations or on local characteristics of the populations such as ethnicity. It is also possible, since none of these diseases have significantly high death rates and since there are inconsistencies in the findings in the groups, the differences may simply reflect the normal variability which one might expect in taking multiple samples from a single population.

The analysis of the population of workers using other definitions of cohorts for study (table 7) did not cause marked changes in previous conclusions. There were no significantly high mortality ratios except for arteriosclerotic heart disease in black males. There were excessive ratios for specific causes of death which would warrant investigation such as the cancers of the digestive organs, larynx and kidney in white males and, in addition, cancers of the liver, prostate and lymphatic system in black males. The mortality ratio for vascular lesions of the central nervous system was also high in the black workers.

In table 17, the range of SMRs for specific causes of death for white males are recorded in order to examine possible differences related to sampling variation. The numbers in any single plant are very small but a persistently high SMR for a disease in all plants might suggest that this cause of death was more important to investigate than others. This did not seem to occur with any cause.

It seemed possible that higher mortality ratios for arteriosclerotic heart disease in black than in white males might result from differences in exposure by race. The range of jobs assigned to white populations might have had more variability, have involved less exposure to potential hazards and have represented a higher socio-economic level that those assigned to black males. To test this hypothesis we have examined white and blue collar workers according to the specific causes of death in table 18. The classification scheme was based on last job held. We have also recorded first and longest job held as well and for most men all three classifications were the same. Thus, most workers had only had one job according to the coding scheme used. Those causes of death which were of interest in previous discussions are noted in the table. The numbers of blacks in white collar jobs are few. The overall mortality ratios do not indicate much difference in death rates despite differences in socio-economic status. The excesses of cancers of the digestive organs appear to be more common among blue collar than white collar workers. Deaths from cancers of the kidney and testis have all occurred in blue collar workers. The small excess in death rates from chronic rheumatic heart disease and chronic nephritis are associated with white collar jobs.

The workers' jobs were classified into four large groups so that each class would contain sufficient numbers of workers to allow for adequate sample size to determine specific risks within the groups. The data are presented in table 19. The total population in this table is less than in table 18 because only workers with specific jobs listed in each of the four work areas have been included, whereas, blue collar jobs included all job classifications which were not defined as white collar. Both tables have eliminated workers for whom no job or work area was listed.

In the production area the mortality ratio for all causes is slightly higher than the ratio for the total population. There are no ratios that are significantly higher than one would expect based on the U.S. population but there are some which are above the overall risk of mortality in the group and, therefore, deserve further attention. These conditions include the cancers of the lung, prostate, kidney, and the lymphatic system. Hodgkins disease appears to have high ratios in all work areas and, therefore, may represent a common exposure or perhaps an artifact.

In the utilities area which includes the refrigeration and power plants, the number of workers are small so it is more difficult to determine the importance of excess ratios. Cancer of the larynx occurs significantly more often in this group of workers than in the U.S. population. According to these findings the risk of this cancer is 4.7 times higher in rubber workers assigned to the utilities work area than it is in the general population. Cancers of the digestive organs and diseases of the respiratory system have high ratios which are not significant. Several other diseases also occur in excess in this group of rubber workers but the numbers are too small to be able to evaluate whether these findings are important.

The workers in maintenance which includes pipefitting, electrical work as well as tank cleaning have a significant excess of testicular cancer with all three cases in the population occurring in individuals from this work area. There are high ratios for cancers of the digestive organs especially cancers of the stomach and large intestine, cancers of the lung and chronic nephritis. There is an increase in the mortality ratio for leukemia not only in workers assigned to this area but also those in utilities and other jobs, except production. Thus if there is an increased risk of leukemia in rubber manufacture as suggested in the NIOSH study, it would not seem to be related to an exposure to styrene or butadiene. The NIOSH study indicated that the highest level of exposure to these chemicals was usually in the production area although occasionally workers in other areas such as maintenance had exposure to butadiene (19).

Work in areas other than production, maintenance and utilities was associated with a significantly increased risk of cancer of the liver. The mortality ratios for cancers of the bladder, larynx, and brain are elevated compared to the overall mortality ratio but the numbers are small and thus excesses may not be important. Disease of the nervous system and vascular lesions of the central nervous system are also elevated in this work group but the excesses are not significant. There is a significant excess mortality from chronic rheumatic heart disease and an non-significant excess of chronic nephritis. Since the rheumatic heart lesions and some cases of nephritis are caused by streptococcal infection it is difficult to determine how these lesions could be associated with work in the rubber polymer manufacture. We must suppose that individuals with these medical conditions were selected for work in this industry perhaps because the work was light. In view of this finding we also must examine more closely the findings for all work groups. With the large number of disease groupings that we have included and four different work areas, it is very likely that some would show an excess and even be significant. Further investigation is needed to establish the validity of the job classifications and then develop a case-control study to see whether these differences are associated with specific jobs. Although in the total population, leukemia did not occur in excess, it was that there were differences in risk by cell-type. Therefore, information on cell-type and characteristics of leukemia were sought from the death certificate. In addition, the specific cell-type was examined for larynx cancer, colon cancer, rectal, stomach and esophagus. This recheck of death certificates also provided us an opportunity to validate the cause of death as they appeared in the analysis. The cell-types for the intestinal cancers as well as the larynx cancers did not show any remarkable difference in cell-type over that expected. Almost all of the lesions were carcinomas. There was no indication of increased risk of unusual cell-types specifically carcinomas among the group who had been exposed to the rubber industry compared to the distribution in a general population. There were nine acute leukemias and five chronic leukemias and three which were not specified as to whether they were acute or chronic. The median duration of the leukemias was 17 years from the time of first employment. The distribution by cell-type were as follows: 6 unspecified, 4 myelocytic, 1 lymphocytic, 1 eosinophilic, 3 blast or stem cell, and 2 monocytic. These types do not have a remarkably different distribution from that seen in the general population.

<u>Summary</u>

The study of workers in the SBR polymer manufacturing industry has examined the mortality experience for males employed for one year or more in eight plants in the U.S. and Canada. Workers have been included if they were

employed at any time from the start of complete records in the plant. Other definitions for inclusion were also used. None of the analyses demonstrated significant excesses in mortality for all causes or for specific diseases in the total population. There are some cancer sites which are associated with higher SMRs for white males than the overall mortality ratio 0.78. These may indicate important health effects from this industry but they need further investigation. These diseases would include cancers of the digestive organs, larynx and kidney, and Hodgkins' disease. The population of black males appears to have a significantly elevated risk of arteriosclerotic heart disease. Vascular lesions of the central nervous system also occurs with increased frequency in black males from this population compared to the general U.S. population but the increase is not significant.

An examination of the mortality of workers according to jobs has suggested several other differences. Testicular cancers are occurring in excess in maintenance workers; liver cancer and chronic rheumatic heart disease in workers who hold other jobs were also excessive. The most interesting observation is the fact that digestive system cancers such as esophagus, stomach and large intestine cancers and larynx cancer appear to be occurring in the utilities and maintenance work areas. This may suggest a common exposure in the two areas. On the other hand, Hodgkins' disease appears to be excessive in all work areas. These findings indicate that, although the overall risk in the industry may be low, there may be specific areas with higher risks. One could also explain some of these differences by area because the large number of diseases investigated for each area may have allowed some fallacious associations to appear.

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Table 3.
Number and Percent of Individuals Excluded from Analysis
By Specified Reasons by Plant

	1		2		3		4		5		6		7		8		Total	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Females	66	9.5	174	9.4	524	9.4	98	8.3	2259	21.7	352	11.1	483	11.2	331	15.5	4267	14.[illegible]
Entry > 1976	17	2.4	51	2.8	53	1.0	46	3.9	124	1.2	3	<.1	6	.1	0	----	300	1.[illegible]
*Exit Before Plant Production	0	----	3	<.1	1	<.1	72	6.1	0	----	1	<.1	0	----	0	----	77	.[illegible]
Worked < 12.mo.	29	4.2	334	18.1	2780	49.8	176	14.9	2216	21.3	997	31.6	1720	39.8	778	38.7	9030	30.[illegible]
Missing Data	102	14.[illegible]	5	<.1	150	2.7	138	11.7	1149	11.1	13	.4	3	<.1	25	1.2	1585	5.[illegible]
Excluded	214	30.7	567	30.7	3508	62.9	530	44.8	5748	55.3	1366	43.1	2212	51.2	1114	55.5	15259	52.[illegible]
Included	482	69.2	1279	69.3	2069	37.1	652	55.2	4641	44.7	1799	56.8	2104	48.7	894	44.5	13920	47.[illegible]
Total	696		1846		5577		1182		10389		3165		4316		2008		29179	

*Some records indicated worker actually left employment before the first processing started. These workers were excluded.

Table 1. SBR Polymerization Formula
Hot Rubber

Butadiene
Styrene
Dodecyl mercaptan
Potassium persulfate
Soap
Water

Short-stop solution
  Hydroquinone
  Sodium sulfite

Table 2. SBR Polymerization Formula
Cold Rubber

Butadiene
Styrene
Potassium soap
Trisodium phosphate
Tamol N
Sodium formaldehyde sulfoxylate
Ferrous sulfate
Versene Fe-3
Para-Menthane hydroperoxide
Tert - dodecyl mercaptan
Water

Short-stop -
  Originally 2,4 dinitrochlorobenzene --
  later dithiocarbamates.

Table 3.
Number and Percent of Individuals Excluded from Analysis
By Specified Reasons by Plant

	General Odessa 1 #	%	American KY 2 #	%	Firestone Lk. Charles 3 #	%	Phillips 4 #	%	Polysar 5 #	%	Copolymer Baton Rouge 6 #	%	Goodyear Houston 7 #	%	Baytown 8 #	%	Total #	%
Females	66	9.5	174	9.4	524	9.4	98	8.3	2259	21.7	352	11.1	483	11.2	331	15.5	4267	14.6
Entry > 1976	17	2.4	51	2.8	53	1.0	46	3.9	124	1.2	3	<.1	6	.1	0	----	300	1.0
*Exit Before Plant Production	0	----	3	<.1	1	<.1	72	6.1	0	----	1	<.1	0	----	0	----	77	.3
Worked < 12.mo.	29	4.2	334	18.1	2780	49.8	176	14.9	2216	21.3	997	31.6	1720	39.8	778	38.7	9030	30.9
Missing Data	102	14.6	5	<.1	150	2.7	138	11.7	1149	11.1	13	.4	3	<.1	25	1.2	1585	5.4
Excluded	214	30.7	567	30.7	3508	62.9	530	44.8	5748	55.3	1366	43.1	2212	51.2	1114	55.5	15259	52.3
Included	482	69.2	1279	69.3	2069	37.1	652	55.2	4641	44.7	1799	56.8	2104	48.7	894	44.5	13920	47.7
Total	696		1846		5577		1182		10389		3165		4315		2008		29179	

*Some records indicated worker actually left employment before the first processing started. These workers were excluded.

Table 4.
Race Distribution by Plant

	1		2		3		4		5		6		7		8		Total	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
White	465	96.5	994	77.7	206	10.0	302	46.3	99	2.1	1369	76.1	1502	71.4	722	80.8	5659	40.6
Black	15	3.1	126	9.9	96	4.6	10	1.6	0	----	423	23.5	201	9.6	120	13.4	991	7.1
Other	1	<.1	1	<.1	0	----	11	1.7	2	<.1	6	0.3	34	1.6	6	.7	61	.4
Unknown	1	<.1	158	12.4	1767	85.4	329	50.4	4540	97.8	1	<.1	367	17.4	46	5.1	7209	51.8
TOTAL	482		1279		2069*		652*		4641*		1799		2104		894		13920	

*Plant 5 had employed few or no blacks at any time in their history. Plants 3 and 4 were known to have employed black workers.

Table 5. First Production Dates for Rubber Plants

Plant	Mo/Yr
1	10-57
2	9-43
3	9-43
4	7-43
5	1-43
6	3-43
7	10-43
8	7-43

Table 6. Definitions of Cohorts for Analysis

All groups - Females, workers employed less than one year, and those with missing birth date or employment date are omitted from all.

Cohort I - All workers employed in each plant at the time the record-keeping system is complete.

Cohort II - All workers employed in each plant whose records were in the system.

Cohort III - All workers who were hired from the time of the complete record system.

Note: Most analyses will be done with cohort I since it provides the largest population which would be appropriate for analysis.

Table 7. Complete Cohort Start Dates

Plant	Cohort Start
1	1964
2	1958
3	1943
4	1970
5	1953
6	1943
7	1943
8	1943

Table 8.
Summary - Contacts Made

	Contacted	Not Contacted	Total	% Contacted
Unmatched/Unknown	265	408	673	39
Not Searched	385	567	952	40
Assumed Living-CN	110	113	223	49
Assumed Living-US	145	185	330	44
Total	905	1273	2178	42

Table 9.
Vital Status of Those Contacted

	Total Contacted	Living #	Living %	Deceased #	Deceased %
Unmatched/Unknown	265	250	94	15	6
Not Searched	385	374	97	11	3
Assumed Living-CN	110	106	96	4	4
Assumed Living-US	145	140	97	5	3
Total	905	870	96	35	4

Table 10.
Vital Status for Population Included for Analysis
By Plant

Vital Status	1		2		3		4		5		6		7		8		Total	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Alive	396	82.1	1037	81.0	1505	72.7	554	85.0	4020	86.6	1380	76.7	1571	74.7	436	48.8	[illegible]	78.3
Deceased	24	5.0	131	10.2	354	17.1	57	8.7	613	13.2	305	17.0	369	17.5	244	27.3	[illegible]	15.1
Lost to Follow-up	62	12.9	111	8.7	210	10.1	41	6.3	8	.2	114	6.3	164	7.8	214	23.9	924	6.6
Total	482		1279		2069		652		4641		1799		2104		894		13920	

Table 11.
Results of Death Certificate Search
for Analysis Population

Plant	Total Employees	Alive	Lost to Follow-up	Known Deaths	DC's Received	% DC's Received
1	482	396	62	24	23	96
2	1279	1037	111	131	125	95
3	2069	1505	210	354	300	85
4	652	554	41	57	49	86
5	4641	4020	8	613	586	96
6	1799	1380	114	305	279	91
7	2104	1571	164	369	307	83
8	894	436	214	244	218	89
Total	13920	10899	924	2097	1887	90

Table 12.
Population Present From Start of Plant Records
By Age, Race and Year of Entry into Follow-up

Cohort I

Age	Year of Entry 1943-1949 W	1943-1949 B	1950-1959 W	1950-1959 B	1960-1969 W	1960-1969 B	1970-1976 W	1970-1976 B	Total W	Total B	Combined Total W & B
<20	267	18	504	8	351	10	319	14	1441	50	1491
20-29	1324	100	1801	104	1975	124	1237	123	6335	451	6786
30-39	1225	128	922	88	651	63	356	46	3154.	325	3479
40-49	596	80	366	45	175	13	130	16	1268	154	1422
50-59	209	41	73	4	28	1	30	3	340	49	389
60-65	21	11	4	1	3	0	0	0	28	12	40
Total	3642	378	3670	250	3183	211	2072	202	12567	1041	13608

Table 13.
Characteristics of Population by Race

Cohort I

	White	Black
Total Persons	12,567	1,041
Average Survival	20.26 years	17.54 years
Average Age of Entry	29.17 years	33.65 years
Average Year of Entry	1,957.69	1,958.36
Average Age of Death	61.01 years	60.88 years
Average Year of Death	1,969.52	1,968.61
Total person-years of follow-up	225,599.6	18,255.8

Table 14.
Standardized Mortality Ratios
by Race and Calendar Time in Cohort I

All Plants

Calendar Years	White Deaths	White SMR	Black Deaths	Black SMR	Total Deaths	Total SMR
<1949	17	0.326	6	0.301	23	0.315
1950-1954	71	0.732	14	0.499	85	0.680
1955-1959	139	0.761	30	0.855	169	0.776
1960-1964	214	0.784	40	0.886	254	0.799
1965-1969	313	0.789	63	1.111	376	0.830
1970-1974	449	0.854	73	1.162	522	0.887
1975-1979	487	0.766	79	1.291	566	0.812
TOTAL	1690	0.782	305	0.984	1995	0.807

TABLE 15.

STANDARDIZED MORTALITY RATIOS BY LATENCY AND DURATION WORKED

COHORT I - TOTAL POPULATION

Latency (Duration of Follow-up) Years

uration orked	10		10-14		15-19		20-24		25-29		30-34		35+		Total	
	Deaths	SMR	Deaths	SMR	Deaths	SMR	Deaths	SMR	Deaths	SMR	Deaths	SMR	Deaths	SMR	Deaths	SMF
10	212	0.459	90	0.726	151	1.087	125	0.841	160	1.166	114	1.045	23	3.121	875	0.7[illegible]
10-14	0	0	129	0.577	49	1.087	44	1.027	40	1.338	16	1.067	2	1.112	280	0.7[illegible]
15-19	0	0	0	0	148	0.630	59	1.008	48	0.976	33	1.100	6	1.671	294	0.7[illegible]
20-24	0	0	0	0	0	0	165	0.764	70	1.213	54	1.355	11	2.028	300	0.9[illegible]
25-29	0	0	0	0	0	0	0	0	124	0.805	57	1.078	15	1.519	196	0.9[illegible]
30-34	0	0	0	0	0	0	0	0	0	0	38	0.600	4	0.961	42	0.6[illegible]
35+	0	0	0	0	0	0	0	0	0	0	0	0	8	1.390	8	1.3[illegible]
OTAL	212	0.459	219	0.630	348	0.831	393	0.843	442	1.033	312	1.006	69	1.817	1995	0.8[illegible]

Table 16 continued

Specific Cause	White Deaths	White SMR	Black Deaths	Black SMR	Total Deaths	Total SMR
Cancer other lymphatic tissue	8	0.82	2	1.68	10	0.92
All lymphopoietic cancer	35	0.80	5	1.41	40	0.85
Benign neoplasms	4	0.67	0	0	4	0.60
Allergic diseases	15	0.42	3	0.56	18	0.44
Diabetes	13	0.43	3	0.63	16	0.45
All diseases blood	2	0.41	1	1.23	3	0.53
All diseases nervous system	16	0.85	1	0.35	17	0.79
All diseases circulatory system	804	0.74	164	1.15	968	0.79
Chronic rheumatic heart disease	19	0.81	1	0.42	20	0.78
Arteriosclerotic heart disease	599	0.77	86	1.28*	685	0.81
All vascular lesions of CNS**	101	0.73	41	1.27	142	0.83
All respiratory diseases	77	0.64	12	0.68	89	0.64
Emphysema	19	0.59	3	1.64	22	0.65
All digestive diseases	48	0.43	13	0.89	61	0.48
Gastric and duodenal ulcers	10	0.65	1	0.55	11	0.64
Cirrhosis of liver	18	0.30	7	0.98	25	0.37
All diseases genito-urinary system	18	0.63	4	0.40	22	0.57
Chronic nephritis	10	0.92	3	0.76	13	0.88
All external causes	135	0.53	32	0.83	167	0.57
All accidents	93	0.55	21	0.97	114	0.59
Motor vehicle accidents	43	0.60	9	1.02	52	0.57
Suicides	30	0.51	3	1.38	33	0.55

* Significantly high ratios with p = 0.05 or less (significantly low ratios not designated) Chi-square test

** CNS = Central nervous system. The majority of lesions in this classification are referred to as "strokes."

Table 16. Standardized Mortality Ratio (SMR) for Specific Causes of Death by Race in Cohort I All Plants

Specific Cause	White Deaths	White SMR	Black Deaths	Black SMR	Total Deaths	Total SMR
All causes	1690	0.78	305	0.98	1995	0.81
All cancers	349	0.83	49	0.96	398	0.84
All infections	13	0.46	6	0.50	19	0.47
Cancer oral cavity	4	0.29	0	0	4	0.25
Cancer all digestive organs	114	0.98	16	0.93	130	0.97
Cancer esophagus	14	1.42	0	0	14	1.08
Cancer stomach	21	0.94	6	1.19	27	0.95
Cancer large intestine	39	1.06	3	0.92	42	1.05
Cancer rectum	7	0.52	1	0.79	8	0.54
Cancer liver	6	0.75	3	2.00	9	0.95
Cancer pancreas	20	0.87	2	0.71	22	0.85
Cancer respiratory system	120	0.84	14	0.93	134	0.85
Cancer larynx	7	1.09	0	0	7	0.95
Cancer lung	112	0.83	14	1.00	126	0.85
Cancer bone	2	0.87	0	0	2	0.79
Cancer skin	3	0.36	1	3.41	4	0.47
Cancer prostate	18	0.75	8	1.40	26	0.88
Cancer testis	3	0.92	0	0	3	0.85
Cancer bladder	8	0.67	1	0.84	9	0.68
Cancer kidney	11	1.03	0	0	11	0.96
Cancer eye	0	0	0	0	0	0
Cancer brain	11	0.78	0	0	11	0.78
Cancer thyroid	1	1.15	0	0	1	1.05
Lymphosarcoma	4	0.41	1	1.65	5	0.49
Hodgkin's disease	8	1.28	0	0	8	1.20
Leukemia	15	0.87	2	1.52	17	0.91

Table 17 continued

	Lowest	Highest
All Vascular Lesions CNS	0.61	1.34
All External Causes	0.40	0.80

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* Remaining plants have too few deaths to consider the SMRs for comparison.

TABLE 17

RANGE OF STANDARDIZED MORTALITY RATIOS FOR SPECIFIC CAUSES OF DEATH IN WHITE MALES IN COHORT I BY PLANTS (2,3,5,6-8)*

	Lowest	Highest
Total Deaths	108	566
All Causes	0.72	0.88
All Cancers	0.64	1.24
All Infections	0	0.64
Cancer of Oral Cavity	0	1.10
Cancer of All Digestive Organs	0.67	1.47
Cancer of Esophagus	0	3.20
Cancer of Stomach	0.43	2.57
Cancer of Large Intestine	0.25	1.81
Cancer of Rectum	0	1.34
Cancer of Liver	0	1.48
Cancer of Pancreas	0.47	1.67
Cancer of Respiratory System	0.60	1.45
Cancer of Larynx	0	4.90
Cancer of Lung	0.54	1.31
Cancer of Prostate	0.62	1.00
Cancer of Bladder	0	0.99
Cancer of Kidney	0.52	1.76
Cancer of Brain	0	1.38
Hodgkins	0	1.84
Leukemia	0	1.48
Disease Circulatory	0.58	0.98
Chronic Rheumatic Heart Disease	0	1.27
Arteriosclerotic Heart Disease	0.56	1.06

Table 13.
Standardized Mortality Ratios for Specific Causes of Death for White-Collar and Blue-Collar Jobs by Last Job Held

Cohort I - Both Races
All plants

	Blue		White	
Number				
Total population	11,180		2,235	
Total deaths	1,700		232	
Standardized Mortality Ratios	No.	SMR	No.	SMR
All causes	1700	0.81	232	0.73
All cancers	353	0.88	34	0.56
Cancer digestive organs	114	1.00	12	0.74
Cancer esophagus	12	1.09	2	1.36
Cancer stomach	27	1.16	0	0
Cancer large intestine	36	1.05	5	0.98
Cancer rectum	6	0.48	2	1.09
Cancer liver	7	0.86	0	0
Cancer pancreas	18	0.82	3	0.93
Cancer respiratory system	123	0.92	20	0.44
Cancer larynx	6	0.96	1	1.11
Cancer lung	116	0.92	8	0.39
Cancer prostate	21	0.32	2	0.64
Cancer testis	3	1.05	0	0
Cancer bladder	8	0.71	1	0.63
Cancer kidney	11	1.13	0	0
Cancer brain	9	0.73	2	0.91
Hodgkins disease	7	1.27	1	0.95
Leukemia	15	0.95	2	0.78
Cancer other lymphatic	9	0.97	1	0.71
All lymphpoietic	35	0.88	4	0.61
All diseases nervous system	13	0.72	4	1.35
All diseases circulatory system	818	0.78	118	0.78
Chronic rheumatic HD	9	0.41	9	2.59
Arteriosclerotic HD	587	0.82	81	0.75
All vasc. lesions CNS	119	0.82	14	0.73
All respiratory disease	78	0.67	9	0.53
Emphysema	19	0.65	3	0.72
Ulcers	9	0.61	1	0.46
Cirrhosis	22	0.39	1	0.10
Chronic nephritis	7	0.56	4	2.34
All external causes	141	0.59	23	0.52

Table 19.

Standardized Mortality Ratios for Specific Causes of Death by Last Job Held

Cohort I - Both Races
All Plants

	Production		Utilities		Maintenance		Other Jobs		Total
Number									
Population	3269		550		3683		3329		10831
Deaths	488		115		799		496		1898
Standardized Mortality Ratios	No.	SMR	No.	SMR	No.	SMR	No.	SMR	
All causes	488	0.88	115	0.82	799	0.89	496	0.83	
All cancers	94	0.89	25	0.95	168	0.98	85	0.76	
Cancer digestive organs	23	0.78	10	1.28	57	1.13	30	0.93	
Cancer esophagus	2	0.68	1	1.30	5	1.04	2	0.66	
Cancer stomach	5	0.83	1	0.63	16	1.51	5	0.76	
Cancer large intestine	7	0.79	4	1.70	21	1.41	9	0.93	
Cancer rectum	1	0.31	1	1.15	4	0.72	2	0.56	
Cancer liver	1	0.47	0	0	0	0	6	2.61*	
Cancer pancreas	4	0.69	1	0.68	9	0.94	5	0.81	
Cancer respiratory system	36	1.01	9	0.81	59	1.04	23	0.62	
Cancer larynx	1	0.60	2	4.76*	1	0.37	2	1.15	
Cancer lung	34	1.01	7	0.86	58	1.09	21	0.60	
Cancer prostate	7	1.13	0	0	11	0.87	7	0.97	
Cancer testis	0	0	0	0	3	2.94*	0	0	
Cancer bladder	2	0.70	1	1.19	2	0.39	4	1.25	
Cancer kidney	3	1.17	0	0	3	0.74	1	.37	
Cancer brain	3	0.89	0	0	3	0.67	4	1.15	
Hodgkins disease	2	1.29	1	3.45	3	1.47	2	1.23	
Leukemia	3	0.72	2	1.98	7	1.08	5	1.11	
Cancer other lymphatic	5	2.02	1	1.67	1	0.26	2	0.78	
All lymphopoietic	11	1.04	4	0.62	13	0.80	10	0.89	
All diseases nervous system	4	0.80	0	0	7	0.96	6	1.15	
All diseases circulatory system	233	0.87	54	0.74	391	0.84	252	0.85	
Chronic rheumatic HD	5	0.85	0	0	3	0.34	12	1.96*	
Arteriosclerotic HD	167	0.90	40	0.80	278	0.89	169	0.83	
All vasc. lesions CNS	34	0.94	7	0.64	53	0.78	44	1.06	
All respiratory diseases	21	0.68	9	1.05	36	0.68	17	0.51	
Emphysema	6	0.80	2	0.94	7	0.53	4	0.50	
Ulcers	3	0.78	0	0	6	0.94	2	0.47	
Cirhosis	10	0.45	2	0.59	8	0.37	3	0.19	
Chronic nephritis	1	0.29	0	0	6	1.10	6	1.71	
All external causes	38	0.54	10	0.74	66	0.80	42	0.59	

* Significant based on confidence limits of exact Poisson distribution not including unity. Only high values tested.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

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OFFICE OF
PREVENTION, PESTICIDES AND
TOXIC SUBSTANCES

MAY 08 1995

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EPA looks forward to continued cooperation with your organization in its ongoing efforts to evaluate and manage potential risks posed by chemicals to health and the environment.

Sincerely,

Terry R. O'Bryan
Terry R. O'Bryan
Risk Analysis Branch

Enclosure

12573A

Triage of 8(e) Submissions

Date sent to triage: 12/14/95

NON-CAP (CAP) [circled]

Submission number: 12573A

TSCA Inventory: (Y) [circled] N D

Study type (circle appropriate):

Group 1 - Dick Clements (1 copy total)

ECO AQUATO

Group 2 - Ernie Falke (1 copy total)

ATOX SBTOX SEN w/NEUR

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Notes:

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CECATS\TRIAGE TRACKING DBASE ENTRY FORM

CECATS DATA:
Submission # 8EHQ- 0992-12573 SEQ. A

TYPE: (INT) SUPP FLWP

SUBMITTER NAME: Phillips Petroleum Company

SUB. DATE: 08/24/92 OTS DATE: 09/02/92 CSRAD DATE: 03/07/95

CHEMICAL NAME:

CAS# 9003-55-8

INFORMATION REQUESTED: FLWP DATE:
0501 NO INFO REQUESTED
0502 INFO REQUESTED (TECH)
0503 INFO REQUESTED (VOL ACTIONS)
0504 INFO REQUESTED (REPORTING RATIONALE)

DISPOSITION:
(0639) REFER TO CHEMICAL SCREENING
(0678) CAP NOTICE

VOLUNTARY ACTIONS:
(0401) NO ACTION REPORTED
0402 STUDIES PLANNED/UNDERWAY
0403 NOTIFICATION OF WORKERS/OTHERS
0404 LABEL/MSDS CHANGES
0405 PROCESS/HANDLING CHANGES
0406 APP./USE DISCONTINUED
0407 PRODUCTION DISCONTINUED
0408 CONFIDENTIAL

INFORMATION TYPE:		P F C	INFORMATION TYPE:		P F C	INFORMATION TYPE:		P F C
(0201)	ONCO (HUMAN)	01 (02) 04	(0216)	EPI/CLIN	01 (02) 04	0241	IMMUNO (ANIMAL)	01 02 04
0202	ONCO (ANIMAL)	01 02 04	0217	HUMAN EXPOS (PROD CONTAM)	01 02 04	0242	IMMUNO (HUMAN)	01 02 04
0203	CELL TRANS (IN VITRO)	01 02 04	0218	HUMAN EXPOS (ACCIDENTAL)	01 02 04	0243	CHEM/PHYS PROP	01 02 04
0204	MUTA (IN VITRO)	01 02 04	0219	HUMAN EXPOS (MONITORING)	01 02 04	0244	CLASTO (IN VITRO)	01 02 04
0205	MUTA (IN VIVO)	01 02 04	0220	ECO/AQUA TOX	01 02 04	0245	CLASTO (ANIMAL)	01 02 04
0206	REPRO/TERATO (HUMAN)	01 02 04	0221	ENV. OCCC/REL/FATE	01 02 04	0246	CLASTO (HUMAN)	01 02 04
0207	REPRO/TERATO (ANIMAL)	01 02 04	0222	EMER INCI OF ENV CONTAM	01 02 04	0247	DNA DAM/REPAIR	01 02 04
0208	NEURO (HUMAN)	01 02 04	0223	RESPONSE REQEST DELAY	01 02 04	(0248)	PROD/USE/PROC	01 02 04
0209	NEURO (ANIMAL)	01 02 04	0224	PROD/COMP/CHEM ID	01 02 04	0251	MSDS	01 02 04
0210	ACUTE TOX. (HUMAN)	01 02 04	0225	REPORTING RATIONALE	01 02 04	0299	OTHER	01 02 04
0211	CHR. TOX. (HUMAN)	01 02 04	0226	CONFIDENTIAL	01 02 04			
0212	ACUTE TOX. (ANIMAL)	01 02 04	0227	ALLERG (HUMAN)	01 02 04			
0213	SUB ACUTE TOX (ANIMAL)	01 02 04	0228	ALLERG (ANIMAL)	01 02 04			
0214	SUB CHRONIC TOX (ANIMAL)	01 02 04	0239	METAB/PHARMACO (ANIMAL)	01 02 04			
0215	CHRONIC TOX (ANIMAL)	01 02 04	0240	METAB/PHARMACO (HUMAN)	01 02 04			

TRIAGE DATA:	NON-CBI INVENTORY	ONGOING REVIEW	SPECIES	TOXICOLOGICAL CONCERN:	USE:	PRODUCTION:
	(YES)	YES (DROP/REFER)	HMN	LOW	Rubber	
CAS SR	NO	NO (CONTINUE)		MED		
	DETERMINE	REFER		HIGH		

COMMENTS:

8E Number and Chemical Name	Rank	Reason or Brief Description
-12573 CAP Styrene & Butadiene Rubber CAS 9003-55-8	Med	The International Institute of Synthetic Rubber Producers employed a university epidemiologist to conduct a cohort mortality study in 8 manufacturing plants to clarify if the production of synthetic rubber (as opposed to chemicals, e.g., solvents used in tire manufacturing) conferred health risks. There was a general increase in mortality with time since first exposure but not with duration of employment and the average age of death among those deceased was lower than expected. Some SMRs in the then present "production" sub-cohort appeared slightly higher than 100, with the U.S. comparison population as reference; testicular cancer was significantly elevated (3 deaths) among maintenance workers employed in the same area of the plant (e.g. including the tank cleaning area). Other studies of the rubber and rubber tire industry have detected risks, but this industry-funded one (possibly because of limitations of the data and study design) did not show similar statistically significantly elevated risk patterns. This study was submitted earlier, referenced as 8E HQ 1282 0370 and was reviewed more extensively in March 1983. Together with other studies it was included in an OTS review of butadiene epidemiology on Nov. 30, 1984. The follow-up case/control study and others by Matanoski et al., were the subject of FYI-OTS-0688-0525 Supplemental Sequences A, B, and C reviewed by C. S. Scott in October 1988. Submission -13446 describes a more recent study focussed on the same industry.